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Late Holocene environmental dynamics in fluvial and aeolian depositional settings: Archaeological record variability at the lower basin of the Colorado river (Argentina)

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ABSTRACT

This paper deals with the way in which the environmental dynamics that took place in the lower basin of the Colorado River (Buenos Aires province, Argentina) have affected the degree of archaeological resolution, integrity, and site preservation in different sectors of the study area (e.g., coastal fringe, delta and interior dune fields). Evidence from geomorphologic, stratigraphic, and sedimentary analyses as well as chemical parameters and zooarchaeological assemblages are used in order to propose spatial and temporal variations in the structure of the archaeological record. These lines of evidence were also used for inferring general paleoclimatic trends. The results obtained indicate that the inland landforms that contained Initial Late Holocene archaeological assemblages (3000–1000 ^{14}C BP) have suffered important morphodynamic processes that produced site destruction, loss of organic material and lower degrees of integrity and site resolution. Conversely, landforms located near the delta and the coastal fringe underwent more stable geomorphic processes (e.g., pedogenesis) that promoted better preservation, resolution, and integrity during the Initial Late Holocene and, particularly, during the Final Late Holocene (1000–250 ^{14}C BP). The recognition of this pattern is crucial in order to evaluate demographic processes linked with the intensity and mode of hunter-gatherer occupation of the area and population dynamics throughout time.

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1. Introduction

The archaeology of the lower basin of the Colorado River is very recently developed as part of a more comprehensive project that includes several lines of evidence. These avenues of inquiry are indispensable for understanding issues such as hunter-gatherer dynamics and adaptations, organization of settlement systems, natural and cultural formation processes, bone assemblage survival, the degree of resolution and integrity of the archaeological record, and processes linked with differential preservation of landforms throughout the landscape. The study area is located in a semi-arid ecotonal landscape, crossed by an allochthonous river which flows into the Atlantic Ocean (Fig. 1). In the ancient delta of the Colorado River, the significant changes that this fluvial system underwent throughout time, and the formation of substantial aeolian mantles that covered most of the area in conjunction with old geomorphic structures created particular conditions that influenced the preservation of the archaeological record. The archaeological sites recorded date to the Late Holocene (*c.* 3000–250 ^{14}C BP). For this period, geomorphological dynamics consisted of alternating patterns of landscape stabilization and pedogenesis with deflation and erosional events. In spite of these common general processes for the whole study area, differences in chronology, stratigraphy and sedimentary record, as well as a differentiated structure of the archaeological record are recognized at specific places and landforms throughout the landscape. These differential patterns are observed along the Atlantic Coast, in sectors belonging to the ancient delta, and in interior dune fields. These places were occupied by hunter-gatherers with differential intensity and for diverse purposes.

Given this background, one of the main objectives of this paper is to evaluate the environmental dynamics that affected the degree of resolution, integrity, and preservation of archaeological sites in different sectors of the study area. A preliminary model for paleoclimatic reconstruction is also proposed. Geomorphological, stratigraphic, sedimentary and chemical parameters, as well as chronology

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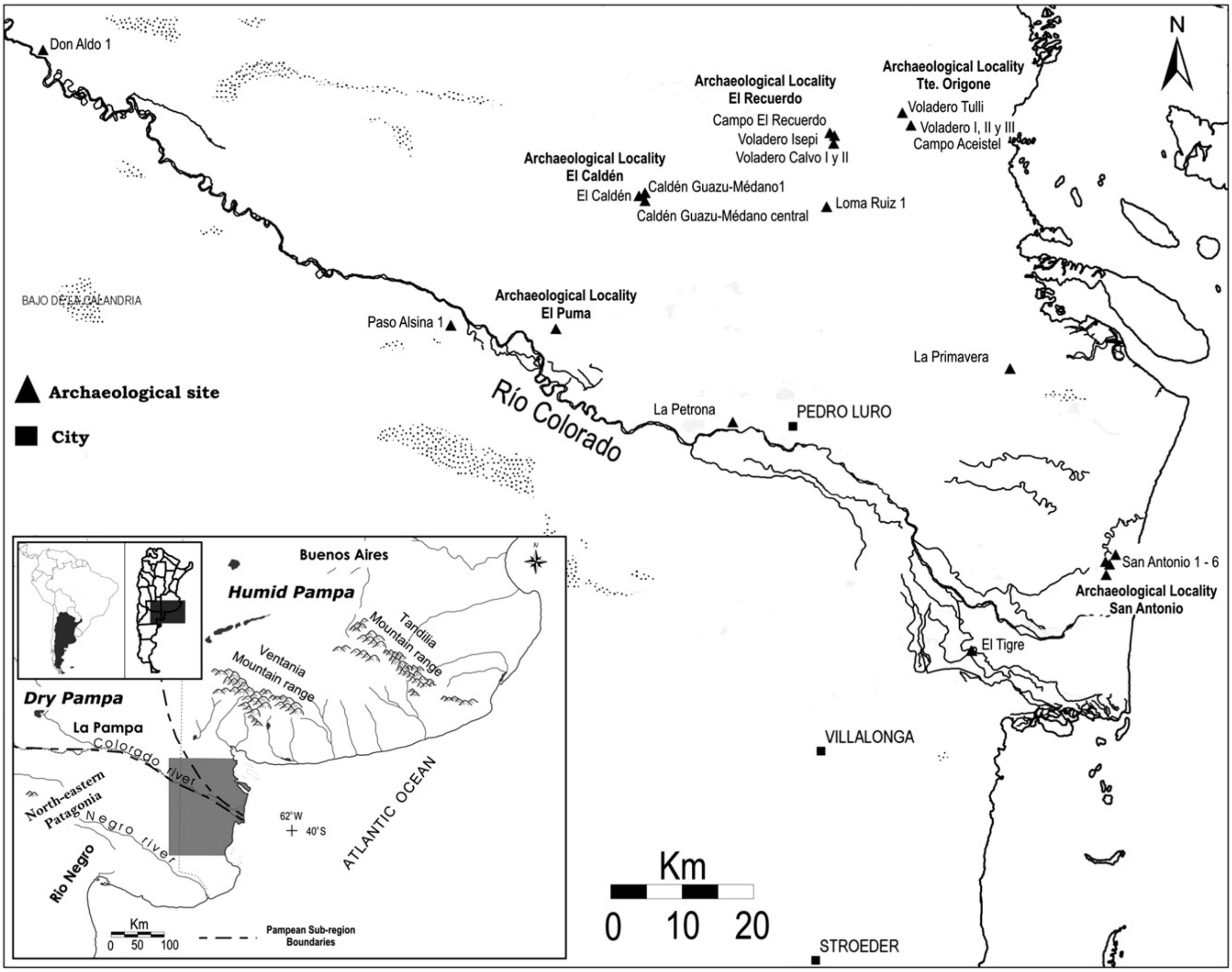

Fig. 1. The lower stream of the Colorado river valley (Argentina) in the context of the Pampean-North-eastern Patagonia transition. Archaeological sites and localities in the study area are shown.

and patterns in the zooarchaeological assemblages are used in order to understand the differential structure of the archaeological record. Satellite Imaginary and Digital Elevation Models are employed for analyzing the degree of site and landform preservation in these particular settings of the landscape.

2. Brief notes on the archaeology of the lower basin of the Colorado River

The lower Colorado River valley is located in the transition between the Pampas and Patagonia regions (Fig. 1). Apart from the few and isolated early archaeological studies (Outes, 1926; Martínez and Figuerero Torres, 2000), an archaeological research program developed in 2001 has yielded archaeological and paleoenviromental evidence for the area. Along these lines, topics such as radiocarbon and OCR chronology, subsistence, isotope analyses on human remains and the construction of an isotopic ecology, organization of lithic technology, mobility and home ranges, settlement systems, human burials and funerary practices, as well as pollen analyses and paleoclimatic reconstructions based on fauna and geoarchaeological studies, have been carried out (Martínez, 2004; Stoessel, 2007; Stoessel et al., 2008; Martínez et al., 2009a,b,c; Armentano, 2010; Bayala, 2010; Flensborg, 2010). The chronology of the human occupation belongs to the Late Holocene (last 3000 ^{14}C BP). The results of the lines of evidence were the basis for distinguishing two different periods of adaptive and organizational properties of hunter-gatherers in the area: the Initial Late Holocene (*c.* 3000–1000 ^{14}C BP) and the Final Late Holocene occupations (*c.* 1000–250 ^{14}C BP) (Martínez, 2008–2009). Some aspects of this model (e.g., faunal exploitation and settlement pattern) will be related with issues discussed here. In this paper, data generated from various lines of inquiry related to the landscape dynamics have allowed a more complete understanding of the resolution, integrity, and differential preservation of archaeological sites and relevant landforms.

3. Methods and concepts

The analysis of the geomorphologic dynamics was based on the identification of landforms, the drawing of stratigraphic profiles, the correlation of allo and pedostratigraphic units, and the study of sedimentary facies. Geomorphological features were identified from Satellite Images (Aster and Landsat) and from Digital Elevation Models (SRTM, 90 m resolution, obtained from SIR-C/X-SAR).

