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Chronological distribution and disturbance factors to evaluate population dynamics in Western Pampas, Argentina

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ABSTRACT

The radiocarbon chronology of the sites and cultural sequences is, at the regional level, a benchmark for evaluating different types of processes: cultural, demographic, taphonomic, environmental. Although it is assumed that chronological signal is closely related to the density and intensity of the processes of settlement, colonization, occupation and use of spaces and landscapes, this signal is mediated by many complex factors affecting its representation. In the case of the province of La Pampa (Argentina), which covers the western part of the Pampean region, where research data discussed in this paper are developed, several of these factors should act or be present. However, in the present state of research in the region it is possible to assess and discuss the significance of the radiocarbon signal, not only intra – regionally but in correlation with neighboring areas. In this paper a set of published radiocarbon dates ($n = 64$) is presented, that constitute all available Western Pampa published ^{14}C dates. While still scarce and random, these dates establish that the timescale in which colonization events and use of regional space happened, archaeologically evaluated, covers a span comprised between mid-Early Holocene and final Late Holocene. The results will be discussed in comparative terms, into two scales: the intra and inter-regional and considering different type of archaeological sites.

1. Introduction

The radiocarbon chronology of the sites and cultural sequences is, at the regional level, a benchmark for evaluating different types of processes: cultural, demographic, taphonomic, environmental (Surovell and Brantingham, 2007; Peros et al., 2010; Williams, 2012). Although it is assumed that a chronological signal is closely related to the density and intensity of the processes of settlement, colonization, occupation, and use of spaces and landscapes, this signal is mediated by many complex factors affecting its representation. These factors should be evaluated in micro- and macro-regional form and the multidimensionality of effects and consequences, whenever possible.

There is a strong influence from research biases, both thematic and spatial. Certain environments such as river valleys, meandering rivers, coasts, volcanic deposits, dune fields and desert landscapes with high erosivity, mean that archaeological sites have less chances of remaining over time or of maintaining their integrity. In recent years, several verification or correction tests of these biases have been developed, under the premise that: "The crux of the argument is that the longer something is in existence, the more chances it has to be removed from the archaeological record by taphonomic processes such as erosion and weathering thereby causing over-representation of recent events relative to older events" (Surovell et al., 2009: 1715).

In the case of the province of La Pampa (Argentina), which covers the western part of the Pampean region, several of these factors should act or be present. Although the archaeology of this area awakened the interest of researchers early in the 20th century (Outes, 1904), research was characterized for decades by discontinuity and a lack of systematic study. This was partly due to the difficulties associated with the archaeological material, mostly surficial and, in another sense, the lack of appreciation showed by some researchers regarding the characteristics of the archaeological record of the hunter–gatherers of this broad sector, compared with Patagonia. However, in the present state of research in the region it is possible to assess and discuss the significance of the radiocarbon signal, not only intra-regionally but in correlation with neighboring areas.

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In this paper, a set of published radiocarbon dates ($n = 64$) is presented, that constitute all available Western Pampa ^{14}C dates (Table 1). While still scarce and random, these dates establish that the timescale in which colonization events and use of regional space happened, archaeologically evaluated, covers a span between mid-Early Holocene and final Late Holocene.

Table 1
Radiocarbon information of Western Pampa.

No	Site	Unit/Level	Sample	Code	^{14}C	±	Reference
1	Casa de Piedra. Sitio 1	Ocup.Inf.-210 cm profundity	Charcoal	I 12067	8620	190	Gradín et al., 1984
2	Casa de Piedra. Sitio 1	Ocup.Inf.-210 cm profundity	Charcoal	I 12159	7560	230	Gradín et al., 1984
3	Casa de Piedra. Sitio 1	Ocup.Medias -100 cm profundity	Charcoal	I 12065	6080	120	Gradín et al., 1984
4	Casa de Piedra. Rinc.Giles C.P.	34 a 42 cm profundity	Charcoal	AC 0731	320	120	Berón, 1991
5	Casa de Piedra. Rinc.Giles C.P.	53 cm profundity	Charcoal	AC 0729	700	100	Berón, 1991
6	L.Tapera Moreira-Sitio 1	Level II	Organic residue in pottery	UGAMS 7446	360	25	Musaubach and Berón, 2012; Berón, 2013
7	L.Tapera Moreira-Sitio 1	Level XXIV	Charcoal in crotovine	Beta 82555	450	70	Berón and Scarafoni, 1993; Berón 1997, 2010a,b
8	L.Tapera Moreira-Sitio 1	Level III	Charcoal	Beta 81694	510	60	Berón 1997, 2004, 2013
9	L. Tapera Moreira. Sitio 5	Level III	Charcoal	Beta 91938	730	40	Berón 1997, 2004, 2013
10	L. Tapera Moreira. Sitio 5	Level IV a	Charcoal	Beta 81698	740	50	Berón 1997, 2004, 2013
11	L.Tapera Moreira-Sitio 1	Level IV	Charcoal	LP 265	1220	60	Berón 1997, 2004, 2013
12	L. Tapera Moreira. Sitio 5	Level IIa	Charcoal	LP 340	1710	90	Berón 1997, 2004, 2013
13	L.Tapera Moreira-Sitio 1	Level Q XXV	Charcoal	UGAMS 7445	1750	25	Berón 2013
14	L.Tapera Moreira-Sitio 1	Level VII	Charcoal	LP 343	1830	80	Berón 1997, 2004, 2013
15	L.Tapera Moreira-Sitio 1	Level XI	Charcoal	LP 352	1860	100	Berón 1997, 2004, 2013
16	L.Tapera Moreira-Sitio 1	Level IX	Charcoal	Beta 81695	1900	70	Berón 2004, 2013
17	L.Tapera Moreira-Sitio 1	Level XII	Charcoal	LP 358	1970	90	Berón 2004, 2013
18	L.Tapera Moreira-Sitio 1	Level X	Charcoal	LP 275	2140	70	Berón 2004, 2013
19	L.Tapera Moreira-Sitio 1	Level XXVI	Charcoal	Beta 91935	2200	40	Berón 2004, 2013
20	L.Tapera Moreira-Sitio 1	Level XX	Charcoal	Beta 82557	2350	70	Berón 1997, 2004, 2013
21	L. Tapera Moreira-Sitio 3	Burial 1	Human bone	Beta 82558	2630	60	Berón 1997, 2004, 2013
22	L. Tapera Moreira. La Lomita	Burial 1	Human bone	Beta 91934	2960	50	Berón 1997, 2004, 2013
23	L.Tapera Moreira-Sitio 1	Level XVII	Charcoal	LP 264	3040	80	Berón 2004, 2013
24	L.Tapera Moreira-Sitio 1	Level XIII	Charcoal	Beta 91936	3500	80	Berón 1997, 2004, 2013
25	L.Tapera Moreira-Sitio 1	Level XIII	Charcoal	AA35955	3685	40	Berón 2004, 2013
26	L.Tapera Moreira-Sitio 1	Level XXVIII	Charcoal	Beta 82556	3900	60	Berón 1997, 2004, 2013
27	L.Tapera Moreira-Sitio 1	Level XXVIII	Charcoal	AA35954	3995	50	Berón 2004, 2013
28	L.Tapera Moreira-Sitio 1	Level XXI	*Lama guanicoe* phalanx	Beta 91937	4550	60	Berón 1997, 2004, 2013
29	Sitio Chenque I	Burial 3	3rd left upper molar	UGAMS 02001	730	50	Berón et al., 2007, 2013
30	Sitio Chenque I	Burial 4	3rd left upper molar	UGAMS 4416	860	20	Berón et al., 2007, 2013
31	Sitio Chenque I	Burial 7	3rd left upper molar	AA 35952	904	43	Berón et al., 2007, 2013
32	Sitio Chenque I	Burial 8/9	3rd left upper molar	AA 35953	901	43	Berón et al., 2007, 2013
33	Sitio Chenque I	Burial 10	3rd left upper molar	UGAMS 7435	790	25	Berón et al., 2007, 2013
34	Sitio Chenque I	Burial 14	Left upper Incisor	UGAMS 10624	700	40	Berón et al., 2007, 2013
35	Sitio Chenque I	Burial 15	Human hand phalanx	UGAMS 10625	830	40	Berón et al., 2007, 2013
36	Sitio Chenque I	Burial 16	1st proximal hand phalanx	UGAMS 10626	370	40	Berón et al., 2007, 2013
37	Sitio Chenque I	Burial 17	3rd right upper molar	UGAMS 02002	990	60	Berón et al., 2007, 2013
38	Sitio Chenque I	Burial 18	1st inferior right molar	UGAMS 01999	890	30	Berón et al., 2007, 2013
39	Sitio Chenque I	Burial 19	2nd left inferior molar	UGAMS 7436	720	20	Berón et al., 2007, 2013
40	Sitio Chenque I	Burial 21/23	3rd left upper molar	UGAMS 02003	320	30	Berón et al., 2007, 2013
41	Sitio Chenque I	Burial 25	3rd left upper molar	UGAMS 4415	435	20	Berón et al., 2007, 2013
42	Sitio Chenque I	Burial 27	3rd left upper molar	UGAMS 02000	370	30	Berón et al., 2007, 2013
43	Sitio Chenque I	Burial29	3rd right upper molar	UGAMS 02004	390	30	Berón et al., 2007, 2013
44	Sitio Chenque I	Burial30	3rd upper molar	UGAMS 7437	890	20	Berón et al., 2007, 2013
45	Sitio Chenque I	Burial 34	Cuneiform	UGAMS 02005	1050	30	Berón et al., 2007, 2013
46	Sitio Chenque I	Burial 38	1st right upper molar	UGAMS 7438	360	20	Berón et al., 2007, 2013
47	Sitio Chenque I	Burial 39 (2)	3rd left upper molar	UGAMS 7439	290	25	Berón et al., 2007, 2013
48	Sitio Chenque I	Burial 40	3rd left upper molar	UGAMS 02007	390	30	Berón et al., 2007, 2013
49	Sitio Chenque I	Burial 41	*Canis familiaris*- rib	UGAMS 02006	930	30	Berón et al., 2007, 2013
50	Sitio Chenque I	Superior Unit-E/6-II-1(z)	3rd left upper molar	AA 35950	1029	43	Berón et al., 2007, 2013
51	Sitio Chenque I	Superior Unit -E/6-II-3(z)	3rd left upper molar	AA 35951	869	43	Berón et al., 2007, 2013
52	Sitio Chenque I	Superior Unit- sector 2 N° 305	1st left upper molar	UGAMS10627	740	70	Berón et al., 2007, 2013
53	Sitio Chenque I	Superior Unit-D/4,IV, sector 2 N° 715	2nd right inferior premolar	UGAMS 10628	730	70	Berón et al., 2007, 2013
54	Loma Chapalcó	Multiple burial, commingled-MNI 6	Proximal hand phalanx	UGAMS 02008	3040	30	Curtoni 2007, Beròn et al., 2009
55	Chillhué 1	Primary simple burial	1st left upper molar	UGAMS 02009	1930	30	Berón et al., 2006; Berón and Luna 2009
56	Bajo de Atreuco	Primary simple burial	2nd left lower molar	UGAMS 4414	2635	25	Berón et al., 2013
57	La Enriqueta	Multiple burial, commingled-MNI 9	Bone (cuneiforme)	UGAMS 4418	1005	25	Berón and Carrera Aizpitarte, 2013
58	Cuchillo Co	Primary simple burial	Bone (rama mandibular)	UGAMS 4417	3035	25	Berón et al., 2013
59	Médano Petroquimica	Multiple burial- Pqca 5.1.1	Human rib	AA 71847	896	58	Mendonça et al., 2010

