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Taphonomic and archaeological perspectives from northern Tierra del Fuego, Argentina

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ABSTRACT

This paper focuses on Late Holocene coastal occupations of hunter–gatherers that inhabited the northern steppes of Grande Island of Tierra del Fuego. Available archaeological data produced by our previous research in the Argentine portion of the island located north of San Sebastian Cape is discussed from a regional taphonomy perspective. Our approach is based on the characterization of the main taphonomic modes recognized in the region. Preservational and other patterns for bones and lithics are presented and discussed. Based on the comparative study of isotaphonomic assemblages, general trends in human coastal occupations are discussed.

1. Introduction

Grande Island (52° 27′ – 55° 05′ S) is the largest in the Fuegian archipelago, in the southernmost border of South America. This island was connected to the continent by a land bridge until 8000 BP, when the sea level rose and definitively flooded the bridge forming the Magellan Strait (McCulloch et al., 1997, 2005). The peopling of the island took place before that event, as the earliest human record was dated *ca.* 10,500 BP and corresponds to terrestrial hunter–gatherers with a diet centered on guanaco (*Lama guanicoe*) (Massone, 1987, 2004, 2009; Massone et al., 1993; Massone and Prieto, 2004). The record of human presence in the northern steppes is discontinuous and no archaeological evidence pertaining to the early Holocene was found. The presence of hunter–gatherers was recorded during the middle Holocene, and that was the dominant way of life until historic times (Gusinde, [1937] 1982; Chapman, 1986). A maritime way of life is minimally represented on the western coasts of the island. Ocampo and Rivas (1996) refer to the presence of probable maritime hunter-gatherers to the south of Puerto Arturo, while Constantinescu (1999) found human skeletal remains attributable to 'canoe people'. Moreover, the archaeological signal for maritime hunter–gatherers at Dawson Island is unquestionable (Legoupil et al., 2011).

This paper focuses on the Late Holocene archaeological record of the northern Atlantic coast of Grande Island of Tierra del Fuego. We apply a regional taphonomy perspective (Borrero, 2001, 2014) to assess the role of natural and cultural formation processes in the configuration of the patterns observed in the coastal record at the regional level. Within this general framework, artifacts were analyzed from a lithic taphonomy perspective (Hiscock, 1985; Borrazzo, 2006, 2010; Thiébaut et al., 2010; Eren et al., 2011). Several taphonomic modes (sensu Behrensmeyer and Hook, 1992) are defined for both bone and lithic remains. Finally, we discuss the main patterns of human coastal occupations detected in the study region.

2. Regional setting

The study region is the northeastern part of Grande Island, extending north to south from Espiritu Santo Cape to San Sebastián Cape, and reaches the international border to the west (Fig. 1). The area is covered by grassland vegetation characteristic of the Magellanic steppe (Collantes et al., 1999).

The geomorphological evolution of the coastal landscape is heterogeneous within the study region. The northern portion of the coast -between Espíritu Santo and Nombre Capes-presents steep to vertical cliffs up to 90 m high (Codignotto and Malumián, 1981; Bujalesky, 1998, 2007) while the southern sector, San Sebastian Bay, is characterized by low plains with minor altitudinal variations (Fig. 1). In addition, while the former

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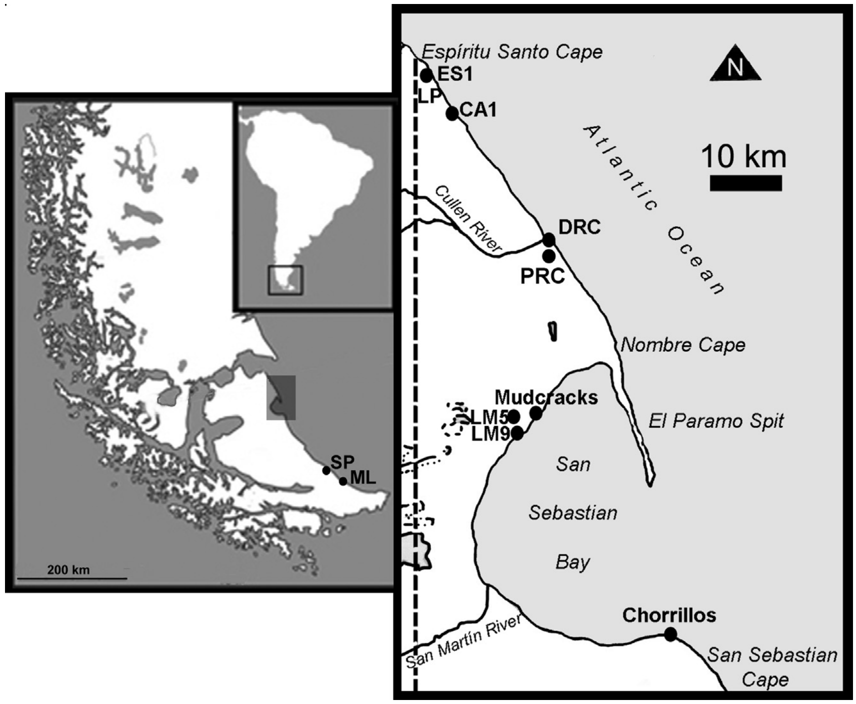

Fig. 1. Map of the study region with the archaeological loci and localities discussed in the text. References: SP = San Pablo; ML=María Luisa; ES1 = Espíritu Santo 1; LP = Laguna Patria; CA1 = Cañadón Alfa 1; DRC = Desembocadura Río Cullen; PRC = Planicie Río Cullen; LM5 and 9 = Las Mandíbulas 1 and 9; Chorrillos = archaeological locality composed of loci San Genaro1, 2, 3–4, 5 and 8.

has been eroding, the latter has prograded seawards since the Mid-Holocene (~5000 BP, Vilas et al., 1986–1987, 1987, 1999; Isla et al., 1991; Bujalesky, 1998). These contrasting processes, northern recession and southern aggradation, have important implications for the study of archaeological patterns, especially those of coastal sites. In the north, the maritime erosion of the shoreline cliffs destroys sites (Horwitz, 2004) and/or reduces their distance to the shoreline, their current location being only a minimum value for their distance to the sea at the time that the sites were occupied. In the south, in San Sebastian Bay, the geological chronology of the region suggests that most of the settings of the archaeological localities studied here became available for human occupation after 3000 BP (Codignotto, 1990; Ferrero, 1996; Vilas et al., 1999). Furthermore, the persistence of progradation in San Sebastian implies that current distance of any location to the shoreline represents a maximum value for its actual distance during human occupations. Therefore, our general expectation for the study region is that all of the archaeological loci on the coast and/or adjacent areas (less than 1 km from the shoreline, following Borrero and Lanata, 1988) exhibiting remains of maritime resources (shell middens, sea mammal and fish bones) are the result of late Holocene occupations. On the northern coast, this trend results from the balance between general home range radii reported for ethnographic hunter–gatherers, and site destruction rate derived from cliff recession. Nevertheless, this expectation requires radiocarbon control. Available radiocarbon dates for coastal loci in the entire region support this expectation (Salemme et al., 2007; Borrero et al., 2008). Thus, what we learn about hunter–gatherer relationships with maritime resources in the region from current coastal archaeological sites will be only relevant and reliable for late Holocene times.

