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EARLY HOLOCENE LONG-DISTANCE OBSIDIAN TRANSPORT IN CENTRAL-SOUTH PATAGONIA

TRANSPORTE DE LARGA DISTANCIA DE OBSIDIANAS EN PATAGONIA CENTRO-SUR DURANTE EL HOLOCENO TEMPRANO

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Chronological based data for Early Holocene obsidian transport is not abundant for sites in continental Patagonia. We present ICP-MS analyses of obsidian samples from two well-dated stratified cave archaeological deposits in the steppe plains of the Aisén region (Chile) and discuss the implications of this data for constraining temporal trends in technological decisions related to hunter-gatherers mobility and use of space. The evidence presented suggests that recurrent obsidian circulation routes were established in central-south Patagonia at the onset of the Holocene.

Key words: Obsidian transport, ICP-MS, Patagonia, Early Holocene.

Los datos con fundamento cronológico para el transporte de obsidiana durante el Holoceno Temprano en Patagonia continental son escasos. Presentamos análisis de ICP-MS en muestras de obsidiana de dos depósitos arqueológicos estratificados bien fechados bajo reparo en las planicies esteparias de la región de Aisén (Chile) y discutimos las implicancias de estos datos para precisar las tendencias temporales de las decisiones tecnológicas relacionadas a la movilidad y uso del espacio de cazadores recolectores. La evidencia presentada sugiere que fue con el inicio del Holoceno que las rutas recurrentes de circulación de obsidianas se establecieron en Patagonia centro sur.

Palabras claves: *transporte de obsidiana, ICP-MS, Patagonia, Holoceno Temprano.*

In Patagonia (southernmost South America) there is a significant amount of geochemical obsidian sourcing data which has identified available sources and provided a great deal of information for discussing the spatial scale of prehistoric transport of high-quality obsidian throughout the region (Barberena et al. 2010; Belardi et al. 2006; Civalero and Franco 2003; Favier Dubois et al. 2009; García-Herbst et al. 2007; Méndez 2004; Méndez et al. 2008-9; Molinari and Espinosa 1999; Morello et al. 2004; Stern 1999, 2004; amongst many others). South of 42°S, a total of six sources have been recognized as systematically exploited and their obsidians widely transported (Figure 1). These include translucent grey obsidian from Chaitén volcano (Stern et al. 2002); black and translucent grey-black obsidians from Sacanana and Sierra Negra sources in Somuncurá plateau (Gómez Otero and Stern 2005; Stern et al. 2000); green obsidian from Seno Otway (Morello et al. 2001; Stern and Prieto 1991); banded grey-green obsidian from Cordillera Baguales (Stern and Franco 2000) and black obsidian from Pampa del Asador (Espinosa and Goñi 1999; Stern 1999). The latter has been the most recurrently transported lithic raw-material in the region, with exceptionally long-distant movements of more than 800 km (Stern 2004). As expected, obsidians are not randomly distributed; for instance while Chaitén and Seno Otway obsidian artifacts occur along western archipelagic areas and thus belong broadly, though not exclusively, to the realm of maritime hunter-gatherers of the Pacific (Méndez et al. 2008-9; Morello et al. 2001, 2004), the other four types are basically recorded at continental locations of the steppes of eastern Patagonia and within the forest/steppe transition at the eastern margin of the Andes mountain range (Stern 2004).

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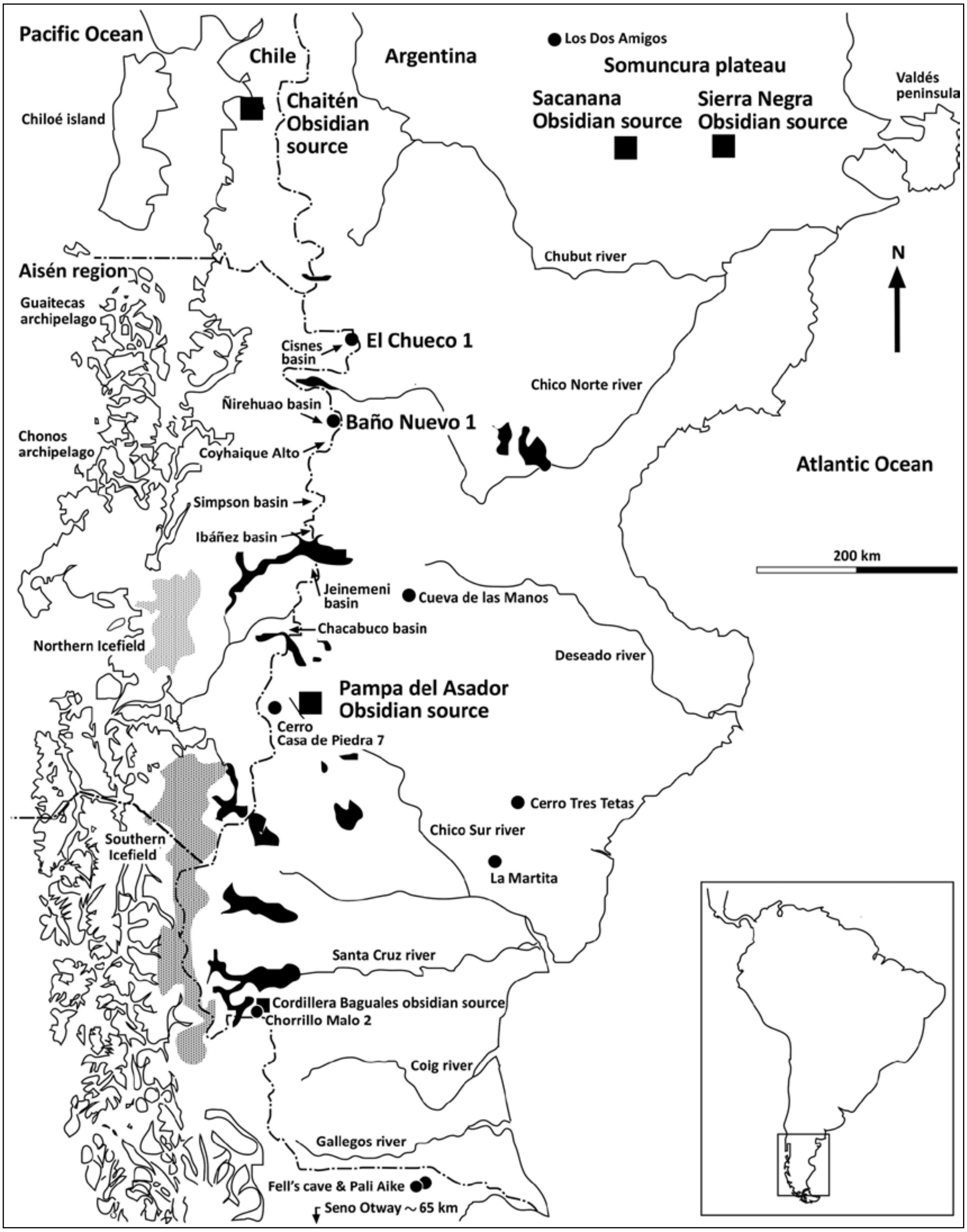

