Hunting and feasting in the pre-Columbian Andes: Exploring the nature and scale of early ceremonial aggregations in Tulan Ravine (5300 to 2400 yr cal. BP) through the circulation of obsidian artefacts

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Abstract

In the pre-Columbian Andes, ceremonial centres were places for large-scale periodic celebrations that facilitated interaction and the reproduction of social life; however, little is known about their role and emergence in early periods. In order to explore the nature and scale of social aggregations, we study the circulation of obsidian artefacts from two early ceremonial centres: Tulan-52 (5300 to 4200 cal. BP) and Tulan-54 (3200 to 2400 cal. BP). Compositional analyses indicate the exploitation of local obsidian, but with a significant contribution from several extra-local sources in the north of the Salar de Atacama (Chile), the Andes highlands (4000 masl) and the northwest of Argentina. According to technological studies and other complementary data, obsidian was employed mainly for the production of bifacial projectile points used in collective hunts and ritual feasts. Our data supports the existence of wide, decentralised inter-community networks fostered by inclusive access to these periodic congregations. We argue that early ceremonial centres were intended to maintain social cohesion and cooperative labour between trans-egalitarian groups in the face of the profound socio-economic changes introduced by the adoption of a more sedentary, pastoralist way of life.

Keywords: Obsidian circulation, Early ceremonialism, South-Central Andes, Compositional analysis, Lithic technology

1. Introduction

Ceremonial centres played a major role in the social organisation of sedentary and agro-pastoralist societies in the South-Central Andes (Adán and Urbina 2007; Callegari et al. 2015; Gordillo 2004; Laguens 2006; Núñez et al. 2005; Tarragó and González 2005; Tartusi and Núñez Regueiro 1993; Uribe 2004). Several works recognise that the construction of religious monumental architecture allowed local elites and political centres to mobilise collective labour and centralise the production and exchange of prestige goods. On the other hand, some authors point out the more corporate and inclusive nature of religious aggregation in these spaces, exercised through political commensalism and public celebrations (Cruz 2007; Nielsen 2006; 2007; Lazzari et al. 2017).

So far, most of these studies have focused on late agro-pastoralist societies. Little is known about the role of large-scale ceremonialism in early periods, or the social conditions of its emergence. Several decades of archaeological research in Tulan Ravine (23.5ºS, 68ºW) have permitted documentation of the construction of two early ceremonial centres from the Late Archaic (5500 to 3500 cal. BP) and Early Formative Periods (3500 to 2400 cal BP) (Figure 1). These findings allowed us to track the beginnings of ceremonial architecture to hunter-gatherer and initial pastoralist groups, prior to institutionalised social inequality and an agriculture-based economy. The evidence in these sites has been interpreted as being the result of large periodic feasts and collective hunts, celebrated periodically by neighbouring local groups (De Souza et al. 2010; Núñez and Perlès 2018; Núñez et al. 2006a; Núñez et al. 2007; Núñez et al. 2017a; Núñez et al. 2017b); however, the extent of these social aggregations and the structure of interaction networks with neighbouring groups are still unknown. Many of our assumptions are based on typological comparisons or on the presence of exotic materials from remote areas that are difficult to determine accurately.

To estimate the scale and nature of inter-community aggregations in these places, and how they evolved over time, we study the circulation of obsidian artefacts recovered in archaeological excavations of two early ceremonial centres in Tulan Ravine: Tulan-52 (5300 to 4200 cal. BP) and Tulan-54 (3200 to 2400 cal. BP). Compositional analyses (X-ray fluorescence and neutron activation analysis) were carried out to determine the source of origin of obsidian samples. In addition, a technological study was applied to a larger lithic assemblage in order to assess the modes of circulation of lithic raw materials. The combination of these methodological approaches allowed us to identify the obsidian sources and the activities in which lithic artefacts participated at both sites. Based on these results, and together with other lines of complementary evidence, we offer a new understanding of the emergence and role of early ceremonialism in the area and its relationships with other archaeological sites of the South-Central Andes.

Figure 1. Map showing the location of the sites and the study area

2. Archaeological background

Located south of the Salar de Atacama basin (22ºS, 67ºW; 3000 masl), Tulan ravine has been a key area for understanding the transition from hunter-gatherer to agro-pastoral societies in the South-Central Andes (Núñez et al. 2006a). We currently know that after the arid Middle Holocene, Late Archaic hunter-gatherers concentrated around the wetlands and springs along the upper course of Tulan Ravine. In this more favourable scenario, the process of camelid domestication was successfully consolidated (Cartajena 2011). This resulted in a demographic increase and a reduction in mobility, leading to the definitive adoption of a more sedentary settlement system by the Early Formative Period. Unlike other cultural developments in the Andes with an agricultural economy, Tulan groups developed a way of life based mainly on breeding and pastoralism of camelids with an important contribution from hunting and gathering. During this period of profound change, the first villages were settled while architectural complexes were erected exclusively as ceremonial centres. These spaces fostered social aggregation and interaction among neighbouring groups through the reproduction of periodic ceremonies. Integrated into wide Andean interaction networks, Tulan became consolidated as an independent cultural and productive node in the South-Central Andes (Núñez et al. 2006a; Núñez et al. 2007).

2.1. Tulan-52

As far as is currently known, the construction of Tulan-52 was the first communal building effort of non-domestic architecture in the area. The evidence recovered at the site indicates that this was a space for temporary use occupied by large aggregations of hunter-gatherer groups that congregated periodically for collective hunts and feasts (Núñez and Perlès 2018). Excavations of 57 m^2 have exposed an architectural complex formed by agglomerated circular and sub-circular structures (Figure 2A), built with large vertical blocks and with recessed wall niches (De Souza et al. 2010; Núñez 1981, 1992; Núñez et al. 2006a). The central enclosures were erected and occupied between 5000 and 4200 cal. BP (Figure 3A); a test-pit in the periphery that provided a date of 4580±90 yr BP (5442-4873 cal. BP) could correspond to a previous phase of occupation (Núñez et al. 2006a).

The large amount of domestic remains consumed and discarded during community aggregations formed a large feasting midden mound that covered the central structures to a depth of 1.3 m. Among the faunal assemblages, vicuña (*Vicugna vicugna*) and guanaco (*Lama guanicoe*) predominate (Cartajena 2009). The presence of domestic camelids (*Lama glama*) was also revealed, which suggests that breeding of camelids was already established (Cartajena 2011; Cartajena et al. 2007, 2013; Valenzuela 2018). The processing and consumption of animals at the site was assisted by a diverse and abundant lithic assemblage discarded around several fire-places (De Souza et al. 2010; Núñez et al. 2006a). The food remains include wild plant species (*Opuntia* sp., *Geoffroea decorticans*, *Prosopis alba*) obtained through gathering and to a lesser extent some cultivated plants (*Lagenaria* sp.) (McRostie 2013; Núñez et al. 2009). Conical lithic mortars and grinding implements are quite abundant at the site, reflecting intensive processing activities.

Inside the narrow structures, there is evidence that indicates the performance of ritual activities (Núñez and Perlès 2018). Among the deposits, a bone with pyrographic engraving, feathers, hematite and red pigment have been recovered that could have been part of the ritual paraphernalia (De Souza et al. 2010; Núñez et al. 2016). A lithic block with linear-parallel incisions was deposited in an undercut pit next to one of the niches. The production of ornamental goods also acquired great importance. A significant number of shell, bone and a few copper mineral beads have been recovered at the site (Soto 2010).

Figure 2. Ceremonial centres of Tulan ravine

2.2. Tulan-54

The Tulan-54 temple consists of a large, semi-subterranean architectural complex built in several stages between 3200 and 2400 cal. BP (Figure 3B) (Núñez et al. 2005; 2016; 2017a; 2017b). Its construction required great mobilisation of communal labour. The single main enclosure involved the extraction of about 500 m^3 of sediment and the transportation of more than 25 tons of rocks, including megalithic blocks (Núñez et al. 2006b). The central nave was built on a large undermined depression, where an oval perimeter wall was erected with large blocks partially buried in a volcanic ash floor and supported by large external buttresses. Recessed wall niches were placed at certain intervals, several of which communicated with external chambers and vaults (Cartajena et al. 2019a; Núñez et al. 2019) (Figure 2B).

The repeated community celebrations outside the temple led to the accumulation of a dense feasting midden mound of about 2800 m^2 and 1.80 m depth that covered the central structures in a period of no more than 200 years (Cartajena et al. 2019b; Núñez et al. 2017a). At meals, wild plants such as *Opuntia* sp., *Scirpus* sp., *Atriplex* sp. (among others) continued to play a central role, although with a limited presence of cultivated species such as chillies (*Capsicum* sp.), maize (*Zea mays)* and quinoa (*Chenopodium quinoa*) (Holden 1991; McRostie 2014; Núñez et al. 2009). Plant processing involved a profuse milling technology of *metates*, *conanas*, grinding implements and pestles. Some "Los Morros" ceramic vessels served as containers for storing, cooking and serving food (Kalazich 2006). The high frequency of bone remains indicates the importance of the hunting of wild camelids, although the evidence shows a significative contribution of domestic camelids (*Lama glama*) (Cartajena et al. 2007; Cartajena et al. 2013; Valenzuela 2018). Food was prepared and consumed on site, as can be seen from the abundant hearths and the massive discard of lithic and bone remains. The production of necklace beads and pendants reaches a remarkable frequency (Soto 2010), also reflected in a disproportionate number of micro-perforators (Núñez et al. 2017a).

Twenty-eight human infants were inhumed in the original floor (Holden 1991), plus one in an outdoor chamber (Núñez et al. 2019). All of them were deposited in excavated pits, accompanied by diverse goods such as shells, gold, copper and lead artefacts, projectile points, minerals, basketry, bone spear-throwers, etc. and then covered with worked stone slabs (Núñez et al. 2017a, 2017b). Similar offerings were also deposited below the niches (Cartajena et al. 2019a; Núñez et al. 2019) and prepared hearths were placed inside the main enclosures. Evidence of cultigens such as cucurbitaceae, quinoa and maize suggests the consumption of non-daily meals, probably served in foreign ceramics such as those recovered in the central enclosure (Núñez et al. 2009). The presence of ceramic pipes also indicate smoking activities and the consumption of hallucinogens such as cebil (*Anadenanthera* sp.). Prior to the definitive abandonment of the site, several graves of adults with a few offerings were buried in the periphery of the site and then sealed by large mounds of rocks (Núñez et al. 2005).

Figure 3. Summed probability distributions of ^{14}C calibrated dates: (A) Tulan-52; (B) Tulan-54. Dates calibrated with OxCal 4.2 software (Bronk Ramsey 2017) using the ShCal020 curve (Hogg et al. 2020)

3. Material and method

In order to explore obsidian circulation we combined compositional and technological analysis. To determine obsidian sources, x-ray fluorescence analysis (XRF) was applied to 87 samples selected from well-dated excavation units located inside the central enclosures (E6SW from Tulan-52 and 8ANW from Tulan-54). Ten samples were submitted to neutron activation analysis (NAA) which offers greater precision and accuracy, and allows more elements to be measured. Through the examination of bivariate plots of different elements and element ratios, a source was assigned to each artefact (Glascock et al., 1998). All XRF and NAA measurements were performed at the Archaeometry Laboratory at the University of Missouri Research Reactor (MURR). Compositional data can be consulted at the MURR website https://archaeometry.missouri.edu/datasets/. The technological studies were carried out on the complete lithic assemblages from two other excavation units at each site (A6SW from Tulan-52 and H-2 from Tulan-54).

