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Fire structures in the Buenos Aires coastline (Bahía San Blas, provincia de Buenos Aires, Argentina): A physical–chemical analysis interpretation

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ABSTRACT

Archaeological investigations carried out in the area of San Blas Bay revealed a great number of surface concentrations of shells, lithic artifacts and in lesser amount, ceramic remains. These places have been occupied by hunter–gatherers from the middle Holocene to recent times. In some cases, cultural materials and combustion structures have been reported in stratigraphic position. In this paper, we present the analysis of a hearth in a cup shape structure located in a sand aeolian deposit, in the La Serranita archaeological site, dated from 5300 BP, compared with another hearth from Las Olas 5 site, dated from 500 BP. The aim is to infer the activities that could be carried out in relation to the combustion structures, by physical–chemical analysis of sediments, and by identifying and quantifying the microremains. An attempt is made to determine the intensity of use of the fire structures.

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1. Introduction

The archaeological investigations in the area of Bahía San Blas, a coastal sector of northern Patagonian (Fig. 1), consider the dynamic use of coastal landscape by human societies, taking into account the characteristic distribution of cultural remains in the coastal area, changes in their strategies use of resources and raw materials, as well as aspects of technology and possible relationships to inland territories. The cultural material evidence of human occupation in the area has been registered since 5500 BP. These remains consist of concentration areas of shell middens, lithic artifacts, and faunal bones of varying size, which apparently have a low stratigraphic or chronological definition. They were generated by hunter–gatherers during the middle and late Holocene, and were interpreted as part of a settlement system that included the inner neighboring plains and probably broader areas to the Andes mountains (Eugenio et al. 1997; Sanguinetti de Bórmida 1999; Eugenio and Aldazabal, 2004; Favier Dubois et al., 2009; López et al., 2009).

In this paper, the aim is to infer the activities that could be carried out in relation to the combustion structures, by physical–chemical analysis of the sediments and by identifying and quantifying the macro- and microremains.

2. Regional setting

The study area comprises a coastal sector of the Atlantic littoral from 40° to 42° S. characterized by extensive beaches, and a low marine pebble terrace covered by sand dunes (Fig. 2). Vegetation is scarce and typically xerophytic, corresponding to the Caldén district, Espinal province, but there are also flora communities of the Monte province, with shrub species such as Jarilla (*Larrea divaricata*), Incienso (*Schinus polygama*) and Piquillín (*Condalia microphylla*), trees such as Caldén (*Prosopis alpataco*), with good calorific wood, and edible fruit species including chañar (*Geoffroea decorticans*) (Hauman, 1947).

Faunal species are characteristic of the Patagonia district (Cabrera and Yepes, 1960), with guanaco, small rodents, as well as marine mammals, especially sea lions, a variety of fish, invertebrates, and bivalves widely distributed, animals that are also represented within the archaeological record. The combination of diverse ecological environments in an area of reduced dimensions favoured the concentration of resources.

The weather is currently dry despite the proximity to the sea. From October to February, the prevailing winds are SE and NE and in the summer months the predominant wind is from NW. The average annual temperature is 15 °C, 1.6 °C in winter and 19.2 °C in summer. Rains are rare, and even in winter, they are drizzles, with an annual average rainfall of 300 mm. Studies directly to the north of the study area suggest that climatic conditions in the late

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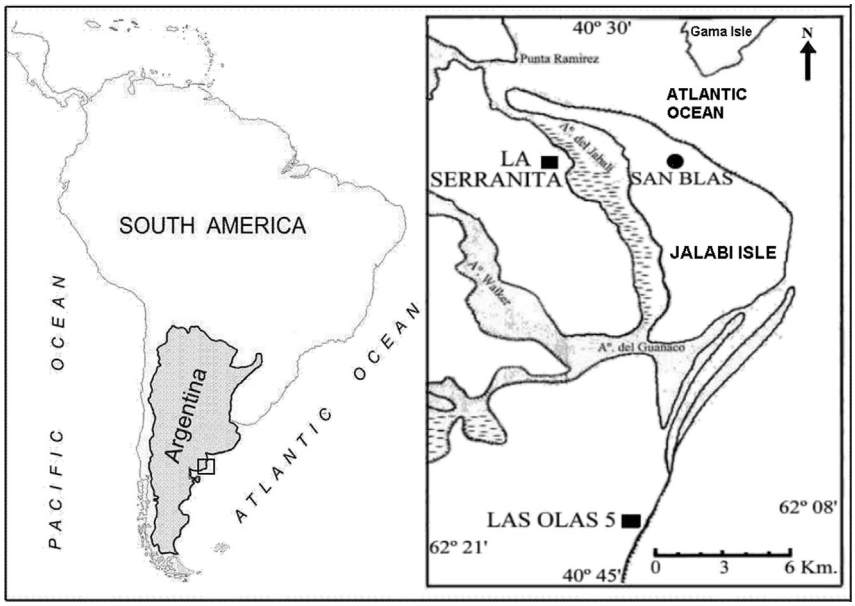

