Population dynamics and human strategies in Northwestern Patagonia: a view from Salamanca Cave (Mendoza, Argentina)

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ABSTRACT – *In this paper we evaluate the role of human strategies in the Andean Piedmont from northern Patagonia across the Holocene. Specifically, we present the analysis of the Early Holocene-Late Holocene archaeological record of Salamanca cave (Mendoza-Argentina). We identified technological changes that occurred during the Late Holocene and the implications of a human occupation hiatus in the Middle Holocene. We follow a multiproxy approach by the analysis of radiocarbon dates, archaeofaunal remains, ceramic, lithics and XRF obsidian sourcing. We also discuss a detailed stratigraphic sequence by geomorphological descriptions, the construction of a radiocarbon sequence model and summed probability distributions, compared with other archaeological sites in the region. We conclude that after the Middle Holocene archaeological hiatus, human populations grew while guanaco populations dropped. The imbalance between demography and resources boosted the incorporation of new technologies such as ceramics and the bow and arrow, allowing people to exploit lower-ranked resources.*

KEY WORDS – *hunter-gatherers; Northern Patagonia; mid Holocene; late Holocene; intensification; Southern Mendoza*

Populacijske dinamike in človekove strategije v severozahodni Patagoniji: pogled iz jame Salamanca (Mendoza, Argentina)

IZVLEČEK – *V članku ocenjujemo vlogo človekovih strategij v andskem Piedmontu iz severne Patagonije v obdobju holocena. Natančneje predstavljamo analizo zgodnje holocenskih do pozno holocenskih arheoloških podatkov iz jame Salamanca (pri mestu Mendoza v Argentini). Prepoznali smo tehnološke spremembe, ki so se zgodile v času poznega holocena, ter posledice hiatusa v poselitvi v času srednjega holocena. Z analizo radiokarbonskih datumov, arheozooloških ostankov, keramike,*

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kamnitih orodij in iskanja izvora obsidiana z metodo XRF smo sledili pristopu z več kriteriji. Razpravljamo tudi o podrobnem stratigrafskem zaporedju s pomočjo geomorfoloških opisov, pa tudi o izgradnji modela radiokarbonske sekvence in o porazdelitvah povzete verjetnosti, vse to pa primerjamo še z drugimi arheološkimi najdišči v regiji. Zaključujemo, da se je število ljudi po obdobju srednjega holocena povečalo, medtem ko se je število gvanakov zmanjšalo. Neravnovesje med demografijo in viri je spodbudilo vključevanje novih tehnologij kot so lončarstvo ter lok in puščice, kar je ljudem omogočilo izkoriščanje manj pomembnih naravnih virov.

KLJUČNE BESEDE – *lovci-nabiralci; severna Patagonija; srednji holocen; pozni holocen; intenziviranje; južna Mendoza*

Introduction

The archaeological record of arid environments presents specific challenges for preservation and site formation. At the same time, it allows us to acquire a better comprehension of human adaptations to these ecosystems. In South America, the Patagonia region became one of the last refuges of a hunter-gather way of life in the world (*Bettinger 2015; Borrero 1994–1995; 2001; Morgan* et al. *2017*). In Mendoza province, the Patagonia phytogeographic unit extends across the Piedmont of the Andes Cordillera, and widens southwards including the volcanic district of Payunia (*Roig 2000; Villagra* et al. *2010; Oyarzabal* et al. *2018*). Several archaeological sites have been found and studied, leading to debates and discussions in the Andes Piedmont from northwestern Patagonia, Argentina (*Gambier 1985; Durán 2000; Gil* et al. *2005; Neme 2007; Neme* et al. *2011; Barberena* et al. *2010*). These discussions were related to the age of the first human occupations in the region and their probable coexistence with megafauna (*Forasiepi* et al. *2010; Neme, Gil 2012; Barberena* et al. *2010*), and also to the occurrence of a Middle Holocene (7000–4000 ^{14}C years BP) human occupation hiatus (*Gil* et al. *2005; Neme, Gil 2008a; 2009; Barberena* et al. *2015a; Durán* et al. *2016*).

During the Late Holocene there was an intensification process in northern Patagonia due to a demographic increase, which triggered important dietary, technological and social changes (*Neme 2007; Neme, Gil 2008a*). However, hunter-gatherer groups kept inhabiting this area, functioning as a barrier to the farmers settled to the north (*Lagiglia 1968; Gil* et al. *2009; 2011*).

Most of the archaeological sites excavated in the Andes Piedmont of northwestern Patagonia are caves and rock shelters, which record the adaptation of small-scale groups to desert environments. The ecotonal nature of the study area, strongly modelled by altitude, provided a wide set of resources due to the presence of different ecosystems with a diverse geological setting.

A recent systematic survey, which compared the Highlands, Piedmont and Lowlands with the same scale and units of analysis (in the Diamante fluvial basin), proved that the Piedmont was by far the most intensely exploited biogeographic environment, with a higher site density, discard rate, and evidence of longer stays on sites (*Franchetti 2019*). Under this scenario, archaeological information available in this area also indicates a strong use of rock shelters, with rich faunal and archaeobotanical assemblages, intense obsidian use and scant ceramic presence, in comparison with northern and western archaeological records (*Durán 2000; Durán* et al. *1999; Neme* et al. *2011; Sugrañes, Franchetti 2012*).

In the year 2007, the 'Salamanca cave'archaeological site was found as part of a cultural resource management study in the 'Puesto Rojas' oil field (Malargüe-Mendoza province, Argentina). The excavation made it possible to identify a human occupation sequence of more than 7000 ^{14}C years BP, with a dense cultural deposit. The study of Salamanca cave allows us to add new information, improving the chronology and regional sequence, as well as aspects of the dietary, technology and cultural adaptations. In this paper we report the stratigraphy of the cave filling, along with the radiocarbon chronology and its associated archaeological record. We discuss the results obtained through different lines of evidence such as archaeofaunal remains, ceramic, lithic and XRF obsidian sourcing, framed into a regional archaeological context, and a geoarchaeological perspective.

Background

The archaeological record of Gruta del Indio and El Chancho sites, located at the Piedmont (Fig. 1), indicates that the first human occupations in southern Mendoza date to *c.* 11 000 ^{14}C years BP (*Lagiglia 1968; Neme, Gil 2012*). In the Andean Piedmont from northwestern Patagonia, the earliest evidence of human occupation comes from the Grande River valley and dates back to *c.* 9000 ^{14}C years BP (*Gambier 1985; Durán 2000; Diéguez, Neme 2004; Neme* et al. *2011; Barberena* et al. *2010*). The first excavated site in the study area was El Manzano cave (*Gambier 1985*), dated 8100 ^{14}C years BP, with a *c.* 7000–2100 ^{14}C years BP archaeological hiatus (*Neme* et al. *2011*). In the same valley, other excavated rock shelters dated a Late Holocene archaeological record (*Durán 2000; 2002; Durán, Ferrari 1991; Durán* et al. *1999; Campos* et al. *2006*). These archaeological sites include Cañada de Cachi, Puesto Carrasco, Cueva de Luna and Caverna de las Brujas (Fig. 1). The most important changes identified by researchers are the technological innovations, including the incorporation of the bow and ceramics that occurred *c.* 2000 ^{14}C years BP (*Durán 2000*). Moreover, a group of cemeteries (Ojo de Agua, Bajada de las Tropas, and Las Chacras) were excavated (Fig. 1) in the surroundings of Salamanca cave, dated in the last *c.* 3000 years BP (*Novellino, Neme 1999; Gil* et al. *2011; Salgán* et al. *2012*).

After the first arrival of human populations, towards the Late Pleistocene-Early Holocene (*Gradín* et al. *1984; Durán 2002; Berón 2006; Gil 2006; Neme, Gil 2008a; Barberena* et al. *2010; 2015a; Tripaldi* et al. *2017*), occupations increased between 9000 and 7000 years BP. However, the majority of environmental eco-zones show a temporal hiatus during almost the entire Middle Holocene, particularly between 7000 and 4000 years BP (*Berón 2006; Gil 2006; Gil* et al. *2005; Neme, Gil 2009; 2010; Barberena* et al. *2010; 2015a*).

The meaning of this Middle Holocene hiatus is a topic of strong debate. The most accepted hypothesis to explain the absence of radiocarbon dates is a drop in human population as a consequence of environmental deterioration. An increase in the aridity affected the location and effective population size, provoking aggregation of human groups across the region (*Gil* et al. *2005; Neme, Gil 2012*). Volcanic activity is an alternative explanation, and some archaeologists suggest that volcanic eruptions may have been of major magnitude both spatially and temporarily (*Durán, Mikkan 2009; Durán* et al. *2016*), and that such events could affect the environmental availability of the land and its productivity.