(*continued on next page*)

Table 1 (*continued*)

No	Site	Unit/Level	Sample	Code	^{14}C	±	Reference
60	Médano Petroquimica	Multiple burial- Pqca 5.1.2	Human rib	AA 71848	823	41	Mendonça et al., 2010
61	Puesto Hernadez	Multiple burial- PH 5.1.1	Human rib	AA 74041	393	41	Mendonça et al., 2010
62	Puesto Hernadez	Multiple burial- PH 5.1.2	Human rib	AA 74042	378	41	Mendonça et al., 2010
63	Laguna Chadilauquen	Scattered remains, Individual 4	Human tooth	AA89807	3714	56	Mendonça et al., 2013
64	Laguna Chadilauquen	Scattered remains, Individual 4	Human tooth	AA89808	3629	56	Mendonça et al., 2013

2. Regional setting and taphonomic bias

The area from which come most of the data analyzed in this work is located between 36 and 39°S and 37 and 64°W, approximately. It comprises four main geomorphological units and several subunits or landscapes (Fig. 1).

2.1. Alluvial strip of Atuel – Salado – Chadileuvú – Curacó Basins

The morphogenetic and fluvial processes are important in the cataloging of this unit. The characteristics of semi-arid and arid environment preclude development of a local-origin hydrographic system. Both the Colorado River and the fluvial system Atuel – Salado – Chadileuvú – Curacó are allochthonous, constituting the only major drainage corridors. During the Neogene and Quaternary, this area became a receptacle of sedimentary materials that formed the existing plateau of accumulation. Sedimentary piles are caused by different erosive processes, and there are fluvial, aeolian, and swamp deposits. Alternating dry and wet cycles occurred from the Neogene to Late Holocene, when arid conditions developed. Among the processes that permanently reshape this landscape are high evapotranspiration, intense sunlight, and dry river beds that rarely reach base level. This led to the accumulation of sand transported by wind, contributing to the formation of dunes, especially in the

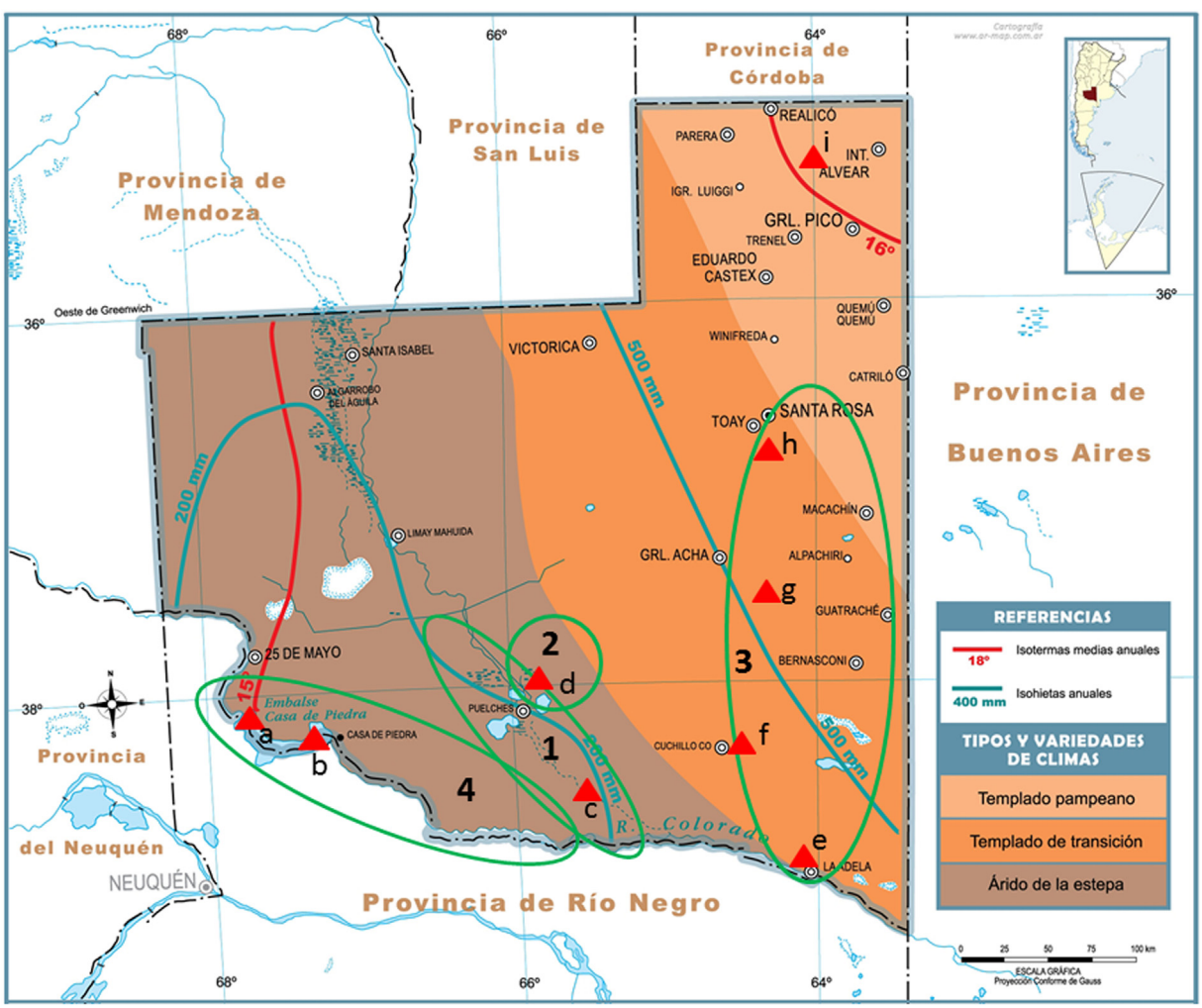

Fig. 1. La Pampa climatic map and geomorphological units of research. 1 – Atuel – Salado – Chadileuvú – Curacó rivers basin; 2 – Southern Pampean Hill Range; 3 – Transverse valleys system and Bajos sin Salida area; 4 – Mid Colorado River Basin. Principal sites: a-Puesto Hernández y Médano Petroquímica; b-Casa de Piedra, sitio 1 y Rinconada Giles; c-Localidad Tapera Moreira; d-Lihué Calel, sitio Chenque I; e-Médano La Enriqueta; f-Cuchillo Có; g-Chillhué; h-Loma Chapalcó; i-Laguna Chadilauquen.

east of the Chadileuvú – Curacó (Centro de Investigaciones Geográficas, 1983 – CIG onwards).

This depressed portion is spotted with isolated hills to a maximum height of 1000 m: Cerros Torres, Centinela, Colón, and others. In the area there are smaller lagoons (La Leona, La Brava) and high rock formations: Sierra Carapacha Grande (319 m asl), Carapacha Chica (287 m asl), Sierra Chata (328 m asl) and some isolated elevations such as Cerro Pichi Choique Mahuida and Cerro Negro. There are several areas covered by salt deposits, including the Gran Salitral located between the departments of Limay Mahuida and Puelén. Thick alluvial deposits occupy an area of great continuity, with depths ranging from 2.50 m to over 5 m. These accumulations consist of silty sand or silt deposits, slightly elevated, indicating that were formed on the occasion of major floods.

To the south in Lihué Calel, a great lake area consists of La Dulce, La Amarga, and Urrelauquen lagoons, connected to the Curacó Basin. In general, the basin is characterized by a shortage of flow, with evaporation and infiltration primarily responsible for the loss of surface flows. Moreover, these processes give rise to intense salinization of waters (CIG, 1983).