3.1. XRF

Non-destructive XRF analyses were performed on a ThermoScientific ARL Quantx energy-dispersive XRF spectrometer equipped with a rhodium-based X-ray tube and thermoelectrically cooled silicon-drift detector (SDD). The X-ray tube was operated at 35kV and the current adjusted automatically to produce an optimal counting rate with a fixed dead time of 30%. A counting time of two minutes each enabled measurement of nine elements (Mn, Fe, Zn, Rb, Sr, Y, Zr, Nb, and Th). Calibration of the Quantx ED-XRF involved measuring a set of 40 well-characterised obsidian source samples previously analysed by NAA, inductively coupled plasma-mass spectrometry (ICP-MS), and XRF at MURR (Glascock 2020). Subsequently, measured counts from ED-XRF were converted to concentration by normalisation to the area of the Compton scattering peak. Samples from sources have been characterised previously by both XRF and NAA by Capriles et al. (2018), Seelenfreund et al. (2010a, 2010b) and Yacobaccio et al. (2004).

3.2. NAA

The samples were prepared by weighing small fragments into high-purity polyethylene and quartz vials used for short and long irradiation periods respectively. All weights were recorded to 0.01 mg. The standard reference material used for obsidian analysis is SRM-278 Obsidian Rock, which was prepared similarly to the artefacts. The short irradiation samples were irradiated in pairs for 5s by a neutron flux of 8×10^{13} n cm^2 s^{-1} (Glascock et al. 1994). Standards were irradiated before and after every 15 artefacts to monitor any flux changes. Short irradiation was followed by a 25-min decay and 12-min count on separate high-purity germanium (HPGe) detectors to measure the following short-lived elements: Al, Ba, Cl, Dy, K, Mn, and Na. Afterward, the samples were submitted to long irradiation of 48 h in a bundle of 30 artefacts and four standards using a neutron flux of 6×10^{13} n cm^2 s^{-1} followed by two counts on each sample. The first count was carried out after a decay of 7 days to measure seven medium-lived elements (Ba, La, Lu, Nd, Sm, U, and Yb). The replicate measure of Ba was included as a check on the consistency between the short and long irradiations. After the samples had decayed for an extra 14-20 days, they were counted once more to measure fifteen additional long-lived elements (Ce, Co, Cs, Eu, Fe, Hf, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn and Zr).

3.3. Technological study

In the first stage of analysis, the lithic assemblages were separated according to major classes of rocks following criteria of texture, colour, cortex and granulometry. All obsidian artefacts were considered as a single petrographic group due to the difficulty of separating them macroscopically. In the second stage, all the artefacts were classified into general technological groups according to the following classes: (1) cores and tested blocks; (2) waste-flakes and debris; (3) flake tools; and (4) bifacial tools. Then they were separated into sub-classes according to the position, orientation and extension of the retouch on the blank and grouped into typological categories of instruments recognised in previous works. The retouched tools were described according to metric, technological and typological variables.

4. Results

4.1. XRF

Multiple log-log scatterplots were compared using pairs of elements and element ratios with 90% confidence ellipses for groups containing more than two samples; the best matches were obtained using Rb vs. Zr (Figure 4A) and Y/Zr vs. Rb/Zr (Figure 4B). Element concentrations of Mn, Fe, Zn, Rb, Sr, Y, Zr, Nb and Th are listed in detail in Appendix A. As a result, 16 different compositional fingerprints were identified. The source assignments and distance to the source of origin are listed in Table 1. Of these, six sources are consistent with known sources in Argentina and Chile. The Argentine sources identified are Ona-Las Cuevas (OLC) (n = 3), Quirón (n = 2), Salar del Hombre Muerto (SHM) (n = 6), Alto Tocomar (n = 8) and Zapaleri/Tara (n = 10). The Chilean source identified is Quebrada Pelun (n = 6). The remaining 52 artefacts are distributed in ten different unknown groups: Unk-AA (n = 31), Unk-CC (n = 4), Unk-BB (n = 6), Unk-DD (n = 2), Unk-EE (n = 2), Unk-FF (n = 2), Unk-GG (n = 2), Unk-HH (n = 1), Unk-II (n = 1), and Unk-JJ (n = 1). Five of the unknown fingerprints (CC, DD, EE, FF, and GG) cluster together in the plots, while the Unk-BB cluster is close to Quebrada Pelun. Unk-AA (n = 31) corresponds to a grey-veined volcanic glass that provides a high percentage of the study samples.

Figure 4. Log-log scatterplot from XRF analysis for obsidian artefacts projected against 90% confidence ellipses for major sources: (A) Zr versus Rb; (B) Y/Zr versus Rb/Zr

Table 1. Source assignment and distance to the source for archaeological obsidian artefacts

Obsidian source	**Geographic zone**	**Tulan-52**		**Tulan-54**		**Distance to the source (km)**
		n	%	*n*	%	
Quebrada Pelun	Atacama basin, Northern Chile	4	8,51	2	5	115
Zapaleri / Tara / Jarellón	Atacama, northern Chile / Jujuy, Argentina	6	12,77	4	10	110-140
Alto Tocomar	Salta, Argentina	0	0	8	20	165
Quirón	Salta, Argentina	2	4,26	0	0	130
Ona - Las Cuevas	Catamarca, Argentina	2	4,26	1	2,50	180
Salar del Hombre Muerto	Catamarca, Argentina	3	6,38	3	7,5	210
Unk-AA	Tulan area (?)	11	23,4	20	50	(?)
Unk-BB	Quebrada Pelun (?)	6	12,77	0	0	(?)
Unk-CC	Atacama (?)	4	8,51	0	0	(?)
Unk-DD	Atacama (?)	1	2,13	1	2,5	(?)
Unk-EE	Atacama (?)	2	4,26	0	0	(?)
Unk-FF	Atacama (?)	1	2,13	1	2,5	(?)
Unk-GG	Atacama (?)	2	4,26	0	0	(?)
Unk-HH	(?)	1	2,13	0	0	(?)
Unk-II	(?)	1	2,13	0	0	(?)
Unk-JJ	(?)	1	2,13	0	0	(?)

4.2. NAA

Ten of the samples previously assigned to unknown sources by XRF were submitted to NAA to verify that they do not match known sources. These samples were RLO002, RLO007, RLO010, RLO015, RLO016, RLO022, RLO024, RLO032, RLO035, and RLO040. Compositional data of the analysis is listed in Appendix B. Artefact RLO016 is consistent with Salar del Hombre Muerto (SHM) while the rest of the pieces did not match previously known sources.

4.3. Technological analysis

In the Tulan-52 assemblage, 26.96% (n = 1562) of a total of 5794 pieces correspond to obsidian artefacts. At Tulan-54, obsidian account for only 4.32% (n = 322) of a total of 7454 pieces. This difference is explained by the large increase in the proportion of siliceous rocks in the Tulan-54 assemblage, used mainly in the production of micro-perforators (Table 2). Unlike the others, the grey-veined obsidian attributed to the Unk-AA source is easily distinguishable from the other sub-varieties, representing between 70% and 85% of the total obsidian assemblages. Obsidian from both sites show a low presence of cortex. In Tulan-52, only 1.47% (n = 23) of the pieces presented cortex, while in Tulan-54 only 2.8% (n = 9) did; in both cases they correspond almost entirely to the Unk-AA grey obsidian.

Table 2. Distribution of major rock classes in lithic assemblages

	Tulan-52	**Tulan-54**

Class of rock	*n*	%	*n*	%
Andesite	484	8,35	600	8,05
Basalt	1163	20,07	493	6,61
Siliceous rocks	2167	37,40	5681	76,21
Obsidian	1562	26,96	322	4,32
Tuff	66	1,14	329	4,41
Others	352	6,08	29	0,39

Based on the technological classification, obsidian is primarily intended for bifacial tool production. Indeed, projectile points are the predominant techno-typological class at both sites (Table 3). Other retouched tools such as perforators, knives and wedges were recognised but to a lesser extent. All of them show unifacial-marginal retouching with low technical investment in production compared to bifacial tools. The significant frequency of debris and waste-flakes and the presence of cores indicate local production, particularly those made of grey obsidian. This also applies to a part of the projectile points considering the moderate frequency of bifacial reduction flakes, especially of those produced in the final stages of knapping. In Tulan-52 assemblages, 76.47% (n = 13) of the projectile points correspond to the lanceolate type with convex base, and in some cases pointed or straight base. They are mainly small in size (Figure 5a) with an average maximum length of 3.5 cm, although some pieces exceed 8 cm. In the Tulan-54 assemblage, projectile points are mostly stemmed with wings (77.61%). The general shapes of the blade are lanceolate or triangular, often with denticulate edges and contracting stem. They are small in size, with average maximum lengths between 1 and 4 cm, except for some unusual larger pieces that, according to their depositional context, do not seem to have been used but rather were part of offerings (Figure 5b). The lanceolate type seems to have continued in use but to a lesser extent (14.93%).

Table 3. Techno-typological classes of obsidian artefacts

Techno-typological class	Tulan-52		Tulan-54	
	n	%	*n*	%
Retouched tools				
End-scraper	0	0	2	3,77
Knife	4	15,38	5	9,43
Notch	0	0	1	1,89
Perforator	3	11,54	9	16,98
Burin	0	0	4	7,55
Wedge	0	0,00	7	13,21
Bifacial Preform	2	7,69	1	1,89
Multifunctional Tool	0	0	5	9,43
Projectile Point	17	65,38	19	35,85
Total retouched tools	**26**	**100**	**53**	**100**
Core	**9**		**6**	
Debris and subproducts				
Flake	1417	92,80	86	32,70
Blade	54	3,54	19	7,22
Bifacial reduction flake	23	1,51	29	11,03
Indeterminate fragment	30	1,96	63	23,95

Indeterminate clast	2	0,13	66	25,10
Undetermined	1	0,07	0	0,00
Total debris and subproducts	**1527**	**100**	**263**	**100**

Figure 5. Projectile Point diversity: (A) Lanceolate type (small-size range) with convex base from Tulan-52; (B) Stemmed type from Tulan-54

5. Discussion

5.1. Obsidian circulation and long-distance contacts

As a result of the provenance analyses, 16 compositional fingerprints were detected. Six of them correspond to known sources which allow us to trace the networks of obsidian circulation (Figure 6). The presence of the Quebrada Pelun source, available at a distance of 110-120 km, reveals a close relationship with the north of the Atacama basin. Although it is not possible to distinguish accurately between the Zapaleri, Jarellón and Tara sources, because their geochemical signatures overlap, in any of these cases transfer to Tulan would imply circulation distances over 100 km from the highlands. The sources of Quirón and Alto Tocomar in the Salta region are located 130-165 km to the east. The sources OLC and SHM located in the Catamarca region are distributed at an even greater distance of 180-210 km to the southwest. A potential local origin can be attributed to most of the unknown sources. Given its frequency (in both technological and provenance analysis), Unk-AA may well be located in the area surrounding the settlements. Another five unknowns (CC, DD, EE, FF, and GG), which cluster closely in the plots, could correspond to related sub-sources, while Unk-BB can be considered as a sub-source of Quebrada Pelun based on its compositional profile. When the two sites are compared, there are no striking differences between them except for the record of Alto Tocomar in Tulan-52 but not Quirón. The reverse situation is observed in Tulan-54. Since both sources are in the same direction and are not far from each other, this situation could be explained by a sampling problem. Another notable difference is the greater presence of unknown sources in Tulan-52, especially Unk-BB; if it is a sub-source of Pelun, its frequency would reinforce the relationship of this site with the northern Atacama basin.