The coastal and inland archaeological record of the study region has a strong late Holocene signature, with only one Mid-Holocene exception (Favier Dubois and Borrero, 2005; Borrazzo et al., 2007). Most of the loci exhibit chronologies from 2000 to 1500 BP to modern times. Late Holocene sites occur in diverse environmental settings: marine cliff, rockshelters, sand and clay dunes, lagoons, and alluvial plains, among others. Large and intensely reoccupied sites are more common on marine coastal environments, while inland sites are usually smaller and ephemeral, a pattern attributed to the attraction exerted by capes for human installation (Borrero, 1985). This archaeological trend was also observed on the island's southern Atlantic coast (Vázquez et al., 2013). Nevertheless, a dense and rich archaeological signal was recorded in small interior lakes of the northern steppes, suggesting an intensive use of these inland settings (Oría, 2012; Pallo, 2012). However, the active and complex geomorphic dynamic of these environments sets taphonomic assessment as mandatory (Guichón et al., 2000; Borrazzo, 2013).

3. Materials and methods

Twenty nine sites and/or localities were recorded and surveyed within the study region (see Borrero et al., 2008; Borrazzo, 2014 and references therein). For the present research, we have selected those currently located on or near (less than 1 km) the maritime coast and/or macrotidal line ($n = 14$). We will focus on the strict coastal sites by almost any definition.

The principles of Site Catchment Analysis suggested that ~10 km is the expected foraging radius from central hubs of hunter–gatherers (Higgs and Vita-Finzi, 1972; Binford, 1982). Previous discussions of the archaeology of northern Tierra del Fuego repeatedly showed that most of the generated sites were transient, a condition that implicates much shorter foraging radii (Borrero, 1985). Erlandson (2001) suggested that hunter–gatherers rarely transport marine resources further than 5 km from the coast. Recent research by Bird et al. (2002) using both ethnoarchaeological and archaeological information showed that shellfish and other maritime resources are likely to be processed near the shore, thus it is not expected that shellfish will be moved more than a kilometer or so off the beach. Thus, we rely on loci placed near the shoreline to discuss the use of maritime resources. For northern coastal sites such as Espíritu Santo 1 (Fig. 1), we also considered the available chronology and/or the frequency of marine resources among their remains in order to test if they were actually coastal loci. The coastal character of those sites should not be assumed, but tested.

3.1. Regional taphonomy

Regional taphonomy is focused on the distribution of preservational pockets in the landscape, as well as the study of the mechanisms that accumulate and preserve archaeological materials (Borrero, 2001). Several of these pockets occurring throughout a region may share their taphonomic properties and thus represent a particular preservational context or taphonomic mode. In Behrensmeyer and Hook's (1992:15) terms, a taphonomic mode is a 'broad assessment of environmental or biogenic contexts'. Therefore, the definition of a taphonomic mode is a way of proving the prevalence of certain environmental properties in specific portions of the landscape. The identification and characterization of taphonomic modes is a valuable tool to select isotaphonomic archaeological samples, those assemblages exhibiting higher degrees of comparability. This improves the ecological, evolutionary or behavioral relevance of the differences and similarities recorded in any archaeological (technological, zooarchaeological) study. This framework aims at controlling taphonomic noise (Behrensmeyer and Hook, 1992:18) and generates expectations for any fossil record recovered from different environments. In sum, the importance of a regional taphonomy approach is that it permits a comparative assessment of the observed distributions of archaeological remains.

4. Results

4.1. Taphonomic modes for bones and lithics

Archaeological and actualistic research carried out in northern Tierra del Fuego during the last decades allowed the identification of specific preservational trends for bones (Guichón et al., 2000, 2001; Borrero, 2003, 2004, 2007; Martin et al., 2004; Martin, 2006; Borrero et al., 2008, among others) and more recently for lithic artifacts (Borrazzo, 2006, 2010, 2011, 2013) located in different environmental units. Furthermore, these studies showed that bones and lithics of both natural and archaeological origin and different ages occur as averaged mixtures throughout the region. This fact led to the thorough examination of conditions and processes involved in differential preservation, such as topographic traps (Borrero et al., 2008; Borrazzo, 2010).

Even when not developed here, the taphonomy of mollusks is also important for a full discussion of archaeological accumulations in relation with taphonomic modes. Recent research by Gordillo and Isla (2011) is relevant on this subject. Following, we will present the main properties of the environmental contexts used to define five taphonomic modes in northern Tierra del Fuego.

4.1.1. Littoral sand dunes

Archaeological sites: San Genaro 1, 2, 3–4 and 8 (Chorrillos archaeological locality) (Horwitz, 1995; Favier Dubois, 2001; Borella, 2004; Favier Dubois and Borrero, 2005; Borrazzo, 2006, 2010; Borrero et al., 2008; Figs. 1 and 2A).

Aeolian erosion is a prominent process within the study region: winds of 60 km/h blow more than 200 days per year, with gusts over 150 km/h (Isla et al., 1991; Vilas et al., 1999; Borrazzo, 2013). Wind has the capacity to remove, transport, and deposit large

Fig. 2. Environmental patches of taphonomic modes characterized in the text. (A) Deflation hollow in sand dunes of Chorrillos where the SG3-4 archaeological site is located. (B) Cliff next to Cullen River mouth near the DRC archaeological site location before it was completely washed out. (C) Northern margin of a lagoon in the muddy tidal flat with sedimentary lumps stabilized by vegetation (*Sarcocornia* sp.) growth. (D) El Páramo Spit ridges near the headlands.