Fig. 1. Location of study area.

Fig. 2. La Serranita, general view of the study area.

Holocene would have been similar, with semiarid characteristics (Schäbitz, 1994).

3. Archaeological remains

Archaeological remains present a scattered horizontal distribution with higher density points separated by distances from 50 to 1000 m. These points of higher concentration are mostly located near the present coastline in deflation hollows or at the base of the dune. They comprise concentrations of shells, with bones and lithic flakes and artifacts. Some of these shell middens, of discrete extent (1–2 m maximum diameter) are 5–20 cm deep, and have cultural material in stratigraphic position. A summary of these results can be seen in Eugenio and Aldazabal (2004).

The research also shows shell middens and combustion areas, which sometimes are close to each other but independent. In other cases, the combustion areas are inside the shell middens. These features could be analyzed in more detail and resolution. We consider that a hearth is bounded in space and time, and related with a specific activity (Las Olas11 site, Aldazabal et al., 2011a, El Lobito site, Aldazabal et al., 2011b). In this paper, we present the analysis of two hearths, one from La Serranita sector 2 A, and the other from Las Olas 5 sector 1 archeological sites.

4. La Serranita sector 2 A

The archaeological site La Serranita sector 2 A is located between two strings of active dunes to the northwest and southeast, in a deflation hollow 24 m (E–O) by 40 m (N–S). Four sectors of

10 × 10 m were delimited in order to carry out a control survey and the collection of surface archaeological material (Figs. 2 and 3). On the NW of this delimited sector, a shell midden 1 m deep was recorded, covering an area of 6 × 2 m, in which a pit survey of 60 × 60 cm side and 100 cm deep was performed where the fire structure was found (Figs. 3 and 4).

The archaeological materials were recovered in the four sectors from the area of surface collection (Fig. 4). The cultural remains include projectile points, preforms, scrapers, bifaces, flakes and debris, predominantly manufactured in chert and basalt. We have also recovered some fragments of grinding implements, and faunal remains such as: vertebrae of fish, shells of *Brachidontes rodriguezi* (common mussel) and to a lesser extent of *Mytilus* sp. (mussel), bones of sea lion (*Otaria* sp.), a femur of guanaco (*Lama guanicoe*) and ñandu eggshell (Rhea sp.) fragments. Many of these egg fragments show traces of fire exposure, and others were decorated with crossed, striped and angled lines, similar to those described in the Puma site (Martínez et al., 2012) and by Fiore and Botella (2010), in a similar context. In the shell midden, only bivalves were collected.

The hearth under study consists of a cup-shaped structure, thermally modified, 25 cm deep and 45 cm diameter. It was found at 47 cm depth. We define it as a fire structure, following Leroi-Gourhan (1979), because it consists of a concentration of combustion residues in a restricted area with a surface modified by heat. The containing sediment at the bottom was more compacted and brown–red, 7 cm thick.

The profile observed in the excavation of the hearth comprises:

0–10 cm: sand with scarce presence of common mussel, *B. rodriguezi*
10–45 cm: sand with mussels and isolated coals.
45–50 cm: the fire structure starts to be defined, ending at 74 cm.
74–95 cm: sand with some isolated natural pebbles no larger than 2 cm diameter.

The hearth contains shells, ashes, charcoal and no faunal remains were recovered.

The total account of the extracted sediment (1520 g), comprises 1190 g of shells of *Brachidontes* sp, 10 fragments of *Mytilus* sp, and 6 fragments of *Ostrea* sp. Some small pebbles, less than 1 cm diameter (*n*:20) and numerous fragments of charcoal were collected. Two ^{14}C dates were obtained from shell samples at the top and bottom of the hearth as well as one on charcoal (Table 1).

