

Chapter 8

Submerged Paleolandscapes: Site GNL Quintero 1 (GNLQ1) and the First Evidences from the Pacific Coast of South America

Diego Carabias, Isabel Cartajena, Renato Simonetti, Patricio López, Carla Morales, and Cristina Ortega

Introduction

Over the last decade, the long-held paradigm of the initial peopling of the New World from Beringia through an ice-free corridor by terrestrially adapted big-game hunting groups who rapidly spread south has been critically revised. In general, innovative theoretical views based in new multidisciplinary evidence suggest that pre-Clovis populations existed and that the colonization of the Americas was the consequence of diverse cultural processes with high diversity of habitats occupied by early hunter-gatherer groups with different subsistence strategies and technologies (Borrero 1999; Dillehay 2000, 2009; Faught 2008; Goebel et al. 2008; Waters and Stafford 2007). In northwestern North America, in particular, the growing interest in submerged prehistoric archaeology as a nascent subdiscipline critical

D. Carabias (✉) · R. Simonetti · C. Morales
ÁRKA—Maritime Archaeology, Casilla 21, 2340000 Valparaíso, Chile
e-mail: dcarabias@arqueologiamaritima.cl

R. Simonetti
e-mail: rsimonetti@arqueologiamaritima.cl

C. Morales
e-mail: cmorales@arqueologiamaritima.cl

I. Cartajena
Departamento de Antropología, Universidad de Chile, Ignacio Carrera Pinto 1045,
Santiago de Chile, Chile
e-mail: icartaje@u.uchile.cl

P. López
Universidad Católica del Norte, IIAM, Gustavo Le Paige 380, San Pedro de Atacama, Chile
e-mail: patriciolopezmend@yahoo.es

C. Ortega
Facultad de Ciencias Físicas y Matemáticas, Departamento de Geología, Universidad de Chile,
Plaza Ercilla 803, Santiago, Chile
e-mail: crortega@ing.uchile.cl

The original version of this chapter has been revised:

The author Diego Carabias was incorrectly presented in the initially published online version of Chapter 8 Submerged Paleolandscapes: Site GNL Quintero 1 (GNLQ1) and the First Evidences from the Pacific Coast of South America. This has now been corrected.

A correction to this chapter can be found at
https://doi.org/10.1007/978-1-4614-9635-9_17.

to understanding early coastal occupations and migration routes (Gusick and Faught 2011) is closely related to the “coastal migration theory” initially proposed by K. Fladmark (1979). This alternative hypothesis suggests that prior to 13,000 cal BP, large coastal plains with terrestrial resources and productive marine environments were available for maritime adapted people due to Pleistocene lower sea levels enabling human and animal migrations (Dixon 2001; Erlandson 2008; Faught 2008; Mandryk et al. 2001; Waters and Stafford 2007).

Recent research projects in northwestern North America are focused on locating evidence to support the hypotheses of a coastal migration into the New World following the Pacific Rim route (Faught and Gusick 2011). By applying paleo-landscape modeling and archaeological sampling these investigations have been successful in locating submerged cultural material (Easton and Moore 1991; Fedje and Christensen 1999; Fedje and Josenhans 2000; Josenhans et al. 1997). A geo-archaeological-based approach and predictive modeling have been applied off the Oregon coast (Davis et al. 2009). Finally, the southern Gulf of California’s archaeological potential has been recently initially explored through a paleo-landscape model and diving operations (Faught and Gusick 2011). In Southern California several hundred mortars and ground-stone artifacts (Masters 1983, 1985), and shell middens (Bickel 1978) have been reported from the early 1900s.

However, evidence for Late Pleistocene and Early Holocene sites on the Atlantic continental shelf, including areas like the Gulf of Mexico and Florida, continues to be far more substantial and recurrent than that for the Pacific (Stright 1990, 1995). This contrasting situation is evident in Florida alone, where these sites are reported to be presumably older, more abundant, and larger in size to those known along the West Coast (Faught 2004).

The relatively reduced evidence of submerged prehistoric sites along the Pacific Coast of North America has been explained due to narrow continental shelves, active volcanism and tectonism, and high-energy marine conditions which are less favorable for preservation, except in bays, inlets, and island clusters (Faught and Gusick 2011). Stright (1995), analyzing the archaeological potential of the continental shelves of North America, stresses that if the rate of relative sea-level change is held constant, the Pacific shelf would have the lowest potential for preservation of in situ archaeological deposits and the Gulf of Mexico would have the highest. Additionally, while geomorphology of the eastern Pacific coastal environments, with rocky shores and deep basins, offers natural shelters for the preservation of archaeological remains, the exceedingly high wave action of the eastern Pacific can erode away sea cliffs and cut terraces (Inman 1983), and represents a powerful disturbing agent for the submerged archaeological record (Gusick and Faught 2011).

When referring to the Americas or the New World, research reviews on marine submerged prehistoric archaeology have addressed basically projects conducted in North America (Faught and Gusick 2011; Gusick and Faught 2011; Johnson and Stright 1992; Masters and Flemming 1983). This is not surprising, since in South America with very rare exceptions, (Bayon and Politis, this volume) early submerged prehistoric sites are virtually unknown, and thus the investigation of the archaeological potential of the Pacific continental shelf is practically nonexistent.