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particles. The presence of vegetation reduces such aeolian effects by retaining clasts within or below it. Moreover, when sand particles are available (dried and loose) for aeolian transportation, coastal dunes offer a differential -more intense-abrasive context within the study region.

Archaeological loci corresponding to this taphonomic mode are emplaced in aeolian deflation hollows, developed within vegetated sand dune plains of Chorrillos archaeological locality. Material remains are scattered through the hollows' surfaces, some forming dense pavement-like distributions. They are also present on recently exposed profiles, suggesting the stratigraphic provenience of materials currently lying on the surface. Moreover, the advance of aeolian erosion during a decade (1995–2005) generated new deflation hollows which exposed previously unnoticed archaeological contexts (e.g. SG8). The removal of the vegetation cover as a consequence of erosion showed that continuous distribution of cultural remains without significant variations in their density existed between the neighboring loci SG3 and SG4 (Favier Dubois, 2001; Martin et al., 2004). In this case, the persistence of erosive conditions reduced grass and shrub cover of sand dunes located between both loci, improving visibility and demonstrating their continuity. This situation highlighted the absence of isomorphism between observational units (sites) and the actual spatial distribution of archaeological remains in Chorrillos, even before the discussion of significant units for hunter gatherer behavior began (Borrazzo et al., 2007). The study of bone assemblages at those loci displayed relatively advanced weathering stages on recently exposed bones, clearly indicating that successive events of exposition and burial occurred in the past (Martin et al., 2004). Also, as was observed on the coasts of the continent, coastal dunes and the accumulation of shell middens are contributing factors to the preservation of human remains (Guichón et al., 2001; Martin, 2004). Large concentrations of guanaco bones were found below the deposits that constitute SG1. These remains are dominated by heavily weathered complete guanaco elements, some found in anatomical order, deposited before ca. 1000 radiocarbon years. These bones do not display any signal of human activities and are not physically associated with archaeological remains. One property exhibited by this particular bone assemblage is that most of the long bone elements lack their epiphyseal ends (Fig. 3). This contrasts with the pattern observed by Belardi et al. (2012) in open-air sites of Southern Patagonia. We believe that the difference can be attributed to the lack of human intervention on this particular bone assemblage at SG1.

Fig. 3. Guanaco bones deposited ca. 1000 YBP before the formation of the SG1 archaeological site. Complete bones exposed sometime between the spring of 2007 and the spring of 2008 in a highly weathered condition, were dominated by diaphysis and diaphysis fragments in the summer of 2013.

Subaerial exposure time is recorded on lithic artifacts through aeolian abrasion (corrasion, *sensu* Breed et al., 1997) intensity. The local velocity of this macroscopic change in artifacts' surfaces suggests corrasion is an indicator for lithic assemblage exposure and stability assessment (sensu Borrero, 2007). In addition, frequent strong winds affect artifact size distribution and therefore technological composition of coastal assemblages located in sand dunes. Aeolian erosion removes small artifacts, such as retouch flakes produce by trimming and sharpening of stone tool edges. Hence, the absence of small components in the local lithic record cannot be assumed to be technologically informative but a taphonomic property of this mode.

Since the first archaeological survey of Chorrillos in 1992 (Horwitz, 1995), we have monitored the changes in the landscape of this locality during subsequent fieldwork. This tracing allowed us to identify new (after 1992) deflated areas and exposed materials. The comparison of surface artifact assemblages exposed at least since 1992 with those recently unearthed showed that the latter exhibited lower corrasion intensity profiles and included a higher frequency of small pieces, suggesting differences in the integrity of samples. On the contrary, some of the recently exposed loci (e.g. SG8) presented higher corrasion intensity and few to none small debris, suggesting those assemblages were unearthed repeatedly in the past or largely exposed before burial (Borrazzo, 2010). These results show that the intensity of aeolian abrasion effectively records the subaerial exposure time of lithic artifacts in coastal sand dunes. In addition, they also highlight the significant role of the moment within the record's transformation cycle when archaeological interception occurs as well as the diversity of situations involved in the formation of local archaeological assemblages.

4.1.2. Cliff

Archaeological sites: Espiritu Santo 1, Cañadón Alfa 1, Desembocadura Río Cullen (Horwitz, 1996–1998; Borella, 2004; Borrero et al., 2008; Borrazzo, 2010, Figs. 1 and 2B).

Cliffs located north of Name Cape have undergone maritime erosion since Mid-Holocene times. Archaeological contexts (surface and stratigraphic) emplaced on this landform are therefore transformed as a result of coastal regression. At least two possible trajectories (secondary contexts) were recorded for the local archaeological record. When swells erode the base of the cliff, upper deposits containing archaeological remains (cliff crest) becomes unstable and large sedimentary lumps may collapse (Bujalesky, 2007). Although this process modifies the general location of remains in the landform (originally on top, now on the beach at the base of the cliff), it preserves their spatial relationships within the sedimentary matrix while the lump persists. Furthermore, a dense vegetation cover may promote the preservation of the 'new' deposit as a whole (Waters, 1996; Morello et al., 2009). Another possible trajectory to that of episodic falls is the constant matrix lost, propitiated by the aeolian erosion, percolation, freezing, and melting action of the cliff scarp (Bujalesky, 2007). In this case, loose archaeological remains fall from the cliff scarp and form surface clusters on the beach in which previous associations are not preserved. In addition, the preservation of stratigraphic organic remains, now re-exposed to subaerial conditions, is threatened and only research programs oriented toward the early interception of such organic remains may make use of their recently lost stratigraphic properties (Martin et al., 2004). In both situations, archaeological remains that were out of the reach of the sea become available for wave action. Subsequently, depending on raw material, size, and weight, waves may move, remove, and/or alter their morphology. Desembocadura Río Cullen site (DRC, Figs. 1

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and 2C) is an example of a secondary context produced by cliff regression. Ten years after its discovery and sampling, none of the DRC materials were left because water washed out their setting located at the base of the cliff.