Figure 1. Map of central-south Patagonia and the study area showing well located obsidian sources (large squares); Early Holocene archaeological sites with PDA obsidian type (circles), including the two sites in Aisén discussed in this paper, and river basins in Aisén with surface obsidian evidence.

Mapa de Patagonia centro-sur y el área de estudio mostrando las fuentes de obsidiana precisamente localizadas (cuadrados grandes); sitios arqueológicos del Holoceno Temprano con obsidiana tipo PDA (círculos), incluyendo los dos sitios dentro de Aisén discutidos en el texto y las cuencas de río en Aisén con evidencias superficiales de obsidiana.

Despite the current knowledge of obsidian transport in the spatial dimension, only few papers have addressed the issue at a temporal scale (e.g. San Román and Prieto 2004; Stern 2000, 2004), this being especially true for the terminal Pleistocene (dates earlier than 10,000 ^{14}C yr. b.p. or ~11,500 calendar years before present, cal. yr. b.p.) and the Early Holocene (10,000 to 8,000 ^{14}C yr. b.p., or ~11,500 to 8,800 cal. yr. b.p.), time periods for which ^{14}C-based records with chemically identified obsidian are infrequent in continental Patagonia. One debitage sample from a >12,020 cal. yr. b.p. level at Cerro Tres Tetas (Figure 1) demonstrates a ~200 km transport of black obsidian east from the Pampa del Asador source (Paunero 2003; Stern 2004). Among the sites with Early Holocene components, Cerro Casa de Piedra 7 (11,100-9,940 cal. yr. b.p.) contains obsidian tools and debitage transported ~40 km from the same source (Civalero and Franco 2003). At Chorrillo Malo 2 (11,180 cal. yr. b.p.), despite local obsidian from Cordillera Baguales being frequent, one debitage of black obsidian (>260 km from the Pampa del Asador source) was identified (Civalero and Franco 2003). At all of these sites, as in Cueva de las Manos (10,520 cal. yr. b.p.) and La Martita (8,850 cal. yr. b.p.) black obsidian has been chemically identified as consistent with types from Pampa del Asador, especially type PDA1 (Stern 1999). Study cases at Fell's cave and Pali Aike, yielding Early Holocene obsidian evidence only at the latter, argue for longer distance transport (>500 km), possibly, however, interrupted during the mid Holocene (Stern 2000, 2004). Throughout the paper, all ages are discussed in calendar years b.p. and were calibrated with OxCal 4.01 program (Bronk Ramsey 2009) using ShCal04 curve (McCormac et al. 2004) for ages younger than 9,500 ^{14}C yr. b.p. and IntCal09 curve (Reimer et al. 2009) for older ages.

The scenario described above suggests a significant level of uncertainty when discussing early high-quality rock transport in Patagonia because of the fragmented nature of the archaeological record. Several questions linger. For instance: (1) are surface obsidian assemblages proper means to measure obsidian transport in time, especially those occurring during the Early Holocene? (2) Which sources were the earliest ones to be used consistently? And, (3) were there temporal interruptions in accessing these sources during the Holocene? All these questions have significant implications for understanding the human use of large areas, as seems to be the case for the movements of hunter-gatherers in central-south Patagonia.

In order to address some of these issues, archaeological research in Northern Aisén region (43°45'-49°S, Chile, central-western Patagonia) has proven of interest for understanding long-distance obsidian transport. The region is located distant from all known high-quality sources, thus all obsidians encountered here should be regarded as exotic (Meltzer 1989). Two recently studied stratified cave sites have yielded recurrent human occupations spanning throughout the Holocene. At El Chueco 1, the earliest human deposit is dated to 11,500 cal. yr. b.p. (Reyes et al. 2007) and at Baño Nuevo 1, the first component starts at 10,870 cal. yr. b.p. (Mena and Stafford 2006). They are both located east of the Andes mountain range, thus directly connected with the known obsidian artifact distributions that occur along the steppes of eastern Patagonia. These sites have produced a significant amount of ^{14}C dates, accurately placing the evidence on a temporal scale. These characteristics make them appropriate candidates for measuring peopling dynamics, and provide especially good datasets for exploring the temporal scale of exotic obsidian artifact distribution. In this paper we present ICP-MS data on obsidian artifacts with known ^{14}C-based chronologies for El Chueco and Baño Nuevo sites. Our main goals are to discuss temporal trends in exotic obsidian distributions in Aisén, compare them to previous non-^{14}C-based datasets, and to discuss some implications of our results and those of others when addressing Early Holocene large-scale hunter-gatherers mobility in Patagonia.