For now, there are no contemporary sites with such a diversity of obsidian sources. The privileged location of Tulan Ravine with respect to the inter-Andean passes must have positioned it as an important node within the mobility and interaction networks between the two slopes of the Andes. The mountain routes in the highlands of Tulan were intensely used by indigenous pastoralists and muleteers until historical periods (Molina Otárola 2011). In fact, Tulan-52 and Tulan-54 received obsidian from both the northern and southern Argentine Puna. This only occurs in very few contemporary archaeological sites of the Salta region (Figure 6). During the final Middle Holocene (5700 to 4400 cal. BP), an obsidian artefact from the Tocomar source was identified at the Alero Cuevas site; while in the neighbouring Alero Pozo Cavado site, several artefacts correspond to the Archibarca source in Catamarca (López 2020). During the Formative Period, obsidian artefacts recovered in a layer dated to around 1900 cal. BP arrived at the site from Quirón, Archibarca, Zapaleri, Tocomar and an unknown source ("Unk-D") (Mercuri and Restifo 2014) which has also been identified in other sites of later periods (Mercuri and Glascock 2011). This last source matches quite well (both for its geochemical fingerprint and macroscopic description) with our presumed local Unk-AA source. Another site in the Salta region is Aldea de Las Cuevas located in Quebrada El Toro, which is considered to be an important node in interaction networks during the initial Formative Period. Obsidian artefacts from Ona-Las Cuevas, Zapaleri, Alto Tocomar and Laguna Cavi were found among the lithic assemblages (Álvarez Soncini and De Feo 2010; Yacobaccio et al. 2002; Yacobaccio et al. 2004). Everything seems to indicate that the exchange area with Tulan is the Salta region; however, no SHM obsidian have been recorded in contemporaneous sites in Salta, despite the fact that these raw materials were widely exploited in Catamarca (Escola et al. 2016). How could transfer of this material to Tulan be explained? A plausible answer is the existence of direct, parallel contacts with groups in the Catamarca region in the southern part of the northwest of Argentina (NWA).

Certainly, our findings force us to rethink our current models of mobility and interaction. Obsidian transfers at these sites reveal an interaction network between remote areas, prior to the development of caravan traffic that seems to have been consolidated only from the Late Formative Period (2400 to 1400 cal. BP onwards) in the area (Núñez 2005; Núñez and Briones 2012). In fact, we had assumed that ties with other groups during the Late Archaic were largely limited to the western slope of the Andes and the coast (De Souza et al. 2010; Núñez et al. 2007). In Tulan-52, conch shell remains from the Pacific (*Oliva peruviana* and *Pecten purpuratus*) have been well recorded, and there are remarkable techno-typological similarities with the Chiu-Chiu Complex in the Loa basin (Druss 1976; Jackson and Benavente 2010). Until now, no evidence of contact with the eastern slope has been observed. Extra-local goods are more recurrent from the Early Formative Period, which has led investigators to suggest a rapid expansion of the interaction networks during this period thanks to the use of pack animals. In addition to the conch-shell remains (Soto 2015), extra-local contacts can be inferred from the distribution of "Los Morros" ceramics (Uribe 2006), smoking pipes and intrusive ceramics common in NWA, as well as the presence of gastropods of the Andean yunga (*Strophocheilus oblongus*) or introduced plants such as cebil and maize (*Zea mays*) (McRostie 2014; Núñez et al. 2007; Núñez et al., 2009).

Figure 6. Obsidian circulation networks of Tulan ceremonial centres: (1) Quebrada Pelun; (2) Jarellón Caldera; (3) Zapaleri; (4) Tara; (5) Caldera Vilama; (6) Quirón; (7) Alto Tocomar; (8) Ramadas; (9) Archibarca; (10) Ona-Las Cuevas; (11) Salar del Hombre Muerto. Obsidian circulation from the source of origin to the sites is indicated by black arrows. Circulation of other types of materials mentioned in the text is shown by dotted arrows.

5.2. Cooperative hunting and feasts

At both sites, obsidian was used primarily for projectile point production. This trend does not appear to have been altered despite morphological and technological changes in weapons systems. During the Late Archaic period, lanceolate points were hafted onto throwing darts which were propelled by spear-throwers. Conversely, by the Formative Period, stemmed points would have been used in bow and arrow weapon systems (De Souza 2004, 2011). The presence of flake-tools shows that obsidian was also employed for other complementary activities. Since the sub-varieties of obsidian cannot be separated macroscopically, distinguishing differential technological management remains impossible for now. However, a significant part at least of the projectile points and other obsidian tools were produced locally. This is especially true for the Unk-AA grey obsidian source. In the case of extra-local sources, they could have arrived already worked.

Although we cannot rule out the existence of inter-group conflicts, which were quite common in trans-egalitarian societies, the significant frequency of projectile points in tandem with the high representation of wild camelids in the faunal record indicate that hunting was an important and recurrent activity in both contexts (Cartajena et al. 2019a, 2019b). Several lines of evidence support interpretation of these sites as aggregation sites for ceremonial practices and feasts preceded by intensive hunts. In the absence of storage, the capture of prey and plant gathering through collaborative labour was probably an effective strategy to provide copious quantities of food. The collection of plants must also have provided a good part of the meals judging by the large number of mortars and grinding tools at the sites. The scene of camelids in motion, depicted in rock art related to the Confluencia-style inside the inner enclosure of Tulan-54 (Núñez et al. 2017), could well be a representation of such a hunting events. Other evidence in the same site also reveal the relevance and social role of hunting. Several spear-throwers and projectile points were deposited as offerings alongside sacrificed infants while about 400 m away from the site, a bundle of mats tied with camelid wool twine was intentionally buried inside the rock-shelter (Tulan-109) (Núñez et al. 2009). The bundle offering contained four spear-throwers made of camelid radio-ulnas, a medial dart component, three carved pieces of wood, and two bone head-ornaments commonly represented on hunters' heads in the Confluencia rock art style. According to ethno-historical data, cooperative hunts of vicuña persisted until recent times. During the summer (February and March), local groups from various neighbouring villages that were practically depopulated after the annual carnival carried out collective drives and hunting forays in the highlands (>3800 masl) (Bowman, 1924). Tulan thus offered a strategic position not only within inter-Andean communication routes, but also for seasonal access to the highlands.

At this point, the acquisition of obsidian artefacts can be attributed to several different modes of circulation. A first mode of circulation could be related to inter-community exchange. It has been suggested that during the Formative Period in NWA, stemmed obsidian points, particularly from the Ona-Las Cuevas source, circulated widely over great distances through exchange as prestige goods (Escola 2007; Yacobaccio 2012). The presence of bifacial points from this and other NWA sources indicate that Tulan could have been integrated into these exchange networks. A similar status can be also argued for those unused projectile points included as offerings below the niches in Tulan-54 (Núñez et al. 2019), which also indicate the presence of obsidian artefacts in ritual performances. However, these cases appear to be exceptional and rare. Most obsidian tools were made from local sources and discarded in the feasting middens, and show traces of having been used. This pattern is consistent with a second mode of circulation related to local household production of weapons for hunting and other domestic tools. A third mode consists in the complementary circulation of some obsidian tools transported by non-local hunters or foreign participants from remote regions. This would explain the presence of exotic obsidian despite its wide local availability. In this case, the long-distance transport was the result of social integration mechanisms on wide spatial scales rather than technological or economic needs. This strategy is also consistent with the presence of some foreign goods and exotic foods such as maize or *Lagenaria* that were not everyday meals but transported for exclusive consumption during feasts.

In sum, the obsidian employed during ceremonial aggregations could be directly sourced and worked on site; transported from remote regions as part of the personal tool-kits of the participants; or acquired indirectly through exchange. All these modes of circulation probably operated simultaneously as part of the diverse forms of interaction and activities carried out in these spaces.

5.3. Early ceremonialism in hunter-gatherer and pastoralist societies of Tulan

Through the study of obsidian circulation, we can trace for the first time the scales of inter-community aggregations that occurred in these spaces. Tulan obsidian artefacts and other exotic objects come from areas as diverse as the Pacific coast, the northern Salar de Atacama, the Loa Basin, the Atacama highlands and the northwest of Argentina. The ceremonial centres of Tulan were nodes with a high degree of centrality within wide inter-community networks. The fact that Tulan-52 shows a similar diversity of obsidian sources to Tulan-54 allows us to assume that Tulan was established as an important cultural node from the Late Archaic Period.

Collective hunting and feasts might have attracted neighbouring groups from contemporaneous residential sites located along the Tulan Ravine, such as Tulan-51, Tulan-122, Tulan-94 and Tulan-85 (see Núñez et al. 2006). Some groups might have even come from other settlements in the Atacama region or the Loa basin. These periodic aggregations of residential groups facilitated the circulation of local obsidian acquired from the Pelun and Tara sources. However, at large spatial scales the mobility cost and distance could have promoted a logistical mobility in the form of entourages, walkabout-style travellers, pilgrims or exchange partners, enabling the circulation of obsidian from even more distant sources.

The construction of religious centres has often been related to administrative centres, elites or charismatic leaders who, through the reproduction of ritual cycles, legitimised their political power and controlled collective labour. The chronology for the emergence of social inequality in the South-Central Andes is not resolved; it probably occurred at different times in each region. In some areas of NWA, social inequalities could have emerged as early as the Middle Archaic (Yacobaccio 2001). However, in Tulan there are no indicators that allow us to sustain categorically the existence of intra-community social differentiation in the sense of institutionalised or hereditary hierarchies. So far we have no evidence of full-time craft specialists attached to a central authority, of intra-site or inter-site hierarchical organisation, of restricted access to resources, of differences in mortuary treatment, or of offerings of prestige goods to adults. On the contrary, the evidence seems to show inclusive group participation, stimulated by open access to religious centres and periodic aggregations (Núñez et al. 2017a). This agrees with a more decentralised and corporate nature of religious practices, ruling out political commensalism and public celebrations such as have been proposed for later periods in the South-Central Andes (Cruz 2007; Lazzari et al. 2017; Nielsen 2006). This long-lived way of social integration through ceremonialism would have had its origin in late hunter-gatherer societies, as also seems to occurred in the Central Andes (Aldenderfer 2005).