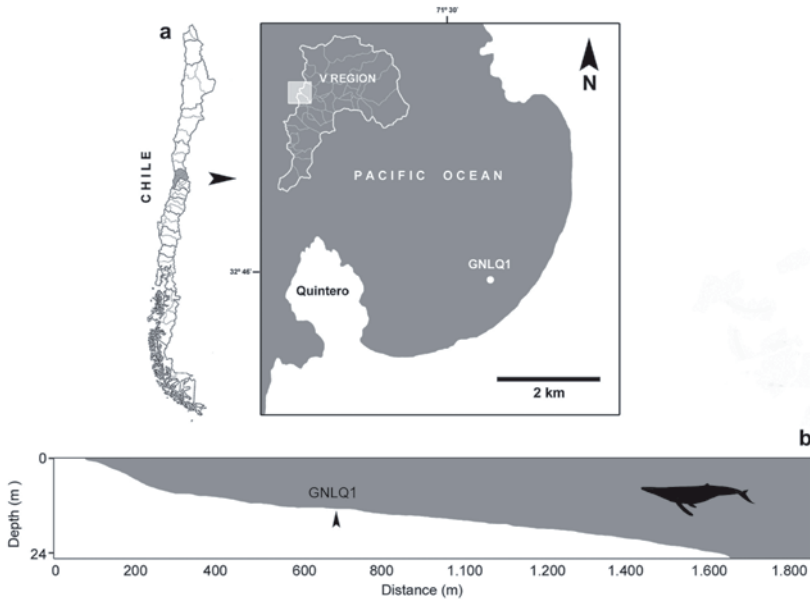


Fig. 8.1 a Location map for the study area in Quintero Bay, central coast of Chile. b Bathymetric profile of the area with site GNLQ1.

In this chapter, the authors provide a general overview of the research conducted on GNL Quintero 1 (GNLQ1), a Late Pleistocene paleontological submerged site located in the Pacific coast of Central Chile, and examine this evidence in light of the known association between extinct megafauna and early human adaptations in the area. Finally, the authors propose and discuss an initial digital simulation model developed to better understand this first postglacial-drowned terrestrial landscape discovered along the Andean Pacific coast.

Site GNL Quintero 1 (GNLQ1)

Site GNLQ1 is located in Quintero Bay ($32^{\circ}46' S$), located ~ 50 km north of Valparaíso, on the Pacific coast of Central Chile (Fig. 8.1a). This is a shallow embayment, ~ 3 miles long and ~ 1.5 miles wide, roughly oriented N–W with a maximum recorded depth of 55–60 m. River Campiche, located at the N–E side of La Herradura beach and some other minor streams drain into the bay, with permanent to perennial flow. Coastal lagoons and wetlands are trapped by mound dunes at the N–E and S–W ends of the bay (Villa-Martínez and Villagrán 1997). The resulting structural context is a shallow bay with gently sloping nearshore bathymetry with little sediment yield from rivers.

Quintero Bay is an active harbor and contains important energy, mining and industrial infrastructure. Site GNLQ1 located 650 m offshore and 13 m underwater (Fig. 8.1b) was discovered in 2005 during an archaeological investigation of the seabed as part of a Cultural Resource Management (CRM) project. Through extensive diver survey operations a cluster of discretely exposed and shallowly buried bone deposits were identified by archaeologists close to a rigid oil submarine pipeline installed by the National Oil Company (ENAP) during the 1970s. Intensive visual examination and hand fanning techniques revealed that these loci were formed by faunal remains deposited within a consolidated bed of sediment and partially buried under 5–10 cm of modern sands.

Methodology

As part of the CRM project, a series of subsurface test excavations and mechanical coring samples were conducted at the site in 2007 at several targeted points distributed across transects within an area of 40 × 25 m (ARKA Consultores 2008). In particular, one locus, a well-delimited bone concentration barely visible on the seabed, was selected and sampled through a test excavation 1 × 1 m unit (unit K8_2). The excavation was carried out using a 3" induction water dredge and the material excavated was deposited first in a 6.5 mm holding basket underwater and then transferred to the surface for further examination. Skeletal remains were exposed by careful excavation using in situ decapage techniques and recovered with their sedimentary matrix in order to be microexcavated in the laboratory, thereby minimizing loss of contextual information and physical deterioration potentially caused during underwater extraction (Fig. 8.2).

A total of 224 bone specimens were recovered (Cartajena and López 2008; Cartajena et al. 2011) (Table 8.1). The remains belong mainly to excavation unit K8_2. Only two isolated bone specimens were registered deposited on the surface of unit K7, while another two surficial bones were recovered at unit K4.

Conservation

Once microexcavated at the laboratory, the structurally sound recovered bones underwent a conservation treatment to remove the soluble salts in order to make the material stable (Hamilton 1998). The salts were diffused out by rinsing in successive baths of water, starting with 100% sea water and increasingly incorporating fresh water (local tap water) until straight fresh water was completed. Distilled water was then substituted for the fresh water until the soluble salts were removed. Mechanical removal of stains was achieved using hand tools (Morales 2008).

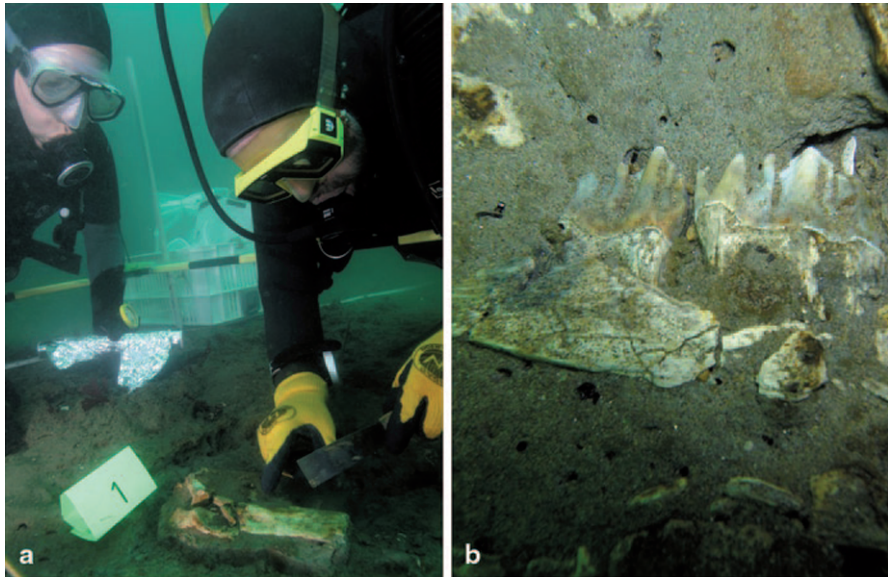


Fig. 8.2 a Controlled recovery of the faunal remains using underwater archaeology excavation techniques. b Megafauna fossil bones deposited within a consolidated bed of sediment