Obsidian Artifact Distributions in Aisén

The Aisén region is characterized by a strong west-east precipitation gradient as consequence of the forced subsidence of the Southern westerly winds and the rainshadow effect produced by the Andes. East of this mountain range, the landscape is composed of extensive sedimentary plains, large lakes and several other glacial and volcanic-origin landforms. As a result of the rainfall gradient, evergreen forests occur in the mountainous west, while open areas to the east are characterized by a cold-dry semiarid climate with steppe vegetation. The available palaeoenvironmental archives for the continental area suggest that the most significant climate and landscape changes occurred during the Pleistocene/Holocene transition, and that the current phytogeographical distribution did not vary substantially since the Early Holocene, except for minor fluctuations in the location of the forest/steppe margins (Markgraf et al. 2007; Reyes et al. 2009; Villa-Martínez et al. 2011).

During the last decade, archaeological research in Aisén has managed to compile a series of obsidian sourcing analyses from locations both along the Pacific coast, and especially inland along the forest/steppe margin and the eastern plains. While most of the plains are located in Argentina, in Aisén (Chile) only small areas near the border exhibit open steppe settings and have concentrated most of the archaeological regional sampling and geochemical analyses. This information, based on surface surveys, was summarized in Méndez et al. (2008-9) and suggested the main lingering issue was to assess whether the incidence of obsidian observed in the archaeological assemblages had a chronological significance, and to what extent could the averaged surface evidence –mainly attributed to the late Holocene– be representative of earlier distributional tendencies.

The main obsidian type represented in Aisén is the black-colored obsidian from Pampa del Asador (47°49'S; 70°48'W; Figure 1; Stern 1999). Obsidian artifacts in this rock has been observed throughout the eastern rim of the study area (Chacabuco, Jeinemeni, Ibáñez, Simpson, Ñirehuao, and Cisnes basins and Coyhaique Alto area) showing a strong relation between distance increase and frequency reduction in comparable south-to-north ordered samples (Méndez et al. 2008-9). This is consistent with research at a larger scale which has identified different chemical varieties of this obsidian (types PDA1, 2, 3ab; García-Herbst et al. 2007; Stern 1999), all widely distributed, having been transported >600 km south, crossing the Magellan strait (Stern 2004), and >800 km north, south of Valdés peninsula (Gómez Otero and Stern 2005; Stern et al. 2000), thus making this the most frequent exotic rock in central-south Patagonia. However, surface findings in Aisén show that besides Pampa del Asador types, obsidians from Somuncurá plateau also occur, but solely at the northernmost sampled area, in the upper Cisnes river basin. Metaluminous rhyolite obsidian (type S1) from Sacanana (42°30'S; 68°36 W) and peralkaline rhyolite obsidian (type T/SC1) from Sierra Negra (42°18'S; 66°36'W) have been described for this area (Méndez et al. 2008-9). Obsidians from Sacanana have been observed east of the Andean foothills at a distance of 230 km west of this source (Bellelli and Pereyra 2002; Stern et al. 2011) and in the Atlantic coast at >380 km east of this source (Favier Dubois et al. 2009; Gómez Otero and Stern 2005). Sierra Negra obsidians are represented up to 230 km east of this source along the Atlantic coast (Favier Dubois et al. 2009; Gómez Otero and Stern 2005). The upper Cisnes basin is 325 km distant from Sacanana and 460 km from Sierra Negra, and corresponds to the current south-westernmost limit of distribution of obsidian artifacts from these sources (Méndez et al. 2008-9).

One other common obsidian in Aisén is grey colored obsidian derived from the Chaitén volcano (Figure 1). However, this type is only recorded at the Pacific coast, west of the Andes, which seems to have acted as an effective population barrier, limiting considerably interaction between peoples to the west and east, respectively (Méndez and Reyes 2008). Besides, no evidences have been found in stratigraphical contexts and all available ^{14}C ages for the coast are yet limited to the last 1,800 cal. yr. b.p. (Méndez et al. 2010). Finally, the only local obsidian type in Aisén corresponds to a highly-brittle variety described for the upper Cisnes river basin (type CIS), whose poor knapping quality limited its prehistoric use considerably (Méndez et al. 2008-9).

Excavating and sampling sites in Aysén with multiple occupations, especially those located where the distribution of obsidians artifacts transported from Somuncurá plateau and obsidian from Pampa del Asador meet, should provide data for assessing continuity and change in long-distance exotic rock transport. If earlier occupations at Cisnes basin included northern and southern types that would imply that surface assemblages –roughly attributed to the latest human presence– are a relatively reliable measure of earlier obsidian artifact distributions. Also, this could suggest two non-mutually exclusive implications: a) the distance factor played a key-role in determining obsidian transport independently of time, and b) once a high-quality desirable raw material was recognized by a group, it would be likely to continue its use, thus generating recurrent mobility and/or exchange networks.

The Sites

El Chueco 1 site is located in the steppe plains of the upper Cisnes river basin (44°29'36''S; 71'11'13''W; 914 masl), in a cave within a welded rhyolite tuff outcrop surrounded by a moraine (Reyes et al. 2007). Excavations within the cave (16 m^2), revealed an ordered and continuous depositional sequence mainly composed by roof-fall particles. A total of 14 ^{14}C ages were used in defining six components starting with a significantly discrete event at 11,500 cal. yr. b.p., and continuing with successive low-impact occupational events with dated ranges between: 10,180-9,890; 9,230-7,700; 6,930-6,780; 5.520-5,400, and 3,180-2,570 cal. yr b.p. (Méndez et al. 2011). The main features at the site include a series of 14 hearths and charcoal concentrations which are associated to very few lithic artifacts; mainly formal tools on high-quality siliceous rocks (Table 1). Bones are restricted to the upper levels, starting at ~7,000 cal. yr. b.p. and are dominated by guanaco (*Lama guanicoe*), the largest available ungulate in the region. The occupational events have been interpreted as characteristic of the recurrent use of marginal environments, possibly in a seasonal basis (Méndez et al. 2011). Locally derived Cisnes (CIS) obsidian occurs naturally at this site as low quantity small nodules within the stratigraphic unit; however excessive brittleness makes this rock unfit for knapping, and thus its use is significantly restricted (Méndez et al. 2008-9). Evidence of other exotic obsidians is very limited, yet present at the site; thus inferences about regional patterning should be regarded as preliminary until new data is available.