Soil profiles were described and characterized according to soil taxonomy (Soil Survey Staff, 2010). Two different methods were used to obtain numerical ages: radiocarbon dating using AMS techniques and Oxidizable Carbon Ratio (OCR) dating. This is

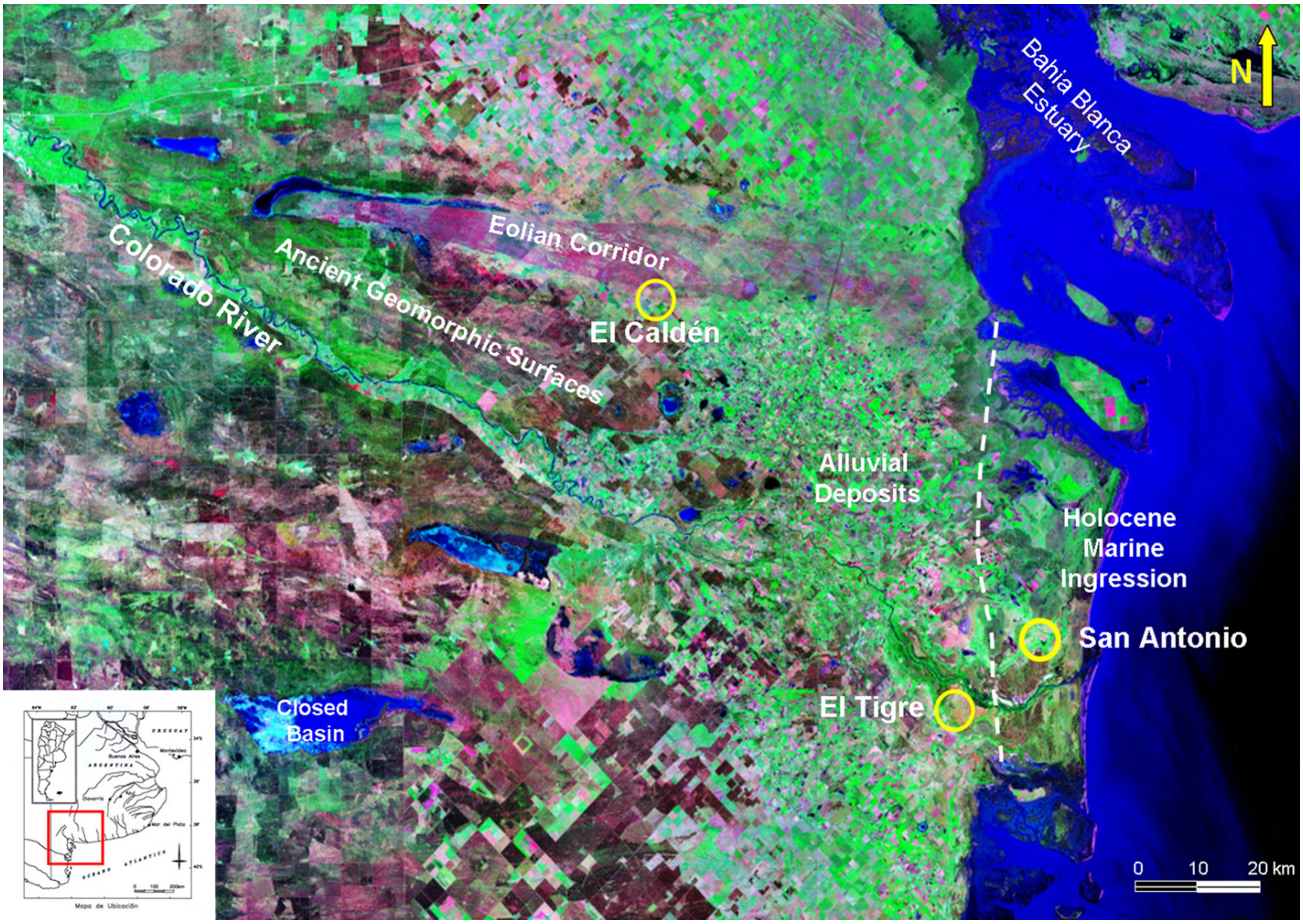

Fig. 2. Landsat image of the study area showing the main geomorphical and sedimentological environments as well as the location of archaeological localities and sites.

a method based on the effect of the biochemical degradation of charcoal and soil humic material, measured as a ratio of the total carbon to the readily oxidizable carbon in the sample (Frink, 1995). All OCR dates are represented as calendrical years before AD 1950. Particle size analysis was determined by sieving and pipetting. Organic carbon was determined by the Walkley–Black method, and pH by the use of a pHmeter in a suspension with a soil:water ratio of 1:2.5.

Integrity and resolution are reflected in the grain (fine "vs." coarse) of the assemblage texture (see Ebert, 1992:145–147). The concept of the archaeological component is applied in this paper to those archaeological deposits that possess finer grain textures: that is, archaeological deposits containing artifacts that can be quite confidently associated with human behavior performed in relative synchrony (e.g., hundreds of years). Consequently, these contexts possess higher degrees of integrity and resolution. The spatial and temporal patterns inferred for an archaeological deposit are clearly influenced by aggradational and erosional processes, intensity and frequency of human occupation in a given landform and, post-depositional processes. The structure of the archaeological record depends on the combination of these factors which are also comprised of different scales of time and space (Binford, 1992; Ebert, 1992; Stein, 1993). Although archaeological assemblages can be considered as palimpsests (Bailey, 2007:203), archaeological and geoarchaeological analyses can be used in order to determine degrees of archaeological integrity.

4. Geology, geomorphology, climate, paleoclimate and resources

The Colorado River is an allochthonous stream that runs from the Andes to the Atlantic Ocean. The lower stream of the Colorado River valley (Fig. 1) is part of the "Arid Diagonal" (Abraham de Vázquez et al., 2000). The study area is located at the morphostructural Colorado Basin (sensu Zambrano, 1974). This is a rift basin formed in the Late Jurassic during the initial opening of the South Atlantic, with a sedimentary fill extending up to Tertiary. The western part of the area is composed by erosional remnants of ancient surfaces (Fig. 2) with local relief ranges between about 10 and 60 m (Cappannini and Lores, 1966; González Uriarte, 1984). These high plains are cut by a wide canyon whose genesis is related to the current Colorado River Valley and its ancient paleochannels (Zárate and Rabassa, 2005). The eastern part of the area is formed by widely distributed Holocene ancient fluvial deposits. Coastal marine deposits corresponding to the last Holocene transgressive–regressive cycle (*c.* 6630 ^{14}C BP–present; Weiler, 1983) are also present. Finally, aeolian deposits generated during different denudational periods, cover the ancient geomorphic surfaces, fluvial and marine deposits.

The ancient delta of the Colorado River, a complex system of paleochannels and ancient floodplains, was covered by younger aeolian mantles that covered most of the area (Spalleti and Isla, 2003). The co-occurrence throughout the landscape of aeolian and fluvial landforms indicates both the dynamics of the ancient

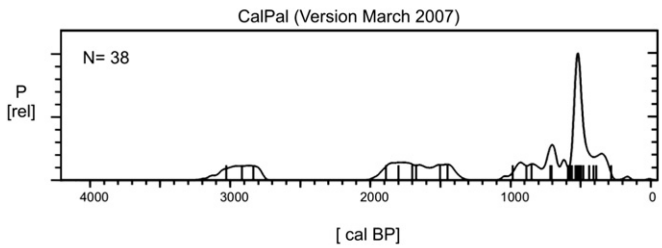

Fig. 3. CalPal (Weninger et al., 2007) sum model from ^{14}C dates taken from Martínez (2008–2009; Table 1) and this paper. Y axis show the relative probability heights of the distribution (P rel) while X axis express calibrated radiocarbon years BP (IntCal04 curve; Stuiver and Reimer, 1993).

delta and the active aeolian deposition that took place in the area. For example, the Colorado River shifted from the Bahia Blanca estuary (*c.* 100 km north) as recent as *c.* 3000 ^{14}C BP and progressively migrated southwards while a sea level similar to the current one became established (Melo et al., 2003).

A steppe arid, warm and dry climate characterizes the area. Average annual rainfall is 466 mm while temperatures vary from 22.2 °C in January to 7.5 °C in July. This region is covered by shrub steppe, an open vegetal formation composed by xeric short trees which are mixed with hard and scarce herbaceous grasses. The dominant vegetation belongs to the Distrito del Caldén, Provincia del Espinal, although vegetal communities of the Provincia del Monte are also recorded in the area (Morello, 1958; Páez et al., 2001). From a zoographic point of view, the area is located in the Subregión Patagónica, Distrito Patagónico (Cabrera and Yepes, 1960). Nevertheless, animal species belonging to other northern zoographic provinces are also recorded (Stoessel et al., 2008). Freshwater fish species belong to an ecotone formed by Provincias Parano-Platense and Patagónica (Baigún et al., 2002). Summing up, the study area is an ecotone when considering the association of different vegetation, animal, and fish communities. Also, the presence of the estuary enhances the primary productivity of the area.

Paleoclimatic data from the study area is scarce. Dry and salt lakes from Northern Patagonia have been the subject of pollen and sedimentary studies in order to infer paleoprecipitation. On this basis, Schäbitz (2003:297) proposed contrasting climatic conditions for north central-west and north-eastern Patagonia through the Holocene: while the former sector was subject to higher aridity, the latter underwent higher precipitation and *vice-versa*. This result indicates a variable regional paleoclimatic scenario.