The joint action of cliff erosion and slope processes was also observed in sites located on valley mouths (e.g. Espíritu Santo 1 and Cañadón Alfa 1, Fig. 1). Research on talus dynamics in the study region showed that it impacts the composition of surface and stratigraphic assemblages (Favier Dubois, 1998; Martin and Borella, 1999; Martin, 2004; Borrazzo, 2009). While surface lithic assemblages exhibit a low frequency of small artifacts, they are frequent in the stratigraphic samples of the same sites. This tendency results from the effect of talus dynamics, in which larger artifacts move further (Rick, 1976; Favier Dubois, 1998) and the higher burial potential offered by small size materials. Moreover, we observed this complex process may impact technological assemblage composition. That is the case of Espíritu Santo 1, a coastal site that originally stood out from the regional technological trend because of the high frequency of end-scrapers (Horwitz, 1996–1998). Subsequent research showed that although end-scrapers were the most frequent tool in the stratigraphic sample, their representation in the site surface assemblage was null and side-scrapers, poorly represented in the stratigraphy, dominated the tool assemblage. The smaller and less variable size of end-scrapers in comparison with side-scrapers was a key factor in determining their differential success in burial (Borrazzo, 2009, 2010).

4.1.3. Lacustrine

Archaeological sites: Laguna Patria, San Genaro 2 (Chorrillos locality), Las Mandíbulas 5 and 9, and Mudracks (Guichón et al., 2000; Horwitz, 2004; Borrero et al., 2008; Borrazzo, 2010, Figs. 1 and 2C).

Westerlies play a central role in the dynamics and evolution of permanent and temporary shallow lakes in the study region (Vilas et al., 1999; Arche and Vilas, 2001; Bujalesky, 2007). The north of San Sebastian Bay is occupied by a wide muddy tidal flat (Vilas et al., 1999; marsh and mudflat sensu Bujalesky, 2007). Wind reworked clay and silt sediments forming dunes and temporary shallow lakes (lagoons) develop in deflation hollows within this area (Vilas et al., 1999; Arche and Vilas, 2001). Ponds collect surface runoff (rainfall, melt water), and usually are dry in summer. When a water body is available, wind gathers and accumulates the thin water sheet laid on flat basins to the northern/northeastern margin of the lakes. Once there, small but intense wave action erodes the base of the scarp (clay dunes) and triggers its collapse into the lagoon. This process poses similar consequences to those described for northern cliff recession: materials located on the scarp or within the eroded matrix may fall loosely or included in a lump, in either case subject to hydraulic action. If vegetation inherited from the crest survives or new plants (e.g. *Sarcocornia* sp.) successfully colonize the lump stabilizing the surface of the relocated deposit, the archaeological remain associations may be preserved. An alternative path for archaeological materials located in this environmental unit is offered by the erosion of dune surfaces by rain and meltwater. Surface runoff erodes the dune surface, exposing and subsequently transporting remains down the dune slope. The base of the dune talus may correspond to the margin of a lagoon, and therefore this process represents an additional mechanism incorporating previously unassociated remains into an assemblage accumulated near the lake.

Once materials are incorporated within northern margins, wave action may transport and/or bury them. Experimental plots set in this environment showed that artifacts deposited on northern margins were transported several meters away from their original location and completely buried after one year-lake cycle. Furthermore, buried artifacts were re-exposed in subsequent years/cycles (Borrazzo, 2013). On western lake margins, a different dynamic was recorded. In these cases sedimentation is the primary process, resulting from the transport of fine particles produced by the return currents of the lagoons (Arche and Vilas, 2001). However, sedimentation rates on these margins are lower than those recorded on the northern margins (Borrazzo, 2013).

Permanent and temporary shallow lakes studied in the study region have high levels of salinity. Lithics recovered within the lagoon influence area present salt crusts (composed of evaporates such as halite, gypsum and carbonate). It was observed that this coating is denser and more extended on artifact exposed surfaces. This phenomenon is useful for assessing (recent) stability conditions within this environment (Borrazzo, 2013). Bones are mineralized and exhibit manganese spots on their surface (Guichón et al., 2000). Contrary to our expectation for lacustrine environments, hydraulic abrasion is not a frequent feature on lithic artifacts. This is probably due to the low energy involved in these shallow lakes, and the fine sediments (clay and silt) available in these basins. High sedimentation rate may be an additional factor reducing the exposure time of lithics to hydraulic abrasion on northern lake coasts. However, bones do exhibit different intensities of abrasion, clearly indicating the differences in the sensitivity of lithics and bones to short-term processes. Finally, fine sediments of the mudflat prevent small artifacts from aeolian removal. Within this taphonomic mode, artifacts such as microflakes are well preserved in surface assemblages because lithics laying on wet muddy substrate are 'attached' to the margin or dune surface and they become firmly adhered to soil once the matrix dries, in both cases inhibiting aeolian transport (Borrazzo, 2013).

4.1.4. Alluvial plain

This taphonomic mode is less represented in the coast of the study region, and further research is needed. Therefore we offer a brief characterization here. Cullen River is located north of Nombre Cape (Codignotto and Malumián, 1981; Bujalesky, 2007, Fig. 1). The river excavates old loess deposits in its lower basin and low sedimentation rates are recorded in this portion of the alluvial plain. Vegetation (*Festuca-Poa* grassland with *Carex andina* and Lepidophylum shrubs) covers 50% of the area where Planicie Río Cullen (PRC), a 40,000 m^2 artifact surface distribution, is located. PRC is ~1 km south of the river coast and 500 m from the marine river mouth. As observed in mudflat lagoons, the fine sediment (clay and silt) substrate of the alluvial plain prevents the aeolian removal of small artifact particles, but the low sedimentation rate affects the preservation of organic remains. Under these conditions, very few highly fragmented bones are recovered from surface and subsurface contexts within this taphonomic mode, and it is extremely difficult to distinguish archaeological from non-archaeological bones.