2.2. Southern Pampean Hill Range

This is a geomorphic unit comprising almost all of Lihué Calel department, the southern part of Utracán department, and eastern Curacó department. This landscape is governed by the structural control imposed by the Lihué Calel and Sierra Chica hill ranges. The surrounding area has a semiarid climate, with limited resources. Its geomorphology indicates the establishment of a more favorable and moist microclimate than the semiarid adjacent areas. The mountain relief helps to retain water from the scarce rainfall and moderate summer temperatures, leading to the existence of numerous waterholes, some standing permanently in the area. This makes possible the existence of a varied flora and fauna. The surrounding area has a semiarid climate, with limited resources. Much of this unit falls within a protected area, the Lihué Calel National Park, ~20,000 ha. These landforms end westward with the emergence of depressions and saltpeter beds. Around these outcrops, esplanades or glacis cemented by successive calcareous layers were developed. The maximum elevation is Cerro Sociedad, 589 m (Inventario Integrado de los Recursos Naturales de la Provincial de La Pampa (IIRN), 1980).

Riverbeds are developed in flat regions surrounding the mountains, except Chadileuvú River Valley, covered by sand in many areas. As Vilela and Riggi (1957) point out, according to climate and soil characteristics of the region, surface waters are scarce and heavily mineralized making its utilization impossible. Small discontinuous and temporary streams of drinking water flow at Lihué Calel and Chica hills, emerging from the slopes with meadows, but groundwater accumulations are scarce. From the phytogeographical point of view, the area is part of the Mount province. Espinal province (Caldén District) is also present in the National Park, although marginally (Covas, 1964).

2.3. Transverse (Pampean) valleys system

These valleys were produced by water erosion and are arranged in a fan with a general direction W–E and an approximate area between 36° 30′ to 38° 30′S, 63°–65° W. The area has a dry subhumid water regime, with an average annual rainfall of 450–600 mm. The characteristic vegetation is an open forest of *Prosopis caldenia,* sammófilo grasslands, and halófilo scrubs. After the incision of the transverse valleys, aeolian dunes formed in the central sector. In most valleys, there are lagoons and saltpeter beds on both sides of the central dune range. The best known are, from north to south, the Nerecó, Quehué, Utracán, General Acha, Argentino, Maracó Chico, Maracó Grande, and Hucal valleys (Calmels, 1996). The Argentine Valley is one of the largest formations of this type, trending NE–SW in the center of the province. It contains recent dunes formed by thick sandy material, whose heights range between 3 and 10 m. The dunes are water reservoirs, flanked by lakes or ponds such as Salinas Grandes in the east and El Carancho at the center of the valley (Medus et al., 1982).

The upper litho-stratigraphic unit in the region, consisting of eolian sands, corresponds to the Meauco Formation, assigned to the Late Pleistocene–Holocene. From the geomorphological point of view, these are part of the Western Pampeans and Mantlesand Dune Fields Aeolian unit, defined for the wind system of central Argentina (Zárate and Tripaldi, 2012; Montalvo et al., 2013). This unit falls within what Bruniard (1982) delineated as Arid Diagonal and is also part of what Iriondo (1990) called the Pampean Sand Sea, covering an area of 300,000 km^2, ranging between 33° and 38°S. This formation originated at the end of the Late Pleistocene, during the last glacial maximum (LGM), simultaneously with a strip of loess located downwind, the Peripheral Loess Belt. Both formations make up the Pampean Aeolian system. The sediments are composed of very fine and silty fine sand and originated mainly in the high mountains through snow and cryogenesis. Physical weathering products were transported by melt water southwards, along the Desaguadero watercourse system, and deflated north and northwest by southerly winds during the LGM and other cold periods. Wet interludes intercalated were characterized by pedogenesis and development of alluvial belts. The thickness of the units is between 5 and 15 m (Iriondo, 1990; Iriondo and Kröling, 1996).

2.4. Mid Colorado River Basin

This lies between the towns of 25 de Mayo (37° 45′ 51″S and 67° 40′ 15″W) and La Adela (38° 58″ 00′ S, 64° 05′0″ W). Previous archaeological research covered three areas: the Casa de Piedra area between the towns of 25 de Mayo and Gobernador Duval; the confluence of the Colorado and Curacó Rivers, where the town of Pichi Mahuida is located; and the area between Pichi Mahuida and La Adela, extending eastward to the 5th meridian bordering the province of Buenos Aires. The route of the Colorado River runs through a valley bounded on each side by large natural terraces. Its average width is 114 m, but at Casa de Piedra the valley narrows to 41 m.

It is an arid area with a moisture deficit, especially in spring and summer. Rainfall does not exceed 250 mm per year, with a short frost-free period. Strong winds blow, coming from the SW, NE and SE, with consequent erosion. It is subject to high evapotranspiration, resulting in the development of low desert vegetation land cover. In the past, the Colorado River was very active, drew broad, well-defined riverbeds located almost parallel to the north of the current course and accumulated boulders that gave rise to conglomerates that cover terraces and plateaus. Such paleo riverbeds converge in the area of the towns of 25 de Mayo and Gobernador Ayala, on the present river basin. They consist of elongated depressions generally aligned WNW–ESE, up to 49 km long and 5 km wide and a minimum of 20–30 m below the surrounding plateau relief (Malagnino, 1987).

Geologically, the area is characterized by a predominance of deposits of different origins, of Neogene and Quaternary ages. Between the layers of surface geology stands the Manto Tehuelche (also called tehuelches boulders, boulder mantle, patagonian boulders, or Sauzal Formation), consisting of clusters composed mainly of volcanic rocks (basalts, andesites, dacites, rhyolites, porphyries) with other rocks (quartz, quartzite and silica), partially cemented by calcium carbonate, attributed to the Late Pliocene or early Pleistocene (IIRN, 1980; Espejo and Silva Nieto, 1985). The thickness of the mantle is

variable, reaching up to 7 m above the Colorado River in the province of Mendoza and occupying a strip of about 30 km in the area between the Colorado River and the Puelén depression (Sobral, 1942; IIRN, 1980). In exposed areas, clasts have dimensions between 5 and 10 cm. The mantle is not continuous, but is missing in the valleys and deep depressions. However, its extent is wider by transport caused by different agents. Thus, in lowlands or erosive areas, "pebble fields" are seen as a product of alluvial and fluvial transport (paleo basins), resulting in smaller clasts, not exceeding 5 cm. It is a comprehensive source of lithic resources for artifact manufacture, available in primary and secondary exposures throughout the SW quadrant of La Pampa and Rio Negro (Berón, 2007).

During the Late Holocene, important climate changes occurred. Between 3500 and 1000 BP in the Chaco-Pampean, semiarid climate was established. There was widespread deflation of the surface sediments and new deposition shaped a mantle of silt and sand, with some associated dune fields (Iriondo, 1990; Iriondo and García, 1993). From other paleo-environmental proxies including pollen studies and reconstruction of paleo-precipitation, Schäbitz (2003) noted an increase in aridity over the past 3–4 ka, also indicated by dune formation and remobilization of sand. Similar changes have been recorded and analyzed through different paleo-indicators in central southern Patagonia, where a dry period is recorded from 2200 BP onwards, with a greater intensification of aridity around 900 BP (Stine and Stine, 1990; Stine, 1994, 2000). This period has been called Medieval Thermal Maximum or Medieval Climate Anomaly (MCA), a phenomenon which occurred during prolonged and severe epic droughts, with abrupt and extreme hydro-climatic changes. The most obvious consequence was a drastic reduction of the amount and distribution of surface water (Jones et al., 1999; Stine, 2000; Tonni et al., 2001). Two major droughts during this period have been differentiated, the second (1250–1380 AD) much more severe than the first (1000–1090 AD). In environments with semi-desert conditions, with high evapotranspiration, decreased groundwater and surface water sources, ecosystem productivity and populations are strongly affected in prolonged drought periods.

Different erosion processes have acted during the Holocene in the region, whose geomorphology is characterized by the action of water and wind on the Chadileuvú and Salado basins. In addition, almost all of the territory is under the predominant control of mechanical morphogenetic processes that are carried out mainly by geomorphic agents such as temperature (heat, frost action) salts, aeolian deposition and deflation, and sporadic water runoff eroding landforms in slopes: canyons and gullies (Calmels, 1996). It is mainly the intense wind action that affects the status of archaeological evidence in the area, which mostly appears on the surface of the ground. The southwest of the province has been one of the areas most affected by deflation, and is characterized by the small thickness of sand left on surface; the wind eroded and transported sediments, revealing consolidated underlying material (calcareous crusts, volcanic boulders, basalt rock outcrops). Thus, the archaeological materials were either exposed or never underwent burial processes. The Chadileuvú lower basin has large areas occupied by active dunes, which cover and uncover the evidence of the past. These were the most suitable places for settlement, offering cover and natural water reservoirs. That is why the vast majority of archaeological sites in the region are shallow, and there are few stratified sites, only two with extensive cultural chronological sequences. Consequently, in these semi-arid environments, significant environmental dynamics have produced a fragmentary archaeological record (Martínez and Martínez, 2011). At the macro-regional scale, comparisons are made among archaeological records existing within 37°–38° S approximately, particularly from Southern Mendoza and Northern Patagonia, where semi-desert environmental conditions with similar paleoclimatic patterns have existed from at least the last 4000 years.