In contrast, other researchers question the existence of the hiatus, assuming sampling problems or biases (*García 2005; Garvey, Bettinger 2018*). Finally, another hypothesis is that the lack of archaeological record is a consequence of anthropic behaviour, such as the cleaning of the occupation floors or pit excavation, which resulted in low visibility of the archaeological record (*García* et al. *1999*). At a macro regional scale, a similar Holocene hiatus was also identified with a different magnitude in neighbouring areas (north of Neuquén and central Chile) and other South American regions (*Barberena* et al. *2015b; 2017; Méndez* et al. *2014; Santoro* et al. *2016; Riris, Arroyo-Kalin 2019*).

Strong and increasing evidence of occupations occurred after 4000 years BP in the northern Patago-

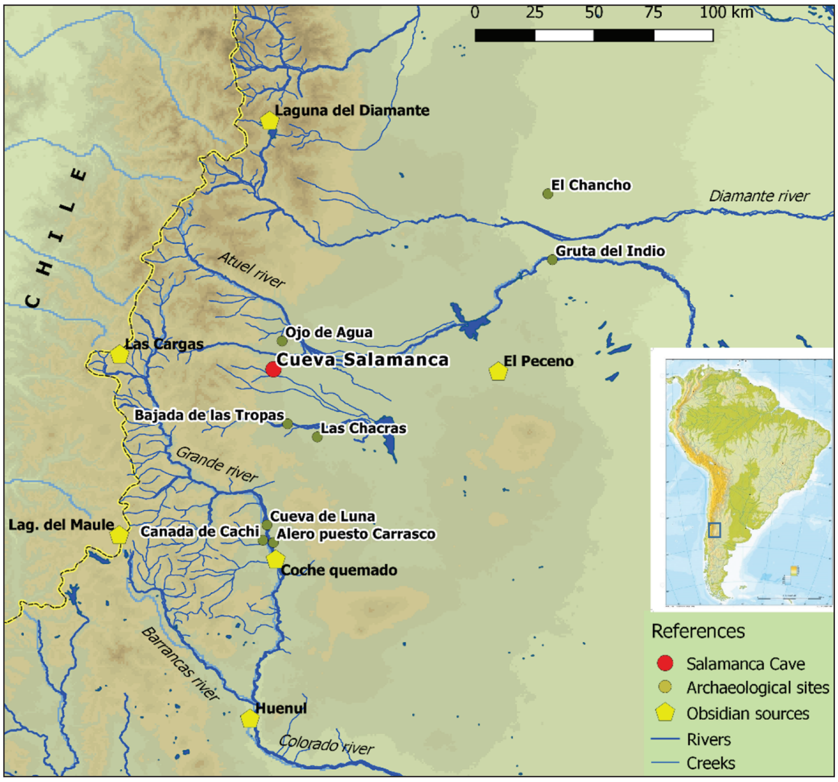

Fig. 1. Salamanca cave location, obsidian sources and the other archaeological sites mentioned in the text.

nia region. During the last 2000 years BP those human occupations spread to all environments including marginal settings, while the dietary breadth expanded (*Gil 2006; Neme 2007; Neme, Gil 2012*). In Patagonia's northern boundary, this process led the human population to incorporate domestic plants, but always as a small part of the diet (*Gil* et al. *2006; 2011; 2020*). While the Patagonian human populations continued with a hunter-gatherer way of life, they adopted a more diverse technological set, more distant social networks, and probably a diminishing residential mobility (*Gil* et al. *2011; Neme, Gil 2008a; 2008b; 2012; Ugan* et al. *2012*).

The archaeological site

Salamanca cave (35°17'4.11"S/69°41'33.34"W) is located in the Andean Piedmont at the rim of a mesa formed by several erosional episodes from the Pliocene to the Present. Following the regional stratigraphic scheme (*Nullo* et al. *2005*), the mesa is made up of a basaltic lava flow (Pleistocene) that buries a 1–2 meter-thick conglomerate (Pleistocene) that unconformably overlies continental Cretaceous reddish sandstones. (Fig. 2a).

The mesa makes up the south valley wall of a minor creek along *c.* 400m. The stream discharge comes from a water spring situated *c.* 500m upstream of the site (Fig. 2.c). The Salamanca cave is developed in the basaltic lava that caps the mesa (Fig. 2.b). It is a chamber-like void (*c.* 8m deep, 1.5m high, 3m wide) of fairly regular morphology (spheroidal in shape), and the entrance is an ample opening (3.5m high, 2.5m wide) (Fig. 2.d). The cave walls are covered by ferric and manganese oxide stains, and show minor spalling. The chamber-like morphology of the cave points to a primary cavity of the basalt formed while the lava flowed on the aggradational land surface made up of conglomerates. During the widening of the valley margin by lateral erosion the volcanic chamber void was gradually opened, and exposed to exogenous processes; eventually it became an available locus for human occupation.

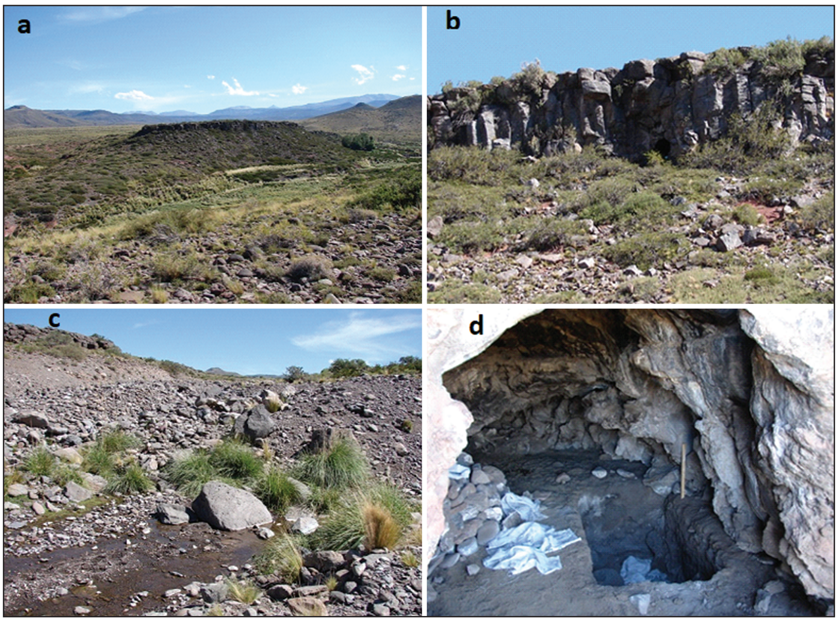

Fig. 2. Landscape at Salamanca cave and the surrounding area:* a *general view towards the north of the mesa;* b *Salamanca cave at the foot of the basaltic lava flow;* c *water spring upstream of Salamanca cave;* d *entrance and the excavation unit.

During January 2010 we excavated a 2x1m unit (A-1) at the west part of the cave, close to the wall (Fig. 3). The excavation unit was subdivided into two 1x1m subunits (north and south sector). We removed 20 artificial levels, five centimetres each, following the natural slope of the surface floor. The excavation reached the weathering bedrock of the cave. We found several medium and small blocks from the cave ceiling at the surface and also in the sedimentary filling.

Chronostratigraphy and archaeological components

The cave is filled with *c.* 1.3m of fine sand that is the sedimentary matrix of the archaeological record; a secondary fraction of blocks (main axis *c.* 10cm long) is present, mainly at the lowermost section of the sequence. Several bioturbation structures were identified throughout the sequence (*e.g.,* rodents caves, roots alteration, insect activity) along with human structures (hearth and trash middens) which became the major hindrance in the stratigraphic analysis of the sedimentary filling. Hence, difficulties were apparent when trying to correlate the artificial excavation layers, the radiocarbon dates and the archaeological record.

The sedimentary filling is subdivided into five stratigraphic units (1, 2, 3, 4, 5 from top to bottom) on the basis of the occurrence of discontinuity surfaces of sedimentation (Tab. 1). The NE angle of the excavation is the less disturbed and relatively complete section (Fig. 4). Units were described following a pedosedimentary approach, a combined sedimentological (grain size, sedimentary structure) and soil description (boundaries, Munsell soil colours).

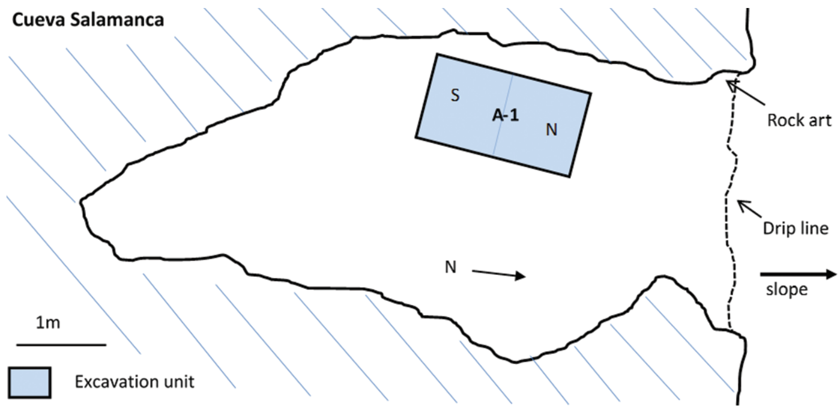

Fig. 3. Salamanca cave view on floor.