Table 8.1 Distribution of recovered bones in survey and excavation units

Survey and excavation unit	Level	NISP	% NISP
K8_2	1 (0–10 cm)	175	78.1
K8_2	1 (0–10 cm)	5	2.2
K8_2	1 (0–10 cm)	13	5.8
K8_2	1 (0–10 cm)	1	0.4
K8_2	1 (0–10 cm)	17	7.6
K8_2	1 (0–10 cm)	2	0.9
K8_2/K8_1	1 (0–10 cm)	5	2.2
K8_2	Cleaning	1	0.4
K4-Surface	Surface	2	0.9
K7-Surface	Surface	2	0.9
Core	Surface	1	0.4
Total	–	224	100.00

Stratigraphy

In particular, one core sample (T1) 74.3 cm long was selected for morphological and sedimentological analyses and represents a complete stratigraphic sequence for the site, with three stratigraphic units exhibiting clearly different sedimentological features (Vargas and Ortega 2008) (Fig. 8.3). Unit 1 contains surficial well-sorted fine sand that is brown in color, 5 cm thick. Underneath, Unit 2 is a clayey-gravel clast-supported formed by high hardness agglomerates of fine sand and clay and

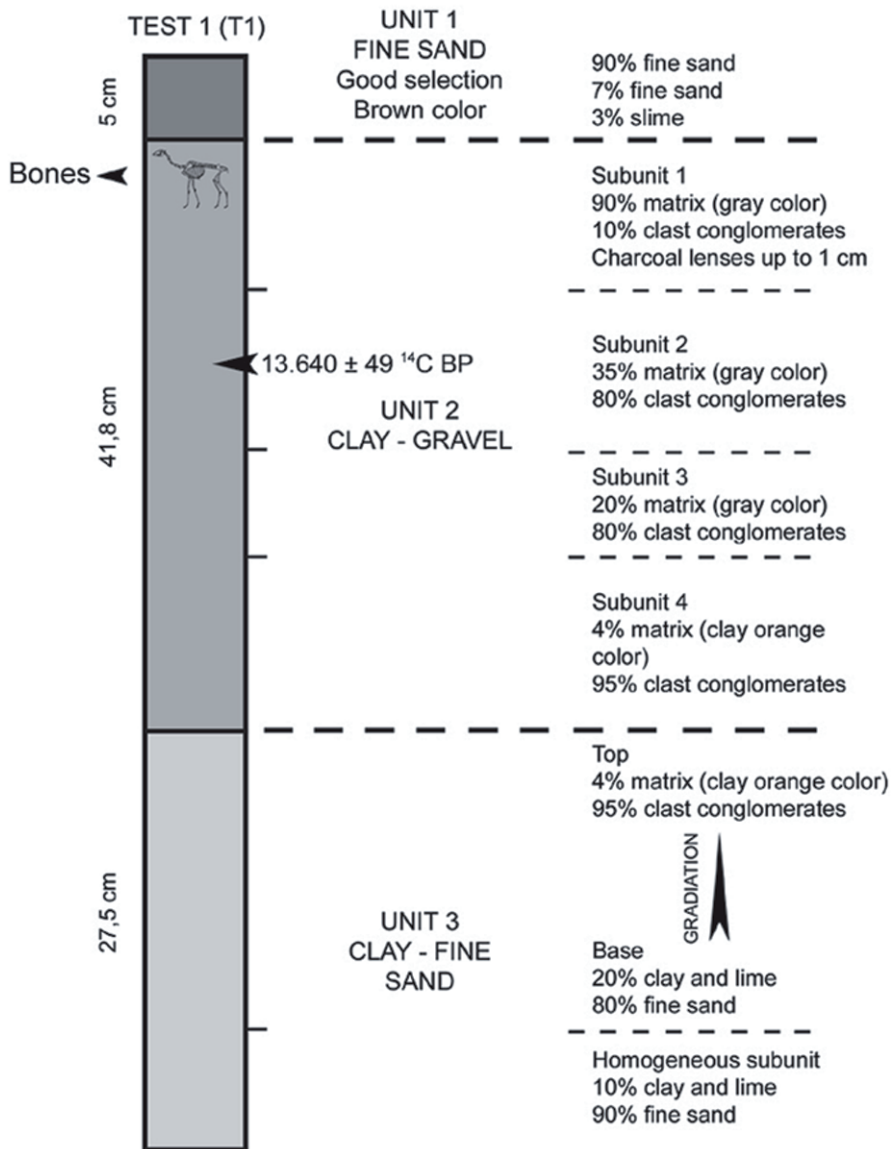


Fig. 8.3 Stratigraphic sequence of site GNLQ1

eventually microcrystalline quartz (chalcedony), orange and gray in color, some exhibiting a patina of charcoal in a fine sand-silt matrix. Millimetric charcoal lenses are intercalated in the higher and lower parts of this unit. The faunal remains were recorded in the upper portions of this deposit, horizontally distributed over an extensive area and in both clear and direct association to charcoal lenses present

within the first 5 cm of Unit 2. Finally, Unit 3 consists of fine clayey sand that is brown and orange in color. Core T1 did not yield pollen remains (A. Maldonado, personal communication).