Baño Nuevo 1 is a cave located in one of several basaltic buttes that stand out above an extensive plain cut by the Ñirehuao river (45°17'36'' S; 71°31'47'' W; 750 masl). As El Chueco, it is surrounded by steppe vegetation and also located near the Chilean-Argentinean border. Excavations (25.13 m^2) revealed an ordered and continuous depositional sequence. A selection of 31 ^{14}C ages was used in defining three anthropogenic components: early 10,870-9,460 cal. yr. b.p., middle 8,770-5,820 cal. yr. b.p., and late 4,660-2,890 cal. yr. b.p. (Mena et al. 2000; Mena and Stafford 2006). Besides its stratigraphic integrity, the site is characterized by stable and low humidity and temperature, allowing the survival of a wide array of organic remains, which includes a ten-individual funerary context directly dated between 10,200-9,700 cal. yr. b.p. A significantly rich bone assemblage characterizes the occupations, guanaco being the most frequent taxa, although other ungulates as huemul (*Hippocamulus bisulcus*) and a wide diversity of birds occur (Mena 2009; Velásquez and Mena 2006). Lithic material at the site was identified through all the sequence, and is comprised primarily by debitage (87.9%) and a small frequency of formal (3.3%) and informal (5.3%) tools (García 2007; Table 1). On the basis of the XRF analysis on one obsidian sample from the lowermost layers (Stern 1999) and macroscopical observations, García (2007) suggested that the only exotic rock was black obsidian from Pampa del Asador, which is especially represented in the middle and late components of the site.

Table 1. Characteristics and data discussed for El Chueco and Baño Nuevo sites (data from stratigraphic samples). *Only debitage.
*Características y datos discutidos para los sitios El Chueco y Baño Nuevo (datos de conjuntos estratigráficos). ** Sólo desechos de talla.*

	El Chueco	Baño Nuevo
# of components (# of ^{14}C ages)	6 (14)	3 (31)
Total lithics	88	1609
Obsidian frequency (*)	4 (4.5%)	163 (10.1%)
General ratio tools/debitage	0.49 (29/59)	0.1 (148/1461)
Obsidian ratio tools/debitage	0.33 (1/3)	0.04 (6/157)
Distance to Pampa del Asador source	360 km	290 km
Distance to Sierra Negra source	460 km	500 km

Methods

Thirty obsidian samples from Baño Nuevo and six samples from El Chueco were selected from archaeological deposits with known ^{14}C-based time frames. Additionally we included five natural obsidian nodules from the latter. Either direct ages or ranges were assigned based on the specific location of the samples within the excavation, with higher precision for those artifacts near dated features, than those within stratigraphic packages with known upper and lower temporal limits. Though color and translucency were recorded for all samples, these criteria were not used in selecting for geochemical analyses based on previous regional experiences that suggest they may not be reliable indicators. Table 2 presents chronological and archaeological information coupled to obsidian types identified and selected chemical elements and Table 3 includes geochemical data on local CIS type obsidian nodules recorded at El Chueco site.

Geochemical characterization of these samples was performed at the Laboratory for Environmental Geochemistry at the University of Colorado (Boulder). The samples were ground into a fine powder and dissolved in a weak solution of HF and HCl. Their trace-element contents were determined by ICP-MS (Inductively Coupled Plasma Mass Spectrometry) using an ELAN DCR-E instrument. U. S. Geological Survey standards were used as the calibration standards, and also to monitor accuracy during ICP-MS analysis (Saadat and Stern 2011). Based on repetitive analysis of these U.S.G.S and other internal laboratory rhyolite standards the obsidian trace-element compositions presented in tables 2 and 3 are considered precise to ±10% at the concentration levels at which they occur (a few parts-per-million). Since obsidian from all the discussed sources in Patagonia south of 42°S have also been analyzed with this same method and in this same laboratory, assignation to individual types is highly reliable. Average compositions of these obsidians are presented in Table 4. The 2 sigma variability of these average compositions are also approximately ±10%, that is essentially within analytical uncertainty, reflecting the fact that the obsidian from these sources are very homogeneous in composition (details are provided in Stern 2000). Analyses on samples from unknown sources were replicated with similar results.

Results

Obsidian types identified at El Chueco and Baño Nuevo sites are summarized in Table 5 and Figure 2. Most of the samples fall in the fields for obsidian from known sources (PDA1, PDA2, PDA3ab, CIS, and T/SC1), with these fields taken from previously published data (Mendez et al. 2008-9; Stern 1999, 2004; Stern et al. 2000), while five samples are from unknown (UK) sources. One of these 5 samples overlaps the field of PDA1 with respect to Ba and Zr, and 2 overlap the field of PDA3ab, but these samples are otherwise chemically different from these known obsidian types with lower Sr content and other differences (Tables 2 and 4).