For north-eastern Patagonia, the Holocene have persistently been arid and semi-arid with alternating patterns of morphogenesis and pedogenesis (Abraham de Vázquez et al., 2000:59, Fig. 2f; see also Schäbitz, 1994, 2003). For the Middle Holocene (7–5 ka BP), higher temperatures, lower values of annual precipitation (*c.* 210–290 mm), processes of salt lake reduction, and dune remobilization suggest arid and warm climates. A transitional pattern toward semi-arid conditions is recorded for the later part of the Middle Holocene (5–3 ka BP). Annual rainfalls increased (*c.* 240–329 mm) and a seasonal pattern of precipitation became established. During the Late Holocene (3 ka BP), annual precipitation increased (260–380 mm) causing higher fluvial discharge rates in addition to lake expansion (see Schäbitz, 1994, 2003:Figs. 4 and 5).

Preliminary aspects of paleoclimatic and environmental dynamics from the study area are outlined in Section 6. All of this data will allow discussion if large scale events such as the Medieval Climatic Anomaly (MCA; *c.* 1200–800 BP) and the Little Ice Age

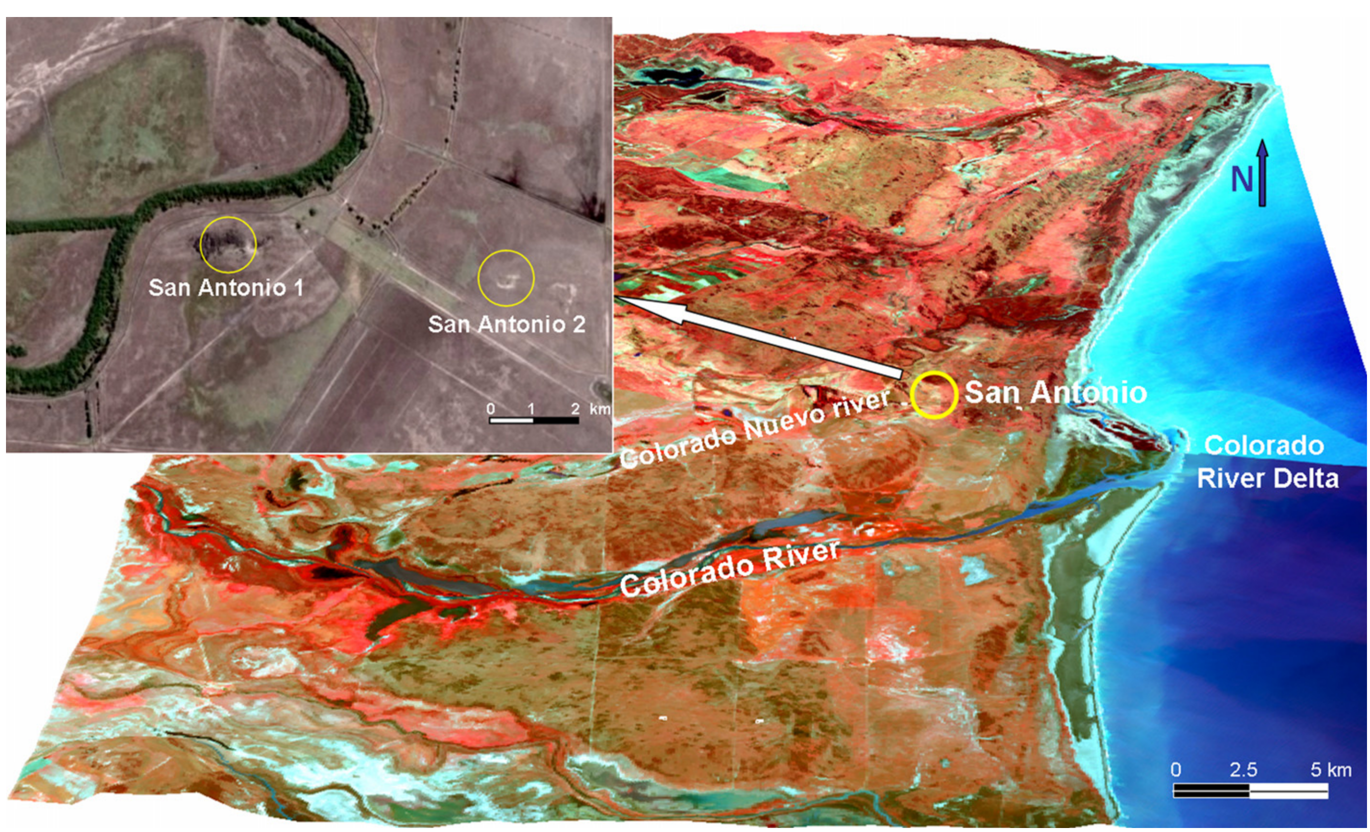

Fig. 4. The landscape around San Antonio Archaeological Locality. 3D view based on SRTM3 digital model + Aster image (VNIR 1, 2 and 3N bands). Upper left corner: sites 1 and 2 located in small dunes closed to the Colorado Nuevo River.

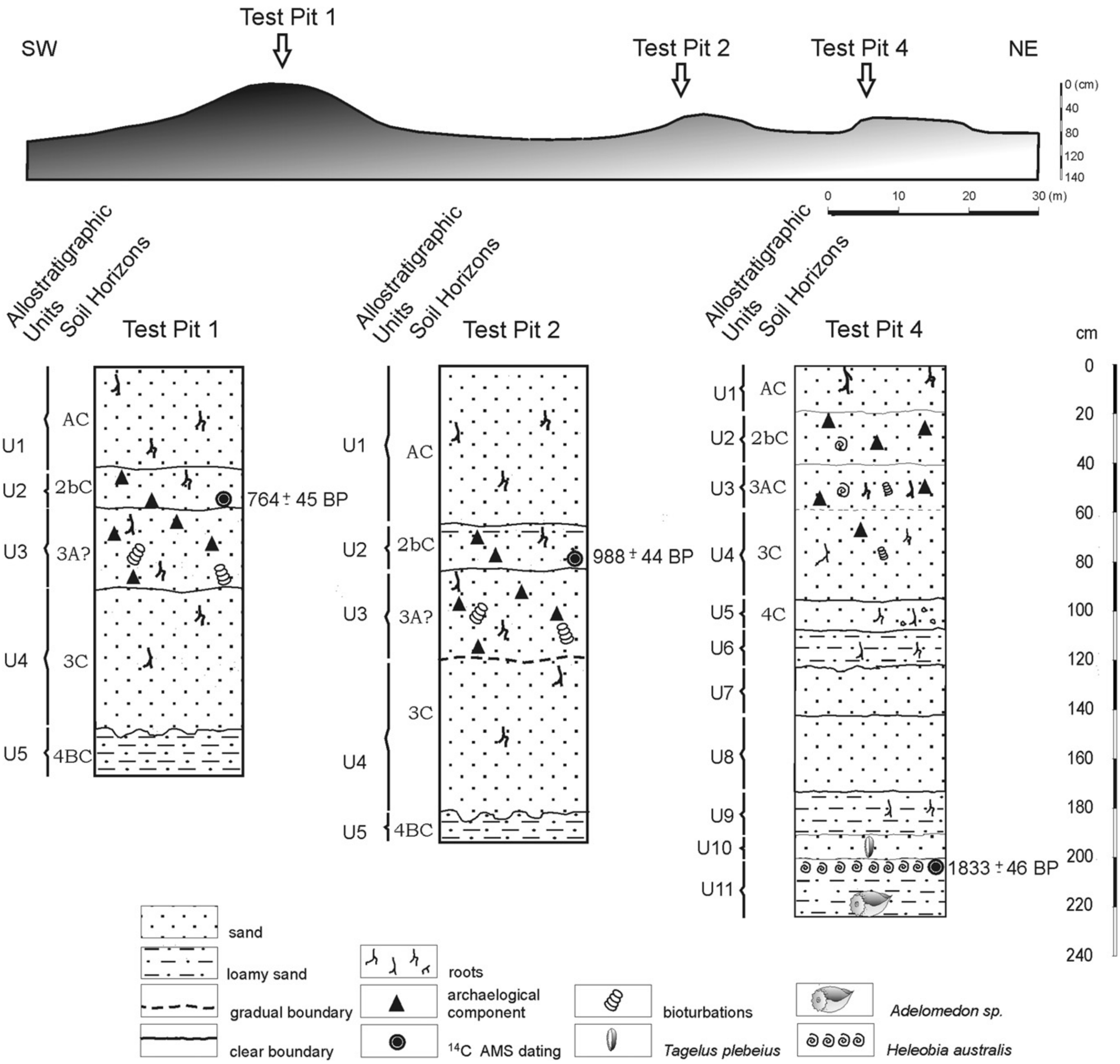

Fig. 5. Stratigraphic profiles of Test Pits 1, 2 and 4 at San Antonio 2 site.

(LIA; *c.* 450–200 BP) (Stine and Stine, 1990; Villalba, 1994; see discussion in Stoessel 2008:201) have any role in the study area.

In sum, geomorphology, pedology, palynology and paleoecology indicate a modern, recently modified and dynamic landscape that should influence archaeological visibility, resolution, and integrity that probably affect the chronology and signature of the human occupations. These issues will be discussed further.