4.1.5. Gravel beaches: El Páramo Spit

Northern cliff retreat supplies gravels that have formed El Páramo Spit, a gravel barrier that partially closes the north of San Sebastian Bay (Isla et al., 1991; Bujalesky, 1998, 2007, Figs. 1 and 2D). The spit grows to the south and recedes to the west. The northeastern portion of the spit is constituted by the oldest coarse gravel beach ridges which are cut by marine erosion. The exploration of the latter showed this environmental unit is an extraordinary lithic source, as chalcedony nodules, a rare raw material in the north of the island which was intensively used by Fuegian hunter gatherers, and other good flaking quality rocks are available there (Franco, 1998; Franco and Borrero, 1999; Borrero et al., 2008; Borrazzo, 2011). The archaeological signal on the spit is highly elusive due to the low visibility of an area in which basically gravels are deposited (Isla et al., 1991; Bujalesky, 1998, 2007; Isla and

Bujalesky, 2008). Sea mammal bones accumulated at different loci along the coasts of the spit, particularly near the location of Punta de Arenas on the distal end of the spit, a now abandoned pinniped rookery (Borella and Muñoz, 2006). The taphonomic and technological analysis of lithic collections obtained through several archaeological surveys performed on the older ridges (closer to the headlands) and the comparison of their technological profile with the regional background concluded that the assemblage is mainly composed of pseudoartifacts, naturally macro and micro-flaked stones generated by the joint action of marine transport and deposition, high turnover rates (Isla and Bujalesky, 2008), the transit of large sea mammals (pinnipeds) and the recent traffic of heavy vehicles involved in gravel extraction at the spit (Borrazzo, 2011). However, there are conditions for the preservation of Holocene occupations, particularly at the headlands of the spit (see Isla and Bujalesky, 2008: 232).

5. Discussion

The taphonomic information presented here emphasizes the environmental diversity of the coastal settings used by Late Holocene terrestrial hunter–gatherers to exploit marine resources in the study region. These observations pose the question: which were the factors behind the selection of those locations? This is basically an operative question. Using the archaeological record of San Pablo and María Luisa Using the archaeological record of San Pablo and María Luisa archaeological localities (Fig. 1), Borrero and Lanata (1988: 172) observed that the location of residential bases from which the exploitation of mollusks took place was not controlled by the distance to the ocean: there were other factors controlling settlement within a 1 km wide band. Given the different processes involved in the northern and southern coasts of our study area, it is clear that an extension of Borrero and Lanata analysis is not valid. Rapidly changing coast lines must be taken into account, with the north coast receding at the time that the south coast was aggrading (Bujalesky, 1998, 2007). One implication is that we have a more complete image of the coastal archaeological record at San Sebastian in comparison with the northern coasts. Another is that in San Sebastian it is easier to assess changes in coastal occupation during the last 200 radiocarbon years (Favier Dubois and Borrero, 2005). Moreover, the archaeological preservation at the northern coast is very good in selected pockets (Horwitz, 1996–1998; Borrero et al., 2008). Therefore, intensity and scale differences in the human activity signal between the latter and San Sebastian -with the presence of the dense and extended archaeological occupations at Chorrillos (Borrero et al., 2008; Borrazzo, 2010)- may not be only attributable to preservational conditions.

At a general level we can maintain that there is environmental heterogeneity in our study area (Borrazzo, 2010). Are there any pockets of differential preservation within each of the major recognizable environmental patches? For example, clay patches exist where no lithic sources can be found. That is the case in muddy tidal plains, on the north of San Sebastian Bay. In contrast, the northern landscape is characterized by the presence of glacially modeled landforms, with an abundance of lithic raw materials (Borrazzo, 2012). It is clear that none of these patches coincide with a credible annual range for hunter–gatherers, since they are too small to offer the critical resources adequate for an annual cycle. The first answer to this spatial incongruity of subsistence resources is mobility, acquiring the different resources at different points along a circuit. Consideration of this alternative is what led us to select a discussion of sites located very close to the coast, those which do not rely on large foraging radii in order to have access to maritime resources. As critical resources can have heterogeneous distributions (marine mammals), or a homogeneous distribution (guanacos), the basic model required to exploit both classes of resources calls for locations with access to the coast.

From an Archaeology of Place perspective (Binford, 1982), homogeneous foraging radii are possible within each environmental patch, rarely providing variable resources. The ethnography indicates a the paradox in the distribution of the Selk'nam territories published by (Gusinde, [1937] 1982), in which not all of the mapped territories have coastal components. However, the available isotopic evidence points to a small but constant marine component in the diet (Zangrando et al., 2003; Barberena, 2004). This contradiction can be explained by invoking that exchange, or aggregation events (ethnographically known and archaeologically expected) helped to provide those marine components. The shape and small size of the north of the island lead us to suggest that more direct ways of access were required. Perhaps a variant of what ethnographically was the right to exploit previous home territories of women married to men from a different territory (Stuart, 1980; Chapman, 1986). This possibility was granted under stress conditions, but definition of stress can be highly flexible. Within a scheme of direct access, the intense archaeological signal recorded at Chorrillos, discontinuously produced during a thousand years or less of human use of the locality (Horwitz, 1995; Favier Dubois and Borrero, 2005; Borrero et al., 2008; Borrazzo, 2010), suggests that such social mechanisms granting access to marine resources were valid in the study region during the last millennium. However, the archaeological record from Bahía Inútil and Punta Catalina areas shows that similar mechanisms were active in the north of the island before that time (Massone, 2004; Morello et al., 2012). Here, we propose that the coastal evolution of southern San Sebastian Bay during the late Holocene created areas with differential properties in terms of resource availability. This geological process created new patches that were preferentially used by hunter–gatherers and may have promoted the geographical expansion of preexisting social mechanisms granting direct access to marine food and goods.

6. Conclusions

The case study presented here highlighted the importance of geomorphic evolution for the study of the coastal archaeological record. The identification and characterization of different taphonomic modes for bones and lithics shows the key role displayed by the interaction of several agents and processes in producing the trends recorded at a smaller spatial scale. No obvious patterns were recorded, and the location of the loci in which observations were made was crucial in terms of preservation and visibility of the archaeological signal. This research puts forth the valuable contribution of applying a regional taphonomy approach to discuss and understand the past human use of coastal environments.

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References

Arche, A., Vilas, F., 2001. Sedimentos eólicos de grano fino en la Bahía San Sebastián, Tierra del Fuego, Argentina. Journal of Iberian Geology 27, 159–173.

Barberena, R., 2004. Arqueología e isótopos estables en Tierra del Fuego. In: Borrero, L.A., Barberena, R. (Eds.), Arqueología del Norte de la Isla Grande de Tierra del Fuego. Editorial Dunken, Buenos Aires, pp. 135–165.

