Quaternary International xxx (2017) 1–16

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Obsidian sources and distribution in Patagonia, southernmost South America

Charles R. Stern

Department of Geological Sciences, University of Colorado, Boulder, CO 80309-0399, USA

ARTICLE INFO

Article history:
Received 18 April 2017
Received in revised form
21 July 2017
Accepted 24 July 2017
Available online xxx

Keywords:
Obsidian
Patagonia
Chile
Argentina
South America

ABSTRACT

Obsidian artifacts occur in some of the earliest occupied late Pleistocene archaeological sites in Patagonia, such as Pilauco (~15,500 cal BP) in south-central Chile, and Cerro Tres Tetas (~12,100 cal BP) in Santa Cruz, Argentina, and they are very common in numerous early Holocene sites. Trace-element analysis of artifacts from these sites indicate long-distance (>300 to >1000 km) transport of obsidian from nine different sources. Two of these sources, Chaitén (CH) and Nevados de Sollipulli (NS), are associated with active Andean volcanoes in southern Chile. One, around Seno Otway (SO), occurs in the Miocene volcanic belt in the southernmost Andes. The six others, Portada Covunco (PC), Cerro de la Planicies/Lago Lolog (CP/LL), Sacanana (S), Telsen/Sierra Negra (T/SN), Pampa del Asador (PDA) and Cordillera Baguales (CB), occur east of the Andes in Argentina. Geologic ages of these obsidians range from 17.8 Ma (Sacanana) to recent (Chaitén). Obsidian from each of these sources is generally homogeneous and chemically distinct from all the other sources. Those from the Chilean Andes are subalkaline in composition, while those from the pampas of Argentina east of the Andes are alkaline and peralkaline. Chaitén obsidian occurs in marine culture sites along the Pacific coast as far as >400 km to the north and south of this volcano, and a few samples has been found >900 km to the southeast along the Atlantic coast, presumably transported there in a canoe. Green obsidian from Seno Otway was also exploited dominantly by marine cultures, but occurs as well in terrestrial hunter-gatherer sites such as Pali-Aike and Fell's caves, from which Junius Bird first reported, in 1938, prehistoric obsidian artifacts in Patagonia. Distinctive black and red-banded “tiger-striped” obsidian from Portada Covunco has also been transported >500 km east to the Atlantic coast, as well as west into Chile and to Mocha Island off the Pacific coast, perhaps because of its aesthetic appeal. Black alkaline obsidian from Pampa del Asador, which includes at least four chemically distinct types, has been distributed by terrestrial hunter-gatherers >800 km northeast to the Atlantic coast and south to Tierra del Fuego, as well as west into Chile. The wide distribution (>300 km) of obsidian from each of these nine sources, well beyond the range considered probable for direct procurement by Patagonian terrestrial hunter-gatherers (≤200 km), implies the possibility of a considerable amount of cultural interaction among the prehistoric peoples of Patagonia throughout the Holocene.

1. Introduction

The earliest published mention of obsidian in Patagonia may be that of William Bollaert, captain of the H.M.S. Adventure, who in 1828 described in his log canoe people with obsidian knives in the Strait of Magellan (Crozier, 1996). Another early account of historic obsidian use was that of Enrico Giglioli (1875), who during the 1865–68 voyage of the Italian ship Magenta was given a dark green obsidian artifact 62 cm in length in the western Strait of Magellan, Chile. San Román and Prieto (2004) suggest that this artifact may be piece #14554 in the Luigi Pigorini National Museum of Prehistory and Ethnography, Rome. Another explorer, George Musters (1871), observed his native guides collecting large pieces of obsidian on September 8, 1869, at a location on the eastern edge of the Pampa del Asador (PDA; Fig. 1; Stern, 1999; Belardi et al., 2006), Argentina. Some years later Clemente Onelli (1904) described a “mine” of obsidian a few kilometers to the west, along the northern edge of this same pampa. Borrero and Franco (2001) report on obsidian arrowheads in the British Museum, London, collected during

E-mail address: Charles.Stern@colorado.edu.

http://dx.doi.org/10.1016/j.quaint.2017.07.030
1040-6182/

Please cite this article in press as: Stern, C.R., Obsidian sources and distribution in Patagonia, southernmost South America, Quaternary International (2017), http://dx.doi.org/10.1016/j.quaint.2017.07.030

expeditions to Tierra de Fuego (Fig. 1) in 1855 and 1874, and Martial (1888) also described obsidian arrowheads used by Onas in Tierra del Fuego.

Junius Bird (1938, 1993) published the first report of prehistoric obsidian artifacts from an archaeological excavation in Patagonia, which he found within both the Pali Aike and Fell's caves located just north of the eastern entrance to the Strait of Magellan (Fig. 1). Bird noted both the scarcity (~1% of all artifacts) and small size of the obsidian artifacts in these two sites and correctly concluded that they were not sourced locally (Stern, 2000a, 2000b). Emperaire and Laming (1961) and Ortiz-Troncoso (1973, 1975, 1979) described an important prehistoric green obsidian industry in maritime archaeological sites in Seno Otway (SO; Fig. 1), and along the coast of the central part of the Strait of Magellan. Stern and Prieto (1991) published chemical analyses of samples of this green obsidian from a number of both marine and terrestrial hunter-gatherer sites in southernmost Patagonia and concluded that they had similar chemistry and were most likely derived from the same source. In the same year, Stern and Porter (1991) published chemical analyses of porphyritic grey obsidian from archaeological sites on Chiloé (Fig. 1) and Gran Guaiteca Islands, Chile, and suggested the Chaitén volcano to the east (CH; Fig. 1) as the possible source of this obsidian.

Over the last 25 years, geologic exploration for obsidian sources and chemical fingerprinting, by various techniques, of obsidian from both different sources and archaeological sites, has located nine major obsidian sources in Patagonia (Fig. 1), from each of which obsidian has been dispersed >300 km, and begun to constrain the distribution in time and space of the obsidians derived from these sources. This paper summarizes the current state of obsidian studies in central and southern Patagonia south of 37°S. Obsidian from sources just to the north (33–37°S) have been described by Seelenfreund et al. (1996), Durán et al. (2004, 2012), De Francesco et al. (2006), Giesso et al. (2008, 2011), Cortegoso et al. (2012, 2014, 2016), Barberena et al. (2011), Fernández et al. (2017) and De Francesco et al. (2017).

2. Methods

Samples of unworked geologic obsidian have been collected from possible sources discovered by either geologists or archaeologists working in different areas of Patagonia (Fig. 1). These are all secondary sources consisting of obsidian cobbles and pebbles distributed over wide areas by fluvial processes. In some cases, such as Chaitén (CH; Stern et al., 2002), Nevados de Sollipulli (NS; Stern et al., 2008), Portada Covunco (PC; Stern et al., 2012a) and Cerro Planicies/Lago Lolog (CP/LL; López et al., 2009a), primary sources formed by obsidian domes are located close by. However, the surrounding fields of rounded obsidian cobbles widely dispersed by fluvial processes occur at lower elevations and are much more easily accessible. Multiple obsidian cobbles from these different secondary sources were collected for the purpose of determining if they include only single unique and homogeneous or multiple chemically diverse obsidian types, and if these types corresponded chemically to obsidian artifacts obtained from nearby and distant archaeological excavations.

Samples of both unworked geologic obsidian from possible sources locations and obsidian artifacts from archaeological excavations have been chemically analyzed for trace elements by either XRF or ICP-MS techniques. The precision of both these techniques is estimated at better than ±10% at the concentration levels in the samples analyzed based on repeated analysis of selected obsidian samples used as secondary standards and both other internal laboratory standards and widely available U.S. Geological Survey standards (Saadat and Stern, 2011). Major element analysis of selected samples was done by Activation Laboratories (Canada) and Sr-isotopic ratios were determined by solid-source mass-spectrometry at the University of Colorado.

3. Results

3.1. General

Nine different obsidian sources (Fig. 1) from which obsidian has been both widely dispersed and transported long distances (>300 km) have been identified in Patagonia south of 37°S. A number of other sources of obsidian with more restricted distribution have also been located and described, and a small number of obsidian types with distinctive chemistry not corresponding to any of the obsidians from known sources have been encountered in a few archaeological sites. The nine major and some of the minor sources, and the extent of the distribution of obsidian from these sources, both in space and time, are described below from south to north.

3.2. Southernmost Patagonia

3.2.1. Seno Otway (SO) green obsidian

Emperaire and Laming (1961) and Ortiz-Troncoso (1973, 1975, 1979) described an important obsidian industry, involving a distinctive olive to dark green obsidian, in maritime hunter-gatherer sites in Seno Otway (SO; Fig. 1), Chile, and along the coast of the central part of the Strait of Magellan. Stern and Prieto (1991) published a K–Ar age of 17.1 ± 0.6 Ma for a sample of this green obsidian, and chemical analysis of samples from various archaeological sites. These data demonstrated both that the green obsidian from numerous marine and terrestrial hunter-gatherer sites in Magallanes and Tierra del Fuego have similar chemistry and were most likely derived from the same source, and that this source was within the Miocene magmatic belt in the Andes of southern Chile. This belt includes both volcanic rocks, such as on Isla Carlos III (21 Ma) in the Strait of Magellan to the south, and uplifted and exposed subvolcanic rocks such as the Cerro Caleta sill (19.7 Ma) and a dike on Punta Baja (18.3 Ma), both located along the south shore of Seno Otway (Morello et al., 2001), and Cerro Fitz Roy (19 Ma) and Torres del Paine (12 Ma) farther to the north.

The actual source of green obsidian remains undiscovered. However, recent reviews (Morello et al., 2001, 2002, 2004, 2015) have concluded that the source must be in the vicinity of Seno Otway based both on the abundance of this obsidian in the archaeological sites around its shores, where it accounts for more than 90% of all artifacts, and the common presence of nodules of this obsidian >10 and in some cases >50 g in these sites. Morello et al. (2015) catalogued 163 archaeological sites with green obsidian in southernmost Patagonia. These include mostly maritime sites along the coast up to as far as >360 km to the southeast of Seno Otway in Tierra del Fuego at Túnel 1 (Fig. 1; Orquera et al., 2011), along the Beagle Canal, and on the south side of Isla Navarino (Legoupil, 1993–1994) just north of Cape Horn, and up to 400 km to the northeast along the Atlantic coast near Monte León

Fig. 1. Location map of the nine main obsidian sources in Patagonia (large circles from south to north): SO=Seno Otway; CB=Cordillera Baguales; PDA=Pampa del Asador; CH=Chaitén; S=Sacanana; T/SN=Telsen/Sierra Negra; CP/LL = Cerro de la Planicies/Lago Lolog; NS=Nevadas de Sollipulli; PC= Portada Covunco, and some general indication of the spatial distribution of archaeological sites containing artifacts fashioned from these different obsidian types. Also shown are the locations of some of the sites with the earliest evidence of obsidian tools, ages given in cal BP. Pilauco (open circle) is the site with the earliest evidence of obsidian use in Patagonia (Pino et al., 2013; Stern et al., 2017).

Table 1
Average compositions of different obsidians from southernmost Patagonia.

Source	S. Otway	Baguales	Pampa del Asador				Río Cisne
Type	SO	CB	PDA1	PDA2	PDA3ab	PDA3c	CIS1
age Ma	17.1	2.3	6.4	6.2	5.5	4.9	Miocene
SiO_2	72.22	74.96	75.56	76.6	74.65	75.8	
TiO_2	0.09	0.11	0.08	0.06	0.16	0.08	
Al_2O_3	11.74	11.74	13.22	12.53	13.35	13.00	
Fe_2O_3	1.20	1.24	0.44	0.48	0.66	0.45	
FeO	0.88	0.95	0.92	0.69	0.98	0.58	
MnO	0.04	0.03	0.04	0.03	0.06	0.03	
MgO	0.08	0.01	0.05	0.01	0.08	0.06	
CaO	0.50	0.16	0.72	0.65	0.73	0.70	
Na_2O	4.00	5.40	4.08	3.92	4.55	4.3	
K_2O	4.50	4.11	4.82	4.70	4.40	4.60	
LOI	5.70	1.35	0.27	0.25	0.25	0.3	
TOTAL	100.95	100.03	100.2	99.92	99.81	99.88	
Ti	763	1078	776	705	1384	734	1135
Mn	252	206	288	236	354	234	380
Cs	6.4	10.6	10.1	12.2	6.0	6.2	2.3
Rb	170	294	196	232	178	144	135
Sr	22	<3	34	<3	56	42	10
Ba	102	<8	236	17	537	476	254
Y	37	129	33	46	28	14	49
Zr	132	693	132	139	251	108	383
Nb	37	160	26	27	27	21	44
Hf	6.1	24.8	5.5	6.3	7.0	3.4	10.1
Th	22.9	44.9	18.7	19.1	21.5	21.2	18.6
U	5.9	12.2	5.5	6.1	5.6	4.7	3.6
La	29.6	44.6	37.9	23.7	42.2	35.7	51.9
Ce	66.1	106.3	70.8	56.3	79.8	58.3	112.8
Pr	7.98	15.5	7.99	6.86	8.11	5.51	12.5
Nd	29.2	50.8	31.1	27.9	28.4	18.5	45.9
Sm	6.74	18.5	6.72	7.75	5.98	3.1	9.24
Eu	0.21	0.65	0.34	0.09	0.71	0.27	0.61
Gd	8.8	24.9	8.45	9.25	7.51	3.52	14.1
Tb	1.15	3.89	1.06	1.36	0.85	0.39	1.62
Dy	6.75	21.8	5.91	7.81	4.6	2.39	8.85
Ho	1.34	4.05	1.11	1.56	0.87	0.43	1.72
Er	4.16	11.6	3.49	4.69	2.98	1.46	5.58
Tm	0.54	1.48	0.44	0.61	0.33	0.15	0.76
Yb	4.04	9.65	3.4	4.65	3.08	1.59	5.26
Lu	0.54	1.31	0.46	0.66	0.47	0.27	0.75
La/Yb	7.3	4.6	11.1	5.2	13.7	22.7	9.9
$(^{87}Sr/^{86}Sr)i$	0.7051						

SO: Stern and Prieto, 1991; Stern, 2004; Morello et al., 2015.
CB; Stern and Franco, 2000; Stern, 2000a, 2004.
PDA: Stern, 1999, 2004; Fernández et al., 2015; Franco et al., 2017.
CIS: Mendez er al., 2012; Castro Esnal et al., 2017.

(Caracotche et al., 2005; Cruz et al., 2011; Stern et al., 2012b), where it makes up ~30% of all the obsidian artifacts. Green obsidian is also found in terrestrial hunter-gatherer sites, including >300 km to the north in the sites Charles Fuhr (Stern and Franco, 2000) and Cordillera Baguales in Argentina (Morello et al., 2015), and in Pali Aike and Fell's caves >150 km to the east in Chile (Fig. 1), where it makes up approximately 25% of all the obsidian artifacts (Stern, 2000a, 2000b).

With regard to the chronology of its distribution, it occurs in cultural Period III in the terrestrial hunter-gatherer sites Pali Aike and Fell's caves (Bird, 1993; Stern, 2000a, 2000b), which Bird dated as between 9500 and 7400 cal BP. However, Morello et al. (2015) consider the chronologic control on the age of this cultural period as uncertain and to be no more precise than mid-Holocene. In a number of coastal marine hunter-gatherer site such as Túnel 1 (Fig. 1) it occurs in occupational levels dated between 7450 and 5200 cal BP. It apparently was not used extensively in the period between 5150 and 2500 cal BP (San Román and Prieto, 2004), but its use became common again after 2000 cal BP (Morello et al., 2015), and there are numerous historic observation of green obsidian use among the Fueguian maritime people, including possibly that of Giglioli (1875) mentioned above.