Ethnographic observations in other hunter-gatherer, pastoralist and horticulturist societies point out that feasting and hunting are exceptional instances for the exchange of goods and information, mate finding, structuring alliances and networking (Benz 2006; Dietler and Hayden 2001; Dietrich et al. 2017; Hayden 2003, 2009). Certainly, these festive aggregations promoted cooperation based on reciprocity and solidarity between and within trans-egalitarian groups of the Andes Puna. But in parallel, lavish feasts are also occasions for competition and ostentation. Through the displays of success, feast hosts and sponsors attract people and create reciprocal debt (Hayden 2014; Kuijt 2009; Twiss 2008). It has been suggested that the restricted, semi-subterranean built spaces of the Tulan ceremonial centres were erected for the purpose of carrying out exclusive rituals for a limited number of participants, while the general public remained outside the central enclosures (Núñez et al. 2005). According to ethnographic accounts of feasts, restricted areas are allocated to representatives of the host households, their political counterparts and supporters (Hayden 2014). If this is so, the ceremonial centres of Tulan Ravine offered ideal environments for the dispute of power by high-ranking individuals, corporate groups and even secret societies as has been suggested in recent works (Hayden 2018). In this class of events, competitive sports such as hunting are also recurring mechanisms for the acquisition of influence and the promotion of individuals. At least, the relevance of this activity in the sites, such as its representation in rock art, seem to point in this direction.

Hunting and feasting in the South-Central Andes was a dynamic arena for the negotiation of social relations. In these events, competition and solidarity were in constant tension. We propose that the increased ritual activities in Tulan were a mechanism that allowed social cohesion to be maintained within non-centralised, multi-community networks in the face of the profound changes of the Archaic-Formative transition. Through the reproduction of festive and ceremonial cycles, trans-egalitarian groups alleviated the scalar stress derived from demographic increase, the shift to a pastoralist-based economy and a more sedentary way of life.

6. Conclusions

The combination of compositional and technological studies of obsidian artefacts provides us with a new understanding of the role of ceremonial centres and aggregations in the Tulan Ravine. Until now, it has been accepted that Tulan acquired greater importance on a regional scale from the Formative Period with the establishment of a village way of life and pastoralism. However, provenance analyses show that ceremonial centres such as Tulan-52 functioned already as congregation sites for multi-community networks from the Late Archaic and throughout the Early Formative Period. The six sources of obsidian detected, as well as other complementary evidence, reflect long-distance circulation that linked the Pacific coast, the north of the Salar de Atacama, the Loa basin, Tulan, the Atacama highlands and the northwest of Argentina. Five other unknown sources, in addition to a source of grey-veined volcanic glass (Unk-AA) suggest the existence of undetected local sources. Future works will be directed towards recognising the unknown sources, as well as comparison with other lines of evidence.

In the study sites, obsidian was mostly used for the production of projectile points for hunting wild camelids which were consumed during periodic feasts. Some of them were even included as part of the offerings taking part in the ritual performances. Through these ceremonial aggregations, trans-egalitarian groups managed to remain connected within large scale cooperation networks. At the same time, feasts and collective hunting were probably arenas for competitive displays and the negotiation of political power. This arrangement allowed them to maintain social cohesion and coordinate cooperative labour in the face of socio-economic changes. These trends give us an extraordinary approach at the last moments of an ancient and long-lived way of life based on hunting, gathering and pastoralism, but also on religious practices, which would change irreversibly with the introduction of agriculture and new and more centralised forms of political organisation during the Late Formative Period. However, the importance and breadth of ceremonial aggregations seems to have persisted over time, even to this day.

Acknowledgments

We would like to first thank the two anonymous reviewers who not only helped us improve the manuscript with their suggestions but also challenged us to go further in our original interpretations. We also thank the *Comunidad Indígena Atacameña de Peine* for allowing us to work in their ancestral territory and for collaborating with us during field work and in the conservation of the materials. We are grateful to the *Consejo de Monumentos Nacionales* (CMN) of Chile and the *Instituto de Investigaciones Arqueológicas de San Pedro de Atacama – Universidad Católica del Norte* (IIA-UCN) under whose permission artefacts were collected and sent out of the country for analysis. We thank Fondecyt Project 1130917 and the Wenner-Gren Foundation for their financial and logistical support. We also thank the US National Science Foundation for grant number 1912776 providing partial support for the XRF and NAA analyses conducted at MURR. In memory of Patricia Escola, who initiated this collaboration between the eastern and western slopes of the Andes.

7. References

Adán, L., Urbina, S., 2007. Arquitectura formativa en San Pedro de Atacama. Estud. Atacameños 34, 7-30. http://dx.doi.org/10.4067/S0718-10432007000200002

Aldenderfer, M., 2005. Preludes to power in the highland Late Preceramic Period. Archaeological Archaeological Papers of the American Anthropological Association 14, 13–35. https://doi.org/10.1525/ap3a.2004.14.013

Álvarez Soncini, M.C., De Feo, M.E., 2010. Obsidianas en contextos tempranos de la Quebrada del Toro: Análisis tecno-morfológico e identificación de fuentes de aprovisionamiento en los sitios Las Cuevas I y V. In: Bárcena, J.R., Chiavazza, H. (Eds.), Arqueología argentina en el bicentenario de la Revolución de Mayo, Tomo 1. Facultad de Filosofía y Letras, INCIHUSA, CONICET, Mendoza, pp. 19-24.

Benz, M., 2006. Zur Bedeutung von Festen während der Neolithisierung im Vorderen Orient. Ethnographisch-Archäologische Zeitschrift 47(4), 439–462.

Bowman, I., 1924. Desert trails of Atacama. American Geographical Society, New York.

Callegari, A., Gonaldi, M.E., Spengler, Rodríguez, M.G., Aciar, M.E., Pappalardo, R., Wisnieski, M.L., 2015. Tras las huellas del Formativo. Norte de la Provincia de La Rioja. Cronicas Materiales Precolombinas. Arqueología de los Primeros Poblados del Noroeste Argentino, In: Korstanje, M.A., Lazzari, M., Basile, M., Bugliani, F., Lema, V., Pereyra-Domingorena, L., Quesada, M. (Eds.). Sociedad Argentina de Antropología, Buenos Aires, pp. 247–275.

Capriles, J., Tripcevich, N., Nielsen, A., Glascock, M.D., Albarracin-Jordan, J., Santoro, C., 2018. Late Pleistocene lithic procurement and geochemical characterization of the Cerro Kaskio obsidian source in southwestern Bolivia. Archaeometry 60(5), 898-914. https://doi.org/10.1111/arcm.12363

Cartajena, I., 2009. Explorando la variabilidad morfométrica del conjunto de camélidos pequeños durante el Arcaico Tardío y el Formativo Temprano, Norte de Chile. Revista del Museo de Antropología, 2(1), 199-212. https://doi.org/10.31048/1852.4826.v2.n1.5418

Cartajena, I., 2011. Cazadores domesticando y pastores cazando durante el Arcaico Tardío y Formativo Temprano en la Cuenca del Salar de Atacama. In: Hubert, A., González, J.A. (Eds.), Temporalidad, interacción y dinamismo cultural. Ediciones Universitarias, Antofagasta, pp. 269-288.

Cartajena, I., Núñez, L., Grosjean, M., 2007. Camelid domestication on the western slope of the Puna de Atacama, northern Chile. Anthropozoologica 42(2), 155-174.

Cartajena, I., López, O., Núñez, L., Linares, C., 2013. Lesiones en extremidades inferiores de camélidos. Una comparación entre los conjuntos del Arcaico Tardio y Formativo Temprano (Vertiente occidental de la puna de Atacama). In: Izeta, A., Mengoni, G.L. (Eds.), De la Puna a las Sierras: Avances y Perspectivas en Zoología Andina. Archaeopress, Oxford.

Cartajena, I., López, P., Núñez, L., 2019a. Una aproximación desde la fauna del templete Tulan-54 (Salar de Atacama, Chile) a los nichos en la arquitectura durante inicios del Formativo (ca. 3.300-2.400 AP). Archaeofauna 28, 85-94. http://doi.org/10.15366/archaeofauna2019.28.007

Cartajena, I., López, P., Santander, B., Núñez, L., 2019b. Discarding practices among early herders on the western watershed of the Puna de Atacama, Chile (ca. 3000-2300 cal. BP). In: Peters, J., McGlynn, G., Goebel, V. (Eds.), Animals: cultural identifiers in ancient societies? VML Verlag Marie Leidorf GmbH (Verlag), München, pp. 65-84.

Cruz, P., 2007. Hombres complejos y señores simples: Reflexiones en torno a los modelos de organización social desde la arqueología del valle de Ambato. In: Nielsen A.E., Rivolta, M.C., Seldes, V., Vázquez, M.M., Mercolli, P.H. (Eds.), Procesos sociales prehispánicos en el sur andino: la vivienda, la comunidad y el territorio. Editorial Brujas, Córdoba, pp 99–122.

Dietrich, O., Notroff, J., Schmidt, K., 2017. Feasting, social complexity, and the emergence of the early Neolithic of Upper Mesopotamia: a view from Göbekli Tepe. In: Chacon, R.J., Mendoza, R. (Eds.), Feast, famine or fighting? Multiple pathways to social complexity. Springer, Cham, pp. 91–132.

Druss, M., 1976. Medioambiente, economia de subsistencia y patrones de asentamiento del Complejo Chiu (ca. 3.000- 2.000BC), Norte de Chile. Estud. Atacameños 4, 17-23.

Escola, P., 2007. Obsidianas en contexto: tráfico de bienes, lazos sociales y algo más. In: Williams, V., Ventura, B., Callegari, A., Yacobaccio, H. (Eds.). En Sociedades precolombinas surandinas; Temporalidad, interacción y dinámica cultural del NOA en el ámbito de los Andes Centro- Sur. Buenos Aires, pp. 73- 87.

Escola, P.S., Hocsman, S., 2007. Procedencia de artefactos de obsidiana de contextos arqueologicos de Antofagasta de la Sierra (c. 4500 - 3500 AP). Comechingonia 10(1), 49-58. https://doi.org/10.37603/2250.7728.v10.n1.27622

Escola, P., Hocsman, S., Babot, M., 2016. Moving obsidian: The case of Antofagasta de la Sierra basin (Southern Argentinean Puna) during the late Middle and Late Holocene. Quatern. Int. 422, 109-122. https://doi.org/10.1016/j.quaint.2016.04.048

De Souza, P., 2004. Tecnologías de proyectil durante los períodos Arcaico y Formativo en el Loa Superior (Norte de Chile): una aproximación a partir del análisis de puntas líticas. Chungara 36(1), 61-76. http://dx.doi.org/10.4067/S0717-73562004000300009

De Souza, P., 2011. Sistemas de proyectiles y cambio social durante el tránsito Arcaico tardío-Formativo temprano de la Puna de Atacama. In: Hubert, A., González, J., Pereira, M. (Eds.), Temporalidad, interacción y dinamismo cultural. La búsqueda del hombre: Homenaje al Profesor Lautaro Núñez Atencio. Ediciones Universitarias, Antofagasta, pp. 201-246.