The analysis of the stratigraphic unit containing the fossil remains (Unit 2) suggests an estuarine-lagoon or wetland environment in the process of desiccation (Vargas and Ortega 2008). Although very preliminary, this evidence is consistent with other studies which suggest essentially a cold and wet environment, with a general tendency toward desiccation around ~13,000 cal BP for the study area (Kim et al. 2002; Valero Garcés et al. 2005; Villagrán and Varela 1990).

Radiocarbon Dating

Two taxon samples were selected for radiocarbon analyses, but the lack of collagen, including that of the dentine, precluded age estimation. For this reason the sedimentary matrix containing the bones was ^{14}C dated and reported 13,640±40 years BP (UGAMS#9194, $\delta^{13}\text{C}$, ‰-25.4) (16,605-16,196 cal. BP, OxCal 4.2, SH Cal 13 [Bronk Ramsey and Lee 2013]).

The Faunal Assemblage: Taxonomic and Taphonomic Analyses

Much of the research effort regarding site GNLQ1 has been focused on the taxonomy and taphonomy of the faunal assemblage recovered (Cartajena and López 2008; Cartajena et al. 2011; Cartajena et al. 2013; López et al. 2012). Most of the materials show a homogenous and slight degree of abrasion on the bone surface as expected in an aqueous environment with abrasive sediment. Early weathering stages also affected most of the sample (Behrensmeyer 1980), supporting the idea that the remains were exposed to subaerial conditions before they were buried and subsequently submerged by sea-level rise. This is coincident with the evidence of root marks on the surface of all the bones, which indicates the growth of a vegetation cover over the fossil deposits previous to the marine transgression.

Although some specimens show signs of initial states of weathering such as longitudinal cracks in diaphysis fragments, which could have affected the fragmentation of the assemblage, the conservation of the bones is optimal. A significant percentage of the assemblage could be reassembled and taxonomically determined, even up to the family level. In most of the cases the bones presented complete epiphyses or diagnostic traits such as tooth. However, some remains have been assigned to more general taxonomic categories (order level), such as a selenodont-type deciduous molar that has been assigned to Artiodactyla, due to the lack of other diagnostic traits.

A total minimal number of eight individuals corresponding to at least seven different taxa were recovered. The identified bones show a high diversity of terrestrial extinct megafauna, including Camelidae, Cervidae, Equidae, and Xenarthra but also smaller size animals such as a fox-size carnivore, a rodent, and a bird (Table 8.2).

Table 8.2 Taxonomical and anatomical unit representation, expressed in NISP and MNI

	NISP	% NISP	MNI
Mammalia	148	66.1	–
Artiodactyla	2	0.9	1
cf. <i>Palaeolama</i> sp.	23	10.3	1
Cervidae	37	16.5	1
Equidae	2	0.9	1
Xenarthra	7	3.1	1
Canidae	2	0.9	1
Cricetidae	1	0.4	1
Ave	2	0.9	1
Total	224	100.00	–

Xenarthra bones correspond to an ungual phalanx (Fig. 8.4a), an osteoderm, and the complete sequence of molariforms of the right mandible. A Camelidae (cf. *Palaeolama* sp.) anterior superior extremity (distal humerus and radius-ulna) was recovered, which corresponds to a large size camelid in the range of *Palaeolama* (López et al. 2004; Fig. 8.4e, f). The Cervidae remains belong to the left and right mandible from a large-size cervid (Fig. 8.4g) and from Equidae two juvenile pre-molars were identified (Fig. 8.4b). A calcaneus and a canine tooth of Canidae were recovered, whose morphology and size are similar to the present day *Lycalopex culpaeus* (Fig. 8.4c, d). An incisor from a Cricetidae rodent of insufficient taxonomic diagnosis was also recovered. Finally, two bird remains from another unit (K7) were registered at the surface. Their morphology and size is compatible with specimens from the Phasianidae family.

The Quintero faunal assemblage exhibits high taxonomic diversity, mostly similar to that of sites yielding extinct Pleistocene fauna located around the coast of Los Vilos District, in the northern semiarid zone (31°29' S) (Jackson 2003; Jackson et al. 2007; Méndez et al. 2004; Núñez et al. 1994b). These coincident evidences suggest similar paleoenvironmental conditions, which during the Terminal Pleistocene favored the congregation of diverse mammalian resources hunted by Paleoindian human groups around productive lowland areas such as streams, lagoons, estuaries, fertile plains, and wetlands, as has been suggested for north-central Chile by Núñez et al. (1987).

Taphonomic analysis allowed macroscopic identification of natural marks (punctures) associated with big and small size carnivores. By applying Scanning Electron Microscope (SEM) micrographs to fossil bones, marks and color alterations were identified. Marks could be related to rodent gnawing and trampling while color alterations were attributed to diagenesis processes.

The distal humerus of the cf. *Palaeolama* sp. presents a spiral fracture on the fresh bone. Although this type of fracture can be considered to be typical of that of human activity, diverse analyses determined the degree of ambiguity of this trait, as it can also be the result of natural agents (Borrero and Martin 1996; Haynes 1983a, 1983b; Myers et al. 1980). Although the humerus does not show any signs of notches or negative characteristics of human modifications, fresh bone flakes (derivates) were found.