The lower boundary of Unit 2 exhibits an irregular shape (deep pocket), the upper part of Unit 3 (erosional surface). In turn, at the NW angle of the excavation the lower boundary of Unit 3 is a well-defined erosional surface carved in Unit 4. It is a *c.* 40cm deep and 50cm wide depression (trash hole, see below) which laterally grades into a depositional boundary (Fig. 4).

Twelve radiocarbon dates were obtained from charcoal samples (Tab. 2). The uncalibrated median chronology ranges from 7335 to 1055 ^{14}C years BP. Considering the stratigraphy and the radiocarbon dates, we defined three archaeological components (younger to older: A, B, C; Tab. 3).

The younger component (A) includes the stratigraphic units 1, 2 and 3. Unit 3 intrudes the NW part of the stratigraphy; the boundary shape and the filling with a chaotic and high concentration of bones along with lithic, charcoal and ceramic remains make it possible to interpret it as a trash hole between 1055 and 1516 ^{14}C years BP (Fig. 4).

The middle component (B) includes the upper section of stratigraphic unit 4 with radiocarbon dates spanning from 1516 and 2200 ^{14}C years BP (Fig. 4).

The lower component (C) comprises the lower section of unit 4. No sedimentary differences were observed between components B and C. However, the presence of much older radiocarbon dates (7100 and 7400 ^{14}C years BP), and differences in the archaeological record (projectile point shape, raw materials, exploited taxa and absence of pottery), lead us to differentiate components B and C.

In the case of component A, even when the radiocarbon dates had ages from the last two millennia, several modern historic remains are present (*e.g.*, goat bones, *etc.*) in the uppermost 20cm. This indicates that part of this component corresponds to occupations of the late historic herders (Fig. 4). In component C, a radiocarbon date yielded 1870±20

Unit	Thickness	Lithological features and archaeological remains	Lower contact
1	0–15cm	Light brownish gray (10YR 6/2) fine sands; moderately compacted to loose,massive; well preserved volcanic ash lenses (1932 Quiza-Pú eruption), thinly laminated on the W wall profile of the excavation.	sharp, irregular
2	15–30cm maximum, average thickness 15 cm	Grayish brown (10YR 5/2) fine sands, massive; goat dung, extensive hearth (20cm long, 12cm thick) in the E wall profile.	sharp, undulating
3	30–50cm	Grayish brown (10YR 5/2) fine sands with coarse clasts; very frequent archaeological remains (organic fragments and lithic artifacts).	sharp, undulating; sharp, smooth
4	(25 to 50cm–100cm) ~70cm maximum thickness	Grayish brown (10YR 5/2) fine sands with basaltic clasts; friable, sedimentary beds dipping towards the central part of the cave; some rodent caves. Abundant archaeological material including organic remains (*e.g.* vegetal macro-remains, vertebrate bones) lithic artifacts, as well as charcoal fragments, several hearths; dark brown (10YR 3/3) silty sand layer, 2cm thick including numerous mm long charcoal fragments.	sharp, smooth
5	(100–110cm)	Light brownish gray (10YR 6/2) very fine sand including coarse basaltic angular fragments; archaeologically sterile. It overlies a weathered basaltic surface.	sharp, irregular

Tab. 1. Lithological features and archaeological remains of Salamanca cave stratigraphic units.

^{14}C years BP. However, considering the identified bioturbation processes, and the resulting discontinuity of layers throughout the sequence, it is highly probable that the charcoal fragment comes from younger layers.

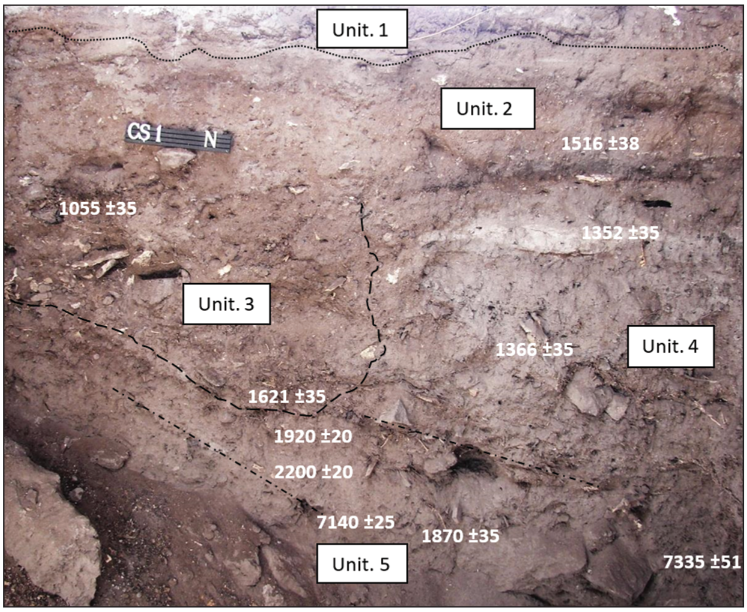

Fig. 4. Stratigraphic units in profile of north wall and the radiocarbon dates.

We calibrated the ^{14}C dates in OxCal 4.3 (*Bronk Ramsey 2009*) using the SHCal13 curve, and modelled them as a phased stratigraphic sequence (Tab. 4). These ^{14}C dates are listed in stratigraphic order from top (younger ages) to bottom (older ages) (Fig. 5). Cultural horizons were modelled as phases assuming that they do not overlap and deposited sequentially, and therefore we relied on our stratigraphic interpretations to organize the dates accordingly. We modelled the dates within components (A, B and C) using the command *phase* and estimated its duration with the command *span*. In addition, we separated each phase with the command *boundary*, assuming they were single events and that they occurred between the different cultural occupations. We used the command *interval* to estimate the duration of the Middle Holocene hiatus. The model demonstrated an overall agreement index of 100%, indicating a good fit for the data used (Fig. 5).

The archaeological record

Zooarchaeological record

A total of 31 035 bone specimens were analysed, of which 5928 were assigned to some taxonomic category. The results show a wide range of species exploitation, dominated by the Camelidae, Chinchillidae and Chlamyphoridae families (Tab. 5). Taphonomic observation (weathering, fresh fractures, cut marks, burnt surfaces) allowed us to discriminate between the species exploited by humans from those introduced by other predators. We confirm that bone specimens of Didelphidae, Caviidae, Ctenomyidae, Cricetidae and *Lestodelphys sp.* as well as suboscine birds were incorporated by the predatory activity of the common owl (*Tyto furcate*).

Component A is the most diverse considering the exploited species (NTAXA=10), even when their sample size (NISP=431) is not much larger than that of

Sample ID	Deep (cm)	Context	Stratigraphic unit	Archaeological component	Material	Lab code	^{14}C age (yrs. BP)	Calib. (‰)	$\delta^{13}C$
CS-1	35	North profile	2	A?	Charcoal	AA-94003	1352±35	1284±19	−23.1
CS-2	25	North profile	2	A?	Charcoal	AA-94004	1516±38	1425±58	−23.2
CS-3	39	North profile	Trash top 3 3	A	Charcoal	AA-94005	1055±35	982±38	−22.9
CS-4	39	North profile	4	A	Charcoal	AA-94006	1366±35	1297±16	−22.8
CS-5	50	North profile	Trash floor 3	B	Charcoal	AA-94007	1621±36	1497±54	−23.4
CS-6	60	East profile	4	B	Charcoal	AA-94002	1561±38	1461±47	−22.9
CS-8	75	Level 15	4	B	Charcoal	UGAMS-7006	2200±20	2234±60	−23.7
CS-9	65	Level 13	4	B	Charcoal	UGAMS-7007	1920±20	1867±23	−22.1
CS-10	95	Level 19	4	C	Charcoal	UGAMS-7004	7140±25	7973±17	−22.9
CS-11	95-100	Level 19–20	4	C	Charcoal	UGAMS-7005	1870±20	1815±41	−23.8
CS-7	100	East profile	4	C	Charcoal	AA-94001	7335±51	8135±67	−24.2

Tab. 2. Radiocarbon dates from Salamanca cave. The calibration was performed by the OxCal program with the southern hemisphere calibration curve (*Hogg et al.* 2013).

component B (NISP=405 and NTAXA=7). On the other hand, component C is the less diverse (NTAXA =5) but it must be mediated by the sample size (NISP =66). With the exception of the domestic taxa (Caprininae) registered and the smaller NTAXA, few differences occur between components A and B (Fig. 6). The most important changes take place between components C and B, which reflect a more intensive exploitation of Chlamyphoridae during the earlier occupation (component C), and a dominance of Chinchillidae and Camelidae families in component B. The latter trend is maintained in component A (Fig. 6). The mollusc fragments identified in component A correspond to marine taxa, probably from central Chile. This is a common scenario identified in the southern Mendoza archaeological record, where we observe molluscs used as tools, containers, and necklaces beads (*Lagiglia 1977; Neme 2007*).