Behrensmeyer, A.K., Hook, R.W., 1992. Paleoenvironmental contexts and taphonomic modes. In: Behrensmeyer, A.K., Damuth, J.D., Di Michele, W.A., Potts, R.,

Please cite this article in press as: Borrazzo, K., Borrero, L.A., Taphonomic and archaeological perspectives from northern Tierra del Fuego, Argentina, Quaternary International (2014), http://dx.doi.org/10.1016/j.quaint.2014.09.004

Sues, Hans-Dieter, Wing, S.L. (Eds.), Terrestrial Ecosystems Through Time. The University of Chicago Press, Chicago, pp. 15–136.
Belardi, J.B., Rindel, D., Bourlot, T., 2012. Much more than it was expected: preservational differences of diaphysis and epiphyseal ends of guanaco (Lama guanicoe) long bones in southern Patagonia (Argentina). Journal of Taphonomy 10 (1), 45–65.
Binford, L.R., 1982. The archaeology of place. Journal of Anthropological Archaeology 1, 5–31.
Bird, D.W., Richardson, J.L., Veth, P.M., Barham, A.J., 2002. Explaining shellfish variability in Middens on the Meriam Islands, Torres Strait, Australia. Journal of Archaeological Science 29, 457–469.
Borella, F., 2004. Tafonomía Regional y Estudios Arqueofaunísticos de cetáceos en Tierra del Fuego y Patagonia Meridional. In: British Archaeological Reports 1257. Archeopress, Oxford.
Borella, F., Muñoz, A.S., 2006. Observaciones tafonómicas sobre restos de pinnípedos en la costa norte fueguina (Argentina). Intersecciones en Antropología 7, 399–403.
Borrazzo, K., 2006. Tafonomía lítica en dunas: una propuesta para el análisis de los artefactos líticos. Intersecciones en Antropología 7, 247–261.
Borrazzo, K., 2009. El uso prehistórico de los afloramientos terciarios en la bahía San Sebastián (Tierra del Fuego, Argentina). In: Salemme, M., Santiago, F., Álvarez, M., Piana, E., Vázquez, M., Mansur, M. (Eds.), Arqueología de Patagonia: Una mirada desde el último confín. Utopías, Ushuaia, pp. 291–305.
Borrazzo, K., 2010. Arqueología de los esteparios fueguinos (Ph.D. thesis). Facultad de Filosofía y Letras, Universidad de Buenos Aires, Argentina.
Borrazzo, K., 2011. Tafonomía lítica y pseudoartefactos: el caso de la península El Páramo (Tierra del Fuego, Argentina). Intersecciones en Antropología 12, 155–167.
Borrazzo, K., 2012. Raw material availability, flaking quality and hunter-gatherer decision making in Northern Tierra del Fuego Island (Argentina). Journal of Archaeological Science 39, 2643–2654.
Borrazzo, K., 2013. Tafonomía lítica y modelo de la dinámica eololacustre del norte de la bahía San Sebastián (Tierra del Fuego, Argentina). Revista Comechingonia 17 (1), 149–169.
Borrazzo, K., 2014. De rocas a instrumentos. La tecnología lítica de los fueguinos septentrionales. In: Oría, J., Tivoli, A. (Eds.), Cazadores de mar y tierra. Estudios recientes en arqueología fueguina. Editora Cultural de Tierra del Fuego, Ushuaia, pp. 269–287.
Borrazzo, K., Martin, F., Barberena, R., Borrero, L.A., 2007. Prospección arqueológica del norte de la isla Grande de Tierra del Fuego. In: Proceedings, XVI Congreso de Arqueología Argentina, vol. III. Universidad Nacional de Jujuy, San Salvador de Jujuy, Argentina, pp. 315–321.
Borrero, L.A., 1985. La economía prehistórica de los habitantes del norte de la Isla Grande de Tierra del Fuego (Ph.D. thesis). Facultad de Filosofía y Letras, Universidad de Buenos Aires, Argentina.
Borrero, L.A., 2001. Regional taphonomy. Background noise and the integrity of the archaeological record. In: Kuznar, L.A. (Ed.), Ethnoarchaeology of Andean South America. Contributions to Archaeological Method and Theory. International Monographs in Prehistory, Ann Arbor, pp. 243–254.
Borrero, L., 2003. Taphonomy of the Tres Arroyos 1 Rockshelter, Tierra del Fuego, Chile. Quaternary International 109–110, 87–93.
Borrero, L., 2004. Tafonomía regional: el caso de los pinnípedos. In: Civalero, M.T., Fernandez, P.M., Guraieb, A.G. (Eds.), Contra viento y marea. Arqueología de Patagonia. Instituto Nacional de Antropología y Pensamiento Latinoamericano y Sociedad Argentina de Antropología, Buenos Aires, pp. 445–454.
Borrero, L.A., 2007. Longitudinal taphonomic studies in Tierra del Fuego, Argentina. In: Gutierrez, M., Miotti, L., Barrientos, G., Mengoni Goñalons, G., Salemme, M. (Eds.), Taphonomy and Zooarchaeology in Argentina, BAR Internacional Series 1601, pp. 219–233. Oxford.
Borrero, L.A., 2014. Regional taphonomy. In: Smith, C. (Ed.), Encyclopedia of Global Archaeology. Springer Reference, New York, pp. 7232–7235.
Borrero, L.A., Lanata, J.L., 1988. Estrategias adaptativas representadas en los sitios de Estancia María Luisa y Cabo San Pablo. In: Precirculados del IX Congreso Nacional de Arqueología Argentina. Buenos Aires, pp. 166–174.
Borrero, L.A., Martin, F.M., Horwitz, V.D., Franco, N.V., Favier Dubois, C., Borella, F., Carballo Marina, F., Campan, P., Guichón, R., Muñoz, A.S., Barberena, R., Savanti, F., Borrazzo, K., 2008. Arqueología de la costa norte de Tierra del Fuego. In: Cruz, I., Caracotche, S., Senatore, X., Ladrón de Guevara, B. (Eds.), Arqueología de la costa patagónica. Universidad Nacional de la Patagonia Austral, Río Gallegos, pp. 250–264.
Breed, C., McCauley, J., Whitney, M., 1997. Wind erosion forms. In: Thomas, D.S.G. (Ed.), Arid Zone Geomorphology. Wiley, London, pp. 284–307.
Bujalesky, G.G., 1998. Holocene coastal evolution of Tierra del Fuego, Argentina. In: Rabassa, J., Salemme, M. (Eds.), Quaternary of South America and Antarctic Peninsula. A.A. Balkema, Rotterdam, pp. 247–280.
Bujalesky, G.G., 2007. Coastal geomorphology and evolution of Tierra del Fuego (Southern Argentina). Geologica Acta 5 (4), 337–362.
Chapman, A., 1986. Los Selk'nam. La vida de los Onas. Emecé Editores, Buenos Aires.
Codignotto, J.O., 1990. Evolución del Cuaternario Alto del sector de la costa y plataforma submarina entre río Coig, Santa Cruz y Punta María, Tierra del Fuego. Revista de la Asociación Geológica Argentina XLV (1–2), 9–16.