De Souza, P., Cartajena, I., Núnez, L., Carrasco, C., 2010. Cazadores recolectores del Arcaico tardío y desarrollo de complejidad social en la Puna de Atacama: las evidencias del sitio Tulan-52 (norte árido de Chile). Werkén 13(2), 91-118.

Dietler, M., Hayden, B., 2001. Feasts: Archaeological and Ethnographic Perspectives on Food. Politics, and Power. Smithsonian Institution Press, Washington, D.C.

Glascock, M.D., 2020. A systematic approach to geochemical sourcing of obsidian artifacts. Scientific Culture 6(2), 35-47. https://doi.org/10.5281/zenodo.3724847

Glascock, M.D., Neff, H., Stryker, K.S., Johnson, T.N., 1994. Sourcing archaeological obsidian by an abbreviated NAA procedure. J. Radioanal. Nucl. Ch. 180, 29-35. https://doi.org/10.1007/BF02039899

Glascock, M.D., Braswell, G., Cobean, R., 1998. A systematic approach to obsidian source characterization. In: Shackley, M.S. (Ed.), Archaeological Obsidian Studies: Method and Theory. Plenum Press, New York, pp. 15-65.

Gordillo, I., 2004. La arquitectura ritual durante el Período Medio del Noroeste Argentino prehispánico. Revista Andina 39, 257-281.

Hayden, B., 2003. Were luxury foods the first domesticaticates? Ethnoarchaeological perspectives from southeast Asia. World Archaeol. 34(3), 458–469. https://doi.org/10.1080/0043824021000026459a

Hayden, B., 2009. The proof is in the pudding: feasting and the origins of domestication. Curr. Anthropol. 50(5), 597–601. https://doi.org/10.1086/605110

Hayden, B. 2014. The Power of Feasts. Cambridge: Cambridge University Press.

Hayden, B. 2018. The power of ritual in prehistory. Cambridge: Cambridge University Press.

Hogg, A., Heaton, T., Hua, Q., Palmer, J., Turney, C., Southon, J., Bayliss, A., Blackwell, P., Boswijk, G., Bronk Ramsey, C., Petchey, F., Reimer, P., Reimer, R., Wacker, L., 2020. SHCal20

Southern Hemisphere Calibration, 0–55,000 Years cal BP. Radiocarbon, 62(4): 759-778. https://doi:10.1017/RDC.2020.59

Jackson, D. Benavente, A., 2010. Complejización de los cazadores y recolectores en Chiu, río Loa Medio (norte de Chile). Estud. Atacameños 39, 5-20. http://dx.doi.org/10.4067/S0718-10432010000100002

Kalazich, F. 2006. Tipología y contextos de uso de la alfarería temprana de Tulan y Puna de Atacama (Unpublished Professional Practice Dissertation). Universidad de Chile, Chile.

Kuijt, I., 2009. What do we really know about food storage, surplus, and feasting in preagricultural communities? Curr. Anthropol. 50(5), 641–644. https://doi.org/10.1086/605082

Holden, T.G., 1991. Evidence of prehistoric diet from northern Chile: coprolites, gut contents and flotation samples from the Tulan quebrada. World Archaeol. 22(3), 320–331. https://doi.org/10.1080/00438243.1991.9980149

Laguens, A., 2006. Continuidad y ruptura en procesos de diferenciación social en comunidades aldeanas del valle de Ambato, Catamarca, Argentina (s. IV-X A.D.). Chungara 38:211–222. http://dx.doi.org/10.4067/S0717-73562006000200005

Lazzari, M., Pereyra Domingorena, L., Stoner, W.D., Scattolin, M.C., Glascock, M.D., Korstanje, M.A., 2017. Compositional data supports decentralized model of production and circulation of artifacts in the pre-Columbian south-central Andes. P. Natl. Acad. Sci. USA 114(20), E3917-E3926. https://doi.org/10.1073/pnas.1610494114.

López, E.J. G., 2020. Macro-regional interaction processes in the south-central Andes along the Holocene (ca. 10000–500 BP): Obsidian circulation, cultural transmission and evidence of allochthonous materials at archaeological sites in the Puna of Salta, north-western Argentina. Journal of Archaeological Science: Reports 29, 102187. https://doi.org/10.1016/j.jasrep.2019.102187

Mercuri, C., Glascock, M.D., 2011. Primeros datos sobre la procedencia de obsidiana de un sitio formativo de Santa Rosa de los Pastos Grandes, Puna de Salta, Argentina. Arqueología 17, 247-258. https://doi.org/10.34096/arqueologia.t17.n0.1845

Mercuri, C., Restifo, F., 2014. Application of physico-chemical and macroscopic methods to lithic artifacts studies from Alero Cuevas site (Salta, República Argentina): a complementary approach. In: Kligmann, D.M., Morales, M.R. (Eds.), Physical, Chemical and Biological Markers in Argentine Archaeology: Theory, Methods and Applications. Bar International Series 2678, British Archaeological Reports, Oxford, pp. 27-38.

McRostie, V., 2013. The role of plant production in subsistence and cultural changes during the Formative period in the Atacama Puna, southern Andes, Chile (1400 BC–500 AD). A re-evaluation based on the analyses of microfossils attached to hoes and grinding tools, and isotopic analyses of human bones (PhD Dissertation). University College London, UK.

McRostie, V., 2014. Arboricultura y silvopastoralismo en el Período Formativo (1.400 a.c.-500 d.C.) de la cuenca del Salar de Atacama. Chungara 46(4), 543-557. http://dx.doi.org/10.4067/S0717-73562014000400002

Molina Otárola, R., 2011. Los otros arrieros de los valles, la puna y el desierto de Atacama. Chungara 43(2), 177-187. https://doi.org/10.4067/S0717-73562011000200002

Nielsen, A.E. 2006. Pobres jefes: Aspectos corporativos en las formaciones sociales pre Inkaicas de los Andes circumpuneños. In: Gnecco, C, Langebaek, C.H. (Eds), Contra la tiranía tipológica en arqueología: una visión desde Sudamérica. Universidad de los Andes, Bogotá, pp 121–150.

Núñez, L., 1981. Asentamiento de cazadores recolectores tardíos en la Puna de Atacama: Hacia el sedentarismo. Chungara 8, 137-168.

Núñez, L., 1992. Ocupación arcaica en la Puna de Atacama: secuencia, movilidad y cambio. In: Meggers, B. (Ed.), Prehistoria Sudamericana: nuevas perspectivas. Taraxacum, Washington, D.C., pp. 85-108.

Núñez, L., 2005. La naturaleza de la expansión aldeana durante el Formativo Tardío en la cuenca de Atacama. Chungara 37(2), 165-193. http://dx.doi.org/10.4067/S0717-73562005000200006

Núñez, L., Perlès, C., 2018. Tulán-52: A Late Archaic ceremonial centre at the dawn of the Neolithisation process in the Atacama Desert. Antiquity 92(365), 1231-1246. https://doi.org/10.15184/aqy.2018.195

Núñez, L., Briones, L., 2020. Interacción entre caravaneros y costeños en el desierto de Atacama. El Puerto de tráfico del salar Soronal (Periodo intermedio Tardío). In: Los desafíos del tiempo, el espacio y la memoria: ensayos en homenaje a Peter Kaulicke. R. Vega-Centeno, J. Dulante (Eds.), pp. 261-308. Pontificia Universidad Católica del Perú, Fondo editorial, Lima.

Núñez, L., Cartajena, I., Carrasco, C., De Souza, P., 2005. El templete de Tulan y sus relaciones formativas panandinas (norte de Chile). Bulletin de l'Institut Français d'Études Andines 34(3), 299-320. https://doi.org/10.4000/bifea.4858

Núñez, L., Cartajena, I., Carrasco, C., De Souza, P., Grosjean, M., 2006a. Emergencia de comunidades pastoralistas formativas en el sureste de la Puna de Atacama. Estud. Atacameños 32, 93-117. http://dx.doi.org/10.4067/S0718-10432006000200008

Núñez, L., Cartajena, I., Carrasco, C., De Souza, P., 2006b. El templete Tulan de la Puna de Atacama: emergencia de complejidad ritual durante el Formativo Temprano (norte de Chile). Lat. Am. Antiq. 17(4), 445-473. https://doi.org/10.2307/25063067

Núñez, L., Cartajena, I., Carrasco, C., De Souza, P., Grosjean, M., 2006c, Patrones, cronología y distribución del arte rupestre arcaico tardío y formativo temprano en la cuenca de Atacama. In: Fiore, D., Podestá, M. (Eds.), Tramas en la piedra. Producción y usos del arte rupestre. Sociedad Argentina de Antropología, Buenos Aires, pp. 191-204.

Núñez, L., De Souza, P., Cartajena, I., Carrasco, C., 2007. Quebrada Tulan: Evidencias de Interacción Circumpuneña durante el Formativo. In: Nielsen, A.M., Rivolta, C., Seldes, V., Vásquez, M., Mercoli, P. (Eds.), Producción y circulación prehispánicas de bienes en el sur andino, Editorial Brujas, Córdoba, pp. 287-304.

Núñez, L., McRostie, V., Cartajena, I., 2009. Consideraciones sobre la recolección vegetal y la horticultura durante el Formativo Temprano en el sureste de la cuenca de Atacama. Darwiniana 47(1), 56-75. https://doi.org/10.14522/darwiniana.2014.471.41

Núñez, L., Cartajena, I., Carrasco, C., López, P., Rivera, F., De Souza, P., Santander, B., Loyola, R., 2016. Nuevas excavaciones en Tulan-54. Revelando la arquitectura ceremonial durante el Formativo Temprano en la puna de Atacama. Revista Chilena de Antropología 34, 65-79. https://doi.org/10.5354/0719-1472.2017.45149

Núñez, L., Cartajena, I., Carrasco, C., López, P., De Souza, P., Rivera, F. Santander, B., 2017a. Presencia de un centro ceremonial formativo temprano en la circumpuna de Atacama. Chungara 49(1), 3-33. http://dx.doi.org/10.4067/S0717-73562017005000003

Núñez, L., Cartajena, I., Carrasco, C., López, P., De Souza, P., Rivera, F., Santander, B., Loyola, R., 2017b. The Temple of Tulan-54: New Insights Concerning Ceremonial Architecture of the Early Formative in the Atacama Desert. Antiquity 91(358), 901-915. https://doi.org/10.15184/aqy.2017.87

Núñez, L., Cartajena, I., López, P., Carrasco, C., Valenzuela, M., Bravo, A., 2019. Nichos, cámaras y ceremonias en el templete Tulan-54 (Circumpuna de Atacama, Chile). Bulletin de l'Institut Français d'Études Andines 48(1), 57-81. https://doi.org/10.4000/bifea.10458

Bronk Ramsey, C., 2017. OxCal 4.3 manual. http://c14.arch.ox.ac.uk/oxcalhelp/hlp_contents.html

Seelenfreund, A., Pino, M., Glascock, M.D., Sinclaire, C., Miranda, P., Pasten, D., Cancino, S., Dinator, M.I., Morales, J.R., 2010a. Morphological and geochemical analysis of the Laguna Blanca/Zapaleri obsidian source in the Atacama Puna. Geoarchaeology 25(2), 245-253. https://doi.org/10.1002/gea.20306

Seelenfreund, A., Sinclaire, C., Dinator, M., Morales, J., Pasten, D., Miranda, P., Cancino, S., Lera L., Rees, Ch., 2010b. Negras y brillantes: explotación y distribución de obsidianas en la macro región del Salar de Atacama. In: Sociedad Chilena de Arqueología (Ed.), Actas del XVII Congreso Nacional de Arqueología Chilena Tomo II. Ediciones Kultrún, Valdivia, pp. 813-824.