Nine camelid bone samples were analysed to extract ancient DNA. Two of them were not considered due to the low coverage. The remaining seven samples confirmed our identification as *Lama guanicoe* specimens (*Abbona* et al. *2020*) in the three defined

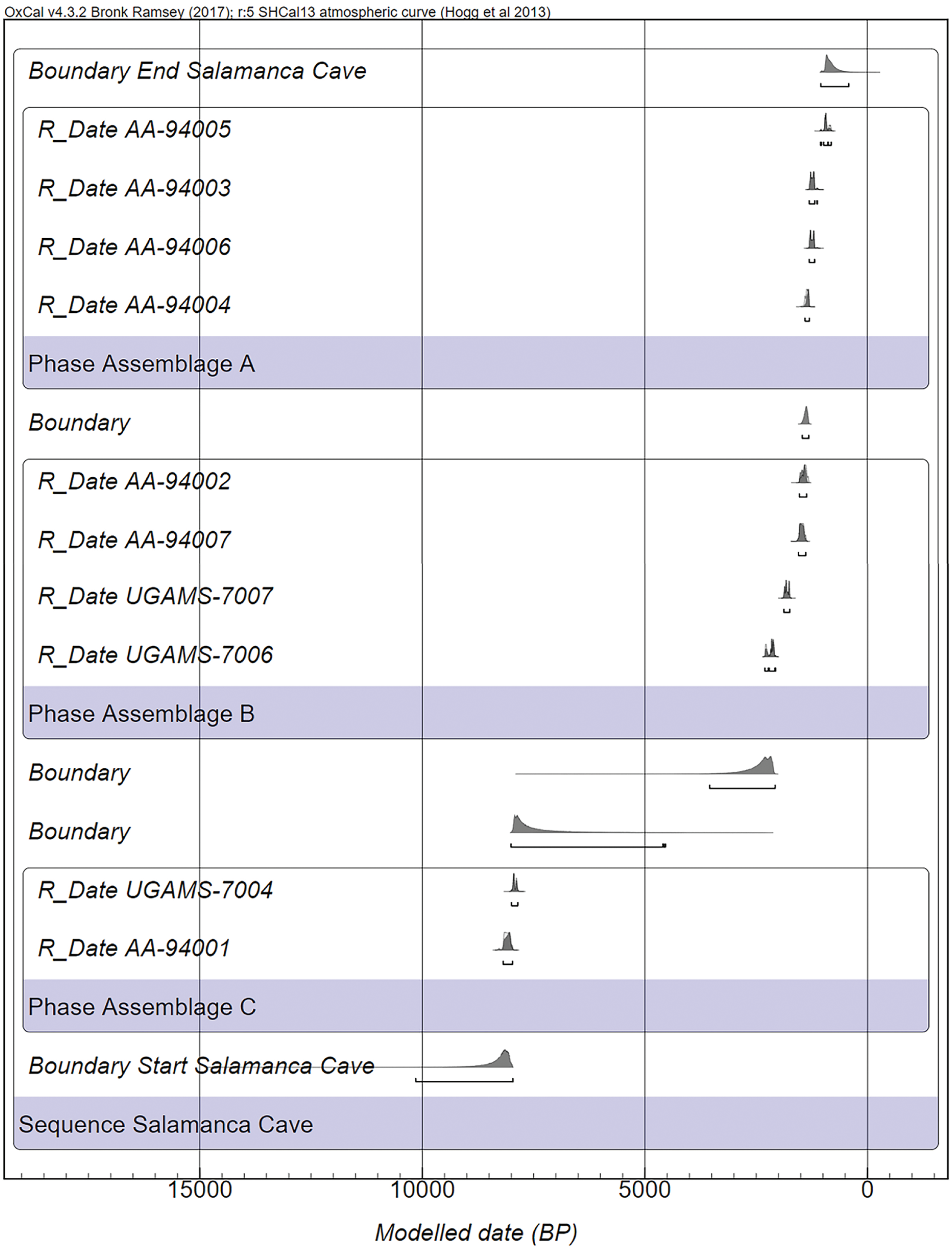

Fig. 5. Chronological model for 11 ^{14}C dates from Salamanca cave. The grey lines show probability estimates trimmed or shifted based on constraints of the Bayesian chronological model developed here. The overall agreement index for this model is strong (Amodel:100).

components (A, B and C). It is important to discard the proposed hypothesis about the existence of domestic camelid (*Lama glama*) in the southern Mendoza region (*Bárcena 1997*).

Lithic analysis

The lithic analysis includes 4987 artefacts of which 2331 (46%) belong to component A, 2608 (53%) to component B and 48 (1%) to component C. Silica or cryptocrystalline was the most used raw material at the site (57%), followed by obsidian (39%) and then basalt (3%). By silica we mean rocks with microcrystalline structure, composed primarily of quartz and including chert, chalcedony, agate, and silcrete. However, their use over time shows changes – silica dominated component C (%), while obsidian was dominant in component A (%) (Fig. 7). The low-quality raw material (mostly basalt) decreased over time (3% A, 4.5% B and 6.5% C). *Debitage* is the most frequent category, with an increase of the discard rate of tools by year during the last two millennia, from 0.1 in the component C to 3 in the component A (Tab. 6). Projectile points and scrapers are the best represented tool category (Fig. 9). The projectile points are the regional triangular types related to Late Holocene human occupation, however in the older component a stemmed one was found (Fig. 8.1). This last point type has no similarities with any other projectile point in the regional context.

Another difference is the increase in the number and diversity of tools over time. Component C includes only one tool; component B encompasses 28 tools within five tool classes; and component A, presents 49 tools within four tool classes. The differences are not due to the sample size. On the contrary, compo-

Date code – Commands	Modeled BP 2σ cal range
Boundary End Salamanca cave	1043–415
Span Phase A	277–543
R_Date AA-94005	1050–809
R_Date AA-94003	1302–1119
R_Date AA-94006	1301–1182
R_Date AA-94004	1396–1299
Boundary	1460–1313
Span Phase B	608–903
R_Date AA-94002	1525–1360
R_Date AA-94007	1545–1381
R_Date UGAMS-7007	1879–1745
R_Date UGAMS-7006	2305–2064
Boundary	3552–2070
Interval Middle Holocene	1837– 5850
Boundary	8010–4529
Span Phase C	0–291
R_Date UGAMS-7004	7998–7854
R_Date AA-94001	8185–7972
Boundary Start Salamanca cave	10 233– 7952

Tab. 4. Modelled radiocarbon sequence for Salamanca cave.

Archaeological component	Excavation units	Stratigraphic units	Chronology (^{14}C years BP)
A	1 to 9	1, 2 and 3	1055–1516
B	10 to 16	4	1561–2200
C	17 to 21	4	7100–7400

Tab. 3. Archaeological components defined in the paper.

	Archaeological components		
	A	B	C
Eudromia elegans #	0	1	0
Phalacrocorax #	1	0	0
Anatidae #	1	0	0
Suboscine	1	0	0
Rheidae #	7 (561)*	8 (180)*	0 (26)*
Rhea pennata #	0	0	1
Thylamys pallidior	92	83	7
Lestodelphys halli	1	11	0
Chlamyphoridae #	2	4	0
C. vellerosus #	0	5	6
C. villosus #	14	65	11
Z. pichiy #	12	7	205
Hystricomorpha indet.	252	265	32
Ctenomys sp.	23	53	6
Galea leucoblephara	3	0	1
cf Galea musteloides	1	0	0
Microcavia australis	9	16	1
Chinchillidae #	148	160	0
Lagidium sp #	0	0	1
Lagidium viscacia #	0	1	1
Cricetidae indet.	1468	175	152
Akodon iniscatus	9	16	9
Paynomys macronix	1	1	0
Phylotis xantopygus	71	90	1
Calomis musculinus	1	14	0
Eligmodontia sp.	161	254	23
Reitrodon auritus	40	50	3
Euneomys petersoni	17	45	2
Carnivora #	0	0	1
Lycalopex griseus #	2	0	0
Lycalopex sp. #	0	5	0
Puma concolor #	2	1	0
Puma cf P. yaguaroundi #	2	0	0
Artiodactila #	90	29	6
Camelidae #	5	7	0
Lama sp. #	99	110	15
Lama guanicoe #	43	49	3
Caprininae #	18	0	0
Mollusk	4	0	0
Total	**2600**	**3099**	**487**

Tab. 5. Faunal taxonomic list and abundance (NISP) in Salamanca cave. *Rheidae eggshell fragments in brackets; # Consumed species.

nent B consists of more artefacts but less tools and categories, while component A has less artefacts but more tools and categories (Tab. 7). In addition, the artefact discard rate increases over time (from one to 46). In component B, there is a higher debitage/instrument index, which implies increased transport of raw materials to the site and a possible increase in manufacturing. On another hand, component A shows an increased discard of tools (Tab. 7). Finally, no cores were recorded in the sequence, and 93% of the debitage has no cortex reserve.