In a study of 2280 artifacts of green obsidian, Morello et al. (2001, 2015) determined that 90% are uniform dark olive green in color, while 10% have either dark or in some case clear bands. Most samples are crystal-free, but up to 20% contain a very small proportion (<1 vol %) of crystals of feldspar. Green obsidian is not only very distinctive among Patagonian obsidians with respect to its color, but also with respect to its chemistry, containing a notable amount, between 4.7 and 6.2 wt %, of H_2O (Loss-on-ignition = LOI in Table 1). Despite this quantity of water, and its age, it has not devitrified and is not a perlite, but remains a glassy rhyolite obsidian. It is a calc-alkaline rhyolite with low concentration of high-field-strength elements such as Ti, Zr, and Hf, typical of calc-alkaline rocks formed along the Andean convergent plate boundary volcanic arc. However, it has lower Sr and Ba (Fig. 2) than other Patagonian obsidians derived from active Andean volcanoes such as that from Chaitén and Nevados de Sollipulli. Fernández and Leal (2013) determined a mean index of refraction n = 1.4870 for this green rhyolite obsidian. They noted the presence of some samples with thin clear bands containing small clusters of opaque grains, which they considered to have formed as a result of incipient devitrification.

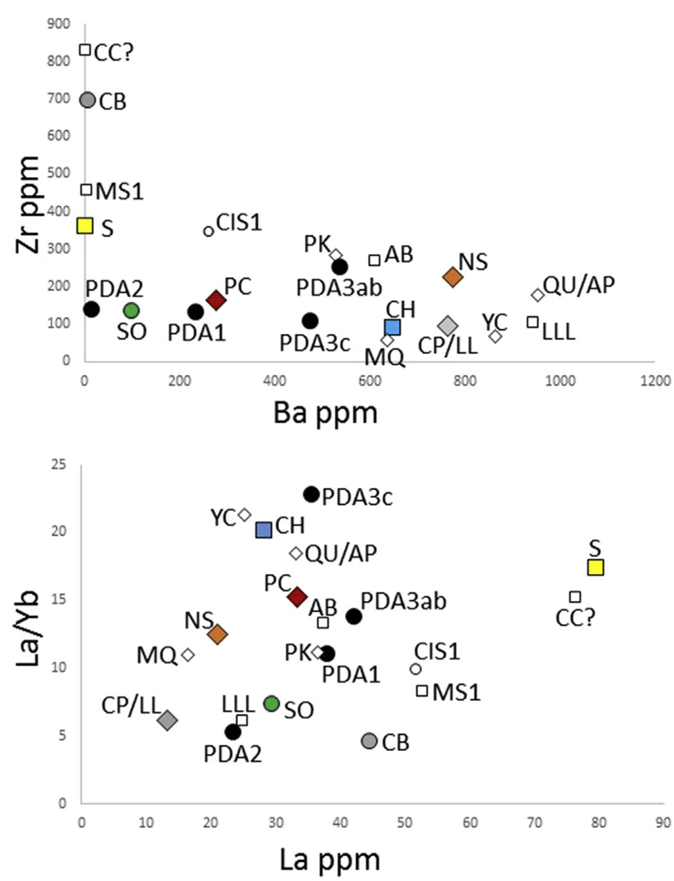

Fig. 2. Plots of Ba versus Zr concentrations (in ppm), and La versus La/Yb ratio, of obsidians from eight of the nine major sources (abbreviations as in Fig. 1; circles from southernmost Patagonia; squares from south-central Patagonia; diamonds from north-central Patagonia), and some of the minor or unknown sources (smaller open symbols, abbreviations as in the text). Highly alkaline T/SN obsidian is not included because of its distinctive very high values of Zr and La which plot off scale in both these figures.

3.2.2. *Cordillera Baguales (CB) banded grey-green obsidian*

Banded grey-green obsidian was reported by Stern and Franco (2000) from hunter-gatherer sites on the northern edge of Cordillera Baguales (Fig. 1), on the southern shores of Lago Argentino, and along the Santa Cruz river valley, Argentina. A K–Ar geologic age of 2.3 Ma for this obsidian is within the range 1.0–2.5 Ma determined by Fleck et al. (1972) for alkaline basalts from the upper part of the Meseta Vizcachas and Cerro Friale in the Cordillera Baguales, and this, as well as the alkaline character of this obsidian (Table 1), suggests that its source is from within this area, but it has not been discovered.

This obsidian also occurs in more distal terrestrial hunter-gatherer sites in Chile, such as Dos Herraduras 125 km to the south (Sierpe et al., 2010; Morello et al., 2015) and Pali Aike and Fell's caves >280 km to the southeast (Fig. 1), within which it represents 25% of all the obsidian artifacts (Stern, 2000a, 2000b). Charlin (2009) considers it to be the most abundant obsidian in all the many terrestrial hunter-gatherer sites with the Pali Aike volcanic field. It is also present >300 km to the east in coastal sites at Laguna Moy Aike and near Monte León (Fig. 1; Caracotche et al., 2005; Cruz et al., 2011), where it comprises ~50% of all the obsidian artifacts. Finally, it has also been documented in maritime sites in Chile such as Punta Santa Ana along the Strait of Magellan and Offing on Isla Dawson ~400 km to the south (Fig. 1; Morello et al., 2015).

The earliest occurrence of this obsidian, at between 11,000 and 7000 cal BP (Civalero and Franco, 2003; Franco and Borrero, 2012), is in the site Chorillo Malo close to the source (Fig. 1). Along the Atlantic coast this obsidian occurs in a site dated as 6550 cal BP (Cruz et al., 2011). It also occurs in cultural Period III in Pali Aike and Fell's caves (Bird, 1938, 1993), consistent with its widespread distribution during the mid-Holocene.

Chemically, banded grey-green obsidian is an alkaline rhyolite with relatively high concentrations of Na_2O, Rb, Th, Nb, Ta, Zr, Hf and Y, but distinctly lower concentrations of Sr and Ba (Fig. 2; Table 1), than green obsidian from Seno Otway. Fernández and Leal (2013) observed up to 20 vol % of very small crystals of alkali feldspar and an unidentified low birefringence prismatic mineral which they interpreted as resulting from incipient devitrification. They determined an index of refraction n = 1.4870, essentially the same as green obsidian from Seno Otway.

3.2.3. *Pampa del Asador (PDA) black obsidian*

The presence of obsidian in the vicinity of Pampa del Asador (PDA) was first noted by the early explorers Musters (1871) and Onelli (1904). Even before PDA was identified as the source of this obsidian, black obsidian artifacts had been described in abundance within a number of archaeological sites such as the Casa de Piedra ~40 km to the southwest (Fig. 1; Aschero, 1981–82, 1996; Aschero et al., 1992a, 1992b; Bellelli and Civalero, 1996), near Lago Po-

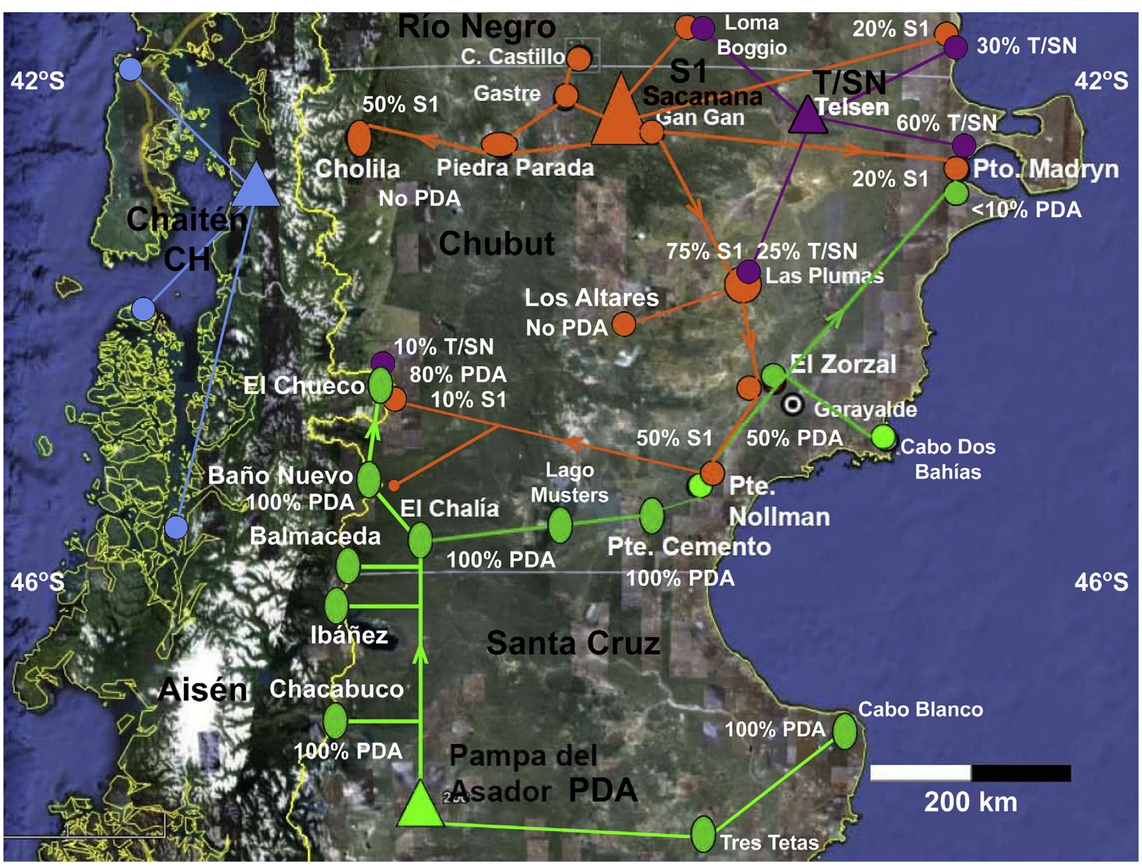

Fig. 3. Map of central Patagonia showing the relative proportions of the different types of obsidians (relative to each other, not to all artifacts) derived from the four most important sources in this region (Pampa del Asador = PDA; Sacanana = S; Telsen/Sierra Negra = T/SN; Chaitén = CH) in different sites and the possible routes along which they were distributed (Gómez Otero and Stern, 2005; Stern et al., 2002, 2007, 2013; Méndez et al., 2008–9, 2012, 2017; Castro Esnal et al., 2012; 2017). Other obsidian types (MS1, CC?, AB, LLL, CP/LL, YC, PK, PC and CIS) also occur in this area, but either their source is unknown (MS1 and CC?), out of the area to the north (CP/LL, YC, PK, and PC), or they occur in only minor amounts derived from nearby sources (AB, LLL and CIS) as described in the text.

sadas, and along the Río Pinturas ~60–80 km to the northeast (Gradin et al., 1976, 1979; Aguerre, 1981–82; Alonso et al., 1984–85). Black obsidian had also been observed in sites more distal to PDA, to the north around Meseta Buenos Aires (Gradin, 1996), to the northwest in Chile (Mena and Jackson, 1991), to the east in the Deseado Massif of Argentina (Fig. 1; Cardich and Flegenheimer, 1978; Aguerre, 1987; Mengoni Goñalons, 1987; Miotti, 1992, 1996), and to the south near Lago Argentino (Franco et al., 1992), and Río Gallegos (Gómez Otero, 1986–87).

Stern et al. (1995a, 1995b) published chemical analysis of 14 samples from nine of these sites, and K–Ar ages of 5.4–6.2 Ma for 3 of these samples, and concluded that there were two chemically different black obsidians, both present in most sites, and that they had similar ages to the Patagonian plateau basalts that surround the fluvial-glacial Pampa del Asador, where the concentration of black obsidian in archaeological sites was most notable. Subsequently, Stern (1999) published analysis of 92 samples of black obsidian cobbles collected from Pampa del Asador, and 67 artifacts from 24 different archaeological sites in southernmost Patagonia, and concluded that all the artifacts corresponded chemically to black obsidian from PDA, and that they were all derived from this source. Civalero (1999), Espinosa and Goñi (1999) and Molinari and Espinosa (1999) all came to a similar conclusion from an archaeologic perspective based on the spatial and size distribution of black obsidian artifacts in southern Patagonia.

Pampa del Asador is an 80 × 15 km (1200 km^2) Plio-Pleistocene fluvial-glacial sedimentary deposit sloping down to the east from 1100 to 650 m.a.s.l. elevation east of the main Andean range. Rounded cobbles of black obsidian, up to >10 cm in maximum diameter, occur in this deposit and are exposed and concentrated in small drainage channels that cross the surface of the pampa as well as in drainage basins on the margin of the pampa such as Bajo la Herradura to the north (Stern, 1999). The original primary sources of the obsidian cobbles are unknown. Obsidian cobbles are also found up to 30 km to the east in a 320 km^2 delta deposit between 750 and 400 m.a.s.l., and to the southeast on the 700 km^2 Pampa de la Chispa which drains southward from the eastern edge of PDA into the valley of the Río Chico (Belardi et al., 2006). Recent work has also identified a site at the Estancia 17 Marzo, located ~170 km to the southeast along the paleo drainage valley of the Río Chico, where small (<5 cm) black PDA-type obsidian pebbles occur (Franco et al., 2017), indicating that the potential source region of black PDA-type obsidian occurs over an extremely extensive region southeast of PDA.

Stern (1999) initially identified six chemical types of black obsidian from PDA, called PDA1, PDA2a and 2b, and PDA3a, 3b and 3c. Subsequent analysis of both more geologic samples and artifacts suggested that PDA2a and 2b, and PDA3a and 3b, were each actually variations of one type, now called PDA2 and PDA3ab (Table 1; García-Herbst et al., 2007; Fernández et al., 2015; Franco et al., 2017). Based on the analysis of approximately 150 randomly collected geologic samples from PDA, type PDA1 comprises 70% of the material, PDA2 about 20%, PDA3ab ≥5% and PDA3c ≤5%. Analysis of more than 200 artifacts of PDA black obsidian reflect similar proportions of each type. PDA1 and PDA2 are crystal free, while PDA3ab and PDA3c often contain a small proportion of feldspar crystals, and in type PDA3ab zircons. All four types are alkaline rhyolites (Table 1). PDA2 has higher Rb, Y and Yb, but lower Sr, Ba, La and La/Yb compared to PDA1, while PDA3ab and 3c both have lower Rb and Cs, and higher Sr, Ba, Th and La/Yb than PDA1. PDA3ab has distinctly higher Zr (Fig. 2) and Ti than other PDA types, and PDA3c has distinctly lower Rb, Nb, Zr, Hf, Y and Yb. A sample of PDA1 was dated at 6.4 Ma and of PDA2 at 6.2 Ma (Stern, 1999). Samples of PDA3ab are 5.5 Ma and PDA3c is 4.9 Ma, respectively, which is a bit, but not greatly younger than the range for the two most abundant PDA obsidian types. Fernández and Leal (2013) determined an n = 1.4825 for a sample of PDA1 type obsidian.