3. Approaches to chronological scale: archaeological sites of reference

The first radiocarbon dates for the Western Pampa were obtained in the early 1980s and correspond to two stratified sites of the Casa de Piedra area. As part of a program of rescue archeology, a total of 62 archaeological sites were surveyed on both sides of the Colorado River, representing the variability of colonization of the landscape through the Holocene. Some correspond to settlements on river terraces, others are located in interior plains and dunes and a third group are located in permanent or temporary coastal lagoons. All of them presented lithic artifacts in the archaeological context, 22 of them preserve pottery fragments, archeofauna is scarce and fragmentary and in only one case a burial was recovered (Gradín et al., 1984; Berón, 1991, 2004). Only two of them have stratified records, Site 1 and Rinconada Giles, in which the first 5 radiocarbon dates were performed, 3 in Casa de Piedra 1 and 2 in Rinconada Giles sites (Fig. 1 and Table 1). Site Casa de Piedra 1 is multicomponent, has a wide stratigraphic sequence in a compact and homogeneous matrix of 2.60 m deep and 25 m^2 excavation. Based on the variability of cultural evidence and chronology, Gradin and Aguerre (1984) proposed three occupations: Lower, Middle and Upper. Two dated occupations correspond to the lower and the remaining to the middle. The site Rinconada Giles is unicomponente, has an archaeological fertility of 0.50 m depth and an area of 41.5 m^2 was excavated. The integration of the results obtained in sites 1 and Rinconada Giles, with data obtained during the survey of surface sites in Casa de Piedra area, have allowed to establish the first cultural chronological sequence in the Colorado River middle basin, which covers from the Early Holocene to prehispanic colonization times. Were also identified and characterized technological trends of different times of occupation of this sector of the southern Pampas and northern Patagonia (Berón, 1984; Gradín et al., 1984).

From the 1990s, the number of radiocarbon dates increased significantly, under programmatic archaeological research undertaken in new areas of the province and the detection of relevant new archaeological sites. One of such areas is the Curacó River Basin, final stretch of an extensive watershed, whose length is 140 km from the town of Puelches, to its mouth at 38° 50′ LS (Fig. 1). Most of the archaeological sites detected in the Curacó area are superficial, but there's an extensive chronological and cultural sequence in the Tapera Moreira Locality, ranging from the late middle Holocene to final Late Holocene. Excavations and radiocarbon analyses were performed at four sites (sites 1, 3, 5 and La Lomita), constituting the reference framework for research in this area, both chrono-stratigraphic and for evaluate cultural and environmental change. A total of 23 radiocarbon dating were obtained, 18 corresponding to Site 1, three to Site 5, and the last two corresponding to human remains from Sites 3 and La Lomita (Berón, 2004, 2010a,b).

Site 1 is located on a terrace 11 m above the Curacó River Basin and is the one of highest density, both on surface and stratigraphic materials. It is a base camp located near a permanent source of water. In addition there are pools in the river that retain rainwater and allow concentration of chañares (*Geoffrea decorticans*) forests and game. Here multiple persistent occupations were detected, four units of analysis were delimited, consisting of three main components that were defined, from the oldest to the most recent: Lower (Summit and Lower Levels), Middle and Upper Components, covering a range between 5000 and 360 BP (Table 1).

4. Burial sites

A significant number of dates were obtained in recent years at sites with burials of different features, marking a change in trends, interests, and goals of research. This is mainly because the archaeological human bones provide a new dimension to the study of past societies, allowing to integrate variables of the physical environment with cultural and biological ones. Five cases involve multiple burials: Site Chenque I, Loma Chapalcó, Médano Petroquímica, Puesto Hernandez, and Médano La Enriqueta. We have also considered a number of isolated burials or sets of few individuals, representing different time trends regarding to funeral arrangements for the region, which will also be evaluated in this work. They are Chillhué 3, Cuchillo Có, Bajo de Atreuco, Tapera Moreira locality site 3, and La Lomita. Also recently were published two radiocarbon dates at Chadilauquen Lagoon, which is outside the area of analysis of this study but whose data and location are presented in Table 1 and Fig. 1.

4.1. Multiple burials

The multiple burial where most of the ^{14}C dates were obtained is Chenque I site, a prehispanic cemetery of hunter–gatherers, with 25 radiocarbon dates are available (Table 1). It is located in Lihué Calel National Park, in the Western Pampean region (38°.00′S, 65° 38′W). Hunter–gatherer societies made use of this site for mortuary purposes during the final Late Holocene, for *ca.* 700 years, between 1050 and 290 BP (Berón et al., 2007, 2014). More than 200 individuals (children and adults of different ages and gender) were recovered in the excavated area (provisional MNI 216 in 49 m^2, about 23% of the total area, Fig. 1). Several hundred bodies have been buried in this cemetery. It is superficially marked with the alignment of rocks in a subcircular structure of 210 m^2. Two stratigraphic units were defined, with very different properties. The upper unit (0–30 cm depth) contains thousands of bone and dental remains with different degrees of fragmentation, commingling, arrangement and anatomic association, due to systematic reuse of the site. In the Inferior Unit (below 30 cm) divided in top and base, 43 burial structures were detected, many of them in association with stone arrangements over, under and/or around the body. The Base Inferior Unit (BIU) corresponds to a pattern of deeper burials where it was necessary to dig in the limestone matrix and to add loessic sediments after the final internment of the bodies. The other pattern of burials, which corresponds to the Top Inferior Unit, is represented by burials deposited in the sedimentary matrix, considerably above the basement. This produced differential preservation of individuals buried in the BIU, as the carbonate matrix in which they were deposited minimized taphonomic deterioration factors (Berón and Luna, 2007; Berón et al., 2012a,b). A great variability of inhumation modes was recorded: primary, secondary, simple, multiple burials as well as a variant not previously registered in Argentina, called disposition which may be considered a variant of secondary burials (Berón and Luna, 2007). Beside the bodies there were also found offerings as beads of necklaces or other kind of ornaments, made of different raw materials, prehispanic metallic ornaments as a copper earring and a silver brooch (usually called *tupu* in *mapundungun* language), mollusks and rock tools. Post-hispanic elements were not found, providing a complementary criterion for the temporal situation of the assemblage. Furthermore, some of the skeletons had embedded projectile points, which in several cases were the cause of death of the individual (Berón, 2010b, 2014). Multiple inhumations, cases of cremation of bones, and ochre applications were identified. Beyond some temporal discontinuities, this cemetery has been a referential place of burial for populations from different provenance and thus constitutes the largest repository of human remains of La Pampa and the entire region (Berón et al., 2012a,b).

The other multiple burial is Médano Petroquímica (37° 55′ S, 67° 48′ W) located in Colonia Chica, Puelén department (Fig. 1). Eight funeral features each contain multiple individuals. While even have not been published accurate data, it has been estimated that about a hundred individuals have been buried in the dune, both genders and all age categories. Two radiocarbon dates have been obtained (Table 1). The evidence recovered show complex funerary practices that consist in performing collective, indirect, secondary burials, and the presence of violence events and/or social stress (Amann et al., 2010; Mendonça et al., 2010a,b).

Close to the latter, the multiple burial site Puesto Hernández is located (38° 13′ 55″ S; 67° 19′ 49″ W), on the northern bank of the Colorado River. There are no published results from the analysis of this site, except a comparison with Médano Petroquímica, for which a lower density of burials and the absence of violence indicators were noted. Two radiocarbon dates were obtained (Table 1).

Médano La Enriqueta I is located at 39° 06′ S and 63° 47′ W, Caleu (Fig. 1). It is an active dune located in a field, 150 m from the northern shore of the Colorado River and 600 south of the fence that frames the old valley of this river course. The dune has three main hollows, which according to the archaeological evidence recovered correspond to differential use of space by aboriginal groups. The archaeological record is composed by prehispanic remains such as stone artifacts, potsherds and beads made of shells, as well as human burials. The latter were concentrated in Hoyada I, in which human remains of at least 9 individuals were recovered, ranging in age from birth to adulthood. Six are male and three have undetermined sex. A radiocarbon date was obtained (Table 1).

Loma de Chapalcó site is located in the Toay district of La Pampa, at the highest topographic point of the plateau (36° 52′ S, 64° 45′ W; Fig. 1). Soil removal by bulldozers uncovered human bones from at least six individuals. The bones are highly fragmented and fragile. The ages of five individuals were calculated, indicating the presence of two young adults and three subadults 12–15 years old. A radiocarbon date was obtained (Curtoni, 2007, Table 1).

4.2. Simple burials

The oldest burial in Western Pampa corresponds to a simple primary burial with grave goods recovered in site Casa de Piedra 1 (6080 ± 120 BP, Gradín et al., 1984, Table 1). There is a gap in such records until the Late Holocene, in which the sites of burial are plentiful.

Laguna Chillhué locality is in the Guatrache district of La Pampa (37°17′ S, 64°09′ W; Fig. 1). Its geographical position corresponds to the ecotone between the dry and wet Pampas, offering access to resources from different ecosystems, such as the pastizal and caldenar. The sites detected around the lagoon have diverse archaeological evidence, such as lithic artefacts, pottery, faunal, and human bones. The human remains were recovered on the southeastern part of the lagoon (Site 3), corresponding to a skull and a few elements of the postcranial skeleton that belonged to an adult female (Berón et al., 2006). A radiocarbon date was obtained (Table 1).

In Tapera Moreira Site 3, the remains of two individuals were located, affected by fluvial erosion. One is a primary burial of an adult male with porotic hyperostosis on the cranium. The other burial corresponds to an adult female and is represented by the skull and some disarticulated postcranial bones. The skulls of both individuals have intentional annular deformation (Berón and Baffi, 2003; Berón and Luna, 2009).