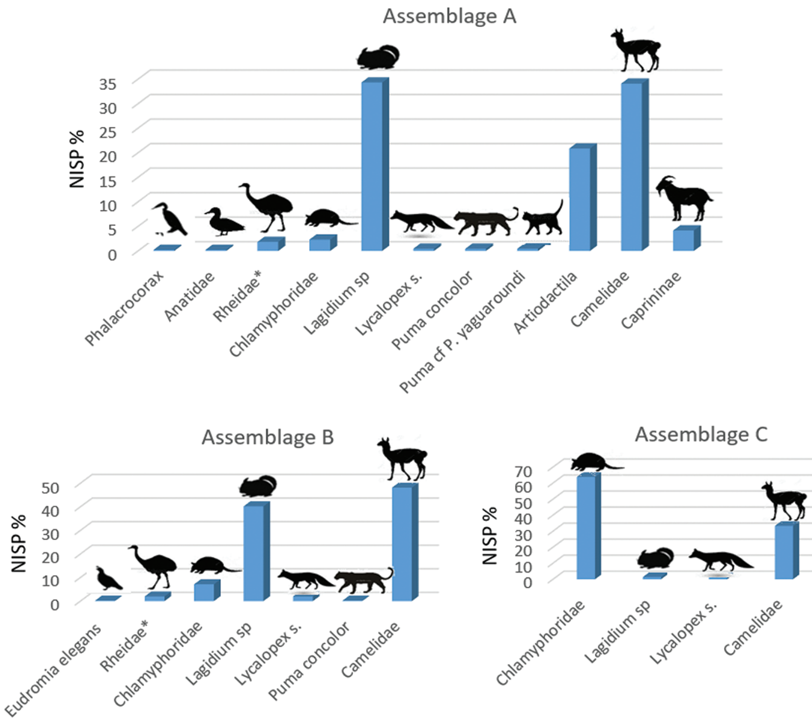

Fig. 6. Proportion of each consumed animal taxa in the Salamanca cave components

XRF analysis

A total of 88 obsidian artefacts were analysed by XRF following the methodology of the University of Missouri Research Reactor Laboratory (MURR) (*Glascock, Ferguson 2012*). The results were compared using the database available in MURR, including seven obsidian sources from northern Patagonia (Fig. 9). We could identify four known obsidian sources and two unknown ones (Tab. 8). The most represented obsidian source is Coche Quemado (72%), located on the south bank of the Grande river, 100km to the south (*Salgán* et al. *2020*), followed by Las Cargas source (11%), located *c.* 70km at the Argentina-Chile border in the Andes (*Salgán* et al. *2015*) (Fig. 1). The other obsidian sources identified are El Peceño (3%), located 100km away, on the plains (*Salgán, Pompei 2017*), and Laguna del Maule (3%), 100km away on the Argentinean-Chilean border in the Andes (*Barberena* et al. *2019*). The unknown source represents 10% of the samples.

The Coche Quemado and Las Cargas sources are present in the three components, in categories asuch as debitage, bifacial artefacts, and artefacts with complementary traces. There was no evidence of cores or unifacial artefacts (Tab. 8). In component B, unknown Group A (*Giesso* et al. *2011*) as well as unassigned artefacts are added, both present as debitage. In component A, the evidence of sources located at distances greater than 100km (*e.g.,* El Peceño and Laguna del Maule) is recorded as bifacial artefacts and debris. Tools are always projectile points, as reported in la Payunia and the Atuel river basin (*Salgán* et al. *2012; 2014; Pompei 2019*).

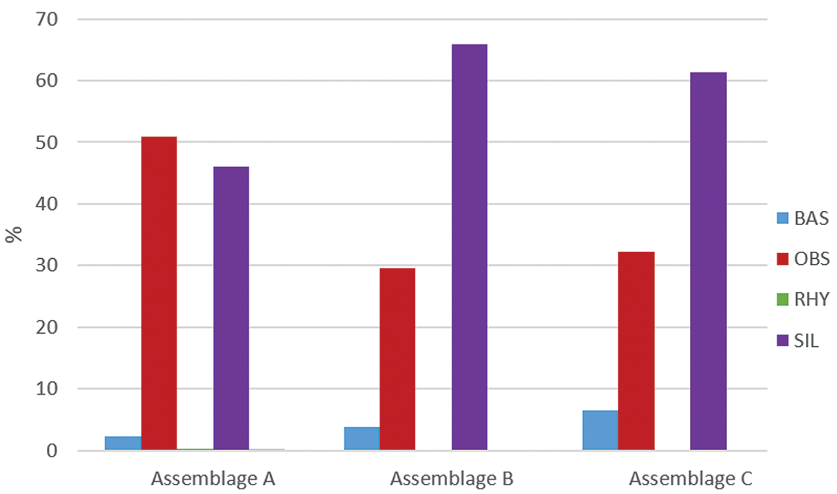

Fig. 7. Raw material by component in Salamanca cave (*BAS *basalt;* OBS *obsidian;* RHY *rhyolite;* SIL *silica).

Ceramic analysis

The ceramic record (Tab. 9) includes 66 sherds from component A (N=62) and B (N=4). The high frequency of sherds

Component	Raw material	Debitage	Bifacial tool	Unifacial tool	Non formal tool	Other art.	Total classes
A	Cryptocristalline	96.2% (628)	1.4% (9)	2.1% (14)	0.3% (2)		653
	Obsidian	95.3% (688)	2.5% (18)	0.7% (5)	1.4% (10)	0.1% (1)	722
	Basalt	84.8% (28)				15.2% (5)	33
	Rhyolite	100% (6)					6
	Others RM					100% (5)	5
Subtotal A		**95.14% (1350)**	**1.90% (27)**	**1.33% (19)**	**0.85% (12)**	**0.77% (11)**	**1419**
B	Cryptocristalline	98.3% (1173)	0.5% (6)	0.7% (9)	0.3% (3)	0.2% (2)	1193
	Obsidian	98.3% (525)	1.5% (8)		0.2% (1)		534
	Basalt	89.9% (62)	1.4% (1)			8.7% (6)	69
	Rhyolite	100% (7)					7
	Others RM	50% (3)				50% (3)	6
Subtotal B		**97.84% (1770)**	**0.83% (15)**	**0.50% (9)**	**0.22% (4)**	**0.61% (11)**	**1809**
C	Cryptocrystalline	94.7% (18)	5.3% (1)				19
	Obsidian	100% (10)					10
	Basalt	100% (2)					2
Subtotal C		**96.77% (30)**	**3.23% (1)**				**31**
Total (n)		**3150**	**43**	**28**	**16**	**22**	**3259**

Tab. 6. Artefact classes by raw material in each component. References, other raw materials: andesite, quartz, vulcanite and indeterminate raw material.

assigned to the Chilean typology highlights the presence of PAT (Early Pottery Period) and 'Marrón Pulido' (Brown polished) types (Figs. 10 and 11). Those Chilean traditions are well dated in Chile between 1800 and 800 years BP (*Falabella* et al. *2016*). PAT style is highly polished black ceramics with utilitarian forms, with conspicuously reduced firing, and fine-grained temper size. Brown polished style is a utilitarian ceramic with brown colours, sometimes with incised decoration, and commonly with a polished surface treatment. Temper size is well selected, consisting of fine grains of sands. The red polished style has similar characteristics to the brown polished style, the only differences is the use of colour. Overo style is a utilitarian ceramic with brown and grey colours, sometimes with incised decoration in the neck section, smoothed surface treatment, oxidized and oxidized incomplete firing. Temper size is poorly selected, medium to large and generally consists of sand.