Soto, C., 2010. Tipología de cuentas de collar en la quebrada de Tulan (salar de Atacama): nueva línea de evidencia para la transición Arcaico-Formativo. In: Sociedad Chilena de Arqueología (Ed.), Actas del XVII Congreso Nacional de Arqueología Chilena Tomo II. Ediciones Kultrún, Valdivia, pp. 1123-1134.

Soto, C., 2015. Distribución y significado de los restos malacológicos en la Fase Tilocalar (3130-2380 ap), quebrada Tulan (salar de Atacama, norte de Chile). Estud. Atacameños 51, 53-75. http://dx.doi.org/10.4067/S0718-10432015000200005

Tarragó, M., González, L., 2005. Variabilidad en los Modos Arquitectónicos Incaicos. Un Caso de Estudio en el Valle de Yocavil (Noroeste Argentino). Chungara 37(2), 129-143. http://dx.doi.org/10.4067/S0717-73562005000200003

Tartusi, M., Núñez Regueiro, V., 1993. Los Centros Ceremoniales del NOA. Instituto de Arqueología, Universidad Nacional de Tucumán, San Miguel de Tucumán.

Twiss, K.C., 2008. Transformations in an early agricultural society: Feasting in the southern Levantine pre-pottery Neolithic. J. Anthropol. Archaeol. 27, 418–442. https://doi.org/10.1016/j.jaa.2008.06.002

Uribe, M., 2004. El Inka y el poder como problemas de la arqueología del Norte Grande de Chile. Chungara 36(2), 313-324. http://dx.doi.org/10.4067/S0717-73562004000200006

Uribe, M., 2006. Sobre cerámica, su origen y complejidad social en los Andes del desierto de Atacama. In: Lechtman, H. (Ed.), Esferas de Interacción Prehistóricas y Fronteras Nacionales Modernas: Los Andes Sur Centrales., Instituto de Estudios Peruanos, Lima, pp. 449-502.

Valenzuela, M., 2018. Uso de fibras animales en un contexto ceremonial Formativo Temprano (3400 a 2400 AP): las evidencias del sitio Tulán-54 (Puna de Atacama, Norte de Chile) (Thesis). Universidad de Chile, Chile.

Yacobaccio, H.D., 2001. Cazadores complejos y domesticación de camélidos. In: Mengoni, G., Olivera, D., Yacobaccio, H.D. (Eds.), El uso de los camélidos a través del tiempo. Ediciones del Tridente, Buenos Aires, pp. 261-282.

Yacobaccio, H.D., 2012. Intercambio y caravanas de llamas en el sur Andino (3000-1000 AP). Comechingonia 16, 31-51. https://doi.org/10.37603/2250.7728.v16.n1.17960

Yacobaccio, H.D. Escola, P.S., Lazzari, M., Pereyra, F.X., 2002. Long-distance obsidian traffic in Northwestern Argentina. In: Glascock, M.D. (Ed.), Geochemical Evidence for Long-Distance Exchange. Bergin and Garvey, Wesport, pp. 167-204.

Yacobaccio, H.D., Escola, P.S., Pereyra, F.X., Lazzari, M., Glascock, M.D., 2004. Quest for ancient routes: Obsidian sourcing research in Northwestern Argentina. J. Archaeol. Sci. 31(2), 193-204. https://doi.org/10.1016/j.jas.2003.08.001

Appendix

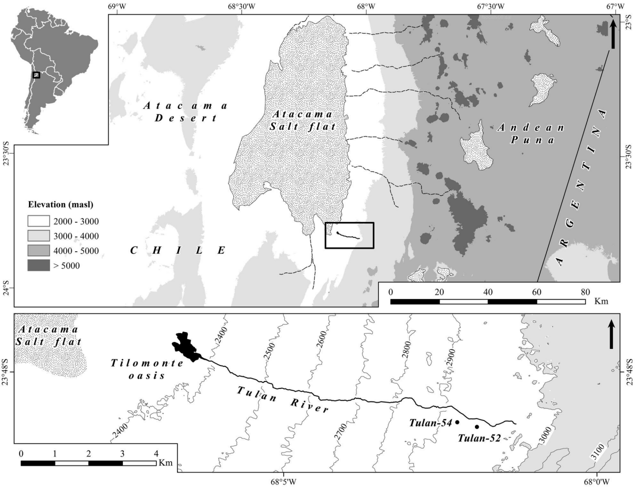
Appendix A. XRF results listing source assignments and element concentrations in parts per million

Sample	Assigned source	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Th
RLO001	Zapaleri	479	8201	50	229	142	37	195	25	23
RLO002	Unk-EE	448	7013	35	181	160	19	144	21	24
RLO003	Unk-AA	369	4068	37	90	231	7	53	20	6
RLO004	Quiron	560	5286	21	561	16	25	31	89	2
RLO005	Ona	408	4932	23	213	124	15	71	17	23
RLO006	Unk-AA	408	5801	48	106	259	8	58	23	7
RLO007	Unk-BB	559	7848	44	231	134	29	145	19	30
RLO008	Unk-AA	380	4023	36	91	223	7	63	20	6
RLO009	Unk-AA	411	4973	46	103	252	8	54	21	7
RLO010	Unk-EE	496	7855	37	188	167	20	149	21	26
RLO011	Unk-AA	401	4774	43	93	254	7	53	20	5
RLO012	Unk-AA	442	5305	52	108	269	8	55	22	8
RLO013	Unk-AA	415	4945	44	107	265	8	55	23	7
RLO014	Quebrada Pelun-1	1150	3861	29	272	18	19	28	39	7
RLO015	Quebrada Pelun-2	559	4775	26	333	49	29	54	20	21
RLO016	Salar del Hombre Muerto	2484	4255	115	690	1	61	33	75	15
RLO017	Quiron	658	5787	24	618	18	25	34	91	6
RLO018	Unk-AA	373	4267	39	91	231	7	49	21	4
RLO019	Unk-AA	338	4426	37	82	209	6	46	19	3
RLO020	Quebrada Pelun-1	1120	3914	27	272	17	20	41	38	7
RLO021	Unk-AA	368	4253	34	88	223	7	48	19	6
RLO022	Unknown	245	18542	50	196	304	23	285	21	26
RLO023	Zapaleri	474	10873	56	225	146	38	226	25	25
RLO024	Unk-BB	576	8374	44	236	135	29	141	19	27
RLO025	Quebrada Pelun-1	1806	5859	44	330	21	20	36	41	7
RLO026	Zapaleri	476	9574	54	219	141	35	209	25	24
RLO027	Quebrada Pelun-1	1382	4586	31	285	18	20	34	40	7
RLO028	Alto Tocomar	1103	4672	51	627	20	21	23	42	5
RLO029	Unk-AA	355	3888	39	89	225	7	49	21	4
RLO030	Zapaleri	523	10343	64	237	149	37	198	25	26
RLO031	Zapaleri	456	10163	54	222	141	37	234	26	23
RLO032	Unk-AA	385	4379	37	94	237	8	50	21	5
RLO033	Unk-AA	433	5090	56	110	267	8	52	21	9
RLO034	Unk-AA	378	4323	47	93	237	7	49	20	5
RLO035	Unk-AA	460	5484	51	107	267	8	52	20	6
RLO036	Alto Tocomar	798	3537	39	582	17	24	22	40	5
RLO037	Unk-AA	420	4595	42	101	247	8	54	21	5
RLO038	Unk-AA	385	4693	44	104	250	8	54	22	5
RLO039	Unk-AA	405	4912	48	96	245	7	54	21	8
RLO040	Unk-CC	484	6530	27	198	114	25	127	18	25
RLO041	Alto Tocomar	845	3653	35	589	17	23	22	39	6

RLO042	Alto Tocomar	853	3937	37	597	18	24	22	40	6
RLO043	Alto Tocomar	855	3842	41	600	18	22	22	41	8
RLO044	Alto Tocomar	1024	4449	47	631	19	23	23	42	5
RLO045	Alto Tocomar	905	4559	50	602	19	23	22	40	2
RLO046	Unk-AA	434	5094	48	92	233	8	60	19	5
RLO047	Quiron	687	5872	25	588	17	28	50	93	1
RLO048	Unk-BB	590	8257	44	235	137	30	141	19	29
RLO049	Ona	510	6051	30	241	140	16	85	20	26
RLO050	Unknown	512	9974	54	277	133	39	313	26	26
RLO051	Quebrada Pelun-2	538	4208	21	298	33	29	52	23	21
RLO052	Salar del Hombre Muerto	1993	5533	69	677	2	88	52	102	23
RLO053	Unk-AA	473	5833	52	108	275	9	57	21	8
RLO054	Zapaleri	542	11062	64	252	152	39	220	26	24
RLO055	Quebrada Pelun-2	592	5177	30	315	48	29	70	22	21
RLO056	Unk-CC	530	7047	33	215	126	28	154	19	26
RLO057	Unknown	559	11053	67	396	145	38	185	24	23
RLO058	Quebrada Pelun-1	1370	4364	33	287	18	21	38	40	6
RLO059	Unknown	534	10294	56	330	143	39	197	24	23
RLO060	Quebrada Pelun-2	564	4698	25	305	47	28	55	23	17
RLO061	Unknown	515	7003	37	235	141	16	136	37	37
RLO062	Quebrada Pelun-2	551	4836	25	302	45	28	57	22	19
RLO063	Quebrada Pelun-2	660	5900	35	343	51	31	62	22	20
RLO064	Zapaleri	671	14312	87	244	149	35	183	21	27
RLO065	Unk-BB	653	8776	49	242	138	28	145	20	30
RLO066	Salar del Hombre Muerto	2402	4006	102	692	1	67	34	80	11
RLO067	Zapaleri	648	13487	75	254	158	39	225	23	26
RLO068	Salar del Hombre Muerto	2093	6308	63	631	4	106	60	94	30
RLO069	Salar del Hombre Muerto	2680	7454	79	661	3	112	90	98	34
RLO070	Ona	508	5884	37	241	143	15	83	19	25
RLO071	Unk-AA	485	5731	53	110	276	8	58	24	7
RLO072	Unk-AA	494	5853	58	114	279	8	60	23	4
RLO073	Alto Tocomar	1211	4817	56	634	20	22	22	41	6
RLO074	Unk-AA	531	6438	68	112	275	7	52	22	5
RLO075	Zapaleri	630	12939	74	257	163	38	210	25	25
RLO076	Unk-AA	454	5398	49	104	260	8	56	21	6
RLO077	Unk-AA	469	5508	52	106	269	8	56	21	6
RLO078	Unk-DD	520	6342	41	225	105	14	109	33	39
RLO079	Zapaleri	646	15330	81	300	188	36	236	26	28
RLO080	Salar del Hombre Muerto	1953	5929	48	641	2	113	62	99	34
RLO081	Quebrada Pelun-1	2029	5890	50	323	21	21	34	41	8
RLO082	Unk-AA	554	6497	69	141	291	10	63	22	6
RLO083	Unk-AA	444	5339	50	104	265	9	57	22	8
RLO084	Unk-AA	470	5588	56	95	237	7	46	19	5
RLO085	Unk-AA	460	5330	49	101	256	8	51	20	7
RLO086	Unk-AA	501	5952	53	113	283	8	59	22	6
RLO087	Unk-AA	475	5723	61	115	273	8	55	22	7

Appendix B. NAA results listing source assignments and element concentrations in part per million.