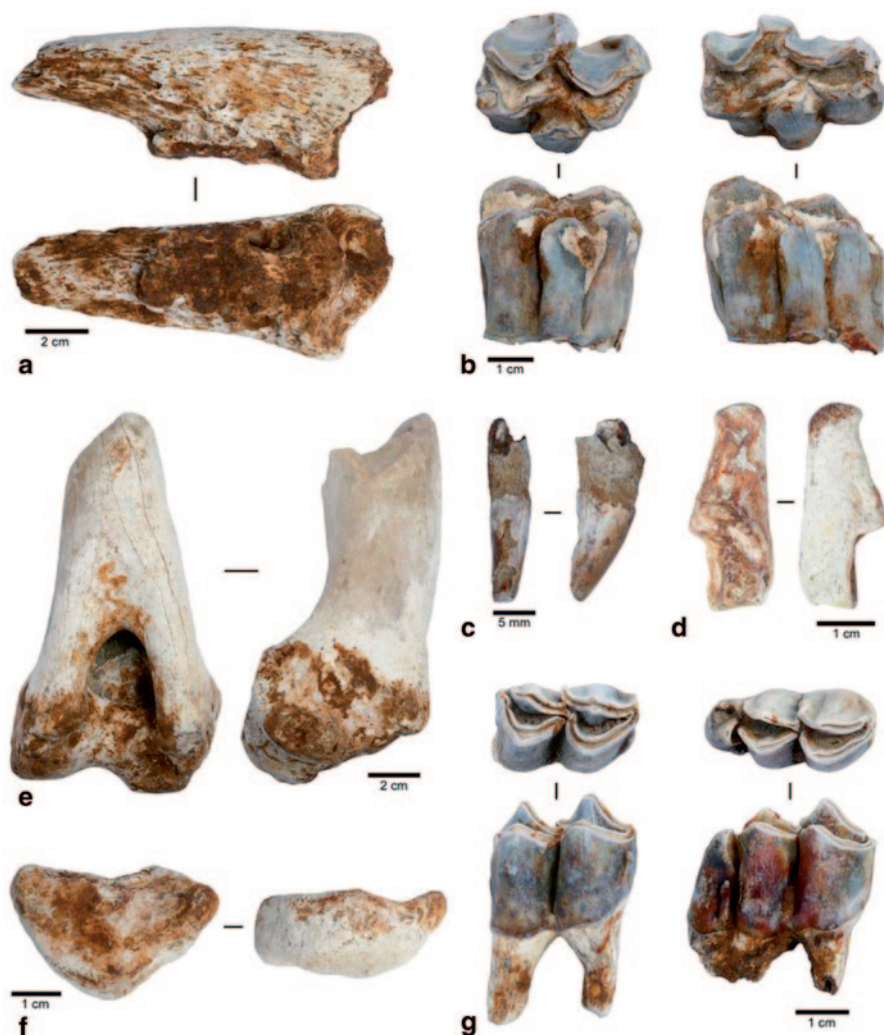


Fig. 8.4 Faunal assemblage recovered from site GNLQ1. **a** Ungual phalanx of *Xenarthra*. **b** Premolars of *Equidae*. **c** and **d** Canine tooth and calcaneus of *Canidae*. **e** and **f** Distal humerus and fourth carpal of cf. *Palaeolama* sp. **g** Molars of *Cervidae*

By means of the use of Energy Dispersive Spectroscopy (EDS) analysis, spheroidal bodies of pyrite in the osseous matrix of the cf. *Palaeolama* sp. humerus were found, suggesting an anoxic depositional environment and the action of sulphur-reducing bacteria (Borrego et al. 2003; Brown et al. 2010; Saheb et al. 2008). This is coincident with the oxidation staining found in all the assemblage resulting from the interaction of the bones with an interface of gravel clay sediment and water, which is characteristic of the depositional environment of the GNLQ1 site (Dunbar et al. 1989; Noakes et al. 2009).

Paleolandscape

One of the critical aspects for finding submerged prehistoric sites is determining local sea-level history. Pleistocene shorelines were inundated around the world largely as a direct consequence of global, eustatic sea-level rise. Global sea levels were ~ 120 m lower than present at the Late Wisconsinan maximum glaciation, 20,000 to 18,000 BP (Fairbanks 1989). However, in areas directly or indirectly affected by glaciation, calculating sea-level history is far more complex due to the intricate interplay between tectonic, eustatic, and isostatic change, which may result in drastic differences from a generalized sea-level curve (Bailey and Flemming 2008; Fedje and Christensen 1999; Stright 1995). This is the case for Chile, where coastal areas register diverse uplift rates and important tectonic activity. However, uplift rates for Holocene marine deposits on the central coast of Chile where Quintero Bay is located have been calculated in a moderate range, with a minimum mean estimate of 0.4 m/ka (Encinas et al. 2006). This range is consistent with the slight Holocene tectonic uplift and low uplift rates since the last Interglacial reported for north-central Chile (Leonard and Wehmiller 1991; Ota and Paskoff 1993).

There are no Holocene sea-level curves available for north-central Chile, therefore to determine the Relative Sea Level (RSL) for Quintero Bay SELEN 3.2 (Spada and Stocchi 2007), the authors used a Fortran computer program for solving the "sea-level equation" (SLE). In this process, a linear integral equation allowed the users to determine the sea-level variations driven by the melting of the Pleistocene ice-sheets, and was corrected with an assumed constant uplift range of 0.5 m/ka.

For reconstructing the paleolandscape underwater, a navigation chart with available high-resolution local bathymetric and terrestrial elevation data was combined and merged using HYPACK Max 10 hydrographic software. Although the navigation chart worked only for general survey area purposes, local bathymetric data processing was combined with sedimentological samples. By combining this information with the SELEN Quintero RSL curve contour maps, 3D wireframe maps representing the simulation of the paleolandscape were created using SURFER 10.