Artifacts of black PDA obsidian are widespread in southern Patagonia (Figs. 1 and 3), occurring over 800 km to the northeast near Puerto Madryn (Stern et al., 2000; Gómez Otero and Stern, 2005) and 650 km to the southeast on Tierra del Fuego (Morello et al., 2012). It occurs in sites along the Atlantic coast (Fig. 1), including Cabo Dos Bahías to the northeast (Gómez Otero and Stern, 2005), Cabo Blanco to the east (Ambrústolo et al., 2012), and Monte León to the southeast (Caracotche et al., 2005; Cruz et al., 2011). PDA black obsidian comprises >35% of all types of lithic artifacts in many sites up to 200 km from the source (Pallo and Borrero, 2015), and 100% of all the obsidian artifacts in sites within ~200 km of PDA (Fig. 3), such as those in Perito Moreno National Park, near Lago Posadas, along the Río Pinturas, around Meseta

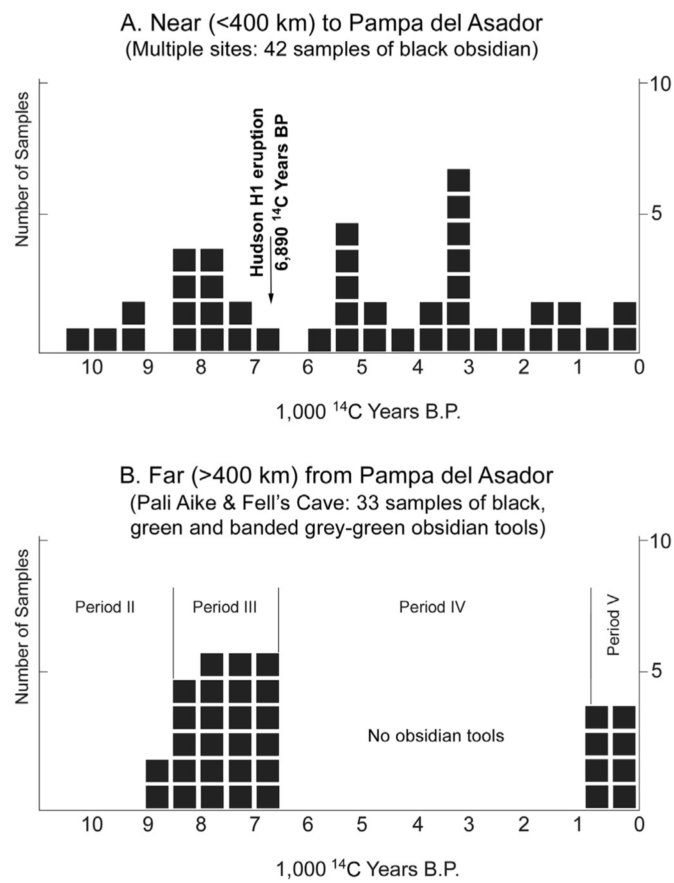

Fig. 4. Chronology of the Hudson H1 eruption (in ^{14}C yrs BP) relative to **A.** the presence of black obsidian from Pampa del Asador in sites within 400 km of this obsidian source area, and **B.** of all obsidian tools in Fell's cave and Pali Aike (Stern, 2000a, 2000b, 2004). Each dark square represents in **A.** a sample of black obsidian from one of many different sites within 400 km southeast of Pampa del Asador, with chronological context provided by archaeologists who collected these samples from these sites (Stern, 1999, 2004); or **B.** a sample of either black, green or banded grey-green obsidian from either Pali Aike or Fell's cave in the collections of Bird (1938, 1993). The figure illustrates the close temporal correlation of the H1 eruption and the haitus in long distance terrestrial transport of obsidian in the area of southernmost Patagonia affected by this event. Ages of the cultural periods in Pali Aike and Fell's cave are from Bird (1993).

Please cite this article in press as: Stern, C.R., Obsidian sources and distribution in Patagonia, southernmost South America, Quaternary International (2017), http://dx.doi.org/10.1016/j.quaint.2017.07.030

Buenos Aires (Fernández et al., 2015), along the Ibáñez River valley west in Chile, in sites in other areas east of the Andes further to the north near Balmaceda, Baño Nuevo, El Chueco and Chalia (Mena et al., 2000; Méndez et al., 2008–9, 2012, 2016, 2017; Castro Esnal et al., 2012; 2017; Stern et al., 2013), around Lago Musters (Reyes et al., 2015) and to the east in the Deseado Massif (Stern, 1999; Miotti et al., 2012; Franco et al., 2017). Further to the north and northeast they mix with obsidian from Sacanana and Telsen/Sierra Negra (S and T/SN in Figs. 1 and 3; Castro Esnal et al., 2012; Stern et al., 2013; Méndez et al., 2008–9, 2012, 2016, 2017), but still comprises at least 50% of the obsidian artifacts in all sites within 500 km of PDA. Further to the south, they mix with green and banded grey-green obsidian from Seno Otway and Cordillera Baguales, but even in Pali Aike and Fell's caves, ~500 to the south (Fig. 1), they comprise 50% of all the obsidian artifacts (Stern, 2000a, 2000b). The large spatial extent of the source of PDA-type black obsidian may be one of the reasons why this type of obsidian has been so widely dispersed in southern Patagonia.

With respect to the chronology of its exploitation, PDA obsidian is found in a late Pleistocene occupational level, dated as >12,100 cal BP, of the Cerro Tres Tetas site 200 km to the east (Fig. 1; Paunero and Castro, 2001; Paunero, 2003). In the Casa de Piedra site, located ~40 km to the southwest in Perito Moreno Nacional Park, it occurs in the oldest occupational levels 15–18 dated as ≤10,850 cal BP (Fig. 1; Civalero and Franco, 2003), and in Cueva de las Manos cave along the Río Pinturas it occurs after 10,500 cal BP (Borrero and Franco, 1997). In Baño Nuevo, to the north in Chile, it occurs in the earliest occupational level between 10,870–9460 cal BP (Mena et al., 2000; Mena and Stafford, 2006), and in El Chueco, ~370 km to the north of PDA in the upper Cisnes river basin (Figs. 1 and 3), black obsidian from this source occurs in all occupational levels after 10,220 cal BP (Méndez et al., 2008–9, 2012, 2017; Stern et al., 2013). A sample of black PDA obsidian was also found in the deepest level, dated as >11,000 cal BP, of the Chorillo Malo site 260 km to the south (Fig. 1; Civalero and Franco, 2003; Franco and Borrero, 2012). Clearly black obsidian from Pampa del Asador circulated widely since late Pleistocene and early Holocene times.

Stern (2004) suggested that there was a hiatus in the long distance transport of PDA obsidian south of this source after ~7400 cal BP (6400 ^{14}C yrs BP; Fig. 4), based on the age distribution of samples from both relatively nearby sites (<400 km to the south) and more distal sites such as Pali Aike and Fell's cave, within which no PDA obsidian (or any obsidian) occurs in occupational Period IV dated to have begun at 7400 cal BP (Bird, 1993; Prieto et al., 2013). Stern (2004) attributed this hiatus to the large mid Holocene H1 eruption of the Hudson volcano, located at 46°S northwest of PDA, which produced a tephra layer over 20 cm in thickness in Tierra del Fuego >800 km to the south (Stern, 1991, 2008; Naranjo and Stern, 1998; Prieto et al., 2013), and thus potentially disrupted long distance exchange of obsidian and all other aspects of life in southernmost Patagonia.

3.2.4. Another minor source

One obsidian with more restricted distribution in southernmost Patagonia is a dark grey to black, highly-brittle variety found as nodules from within a Miocene rhyolite pyroclastic flow exposed in the upper Cisnes river basin near the El Chueco site (Figs. 1 and 3; Méndez et al., 2008–9, 2012, 2017). Small chemical variations allow the distinction of four chemical types among samples analyzed (Méndez et al., 2017). The poor knapping quality of this type CIS (Table 1) obsidian limited its prehistoric use considerably. This obsidian is found in small quantities in the archaeological sites of Baño Nuevo and El Chueco, located close to the source, after 8500 cal BP (Méndez et al., 2008–9, 2012, 2017; Stern et al., 2013), and one sample also occurs in level 6 (≤8500 cal BP) of the principle cave (CP1) of the site Casa de Piedra de Aldea Beleiro (Castro Esnal et al., 2017) in southwestern Chubut, Argentina, located between Baño Nuevo and Chalia (Fig. 3), ~100 km southeast of the source.

3.3. South-central Patagonia

3.3.1. Telsen/Sierra Negra (T/SN) translucent grey-green obsidian

Nodules of translucent dark grey to green obsidian occur in the Salamanca canyon in Sierra Negra east of Telsen (Fig. 1). Sierra Negra corresponds to a weathered basalt outcrop considered to be part of the Miocene Telsen volcanic complex on the southeastern margin of the Somuncurá Massif. Basalts from the Telsen volcanic complex have been dated by Ardolino and Franchi (1993) as 15 to 17 Ma. The obsidian nodules in Salamanca canyon may be derived from domes within the large effusive centers to the north that produced the Quiñelaf pyroclastic rhyolites that are associated with the Telsen volcanic complex and the basalts of Sierra Negra. A K–Ar age determined for one sample of this obsidian is 14.6 Ma (Stern et al., 2000; Stern, 2004), which is consistent with the late stage of formation of the Telsen volcanics.

Telsen/Sierra Negra obsidian (T/SN; previously called T/SC in some publications) is crystal free, with occasional fine bands (1 mm thick) of colorless and light brown glass. Microlites of alkali feldspar and very tiny opaque minerals were observed by Fernández and Leal (2013), who determined an index of refraction n = 1.4905 for this obsidian. The nodules from Salamanca canyon are a chemically very distinctive peralkaline rhyolite type (T/SN1; Table 2) with high totals of $Na_2O + K_2O$ (>11 wt %) and Fe_2O_3 + FeO (>3 wt %) compared to any other Patagonian obsidians, and very high concentrations of Rb, Th, Zr, Nb, Hf, Y, La and Yb. Another, chemically very similar obsidian (T/SN2; Table 2), with comparable high total alkalies, Fe, and trace-elements, has been identified in many of the archaeological sites in which T/SN1 occurs, including within the Salamanca canyon itself, but this type was not found among the 21 geologic samples of obsidian collected from the canyon (Gómez Otero and Stern, 2005). However, the magmatic processes that generated this second T/SN2 obsidian type were very similar to those that generated T/SN1 obsidian, and its source must be close by.

Archaeological materials made from T/SN obsidian have been identified within the Salamanca canyon at the foot of Sierra Negra (Stern et al., 2000), in coastal sites around the Gulf of San Matías >250 km to the northeast (Figs. 1 and 3; Favier Dubois et al., 2009; Alberti et al., 2016), on Valdés Península up to 250 km to the east, and up to 300 km southeast along the Atlantic coast (Gómez Otero and Stern, 2005). It has also been found in a site Loma Baggio ~150 km to the northwest in the interior of Somuncurá plateau (Figs. 1 and 3; Boschín and Massaferro, 2014), ~150 km to the southwest at Las Plumas (Castro Esnal et al., 2012) and ~450 km to the southwest at El Chueco in Chile (Méndez et al., 2008–9, 2012, 2017; Stern et al., 2013).

With regard to the chronology of its distribution, the earliest archaeological sample identified is that from the furthest site, El Chueco in Chile, where it occurs in the one of the deepest levels 190–200 cm below the surface dated as 10,200 cal BP (Méndez et al., 2008–9, 2012, 2017). The chronology of obsidian in the coastal sites is not well controlled, but the oldest age dates from these sites are only middle Holocene (Gómez Otero et al., 2017), and the age of the oldest documented obsidian is 2660 cal BP in the site Lisa Conchero on Península Valdés (Gómez Otero and Stern, 2005).

Table 2
Average compositions of different obsidian types in central-south Patagonia.

Source	Telsen	Telsen	Sacanana	C. Castillo	Somuncura	Ang. Blanco	L. Larga	Chaitén
Type	T/SN1	T/SN2	S1	CC?	MS1	AB (DesX)	LLL	CH
age Ma	14.6	Miocene	17.8	Miocene	Miocene	Miocene	Miocene	<10,000
SiO_2	72.40	74.86	74.59	75.35	75.42	74.13	70.85	75.58
TiO_2	0.14	0.14	0.08	0.15	0.11	0.26	0.04	0.11
Al_2O_3	11.41	10.68	12.67	11.19	11.53	13.38	12.76	13.78
Fe_2O_3	2.39	2.57	1.00	1.56	0.47	2.01	1.35	1.58
FeO	1.00	1.08	0.83	0.91	1.32			
MnO	0.14	0.12	0.05	0.05	0.13	0.04	0.07	0.07
MgO	0.01	0.02	0.04	0.02	0.04	0.32	0.06	0.22
CaO	0.07	0.16	0.71	0.29	0.16	1.16	0.73	1.33
Na_2O	7.35	5.86	4.48	4.6	4.77	4.23	4.16	4.16
K_2O	4.44	4.00	5.10	4.58	4.42	3.98	3.48	3.07
LOI	0.50	0.39	0.60	0.45	1.21	0.10	6.39	0.16
TOTAL	99.85	99.88	100.15	99.15	99.58	99.61	99.89	100.06
Ti	1035	1113	971	1140	1012	1665	509	985
Mn	936	783	380	363	957	286	554	548
Cs	8.6	6.3	4.4	4.6	8.4	2.9	5.1	8.6
Rb	640	502	290	324	352	133	160	127
Sr	<1	3	3	<1	<1	98	76	148
Ba	<3	7	<3	<3	5	612	945	650
Y	322	170	66	80	56	23	36	13
Zr	3156	2240	360	827	456	266	103	88
Nb	616	332	146	170	164	19	21	9
Hf	76.2	57.0	14.0	21.1	17.2	6.6	3.8	2.9
Th	66.6	57.8	24.2	26.0	42.5	16.0	9.2	15.8
U	21.0	14.1	4.2	6.9	16.5	3.6	2.1	4.3
La	181	151	79.7	76.5	52.9	37.6	25.0	28.3
Ce	404	326	164	153	103	66.1	50.1	49.5
Pr	48.5	39.3	17.0	16.9	12.7	6.48	5.69	4.49
Nd	170	141	63.2	65.9	38.1	25.1	23.9	18.3
Sm	42.8	31.8	13.2	13.9	8.09	4.61	5.47	2.96
Eu	2.84	2.24	0.10	0.78	0.30	0.66	0.56	0.59
Gd	39.5	32.0	13.7	13.9	9.32	4.49	6.88	2.89
Tb	6.51	5.30	1.74	2.04	1.49	0.65	0.97	0.36
Dy	39.3	31.8	9.43	10.2	10.1	4.44	5.92	2.02
Ho	7.19	5.82	1.71	1.89	2.46	0.85	1.18	0.35
Er	20.5	15.4	5.09	5.29	5.98	2.55	3.61	1.21
Tm	2.71	1.99	0.55	0.59	0.71	0.45	0.64	0.11
Yb	17.8	14.8	4.61	5.04	6.35	2.82	4.11	1.41
Lu	2.71	1.88	0.82	0.82	0.98	0.53	0.76	0.22
La/Yb	10.2	10.2	17.3	15.2	8.3	13.3	6.1	20.1
$(^{87}Sr/^{86}Sr)i$								0.7059

T/SN, S1, CC? and MS1: Stern et al., 2000; Stern, 2004; Gómez Otero and Stern, 2005.
AB: Bellelli and Pereyra, 2002; Bellelli et al., 2006; Stern et al., 2007.
LLL: Bellelli and Pereyra, 2002; Bellelli et al., 2006, 2017; Stern et al., 2007.
CH; Stern and Porter, 1991; Stern and Curry, 1995; Stern et al., 2002, 2008, 2009.