5. The archaeological record

Nearly 30 archaeological sites have been recorded in the study area and the chronology of the human occupation dates to the Late Holocene (3000–250 ^{14}C BP). Nevertheless, as can be noted in Fig. 3, significant gaps are observed during the Initial Late Holocene (radiocarbon dates are available at Table 4 in Martínez et al., 2009a: 287; see also Table 1 here).

Sites which were intensively investigated are La Primavera, Loma Ruiz 1, El Tigre, Don Aldo 1, La Petrona, and Paso Alsina 1, as well as the Teniente Origone, El Recuerdo, El Caldén, El Puma and San Antonio Archaeological Localities (Fig. 1). As will be described later, not all sites were recovered in sealed, stratigraphic deposits, but some only consist of surface materials. In order to deal with the aims of this paper, three archaeological sites and localities placed on different settings throughout the landscape are taken into account: the San Antonio and El Caldén Archaeological Localities and the El Tigre site (Fig. 2). Site descriptions will be provided in order of those located near the Atlantic Ocean to those placed in the interior in an east–west axis.

5.1. San Antonio archaeological locality

The San Antonio Archaeological Locality is located *c.* 4 km from the Atlantic coast (39°39′34″S - 62°09′36″ W). The locality is composed of six archaeological sites. Radiocarbon dates indicate a chronology of *c.* 1000–800 ^{14}C BP (Table 1). The sites were located on low aeolian sand dunes partially affected by deflation processes

Table 1
Radiocarbon chronology of the main sites mentioned in the text.

Archaeological site	Lab. code	Sample	^{14}C years BP	Cal. years BP[a]	δ^{13}C ‰	References
El Tigre	AA-70565	*Percichthys* sp. (bone)	930 ± 47	742–928	−23.1	Martínez et al., 2009b
El Tigre	AA-81830	*Lama guanicoe* (bone)	437 ± 43	325–540	−20.1	Martínez et al., 2009b
El Tigre	AA-81834	*Lama guanicoe* (bone)	536 ± 43	506–644	−20.2	Martínez et al., 2009b
El Tigre	Ua−22561	*Lama guanicoe* (bone)	455 ± 45	330–617	−19.9	Martínez et al., 2009b
Loma Ruiz 1	AA-53331	*Lama guanicoe* (bone)	1615 ± 50	1389–1686	−17.8	Martínez 2008–2009
Loma Ruiz 1	AA-53332	*Lama guanicoe* (bone)	1935 ± 44	1740–1992	−16.2	Martínez 2008–2009
Loma Ruiz 1	AA–88418	*Lama guanicoe* (bone)	1749 ± 64	1413–1776	−19.7	This paper
Loma Ruiz 1	AA- 88419	*Lama guanicoe* (bone)	1775 ± 66	1542–1864	−18.8	This paper
San Antonio 1	AA-81832	*Lama guanicoe* (bone)	773 ± 44	661–773	−19.9	Martínez 2008–2009
San Antonio 2	AA-81831	*Lama guanicoe* (bone)	988 ± 44	790–971	−19.7	Martínez 2008–2009
San Antonio 2	AA-77966	*Lama guanicoe* (bone)	764 ± 45	656–773	−20.9	Stoessel et al., 2008
San Antonio 2	AA–85152	Human bone	1053 ± 53	804–1064	−17.0	This paper
El Puma 4	AA–88420	*Lama guanicoe* (bone)	1862 ± 51	1573–1871	−19.4	This paper

[a] calibrated with CALIB 6.0 at 2σ (Stuiver, M.; P. J. Reimer and R. W. Reimer, 2005).

(blowouts), overlying alluvial deposits of the Colorado River. At the coastal fringe, marine deposits that belong to Holocene ingressions underlie fluvial and aeolian deposits. In this archaeological locality, both surficial and stratigraphic archaeological material was recovered from dune settings. An outstanding feature of these two kinds of sites located in a sand dune environment is the recovery of well preserved bone and pottery sherds (Martínez et al., 2009b). The San Antonio 1 and 2 sites are described in this paper.

The San Antonio 1 site corresponds to an east–west elongated dune of about 200 m long by 50 m wide, located close to a meander of the Colorado Nuevo River (Fig. 4). The San Antonio 2 site is located 700 m from San Antonio 1 (Fig. 4). It is a smaller subcircular dune deeply eroded by a blowout. These two sites present similar stratigraphic sequences and for this reason their characteristics are described in conjunction.

In San Antonio 2 (Test Pit 4), basal units (U10 and U11) contain fossiliferous material consisting in well preserved shells of *Heleobia australis* and *Tagelus plebeius* in "life position" and also reworked specimens of *Adelomedon* sp. (Fig. 5). These species correspond to a costal marine environment which includes tidal flats, sandy barrier islands and coastal lagoons (Weiler, 1983). The overlying alluvial facies could correspond to an old meandering system

Table 2
Field descriptions and laboratory data for different site profiles.

SITE	AU	Deph (cm)	SH	AC	Sand %					% Sand	% Silt	% Clay	T	S	DC	B	pH	OM (%)	P (ppm)
					VC (0φ)	C (1φ)	M (2φ)	F (3φ)	VF (4φ)										
CALDEN GUAZU-Médano Central	1	21	AC		0	0	6	2	28	97	2	1	S	0-sg	so	gw	8.4	0.0	4.7
	2	38	2AC		0	0	8	3	25	95	4	1	S	1-sg	sh	aw	8.2	0.1	8.9
	3	59	3C		0	0	5	2	29	95	4	1	S	0-sg	so	as	8.7	1.3	6.0
	4	135	4C		0	0	4	2	29	95	4	1	S	0-sg	so	as	8.7	0.1	8.1
	5	187	5Cb		2	5	7	1	14	82	14	1	GLS	2-ma	sh	sh-w	8.8	0.6	8.3
	6	200	6Cb		0	0	6	2	18	87	12	1	GLS	2-ma	sh	cs	8.8	0.1	6.6
SAN ANTONIO 1 Test Pit 3	1	12	AC		1	7	16	16	9	88	4	8	S	0-sg	so	gs	6.8	1.1	77.9
	2	31	2bC	▲	1	9	17	20	8	91	5	4	S	1-sg	sh	cb	8.6	2.2	47.7
	3	50	3AC	▲	1	9	18	17	7	95	2	3	S	0-sg	so	gi	9.6	0.4	10.5
	4	58	4AC	▲	1	9	18	17	7	94	3	3	S	1-sg	sh	as	9.6	0.5	9.83
	5	88			0	0	0	0	0	19	69	12	SL	1-sg	sh	sh-s	9.4	0.9	4.0
	6	105			0	6	24	1	6	97	2	1	S	0-sg	so	sh-w	9.9	0.4	4.0
	7a	137			0	0	0	0	3	46	50	4	LS	2-m	sh	g-s	9.4	0.4	6.6
	7b	139	Bw		0	0	1	0	0	14	56	30	SCL	2-sb	sh	sh-s	9.2	0.9	2.8
	8	173			0	11	20	1	5	96	2	2	S	0-sg	so	cs	9.5	0.4	1.9
SAN ANTONIO 2 Test Pit 4	1	19	AC		0	0	0	0	33	93	4	3	S	0-sg	so	cs	8.4	0.9	30.1
	2	41	2bC	▲	0	0	0	0	33	92	7	1	S	1-sg	sh	cs	8.8	1.4	58.9
	3	74	3AC	▲	0	0	0	0	34	91	7	2	S	1-sg	sh	gs	8.4	0.4	9.1
	4	87	3C	▲	0	0	0	0	33	92	6	2	S	0-sg	so	cs	8.2	1.3	9.9
	5	103	4C		0	0	0	0	33	90	8	2	S	2-m	h	cs	9.2	1.2	7.2
	6	115			0	0	0	0	12	43	49	8	L	1-sg	so	cw	8.9	1.9	17.5
	7	155			0	0	0	0	33	93	5	2	S	1-sg	sh	cs	9.6	0.9	11.0
	8	173			0	0	0	0	36	96	2	2	S	0-sg	so	as	9.5	0.4	9.1
	9	183			0	0	0	0	16	51	44	5	L	2-m	h	as	9.8	0.1	13.3
	10	199			0	0	2	2	27	94	4	2	S	1-sg	sh	as	9.1	0.1	4.4
	11	224			0	0	0	0	9	39	51	10	L	1-sg	sh	as	8.8	1.4	20.5
EL TIGRE	1	11	Ap		0	0	2	98	0	93	4	3	S	1-sg	sh	ai	9.1	0.2	–
	2	22	C		0	0	1	98	1	41	53	6	SL	2-ma	sh	aw	8.5	0.1	–
	3	52	Ab1	▲	0	0	3	97	0	94	2	4	S	0-sg	so	gs	9.0	0.0	–
	4	80	ACb1	▲	0	0	2	98	0	93	4	3	S	0-sg	so	gw	9.0	0.0	–
	5	140	Cb1		0	1	2	97	0	90	6	4	S	0-sg	so	gs	8.7	0.1	–

Notes: AU = Allostratigraphic Unit; SH = Soil Horizon; AC = Archaeological Component; Sand (%): VC = Very Coarse (2000–1000 μ); C = Coarse (1000–500 μ); M = Medium (500–250 μ); F = Fine (250–100 μ); VF = Very fine (100–50 μ). T = Texture; S = Structure; DR = Dry Consistence; B = Boundary; OM = Organic Matter; P = Phosphorus. Texture: S = Sand; SL = Sandy loam; L = Loam; SiCL = Silty clay loam; LS = Loamy sand; GLS = Gravelly loamy sand. Structure: 0 = Structureless; 1 = Weak; 2 = Moderate; 3 = Strong. Type: sb = subangular blocky; sg = single grained; ma = massive. Consistence: so = soft; sh = slightly hard; h = hard. Boundary. Distinctness: a = abrupt; c = clear; g = gradual; sharp. Topography: s = smooth; w = wavy; i = irregular; b = broken. ▲ = Archaeological Materials. Shadow lines indicate important changes in grain size and sedimentary structures.