Table 1
^{14}C dating from La Serranita sector 2 A archeological site.

5.300 ± 60	LP-1138 charcoal	La Serranita, sector 2, sitio A,
5.310 ± 70	LP-1155 marine shell	La Serranita, sector 2, sitio A,
5.320 ± 60	LP-1154 marine shell	La Serranita, sector 2, sitio A,

5. Las Olas 5 sector 1 archeological site

This site is also located on the shore. The concentration of cultural remains is located on the base and slope of a small and partially vegetated dune. A date of 570 ± 40 BP (LP-1158) was obtained from a marine shell sample.

The cultural remains were registered only on the surface, and no excavation was made. Surface cultural materials comprise: skeletal remains of fish, large and small sea lion, burned bones, and furry epidermal plates, and few remains of marine bivalves, stone artifacts, and pottery. On the slope of the dune and next to the base, erosion exposed part of a hearth. A pit profile was made in the combustion area where a top level of 80 cm thick of sand was observed (sample SP3) above the hearth, overlying the combustion layer, 10–15 cm thick with coal and burned bones (sample SP4), and the bottom layer, 15 cm thick, of sand with isolated coals and lithic artifacts (sample SP5). This layer rests on the pebble terrace (Figs. 5 and 6).

6. Some background studies on hearths

One of the earliest studies on fire structures was conducted by Cruxent (1962), who used phosphate analysis to determine whether certain hearths were the result of human activity or natural fires. Archaeological fire structures have been studied in various aspects (Garcia and Zárate, 1999: 113–114). These authors analyzed, in particular, the relationship between the durability of

Fig. 3. La Serranita view of the hearth.

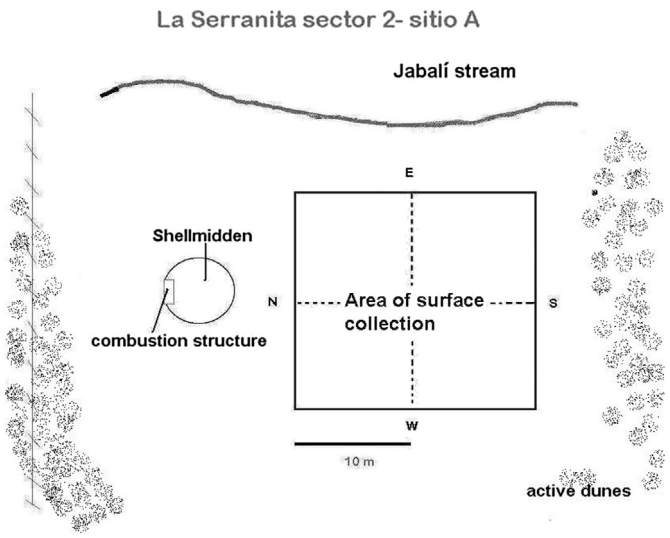

Fig. 4. La Serranita map of the archaeological site.

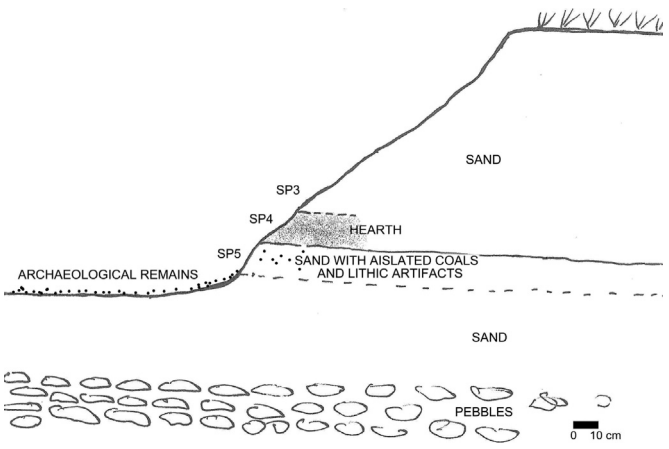

Fig. 6. Profile of the hearth of Las Olas 5 sector 1 site.

the structural features of a combustion area and the location conditions, through experimental studies in the foothills of Mendoza. They conclude that the best indicator of the existence of the hearth would be thermal modification of the substrate, observing a very low probability of finding coal and ash concentrations associated with it, due to the low degree of preservation. They note that the preservation of the structure, and the original organization conditions, in open environments, with low repair, with sparse vegetation and in moderate to very steep slopes even if a very short time has passed (three years), is ephemeral. In reference to the function of fire structure hearths, March (1995) has been a pioneer in their study in archaeological sites of Tierra del Fuego, applying physicochemical methods and mathematical models, in order to recognize organic residues and determine forms of use of fire, burnt resources, and cooking methods (Joly and March 2003; March and Wunsch, 2003, among others).