3.3.2. *Sacanana (S) shiny black obsidian*

Nodules up to >10 cm in maximum diameter of a very shiny black obsidian are found within the fluvial sediments of the Sacanana canyon around Cerro Gaucho west of the town of Gan Gan (Figs. 1 and 3; Stern et al., 2000). This obsidian, one sample of which was dated as 17.8 Ma, may have its origin to the north in the Talagapa volcanic centers (Ardolino and Franchi, 1993) or more to the northwest in the Pire Mahuida volcanic centers (Salani and Page, 1989) within the Somuncurá Plateau. Fernández and Leal (2013) examined geologic samples of obsidian from the Pire Mahuida complex, but did not present a chemical analysis of this obsidian so it is not certain if it is the same as that found in the Sacanana sediments.

Shiny black S1 obsidian from Sacanana is a crystal-free peralkaline rhyolite, with relatively high concentrations of Rb, Nb, Zr, Y and rare-earth elements (REE), but not as high as the obsidians from Telsen/Sierra Negra (Table 2). A second type S2 occurs, but in much smaller proportions than S1 (Stern et al., 2000).

Obsidian from Sacanana is widely distributed in sites around south-central Patagonia. It occurs along the coast of the gulf of San Matías ~380 km to the northeast (Figs. 1 and 3; Favier Dubois et al., 2009; Alberti et al., 2016), on Península Valdés ~380 km to the east (Stern et al., 2000), and to the southeast along the Atlantic coast (Gómez Otero and Stern, 2005). It also occurs in the interior of the continent in sites within the Somuncurá plateau to the northeast, north and northwest (Figs. 1 and 3; Boschín and Massaferro, 2014), to the southeast and south at Las Plumas and Los Altares (Fig. 3), to the west at Piedra Parada (Bellelli et al., 2006; Stern et al., 2007, 2013; Castro Esnal et al., 2012), and in sites ~250 km to the west near Cholila, El Hoyo and El Manso, where it still accounts for 50% of all the obsidian artifacts (Bellelli et al., 2006, 2017). Finally, it occurs far to the southwest at Appeleg1 in Chile (Méndez et al., 2008–9, 2012, 2017; Stern et al., 2013) and in Casa de Piedra de Aldea Beleiro (Figs. 1 and 3; Castro Esnal et al., 2017) in southwestern Chubut, Argentina, ~400 km southwest of the source. With regard to the chronology of its distribution, S1 obsidian from sites in the interior occur in levels <3200 cal BP (Bellelli, 1988; Pérez de Micou et al., 1992; Stern et al., 2000, 2007; Bellelli et al., 2006, 2017; Boschín and Massaferro, 2014). Along the coast middle Holocene sites occur (Gómez Otero et al., 2017), but the age of the oldest documented obsidian is 2660 cal BP in the site Lisa Conchero on Península Valdés (Gómez Otero and Stern, 2005). In the far distal sites to the southwest the samples of S1 obsidian are at the surface (Méndez et al., 2012; Stern et al., 2013; Castro Esnal et al., 2017).

3.3.3. Chaitén (CH) porphyritic grey obsidian

Stern and Porter (1991) reported on porphyritic grey to black obsidian artifacts from marine hunter-gatherer sites on Chiloé and Gran Guaiteca Islands, along the Pacific coast of Chile, and suggested that this obsidian was derived from the Chaitén Volcano to the east, the summit of which was known to be an obsidian dome of similar chemistry to the artifacts. Stern and Curry (1995) described petrochemically similar obsidian from the Traiguen Island ~350 south in the canals of Chile (Fig. 1). Stern et al. (2002) confirmed the presence of nodules of porphyritic grey-black obsidian in drainage valley on the flanks of the Chaitén Volcano, and in their delta deposits along the coast.

Chaitén obsidian is a calc-alkaline rhyolite with 1–3 vol % of plagioclase feldspar crystals. It has low concentrations of high-field-strength elements such as Ti, Zr, Hf, Nb and Y, but higher $^{87}Sr/^{86}Sr = 0.7059$ (Fig. 5b; Table 2) compared to other rhyolite obsidians derived from active Andean volcanoes such as Sollipulli (Stern et al., 2002, 2008, 2009) and Puyehue (Stern et al., 2017).

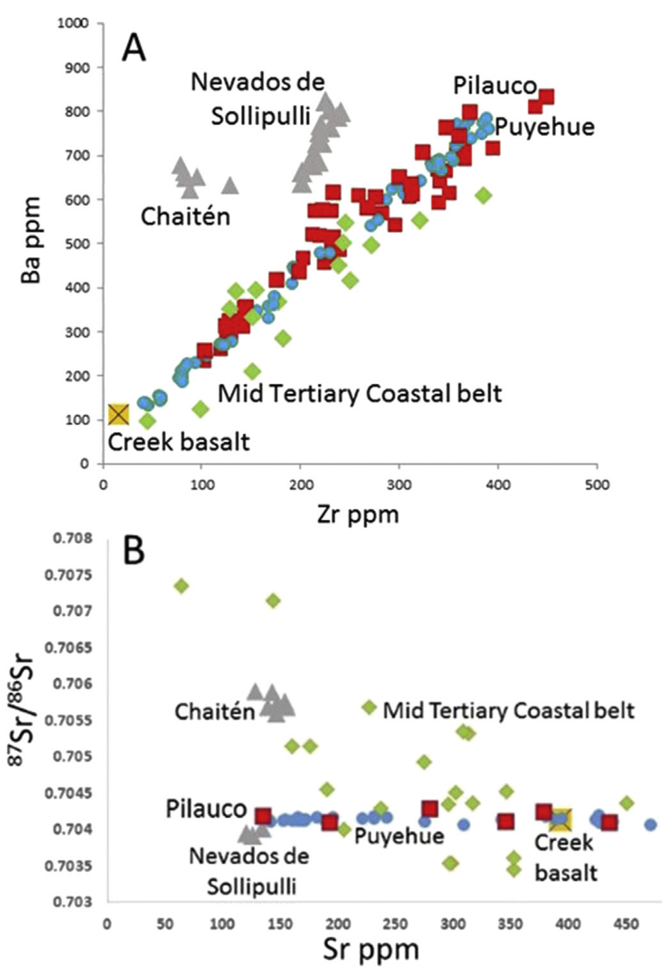

Fig. 5. A. Ba verus Zr concentrations (in ppm), and **B.** measured $^{87}Sr/^{86}Sr$ ratios versus Sr concentrations for samples of lithic tools from Pilauco (squares), volcanic rocks from the mid Tertiary volcanic belt (diamonds) and Puyehue Volcano (circles) in south-central Chile, as well as rhyolite obsidian from Chaitén and Nevados de Sollipulli Volcanoes (triangles).

Obsidian from Chaitén Volcano has been described from Pacific coast archaeological sites ~350 km to the south (Stern and Curry, 1995; Reyes et al., 2007) and 400 km north at Chan Chan (Fig. 1; Stern et al., 2002). The oldest occupational levels in these sites is 6450 cal BP at Chan Chan. No samples of Chaitén obsidian have been found in archaeological sites east of the Andes at the latitude of this volcano (Figs. 1 and 3; Bellelli and Pereyra, 2002; Bellelli et al., 2006, 2017; Stern et al., 2007; Boschín and Massaferro, 2014; Pérez et al., 2012, 2015). However, samples of Chaitén obsidian have been described from more than 900 km to the southeast along the Atlantic coast near Monte León and in sites <25 km from the coast in the Pali Aike volcanic field (Fig. 1; Cruz et al., 2011; Stern et al., 2012b), presumably transported there through the Chilean canals and the Strait of Magellan in a canoe.

3.3.4. Other obsidian sources

Two obsidian sources with only local distribution have been described from this region. One is at Angostura Blanca (AB; Table 2) in the valley of the Chubut river near Piedra Parada (Fig. 3; Bellelli and Pereyra, 2002; Bellelli et al., 2006; Stern et al., 2007). The geologic samples of this obsidian are highly hydrated perlites, which may be derived from the Buitrera Vitrophere or Domo de Escuela Piedra Parada (Aragón et al., 2004), a component of the volcanic–pyroclastic complex of the middle Chubut River formed by late Paleocene through mid-Eocene volcanism (Aragón and Mazzoni, 1997). Obsidian artifacts with chemistry similar to the highly hydrated type AB perlite were initially called DesX (Bellelli and Pereyra, 2002), and subsequently Group D (Bellelli et al., 2006), but they are similar chemically to the perlite from Angostura Blanca, and are now considered to be less hydrated examples of material from this same source. Artifacts of this obsidian occur in sites near Piedra Parada (Bellelli and Pereyra, 2002; Bellelli et al., 2006; Stern et al., 2007), and two sample has been documented from ~200 km further north in the sites Pilcaniyeu Viejo and Loncomán (Boschín and Massaferro, 2014) and one from ~265 km south at Altos de Moro (Méndez et al., 2017).

Another obsidian source is at Laguna La Larga in the Los Alerces National Park near Cholila (Bellelli and Pereyra, 2002; Bellelli et al., 2006, 2017). Samples (LLL; Table 2) from this site, and other outcrops described from nearby (Arrigoni, 2005), are perlites. Archaeological samples of this type of obsidian have been observed only in local sites near Cholila (Bellelli et al., 2006, 2017).

3.3.5. Obsidians with unknown sources

Two other peralkaline obsidians with unknown sources are types CC?, which was first described from archaeological sites near Cerro Castillo (Stern et al., 2000), and MS1, first described from sites along the Atlantic coast (Gómez Otero and Stern, 2005). Their peralkaline chemical character (Table 2) suggests that both were derived from somewhere within the volcanic units of the Somuncurá Plateau. Obsidian CC?, also called DesZ by Bellelli and Pereyra (2002), has been found in archaeological sites near Cerro Castillo, to the west near Cholila (Bellelli et al., 2017), to the south near Piedra Parada (Stern et al., 2007), and in three sites to the east along the Atlantic coast (Gómez Otero and Stern, 2005; Favier Dubois et al., 2009; Alberti et al., 2016). MS1 is just as widely dispersed and even more common. It occurs along the Atlantic coast (Gómez Otero and Stern, 2005; Favier Dubois et al., 2009; Alberti et al., 2016), in numerous sites within the Somuncurá Plateau area (Boschín and Massaferro, 2014), and further to the west in the sites Casa de Piedra de Ortega (Fernández and Vítores, 2015) and Población Anticura along the Manso River (Bellelli et al., 2017). At this site it occurs in a stratigraphic level dated as 9200 cal BP (Bellelli et al., 2017). Boschín and Massaferro (2014) also encountered other peralkaline types of obsidian they called MS2 and MS3 from archaeological sites with the Somuncurá Plateau area, but these have not been described from coastal sites or to either the south or west.

3.4. North-central Patagonia

3.4.1. Cerro de la Planicies/Lago Lolog (CP/LL) black obsidian

López et al. (2009a) described obsidian cobbles found on the shores of Lolog Lake and a possible quarry in a primary source on Cerro de la Planicies (1732 m.a.s.l.), located just to the north of the lake in Nuequén, Argentina (CP/LL; Fig. 1). They determined that obsidian from these two localities had the same chemical composition. Cerro Planicies is formed by volcanic rocks of the Pliocene Aseret Formation (Turner, 1973).

Cerro de la Planicies/Lago Lolog (CP/LL) obsidian is black to grey in color, with minor amounts of translucent or red banded varieties. It is a high silica rhyolite obsidian with low Ti, Sr, Zr, Nb, Y, Th, Hf, La and Yb, but high Ba content (Table 3), which distinguishes it from other Patagonian obsidians (Fig. 2). A few geologic samples of a second type CP/LL2 occur, with even lower Sr, Y, Th, La and Yb, but this type has not been observed as an artifact.

CP/LL obsidian is found in many nearby sites around Lacar and Meliquina Lakes in Neuquén (López et al., 2009a, 2010; Pérez et al., 2012, 2015) and in sites in Río Negro (Fernández and Vítores, 2015), but also much further away ~250 km to the south in sites near Cholila (Bellelli et al., 2017), ~350 km to the southeast in sites within the Somuncurá Plateau (Boschín and Massaferro, 2014), >550 km to the east along the Atlantic coast (Fig. 1; Favier Dubois et al., 2009; Alberti et al., 2016), and >600 km to the northeast in the Tapera Moreira site in the province of La Pampa (Fig. 1; López et al., 2009b; Stern and Aguerre, 2013).

With respect to chronology, CP/LL obsidian has been found in the earliest occupational level, dated at 11,535 cal BP, of the Epullán Grande site located ~100 km east of the source (Fig. 1), and in level 7, dated as 8725 cal BP, of the Traful 1 cave located 70 km southeast of the source (Fernández and Vítores, 2015). In all the more distal sites this obsidian occurs in much younger mid to late Holocene

Table 3
Compositions of obsidians from west-central Patagonia.

Source	L Lolog	Sollipulli	Covunco	L. Lácar	Yuco	Meliquina	Paillakura
Type	CP/LL1	NS	PC1	QU/AP	YC	MQ (Des2)	PK (Des1)
age Ma	Pliocene	<1 Ma	Pliocene	Pliocene	Pliocene	Pliocene	Pliocene
SiO_2	74.14	73.59	75.52	73.92	76.61	74.63	70.91
TiO_2	0.11	0.19	0.14	0.23	0.12	0.05	0.21
Al_2O_3	13.31	13.84	13.19	13.98	13.08	13.22	14.33
Fe_2O_3	0.85	1.84	1.23	1.29	0.87	0.71	1.98
MnO	0.12	0.06	0.05	0.09	0.06	0.07	0.08
MgO	0.14	0.21	0.09	0.22	0.13	0.11	0.21
CaO	0.47	1.25	0.54	1.18	1.02	0.78	0.82
Na_2O	4.62	4.71	4.44	4.53	4.03	3.91	4.78
K_2O	4.24	3.95	4.71	3.95	4.01	4.43	4.87
LOI	1.23	0.52	0.32	0.44	0.46	1.38	1.06
TOTAL	99.23	100.16	100.23	99.83	100.39	99.29	99.25
Ti	790	1495	982	1410	691	536	1370
Mn	971	496	438	767	541	579	681
Cs	5.2	5.5	8.4	5.1	6.3	8.2	5.9
Rb	145	113	177	128	145	154	163
Sr	44	134	48	188	120	99	81
Ba	765	774	278	954	863	637	528
Y	22	15	18	17	14	15	27
Zr	96	226	163	176	66	58	282
Nb	17	7	29	14	13	16	21
Hf	3.7	5.2	4.9	4.5	2.5	2.4	7.0
Th	11.6	11.2	26.8	17.6	19.1	19.0	19.1
U	3.6	3.5	7.9	4.6	5.1	6.5	4.7
La	13.3	21.1	33.4	33.1	25.3	16.4	36.5
Ce	29.9	41.1	63.7	62.3	47.7	35.2	78.5
Pr	3.27	4.26	5.85	6.29	4.88	3.77	8.21
Nd	11.9	15.8	18.7	21.3	15.2	11.9	29.7
Sm	2.95	2.55	2.79	3.53	2.68	2.15	5.44
Eu	0.53	0.66	0.43	0.89	0.55	0.50	0.81
Gd	3.16	2.93	3.08	3.35	2.52	2.39	5.2
Tb	0.59	0.43	0.55	0.50	0.4	0.42	0.85
Dy	3.31	2.56	2.95	2.84	2.04	2.54	4.49
Ho	0.73	0.57	0.61	0.59	0.49	0.54	1.09
Er	1.93	1.62	1.78	1.65	1.18	1.35	2.73
Tm	0.34	0.23	0.32	0.27	0.21	0.26	0.39
Yb	2.14	1.69	2.19	1.79	1.19	1.49	3.27
Lu	0.35	0.31	0.36	0.37	0.22	0.24	0.6
La/Yb	6.2	12.5	15.3	18.5	21.3	11.0	11.2
$(^{87}Sr/^{86}Sr)i$		0.7040					

CP/LL1, QU/AP, YC, MQ, PK: López et al., 2009a, 2010; Pérez et al., 2012, 2015.
NS: Stern et al. (2008, 2009).
PC: Bellelli et al. (2006), Stern et al. (2012a), Salazar and Stern, 2013.