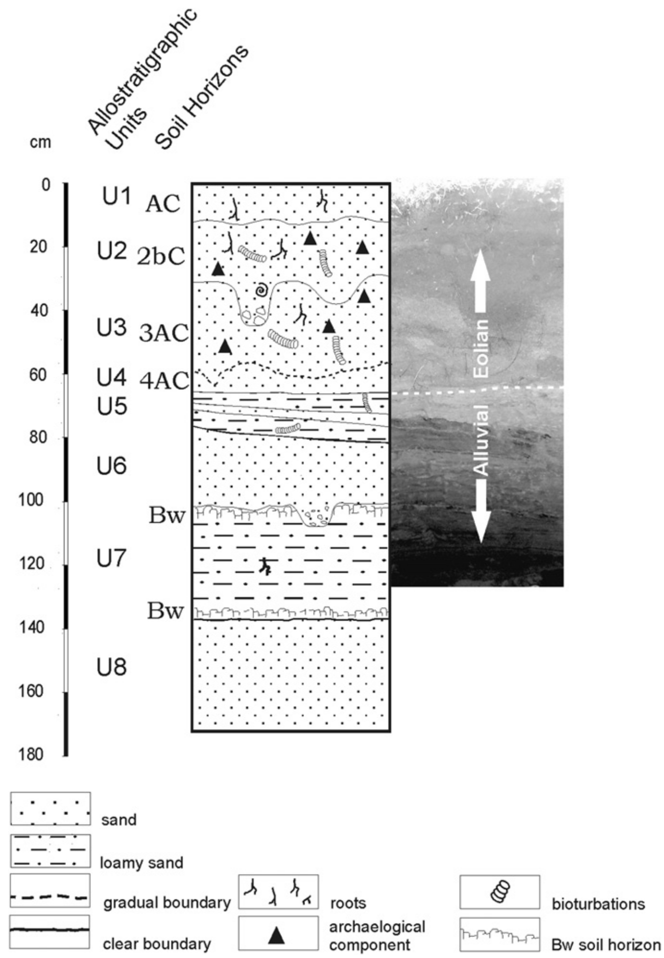

Fig. 6. Stratigraphic profile of Test Pit 4 at San Antonio 1 site.

composed of alternating processes of lateral accretion (point bar) and vertical accretion (backswamps) whose deposits are recognizable by grain size and sedimentary structures (Fig. 5; Table 2). The point bar deposits are represented in Unit 6 and 8 in San Antonio 1 (Test Pit 3; Fig. 6) and in Unit 5, 7 and 8 in San Antonio 2 (Test Pit 4; Fig. 5). Backswamp deposits are recognized in U7 in San Antonio 1 (Test Pit 3) and Unit 6 and 9 in San Antonio 2 (Test Pit 4). The silty loam texture of Unit 5 in San Antonio 1 (Test Pit 3) probably indicates a natural levee deposit.

The upper stratigraphic units consist of four aeolian sand deposits which overlie the alluvial deposits mentioned above, corresponding to an ancient flood plain of the Colorado River system. A buried soil horizon (2bC) (Figs. 5 and 6) was identified in aeolian Unit 2 at both sites and it is also distinguishable by physical parameters and organic matter content (2.2 and 1.4%, see Table 2). While the percentage of organic matter is according to the expected values for the buried soils, abnormal phosphorous values in surficial horizons (AC and 2bC) are recognized. These higher values are due to daily presence of cattle and horses in the surrounding area of the sites.

From these aeolian deposits, Units 2 and 3 commonly include archaeological materials and are treated as an archaeological component. The most common artifacts recovered are small stemless triangular projectile points, scrapers, a variety of lithic debris and raw materials, bone tools and pottery. The exploited fauna which were recorded include marine fish, freshwater fish, and artiodactyls (Table 3). In addition, a species of marine bivalve

Table 3
Bone assemblages from sites belonging to the Initial and Final Late Holocene (3000–250 ^{14}C BP). Taxonomic abundances per sites placed in different landforms from the interior to the Atlantic coast are compared.

	Late Holocene							
	Initial Late Holocene				Final Late Holocene			
	El Caldén archaeological locality (60 km) ca. 3000 –1500 BP		Loma Ruiz (30 km) 1900 –1600 BP		El Tigre (20–15 km) 900–400 BP		San Antonio 1 (4 km) 1000–800 BP	
	Interior dune Fields		Interior dune Fields		Ancient delta		Ancient delta + estuary	
Faunistic resources	NISP (NISP%)	MNI	NISP (NISP%)	MNI	NISP (NISP%)	MNI	NISP (NISP%)	MNI
Lama guanicoe (Wild camelid; "Guanaco")	–	–	55 (100%)	2	358 (26.81%)	3	20 (1.54%)	1
Ozotoceros bezoarticus (Pampean deer)	–	–	–	–	18 (1.34%)	2	7 (0.54%)	1
Rhea Americana (greater Rhea)	–	–	–	–	7 (0.52%)	1	–	–
Nycticorax nycticorax (Black-crowned Night)	–	–	–	–	1 (0.07%)	1	–	–
Cf. Pitangus sulphuratus (Great Kiskadee)	–	–	–	–	1 (0.07%)	1	–	–
Myocastor coipo (Otter)	–	–	–	–	1 (0.07%)	1	–	–
Percichthys sp. (Perch)	–	–	–	–	948 (71.01%)	28	29 (2.23%)	4
Genidens barbus (Sea catfish)	–	–	–	–	–	–	1065 (82.17%)	298
Micropogonias furnieri (White croaker)	–	–	–	–	–	–	132 (10.18%)	56
Scienidae indet.	–	–	–	–	1 (0.07%)	1	35 (2.70%)	1
Chondrichthyes	–	–	–	–	–	–	8 (0.61%)	2
Total	–	–	55 (100%)	2	1335 (100%)	38	1296 (100%)	363
References	Martínez 2008–2009		Stoessel, 2007		Stoessel 2007; Martínez et al., 2009c		Martínez et al., 2009b	

Fig. 7. The El Tigre site in the context of the ancient delta, besides a non-functional stream (the Colorado Viejo River). Archeological materials are found in small sand dunes and blowouts overlying alluvial deposits corresponding to a natural levee. Upper left corner: Arrow indicates the excavated area located besides the main dune and their adjacent blowout.

(*Mesodesma* sp.) was consumed. These sites are interpreted as domestic, residential bases, seasonally used (spring and summer) mainly for fish procurement, processing and consumption (Martínez et al., 2009b). The mode of use of this part of the landscape could be classified as multiple occupations (sensu Ebert, 1992).

As mentioned, archaeological materials are found in surface and stratigraphic contexts (aeolian Units 2 and 3). In the latter case an archaeological component can be defined and the chronological dates from sites 1 and 2 (Table 1) are coherent (Martínez, 2008–2009). In these cases, the archaeological component is associated with pedogenetic horizons that represent periods of landscape stability in dune settings. With the exception of these landscape stability events, the rest of the stratigraphic sequence consisted of a rather continuous process of sedimentation.

5.2. El Tigre site

This site is located in the ancient delta, beside an abandoned stream channel (the Colorado Viejo River), 15–20 km from the current Atlantic coast (39°46′49″ S–62°22′32″ W). The mature alluvial plain is composed of the ancient delta complex meandering system. Small sub-circular sand dunes (approximately 20 m in diameter) overlie the alluvial deposits (natural levee). The dunes were partially affected by deflation processes producing blowouts. The archaeological materials are founded both in sealed deposits and distributed throughout the surface in the blowouts (Fig. 7). The chronology of the human occupation is *c*. 900–400 ^{14}C BP (Table 1) (Martínez et al., 2009c).

The stratigraphic sequence is composed of four aeolian sand units (Units 1, 3, 4 and 5) and a recent alluvial flood deposit (Unit 2) (Fig. 8). Unit 5 is composed of non-pedogenic aggrading sediments, while upper units (Units 4 and 3) represent a buried soil (Ab1–ACb1). These units are separated from Unit 2 by an erosive contact. Unit 2 is composed by alluvial sandy loam sediment that represents a historical flood event by the nearby Colorado Viejo River which is now abandoned. The uppermost aeolian unit corresponds to a Ap horizon that reveals recent plowing perturbation (see Martínez et al., 2009c).

The obtained OCR chronology for the entire stratigraphic sequence suggests that the last *c*. 3000 cal BP are represented. The ages suggest a more or less continuous aggradational process with the exception of the chronological gap recorded between 1210 and 823 cal BP (Fig. 8). Nevertheless, this gap is not physically recognizable (e.g., unconformity, erosional contact, “stone line”, etc.) at the sequence (see discussion in Martínez et al., 2009c). The distribution of archaeological material located in an “A” buried soil horizon and available radiocarbon dating (Table 1) indicate that the site was reoccupied through time at *c*. 900–400 ^{14}C BP (Martínez et al., 2009c).