La Lomita site is located 200 m to the southeast of Tapera Moreira locality. It is an open-air site with surface archaeological traces. The human remains recovered correspond to two

incomplete adult individuals (one male and the other female). They were found semi-buried in a small ditch of alluvial erosion. The female skull also has intentional annular deformation (Berón and Baffi, 2003; Berón and Luna, 2009). Two ^{14}C dates locate these burials at the beginning of the Late Holocene (Table 1).

Cuchillo Có is a locality in Lihué Calel district (38° 20′ 02″ S, 64° 36′ 58″ W, Fig. 1). Nearby, there are different archaeological manifestations as stopping points with abundant material of various kinds, fixed mortars and dams (Piana, 1981). A simple primary burial, covered by a slab, was found in a canyon of alluvial erosion. It was left in situ, but the skull that had been removed by a poacher was rescued. One radiocarbon date was obtained (Table 1).

Bajo de Atreuco is an extensive surface site located 20 km south of the town of Macachín (37° 07′ 59″ S, 63° 49′ 00″ W, Fig. 1). Generally this low land is covered with water of fluctuating depth. Archaeological materials are dispersed on the ground. A human burial was exposed by erosion. The condition was very bad but several teeth were rescued. One radiocarbon date was obtained (Table 1).

Two other recently published ^{14}C dates come from Laguna Chadilauquen, located in the northeast corner of La Pampa (35° 24′ 02″ S 64° 16′ 30″ W, Fig. 1). The dates obtained on teeth (Table 1) are isolated findings of human remains, decontextualized by taphonomic processes, which do not correlate with other cultural material. Two maxillary teeth were dated, both from different skulls with deformation (Mendonça et al., 2013). Its importance lies mainly in that they are the first ^{14}C dates from northern La Pampa, although the site lies outside the area of interest for this work. Due to the contextual situation of the dates and lack of integrity of the archaeological record, they have not been considered in the radiocarbon series.

5. Material and methods

The database of ^{14}C dates published for the south-central La Pampa province is composed of 64 radiocarbon samples obtained in 15 archaeological sites. In this work a total amount of 62 dates obtained on four main research areas are evaluated: mid basin of Colorado River, Curacó area, Transverse Valleys and Serranías Pampeanas (Fig. 1). Table 1 shows the main data of these dates: site, origin, and nature of the sample, laboratory code, ^{14}C age, sigma and bibliographic references.

The first five ^{14}C dates were obtained in the mid-basin of the Colorado River, in the early 1980s, from two stratigraphic sequences, sites 1 and Rinconada Giles. Recently were obtained four more ^{14}C dates in burial sites (Puesto Hernández and Médano Petroquímica), totalling nine ^{14}C dates for this area, that is 14% of the total available for the province. Most of the ^{14}C dates come from two stratified archaeological sites with different characteristics. With respect to the Curacó area, in Tapera Moreira locality 23 radiocarbon dates were performed, which constitutes 35.93% of the total available for the province. In Serranías Pampeanas, from the cemetery Chenque I, 25 radiocarbon dates were obtained (39% of total available).

The ^{14}C dates from the south Western Pampa were obtained at different times and in different laboratories. With the aim of improving the inter-comparability of results, a program of data recalibration was applied to all ^{14}C dates done by the different laboratories: Teledyne (I), Instituto de Geocronología y Geología Isotópica (INGEIS), Beta Analytic Radiocarbon Dating (BETA), Center for Applied Isotopes Studies (UGAMS, University of Georgia), University of Arizona AMS Facility (AA) and Laboratorio of Tritio and Radiocarbono (LATYR). The calibrations of ^{14}C ages were done using Calib Rev. 7.0.1 (Reimer et al., 2013). For dispersion curves, the Cal Pal Program (Weninger and Jöris, 2004) was used.

In a first instance of radiocarbon series evaluation (in 2004) and in order to analyze the magnitude and significance of the differences introduced by the different calibration criteria proposed by various authors (McCormac et al., 2004 *i.e.*), it was conducted in cooperation with G. Barrientos, the application of three different test treatments to the set of conventional radiocarbon ages (Berón, 2004). Three sets of calibrated ages were generated, one by subtracting 40 years prior to conventional calibration age, another by subtracting 24 years, and the last without performing any removal from the conventional ^{14}C age. The statistical analysis consisted of comparing distribution limits ranges (upper and lower) of calendrical ages expressed at two-sigma confidence level, using the StatSoft STATISTICA 5.0 and SPSS 10.0 software. The results indicate significant differences between the distributions of calibrated ages. However, there is a highly significant intraclass correlation (coefficient 0.99), so that such differences are irrelevant to the timescale that is handled in Pampean archeology. Therefore, no correction was applied to the radiocarbon series of the Southern Hemisphere, following the recommendations of Figini (1999) for a series of experiments that showed that there are no systematic differences between the Northern and Southern Hemispheres for the entire Holocene (Barbetti et al., 1992, 1995 in Figini, 1999).

Other recent proposals (McCormac et al., 2004; Hogg et al., 2013) were considered. These proposals were not implemented, as these adjustments do not offer significant differences for the time scale and the number of samples analyzed in this work. As mentioned by Reimer et al. (2013) "As always, ^{14}C calibration should be seen as a work in progress." (p. 1883).

6. Results

Regional radiocarbon series, according to the research areas mentioned at the beginning of this work are evaluated: Atuel – Salado – Chadileuvú- Curacó riverbed, mid basin Colorado River, Serranías Pampeanas Meridionales, and Valles Transversales system (Fig. 1). During the Early Holocene and beginning of Middle Holocene the only occupation dated in Western Pampa is the Site 1 of Casa de Piedra Area, in the middle valley of the Colorado River (Fig. 2). The ^{14}C dispersion curves obtained on this site indicate an early stage of colonization of this space (*sensu* Borrero, 1989–1990, 1994–1995) which is continued in the early middle Holocene. At the base of the Lower Occupations, bounded between 2.00 and 2.50 m depth, two ^{14}C dates, which yielded ages of 8620 BP and 7560 BP, were obtained. However, these radiocarbon dates have very large standard deviations because of the characteristics of the samples (charcoal spicules) and the laboratory control methods. The curve in Fig. 2 shows a moderately continued use of the site during the Early Holocene which may reflect a biased view due to large standard deviations. Nonetheless as these are the earliest dating for the region and, for the moment, appear to be exceptional, we have considered them in this chronology evaluation.

At the top of the Intermediate Occupations, between 0.80 and 1.40 m depth, a third ^{14}C date of 6080 BP was obtained. Unfortunately, the upper part of the stratigraphic sequence at Site 1 was not dated, but it is possible to state that this location continued to be occupied for much of the mid-Holocene and perhaps early Late Holocene (Gradín et al., 1984), but was interrupted in the final Late Holocene, given the absence of archaeological indicators belonging to this stage, such as pottery. However, this last stage is well represented from the chronological point of view in the Rinconada Giles site (Fig. 2), located 2000 m to the north, as well as in 22 other surface sites with abundant fragments of pottery among other evidence, surveyed in Casa de Piedra Area, on both sides of the river.

For the Curacó River Basin, in Tapera Moreira locality, a continuous occupation is recorded from the latter part of Middle

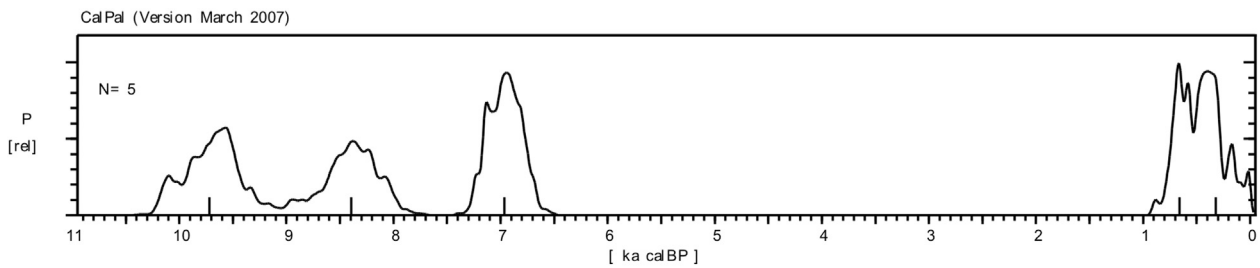

Fig. 2. ^{14}C Dispersion curves of Casa de Piedra area.

Holocene (*ca.* 5000 BP), with a marked intensity around 2000 BP and a recurrence of use until the final Late Holocene (360 BP, Fig. 3). Samples in this site were not statistically discriminated because the main purpose of this paper is to show the actual data availability, which should be increased in the future for a better understanding of the chronological trends. The intensification of the occupation around 2000 years ago is also reflected in material culture densities, and is correlated with intensification records of other areas (García, 1992; Berón, 2004; Pérez and Erra, 2011). Anyway an over-representation for this occupation in dispersion curves should be considered.

Sedimentological and phytolithic studies of archaeologically sterile levels were performed (Berón, 2004; Osterrieh pers. com., 2010). As a result, in the lowest levels (XXXI and XXXII) a mineralogical change in the variability is observed with respect to the overlying levels. They are enriched with volcanic ash of all sizes and are correlated with a notable absence of cultural evidence. Through the analysis of plant micro-remains, large amounts of phytoliths articulated in very large fragments (>a 100 μ) that are not covered by organic material were recorded, which may result from the effect of calcination contact with the ashes. In support of this hypothesis, it is observed that some ash particles were overlapped between articulated phytoliths. The absence of micro-charcoal indicates that the events of death of flora were not linked to fires. Both data (presence of ash and death of flora) are relevant, because it is correlated with a total absence of evidence, which, in turn, is coincident with a hiatus of archaeological information recorded for the Middle Holocene (Berón, 1997, 2004). Thus, in addition to pointing out the restarting of human occupation in southern La Pampa, site 1 provides important paleoecological data in the bottom of the stratigraphic sequence which, remarkably, is not associated with cultural events and could help to explain the gap of information from a long period of Middle Holocene. This gap is also recorded in nearby areas of similar latitude. Suggestively projectile points of the earliest cultural levels (XXVIII excavation level to 3.25 m deep) include a preform of "fishtail" type (Table 1 and Fig. 4) manufactured in a variety of heat-treated silica that only appears in the deepest levels of the sequence (Berón and Carrera Aizpitarte, 2013).