Please cite this article in press as: Stern, C.R., Obsidian sources and distribution in Patagonia, southernmost South America, Quaternary International (2017), http://dx.doi.org/10.1016/j.quaint.2017.07.030

levels.

3.4.2. Nevados de Sollipulli (NS) black obsidian

Stern et al. (2008, 2009) described black obsidian from both an outcrop of a dome at 1578 m.a.s.l. and its associated erosional products at lower elevations in the Nevados de Sollipulli, Chile (Fig. 1). Nevados de Sollipulli consists of Plio-Pleistocene volcanic rocks associated with the early stages of formation of the active Sollipulli Volcano (Naranjo et al., 1993). This obsidian was originally referred to as MEL, because of the sources proximity to the town of Melipeuco, but it has now been renamed as NS obsidian (Table 3).

NS obsidian is a crystal-free calc-alkaline rhyolite obsidian with many chemical characteristics similar to obsidian from Chaitén Volcano to the south (Table 3), but it has significantly higher Zr, lower La and La/Yb, and lower $^{87}Sr/^{86}Sr = 0.70392$ to 0.70402 (Fig. 5b; Stern et al., 2002), the Sr isotopic values being more typical of most rocks erupted from Andean volcanoes in south-central Chile.

This type of obsidian occurs in numerous nearby sites, both north and south of Nevados de Sollipulli, in the central valley and Andean foothills of Chile (Stern et al., 2009), ~150 km to the southwest along the coast at Chan and ~350 km to the south at Quilo on Chiloé Island (Fig. 1; Stern et al., 2009). It also occurs on Mocha Island ~200 km to the west (Campbell et al., 2017a, 2017b). No samples of this type of obsidian have been found to the east across the Andes in Argentina (Fig. 1; Stern et al., 2012a; Salazar and Stern, 2013). At Chan the earliest occupation age is 6450 cal BP, and obsidian was found in this early level. At Quilo on Chiloé and Quillen 1 in the central valley this obsidian occurs in the earliest occupation levels which have been dated as 5790 and 5350 cal BP, respectively (Stern et al., 2009). On Mocha Island, NS obsidian was found in occupational levels dated as late prehistoric, from 950 to 250 cal BP, although the island had been peopled by Archaic maritime hunter-gatherers, dated to as early as 3400 cal BP (Campbell et al., 2017a, 2017b).

3.4.3. Portada Covunco (PC) obsidian

Obsidian derived from the area of Portada Covunco, the location where Ruta 40 crosses Río Covunco in west-central Neuquén Province (Fig. 1), Argentina, was first reported by Bellelli et al. (2006). Giesso et al. (2008) published bulk-rock INAA analysis of five samples from archaeological sites in La Pampa Province, >300 km north-east of Portada Covunco, which they concluded were derived from a source that they referred to as La Bandera. López et al. (2009a, 2009b) later suggested that La Bandera, which is a small basaltic cone on the top of which a flag (bandera) has been installed, was in fact part of the same extended secondary source as Portada Covunco, since this location occurs only a few kilometers north of Portada Covunco.

Stern et al. (2012a) concluded that cobbles and pebbles of Portada Covunco obsidian were derived from at least two primary sources located further to the west. These primary sources, which are both at higher elevation (>1500 m.a.s.l.) and not accessible during the winter, occur along the southeastern extension of the chain of Plio-Quaternary volcanoes that runs from Copahue through Pino Hachado (Muñoz and Stern, 1988). The highest peak in this area is Cerro Las Lajas (2650 m.a.s.l.). One of the two primary sources is Cerro Volcán or Bayo (38°45′42″S and 70°41′57″W), located along the north-west flank of Cerro Las Lajas. Cerro Volcán drains to the north along Arroyos Liu Cuyin and Las Lajitas, both of which flow into the Río Agrio near the city of Las Lajas. The other primary source is located a few kilometers to the southwest of Cerro Las Lajas, along the eastern side of the Arroyo Cochicó Grande (38°49′46″S and 70°45′52″S), which flows southwards into the Río Kilca. Large cobbles of rhyolite obsidian occur in the drainage valley in the general vicinity of both these two sources, and smaller pebbles of the same obsidian were also collected from the drainage valley of Río Kilca >30 km to the south downstream, near where the Río Kilca joins with the Río Aluminé (Stern et al., 2012a).

The overall source of Portada Covunco (PC) obsidian thus involves both multiple primary sources and a very extensive secondary source region extending 60 km in an east-west direct and 70 km in a north-south direction. Portada Covunco obsidian is visually very variable, with black, grey, translucent, banded, and a very distinctive black and red tiger-striped variety. All these samples have similar unique chemistry, with Ba between 220 and 340 ppm (Fig. 2; Table 3), which distinguishes them from all other obsidian types from the regions of Neuquén, Argentina, and south-central Chile, all of which have Ba >500 ppm (Fig. 2). Obsidians from closer to Mendoza to the north are also characterized by a significantly higher Ba >500 ppm (Seelenfreund et al., 1996; Durán et al., 2004, 2012; De Francesco et al., 2006; Giesso et al., 2008, 2011), while the peralkaline obsidians T/SN and S associated with the Somuncurá Plateau to the south are characterized by very low Ba <20 ppm (Stern et al., 2000; Bellelli and Pereyra, 2002; Gómez Otero and Stern, 2005; Bellelli et al., 2006). The only other obsidian type in all of Patagonia with values of Ba similar to those of PC obsidian is type PDA1 black obsidian from Pampa del Asador (Fig. 2; Table 1; Stern, 1999, 2004), which is located far to the south (Fig. 1). However, PDA1 obsidian is otherwise chemically distinct from the PC obsidian, having, for example, higher Cs, Rb, La and Yb, and lower Sr, Th and La/Yb (Table 1), and it has clearly not circulated this far to the north.

PC obsidian has been identified in archaeological sites close to this source (Fig. 1; López et al., 2009a, 2009b; Stern et al., 2012a; Salazar and Stern, 2013), >75 km to the west in Chile (Stern et al., 2009), including on Mocha Island in the Pacific (Campbell et al., 2017a, 2017b), over 300 km to the northeast in La Pampa Province (López et al., 2009a; Stern et al., 2012a; Stern and Aguerre, 2013), >400 km to the south in Chubut (Bellelli et al., 2006, 2017), and >500 km to the east along the Atlantic coast (Alberti et al., 2016). Like PDA obsidian, its widespread distribution may relate in part to the regionally widespread source area. However, the potential aesthetic value of the unique red and black tiger-striped obsidian from Portada Covunco may have also motivated its extensive distribution. This is suggested by the fact that although PC obsidian has been passed west across the Andes into Chile, grey-black NS obsidian from Nevados de Sollipulli at essentially the same latitude (Fig. 1) has not been found in Argentina. Interchange, at this same latitude during the past ~1000 years, of Complejo Pitrén and Vergel-Valdivia ceramics across the Andean drainage divide from Chile into Neuquén, Argentina, has also been documented (Hajduk, 1986; Fernández, 1988–90; Goñi, 1991; Hajduk et al., 2011; Campbell et al., 2017a, 2017b). However, in contrast to the PC obsidian, this exchange was from west-to-east, from Chile into Argentina, rather than from east-to-west.

The oldest sample of PC obsidian from a site close to the source, Alero Tromen IV, is 5050 cal BP (Stern et al., 2012a). The age of PC obsidian in the site Casa de Piedra 1 in La Pampa province (Fig. 1) has been estimated to be about the same (Stern and Aguerre, 2013). All other sites with PC obsidian, including those in Chile, are younger than 2500 cal BP.

3.4.4. Other sources

López et al. (2009a, 2010) and Pérez et al. (2012, 2015) have identified a number of other sources of obsidian in southern Neuquén south of Cerro de la Planicies/Lago Lolog (Table 3). These include Lacar Lake (chemical group QU/AP), Filo Hua-Hum (FHH), Paillakura (PK, ex Unknown #1), Meliquina Lake (MQ, ex Unknown #2) and Yuco (YC). Obsidians from all these sources are grey to black in color. Obsidian types QU/AP, PK and YC are found >200 km to the south in sites near Cholila (Bellelli et al., 2017), indicating significant north to south transportation within the interior of the forested Andean foothills, but they have not been distributed out as far to the east as obsidian from Cerro de la Planicies/Lago Lolog. Only PK has a long history of distribution, occurring in the earliest occupational level, dated as 11,535 cal BP, of the site Epullán Grande ~100 km to the east (Fig. 1), and in level 8, dated at 10,550 cal BP, of the nearby Traful 1 cave site. (Fernández and Vítores, 2015; Pérez et al., 2015).

3.4.5. Obsidian with uncertain sources

An important site which contains obsidian from a yet to be determined source is Pilauco (Fig. 1), located in the city of Osorno in southern Chile, 100 km north of the late Pleistocene Monte Verde site, the earliest known site to be occupied in Patagonia (Dillehay, 1989, 1997, 2009, 2013). The earliest occupation of Pilauco has also been dated as late Pleistocene in age, between 15,550 and 16,250 cal BP (Pino et al., 2013). However, unlike Monte Verde, which lacks obsidian, Pilauco contains obsidian artifacts, and it is the oldest known site in Patagonia with obsidian artifacts.

Rhyolite obsidian artifacts in Pilauco occur along with other lithic tools made from volcanic rocks, including aphanitic basalts and andesites, and vitreous dacites. The artifacts were made by direct percussion of small and medium sized river pebbles. They occur in level PB7 of the site. The underlying layer PB6 is composed by boulders and cobbles deposited in a high energy fluvial environment related to the reworking and redeposition of glacial moraine material derived from the high Andes.

Trace element analysis of 50 archaeological samples define a field of variable composition from low to high concentrations of incompatible element such as Ba and Zr (Fig. 5a) that reflect the range of lithic types from basalt to rhyolite. The data indicate that the Pilauco rhyolite obsidian samples are chemically distinct to obsidians from both the Nevados de Sollipulli source to the north and the Chaitén source to the south. The data are compatible with derivation of the Pilauco lithic artifacts from either volcanic units of the mid Tertiary coastal magmatic belt in central Chile (Muñoz et al., 2000), which outcrops in the vicinity of Pilauco, or from glacially and fluvially transported cobbles and pebbles derived from the recently active Puyehue volcano in the high Andes (Singer et al., 2008; Naranjo et al., 2017). Although the trace element chemistry does not distinguish one or the other of these possibilities, Sr-isotopic data show that the full range of rock types in the Pilauco lithic assemblage, from basalt to rhyolite, has very uniform $^{87}Sr/^{86}Sr = 0.704089$ to 0.704274 (Fig. 5b), similar to a comparable range of rock types from the Puyehue volcano in the high Andes, and distinct from the rocks of the mid Tertiary volcanic belt (Stern et al., 2017).

One sample of basalt from level PB6 in the site also has a Sr-isotopic ratio of 0.704128 within the range of the lithic artifacts found in level PB7 of the site (Fig. 5b). This suggests that the source of the lithic materials used to make the artifacts found in the Pilauco site could have been local, from within the volcanic cobbles and pebbles found in the reworked moraine material of level PB6 of the site. This is consistent with evidence that lithic materials within other late Pleistocene settlements across various regions of South America are derived mainly from locally sourced materials and rarely from foreign materials (García, 2003; Gnecco and Aceituno, 2004; López, 2008; Aceituno et al., 2013).

4. Discussion and conclusions

Twenty five years of geo-archaeological work since the first chemical analyses of obsidian from Patagonia were obtained indicates nine major sources of obsidian from which material has been widely circulated (>300 km; Fig. 1), as well as a number of sources with only more local distribution, and a few types of obsidian for which a source has not yet been located. These obsidian sources range from Miocene to recent in age. Given the vast volume of volcanic rocks formed both in the southern Andes and to the east in the pampas of Patagonia over this period of time, the number of sources of rhyolite obsidian are relatively few and the volume of rhyolite obsidian in all these source is relatively small compared to the much larger amounts of basalts, andesites and dacites.

Geochemical analysis of both geologic and archaeologic material indicates that all the different obsidian types so-far encountered in Patagonia are distinguishable chemically (Fig. 2; Tables 1–3), which allows for their spatial and temporal distribution to be well documented. This documentation indicates long distance (>300 km) distribution of this lithic material from soon after the very earliest late Pleistocene occupation of Patagonia (Fig. 1). The earliest evidence of obsidian use, found in the late Pleistocene Pilauco site in south-central Chile, suggests that the obsidian in this site was derived locally from the volcanic rocks in the fluvial deposits the site was occupied on. However, other somewhat younger late Pleistocene sites, such as Tres Tetas in central Patagonia, and many early Holocene sites, such as Chorillo Malo, Epullán Grande, Casa de Piedra, Baño Nuevo and El Chueco (Fig. 1), contain evidence of long distance transport of obsidian.

The distribution of obsidian may occur as a result of direct acquisition by a nomadic group, or through material exchange between different groups occupying different regions. Borrero and Barberena (2006) and Zubimendi and Ambrustolo (2011) estimate distances of 100–150 km for the movements of prehistoric terrestrial hunter-gatherers in southern Patagonia. Pallo and Borrero (2015) suggest that, at least during the mid to late Holocene "colonization" phase of southernmost Patagonia (Borrero, 1994–95), direct acquisition of Pampa del Aasador black obsidian was, with a few exceptions, restricted to sites within approximately 140 km of PDA, because this was the "fall-off" distance beyond which the percentage of PDA obsidian decreased from as high as >60% to <15% compared to all other types of lithic artifacts. Méndez et al. (2012) suggest that this "colonization" stage actually extended back to the early Holocene, because PDA obsidian use occurred in uninterrupted fashion since ≤10,870 cal BP in the Baño Nuevo and El Chueco sites in Chile north of PDA (Figs. 1 and 3). In sites beyond 140 km from PDA, and clearly for those beyond 400 km in which PDA obsidian is always <1% of all lithic artifacts, sporadic visits or possibly material interchange between different nomadic terrestrial hunter-gatherer groups might have been more significant than direct acquisition (Pallo and Borrero, 2015).