Another perspective was applied at the cave site "Cerro Tres Tetas", considering the stratigraphic position, spatial distribution, radiocarbon dating and the associated faunal remains and lithic sets, which allowed Paunero (2009) to interpret the four hearths recorded as not synchronous, the product of several occupations. The principal activity performed in them was not consumption but alternative activities, considered complementary, including techniques of heat treatment of minerals and probably bones, and secondly skins drying or heating wood to bend and form it in artefacts (Alvarez et al., 2000:289).

From these same structures, Frankl (2012) evaluated the strategies of intrasite use of the space, combining its location, morphology and size. Variations in size could be linked to changes in the intensity of occupation. In addition, the abundance of heated places located close one to another or even in an overlapping way, was interpreted as evidence of a succession of occupations in the cave as well as a redundancy in the choice of the places used to light fires.

South of the study area, on the coast of the Golfo San Matías, Rio Negro province, Marconetto (1998) focused her study on charcoal

Fig. 5. General view of the hearth of Las Olas 5 sector 1 site.

recovered in shell middens contexts dating from 3000 to 1000 BP, identifying plant species exploited by human groups and the way they were gathered (Ortega and Marconetto, 2011). Different taxa are present at the sites, indicating that it is important to consider the bias resulting from the differential combustion rates of the species, its particular conservation characteristics and the depositional context (Marconetto, 1998).

Our perspective assumes that the study of sediments of hearth and combustion structures, applying physical and chemical analysis and incorporating information of the microremains accompanying the matrix sediment, allowed us to differentiate between natural and anthropogenic deposits. Using this analysis, we assess the intensity of use of the space, and in the specific case of the combustion structures obtain evidence on use and function.

7. Analytical methods

From La Serranita sector 2 sitio A, samples of the sandy upper level (SP1) and from the combustion layer (SP2) were taken. From the combustion area, of Las Olas 5 sector 1 site, three samples were taken: from the sandy upper sediment (SP3), combustion layer (SP4) and bottom sandy matrix (SP5).

The samples were sieved with 2 mm sieve aperture (mesh 10). The analytical methods applied were: texture made by pipette analysis and textural classification, following the criteria of the U. S. Department of Agriculture (U.S.D.A).

The pH was determined using a 1:2.5 soil–water ratio and the measurement was performed with a handheld pH meter, Hanna brand. The calcium carbonate content was estimated by etching with hydrochloric acid and a semiquantitative determination, and was made by comparing patterns of calcium carbonate. The assessment of the organic matter was performed by oxidation with potassium dichromate and colorimetric determination based on pattern matching (Jackson, 1958).

In the determination of available phosphorus, 0.75 N HCl was used. The determination of phosphorus was conducted using the colorimetric method of vanadomolybdophosphoric yellow complex system acidified with sulfuric acid. Soil-extracting ratio employed was 1:10 and the stirring time was 2 min.

Potassium, nitric nitrogen and ammonia nitrogen, extracted by Morgan's solution (sodium acetate 0.73 N in acetic acid 0.52 N), soil-extracting ratio was 1:10 and the stirring time a minute. Potassium determination was turbidimetric using sodium cobalt nitrite, nitric nitrogen by diphenylamine, and ammonium nitrogen by Nessler's reagent (Jackson, 1958; Alexéiev, 1975). Analytical results are expressed as percentages for organic matter (OM) and phosphorus (P), potassium (K), nitrate (Ni) and ammonia nitrogen (Am) in parts per million (ppm).

We analyzed the organic and inorganic debris recovered by sieving of sediment samples. We consider as macroremains all the debris retained on the 2 mm sieve mesh, and as microremains all those retained on the 1 mm sieve mesh and poured through it. Macro ($\geq$2 mm) and microremains ($\leq$1 mm) study was performed in each case from a sample of 5 g of sieved sediment from all the layers of the profiles analyzed, observing remains retained by 2 mm mesh and 1 mm waste sieving. Each fraction was analyzed and the account of remains or fragments was counted under a binocular microscope of 5× and 45×, recording the presence and abundance of charcoal, shell, bone fragments, sherds, debitage, and roots.