Further increases in the range of rock employed, some local and of very good quality as well as increased frequency and artefactual variability, are interpreted as changes in this situation, as an advanced exploration (perhaps colonization) of this environment that over time was transforming into a social landscape. This site records a remarkable continuity and recurring use of space from the late middle Holocene, along all the Late Holocene, till pre-contact times. An artefactual marked increase in density to approximately the last 2000 years is recorded, which would be in relation to a marked population increase from this period onwards.

The two sites of burials of this locality (site 3 and La Lomita) correspond to circa 3000 BP (Table 1). Remains of at least 4 adults whose skulls showed deformation of circular type (*sensu* Imbelloni, 1924–1925), which constitutes the oldest type of deformation detected in West Pampa (Berón and Baffi, 2003; Berón and Luna, 2009). Further studies in the province of Neuquén extend the use of this deformatory type to the middle-late Holocene boundary (*ca.* 4000 BP) in western Norpatagonia according to skulls ^{14}C dated from the Aquihuecó site (Perez et al., 2009) and *ca.* 3000 BP in NE Norpatagonia (Bernal et al., 2008). Based on this, the range of circular deformation in transitional Pampa-Patagonia area is 4000–2500 BP.

With respect to Chenque I site, to date, 25 ^{14}C dates and 70 isotopic values of $d^{13}C_{COL}$, $d^{15}N$, $d^{13}C_{CAP}$ and $d^{18}O$ have been obtained, from which have been assessed time trends regarding mortuary patterns, paleodiet and geographical origin of some individuals (Berón et al., 2007, 2009, 2014). The radiocarbon signal indicates intensive and repeated use of this space between *ca.* 1000 to 300 BP (Fig. 5). It is possible to distinguish two periods of use of the cemetery. The first extends between 1050 and 700 BP. The second intensive range goes from 435 to 290 BP. A gap in use between 700 and 435 BP was identified. During the last period of use of this cemetery, between 435 and 290 BP, the assembly of burials

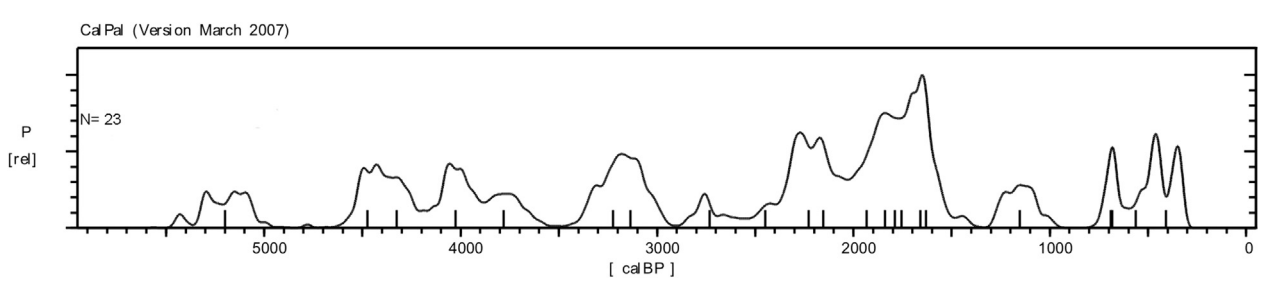

Fig. 3. ^{14}C Dispersion curves of Tapera Moreira Locality.

Fig. 4. ^{14}C Preform of fishtail type projectile. Lower levels of site 1. Tapera Moreira locality.

shows particularities that are worth mentioning. All burial structures of this period are multiple. Three of them (Burials 21/23, 27 and 29) show abundant signs of violence, as projectile points inserted in bones or tissues which, in most cases, were the cause of death of individuals. In the previous period, the conflict indicators appear in individual primary graves (Berón and Bosio, 2008, Berón, 2010b, 2014).

Given that the societies that generated this cemetery had a hunter–gatherer organization and an elevated logistic mobility, this provides an impressive case in terms of the redundancy of use of this place for mortuary practices (Berón, 2004; Berón and Luna, 2007; Berón et al., 2007, 2014). This cemetery is dated about the same span time as the third component of Site 1 in Tapera Moreira locality (Berón, 2004). Considering the several kinds of bioarchaeological evidence and the great amount of information obtained, Chenque I site is probably one of the most important hunter–gatherer mortuary sites in South America.

Besides these sites, comprising the bulk of ^{14}C dates in the province of La Pampa, in recent years ^{14}C dates have been obtained at sites with human remains of different characteristics, as they have been described in previous paragraphs. In some, a single ^{14}C date is available, because it is unique finds of simple burials (Chillhué lagoon site 3, Cuchillo Có, and Bajo de Atreuco), or multiple burials where the contextual situation suggests that they belong to a synchronous event (La Enriqueta and Loma Chapalcó). In other cases data have been duplicated, obtaining consistent ^{14}C dates, further suggesting unique or quasi-synchronous events of burial, as they consist of multiple burials (Puesto Hernández y Médano Petroquímica, Table 1, Fig. 6).

7. Discussion

Even though the chronology is not a goal in itself, the importance of assessing the distribution of radiocarbon dates provides the possibility of having a framework to integrate the information and relate regional stages, events and/or cultural markers both to regional and supraregional level. Moreover it allows us to calibrate occupancy events, recurrent use, disruptions and hiatuses use of the same landscape or locus and control, and by this way, disturbance factors or stressors that affect the integrity of the archaeological record at different scales (Surovell and Brantingham, 2007; Surovell et al., 2009; Williams, 2012). The results will be discussed, in relation to this and in comparative terms, on two scales: the intra and inter-regional. From Fig. 8, and taking into account the 2 sigma calibrated ages, some points emerge for discussion. During the Early Holocene, the only occupation in the subregion is Site 1 of Casa de Piedra, in the middle valley of the Colorado River. From about 6000 BP, the Casa de Piedra Area seems depopulated or at least lacking a clear signal that transcended time. According to the distribution of calibrated ages, a gap of information is observed between *ca.* 6500 and 5500 BP (*ca.* 6000–5000 according to radiocarbon ages).

No evidence of settlement has been recorded in the south central Pampas during this period of 1000 years. At macro-regional

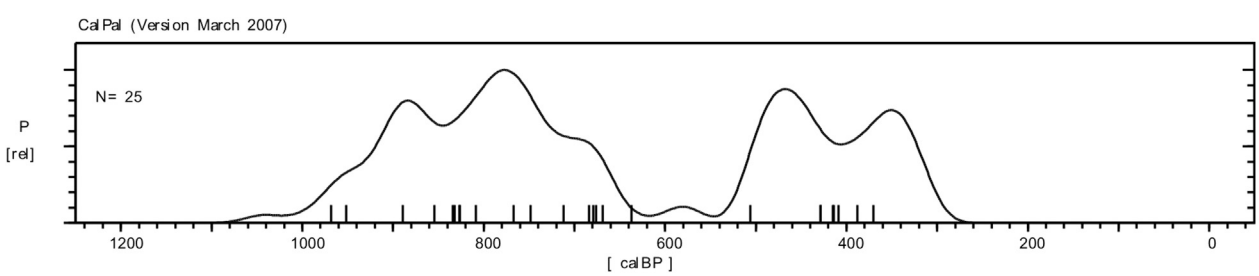

Fig. 5. ^{14}C Dispersion curves of Chenque I site.

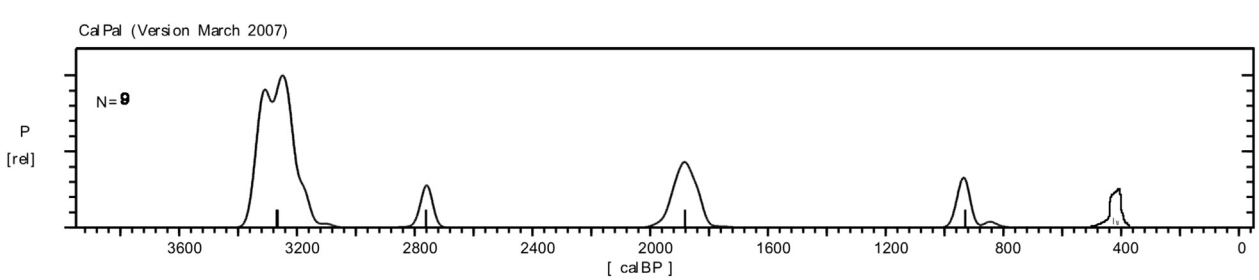

Fig. 6. ^{14}C Dispersion curves of other burial sites.