The site presents a diverse assemblage of exploited species: artiodactyls, large, medium and small sized birds, rodents, and freshwater fish (Table 3). The lithic assemblages are dominated by tools such as small triangular stemless projectile points, scrapers, knives, fragments of ground stone tools, etc. A diversity of local raw materials and *chaînes opératoires*, and the presence of micro-debris related to final stages of lithic reduction, tool rejuvenation, artifact replacement and heat treatment were recorded. Plain and decorated pottery as well as grinding tools is also present. All of this evidence suggests that the site was a multipurpose residential base intensively inhabited throughout time (Martínez,

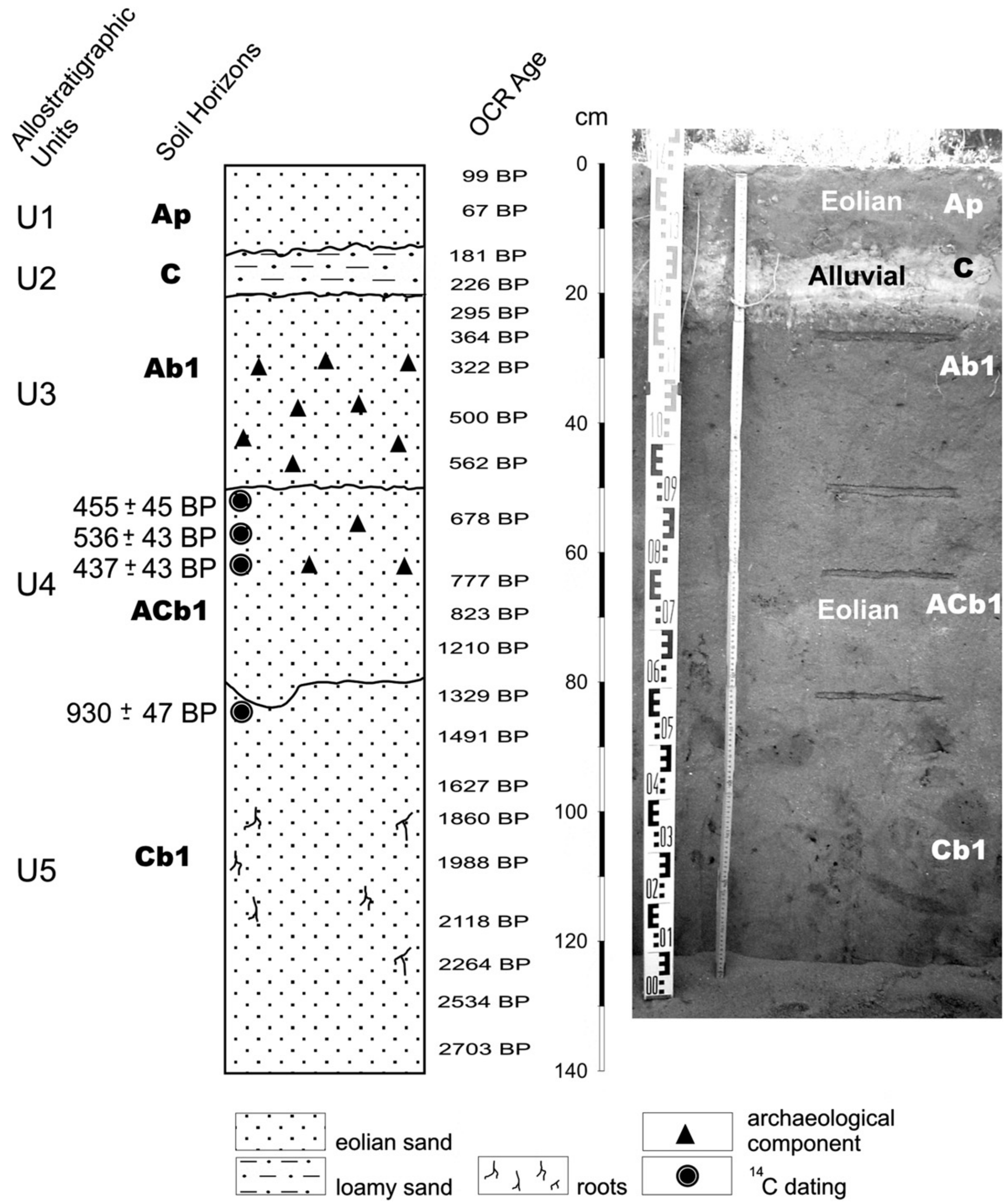

Fig. 8. Stratigraphic profile at El Tigre site.

2008–2009; Martínez et al., 2009c) and reoccupation (sensu Ebert, 1992:147) is proposed.

The site reveals a good degree of resolution and archaeological integrity. On the one hand, the archaeological component located in an "A" buried soil horizon was covered by flood plain sediments that acted as a "seal" promoting the preservation of the lower deposits and preventing them further erosional processes. On the other hand, as in the case of San Antonio Archaeological Locality, very good bone and pottery preservation is recognized both in stratified deposit and in the surface record. To sum up, the information discussed above suggests a good preservation of site without recording important processes of site and landform destruction.

5.3. *El Caldén archaeological locality*

The El Caldén Archaeological Locality is located 60 km from the Atlantic coast (39°13′08″ S – 62°56′50″ W). It is composed of three sites (El Caldén, Caldén Guazú-Medano 1-sector Este and El Caldén Guazú-Médano Central). The archaeological locality is located in an east–west large depression of fluvial origin limited by old geomorphic surfaces. The origin of these depressions probably belongs to an ancient palaeo-valley of the Colorado River (Fig. 9A). These depressions were filled by alluvial deposits. Afterwards, they have been covered by aeolian sands, both as shallow mantles and forming important aeolian corridors. The latter are formed by

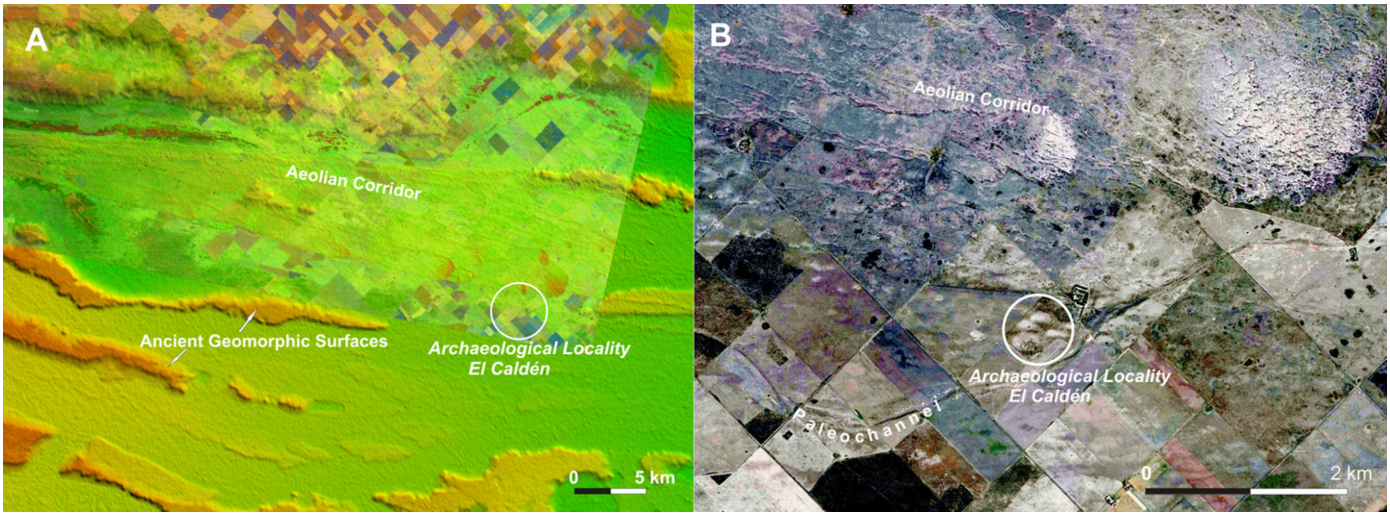

Fig. 9. A. 3D view of the El Calden Archaeological Locality based on SRTM3 digital model + Aster image (VNIR 1, 2 and 3N bands). The locality is adjacent to an important aeolian corridor associated to an ancient geomorphic structure. 9. B. Sites are located at shallow aeolian mantles overlying ancient alluvial deposits. Note the old paleochannel placed immediately southern the sites.

parabolic and linear dunes up to 10–15 m high and 1.500 m long (W–E direction) (Fig. 9A).

The sites are located on low and small dunes of sub-circular shape (e.g., 270 m long by 200 m wide). These dunes are *c.* 2 m in height with blowouts on their sides. The archaeological materials are almost exclusively recovered for surface contexts recognized at these blowouts (see below). A paleochannel located *c.* 340 m south from the sites can be observed (Fig. 9B).

Six allostratigraphic units were defined at the Médano Central Site (Fig. 10). The lowermost units (U6 and U5) are composed by gravelly loam sand corresponding to channel-lag deposits. The overlying units (U4 and U3) consist of sands with 5–10% of rounded pebbles that come from the reworked deposits of basal units (e.g., U5). The uppermost part of the sequence is composed of two aeolian sand units (U2 and U1). Unit 2 is separated from Unit 3 by an erosional contact characterized by a concentration of coarse-grained material (pebbles and isolated archaeological artifacts). This "stone line" (sensu Johnson and Balek, 1991) represents an erosive and deflational event. Unit 1 belongs to a modern "A" horizon modified by anthropogenic perturbation (plowing and/or cattle grazing).