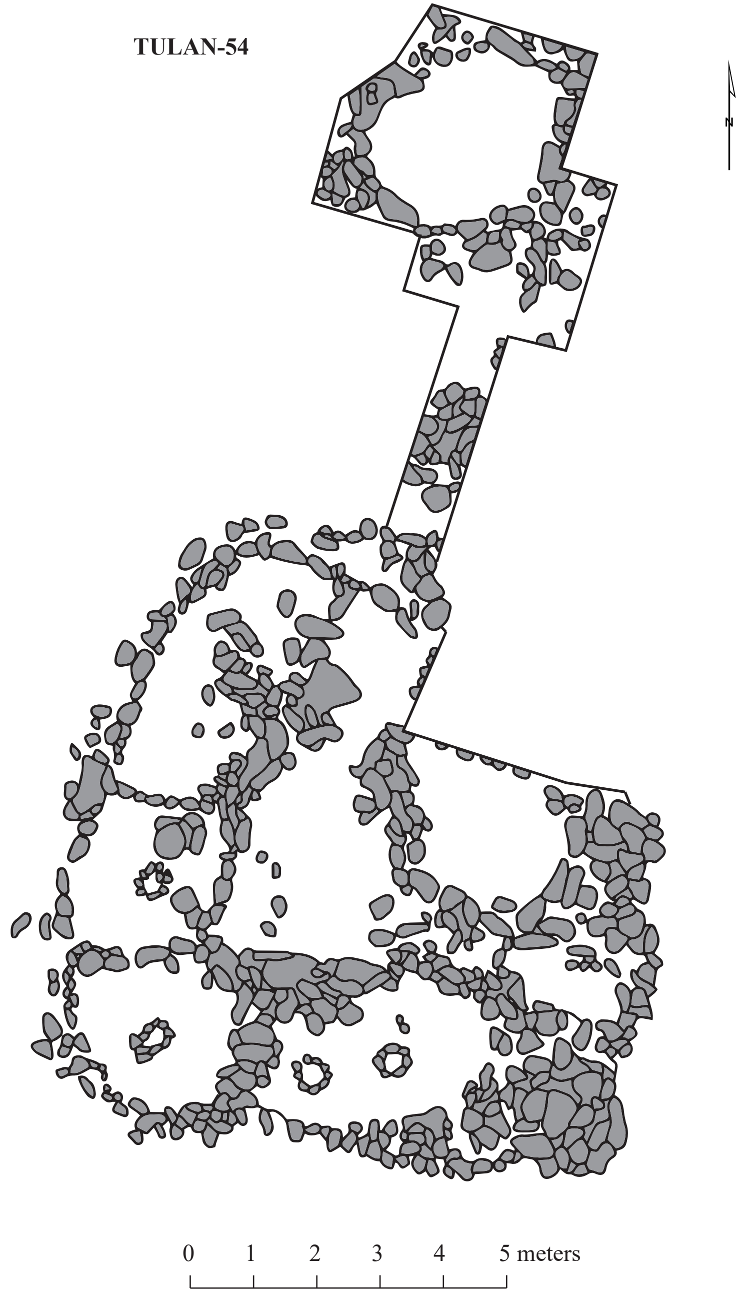
Sample	RLO002	RLO007	RLO010	RLO015	RLO016	RLO022	RLO024	RLO032	RLO035	RLO040
	Unk-EE	Unk BB	Unk-EE	Quebrada Pelun-2	SHM	Unknown	Unk BB	Unk AA	Unk AA	Unk CC
La	42,2575	39,3172	42,7444	16,4587	16,9085	47,8037	39,2717	22,0307	21,949	38,8151
Lu	0,3418	0,512	0,3411	0,6175	0,6389	0,3865	0,5037	0,1149	0,1094	0,4966
Nd	28,0202	30,1632	27,0175	16,786	26,9093	38,6791	30,3213	17,724	16,3924	30,4493
Sm	4,8324	5,8416	4,8398	4,4267	10,4506	6,9737	5,7645	3,131	3,0628	5,7653
U	6,1096	9,4106	5,8774	14,5062	28,8843	5,6291	9,6074	2,7442	2,3261	9,3537
Yb	1,8411	2,6033	1,8959	2,4582	1,5171	2,0611	2,5982	0,5824	0,6386	2,637
Ce	80,7102	77,9553	85,153	37,568	56,9954	95,4677	78,1886	44,0312	42,61	77,3379
Co	0,5257	0,4733	0,6908	0,4418	0,2204	5,578	0,5168	0,3572	0,3291	0,5121
Cs	5,0837	15,6984	5,3194	33,0514	93,6679	7,2109	15,7331	2,61	2,5303	15,7045
Eu	0,7802	0,8149	0,8172	0,4358	0	1,3042	0,8333	0,6834	0,6657	0,8293
Fe	7954,1758	6768,8872	8348,8115	4048,6594	2975,8357	21377,2227	6822,0776	5102,2505	4900,2363	6788,417
Hf	4,7371	4,4477	4,9126	2,5708	4,7185	7,7124	4,434	2,3959	2,2888	4,4692
Rb	175,9849	202,6442	183,5815	283,7282	1109,2375	185,2393	205,2879	98,8008	95,1878	205,0907
Sb	0,2581	1,6981	0,2483	3,566	1,2638	0,3441	1,6982	0,1262	0,1125	1,6926
Sc	1,903	2,9533	1,9952	3,1237	13,6118	7,6211	2,978	1,4913	1,4481	2,9447
Sr	200,5744	149,6845	217,4482	62,5273	0	378,1152	165,1696	324,2911	331,502	236,1066
Ta	1,5997	1,9902	1,7014	2,8713	16,2525	1,5432	2,0129	1,4955	1,4714	1,9968
Tb	0,4906	0,6896	0,5417	0,5881	1,2235	0,695	0,6784	0,2998	0,2949	0,6758
Th	22,2107	23,0055	23,4071	16,3579	9,6607	24,1771	23,1537	6,2225	6,0635	22,8972
Zn	47,5803	46,0421	52,8163	33,2293	127,2433	62,6793	47,4333	59,8993	58,0596	44,8568
Zr	178,1002	203,9513	203,6971	193,4249	195,1948	314,6866	214,6154	76,4911	78,2912	211,7107
Al	74131,9766	72911,5	73843,8516	71343,4531	70655,2578	85374,0234	72453,7266	67203,3594	70375,6172	71939,6953
Ba	723,6409	604,3943	733,5225	337,1949	116,7515	726,0747	620,3607	1056,655	982,0949	600,0646
Cl	661,5444	724,3487	585,7221	582,6152	178,7696	296,6587	639,3314	398,0739	473,9189	634,4874
Dy	3,2679	4,2655	3,0594	3,2971	6,5183	4,0614	4,1494	1,3171	1,4947	4,0312
K	35830,8516	38593,5469	33319,8008	40983,8672	33342,5273	31155,0566	35464,5469	33468,1875	32104,5918	36122,168
Mn	490,907	511,5636	479,9951	460,0249	1886,6637	413,576	494,3583	370,8219	374,4962	503,0511
Na	29567,8691	27385,3164	29218,2344	24262,3359	33294,8203	30294,0059	26885,8379	30532,0234	31101,8008	27094,3086

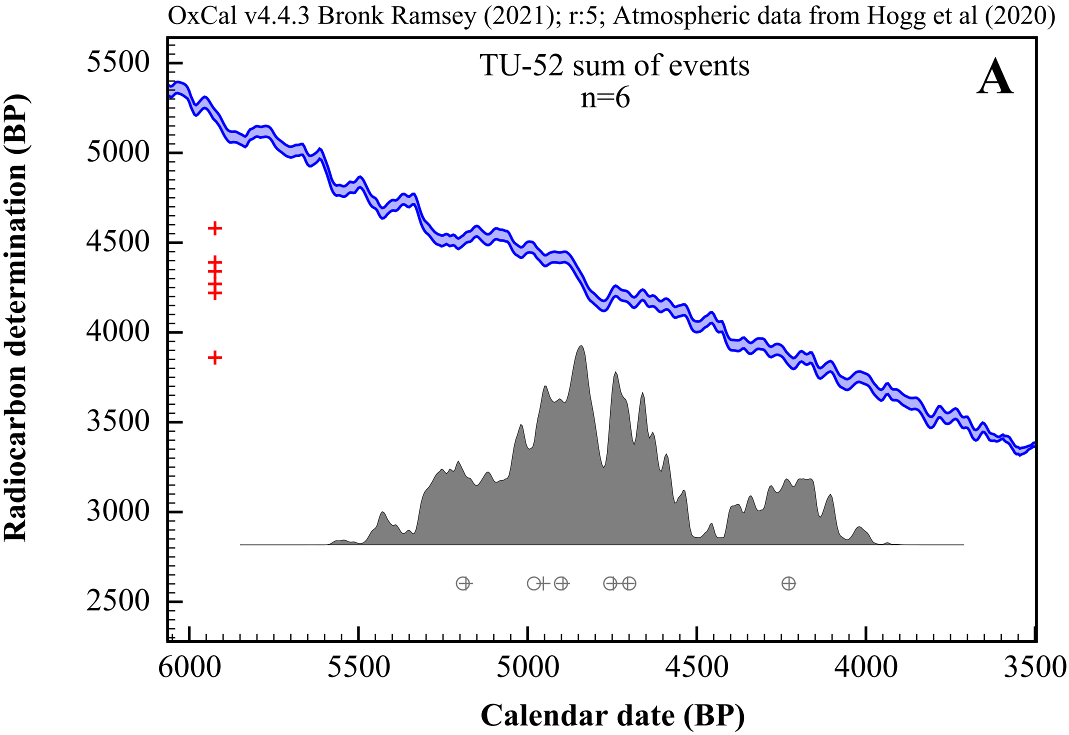


69°W
68°30'W
68°W
67°30'W
67°W
23°S
23°30'S
24°S
Atacama Desert
Atacama Salt flat
Andean Puna
ARGENTINA
CHILE
Elevation (masl)
2000 - 3000
3000 - 4000
4000 - 5000
> 5000
0
20
40
60
80
Km
Atacama Salt flat
Tilomonte oasis
Tulan River
Tulan-54
Tulan-52
2400
2500
2600
2700
2800
2900
3000
3100
23°48'S
0
1
2
3
4
Km
68°5'W
68°0'W