Codignotto, J.O., Malumian, N., 1981. Geología de la región al norte del paralelo 54° S de la Isla de Tierra del Fuego. Revista de la Asociación Geológica Argentina XXXVI (1), 44–88.
Collantes, M.B., Anchorena, J., Cingolani, A.M., 1999. The steppes of Tierra del Fuego: floristic and growthform patterns controlled by soil fertility and moisture. Plant Ecology 140, 61–75.
Constantinescu, F., 1999. Evidencias bioantropológicas para modos de vida cazador recolector terrestre y marítimo en los restos óseos humanos de Tierra del Fuego. Anales del Instituto de la Patagonia 27, 137–174.
Eren, M., Boehm, A., Morgan, B., Anderson, R., Andrews, B., 2011. Flaked stone taphonomy: a controlled experimental study of the effects of sediment consolidation on flake edge morphology. Journal of Taphonomy 9, 201–217.
Erlandson, J.M., 2001. The archaeology of aquatic adaptations: paradigms for a new millennium. Journal of Archaeological Research 9, 287–350.
Favier Dubois, C., 1998. Dinámica sedimentaria y cambios ambientales en relación al registro arqueológico y tafonómico del Cerro Cabeza de León. Anales del Instituto de la Patagonia, Serie Cs. Humanas 26, 137–152.
Favier Dubois, C., 2001. Análisis geoarqueológico de los procesos de formación del registro, cronología y paleoambientes, en sitios arqueológicos de Fuego-Patagonia (Ph.D. thesis). Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina.
Favier Dubois, C., Borrero, L.A., 2005. Playas de acreción: Cronología y procesos de formación del registro arqueológico en la costa central de la bahía San Sebastián, Tierra del Fuego (Argentina). Magallania 33 (2), 83–98.
Ferrero, M., 1996. La sedimentación intermareal en la bahía de San Sebastián, Tierra del Fuego, Argentina (Ph.D. thesis). Universidad de Vigo, España.
Franco, N.V., 1998. La utilización de recursos líticos en Magallania. In: Borrero, L.A. (Ed.), Arqueología de la Patagonia Meridional (Proyecto Magallania). Ediciones Búsqueda de Ayllu, Concepción del Uruguay, pp. 29–51.
Franco, N.V., Borrero, L.A., 1999. Metodología de análisis de la estructura regional de recursos líticos. In: Aschero, C., Korstanje, M., Vuoto, P. (Eds.), En los tres reinos: prácticas de recolección en el cono sur Instituto. Magna Publicaciones, San Miguel de Tucumán, pp. 27–37.
Gordillo, S., Isla, F.I., 2011. Faunistic changes between the Middle/Late Pleistocene and the Holocene on the Atlantic coast of Tierra del Fuego: molluscan evidence. Quaternary International 233, 101–112.
Guichón, R., Barberena, R., Borrero, L.A., 2001. ¿Dónde y cómo aparecen los restos óseos humanos en Patagonia austral? Anales del Instituto de la Patagonia, Serie Cs. Humanas 29, 103–118.
Guichón, R.A., Muñoz, A.S., Borrero, L.A., 2000. Datos para una tafonomía de restos óseos humanos en Bahía San Sebastián, Tierra del Fuego. Relaciones de la Sociedad Argentina de Antropología XXV, 297–311.
Gusinde, M., [1937] 1982. Los selk'nam. Los indios de Tierra del Fuego. Centro Argentino de Etnología Americana, Buenos Aires.
Higgs, E.S., Vita-Finzi, C., 1972. Prehistoric economies: a territorial approach. In: Higgs, E.S. (Ed.), Papers in Economic Prehistory. Cambridge University Press, Cambridge, pp. 27–36.
Hiscock, P., 1985. The need for a taphonomic perspective in stone artefact analysis. Queensland Archaeological Research 2, 82–95.
Horwitz, V., 1995. Ocupaciones prehistóricas en el sur de Bahía San Sebastián (Tierra del Fuego, Argentina). Arqueología 5, 105–136.
Horwitz, V., 1996–1998. Espíritu Santo 1: primeros trabajos de campo en el extremo norte de la costa atlántica fueguina. Palimpsesto 5, 151–159.
Horwitz, V., 2004. Arqueología de la costa atlántica septentrional de Tierra del Fuego, Argentina. In: Borrero, L.A., Barberena, R. (Eds.), Arqueología del Norte de la Isla Grande de Tierra del Fuego. Editorial Dunken, Buenos Aires, pp. 29–54.
Isla, F., Bujalesky, G., 2008. Coastal geology and morphology of Patagonia and the Fuegian Archipelago. Developments in Quaternary Sciences 11, 227–239.
Isla, F., Vilas, F., Bujalesky, G., Ferrero, F., Gonzalez Bonorino, G., Arche, A., 1991. Gravel drift and wind effects over the macrotidal San Sebastian Bay, Tierra del Fuego. Marine Geology 97, 211–224.
Legoupil, D., Christensen, M., Morello, F., 2011. Una encrucijada de caminos: el poblamiento de la isla Dawson (Estrecho de Magallanes). Magallania 39 (2), 137–152.
Martin, F.M., 2004. Tendencias tafonómicas en el registro óseo humano del Norte de Tierra del Fuego. In: Borrero, L.A., Barberena, R. (Eds.), Arqueología del Norte de la Isla Grande de Tierra del Fuego. Editorial Dunken, Buenos Aires, pp. 108–133.
Martin, F.M., 2006. Carnívoros y huesos humanos de Fuego-Patagonia. Aportes desde la tafonomía forense. Sociedad Argentina de Antropología, Buenos Aires.
Martin, F.M., Barberena, R., Guichón, R.A., 2004. Erosión y huesos humanos. El caso de la localidad Chorrillos, Tierra del Fuego. Magallania 32, 125–142.
Martin, F.M., Borella, F., 1999. Tafonomía de Tierra del Fuego: reevaluación de la arqueología de Cabeza de León. In: Soplando en el Viento. Actas de las III Jornadas de Arqueología de la Patagonia. Instituto Nacional de Antropología y Pensamiento Latinoamericano y Universidad Nacional del Comahue, Neuquén-Buenos Aires, pp. 439–450.
Massone, M., 1987. Los cazadores paleoindios de Tres Arroyos (Tierra del Fuego). Anales del Instituto de la Patagonia 17, 47–60.
Massone, M., 2004. Los cazadores después del hielo. Ediciones de la Dirección de Bibliotecas, Archivos y Museos, Santiago de Chile.
Massone, M., 2009. Abrigos rocosos de Magallanes en la transición pleistoceno–holoceno. In: Troncoso, A. (Ed.), Actas del XVII Congreso Nacional de Arqueología Chilena. Ediciones Kultrun, Valdivia, pp. 729–740.
Massone, M., Jackson, D., Prieto, A., 1993. Perspectiva arqueológica de los selk'nam. Centro de Investigaciones Diego Barros Arana, Dirección de Bibliotecas, Archivos y Museos, Santiago de Chile.
Massone, M., Prieto, A., 2004. Evaluación de la modalidad cultural Fell 1 en Magallanes. Chungara 303–315. Volumen especial.