The presence of different obsidian types from multiple far away (>300 km) sources in numerous sites, such as Pali Aike and Fell's cave, El Chueco, Tapera Moreira, near Cholila, on Mocha Island, and along the Atlantic coast near Puerto Madryn and the Gulf of San Matías (Fig. 1), implies that different groups or individuals, with access to different obsidian sources far separated from each other, visited the same sites during roughly similar time periods. This suggests the possibility of both material and cultural exchange among different terrestrial hunter-gatherer groups across large regions of Patagonia beginning from at least the mid-Holocene. By the late Holocene, systematic exchange of obsidian, as well as other material such as metals and ceramics, may have begun in some areas such as central-south Chile, as evidenced by patterns of obsidian occurrence that possibly reflect intensification of exchange networks (Campbell et al., 2017a, 2017b).

Direct procurement and long distance transport of obsidian might have extended over much greater regions for maritime culture hunter-gatherers traveling in canoes, as indicated by the presence of a nodule of Chaitén obsidian along the Atlantic coast near Monte León, >900 km to the southeast (Fig. 1; Cruz et al., 2011; Stern et al., 2012b). Overland transport of this type of obsidian is unlikely as it is not found in any sites east of the Andes at the same latitude as Chaitén (Fig. 3), or in any terrestrial hunter-gatherer sites anywhere in the pampas of Argentina (Bellelli and Pereyra, 2002; Bellelli et al., 2006, 2017; Stern et al., 2007; Méndez et al., 2008–9, 2012, 2017; Boschín and Massaferro, 2014; Pérez et al., 2012, 2015).

Asymmetric distribution of obsidian types also occur in Patagonia. For example, CP/LL obsidian has been distributed >550 km to the east and northeast, but has not been found in any sites in Chile to the west of this source, and NS and CH obsidians have been distributed far to the north and south in Chile but have not been found in Argentina (Fig. 1). This is obviously due to the biogeographical barrier created at these latitudes by the densely forested Andean mountain chain which separates these two countries in Patagonia. PDA obsidian is also only found in sites within Chile such as Baño Nuevo and El Chueco that are east of the Andes (Figs. 1 and 3), or along rivers such as in the Ibáñez River valley that cross the mountains and now drain to the west. An exception to this is the uniquely colored red and black tiger-striped PC obsidian from Portada Covunco, which has crossed the Andes from its source in Argentina into sites in Chile (Fig. 1; Stern et al., 2009) and is even found on the off shore Mocha Island (Campbell et al., 2017a, 2017b). This may possibly be due to the unusual aesthetic aspects of this obsidian, and the increased complexity of the social networks developed in the region after ~1000 cal BP when this obsidian was transported across the Andes along with other items such as ceramics (Campbell et al., 2017a, 2017b).

Temporal variations in obsidian use has been documented in some specific cases, such as the hiatus in the use of green obsidian in southernmost Patagonia between 5150 and 2500 cal BP (San Román and Prieto, 2004). They suggest that this might be due to the immigration into the region of a new maritime cultural group that did not have knowledge of the source of this obsidian. Stern (2004) also noted the lack of black PDA and other obsidian types in Pali Aike and Fell's caves during cultural Period IV that Bird (1993) dated beginning at 7400 cal BP. This may have been due to disruption of long distance material trade connections in southernmost Patagonia after the mid Holocene eruption of the Hudson volcano (Stern, 2004; Prieto et al., 2013), which must have had a significant negative impact on the environment to the southeast of the volcano.

The main conclusion from the compiled information concerning obsidian distribution in Patagonia is that it provides strong evidence for physical and cultural contacts over large regions from at least the mid Holocene, as indicated by the observation of multiple obsidian types, derived from both far-distant (>300 km) and greatly separated sources, found together in many different archaeological sites (Figs. 1 and 3). Future studies integrating chronological constraints of obsidian distribution with the distribution of other materials, such as marine shells (Pallo and Borrero, 2015), ceramic and metals (Campbell et al., 2017a, 2017b), will continue to enhance our understanding of the cultural and economic evolution of the prehistoric Patagonian people.

Acknowledgements

This paper represents the results of an extended >25 year period of still ongoing collaboration, both in the field and through sharing of samples, data and ideas, between the author and numerous archaeologists and geologists in both Chile and Argentina. In Chile these include F. Mena, A. Prieto, P. Cardenas, F. Morello, C. Méndez, M. San Román, X. Navarro, M. Pino, M. Massone, J. Muñoz, J. Naranjo, O. Reyes, C. García, R. Campbell, A. Peñaloza, A. Nuevo Delaunay, H. Velasquez, V. Trejo, A. Seelenfreund, V. Sierpe, F. Martin, the late C. Porter, and especially M.A. Skewes. In Argentina these include J. Gómez Otero, R. Goñi, T. Civalero, N. Franco, C. Bellelli, J.B. Belardi, A. Aguerre, S. Caracotche, I. Cruz, S. Espinosa, F. Carballo, I. Pereda, A. Pérez, L. López, A. Castro Esnal, C. Pérez de Micou, V. Fernández, C. Favier-Dubois, J. Alberti, M. Cardillo, C. Aschero, L. Borrero, P. Ambrústolo, M. Zubimendi, R. Barberena, V. Durán, P. Tiberi, A. Sunico, M. Carballido, J. Charlin, M. Berón, P. Leal, A. Guráieb, G. Mengoni, M.J. Fernández, R. Paunero, L.A. Orquera, M. Boschín, M. Reyes, E. Moreno and G. Salazar. The early stages of this work were supported by National Geographic Society grants NGS3425-86, NGS4238-89, NGS4889-92 and NGS5610-96, and FONDECYT (Chile) grants #1100161, #1030560 and #1070709. This paper is dedicated to the memory of Junius Bird, the first to describe obsidian from an archaeological site in Patagonia, who in 1976 greatly encouraged me to continue my work on volcanologic problems in Patagonia. Very good advice!

References

Aceituno, F.J., Loaiza, N., Delgado-Burbano, M.E., Barrientos, G., 2013. The initial human settlement of Northwest South America during the Pleistocene/Holocene transition: synthesis and perspectives. Quat. Int. 301, 23–33.

Aguerre, A.M., 1981–1982. Los niveles inferiores de la Cueva Grande (Arroyo Feo), área Río Pinturas, Provincia de Santa Cruz. Relac. Soc. Argent. Antropol. 14, 211–239.

Aguerre, A.M., 1987. Investigaciones arqueológicas en el área de la Martita, Dto. Magallanes, Provincia de Santa Cruz. Comunicaciones de las Primeras Jornadas de Arqueología de la Patagonia. Gobierno de la Provincia de Santa Cruz, Dirección de Impresiones Oficiales, Rawson, Argentina, pp. 11–16.

Alberti, J., Cardillo, M., Stern, C.R., Favier-Dubois, C.M., 2016. New results concerning expanded networks of obsidian procurement in San Matías Gulf, Río Negro, Patagonia, Argentina. J. Isl. Coast. Archaeol. http://dx.doi.org/10.1080/15564894.2016.11633757.

Alonso, F., Gradin, C.J., Aschero, C.A., Aguerre, A.M., 1984–1985. Algunas consideraciones sobre recientes dataciones radiocarbónicas para el área del río Pinturas, Provincia de Santa Cruz. Relac. Soc. Argent. Antropol. 16, 275–285.

Ambrústolo, P., Zubimendi, M., Stern, C.R., 2012. Explotación de obsidiana negra en la costa norte de Santa Cruz (Patagonia Argentina). Cazadores Recolectores del Cono Sur 6, 77–86.

Aragón, E., Mazzoni, M.M., 1997. Geología y estratigrafía del complejo piroclástico del río Chubut medio (Eoceno), Chubut. Argent. Rev. Asoc. Geol. Argent. 52 (3), 243–256.

Aragón, E., González, P., Aguilera, Y., Marquetti, C., Cavarozzi, C., Ribot, A., 2004. El domo vitrofírico Escuela Piedra Parada del Complejo Volcánico piroclástico del río Chubut Medio. Rev. Asoc. Geol. Argent. 59 (4), 634–642.

Ardolino, A., Franchi, M., 1993. Hoja Geológica 4366-1 Telsen. Dirección Nacional del Servicio Geológico, Buenos Aires, Boletín 215.

Arrigoni, G., 2005. Análisis del territorio de explotación de los recursos básicos para la subsistencia de los grupos prehistóricos que habitaron el valle del Río Desaguadero, Parque Nacional Los Alerces, Chubut. In: Actas, XIII Congreso Nacional de Arqueología Argentina. Córdoba, Tomo 4, pp. 63–72.

Aschero, C.A., 1981-1982. Nuevos datos sobre la arqueología del Cerro Casa de Piedra, sitio CCP5 (Parque Nacional Perito Moreno; Santa Cruz, Argentina). Relac. Soc. Argent. Antropol. 16 (2), 267–284.

Aschero, C.A., 1996. El área Río Belgrano-Lago Posadas: problemas y estado de problemas. In: Gómez Otero, J. (Ed.), Arqueología: Sólo Patagonia. Ponencias de las Segundas Jornadas de Arqueología de la Patagonia. Centro Nacional Patagónico, Puerto Madryn, Argentina, pp. 17–26.

Aschero, C.A., Bellelli, C., Goñi, R., 1992a. Avances en las investigaciones arqueológicas del Parque Nacional Perito Moreno (Provincia Santa Cruz, Patagonia). Cuad. del Inst. Nac. Antropol. 14, 143–170.

Aschero, C.A., Bellelli, C., Civalero, M.T., Goñi, T., Guráieb, A., Molinari, T., 1992b. Cronología y tecnología en el Parque Nacional Perito Moreno (PNPM): ¿continuidad o reemplazos? Arqueología 2, 89–105.

Barberena, R., Hajduk, A., Gil, A., Neme, G., Durán, V., Glascock, M., Giesso, M., Borrazzo, K., de la Paz Pompei, M., Salgán, M.L., Cortegoso, V., Villarrosa, G., Rughini, A., 2011. Obsidian in the south-central Andes: geological, geochemical and archaeological assessment of north Patagonian sources (Argentina). Quat. Int. 245, 25–36.

Belardi, J.B., Tiberi, P., Stern, C.R., Sunico, A., 2006. Al este del Cerro Pampa: ampliación del área de disponiblidad de obsidiana de la Pampa del Asador (Provincia de Santa Cruz). Intersecc. Antropol. 7, 27–36.

Bellelli, C., 1988. Recursos minerales: su estrategia de aprovisionamiento en los niveles tempranos de Campo Moncada 2, Valle de Piedra Parada, Río Chubut. In: Yaccobaccio, H. (Ed.), Arqueología Contemporánea Argentina. Búsqueda, Buenos