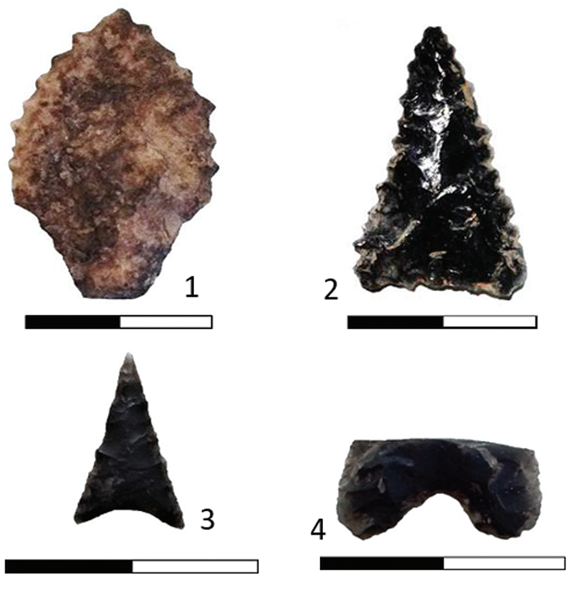

Fig. 8. Projectile points in Salamanca cave:* 1 *component C;* 2 *component B;* 3, 4 *component A.

Only a small part of the ceramic record (16%) belongs to the local 'Overo' typology (*Lagiglia 1997*), suggesting that ceramics were mainly acquired by extra-local exchange systems, in agreement with other sites of the region (*Sugrañes 2019*). The small size of the ceramic component reinforces this idea, and is coherent with the mobility constraints on north Patagonia hunter-gathers way of life. The ceramic record presents thin sherds (average 4.9mm), predominantly polished surface treatment (79%), fine temper size (63%) and reduce firing (40%).

We consider some macroscopic characteristics in the ceramics as a proxy of labour investment. The use of fine temper size impacts the wall thickness and therefore implies more labour and skill by the potter to produce a piece (*Eerkens 2008*). Reduced firing involves more investment, as the process needs more supervision and precision to acquire the expected effect. A polished surface treatment involves more labour and time once the piece has dried.

Discussion

The Salamanca cave archaeological record suggests a long human occupation sequence at the Andean Piedmont, starting 7335 ^{14}C years BP, with a notorious Middle to Late Holocene hiatus from 7140 to 2200 ^{14}C years BP. The sedimentary analysis and the numerical ages indicate major, important post-depositional processes affecting the archaeological record. We defined three archaeological components to identify changes or continuities in the archaeological record. The earliest component (C), radiocarbon dated between 7335 and 7140 years BP, is characterized by a low archaeological depositional rate (0.1lithic/year), with a narrow set of subsistence activities that involved hunting, cooking, tool making and maintenance. This evidence suggests that the cave was occupied by small hunter-gatherer bands during short stays. Chlamyphoridae (armadillos) and Camelidae (guanaco) were the most important faunal resources exploited, followed by some few Rheidae and Chinchillidae specimens. Local raw materials represent *c.* 70% of the lithic record in component C, coming from a less than 20km radius. Obsidian represents less than 30% of the total used raw material. The sourcing analysis indicates that it was obtained from sources located 70–100km away (Tab. 8 and Fig. 1).

The radiocarbon dates discontinuity of more than 5000 years (from 7973 to 2234 cal years BP) is similar to the gap identified in El Manzano cave (from 7907 and 2105 cal years BP; *Neme* et al. *2011*) and Huenul cave (*Barberena* et al. *2015a; 2015b*) located 70km and 180km away, respectively, in the Andean Piedmont. A sum probability curve (Fig. 12) was done using the radiocarbon calibrated dates from Salamanca cave (Tab. 2) and from the two other cave sequences (*Neme* et al. *2011; Barberena* et al. *2015b*). It shows a bimodal curve with Early and Late Holocene occupations. At the same time, it defines a significant occupational gap, including most of the Middle Holocene and the Early-Late Holocene from 7400 to 2400 cal years BP, suggesting the existence of a very similar regional pattern.

Component	A	B	C
Debitage/tools	29.3	73.8	30.0
Temporal span (years)	460	640	200
Artifact discard rate/years	3.1	2.8	0.2

Tab. 7. Lithic discard rates in Salamanca cave.

In the case of Salamanca cave, this discontinuity appears to be chronological and stratigraphical (*Veth* et al. *2017*). The obtained radiocarbon dates indicate that there may be a stratigraphic gap with no sedimentation between 2200 and 7140 years BP (see Fig. 4). This absence of sedimentation makes it difficult to make definitive assumptions related to the Middle Holocene gap regionally considered.

Different explanations have been proposed to understand this regional gap. Plausible explanations include a regional depopulation, settlement reorganization, changes in mobility, or in site size (*Neme, Gil 2009*), although aridization is accepted as the most plausible (*Gil* et al. *2005; Neme, Gil 2008a; Barberena* et al. *2017*). Other researchers discuss the significance of local volcanism and glacier events with regard to the regional productivity (*Durán, Mikkan 2009; Durán* et al. *2016*). However, the human response to drier climatic conditions remains undetermined and debatable. Based on obsidian hydration data, mitochondrial DNA and radiocarbon trends, other authors suggest a continuity in human occupation throughout northern Patagonia (*Garvey, Bettinger 2018; Gordón* et al. *2019; Pérez* et al. *2016a*). Nonetheless, the Patagonian human demography seemed to be non-homogeneous, with non-inhabited areas (*Pérez* et al. *2016b*).

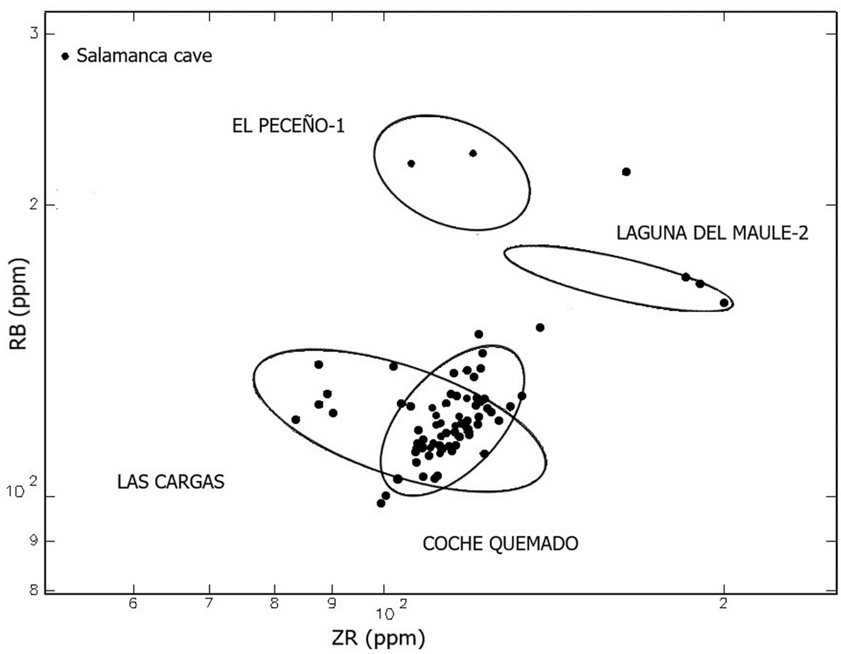

Fig. 9. XRF obsidian source analysis from Salamanca cave site artefacts. Ellipses are the 90% confidence interval around each source.

Components	Artifact classes	Coche Quemado	Las Cargas	El Peceño 1	Laguna del Maule-2	Unassigned	Unknown group A
A	Debitage	39% (11)	11% (3)	4% (1)	11% (3)		
	Bifacial tool	25% (7)		4% (1)			
	Non formal tool	7% (2)					
	Total	**71% (20)**	**11% (3)**	**7% (2)**	**11% (3)**		
B	Debitage	57% (16)				4% (1)	4% (1)
	Bifacial tool	32% (9)	4% (1)				
	Total	**89% (25)**	**4% (1)**			**4% (1)**	**4% (1)**
C	Debitage	70% (7)	10% (1)				
	Bifacial tool		10% (1)				
	Non formal tool	10% (1)					
	Total	**80% (8)**	**20% (2)**				

Tab. 8. Artefact classes present in the obsidian components analysed from XRF Salamanca cave.

The analysis of Neuquén province (northern Patagonia) fauna shows an increase in guanaco dependence during the Middle Holocene (*Rindel 2017*), similar to the Middle Holocene pattern of southern Mendoza (*Neme, Gil 2009*). The guanaco demographic curve, reconstructed using mitochondrial DNA from the entire Patagonia, indicate a population increase during the beginning of the Middle Holocene *c.* 7500 years BP (*Pérez* et al. *2017; Moscardi* et al. *2020; Abbona* et al. *2021*), which could explain the human focus on this resource. Guanacos are adapted to cold and grassland environments (*Puig* et al. *2011*), and changes in the environmental conditions that favour guanaco populations can reduce plant productivity in environments outside the Andes, as well as smaller animal populations, leading humans to focus on this target.