Two stratigraphic sequences were dated by OCR method at the El Caldén Guazú-Medano 1-sector Este site comprising the last *c.* 3000 cal BP. The stratigraphic features recorded from these test pits were related to those already described for the El Caldén Guazú-Médano Central site. The most outstanding feature is the temporal hiatus founded at *c.* 1150–795 and 1355–783 cal BP (see Fig. 10) associated with the occurrence of the above mentioned "stone lines" at both sites.

Concentrations of lithic surficial scatters were recognized in the blowouts. Among these a diverse lithic assemblage composed by bifacial roughout, projectile point preforms, triangular projectile points, artifacts made in extra-areal quartzite (Humid Pampa subregion), *raclettes*, double side scraper (*raedera*), retouched edge pebble (Choppers), *pièces esquillées*, denticulated, etc. was recorded (Armentano, 2010). Bones and pottery were not recovered from the three studied surficial contexts. Sites from this locality have been related to base camps characterized by short term, ephemeral occupations (Martínez, 2008–2009; Armentano, 2010).

Due to the almost absence of materials in stratigraphic position and the concomitant lack of bones no radiocarbon data are available. The chronology of the human occupations was then estimated on the basis of the absence of pottery in all the sites that composed the archaeological locality. The lack of pottery, the pattern of lithic raw material exploitation, specific *chaînes opératoires* and lithic artifactual contents indicate an Initial Late Holocene human occupation (*c.* 3000–1000 ^{14}C BP) (Martínez, 2008–2009; Armentano, 2010). As it was discussed elsewhere (Martínez, 2008–2009) the appearance of pottery technology in the study area is assigned to a moment *c.* 1500 ^{14}C BP. A similar chronology for this technology is described by Favier Dubois et al. (2009) for the northern Rio Negro province.

Throughout the stratigraphic sequence only a few isolated archaeological materials where found, although no archaeological component can be defined: only a few lithic artifacts were recovered associated with the "stone lines". The "stone lines" are the product of a deflational process that eroded the upper part of Unit 3 producing a palimpsest of natural and cultural items. According with the OCR ages such palimpsests should have occurred at some time *c.* 1500–1300 cal BP. That interpretation is coherent with the chronology estimated for the human occupation. The important amount of lithic materials (see Armentano, 2010) and natural pebbles recovered from the blowouts are the outcome of intense deflational processes that vertically and laterally strongly affects a bigger portion of the entire stratigraphy of dunes, particularly Unit 3.

The analyses of these sequences indicate that at a local scale the sedimentary environments would have been more stable at *c.* 3000–1000 cal. BP. Nevertheless, the previous interpretation suggests that the environmental conditions at the locality promote a low integrity and resolution of the archaeological record linked with intense geomorphic activity, abrupt changes in depositional facies (e.g., channel-lag "vs." sandy aeolian deposits) and high rates of erosion (e.g., "stone lines"). In this sense, the original archaeological context have been severely modified or destroyed as a result of post-occupational geomorphic processes.

6. Discussion

As it was already mentioned for north-eastern Patagonia (Schäbitz, 1994, 2003; Abraham de Vázquez et al., 2000) and exemplified by this case study, the study region during the Holocene experienced arid and semi-arid conditions with alternating processes of morphogenesis and pedogenesis. The information presented for the late Holocene for the lower basin of the Colorado

River highlighted these processes. Under the above mentioned conditions, the first recognized pattern suggests that the west (interior dune fields) and east (the delta and the coastal fringe) portions of the area present a different archaeological record structure. In this sense, differences in site preservation, resolution and archaeological integrity are recorded. Apart from the Paso Alsina 1 and La Petrona sites (*c.* 500–250 ^{14}C BP, see Martínez et al., 2009a; see Fig. 1) located in modern sand dunes, very scarce stratified archaeological materials were recorded in the portion of the landscape located between *c.* 100–30 km inland from the Atlantic coast. Recent surveys and test pits carried out at El Puma Archaeological Locality (*c.* 80 km from the Atlantic coast; Fig. 1) reinforced this pattern. Extensive surveys carried out at this locality (four archaeological sites) show the absence of pottery, and scarce

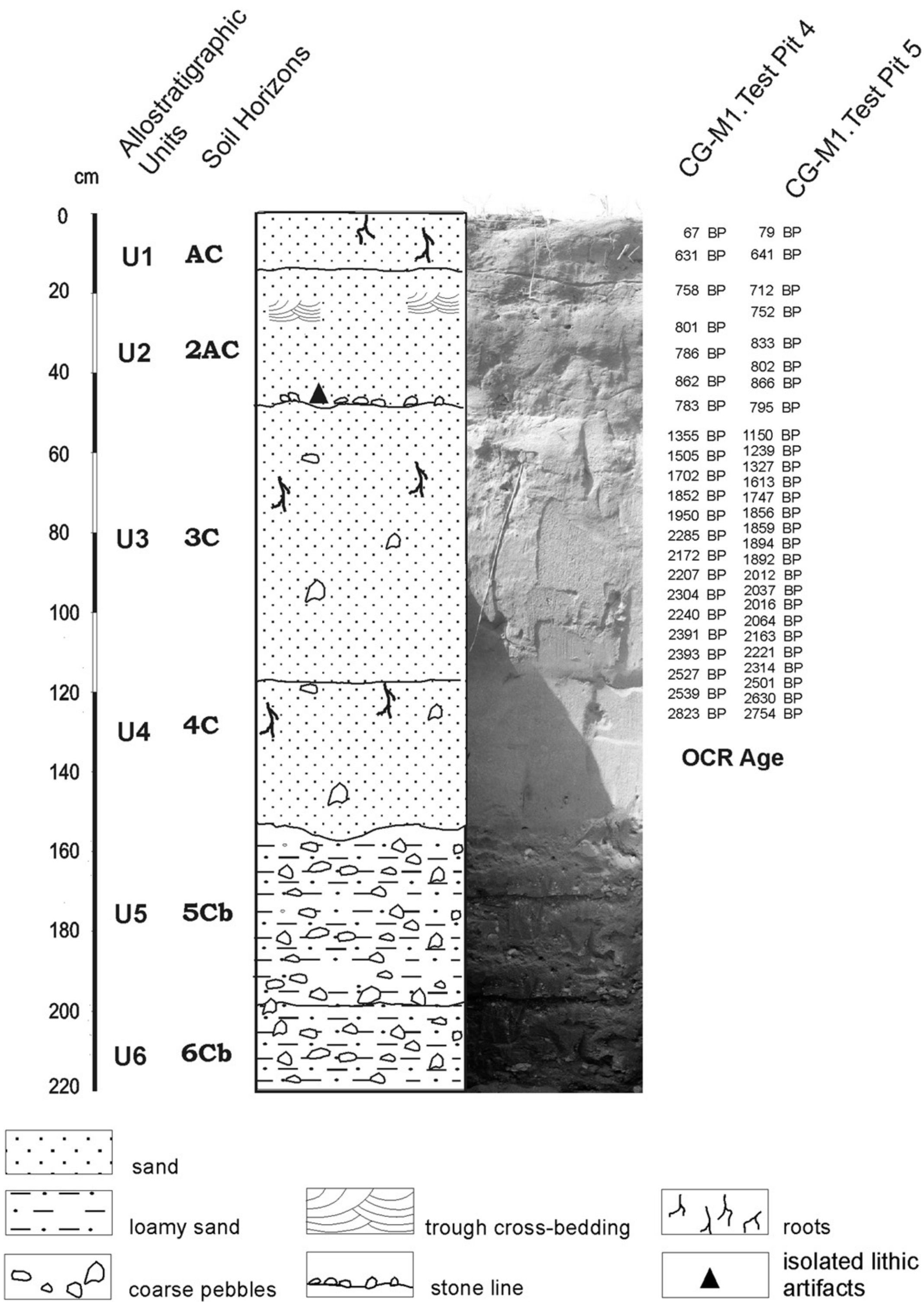

Fig. 10. El Calden-Médano Central site stratigraphic profile. The OCR ages were extrapolated from Test Pits (4 and 5) from El Caldén-Médano 1-sector Este 1 site on the basis of stratigraphic criteria (presence of "stone lines" and the base of the aeolian deposits -Units 3 C and 4 C). The distance between these two sites is ca. 280 m (see Fig. 9).

faunal remains at both surface and stratified contexts were recorded. For instance, at El Puma 3 site, from 8 test pits (1 m × 1 m), only 45 indeterminate bone fragments smaller than 2 cm were recorded.A radiocarbon date of *c.* 1800 ^{14}C BP from site 4 of the locality (Table 1) is in accordance with the chronological expectations. This latter case and the results obtained from El Caldén Archaeological Locality indicate that dynamic geomorphic processes probably had a significant impact on landforms and site preservation, particularly affecting organic materials (e.g., bones) and the resolution and integrity of sites related to the Initial Late Holocene (3000–1000 ^{14}C BP). On the contrary, in the eastern portion of the study area (*c.* 20 km from the Atlantic coast) different sorts of archaeological materials are very well preserved and archaeological components can be defined. At the La Primavera site (20 km form the Atlantic coast; Fig. 1), sealed archaeological materials (burials) and surface findings were radiometrically dated at about 3000–2800 ^{14}C BP, in the Initial Late Holocene (Martínez, 2008–2009). That is also the case of the El Tigre and San Antonio archaeological sites, but during the Final Late Holocene (*c.* 1000–400 ^{14}C BP). Thus, the Initial and Final Late Holocene archaeological deposits located at the eastern portion present higher degrees of resolution and archaeological integrity.