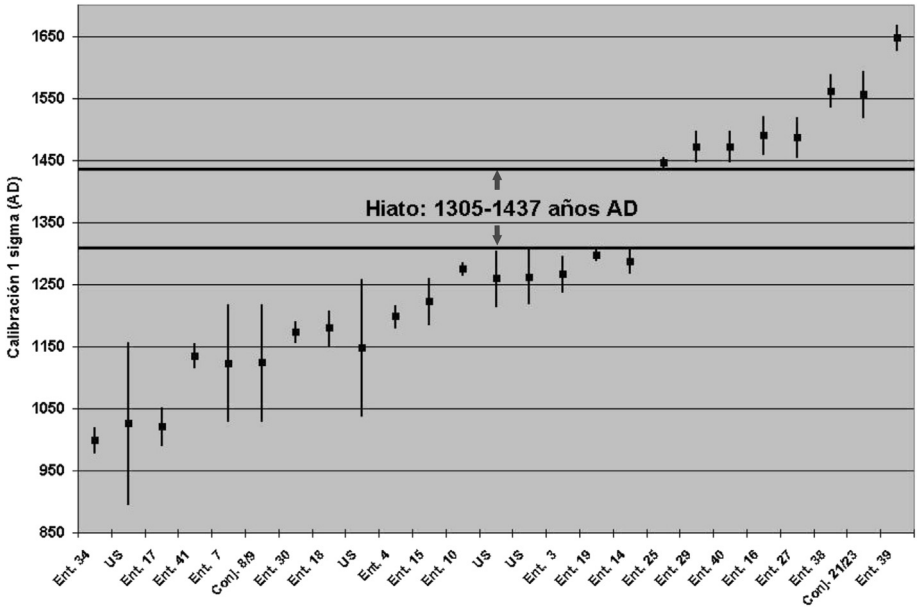

Fig. 7. Chenque I site. Chronological haitus and periods of use.

scale, there is a hiatus of information for the mid-Holocene in neighboring regions: south-central Mendoza (*ca.* 7500–4000 BP, Gil and Neme, 2010), Western Pampa (*ca.*6000–5000 BP, Berón, 2004), and south-central Chile (Méndez Melgar et al., 2012). This gap has been attributed by some authors to the effects of volcanism, that could have produced significant areal disasters (Durán, 1997; Durán and Mikkan, 2009), while others believe that the main motivation was the alternating periods of increased aridity, which caused the absence of archaeological records as a result of a change in human strategies, in response to changing conditions in the regional structure of resources (Durán, 2002; Gil et al., 2005; Gil and Neme, 2010). At the Tapera Moreira locality, the lowest levels are enriched with volcanic ash of all sizes which is correlated with a total absence of evidence. Therefore, it represents the period when site 1 was first used consistently. Although there are no radiocarbon dates at these levels, it seems that its temporality precedes by several hundred years the process of human use of this space. In sum, this evidence suggests that some potent volcanic event occurred, before the environment of site 1 was occupied. It is considered that this event could be one of the causes that produced a discontinuity between occupations of Casa de Piedra 1 and those of this new environment (Berón and Carrera Aizpitarte, 2013). Around 4000–3000 BP, climate conditions begin to stabilize, acquiring the characteristics of semi-desert, with similar current patterns, as shown by paleoclimatic proxies analyzed in Southern Mendoza and Northern Patagonia (Markgraf, 1993). Certainly, by the end of the Middle Holocene, occupation of the Curacó area started. This seems to be the only area of the subregion with records of continued colonization and recurrent use of an encampment from *ca.* 5000 BP until the end of the Late Holocene (*ca.* 300 BP). The availability of an abundant and permanent water source gave rise to this situation.

At the macro-regional scale, and in agreement with these data of stabilization in similar conditions to the current environment, the appearance of burial sites is observed at 37°–38° S approximately (Table 2). The westernmost and oldest are Aquihuecó (37°05′00″ S, 70°22′00″ W) and Hermanos Lazcano (37°14′01″ S and 70°22′02″ W), department Chosmalal, both to the NW of Neuquén province, dating to around 4000 BP. In La Pampa, the bioarchaeological record shows this same strategy from burial sites dated between *ca.* 3000 and 2000 BP (Tapera Moreira sites 3 and La Lomita, Laguna Chillhué, Bajo de Atreuco, Cuchillo Có, and Loma Chapalcó; Table 2, Figs. 1 and 7), all located near water sources, enduring or permanent.

Table 2
Radiocarbon information from burial sites within 4000 and 2000 years BP.

Site	Modality-MNI-Sample	Code	^{14}C	1s	Reference
Loma Chapalcó	Multiple burial – MNI 6	UGAMS 02008	3040	30	Curtoni, 2007
Chillhué 1	Simple primary burial?	UGAMS 02009	1930	30	Berón and Luna, 2009
Bajo de Atreuco	Simple primary burial?	UGAMS 4414	2635	25	Berón et al., 2009
Cuchillo Có	Simple primary burial	UGAMS 4417	3035	25	Berón and Luna, 2009
Tapera Moreira. Sitio 3	Double burial? – MNI 2 – Ind.1	Beta 82558	2630	60	Berón, 2004
Tapera Moreira. La Lomita	Double burial? – MNI 2 – Ind.1	Beta 91934	2960	50	Berón, 2004
Hermanos Lazcano	Multiple burial – MNI 13	LP-1440	3780	50	Perez et al., 2009
Aquihuecó	Multiple burial – MNI 56 – N/D	LP-1418	3650		Perez et al., 2009
Aquihuecó	Multiple burial – MNI 56 – Ind 16	AA78841	3817	59	Perez et al., 2009
Aquihuecó	Multiple burial – MNI 56 – Ind 22	AA78840	4050	61	Perez et al., 2009
Aquihuecó	Multiple burial – MNI 56 – Ind 23	AA78839	4172	55	Perez et al., 2009

During final Late Holocene Casa de Piedra repopulates, continues the occupation of the Curacó area and new spaces are colonized such as mountainous area of Lihué Calel. Paleoenvironmental records of SE La Pampa and southern Mendoza indicate

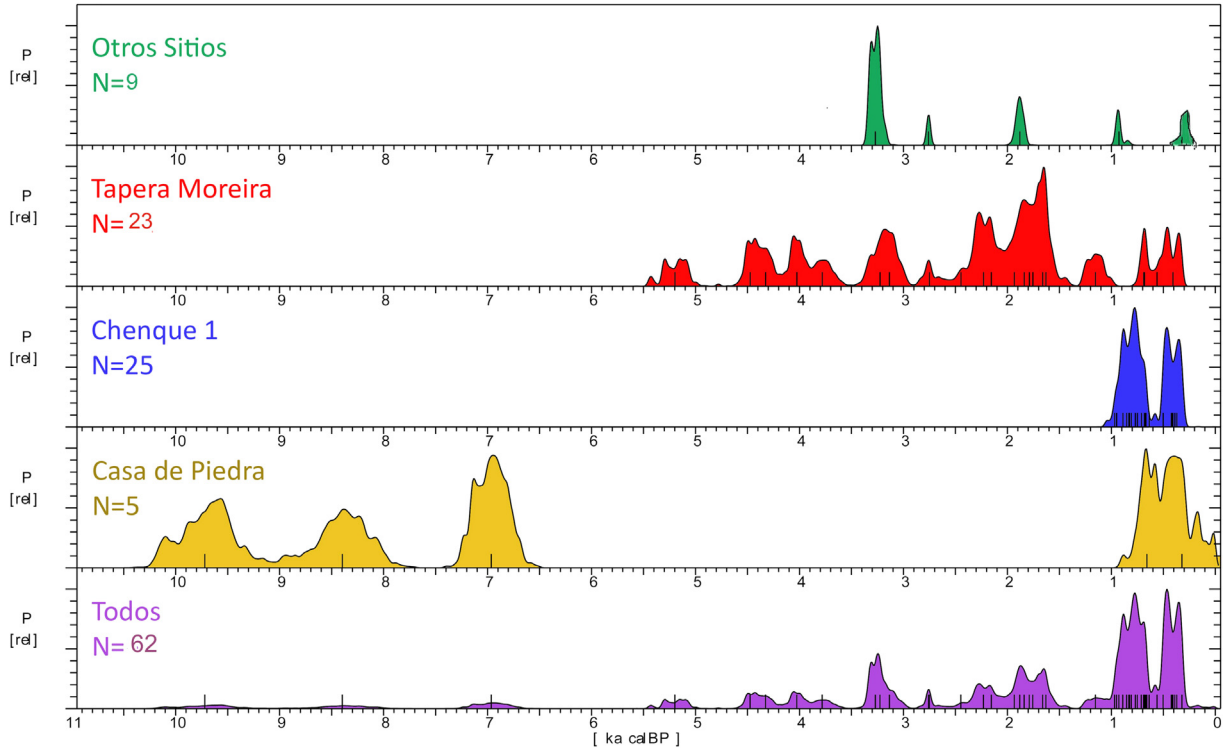

Fig. 8. ^{14}C Compared Dispersion curves of Western Pampa.

that during the last 1000 years occurs alternating warmer and dry cycles, some more severe than others (Villalba, 1994; Schäbitz, 1994, 2003). That is probably the time of occupation of other areas such as the Chadileuvú lower basin and most sites recorded in the West Pampa Basaltic Plateau (Aguerre, 2002), which still have no radiocarbon dates.

With respect to the timing of the surface sites, except for the presence of chronological markers as potsherds or post-Hispanic elements, it cannot be assumed that the surface materials represent the whole temporal spectrum of the area. However, it is assumed that the best expression of human colonization of the semidesert Pampas began during the Late Holocene, particularly from 3000 to 2200 BP, onwards since environmental conditions stabilized similar to present, and this tendency intensified in the last 1000 years. The latter seems to be the period to which also correspond to sites in the lower basin of Atuel river (Badal, Vallejo and Médanos Colorados sites, Fig. 1) according to the records made by Austral (1971, 1972 and 1975). This means that for the second half of the Late Holocene it could be posed an effective occupation of almost all areas of the Western Pampas.