8. Results

The results were tabulated. Table 2 shows the results of the textural determination and Table 3 the results of the chemical analysis. Figs. 7–9 illustrate the values of organic matter, phosphorus and potassium comparatively between samples and from both archeological sites. The macro and microremains analysis are shown in Tables 4–6.

Table 2
Texture.

Sample	% Sand	% Silt	% Clay	Texture
SP1 La Serranita Sector 2 Sitio A. Shell midden, superficial sand	90	7	3	Sand
SP2 La Serranita Sector 2 Sitio A. Hearth	85	10	5	Loamy-sand
SP3 Olas 5 Sector 1 superficial sand	95	4	1	Sand
SP4 Olas 5 Sector 1. Hearth	73	18	9	Sandy-loam
SP5 Olas 5 Sector 1. Hearth bottom	85	10	5	Loamy-sand

Table 3
Chemical analysis.

Sample	pH	Ca CO_3 %	OM %	C %	P ppm	K ppm	N (ppm) Ni	Am
SP1 La Serranita Sector 2 Sitio A. Shell midden, superficial sand	8.5	2.1–8.5	0.285	0.165	130	120	10	5
SP2 La Serranita Sector 2 Sitio A. Hearth	8.5	4.2–17	1.43	0.83	250	500	10	12
SP3 Olas 5 Sector 1 superficial sand	7.5	0.8–3.4	0.34	0.20	200	120	0	0
SP4 Olas 5 Sector 1. Hearth	8.5	0.8–3.4	4.55	2.64	1400	600	10	12
SP5 Olas 5 Sector 1. Hearth bottom	9.1	0.8–3.4	0.86	0.50	560	400	5	5

Table 4
Microremains. Sample less than 1 mm.

Sample < 1 mm	Charcoal *n*	Bone fragments *n*	Shell fragments *n*	Lithics *n*
SP1 La Serranita Sector 2 Sitio A. Shell midden, superficial sand	<10	0	<10	0
SP2 La Serranita Sector 2 Sitio A. Hearth	>20 < 50	0	>10 < 20	0
SP3 Olas 5 Sector 1 superficial sand	0	0	<10	0
SP4 Olas 5 Sector 1. Hearth	>50 < 100	>50 < 100	<10	0
SP5 Olas 5 Sector 1. Hearth bottom	>10 < 50	>10 < 20	<10	0

Table 5
Microremains. 1 mm sieve retained.

1 mm Sieve sample retained	Charcoal	Bone fragment	Shell fragment	Líthic
SP1 La Serranita Sector 2 Sitio A. Shell midden, superficial sand	1	0	1	0
SP2 La Serranita Sector 2 Sitio A. Hearth	2	0	2	0
SP3 Olas 5 Sector 1 superficial sand	0	0	0	0
SP4 Olas 5 Sector 1. Hearth	3	2	1	1
SP5 Olas 5 Sector 1. Hearth bottom	2	2	1	1

0: absence; 1: scarce; 2: abundant; 3: very abundant.

Table 6
Macroremains. 2 mm sieve retained.

2 mm Sieve sample retained	Charcoal	Bone fragments	Shell fragments	Líthic
SP1 La Serranita Sector 2 Sitio A. Shell midden, superficial sand	1	0	1	0
SP2 La Serranita Sector 2 Sitio A. Hearth	3	0	2	0
SP3 Olas 5 Sector 1 superficial sand	0	0	0	0
SP4 Olas 5 Sector 1. Hearth	3	3	1	1
SP5 Olas 5 Sector 1. Hearth bottom	2	3	1	1

0: absence; 1: scarce; 2: abundant; 3: very abundant.

The matrix texture of the two analyzed hearths is sandy to sandy loam. In both cases, combustion levels contain more silt. The texture is sandy in the overlying samples from both hearths. Samples from the combustion layers have a higher content of fine particles of silt fraction resulting in a loamy–sandy texture in the hearth of Serranita 2A and sandy loam to loamy-sand in the hearth of Las Olas 5.1. No significant differences were recorded in the percentages of each fraction that may influence the determinations of chemical compounds (Table 2).