According to this initial simulation, the inlet of land oriented SE which forms modern Quintero Bay did not exist prior to $\sim 16,000$ BP (Fig. 8.5). Between about 16,000 BP and 14,000 BP the sustained postglacial sea-level rise caused the progressive and substantial inundation of ~ 3.2 km of the coast in a general SE direction. Due to local geomorphology, the shoreline prograded ~ 0.9 km between 14,000 BP and 12,000 BP. Between 12,000 BP and 10,000 BP the shoreline moved forward another ~ 1.5 km, with most of this progress occurring during the first thousand years, when Quintero Bay acquired most of its modern shape. Site GNLQ1 was last under subaerial conditions by $\sim 11,000$ BP (Fig. 8.6).

A side-scan sonar remote sensing survey was conducted on the GNLQ1 site area in 2011. The seafloor sediments in the area are characterized by uniform low-backscatter acoustic data, typical of fine-grained sediments, with no recognizable topographic features. This surficial layer of unconsolidated modern sands exhibits ripple-marks indicating a high-energy marine environment. High-resolution acous-

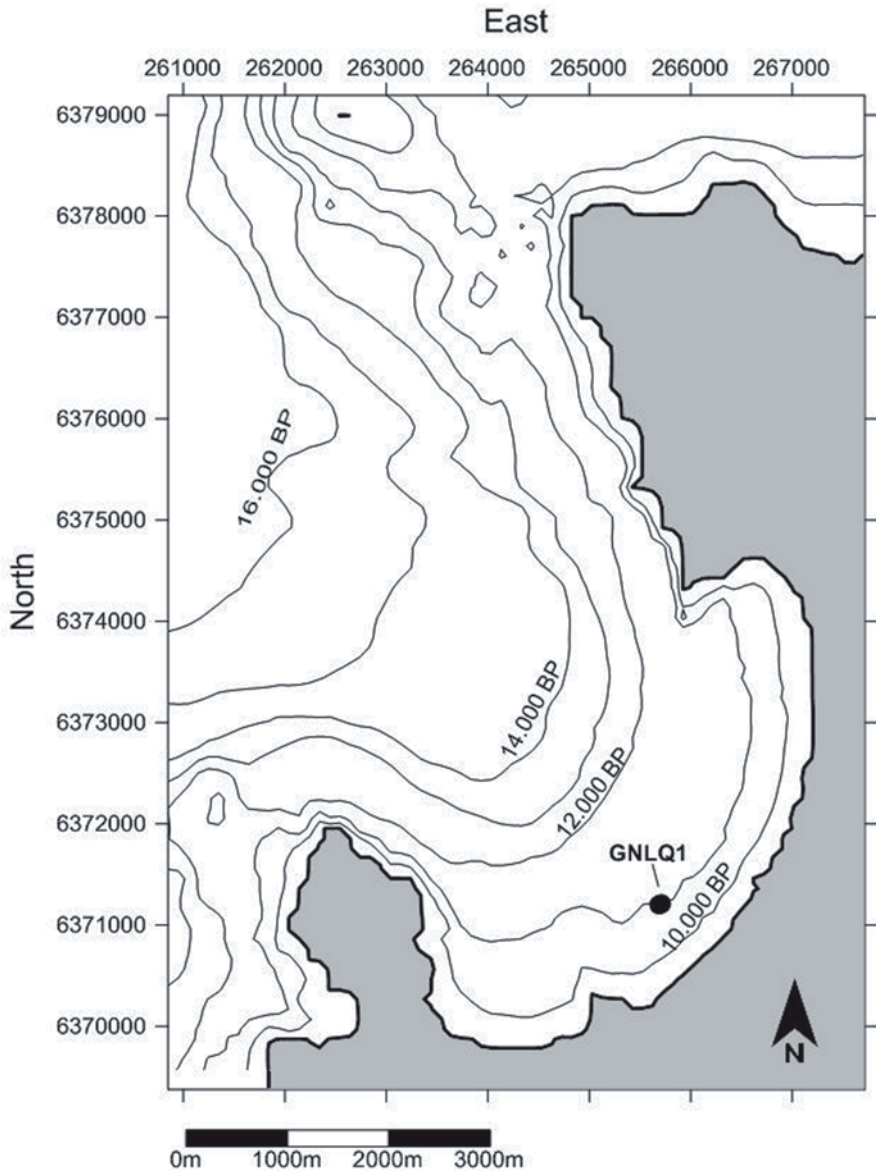


Fig. 8.5 General contour map of Quintero Bay's early postglacial sea-level change

tic images of site GNLQ1 depicts the partially exposed Pleistocene consolidated clayey gravel deposits containing the fossil bones as a discrete reflector with a general NE-SW distribution (Fig. 8.7). ENAP's Ø 42" pipeline, orientated NW-SE is clearly visible as a strong reflector toward the center of the sonograph. Remote

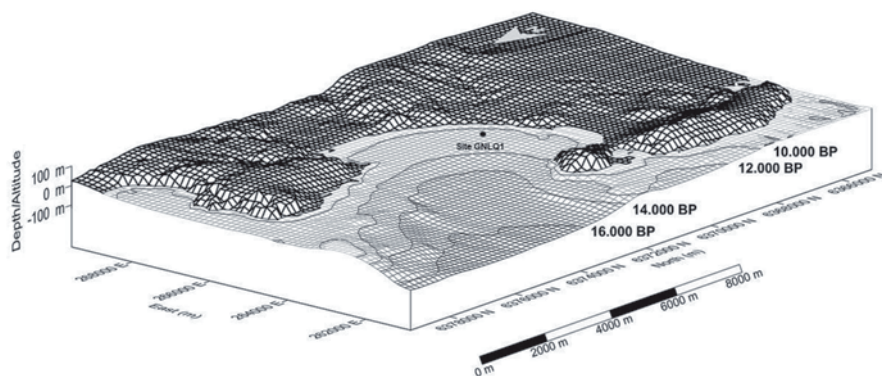


Fig. 8.6 Orthographic 3D wireframe of Quintero Bay with site GNLQ1's location enhanced by 400% vertical. Estimated early postglacial paleoshorelines at 16 ka, 14 ka, 12 ka, and 10 ka are represented

sensing data is consistent with sediment analysis and bathymetry data processing which indicated that the area is located in the upper shoreface under the influence of tidal and wave activity dominated by SW winds (Vargas and Ortega 2008).