It is expected that the archaeological record, particularly bone assemblages, would have been affected by the above described environmental processes and dynamics. In this sense, Table 3 shows the characterization of bone assemblages presented in a west–east axis. In order to sum up the information, in this table only the prey with evidence of consumption are shown, although a major number of taxa were recovered in the sites (e.g., $n = 11$ at San Antonio 1 site; $n = 15$ at El Tigre site and $n = 3$ at the Loma Ruiz 1 site; see Martínez, 2008–2009). The only exception is the El Caldén Archaeological Locality (*c.* 3000–1500 ^{14}C BP) where no bones have been preserved. The Loma Ruiz 1 site (Fig. 1) was interpreted as base camps produced by short term occupations during *c.* 1900–1600 ^{14}C BP. Although species diversity is low ($n = 3$), bone preservation is good. When considering the four radiocarbon dates obtained from bones coming from the same archaeological component (Table 1), not all ages overlapped each other. This pattern may indicate different human occupations (multiple occupations sensu Ebert, 1992) at this site. Thus, the homogeneous vertical distribution of bones in the archaeological component may be an "artifact"created by erosional/depositional processes.

The pattern of bone assemblages recovery and preservation considerably change toward the Final Late Holocene at El Tigre and San Antonio archaeological sites. Besides these sites have the higher number of bone specimens and taxa (Table 3) they also present the higher resolution and integrity of the area. Bone preservation is very good when considering that fragile specimens of fish have successfully been recovered (Table 3; see Martínez et al., 2009b,c). Although these results can be biased by factors such as site functionality, local availability of resources, and they are also dependant of the intensity of faunal exploitation, the general trend indicates that those sites located at the west portion of the study area possess lower degrees of bone preservation, resolution and archaeological integrity, particularly during the Initial Late Holocene. Moreover, the slightly alkaline pH values recorded for all sites of the area (Table 2) are in tune with the good bone preservation (Hedges and Millard, 1995; Gutiérrez, 1998; Stiner et al., 2001), supporting the idea that when the bones do not survive (e.g., El Calden and El Puma Archaeological Localities) it is due to mechanical forces such as physical weathering and erosion. These preliminary results support the assessment that a pattern of differential bone preservation within particular environments can be recognized in the studied area. Taking this into consideration, different taphonomic modes (sensu Behrensmeyer and Hook, 1992) can be proposed for the western and eastern portions of the studied area.

Geoarchaeological studies carried out at the study area also shed light on the availability of specific settings for being settled and the chronology of their human occupation. That is the case of the coastal areas such as the San Antonio Archaeological Locality. The already presented stratigraphic scheme offers a dynamic scenario where marine, fluvial and aeolian processes took place. According to Weiler (1983), marine regression would have been occurring at *c.* 3000–2500 ^{14}C BP. In San Antonio 2 (Test Pit 4), basal units (U10 and U11) contain well preserved bivalves and gastropods including *Heleobia australis*, *Tagelus plebeius* (in "life position") and reworked specimens of *Adelomedon* sp. (Fig. 5). *Heleobia australis*, whose ecological requirements are brackish environments (myxohaline to poly-euhaline) and inhabit the high tide level of estuarine areas, would indicate an intertidal and subtidal zone, near the mouth of an ancient estuary or coastal lagoons. *Heleobia australis* shells were dated at 1833 ± 46 ^{14}C BP (δ^{13}C + 1.7; AA - 88422) indicating that the above mentioned environments could have been established in this part of the landscape (see Fig. 4) at around this chronology. Reservoir effect would have not affected the radiocarbon age very much. In Northern Río Negro Province (see Fig. 1), at San Matías Gulf, on the basis of marine shells, Favier Dubois (2009) calculated a reservoir effect with a mean value of 266 ± 51 years. Unlike these bivalves (*Mytilus edulis* and *Aulacomya ater*) that live attached to marine rocky substrates, *Heleobia australis* inhabit estuaries where atmosphere-ocean ^{14}C imbalance is either minor or nil (Fontana, 2007; Carbonari personal communication, 2010).

The overlying units of this profile (8–5; Fig. 5) belong to an active fluvial setting. The top of the sequence is characterized by aeolian sediments that contain the archaeological material. These upper units have been consistently dated at *c.* 1000–800 ^{14}C BP (see Table 1 and Figs. 5 and 6) which are in accordance with the chronological data obtained from the underlying marine deposits. These results suggest that these portions of the landscape would have been stabilized and converted into a more favorable setting for human occupation at the Final Late Holocene. The chronology obtained from the archaeological bones provides an indirect temporal marker for the formation of the aeolian mantles recorded at the top of the sequence.

Regarding the paleoclimatic scenario some trends can be drawn from this study. The study of dune stratigraphy allows recognition of periods of stability and aggradation of landscape. The most outstanding trait of landscape stability is the presence of buried soils horizons (e.g., El Tigre site and San Antonio Archaeological Locality) that led to the proposed processes of pedogenesis by *c.* 1000–400 ^{14}C BP. A regional process of erosion or landscape reactivation buried these soils at the very end of the Final Late Holocene (probably post 400 BP) as indicated by a modern aeolian event in the recorded sequences of the area. The presence of a temporal gap of *c.* 1300–800 cal BP at Caldén Guazú Archaeological Locality (indicated by a "stone line") and at El Tigre site may reflect another regional erosion process or landscape reactivation during the Late Holocene.

The faunal record can also be used as an independent line of evidence for paleoclimatic reconstructions. In this sense, toads (*Ceratophrys* sp.) and rodents (*Holochilus brasiliensis*) of northern latitudes (Brazilian, Chaco and Pampean regions) are also recorded at archaeological sites during the Final Late Holocene (*c.* 900–500 ^{14}C BP). Warm and wet regimes were inferred from these data (Stoessel et al., 2008; see also Prates, 2008).

These preliminary paleoenvironmental data are still insufficient for discussing the effects of the MCA (Medieval Climatic Anomaly) and the LIA (Little Ice Age). Due to the fact that these climatic events are regionally and climatically variable at different spatial scales

(Soon et al., 2003; Agosta et al., 2005) and the ecotonal nature of the study area (Páez et al., 2001; Quattrocchio et al., 2008) which tends to buffered the effects of these climate changes, it is still premature to propose any correlations with them.

7. Conclusions

The information previously discussed indicated that in spite of a modern and very dynamic landscape related to the mouth of the river, its ancient delta, and the abundant aeolian mantles which overlie fluvial sediments, the temporal resolution and archaeological integrity of sites located in the eastern portion of the study area is significantly higher during the Late Holocene. Data indicates that places in landscape as the current coastal fringe may have stabilized from hunter-gatherers settling at the Final Late Holocene.

Human occupation in the area is not older than 3000 ^{14}C BP, there are important gaps during the Initial Late Holocene (Fig. 3) and an increase in the intensity of hunter-gatherer occupation toward the Final Late Holocene is recorded (see discussion in Martínez, 2008–2009). It is well known that higher demography and a more intense hunter-gatherer occupation took place in several areas of the Pampa, Patagonia and the transitional area among these regions, during the latter period (Berón, 2004; Barrientos and Pérez, 2004; Politis, 2008; Prates, 2008; Martínez, 2008–2009; Favier Dubois et al., 2009; among others). Nevertheless, at least in some of these regions, and under specific climatic trends (e.g., aridity), it should be considered that the archaeological record earlier than the Late Holocene can be masked, biased, or lost due to a more intense geomorphic activity. Similar conclusions were reached by Luchsinger (2006) for the middle valley of the Negro river. As well, this kind of explanation was proposed for other arid-semi-arid environments of the world (see Meltzer, 1999; Veth, 2005; Hiscock, 2008; Holdaway et al., 2008; Smith and Ross, 2008; Fanning et al., 2009; among others). In this sense, patterns of landforms and site preservation play a key role in the interpretation of the intensity of human occupation and related social processes. The geomorphological scenario previously proposed explains the lack of parts of the archaeological record in the study area for the Late Pleistocene and Early and Middle Holocene. This pattern contrasts with the chronological trends of the human occupations recorded at some of the neighboring regions mentioned above (e.g., Pampa and Patagonia) suggesting that site destruction may have played a stronger role in the study area. The fact that the entire archaeological record was registered in aeolian dune deposits and that these landforms are prone to destruction in some parts of the landscape, may preclude the finding of sites earlier than the Late Holocene. Nevertheless, more intensive surveys in different landforms of the area (e.g., old geomorphic structures and fluvial settings) are still needed.

A stronger hunter-gatherer archaeological signature and locally developed arid-semi-arid riverine adaptations are proposed for the Final Late Holocene (Martínez, 2008–2009). These hunter-gatherer organizations temporally coincide with the proposed chronology for the MCA and LIA, but if eventually these climatic events took place they were not so severe that they have affected human populations.

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