For El Chueco site, obsidians include local Cisnes (CIS) type as natural (unflaked) nodules and only two pieces of debitage. Two other small obsidian flakes recorded within the 10,180 cal. yr. b.p. level are identified as exotic obsidians, one from Pampa del Asador (PDA 1 type) and one possibly from the Sierra Negra source. This latter sample is very similar to T/SC1 and T/SC2 obsidian types with respect to Ba, Sr, Zr, Y, Hf, Th, and rare-earth-elements, and therefore considered derived from this same source. However this sample shows lower Rb and Nb contents than either types T/SC1 and T/SC2 and thus is not definitively attributable to either one of these two particular types of Sierra Negra obsidian, for which reason we refer to it as T/SC? One highly-curated bifacial point, showing several reutilized edges, and dating to 5,520 cal. yr. b.p., was also identified as PDA1 type (Figure 3).

Previously, geochemical analyses on surface obsidian samples within a 13 km radius from El Chueco identified PDA1, T/SC1, and S1 types at sites with latest Holocene occupations (roughly the last 1,500 cal. yr. b.p.; Méndez et al. 2008-9). These samples showed late stages in the reduction sequence of obsidian (mainly small retouch debitage), as is always the case for obsidian from El Chueco. The spatial coexistence of exotic raw materials from both one of the northern sources at Somuncurá plateau and from the southern source at Pampa del Asador –at least during two different moments (early and latest Holocene)– suggests similar mobility ranges and/or indirect acquisition practices including sources >360 km distant. On the other hand, the poor knapping quality of local Cisnes obsidian has resulted in a significantly low

Table 2. ICP-MS geochemical results for obsidian samples presented in the paper. All values are expressed in parts-per-million. BN: Baño Nuevo; EC: El Chueco; N/D: no data. UK: unknown source; (r): replicated. All individual dates and ranges are expressed in cal. yr. b.p.

Resultados geoquímicos ICP-MS de muestras de obsidiana presentados en el trabajo. Todos los valores se expresan en partes por millón; BN: Baño Nuevo; EC: El Chueco; N/D: sin datos. UK: fuente desconocida; (r): replicado. Todas las edades individuales y por rangos se expresan en años cal. a.p.

Lab. # (site)	Layer/level	^{14}C age/range	Lithic category	Type	Rb	Sr	Y	Zr	Nb	Ba	La	Yb	Th	Hf	Cs
CS901 (BN1)	layer 2a	4240	unretouched tool	PDA1	217	37	30	134	26	243	34.8	3.01	17.7	5.1	10.2
CS902 (BN1)	layer 2	5660-3080	flake	PDA1	222	37	32	139	27	254	36.9	3.26	17.8	5.1	10.9
CS903 (BN1)	layer 2	5660-3080	debitage	PDA2	241	6	39	147	32	29	25.5	4.25	17.1	6.3	11.6
CS904 (BN1)	layer 2	5660-3080	debitage	PDA1	212	36	30	132	26	241	34.6	3.15	17.2	5.1	10.4
CS905 (BN1)	layer 2	5660-3080	by-product	PDA2	246	3	41	134	32	7	19.6	4.64	16.7	6.3	11.8
CS906 (BN1)	layer 2	5660-3080	debitage	PDA2	248	3	43	145	33	8	20.7	4.30	17.7	6.0	12.8
CS907 (BN1)	layer 2	5660-3080	flake	PDA1	211	35	30	131	26	238	35.7	3.18	16.8	4.9	10.4
CS908 (BN1)	layer 3	5660-3080	flake	PDA1	210	33	30	130	25	234	34.2	2.98	16.6	4.8	10.0
CS909 (BN1)	layer 2	5850-5660	debitage	PDA1	212	35	31	134	26	247	35.7	3.15	17.5	5.0	10.7
CS912 (BN1)	layer 3	8770-5660	debitage	PDA2	259	4	46	149	34	8	21.8	4.80	18.8	6.4	13.1
CS913 (BN1)	layer 3	8770-5660	bifacial thinning flake	UK (r)	161	16	42	279	27	554	44.8	5.23	16.4	8.9	5.6
CS973 (BN1)	layer 3	8770-5660	bifacial thinning flake	UK (r)	163	18	44	303	26	581	48.5	5.30	17.9	8.3	6.2
CS914 (BN1)	layer 3	8770-5660	debitage	UK (r)	147	12	28	280	26	374	26.8	3.34	13.2	8.4	4.9
CS974 (BN1)	layer 3	8770-5660	debitage	UK (r)	160	18	42	297	25	568	46.4	5.19	17.0	8.5	6.1
CS915 (BN1)	layer 3	8770-5660	debitage	PDA1	216	35	32	139	26	245	36.2	3.17	17.7	4.9	10.7
CS916 (BN1)	layer 3	8770-5660	bifacial fragment	PDA1	207	33	28	122	25	219	33.3	3.23	16.8	5.4	9.6
CS917 (BN1)	layer 3	8770-5660	bifacial thinning flake	PDA1	202	36	30	126	26	235	33.9	3.05	16.6	5.0	10.0
CS918 (BN1)	layer 3	8770-5660	by-product	PDA2	250	4	41	138	33	7	19.9	4.47	16.9	6.4	12.6
CS911 (BN1)	layer 3	8770	debitage	UK (r)	190	8	35	149	21	221	39.6	3.87	20.0	5.6	7.1
CS976 (BN1)	layer 3	8770	debitage	UK (r)	178	8	31	148	20	204	37.3	3.99	19.5	5.4	6.9
CS924 (BN1)	layer 3	9480	flake	PDA1	206	34	30	127	25	230	33.8	2.94	16.8	4.9	10.2
CS925 (BN1)	layer 3	9700	blade	PDA1	207	36	30	131	26	235	34.3	3.00	17.2	4.9	10.4
CS919 (BN1)	layer 3a	9910-8770	debitage	PDA1	209	32	28	125	28	219	33.0	3.21	18.5	5.8	9.6
CS926 (BN1)	layer 3	9910	debitage	PDA1	213	36	32	134	26	237	35.8	3.24	17.8	5.2	10.6
CS927 (BN1)	layer 3	10170	debitage	PDA1	212	35	31	133	28	246	35.1	3.11	17.5	5.0	10.2
CS928 (BN1)	layer 3	10250	debitage	PDA1	216	35	31	136	28	242	35.8	3.14	17.6	5.1	10.6
CS929 (BN1)	layer 4	10250	flake	PDA3ab	189	64	27	290	31	552	40.2	2.93	19.8	7.5	6.0
CS931 (BN1)	layer 3	10700-8770	flake	PDA2	258	2	45	147	33	8	21.2	4.62	18.3	6.0	13.4
CS920 (BN1)	layer 3	10700-9910	debitage	PDA1	208	34	30	127	25	224	33.2	3.12	15.8	5.2	10.0
CS921 (BN1)	layer 3	10700-9910	blade	PDA2	246	3	42	138	35	10	20.3	4.41	17.1	6.1	12.4
CS922 (BN1)	layer 4	10700-9910	flake	UK (r)	173	15	30	162	22	385	39.2	3.38	19.9	6.9	6.7
CS975 (BN1)	layer 4	10700-9910	flake	UK (r)	164	15	26	161	19	334	35.1	3.42	19.3	5.9	6.0
CS923 (BN1)	layer 3b	10700-9910	debitage	PDA1	206	34	31	132	28	236	34.4	3.18	17.3	4.9	10.2
CS932 (BN8)	Surface	N/D	scraper	PDA1	213	35	31	134	26	236	35.1	3.16	17.4	5.0	10.7
CS1219 (EC1)	90-100 cm	3180	debitage	CIS	126	8	51	372	44	234	51.1	5.51	15.9	10.6	1.6
CS1221 (EC1)	110-120 cm	5400	debitage	CIS	123	8	52	352	45	242	49.2	5.42	15.5	10.3	1.5
CS1302 (EC1)	120-130 cm	5520	projectile point	PDA1	201	35	32	138	26	239	38.3	3.39	19.2	5.5	10.8
CS1217 (EC1)	190-200 cm	10180	debitage	PDA1	198	37	31	139	29	245	34.4	3.25	19.7	5.36	9.5
CS1218 (EC1)	190-200 cm	10180	debitage	T/SC?	346	4	214	2595	180	14	145.6	22.8	53.6	58.3	9.9
CS1301 (EC1)	Surface	N/D	retouched flake	UK	131	12	63	821	49	106	68.1	7.31	19.3	20.1	3.7