Consistent with the environmental changes and population growth, changes of the mortuary practices were recorded in various sectors of Pampa and Norpatagonia from *ca.* 1000 BP (Gómez Otero and Dahinten, 1998; Gómez Otero, 2006; Prates, 2008; Martínez, 2010; Martínez et al., 2012) as formal areas or communal burial cemeteries appear. Undoubtedly, the most representative in this regard is the Chenque I site, which began to be used exclusively as cemetery *ca.* 1000 years BP and continued with the same functionality up to *ca.* 300 years BP. Two other sites of burials that arise in the same period in the region are Médano La Enriqueta and Médano Petroquímica, although both have an MNI more limited than Chenque I site and ^{14}C dates seem to represent unique or quasi-synchronous events (Table 1). All share the characteristic of being located in high places with respect to the surrounding landscape, and with permanent water sources. In Chenque I site in the first period of use (*ca.* 1000–700 BP) there is variability in the modalities of burial (primary, single and multiple secondary) and signs of violence on two simple primary interments (Burials 17 and 19, Table 1). Given the concurrency of several radiocarbon ages, there is the possibility that two or more individuals were buried at the same time or in close ones.

However, a gap in use between 700 and 435 BP was identified in Chenque I site, that coincides with a period of intensification of aridity, which could be correlated with an abandonment of that territory by the people who used this cemetery, perhaps moving to other areas (Fig. 7). In neighboring areas but on the margins of permanent water resources, other burial structures were located during this period, such as Paso Alsina 1 (500–450 BP), La Petrona (*ca.* 800–250 BP), (Martinez et al., 2006; Flensborg et al., 2011; Flensborg, 2011), and Puesto Hernandez (Mendonça et al., 2010a, 2010b) along the Colorado River; Añelo cemetery (Loma de La Lata site) to the north of Neuquén (740 ± 40; 600 ± 60 BP, Biset, 1989, Perez et al., 2009) and Laguna de Los Chilenos 1 (476 ± 80 BP, Barrientos et al., 1997), which partially cover the gap in chronology recorded in Chenque I. After this hiatus, the chronological distribution of events in the Chenque I site refocuses between 400 and 290 BP, the latest period of use of the cemetery. So far there have been no other burials during this period in south-central Pampas, so the entombment of individuals would have concentrated on this single locus, prior to contact with European colonizers. Burial structures of this period have peculiarities: all are multiple and most have high degrees of modification of the anatomical structure of individuals. Three (Burials 21/23, 27 and 29) show abundant signs of violence and represent different types of conflicts as posed by Berón (2014).

Another three burials (# 16, 38, and 40) are very similar and closely spaced. They are made up of adults whose mode of burial is a particular way of secondary modality called "arrangement" (Berón and Luna, 2007) buried next to multiple sub-adults in primary mode (3 adults buried alongside 7 subadults in interment 38,

3 adults and 6 subadults in burial 40, 1 adult together with 5 subadults in burial 16). All have signs of being funeral packages, made up with leather, painted with ochre and decorated with malacological raw material beads (Berón et al., 2012a,b). This means that in the early period, a greater variability is observed in the types of burial, associated with less complexity in the treatment of the bodies, while the opposite occurs in the last period, with less variability of types of burial and greater complexity in the mortuary treatments (Berón et al., 2014).

Early burials with signs of violence have oxygen isotope values and adornments that indicate origins from the Andean region, probably from its western side (Berón et al., 2012a, 2014; Barberena et al., 2015). Conversely, posthiatus burials with violence signals (burials 21/23, 27 and 29, Table 1, Fig. 7) show oxygen isotopic signals compatible with the local isotopic range, spanning large geographical areas including the Western Pampa, the south end of Mendoza and north and east Neuquén (Berón et al., 2014).

All these records suggest that recurrent mortuary practices were conducted in different parts of south-central La Pampa for much of the Late Holocene, within *ca.* 3700 to 300 BP. The only account of previous mortuary behavior corresponds to the simple primary burial with grave goods recovered in Casa de Piedra 1 (6080 ± 120 BP, Gradín et al., 1984, Table 1). Here a void of information is recorded, as there are no burial records for about 2000 years (6080–3700 BP). This may be the result of taphonomic factors, or a sampling issue in that isolated burials are more difficult to identify or to preserve over time.

8. Conclusions

As a result of this set of radiocarbon dates and the analysis of calibrated ^{14}C dispersion curves, it has been established that the timescale in which befell events of exploration, colonization and use of space archaeologically evaluated in south-central La Pampa covers a period ranging from the early Holocene, part of the mid-Holocene, and throughout the Late Holocene. However, this archaeological record shows discontinuities or silences that could be due to catastrophic or environmental stress situations that caused demographic shrinkage or reduction of human populations to the point of not leaving an identifiable signal. Other possible reasons should not be ignored, such as sampling bias, severe erosion, different types of deflation and morphogenetic processes that acted destructively in the archaeological record, or preservation problems of materials to date.

The central and southern La Pampa has a long history of use and occupation that extends beyond 8000 years. Starting from the assumption that human settlement strategies in Pampa Seca Subregion are based upon the availability of a critical resource such as drinking water, it may be assumed that human groups explored and colonized new environments guided by goals and possibilities. Many areas without stable water sources were used after exhausting the previous alternatives of valleys, lakes, or permanent freshwater springs.

Therefore the existing climatic and geomorphological conditions during the early Holocene, coupled with limited knowledge of an unexplored landscape, only would have favored the use and occupation in specific sectors of the landscape, such as the mid Colorado River Valley, where water is permanent and plentiful. Towards late Middle Holocene and early Late Holocene, stabilization of environmental conditions allowed the exploitation and use of larger spaces, which increased during the final Late Holocene, accompanied by a sustained population growth, resulting in effective occupation. Thus, the Colorado River Basin, far from functioning as a barrier, was an important mean of communication and interaction between the peoples of both sides, since pre-Hispanic times to recent times (Berón, 2010a).

Site 1 in Casa de Piedra area and site 1 of the Tapera Moreria locality are the earliest record of human occupation in the province of La Pampa. The first hint of exploration in Tapera Moreira locality marks the end of the information gap for the Middle Holocene. Characterization of volcanic ashes contained in the pre-occupation sediments of the site will assess whether this was a cause of later exploration. The consequences of eruptive events are varied and could affect hunter–gatherer societies in different ways. Ash scattering causes a decrease in the visibility, which would affect hunting activities. It covers large areas, eliminating the flora, and in turn altering the distribution of fauna. Thus, the aforementioned events could be manifested in the middle basin of the Colorado River, slowing exploration and colonization (Berón and Carrera Aizpitarte, 2013). Thus, the isolated signs of initial colonization in Western Pampa show a gradual process of knowledge of random points in the landscape, related in all cases with aquatic environments. Commenting on the evaluation of demography from distribution of radiocarbon dates, Peros et al. (2010) state, "The fundamental premise of this approach is that radiocarbon date frequency is proportional to prehistoric population. However, the "growth rate" of radiocarbon dates is probably proportional to population during times when settlement size, site occupation length, and mobility were relatively constant. During and following periods of broad cultural change, the relationship between radiocarbon date frequency and population may be different" (663–664). This may be the scenario reflected by the radiocarbon date frequency of the earliest moments of exploration and occupation of this environment. Cultural change may be reflected in chronological gaps, caused by harsh environmental conditions, but taphonomic biases should also be considered.

Towards *ca.* 3000 BP, once environmental conditions stabilized, populations of hunter–gatherers had a greater awareness of their potential and developed their mortuary practices, which would account for the re-creation of the history of a landscape (Bradley, 1991; Curtoni and Berón, 2011). The presence of more than one individual in each of the identified burials shows recurrent social activities and intentionality in choosing these spaces to perform mortuary practices. Between *ca.* 3000 and 1900 BP, burials are located in the vicinity of settlement areas or camps, a situation that would represent the existence of persistent places, in the sense of Schlanger (1992) and Littleton (2007). No burials have been discovered in Western Pampa dated between *ca.* 1900 and 1050 BP, even in camp occupations such as Tapera Moreira. It is likely that this bioarchaeological silence is a consequence of taphonomic or research biases, but it is also likely to reflect social behaviors whose motivations are still unknown.

In summary, climatic and geomorphological conditions existing during the early Holocene would not have favored the use and occupation of Western Pampa subregion, except in very specific sectors, such as the Colorado River Basin, where the water is permanent and plentiful. By the end of the middle Holocene and early Late Holocene, stabilization of environmental conditions led to the exploration and use of different spaces within these landscapes. However, during the final Late Holocene, population growth resulted in the effective occupation of a diversity of locations, and the exploration and use of almost all Pampean semi-desert environments. Due to the systematic scarcity of surficial water, human groups probably explored and colonized new environments according to hierarchies generated by perceptions, goals, and information transmission. Therefore, an area without stable water sources could be used after exhausting alternatives including valleys, lakes, springs, and other water reservoirs.

Referencing the proposal of Miotti (2006), the Western Pampa may have seen a slow, early, and discontinuous exploration that

used the main rivers of the Atlantic slope as axes. For the south and center of La Pampa, axes of walkability operated in different ranges and scales: major access routes to the mainland such as the Colorado River, and secondary roads for dispersal such as Atuel – Salado – Chadileuvú – Curacó system and paleo streams, currently recognized along the Transverse Valleys and Colorado paleo riverbeds. A third range of movement and residence was given by the springs, waterholes, permanent or temporary ponds, pools and other water reservoirs as dune chains, which were linked by the ancient Indians tracks or "*rastrilladas*", forming a network of strategic places sustained by different types of social interaction (peaceful or belligerent). Analysis of the reasons for the difference in the forms of social interaction is a subject to be treated in other papers.

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