The suggestive contemporaneity in the Middle Holocene radiocarbon hiatus among all the Andean Piedmont from northern Patagonia Piedmont sites (El Manzano cave, Huenul cave and Salamanca cave), needs to be explored and explained. More importantly, this trend is also identified at a larger regional scale in other archaeological sites with a noticeable decrease in the archaeological record (*Neme, Gil 2009; 2012*). Even if we consider the obsidian hydration from the area in El Manzano cave (*Garvey, Bettinger 2018*), the number of obsidian samples assigned to the Middle Holocene is much smaller than those compared with the Early and Late Holocene from the same site. This suggests a human depopulation process or changes in the settlement pattern related to a rearrangement to the new environmental conditions.

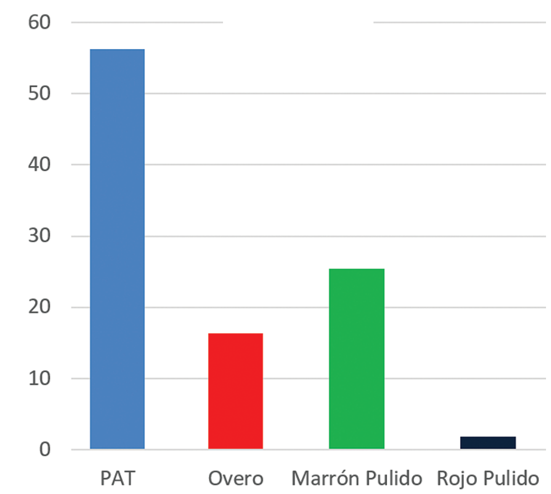

Fig. 10. Percentages of ceramic types in Salamanca cave site.

After this long discontinuity in the Salamanca cave archaeological record, the human occupations rise again during component B with an increase in the faunal and lithic diversity as well as in the deposition rate (2.8 lithic artefacts discarded by year), and probably more reoccupation events. In the lithic record the use of local raw materials in older components is also recorded. It is associated with a Late Holocene increase in the use of obsidian and an increase in the number of obsidian sources exploited. In El Manzano cave, the Laguna del Maule source is recorded in the oldest components (*Barberena* et al. *2019*), while in the Late Holocene there is a significant increase in obsidian over local resources, incorporating the Las Cargas obsidian source (*Neme* et al. *2011*). In Huenul cave, the infrequent use of Laguna del Maule subtypes 1 and 2 is incorporated in the Late Holocene, together with a Huenul local source (*Fernández* et al. *2017*).

Two technological innovations are evident in component B: ceramics and the bow and arrow, as suggested by the projectile point size (*Martínez 2003; Ratto 2003; Banegas* et al. *2014; Castro 2015*). The projectile points change from stemmed to triangular notched types (Fig. 9). A more diverse use of raw material is apparent, with silica increasing and basalt decreasing. Four ceramic sherds were recovered in this component. But even when the chronology is coherent with the regional arrival of ceramics dated at *c.* 2000 years BP (*Marsh 2017; Sugrañes 2017*), these sherds, which share the same characteristics, are more likely the result of vertical migration by some post-depositional disturbance.

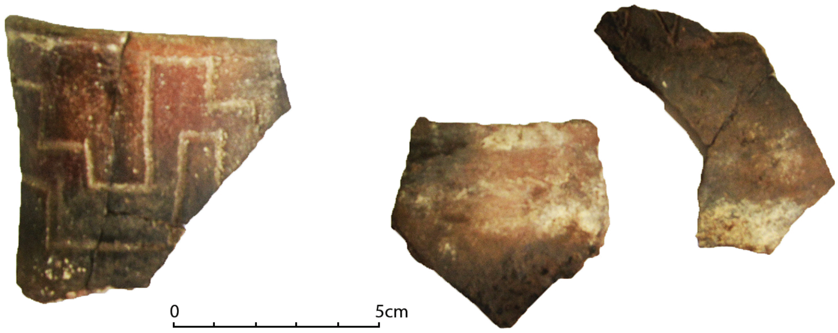

Fig. 11. Ceramic sherds from Salamanca cave. Types: PAT, Early Ceramic Period (left), Brown Polished (centre), and Overo (right).

The exploited faunal resources increase from NTAXA =5 in component C to NTAXA=7 in component B. There is an increase in chinchilla hunting, a smaller species, uncommon in the regional zooarchaeological record. Framed within the diet breadth model, chinchilla is lower ranked among the rest of species in the region (*Corbat* et al. *2021*). This taxon replaces the Chlamyphoridae as the most abundant small mammal on the site. This increase in the number of consumed taxa and the incorporation of smaller animals agrees with the regional northern Patagonia trends (*Neme 2007; Otaola* et al. *2015; Rindel 2017*). However, the guanaco continues as the main faunal resource at Salamanca cave and in the other sites of the region.

Component A is the most diverse in terms of fauna exploitation, lithic and ceramic types, with the highest depositional rate of the sequence (3 lithic artefacts discarded by year) and a decrease in the waste discard rate in relation to the tools. This implies a change in the mode of transport of raw materials, from preform in component B to the transport of tools in component A. This evidence is the result of a higher reoccupation pattern and a larger number of activities carried on. The faunal record shows a strong dependence on guanaco and chinchilla, but several carnivores, birds and armadillos could be part of the diet too, as the taphonomic observations suggest. Only the small rodents (Cricetidae and Sigmodontinae) were clearly introduced to the site by avian predators (mainly owls).

Components A and B are difficult to discriminate due to the stratigraphic complexity, the absence of a clear unconformity, and the presence of crossing radiocarbon dates. Alternatively, both units (A and B) might be a single component instead of two. However, on the basis of the presence of older radiocarbon dates, and the absence of historic remains in component B as well as other archaeological aspects (*e.g.,* zooarchaeology, proportion of lithics raw materials) support the identification of two components.

Variable		Style							
		PAT		MP		OV		RP	
Thickness average mm		4.8		5.6		5.8		4.3	
Residues		3		1		1		0	
		Count	%	Count	%	Count	%	Count	%
Temper size	F	18	64.3	8	72.7	4	50	0	0
	M	10	35.7	3	27.3	4	50	1	100
Surface treatment	S	2	6.3	2	14.3	7	77.8	0	0
	P	30	93.8	12	85.7	2	22.2	1	100
Section	S	27	84.4	11	78.6	9	100	1	100
	R	5	15.6	3	21.4	0	0	0	0
Decoration	I	9	90	0	0	0	0	0	0
	P	1	10	0	0	0	0	0	0
Firing	O	2	6.3	1	7.1	1	11.1	1	100
	OI	13	40.6	7	50	4	44.4	0	0
	R	17	53.1	6	42.9	4	44.4	0	0

Tab. 9. Ceramic sherd properties from the Salamanca cave site. References:* F *fine;* M *medium;* P *polished;* S *smoothed;* PAT *Early Ceramic Period;* OV *Overo;* MP *brown polished;* RP *red polished;* O *oxidized;* OI *oxidized incomplete;* R *reduced;* I *incised;* P *painted, in section* S *sherd,* R *rim.

Obsidian trace element analysis indicates an increase in the use of raw material sources during the Late Holocene. Component C has the presence of Coche Quemado and Las Cargas sources, while components A and B incorporate at least four obsidian sources in low frequencies. Specifically, in component A, obsidian artefacts from Laguna del Maule 2 are recorded. This source was located in the Barrancas and Colorado rivers at a distance between 100 and 160km (*Barberena*