Aires, pp. 147–176.
Bellelli, C., Civalero, M.T., 1996. Campo Río Robles 3 (CRR3): más datos para la arqueología del Parque Nacional Perito Moreno (Santa Cruz). In: Gómez Otero, J. (Ed.), Arqueología: Sólo Patagonia. Ponencias de las Segundas Jornadas de Arqueología de la Patagonia. Centro Nacional Patagónico, Puerto Madryn, Argentina, pp. 297–306.
Bellelli, C., Pereyra, F., 2002. Análisis geoquímicos de obsidiana: distribuciones, fuentes y artefactos arqueológicos en el Noroeste del Chubut (Patagonia Argentina). Werken 3, 99–118.
Bellelli, C., Pereyra, F., Carballido, M., 2006. Obsidian localization and circulation in northwestern Patagonia (Argentina): sources and archaeological record. In: Maggetti, M., Messiga, B. (Eds.), Geomaterials in Cultural Heritage. Geological Society of London, pp. 241–255. Special Publication 257.
Bellelli, C., Carballido, M., Stern, C.R., 2017. Obsidiana en el bosque: determinación geoquímica de artefactos arqueológicos del NO de Río Negro (Patagonia Argentina). Chungara (in press).
Bird, J., 1938. Antiquity and migrations of the early inhabitants of Patagonia. Geogr. Rev. 28 (2), 250–275.
Bird, J., 1993. Viajes y arqueología en Chile Austral. Ediciones de la Universidad de Magallanes, Punta Arenas.
Borrero, L.A., 1994-5. Arqueología de la Patagonia. Palimpsesto Rev. Arqueol. 4, 9–69.
Borrero, L., Barberena, R., 2006. Hunter-gatherer home ranges and marine resources. An archaeological case from Southern Patagonia. Curr. Anthropol. 47 (5), 855–867.
Borrero, L.A., Franco, N., 1997. Early Patagonian hunter-gatherers: subsistence and technology. J. Anthropol. Res. 53, 219–239.
Borrero, L.A., Franco, N., 2001. Las colecciones líticas del Museo Británico. An. del Inst. Patagon. 29, 207–210.
Boschín, M.T., Massaferro, G.I., 2014. La obsidiana: una señal geoarqueológica del alcance de las relaciones sociales en la Patagonia Pre y Post-Hispánica. In: Hernández de Lara, O., Rocchietti, A.M. (Eds.), Arqueología Precolombina en Cuba y Argentina: Esbozos desde la Periferia. Aspha, Buenos Aires, pp. 227–258.
Campbell, R., Stern, C.R., Peñaloza, A., 2017a. Obsidian from Isla Mocha, Chile. J. Archaeol. Sci. Rep. 13, 617–624.
Campbell, R., Carrión, H., Figueroa, V., Peñaloza, Á., Plaza, M.T., Stern, C.R., 2017b. Materias primas líticas, artefactos metálicos y cuentas en isla Mocha (1000–1700 B.C.). Chungara (in press).
Caracotche, S., Cruz, I., Espinosa, S., Carballo, F., Belardi, J.B., 2005. Rescate arqueológico en el Parque Nacional Monte León (Santa Cruz, Argentina). Magallania 33 (2), 143–163.
Cardich, A., Flegenheimer, N., 1978. Descripción y tipología de las industrias líticas más antiguas de Los Toldos. Relac. Soc. Argent. Antropol. 12, 85–123.
Castro Esnal, A., Pérez de Micou, C., Stern, C.R., 2012. Circulation of Obsidian in Chubut, Argentina Using Primary Lithic Materials as Indicators of Mobility and Interaction of Hunter-gatherer Groups. Revista del Museo de Arqueología y Etnología de la Universidad de San Pablo, Brazil 21, pp. 93–102.
Castro Esnal, A., Stern, C.R., Pérez de Micou, C., 2017. Aplicación de estudios geoquímicos sobre artefactos de obsidiana procedentes de contextos estratigráficos y superficiales en Aldea Beleiro, SO de Chubut (Patagonia, Argentina). Magallania 45 (1), 141–153.
Charlin, J., 2009. Aprovisionamiento, explotación y circulación de obsidianas durante el Holoceno tardío en Pali Aike (provincia de Santa Cruz). Relac. Soc. Argent. Antropol. 34, 53–73.
Civalero, T., 1999. Obsidiana en Santa Cruz, una problematica a resolver. In: Belardi, J.B., Fernández, P.M., Goñi, R.A., Guráieb, A.G., De Nigris, M. (Eds.), Soplando en el Viento: Actas de las terceras Jornadas de Arqueología de la Patagonia. INAPL-Universidad Nacional de Comahue, Buenos Aires-Neuquén, Argentina, pp. 155–164.
Civalero, M.T., Franco, N.V., 2003. Early human occupations in western Santa Cruz province, southernmost South America. Quat. Int. 109–110, 77–86.
Cortegoso, V., Neme, G., Giesso, M., Durán, V., Gil, A., 2012. El uso de la obsidiana en el sur de Mendoza. In: Neme, G., Gil, A. (Eds.), Paleoecología humana en el Sur de Mendoza. Sociedad Argentina de Antropología, Buenos Aires, pp. 181–211.
Cortegoso, V., Glascock, M., De Francesco, A.M., Durán, V., Neme, G., Gil, A., Giesso, M., Sanhueza, L., Cornejo, L., Barberena, R., Bocci, M., 2014. Chemical characterization of obsidian in central western Argentina and central chile: archaeological problems and perspectives. In: Kligmann, D.M., Morales, M.R. (Eds.), Physical, Chemical and Biological Markers in Argentine Archaeology: Theory, Methods and Applications, British Archeological Reports (BAR) International Series 2678. Oxford, pp. 17–26.
Cortegoso, V., Barberena, R., Durán, V., Lucero, G., 2016. Geographic vectors of human mobility in the Andes (34–36°S): comparative analysis of 'minor' obsidian sources. Quat. Int. 422, 81–92.
Crozier, R., 1996. William Bollaert: explorador y publicista. Bol. Acad. Chil. Hist. 106, 205–250.
Cruz, I., Caracotche, M.S., Muñoz, A.S., Suby, J.A., Lobbia, P.A., Ercolano, B., Cañete Mastrángelo, D., 2011. Obsidianas y otros indicadores de circulación y uso del espacio en Punta Entrada y P. N. Monte León (Santa Cruz, Argentina). In: Zangrando, A.F., Barberena, R., Gil, A., Neme, N. (Eds.), Libro de resúmenes de las VIII Jornadas de Arqueología de Patagonia. Malargüe, Mendoza, Argentina, pp. 28–29.
De Francesco, A.M., Durán, V., Bloise, A., Neme, G., 2006. Caracterización y procedencia de obsidianas de sitios arqueológicos del área natural protegida Laguna del Diamante (Mendoza, Argentina) con metodología no destructive por fluorescencia de rayos (XRF). An. Arqueol. Etnol. 61, 53–67.
De Francesco, A.M., Barca, D., Bocci, M., Cortegoso, V., Barberena, R., Yebra, L., Durán, V., 2017. Provenance of obsidian artifacts from the Natural Protected Area Laguna del Diamante (Mendoza, Argentina) and upper Maipo valley (Chile) by LA-ICP-MS method. Quat. Int. this Vol.
Dillehay, T.D., 1989. Monte Verde: a Late Pleistocene Settlement in Chile. In: Paleoenvironmental and Site Context, vol. 1. Smithsonian Institution Press, Washington, DC.
Dillehay, T.D., 1997. Monte Verde: a Late Pleistocene Settlement in Chile. In: The Archaeological Context and Interpretation, vol. 2. Smithsonian Institution Press, Washington, DC.
Dillehay, T.D., 2009. Probing deeper into first American studies. Proc. Natl. Acad. Sci. 106 (4), 971–978.
Dillehay, T.D., 2013. Entangled Knowledge: old trends and new thoughts in first South American studies. In: Graf, K.E., Ketron, C.V., Waters, M.R. (Eds.), Paleoamerican Odyssey. Center for the Study of the First Americans. Department of Anthropology, Texas A&M University, College Station, Texas, pp. 377–396.
Durán, V., Giesso, M., Glascock, M.D., Neme, G., Gil, A., Sanhueza, L., 2004. Estudio de fuentes de aprovisionamiento y redes de distribución de obsidiana durante el Holoceno Tardío en el sur de Mendoza (Argentina). Estud. Atacameños 28, 25–43.
Durán, V., De Francesco, A.M., Cortegoso, V., Neme, G., Cornejo, L., Bocci, M., 2012. Caracterización y procedencia de obsidianas de sitios arqueológicos del Centro Oeste de Argentina y Centro de Chile con metodología no destructiva por fluorescencia de Rayos X (XRF). Intersecc. Antropol. 13, 423–437.
Emperaire, J., Laming, A., 1961. Les Gisements des Iles Englefield et Vivian dans la Mer d' Otway, Patagonie Australe. J. de Soc. des Am. 50, 7–75.
Espinosa, S., Goñi, R., 1999. ¡Viven!: una fuente de obsidiana en la provincia de Santa Cruz. In: Belardi, J.B., Fernández, P.M., Goñi, R.A., Guráieb, A.G., De Nigros, M. (Eds.), Soplando en el viento: Actas de las terceras Jornadas de Arqueología de la Patagonia. INAPL-Universidad Nacional de Comahue, Buenos Aires-Neuquén, Argentina, pp. 177–188.
Favier Dubois, C.M., Stern, C.R., Cardillo, M., 2009. Caracterización de la distribución y tipos de obsidiana presente en la costa rionegrina, Argentina. In: Salemme, M., Santiago, F., Álvarez, M., Piana, E., Vázquez, M., Mansur, M.E. (Eds.), Arqueología de Patagonia: una mirada desde el último confín. Editorial Utopías, Ushuaia, Argentina, pp. 254–266.
Fernández, J., 1988-1990. La cueva de Haichol. Arqueología de los pinares cordilleranos del Neuquén. An. Arqueol. Etnol. 43/45.
Fernández, M.V., Leal, P., 2013. Determining the provenance of obsidian in Southern Patagonia using optical properties. Archaeometry 56, 1–18.
Fernández, M.V., Vítores, M., 2015. Aprovisionamiento y uso de obsidianas en la cuenca del río Limay (Provincias de Río Negro y del Neuquén). In: Pifferetti, A., Dosztal, I. (Eds.), Arqueometría Argentina. Aspha, Buenos Aires, Argentina, pp. 285–296.
Fernández, M.V., Stern, C.R., Leal, P., 2015. Obsidian from northwestern Santa Cruz province, Argentina. Quat. Int. 375, 44–54.
Fernández, M.V., Barberena, R., Rughini, A.A., Giesso, M., Cortegoso, V., Durán, V., Villanueva, G.T., Borrazzo, K., Lucero, G., Garvey, R., MacDonald, B.L., Glascock, M.D., 2017. Obsidian geochemistry, geoarchaeology, and lithic technology in northwest Patagonia (Argentina). J. Archaeol. Sci. Rep. 13, 372–381.
Fleck, R., Mercier, J., Nairn, A., Peterson, D., 1972. Chronology of late Pliocene and early Pleistocene glacial and magmatic events in southern Argentina. Earth Planet. Sci. Lett. 16, 15–22.
Franco, N.V., Belardi, J.B., Campán, P., García, F., 1992. Primeras observaciones arqueológicas en cotas altas entre Lago Argentino y Lago Viedma (Santa Cruz, Argentina). Palimpsesto 2, 139–143.
Franco, N.V., Borrero, L.A., 2012. Chorrillo Malo 2: initial peopling of the upper Santa Cruz basin, Argentina. In: Miotti, L., Salemme, M., Flegenheimer, N. (Eds.), Ancient evidence for Paleo South Americans: from where the South Winds Blow. Center for the Studies of the First American (CSFA) and Texas A&M University Press, Texas.
Franco, N.V., Brook, G.A., Cirigliano, N.A., Stern, C.R., Vetrisano, L., 2017. 17 de Marzo (Santa Cruz, Argentina): a new distal source of Pampa del Asador type black obsidian and its implications for understanding hunter-gatherer behavior in Patagonia. J. Archaeol. Sci. Rep. 12, 232–243.
García, A., 2003. La ocupación temprana de los Andes Centrales argentinos (ca. 11.000-8.000 años C14AP). Relac. Soc. Argent. Antropol. 28, 153–165.
García-Herbst, A.E., Stern, C.R., Neff, H., Lanata, J.L., Garcia Albarido, L., Mengoni, G.L., 2007. Laser ablation ICP-MS analysis of black obsidian nodules from Pampa del Asador and archaeological samples from southernmost Patagonia. In: Morello, F., Martinic, M., Prieto, A., Bahamonde, G. (Eds.), Arqueología de Fuego-Patagonia: Levantando piedras, desenterrando huesos y develando arcanos. Edition CEQUE, Punta Arenas, Chile, pp. 235–247.
Giesso, M., Berón, M.A., Glascock, M.D., 2008. Obsidian in Western Pampas, Argentina: source characterization and provisioning strategies. Int. Assoc. Obsidian Stud. Bull. 38, 15–18.
Giesso, M., Durán, V., Neme, G.A., Glascock, M.D., Cortegoso, V., Gil, A.F., Sanhueza, L., 2011. A study of obsidian source usage in the central Andes of Argentina and Chile. Archaeometry 53 (1), 1–21.
Giglioli, E., 1875. Viaggio Intorno al Globo della Pirocorvetta Italiana Magenta. Maisner e Cia, Milano, Italy.
Gnecco, C., Aceituno, J., 2004. Poblamiento temprano y espacios antropogénicos en el norte de Suramérica. Complutum 15, 151–164.
Gómez Otero, J., 1986-87. Investigaciones arqueológicas en el Alero Potrok-Aike,