Discussion

The paleontological record of site GNLQ1 reveals the presence of exposed Late Pleistocene deposits on the seabed containing a primary stratigraphic context of continental faunal remains with scarce postdepositional alterations. Although located in a relatively low-depth coastal high-energy marine environment, and partially affected by development projects, the site indicates a high integrity and resolution.

As indicated, the recurrent association between extinct fauna and early human occupation of north-central Chile has been interpreted as a circum-lacustrine adaptation at the Pleistocene/Holocene transition, during which megafauna restricted to shrinking lacustrine environments subject to aridity stress, were exploited by Paleoindian groups (Núñez et al. 1987). During this period human occupations were characterized by open campsites, near to aquatic environments, and with high residential mobility (Jackson et al. 2004; Méndez 2011). Examples of classic Paleoindian occupations that exhibit definitive evidence of human-megafauna interaction dating to ~13,000 calibrated years are Quebrada Santa Julia (Jackson et al. 2007) and sites Tagua-Tagua 1 and 2 (Núñez et al. 1994a).

In the semiarid zone of Chile, despite the presence of early prehistoric sites located close to the Pacific coastline, sites do not exhibit relevant exploitation of marine resources until the Early Holocene (Jackson et al. 2007). It is noteworthy that consistently a substantial part of the paleontological records of Terminal Pleistocene fauna found near the coast corresponds eminently to terrestrial fauna as well

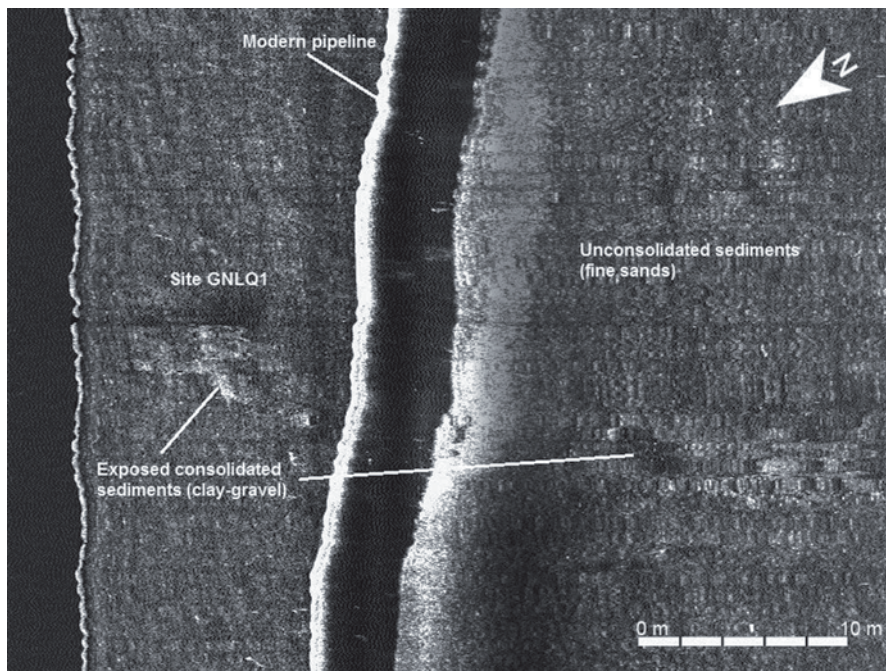


Fig. 8.7 780 kHz sonograph of site GNLQ1. Note the exposed Pleistocene-consolidated deposits with a general NE–SW distribution covered by modern sands. The National Oil Company (ENAP) Ø 42" pipeline runs across it in a NW–SE direction

(Méndez et al. 2004). In particular, the record of site GNLQ1 and those of other sites with similar faunal assemblages like Quereo (López et al. 2004; Núñez et al. 1994b) indicate a wide distribution of grazers and browsers taxa, suggesting environments that combine pasture lands and woods (Cartajena et al. 2011; Cartajena et al. 2013). This evidence is consistent with the assumption that a significant coastal area, now covered by the sea, was available during late glacial and early postglacial periods to both fauna and early terrestrial hunter-gatherers in the New World, who occupied valleys and estuaries (Bonnichsen et al. 2005; Richardson III 1981; Sandweiss 2003).

No evidence of human activity has been inferred at GNLQ1 so far. Neither artifacts nor evident human modifications of bones were found. However, the excavated sample is still small and identifying conclusive cultural indicators on early terrestrial sites is not an unproblematic research issue. Of at least 24 known sites in the semiarid coast of Chile with Pleistocene extinct fauna there are only two, Quebrada Santa Julia and Quereo, which exhibit primary stratigraphic records of anthropogenic origin (Jackson et al. 2007). In this latter site, artifactual evidence is undiagnostic and ephemeral, and most human intervention is represented by bone artifacts and cut marks, and fractures of the bones (Jackson et al. 2004). It is known that several factors will affect the visibility of potential cultural features within the

archaeological record of a prehistoric submerged site, including site functionality, taphonomic agents, and differential conservation, among others (Stewart 1999; Stright 1995; Waters 1992). Thus, human agency on underwater sites similar to GNLQ1 should be carefully evaluated and tested considering that substantial recovered prehistoric evidence on land suggests a rather discrete but recurrent human occupation of a well-delimited area during the Late Pleistocene (Méndez 2011). Applying proxy indicators might prove an efficient research strategy in light of the presence of charcoal lenses and charcoal patina in the stratigraphic unit containing the fossil remains.