The pH is basic in almost all the processed samples (base saturation) and in one case saline–alkaline (pH 9, 1), with soluble salts. The organic matter (OM) is high in the hearth of Serranita 2A but much higher in Las Olas 5.1 (Table 3, Fig. 7). The enrichment in the content of OM would be explained by the use of plant fuel, and the processed samples contained traces of charcoal. Surface sand samples from both sites contain organic matter in percentages similar to those obtained from the soils of the area (INTA, 1989, Domain 27b).

Samples of hearth levels present high P values, as the combustion processes released compounds of this element besides the incorporation of organic residues, and that the mineralized bones produce phosphates among other compounds. The same applies to K: highest values were recorded in sediments from the combustion layers, as when wood is burned, K content rises in the ground.

The content of ammonia nitrogen and nitrates do not indicate any significant differences. This may be because denitrification reaches its maximum extent in pH from 8 to 8.6, and to the volatilization of ammonia if there is temporary desiccation. The presence of microremains (Mv) of less than 1 mm size of charcoal and bone fragments is another source of enrichment in the values of P

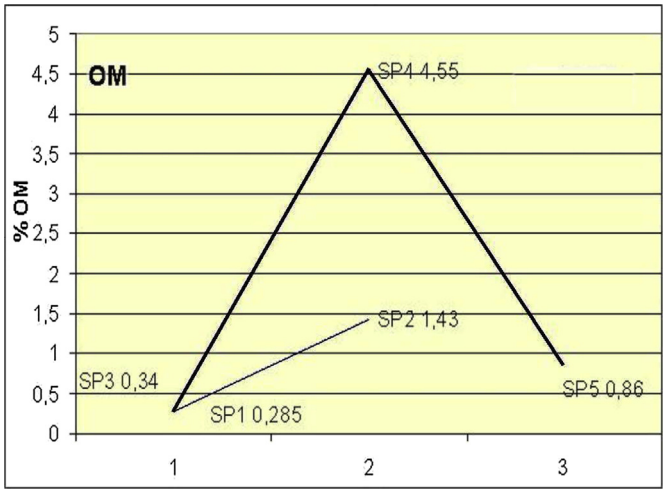

Fig. 7. Comparison of the percentage of organic matter between samples and sites.

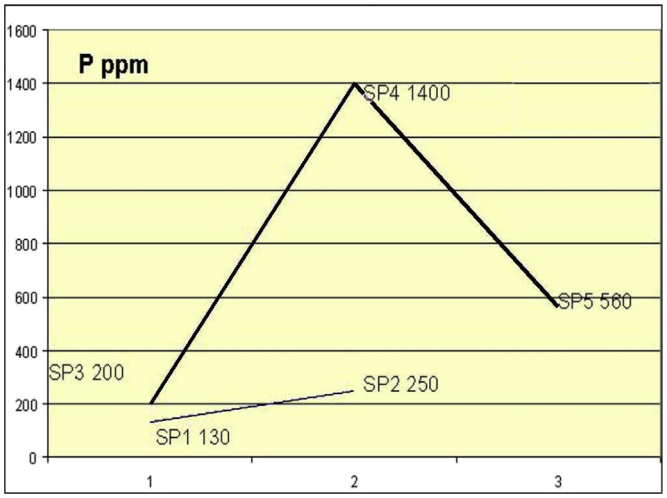

Fig. 8. Comparison of the amount (in ppm) of phosphorus (P) between samples and sites.

and K (Table 3; Figs. 7–9). The presence of carbonate is high in the samples of La Serranita 2A, compared to the samples from Las Olas site 5.1. The sediments of the first hearth, being oldest, represent a long time in a semi-arid environment.

Microremains from the different samples are presented in Tables 4–6. In both hearths, wood charcoal is abundant suggesting that the fuel used probably was wood. Bone fragments and lithic artifacts are unique to Las Olas 5.1, while shell fragments are more numerous in La Serranita (Tables 4–6 and Fig. 10).

9. Discussion

Fire areas are an important integrating features, as places around which people perform or organize tasks in a campsite of hunter–gatherers (Aldazabal et al., 2012; Frankl, 2012). In relation with its performance, the cup shape fire places usually are associated with longer combustion and with a higher temperature (Leroi-Gourhan, 1979; Marconetto, 1998; Frankl, 2012).