Provincia de Santa Cruz. Relaciones 17, 173–200.
Gómez Otero, J., Stern, C.R., 2005. Circulación, intercambio y uso de obsidianas en la costa de la provincia del Chubut, (Patagonia Argentina) durante el Holoceno tardío. Intersecc. Antropol. 6, 93–108.
Gómez Otero, J., Schuster, V., Banegas, A., 2017. Archaeology of the Península Valdés: spatial and temporal variability in the human use of the landscape and geological resources. In: Bouza, O., Bilmas, A. (Eds.), Late Cenozoic of Península Valdés: an Interdisciplinary Approach. Springer, Cham, Switzerland, pp. 233–261.
Goñi, R., 1991. Arqueología de sitios tardíos en el valle del arroyo Vilcunco (Provincia del Neuquén, Argentina). In: Actas del XI Congreso Nacional de Arqueología Chilena. Museo Nacional de Historia Natural, Sociedad Chilena de Arqueología, Santiago. Tomo III, pp. 217–226.
Gradin, C.J., 1996. Grabados y parapetos de la zona sur de la Meseta del Buenos Aires (Provincia Santa Cruz). In: Gómez Otero, J. (Ed.), Arqueología: Sólo Patagonia. Ponencias de las Segundas Jornadas de Arqueología de la Patagonia. Centro Nacional Patagónico, Puerto Madryn, Argentina, pp. 173–184.
Gradin, C.J., Aschero, C., Aguerre, A., 1976. Investigaciones Arqueológicas en la Cueva de las Manos, Estancia Alto Rio Pinturas, Provincia de Santa Cruz. Relac. Soc. Argent. Antropol. 10, 201–270.
Gradin, C.J., Aschero, C.A., Aguerre, A.M., 1979. Arqueología del Área Río Pinturas (Provincia de Santa Cruz). Relac. Soc. Argent. Antropol. 8, 183–227.
Hajduk, A., 1986. Arqueología del Montículo Angostura. Primer fechado radiocarbónico. Provincia del Neuquén. Ediciones Culturales Neuquinas, Neuquén.
Hajduk, A., Albornoz, A., Lezcano, M., 2011. Espacio, cultura y tiempo: el corredor bioceánico norpatagónico desde la perspectiva arqueológica. In: Navarro Floria, P., del Río, W. (Eds.), Cultura y espacio. Araucanía-norpatagonia. Instituto de Investigaciones en Diversidad Cultural y Procesos de Cambio and Universidad Nacional de Río Negro, San Carlos de Bariloche, Argentina, pp. 262–292.
Legoupil, D., 1993-1994. El archipiélago del Cabo de Hornos y la costa sur de la isla Navarino: poblamiento y modelos económicos. An. del Inst. Patagon. 22, 101–122.
López, C.E., 2008. Landscape development and the Evidence for Early Human Occupation in the Inter-Andean Tropical Lowland of the Magadalena River, Colombia. Syllaba Press, Miami, Florida, p. 193.
López, L., Pérez, A., Stern, C.R., 2009a. Fuentes de aprovisionamiento y distribución de obsidianas en la Provincia del Neuquén, noroeste de la Patagonia Argentina. Intersecc. Antropol. 10, 75–88.
López, L., Pérez, A., Batres, D., Stern, C.R., 2009b. Obsidian artifacts in La Pampa, Argentina, from sources in southwest Neuquén. Int. Assoc. Obsidian Stud. Bull. 41, 4–8.
López, L., Pérez, A., Stern, C.R., 2010. Obsidian use among hunter-gatherers in Traful Lake woodland, northwest Patagonia, Argentina. Magallania 38, 239–247.
Martial, L., 1888. Mission Scientifique du Cap Horn. Tomo 1- Histoire de Voyage, Paris.
Mena, F., Jackson, D., 1991. Tecnología y subsistencia en el Alero Entrada Baker, Región de Aysen, Chile. An. del Inst. Patagon. 20, 169–203.
Mena, F., Stafford, T., 2006. Contexto estratigráfico y fechación directa de esqueletos humanos del Holoceno temprano en Cueva Baño (Patagonia Central, Chile). In: Jiménez, J., González, S., Pompa, J., Ortíz, F. (Eds.), 2° Simposio Internacional del Hombre Temprano en América. INAH, Ciudad de México, pp. 139–154.
Mena, F., Lucero, V., Reyes, O., Trejo, V., Velásquez, H., 2000. Cazadores tempranos y tardíos en la cueva Baño Nuevo-1, margen occidental de la estepa centropatagónica (XI Región de Aisén, Chile). An. del Inst. Patagon. 28, 173–195.
Méndez, C., Stern, C., Reyes, O., 2008-9. Transporte de obsidianas a lo largo de los Andes de Patagonia Central (Aisén, Chile). Cazadores Recolectores del Cono Sur 3, 51–68.
Méndez, C.A., Stern, C.R., Reyes, O., Mena, F., 2012. Early Holocene long-distance obsidian transport in central-south Patagonia. Chungara 44, 363–375.
Méndez, C., Reyes, O., Nuevo Delaunay, A., Velasquez, H., Trejo, V., Stern, C.R., 2016. Las Quemas rockshelter, a key for understanding human occupations of Andean forests of Patagonia (Aisén, Chile). Lat. Am. Antiq. 27, 207–226.
Méndez, C., Stern, C.R., Nuevo Delaunay, A., Reyes, O., Gutiérrez, F., Mena, F., 2017. Spatial and temporal distributions of exotic and local obsidians in Central Western Patagonia, southernmost South America. Quat. Int. (this volume).
Mengoni Goñalons, G., 1987. Investigaciones arqueológicas en el noroeste de la meseta central de Santa Cruz. Comunicaciones de las primeras Jornadas de Arqueología de la Patagonia, Chubut, Argentina, pp. 171–175.
Miotti, L.L., 1992. Paleoindian occupation at Piedra Museo locality, Santa Cruz province, Argentina. Curr. Res. Pleistocene 9, 30–31.
Miotti, L.L., 1996. Piedra Museo, Nuevos datos para la ocupación Pleistocénica en Patagonia. In: Gómez Otero, J. (Ed.), Arqueología. Sólo Patagonia. Centro Nacional Patagónico-Consejo Nacional de Investigaciones Científicas y Técnicas, Puerto Madryn, Argentina, pp. 93–101.
Miotti, L.L., Terranova, E., Barberena, R., Hermo, D., Giesso, M., Glascock, M.D., 2012. Geochemical sourcing of obsidian fishtail points: studies for the Somuncurá Plateau (Río Negro, Argentina). In: Miotti, L.L., Salemme, M., Flegenheimer, N., Goebel, T. (Eds.), Southbound. Late Pleistocene Peopling of Latin America. Center for the Study of the First Americans, Texas A&M University, Texas, pp. 127–131.
Molinari, R., Espinosa, S., 1999. Brilla tú, diamante "loco". In: Belardi, J.B., Fernández, P.M., Goñi, R.A., Guráieb, A.G., De Nigrs, M. (Eds.), Soplando en el viento: Actas de las terceras Jornadas de Arqueología de la Patagonia. INAPL-Universidad Nacional de Comahue, Buenos Aires-Neuquén, Argentina, pp. 189–198.
Morello, F., San Román, M., Prieto, A., Stern, C.R., 2001. Nuevos antecedentes para una discusión arqueológica en torno a la obsidiana verde en Patagonia meridional. An. del Inst. Patagon. 29, 129–148.
Morello, F., San Román, M., Prieto, A., 2002. Puntas de proyectil lanceoladas en Patagonia Meridional y Tierra del Fuego. An. del Inst. Patagon. 30, 155–166.
Morello, F., San Román, M., Prieto, A., 2004. Obsidiana verde en Fuego-Patagonia: distribución y estrategias tecnológicas. In: Civalero, M.T., Fernández, P.M., Guráieb, A.G. (Eds.), Contra viento y marea. Arqueología de Patagonia. INAPL y SAA, Buenos Aires, pp. 149–166.
Morello, F., Borrero, L., Massone, M., Stern, C.R., García-Herbst, A., McCulloch, R., Arroyo-Kalin, M., Calás, E., Torres, J., Prieto, A., Martínez, I., Bahamonde, G., Cárdenas, P., 2012. Tierra del Fuego peopling during the Holocene: discussing colonization, biogeographic barriers and interactions in southernmost Patagonia, Chile. Lat. Am. Antiq. 86, 71–87.
Morello, F., Stern, C.R., San Román, M., 2015. Obsidiana verde en Tierra del Fuego y Patagonia: caracterización, distribución y problemáticas culturales a lo largo del Holoceno. Intersecc. Antropol. 139–153 volumen especial 2 (Materias primas líticas en Patagonia).
Muñoz, J., Stern, C.R., 1988. The Quaternary volcanic belt of the southern continental margin of South America: transverse structural and petrochemical variations across the segment between 38°S and 39°S. J. S. Am. Earth Sci. 1, 147–161.
Muñoz, J., Troncoso, R., Duhart, P., Crignola, P., Farmer, G.L., Stern, C.R., 2000. The relation of the mid-Tertiary coastal magmatic belt in south-central Chile (36-44ºS) to the Late Oligocene increase plate convergence rates. Rev. Geol. Chile 27, 177–203.
Musters, G., 1871. At Home with the Patagonianas. A Years Wandering over Untrodeen Ground from the Straits of Magellan to the Río Negro. Colección El Pasado Argentino 1964. Editorial Solar-Hachette, Buenos Aires, Argentina.
Naranjo, J.A., Stern, C.R., 1998. Holocene explosive activity of Hudson volcano, southern Andes. Bull. Volcanol. 59, 291–306.
Naranjo, J., Moreno, H., Emparan, C., Murphy, M., 1993. Volcanismo explosivo reciente en la caldera del volcán Sollipulli, Andes del Sur (39ºS). Rev. Geol. Chile 20 (2), 167–191.
Naranjo, J.A., Singer, B.S., Jicha, B.R., Moreno, H., Lara, L.E., 2017. Holocene tephra succession of Puyehue-Cordón Caulle and Antillanca/Casablanca volcanic complexes, southern Andes (40–41°S). J. Volcanol. Geotherm. Res. http://dx.doi.org/10.1016/j.jvolgeores.2016.11.017.
Onelli, C., 1904. Trepando Los Andes, third ed. Marymar Ediciones, Buenos Aires, Argentina. 1977.
Orquera, L.A., Legoupil, D., Piana, E.L., 2011. Littoral adaptation at the southern end of South America. Quat. Int. 239, 61–69.
Ortiz-Troncoso, O., 1973. Aspectos Arqueológicos de la Península de Brunswick. An. del Inst. Patagon. 6, 109–130.
Ortiz-Troncoso, O., 1975. Los Yacimientos de Punta Santa Ana y Bahía Buena (Patagonia Austral). Excavaciones y Fechados Radiocarbónicos. An. del Inst. Patagon. 7, 93–122.
Ortiz-Troncoso, O., 1979. Punta Santa Ana et Bahía Buena: deux Gisements sur une ancienne ligne de rivage dans le détroit de Magellan. J. de Soc. des Am. 60 (6), 133–204.
Pallo, M.C., Borrero, L.A., 2015. Intercambio o movilidad?: una evaluación sobre el uso de escalas de análisis espaciales y curvas de declinación en Patagonia centro-meridional (Argentina). Lat. Am. Antiq. 26, 287–303.
Paunero, R.S., 2003. The Cerro Tres Tetas (C3T) locality in the central plateau of Santa Cruz, Argentina. In: Bonnichsen, R., Miotti, L., Salemme, M., Flegenheimer, N. (Eds.), Where the South Winds Blow. Ancient Evidences of Paleo South Americans. Center for the Studies of the First Americans (CSFA) y Texas A&M University Press, Texas, USA, pp. 133–140.
Paunero, R.S., Castro, A., 2001. Análisis lítico y funcionalidad del componente inferior del sitio Cueva 1, Localidad Arqueológica Cerro Tres Tetas, provincia de Santa Cruz, Argentina. An. del Inst. Patagon. 29, 189–206.
Pérez, A.E., López, L.G., Stern, C.R., 2012. Descripción y caracterización química de distintas fuentes y tipos de obsidiana en la cordillera de los Andes sudoeste del Neuquén, norpatagonia Argentina. Actas del XVIII Congr. Nac. Arqueol. Chil. 459–470.
Pérez, A.E., Giesso, M., Glascock, M.D., 2015. Fuentes de aprovisionamiento y uso de obsidianas del ámbito boscoso y lacustre andino norpatagónico (provincia del Neuquén, Argentina). Intersecc. Antropol. Vol. Espec. 2, 17–26.
Pérez de Micou, C., Bellelli, C., Aschero, C., 1992. Vestigios minerales y vegetales en la determinación del territorio de explotación de un sitio. In: Borrero, L.A., Lanata, J.L. (Eds.), Análisis Espacial en la Arqueología Patagónica. Ayllu, Buenos Aires, pp. 53–82.
Pino, M., Chavez, M., Navarro, X., Labarca, R., 2013. The late Pleistocene Pilauco site, south central Chile. Quat. Int. 299, 3–12.
Prieto, A., Stern, C.R., Esterves, J., 2013. The peopling of the Fuego-Patagonian fjords by littoral hunter-gatherers after the mid-Holocene H1 eruption of Hudson volcano. Quat. Int. 317, 3–13.
Reyes, M., Moreno, E., Stern, C.R., 2015. Obsidian use among hunter-gatherers in the Musters lake basin (Chubut, Argentina): an approach from techno-morphological and geochemical analysis. Intersecc. Antropol. 16, 491–495.
Reyes, O., Méndez, C., San Román, M., Cárdenas, P., Velásquez, H., Trejo, V., Morello, F., Stern, C., 2007. Seno Gala I: Nuevos resultados en la arqueología de los canales septentrionales (44°S, Región de Aisen, Chile). Magallania 35 (2), 105–119.
Saadat, S., Stern, C.R., 2011. Petrochemistry and genesis of olivine basalts from small

monogenetic parasitic cones of Bazman stratovolcano, Makran arc, southeastern Iran. Lithos 125, 609–617.
Salazar, G., Stern, C.R., 2013. Sources of obsidian from the Lago Aluminé area, Neuquén, Argentina. Magallania 41, 275–284.
Salani, F., Page, A., 1989. El Complejo volcánico Pire Mahuida, provincia del Chubut. Rev. Asoc. Geol. Argent. XLIV (1–4), 364–380.
San Román, M., Prieto, A., 2004. (Dis)continuidad del uso de la obsidiana verde entre poblaciones de adaptación marítima del mar de Otway y estrecho de Magallanes. In: Civalero, M.T., Fernández, P.M., Guráieb, A.G. (Eds.), Contra viento y marea. Arqueología de Patagonia. INAPL y SAA, Buenos Aires, pp. 571–580.
Seelenfreund, A., Rees, C., Bird, R., Bailey, G., Bárcena, R., Durán, V., 1996. Trace element analysis of obsidian sources and artifacts of central Chile (Maule River basin) and western Argentina (Colorado River). Lat. Am. Antiq. 7, 7–20.
Sierpe, V., Prieto, A., Huidobro, C., Stern, C.R., 2010. Excavaciones arqueológicas en el sitio "Alero Quemado" (Ultima Esperanza, Magallanes, Chile). Magallania 37, 177–189.
Singer, B.S., Jicha, B.R., Harper, M.A., Naranjo, J.A., Lara, L.E., Moreno-Roa, H., 2008. Eruptive history, geochronology, and magmatic evolution of the Puyehue-Cordón Caulle volcanic complex, Chile. Bull. Geol. Soc. Am. 120, 599–618.
Stern, C.R., 1991. A mid-Holocene tephra on Tierra del Fuego derived from the Hudson volcano (46ºS): evidence for a large explosive eruption. Rev. Geol. Chile 18, 139–146.
Stern, C.R., 1999. Black obsidian from central-south Patagonia: chemical characteristics, sources and regional distribution of artifacts. In: Belardi, J.B., Fernández, P.M., Goñi, R.A., Guráieb, A.G., De Nigris, M. (Eds.), Soplando en el viento: Actas de las terceras Jornadas de Arqueología de la Patagonia. INAPL-Universidad Nacional de Comahue, Buenos Aires-Neuquén, Argentina, pp. 221–234.
Stern, C.R., 2000a. Sources of obsidian artifacts from the Pali-Aike, Fell's Cave and Cañadón la Leona archaeological sites in southernmost Patagonia. In: Goñi, R. (Ed.), Desde el Pais de los Gigantes: Perspectivas Arqueológicas en Patagonia. Universidad Nacional de la Patagonia Austral, Rio Gallegos, Argentina, pp. 43–54.
Stern, C.R., 2000b. Fuentes de artefactos de obsidiana en la sitios arqueológicos de Pali Aike y Cueva de Fell, Patagonia Austral. An. del Inst. Patagon. 28, 251–263.
Stern, C.R., 2004. Obsidian source and distribution in southernmost Patagonia: review of the current information. In: Civalero, T., Fernández, P., Guráieb, G. (Eds.), Contra viento y marea. Arqueología de Patagonia. INAPL, Buenos Aires, Argentina, pp. 167–178.
Stern, C.R., 2008. Holocene tephrochronology record of large explosive eruptions in the southernmost Patagonia Andes. Bull. Volcanol. 70, 435–454.
Stern, C.R., Aguerre, A., 2013. Sources of obsidian from archaeological sites in La Pampa Argentina. Intersecc. Antropol. 14, 5–11.
Stern, C.R., Curry, P., 1995. Obsidian from IIsla Traiguen, Chilean canals. An. del Inst. Patagon. 23, 119–124.
Stern, C.R., Franco, N., 2000. Obsidiana gris verdosa veteada de la cuenca superior del río Santa Cruz, extremo sur de Patagonia. An. del Inst. Patagon. 28, 265–273.
Stern, C.R., Porter, C., 1991. Origin of the grey to translucent obsidian of Chiloé and the gran Guaiteca Islands. An. del Inst. Patagon. 20, 97–102.
Stern, C.R., Prieto, A., 1991. Origin of the green obsidian of Magallanes. An. del Inst. Patagon. 20, 89–97.
Stern, C.R., Prieto, A., Franco, N., 1995a. Black obsidian from southernmost Patagonia. An. del Inst. Patagon. 23, 105–109.
Stern, C.R., Mena, F., Ashero, A., Goñi, R., 1995b. Black obsidian from central Patagonia. An. del Inst. Patagon. 23, 111–118.
Stern, C.R., Gómez Otero, J., Belardi, J.B., 2000. Características químicas, fuentes potenciales y distribución de differentes tipos de obsidianas en el norte de la provincia del Chubut, Patagonia Argentina. An. del Inst. Patagon. 28, 275–290.
Stern, C.R., Navarro, X., Muñoz, J., 2002. Obsidiana gris translúcida del volcán Chaitén en los sitios arqueológicos de Quilo (Isla Grande de Chiloé) y Chanchan (X region), Chile, y obsidiana de Mioceno en Chiloe. An. del Inst. Patagon. 30, 167–174.
Stern, C.R., Bellelli, C., Pérez de Micou, C., 2007. Sources and distribution of obsidian nodules and archaeological samples from north-central Chubut. In: Morello, F., Martinic, M., Prieto, A., Bahamonde, G. (Eds.), Arqueología de Fuego-Patagonia: Levantando piedras, desenterrando huesos y develando arcanos. Edition CEQUE, Punta Arenas, Chile, pp. 205–209.
Stern, C.R., Navarro, X., Pino, J.D., Vega, R.M., 2008. Nueva fuente de obsidiana en la región de la Araucania, centro-sur de Chile: química y contexto arqueológica de la obsidiana riolítica negra de los Nevados de Sollipulli. Magallania 36, 207–216.
Stern, C.R., Garcia, C., Navarro, X., Muñoz, J., 2009. Sources and Distribution of different types of obsidian from archaeological sites in Central-South Chile (38-44°S). Magallania 37, 179–192.
Stern, C.R., Pereda, I., Aguerre, A., 2012a. Primary and secondary sources of a visually variable but chemically distinct obsidian from west-central Neuquen. Archeometry 54, 442–453.
Stern, C.R., Cruz, I., Caracotche, S., Charlin, J., 2012b. Grey porphyritic obsidian from Chaiten volcano found south of the Santa Crus River in southernmost Patagonia. Magallania 40, 135–142.
Stern, C.R., Castro Esnal, A., Pérez de Micou, C., Méndez, C., Mena, F., 2013. Circulation of obsidian in Patagonia central-sur (44 y 46°S; Chubut, Argentina, y Aisén, Chile). In: Zangrando, A.F., Barberena, R., Gil, A., Neme, G., Giardina, M., Luna, L., Otaola, C., Paulides, S., Salgán, L., Tivoli, A. (Eds.), Tendencias teórico-metodológicas y casos de estudio en la arqueología de la Patagonia. Altuna Impresiones, Mendoza, Argentina, pp. 243–250.
Stern, C.R., Navarro, X., Pino, M., 2017. Sources of rhyolite obsidian, vitreous dacite and aphanitic basalt artifacts in Pilauco, central-south Chile. In: Abstracts, 11th International Symposium on Knappable Materials, Buenos Aires.
Turner, J.C.M., 1973. Descripción Geológica de la hoja 37a and b, Junín de los Andes, Provincia de Neuquén. Carta Geológico-Económica de la República Argentina, Escala 1:200.000. Ministerio de Economía, Secretaría de Estado de Recursos Naturales y Ambiente Humano, Subsecretaría de Minería, Servicio Nacional Minero Geológico, Boletín Nº 138. Buenos Aires.
Zubimendi, M., Ambrustolo, P., 2011. La presencia de items marinos en el interior de la Patagonia central. In: Guiance, A. (Ed.), Movilidad y Migraciones. Editorial Dunken, Buenos Aires, pp. 291–308.

Please cite this article in press as: Stern, C.R., Obsidian sources and distribution in Patagonia, southernmost South America, Quaternary International (2017), http://dx.doi.org/10.1016/j.quaint.2017.07.030