Table 3. ICP-MS geochemical results for CIS type obsidian nodules recorded at El Chueco site. All values are expressed in parts-per-million. All individual dates and ranges are expressed in cal. yr. b.p.
Resultados geoquímicos ICP-MS de nódulos de obsidiana tipo CIS registrados en el sitio El Chueco. Todos los valores se expresan en partes por millón. Todas las edades individuales y por rangos se expresan en años cal. a.p.

Lab. # (site)	Layer/level	^{14}C age/range	Rb	Sr	Y	Zr	Nb	Ba	La	Yb	Th	Hf	Cs
CS1226	110-120 cm	5400	126	8	54	366	44	236	55.0	5.84	16.7	10.4	1.6
CS1223	130-140 cm	6780	119	8	50	346	42	229	50.9	5.28	16.0	9.90	1.6
CS1224	130-140 cm	6780	122	9	51	353	43	231	52.3	5.56	16.5	10.1	1.6
CS1225	150-160 cm	7700-6930	141	9	46	307	39	155	51.0	5.25	21.0	11.1	2.5
CS1220	200-210 cm	11500	136	10	49	347	44	266	49.8	5.02	16.0	9.57	1.5

Table 4. ICP-MS geochemical standard average values for obsidian types discussed in the paper. All values are expressed in parts-per-million.
Valores estándar ICP-MS de tipos de obsidianas discutidos en el trabajo. Todos los valores se expresan en partes por millón.

Type	# samples	Rb	Sr	Y	Zr	Nb	Ba	La	Yb	Th	Hf	Cs
CIS	6	135±8	9±1	52±3	356±20	43±2	223±31	52±3	5.6±0.5	18±2	11±0.6	1.8±0.4
PDA1	179	210±14	35±3	31±4	132±8	26±3	237±28	35±4	3.2±0.3	18±2	5.1±0.6	10±0.7
PDA2	24	250±19	4±2	42±4	143±9	33±4	11±3	21±3	4.5±0.5	17±2	6.2±0.8	13±0.9
PDA3ab	6	200±18	53±5	28±4	239±17	31±4	500±38	40±5	2.8±0.4	19±2	6.2±0.9	6.8±0.9
T/SC1	30	640±52	1±1	322±28	3150±272	616±48	1±1	181±14	18±1.5	67±6	76±7	8.6±0.9
T/SC2	8	502±55	3±2	170±15	2240±204	332±29	7±3	151±15	15±1.6	58±6	57±6	6.3±0.8

use, at both surface and stratigraphic sites, despite the ease of local procurement.

For Baño Nuevo site, sourcing obsidian analyses resulted in the identification of types exclusively procured at Pampa del Asador (PDA1, 2, 3ab). In four cases unknown types were identified (replicated and confirmed). Obsidian at Baño Nuevo occurs mainly as debitage, though also includes larger-sized flakes than in the case of El Chueco site. Also the lithic assemblage shows higher obsidian debitage frequencies (early: n = 2, 4.3%; mid: n = 144, 12.7%; and late component: n = 11, 5.4%) especially during

Table 5. Obsidian types and chronological distribution at El Chueco and Baño Nuevo sites.
Tipos de obsidianas en los sitios El Chueco y Baño Nuevo y su distribución cronológica.