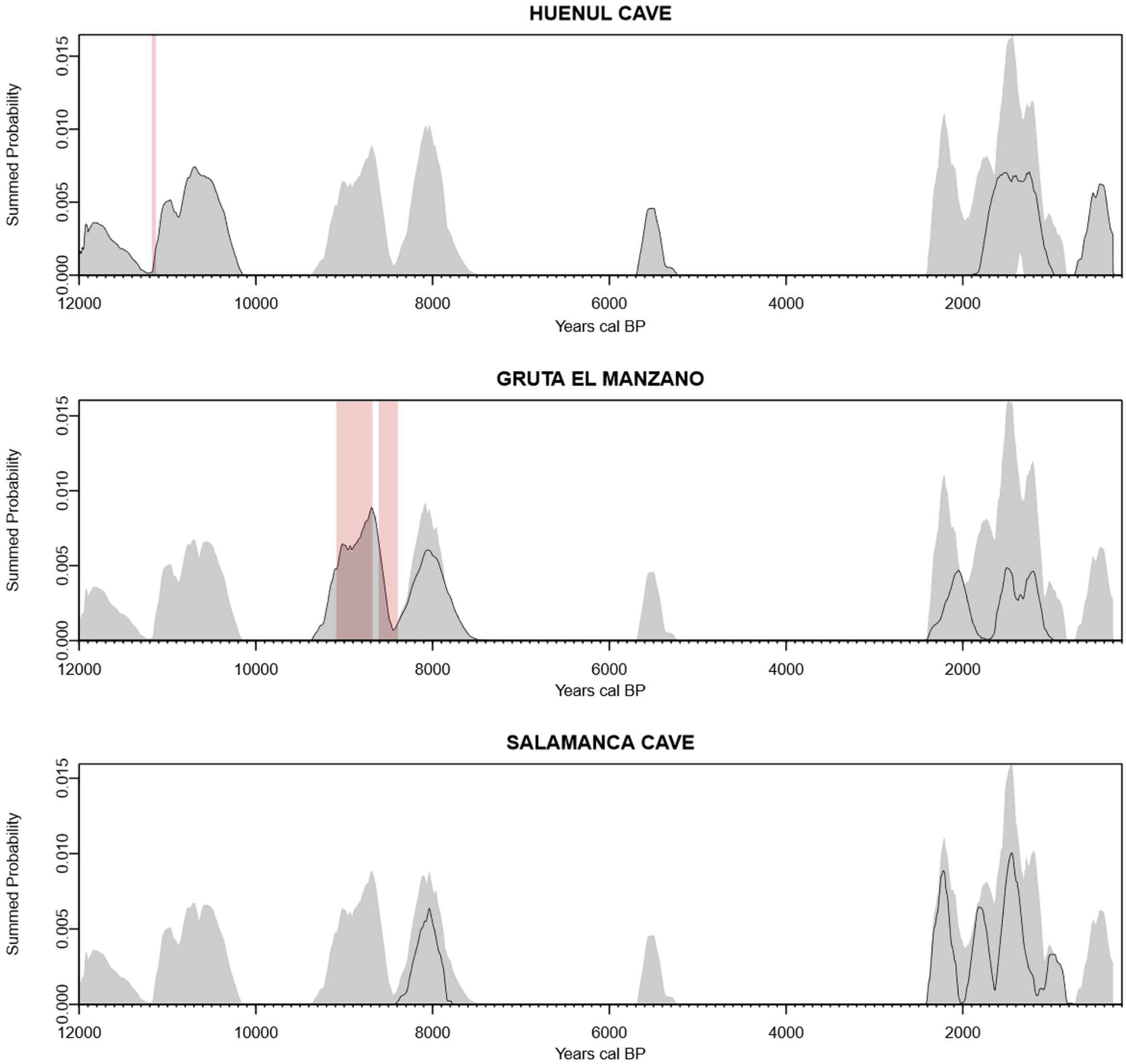

Fig. 12. Permutation tests showing variation between regional population growth. Grey areas represent the confidence envelope for the null model, red areas represent where the empirical SPD significantly deviates from the null model. The black line represents the empirical SPD for each archaeological site (*Crema, Bevan 2021*).

et al. *2019*). The presence of debitage from this source could indicate a home range increase, or greater human interaction with populations located to the south.

The ceramic sherds appear from level one to level twelve, radiocarbon dated in 1530 years BP. The presence of ceramics in the latter components could reinforce the idea of a higher number of subsistence activities, reflected in the mentioned number and diversity of both the faunal and lithic records. In addition, the ceramics recovered show high manufacture inversion, as reflected in the average thickness (4.9mm), surface treatment (79% polished), temper size (63% fine) and firing (40% reduced). Following Sturm *et al.* (*2016*) this conjunction of traits on the ceramic assemblage suggests a high reuse of vessels, probably for several years. The high proportion of non-local ceramic (mainly from the Chilean side of the Andes) indicates a high value of this technology in the area, not only for subsistence but also for trade networks. These networks could have worked like the Hxaro system (*Weisner 2020*), in which the interchange of gifts assured the access to complementary environments when conditions of rainfall and resources got harsh (*Neme, Gil 2005; Eerkens 2011*). El Manzano cave (90km to the south) registers a highly diverse ceramic assemblage made up of non-local types, suggesting that the northwestern Patagonia ceramic assemblages were obtained mostly from neighbouring societies. The sites located in the Andean Piedmont from northwestern Patagonia are among the more diverse in faunal taxa, and probably plant resources too (*Neme* et al. *2011; Llano 2011; Llano, Barberena 2013; Otaola* et al. *2015*).

The Late Holocene archaeological record in Salamanca cave (components A and B) suggests a major change after the Middle Holocene gap. The described species faunal consumption in component C indicates a narrow dietary focus on guanaco and armadillos. These two species are placed at the top of the regional faunal ranking (*Corbat* et al. *2021*), and represent more than 90% of the total NISP in component C, while in later components A and B, those species represent only 50% and 40%, respectively. This change shows a broader diet later, and an increase in the consumption of lower return rate species such as chinchilla, birds and probably carnivores too. This change in favour of a broader diet in later components is in agreement with the intensification process proposed for the region for the last 2000 years BP (*Neme 2007; Neme, Gil 2008a*). This intensification process was criticized by latter research, arguing that it could be an effect of the spatial scale considered, instead of the diminution in guanaco population by human hunting pressure (*Otaola* et al. *2015; Wolverton* et al. *2015*). However, the faunal changes that took place from the same sequence in Salamanca cave are in agreement with the intensification process. A recent ancient DNA guanaco study (including some samples from Salamanca cave sequence) also demonstrate the existence of a decline in guanaco population in northwestern Patagonia during the las 2500 years BP (*Abbona* et al. *2021*), reinforcing the proposed regional intensification process.

The implications of these intensification processes move beyond the faunal, and are in line with other changes identified in Salamanca cave. Among them are the increase in obsidian use, the presence of Pacific mollusc shells, and the introduction of Chilean pottery during the last 2200 years. Those records show the inclusion of more diverse and distant sites of acquisition, including new obsidian sources, molluscs, and Chilean ceramics, suggesting the establishment of a stronger regional network, which allowed regional hunter-gatherers access to non-locally available resources. The increase in utilitarian pottery, especially in component A, indicates new resources being processed (including plants not yet analysed in Salamanca). The human occupations are more redundant and possibly longer than those from earlier times, which is concordant with the increase in the discard rate mentioned in this paper.

The presence of shelters, water, raw materials, and the biological diversity could favour human occupation in places like Salamanca cave, El Manzano cave, Cueva de Luna, El Chacay, Cañada de Cachi or Puesto Carrasco. There is an important plant record in the sequence, some burnt, but not analysed yet. Perhaps, the vegetal resources at the site can explain the occurrence of ceramic sherds, with the ceramics used to process, transport or store seeds.

Final remarks

The Andean Piedmont in northwestern Patagonia has diverse and rich resources. Located between the Andean foothills and the Lowlands, it allows access to wide and varied faunal, plants and lithic resources. The predominance of Patagonia phytogeography province ensures an abundant guanaco presence, as well as armadillos, and Rheidae, the three top ranking animals of the region. The characteristics of the Salamanca archaeological record agree with most of the Piedmont excavated caves, which shows a wide diversity in their faunal, lithic and ceramic record, and intense signal of human occupations (*Gambier 1985; Durán* et al. *1999; Durán 2000; Neme* et al. *2011; Barberena 2015*). The chronological sequence follows a common pattern among the caves in the region. After a first increase of human occupation, during the colonization *c.* 7300 years BP, the archaeological record discontinues until *c.* 2200 years BP.

In Salamanca cave, the observations made on the stratigraphy shows different post-depositional processes that altered the sediments and disposition of archaeological materials. Human groups carried out a diverse set of activities on the site, including those related to food (animal and plant) acquisition and processing, as well as lithic tool preparation and maintenance. The ceramic diversity indicates that cooking, transport and storage were part of the subsistence activities.

The fauna analysis shows a strong exploitation of middle size mammals at the beginning of the sequence, especially armadillos, which changes in favour of chinchilla towards the last two millennia. Beyond this trend, as in many other northwestern Patagonian environments, camelids were the base of human subsistence.

The lithic assemblage shows an increasing use of non-local raw materials, consistent with the observations in other sites from the region. The artefactual categories suggest the presence of the last stages of the operative sequence, formalisation and reactivation of tools. The few ceramic sherds and their attribution to styles from the western side of the Andes reinforce the idea of the high investment and low production scale for this type of technology, incorporated mainly from exchange.

Finally, the archaeological information from Salamanca cave indicates that the site was occupied by hunter-gatherer groups which colonized and occupied the Andean Piedmont environment, facing environmental constraints, especially during the Middle Holocene. The lack of a Middle to Late Holocene sedimentary record is a hindrance to interpreting cultural discontinuities (*Veth* et al. *2017*). Salamanca cave also provides insights on the important challenge related to the resource structure and demographic dependent factors, and especially the intensification process, which forced changes in resource use, technology and human relations with neighbouring populations, increasing long distance exchange. Future excavations, as well as the use of new methodology, will allow us to confirm and reject some of the ideas presented here, and improve our comprehension of the complex site formation processes.

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