In the case under study, in the hearth of La Serranita 2A we recovered remains of wood charcoal and branches that have not been completely destroyed or burnt. This could indicate low temperatures or short duration of the combustion event. However, the

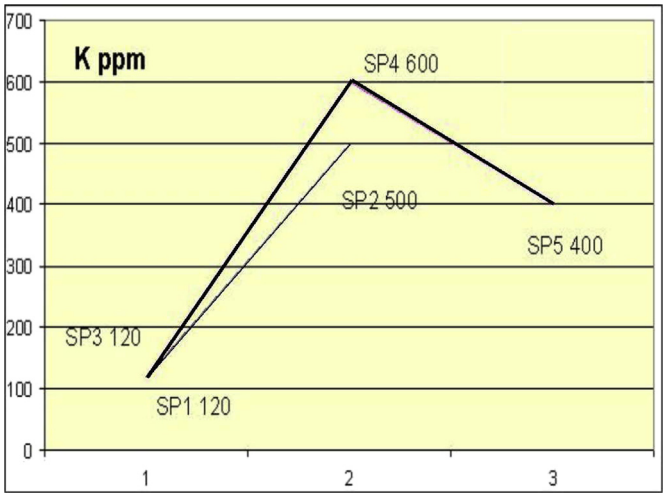

Fig. 9. Comparison of the amount (in ppm) of potassium (K) between samples and sites.

Fig. 10. Macro- and microremains. Above, right: SP2, left: SP4 2 mm retained macroremains; Below, right: SP2; left: SP4 1 mm retained microremains.

effects of the fire on the ground (hardening and discoloration) indicate that the fire had continuous and intense combustion. It could be also the case that these branches had been the last ones incorporated to a long duration hearth ended suddenly by an extraordinary event such as rain. Regarding the possible reuse, the radiocarbon dates indicate a minimum variation range between the two shell samples obtained at different levels, and between them and the coal sample. These values suggest a single combustion event or events of limited time within a short occupation. Another option could be that the hearth was cleaned after each use, so the evidence recorded is only the last, but the thermal alteration suggests more than one use or reuse.

The combustion structures analyzed, located in a semi-arid environment with scarce vegetation present, do not show the expected behaviour about integrity and visibility proposed by García and Zarate (2009) for these open spaces and with any erosion. Considering possible resources for fuel, they are not critical in the area: there is a high availability in both environments of the following species: Jarilla *(L. divaricata)*, Piquillín *(C. microphylla)*, Alpataco *(P. alpataco)* and chañar (*G. decorticans*).

The recovered remains within the hearth of La Serranita 2A, as well as the context, allow us to interpret it as used to processing food resources for consumption as the main function. The species recovered, identified as *Mytilus* sp, *B. rodriguezi* and *Perumytilus purpuratus*, suggest that human groups that used this hearth had to move in different directions to obtain them: the sea coast, the river bank, and into the stream, as they are specific to different ecological needs. *Mytilus* sp is a very plastic species which can live from the sandy intertidal to deep water exceeding 100 m. *B. rodriguezi* exclusively inhabits rocky intertidal muddy areas (Adami et al., 2004). The identification of some shells of *P. purpuratus*, characteristic of a slightly colder environment (J. Orensanz, personal communication 2013) is interesting because it is now extinct in the area.

The analyses made on the sediments allow us to make some inferences from the results and their behaviour in relation to the activities of hunter–gatherers in the region. The two fire structures contain fuel of vegetable origin. However, they differ in the chemical elements values and in the microremain contents.

La Serranita 2 A recorded higher content of carbonate, which could be explained by several factors. As the oldest, we could expect that sediments in a semiarid environment would contain higher concentrations of calcium carbonate by precipitation. However, the microremains consist mostly of shell fragments. Bivalve processing may have been the cause of a high content of carbonates in the sediment. Values based on the amount of charcoal remains, OM, K, and P are lower than in the hearth of Las Olas 5.1. In the case of Las Olas 5.1, the concentration of the chemical elements is higher, as well as the account and diversity of the microremains: charcoal, bones, and lithic debitage, with almost no traces of shells, are recorded.

The results can be interpreted as the products of different activities. In the first case, it is possible that La Serranita 2 A has been used primarily for processing bivalves. In contrast, the fire structure of Las Olas 5.1 may have been used for processing sea mammals and even for heat treatment of lithic raw materials. In conclusion, we propose that the fire structure of La Serranita A 2 have been used to heat and open bivalves for eventual consumption, while other activities were performed, including gathering, fishing pinnipeds, or manufacturing lithic artifacts, assumptions to be tested in future research.

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