Sites; ^{14}C ages/ranges	Obsidian types						
	UK	CIS	T/SC?	PDA1	PDA2	PDA3ab	Total
El Chueco							
Surface	1						1
3.180 cal. yr. b.p.		1					1
5.520-5.400 cal. yr. b.p.		1		1			2
10.180 cal. yr. b.p.			1	1			2
Baño Nuevo components							
Surface (Baño Nuevo 8)				1			1
late (5660-3080 cal. yr. b.p.)				5	3		8
mid (8.770-5.660 cal. yr. b.p.)	3			4	2		9
early (10.700-8.770 cal. yr. b.p.)	1			8	2	1	12
Total of both sites	5	2	1	20	7	1	36

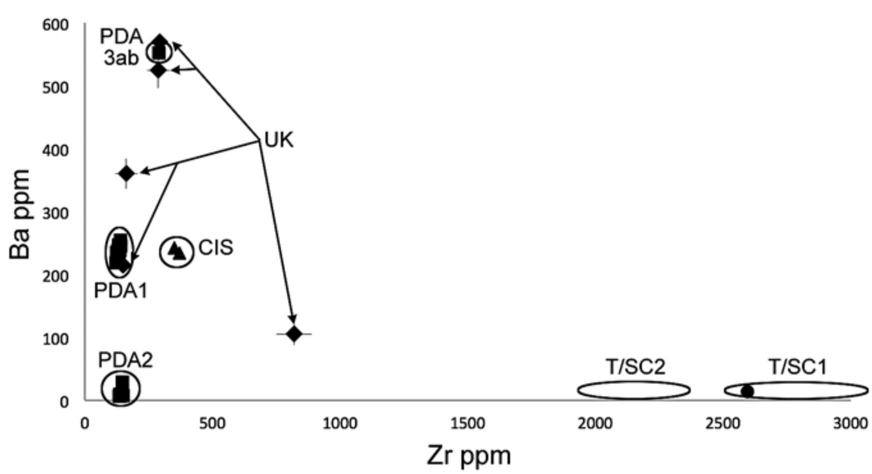

Figure 2. Plot of Ba versus Zr concentrations, in parts-per-million (ppm), for obsidian artifacts from El Chueco and Baño Nuevo. Error bars (±10%) are indicated for three samples from unknown (UK) sources. The analytical uncertainties for the others samples fall within the 95% confidence ellipses defining the fields (taken from Stern 2004, and Mendez et al. 2008-9) for the chemistry of the obsidian from these known sources (PDA1; PDA2; PDA3ab, CIS, T/SC1, and T/SC2).
Gráfico de concentraciones de Ba versus Zr en partes por millón (ppm) para artefactos de obsidiana de El Chueco y Baño Nuevo. Se indican los errores (±10%) para tres muestras de fuentes desconocidas (UK). Las incertidumbres analíticas para todas las otras muestras caen dentro de las elipses de 95% de confianza que definen los campos (obtenidos de Stern 2004 y Méndez et al. 2008-9) para la química de la obsidiana de estas fuentes conocidas (PDA1; PDA2; PDA3ab, CIS, T/SC1 y T/SC2).

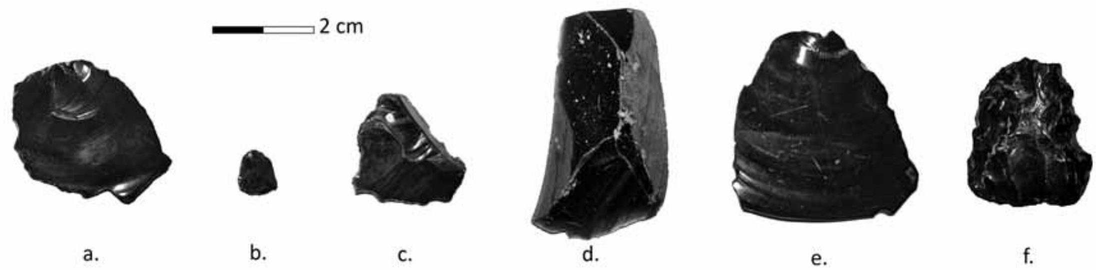

Figure 3. Selected obsidian artifacts sampled for ICP-MS analysis, (a) CS90, (b) CS915, (c) CS920, (d) CS922/975, (e) CS924, and (f) CS1302; (a-e): Baño Nuevo 1, (f) El Chueco 1. All artifacts are PDA1, except CS922/975 which is from unknown source. *Algunos artefactos de obsidiana muestreados para análisis de ICP-MS, (a) CS90, (b) CS915, (c) CS920, (d) CS922/975, (e) CS924 y (f) CS1302; (a-e): Baño Nuevo 1, (f) El Chueco 1. Todos los artefactos son PDA1, excepto CS922/975 que es de fuente desconocida.*

the middle Holocene, which in this case argues in favor of direct procurement strategies. The site yields both middle and later stages in obsidian reduction sequences (based on the size and shape of flakes, and a 0.5% frequency of cortex in the evidences), and only two formal (i.e. curated) bifacial tools (one knife and one projectile point) for the middle Holocene component (García 2007). Unknown sources in the Baño Nuevo assemblage are limited to the early and middle Holocene components, thus suggesting that alternative less-known sources were probably abandoned or less used afterwards. The fact that geochemical analyses on surface materials within Aisén and in wider central-south Patagonia have not recorded these types previously corroborates this idea. Finally, the only analyzed sample from a surface site (BN8) 500 meters away from Baño Nuevo 1 also resulted in PDA1 type.