TULAN-52

TULAN-54

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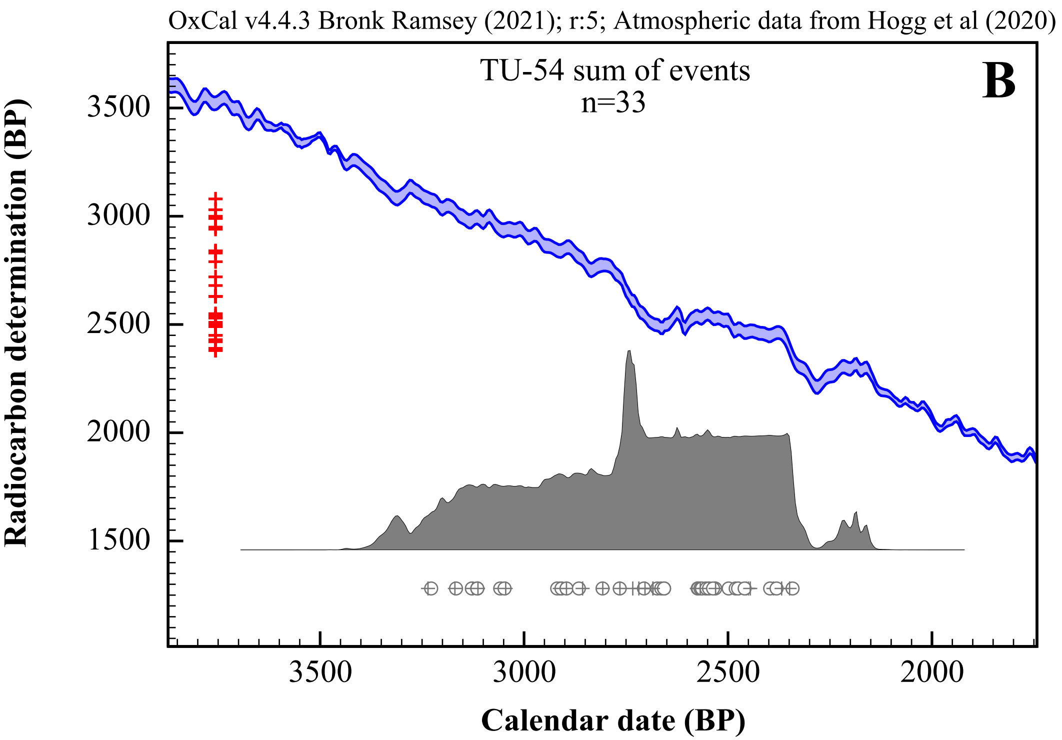
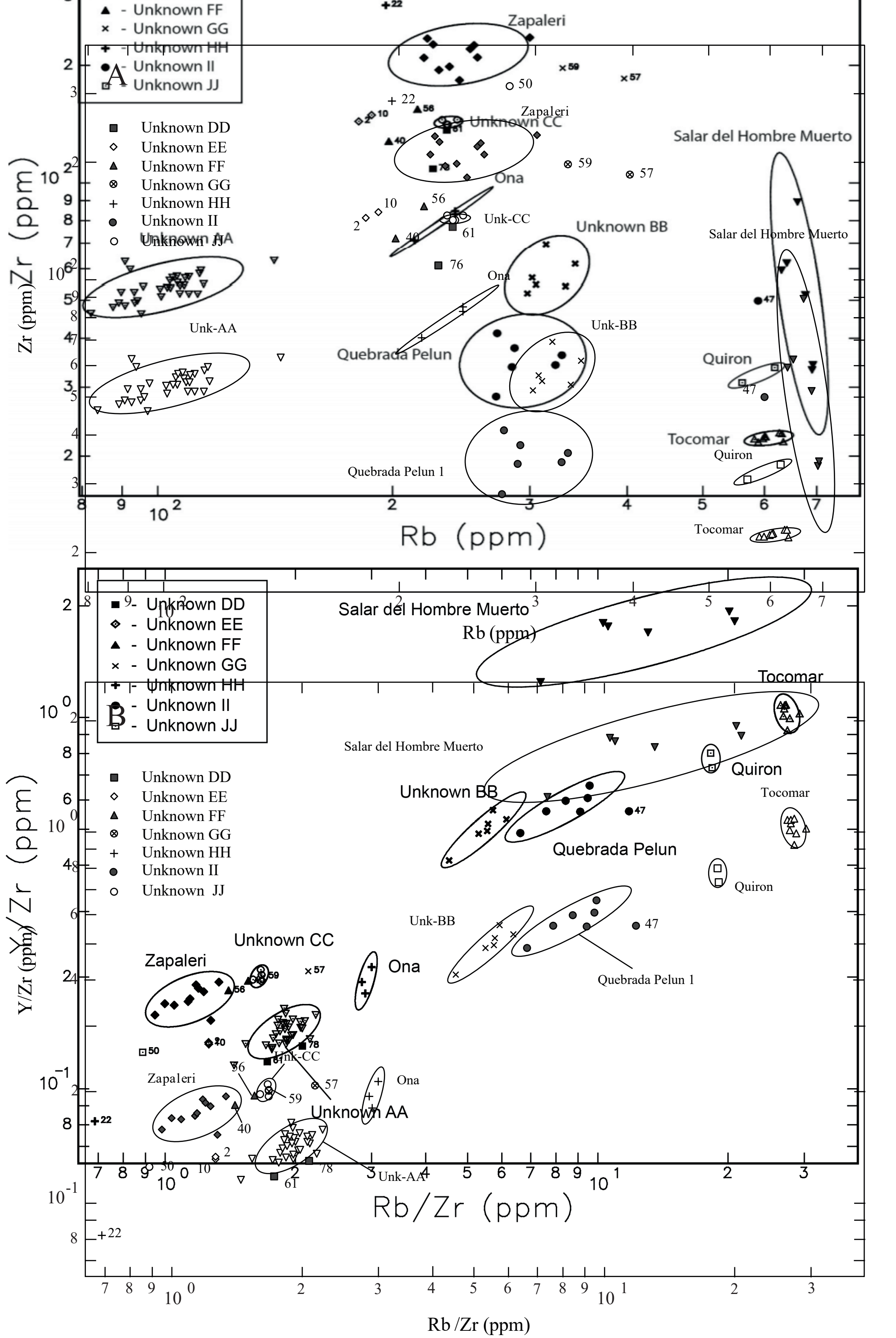
TU-52 sum of events
n=6
A
Radiocarbon determination (BP)
5500
5000
4500
4000
3500
3000
2500
6000
5500
5000
4500
4000
3500
Calendar date (BP)


OxCal v4.4.3 Bronk Ramsey (2021); r:5; Atmospheric data from Hogg et al (2020)
TU-54 sum of events
n=33
B
Radiocarbon determination (BP)
3500
3000
2500
2000
1500
3500
3000
2500
2000
Calendar date (BP)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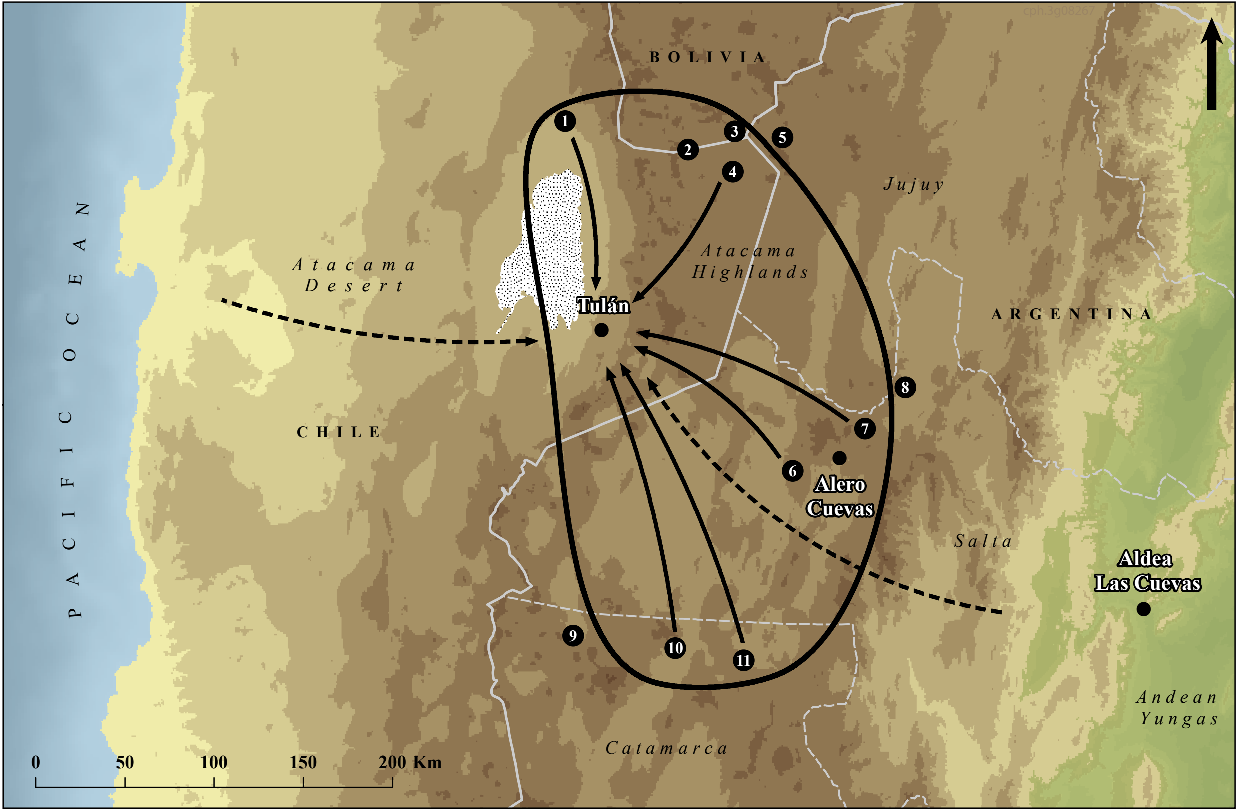
Unknown FF
Unknown GG
Unknown HH
Unknown II
Unknown JJ
Zapaleri
Unknown CC
Unk-CC
Ona
Unknown AA
Unk-AA
Unknown BB
Unk-BB
Quebrada Pelun
Quebrada Pelun 1
Salar del Hombre Muerto
Quiron
Tocomar
Zr (ppm)
Rb (ppm)
B
Unknown DD
Unknown EE
Unknown FF
Unknown GG
Unknown HH
Unknown II
Unknown JJ
Salar del Hombre Muerto
Tocomar
Quiron
Unknown BB
Unk-BB
Quebrada Pelun
Quebrada Pelun 1
Unknown CC
Unk-CC
Zapaleri
Ona
Unknown AA
Unk-AA
Y/Zr (ppm)
Rb/Zr (ppm)


A
B
0
1
2
3
4
5 cm



BOLIVIA
Jujuy
Atacama Highlands
Atacama Desert
Tulán
ARGENTINA
PACIFIC OCEAN
CHILE
Alero Cuevas
Salta
Aldea Las Cuevas
Andean Yungas
Catamarca
1
2
3
4
5
6
7
8
9
10
11
0
50
100
150
200 Km