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McCulloch, R., Clapperton, C., Rabassa, J., Currant, A., 1997. The natural setting. The glacial and Post-Glacial environmental history of Fuego-Patagonia. In: Mc Ewan, C., Borrero, L.A., Prieto, A. (Eds.), Patagonia. British Museum Press, London, pp. 12–31.

McCulloch, R., Bentley, M.J., Tipping, R.M., Clapperton, C., 2005. Evidence for late-glacial ice dammed lakes in the central Strait of Magellan and Bahía Inútil, southernmost South America. Geografiska Annaler 87A (2), 335–362.

Morello, F., Borrero, L.A., Massone, M., Stern, C., Garcia-Herbst, A., McCulloch, R., Arroyo Kalin, M., Calas, E., Torres, J., Prieto, A., Martínez, I., Bahamonde, G., Cárdenas, P., 2012. Hunter-gatherers, biogeographic barriers and the development of human settlement in Tierra del Fuego. Antiquity 86, 71–87.

Morello, F., Borrero, L.A., Torres, J., Massone, M., Arroyo, M., McCulloch, R., Calás, E., Lucero, M., Martínez, I., Bahamonde, G., 2009. Evaluando el registro arqueológico de Tierra del Fuego durante el Holoceno temprano y medio: lo positivo de los balances negativos. In: Salemme, M., Santiago, F., Álvarez, M., Piana, E., Vázquez, M., Mansur, M. (Eds.), Arqueología de Patagonia: Una mirada desde el último confín. Utopías, Ushuaia, pp. 1075–1092.

Ocampo, C., Rivas, P., 1996. Caracterización arqueológica preliminar del suroeste de la Tierra del Fuego. Anales del Instituto de la Patagonia 24, 125–151.

Oría, J., 2012. Patrones de movilidad pre-europeos en el norte de Tierra del Fuego (Ph.D. thesis). Facultad de Ciencias Naturales y Museo, Universidad de La Plata, Argentina. http://hdl.handle.net/10915/34272.

Pallo, M.C., 2012. Análisis biogeográfico sobre el uso del espacio en Magallania (Ph.D. thesis). Facultad de Filosofía y Letras, Universidad de Buenos Aires, Argentina.

Rick, J., 1976. Downslope movement and archaeological intrasite spatial analysis. American Antiquity 41 (2), 133–144.

Salemme, M., Santiago, F., Suby, J., Guichón, R., 2007. Arqueología funeraria en el norte de Tierra del Fuego. In: Proceedings, XVI Congreso de Arqueología Argentina, vol. II. Universidad Nacional de Jujuy, San Salvador de Jujuy, Argentina, pp. 71–77.

Stuart, D.E., 1980. Kinship and social organization in Tierra del Fuego: evolutionary Consequence. In: Corell, L., Becker, S. (Eds.), The Versatility of Kinship. Academic Press, New York, pp. 269–284.

Thiébaut, C., Coumont, M.-P., Averbouh, A., 2010. The taphonomic approach: an archaeological necessity. In: Thiébaut, C., Coumont, M.-P., Averbouh, A. (Eds.), Mise en commun des approaches en taphonomie. Actes du workshop N° 16-XVe Congress International de l'UISPP, pp. 21–28.

Vázquez, M., Borrero, L.A., Elkin, D., Grosso, M., Murray, C., Oría, J., Salemme, M., Santiago, F., 2013. Nuevos resultados sobre la localización de sitios en la costa atlántica fueguina: programa Arqueológico Costa Atlántica (PACA). In: Zangrando, A.F., Barberena, R., Gil, A., Neme, G., Giardina, M., Luna, L., Otaola, C., Paulides, S., Salgán, L., Tivoli, T. (Eds.), Tendencias teórico-metodológicas y casos de estudio en la arqueología de Patagonia. Museo de Historia Natural de San Rafael y Sociedad Argentina de Antropología, San Rafael, pp. 609–616.

Vilas, F.E., Arche, A., Ferrero, M., Bujalesky, G., Isla, F., González Bonorino, G., 1986–1987. Sedimentación intermareal en Bahía San Sebastián, Tierra del Fuego, Argentina. Acta Geológica Hispánica 21-22, 253–260.

Vilas, F.E., Arche, A., Ferrero, M., Bujalesky, G., Isla, F., González Bonorino, G., 1987. Esquema evolutivo de la sedimentación reciente en la Bahía de San Sebastián, Tierra del Fuego, Argentina. Thalassas 5 (1), 33–36.

Vilas, F.E., Arche, A., Ferrero, M., Isla, F., 1999. Subantarctic macrotidal flats, cheniers and beaches in San Sebastian Bay, Tierra del Fuego, Argentina. Marine Geology 160, 301–326.

Waters, M., 1996. Principles of Geoarchaeology: a North American Perspective. The University of Arizona Press, Tucson.

Zangrando, A., Tessone, A., Valencio, S., Panarello, H., Mansur, M.E., Salemme, M., 2003. Isótopos estables y dietas humanas en ambientes costeros. In: Ortega, M., Calleja, J., Sánchez, M., Lorenzo, M., Brell, M., Montero, A., Puerto, R. (Eds.), Avances en Arqueometría. Universidad de Cádiz, Cádiz, pp. 91–97.

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