Discussion

Evidence presented here and elsewhere indicates that Pampa del Asador was the obsidian source most recurrently represented in the exotic raw material artifact distributions in central-south continental Patagonia (García-Herbst et al. 2007; Stern 1999). Although located at a relatively high-altitude (1100 masl), it constitutes a large >50 km^2 area (Rafael Goñi personal communication 2011) where high-quality obsidian nodules, widely distributed by fluvial processes, and other resources are abundant (Espinosa and Goñi 1999). Recent research has pointed out lower-altitude more easy-accessible procurement locations to the east for this same obsidian (Belardi et al. 2006). These characteristics, along with its exceptional knapping quality, justify the preferential selection and long-distance transport it was subjected to. Considering a mid-point at the source, Baño Nuevo site is located 290 km distant, while El Chueco is 360 km away. These sites show a long-distance transport of this rock since at least 10,700 cal. yr. b.p., which is a comparable age as the evidence for the exploitation of this obsidian at the less distant site of Cerro Casa de Piedra 7 (Stern 1999), and younger than other long distant sites such as Cerro Tres Tetas (Paunero 2003; Stern 2004).

As distance from this location increased, and distance to the Somuncurá plateau, particularly the Sierra Negra source, decreased, making both procurement areas "relatively" equidistant, we observe the incorporation of northern sources, as shown by the Early Holocene evidence at El Chueco and from later surface sites in the environs (Méndez et al. 2008-9). Obsidian at the Somuncura plateau sources of Sierra Negra and Sacanana occur also as surface nodules widely distributed by fluvial processes (Stern et al. 2000). Recent studies of sites to the east of Aisén, in Chubut (Argentina), also confirm a distance dependent increase in the abundance of obsidian from Somuncurá plateau sources and decrease in the abundance of Pampa del Asador obsidian to the northeast (Stern et al. 2011). This implies that distance played a key-role in determining obsidian transport, and –answering our first question– it indirectly suggests that geochemical analyses on surface samples should be considered in building hypotheses for understanding earlier exotic rock transport.

The fact that Baño Nuevo yields exclusively obsidians from Pampa del Asador and has no evidence of types from the sources located to the north (despite no biogeographical barriers conditioned transit), further suggests that people occupying the site participated in mobility ranges linked to southern Patagonia, either by moving themselves or through exchange. Besides the obsidian evidence, mtDNA analyses on the Early Holocene human remains deposited at the site shows shared haplogroups (B and C) with southern sites around 52°S (Moraga et al. 2009).

Chronological data presented in this paper suggests Pampa del Asador obsidian source was utilized at areas near the eastern rim of the Andes at least since 10,700 cal. yr. b.p. These data, along with that produced at one terminal Pleistocene (Cerro Tres Tetas) and other Early Holocene sites with the same obsidian types such as Cerro Casa de Piedra 7, Chorrillo Malo 2, Cueva de las Manos and La Martita, further confirms the previously known fact that this source was the most recurrently used south of 42°S.

Kelly and Todd (1988), studying the early peopling of North America, have suggested that human groups colonizing unfamiliar spaces, rather than orienting themselves towards localities, would have developed a technological orientation where the major concern were resources and their availability. This would have probably made individuals more selective regarding which aspects to consider while learning new landscapes (Kelly 2003). Once a high-quality lithic raw-material concentration was recognized as a potential source, this was transformed into a place where recurrent visits transformed it into a central spot from which mobility was organized (Gamble 1999). This scenario seems to be the case with Pampa del Asador source within central-south Patagonia. The paucity of obsidian evidence during the terminal Pleistocene and the posterior increase in frequency (both quantitative and in a site-by-site basis) suggests a cumulative –and probably long-term– process of human management of key-lithic resources and information flows among early settlers. Answering our second question, data from the sites discussed here and elsewhere shows a continuous presence of Pampa del Asador obsidian after the Early Holocene (García-Herbst et al. 2007; Stern 2004), thus suggesting that the mid-Holocene interruption of obsidian transport might have been limited to some regional datasets, as the one described for Fell's cave and Pali Aike (Stern 2000). This remarkably stable pattern of long-distance obsidian transport requires further testing with obsidian samples from additional well-dated multicomponent sites.

Conclusions

Borrero (1994-5) has developed an ecological model for understanding the peopling of new regions using the case of Patagonia. Following this model, Borrero and Franco (1997) focused on a series of expectations, including the lithic behavior. Among them was that exploratory occupations within a region would most probably rely on locally available lithic resources independently of their quality. Data presented by the authors suggests a dominant majority of local raw material for the earliest occupations and an increase in variability only in younger deposits (Borrero and Franco 1997). For instance, geochemical data on undated obsidian fishtail projectile points (appropriate terminal Pleistocene chronological markers in the region) from Los Amigos 2 locality suggests an early use of only local sources around the Somuncurá plateau (Miotti et al. 2010). In the Aisén region, limited evidence dated at 11,500 cal. yr. b.p. at El Chueco shows only one short-lived discarded tool, and this tool is made of local microgranodiorite (Reyes et al. 2007), but by the onset of the Holocene, exotic obsidian and other high-quality siliceous raw materials appear in a series of recurrent occupations at both El Chueco and Baño Nuevo sites (García 2007; Méndez et al. 2011). Thus these observations would be consistent with the suggestion of Borrero and Franco (1997) that the early recognition of sources was primarily coupled with short-distance transport.

After the initial latest Pleistocene regional exploration, recurrent long-distance transport of obsidians beginning in the Early Holocene is supported at El Chueco and Baño Nuevo, where obsidian appears at 10,180 cal. yr. b.p. in the former, and 10,700 cal. yr. b.p. in the latter. These data gathered for the Early Holocene occupational levels in Aisén shows that by this time we are not facing an exploratory stage of the peopling model, but rather the following stage, –colonization–, where recurrent mobility circuits (expressed through raw material transport) would have been established (Borrero 1994-5). Thus, answering our third question, recurrent long-distance obsidian circulation routes originated during or immediately after the onset of the Holocene, as suggested by data presented here and sites elsewhere in central-south Patagonia (Civalero and Franco 2003; Stern 1999, 2004).

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