At first, the AMS ^{14}C date for GNLQ1 (16,605-16,196 cal. BP) seems substantially earlier than the $\sim 13,000$ cal. BP date of the earliest human occupations in the area. However, this indicates the age of the sediments containing the fossil bones. It is worth noting that Jackson (2003) obtained a similar date for a *Mylodon* sp. sacrum associated with lithic remains from the site El Membrillo, near Los Vilos, 16,677 cal year BP, but this evidence should be interpreted with caution since it is a surface site (Jackson et al. 2007). New chronostratigraphic evidence of site GNLQ1 is needed, including AMS ^{14}C dates on single bones of stratigraphically associated taxa.

At this stage of the investigation, a precise model of the Quintero paleolandscape cannot be reconstructed without a better understanding of both local uplift rates and sea-level variations. However, the initial simulation created by combining the SELEN Quintero RSL curve with a mean estimated uplift rate of 0.5 m/ka is considered to provide a reasonably accurate model of the submerged landscape and is consistent with more global sea-level curves (Lambeck et al. 2002). The latter suggests that by early postglacial times ($\sim 16,000$ BP), a significant part of modern Quintero Bay was exposed due to lower sea-levels and available for terrestrial fauna. Site GNLQ1 would have been located several kilometers inland as the paleoshoreline was farther out on the continental shelf, close to the 90 m isobath (≤ 5 km). This hypothesis is consistent with the taxonomical homogenous composition of the assemblage of vertebrate fossils and the absence of marine resources at the record, at least in the evidence documented so far.

In the future, a refined model of the Quintero paleolandscape should enable researchers to identify geomorphological, topographical, and sedimentary conditions most conducive to the underwater preservation and discovery of submerged landscapes. A better understanding of the formation processes involved in GNLQ1 might help explain where to search in Quintero Bay for exposed or shallowly buried terrestrial surfaces and Pleistocene landforms and the amount of marine sediment accumulation expected. According to the present model, the local paleoshoreline contemporaneous to the earliest human occupation of north-central Chile should be located close to the 50 m isobath implying necessarily a fragmentary and biased coastal archaeological record. As it has been suggested elsewhere (Bailey and Flemming 2008), this potential underwater archaeological record does not simply add to what we already know about prehistoric sites on land, but might provide critical evidence about coastal environments that are now submerged and that provided productive conditions for plant and animal life during lowered sea level, late glacial, and early postglacial times.

Conclusions and Perspectives

Site GNLQ1 provides the first conclusive evidence for the existence and preservation of a drowned landscape viable for both extinct megafauna and early human occupation and movement along the Pacific Coast of South America during the Late Pleistocene. Although still necessarily limited, the data presented fills a gap in the record of sites in submerged contexts in the New World while offering significant possibilities for future research.

Effectively, the high inferential status of this remarkable and unique site is extremely promising. Although identified as part of a CRM project, the paleontological record has been studied by research methods and strategies common to submerged prehistoric archaeology projects in North America (Gusick and Faught 2011). The development of an initial paleolandscape model for Quintero Bay to be tested is considered to be an important first step for further archaeological investigation of the Chilean continental shelf and may help improve our understanding of the environmental resources available for the earliest colonizing human groups in the region.

A new phase of focused research is already being conducted at GNLQ1. This geoarchaeological approach includes the comprehensive application of remote sensing tools (including high-resolution side-scan sonar and sub-bottom profiler surveys), paleoecological reconstructions, and systematic underwater excavations. The latter have enabled the recovery of a larger sample of fossil bones which confirms a high taxonomic diversity of Terminal Pleistocene terrestrial extinct fauna and substantiates site integrity and high-resolution contexts. Analysis is currently ongoing and any potential evidence of human modification is being carefully assessed.

Site GNLQ1 represents a primary and so far unknown source of data on now-submerged paleolandscapes, and although human association remains to be seen by future research, it provides a new and challenging insight into the early postglacial environment and habitats common to both extinct fauna and the initial human populations of the Andean Pacific coast.

Acknowledgments We would like to thank Nicholas Flemming, Joe Flatman, and Amanda Evans for inviting us to contribute in this volume. Giogo Spada kindly provided the GIA curve for Quintero Bay using the SELEN 3.2 model. David Letelier provided underwater photography images and Álvaro López prepared laboratory photography images. This study has been financially supported by GNL Quintero S.A.

References

ARKA Consultores. (2008). Evaluación Arqueológica Subacuática Sitio GNL Quintero 1, Proyecto “Terminal de GNL en Quintero”, Comuna de Quintero, V Región de Valparaíso, report prepared for SGA Ltda. September 2008.

- Bailey, G. N., & Flemming, N. C. (2008). Archaeology of the continental shelf: Marine resources, submerged landscapes and underwater archaeology. *Quaternary Science Reviews*, 27(23–24), 2153–2165.
- Behrensmeyer, A. K., & Hill, A. (1980). *Fossils in the Making: Vertebrate Taphonomy and Paleoecology*. Chicago: University of Chicago Press.
- Bickel, P. M. (1978). Changing sea levels along the California coast: Anthropological implications. *Journal of California Anthropology*, 5(1), 6–20.
- Bonnichsen, R., Lepper, B., Stanford D., & Waters, M. (2005). *Paleoamerican origins: Beyond Clovis*. Orono: Center for the study of the first Americans, Texas University Press.
- Borrero, L. (1999). The prehistoric exploration and colonization of Fuego-Patagonia. *Journal of World Prehistory*, 13, 321–355.
- Borrero, L. A., & Martin, F. (1996). Tafonomía de Carnívoros: un Enfoque Regional. In J. Gómez Otero (Ed.), *Arqueología Solo Patagonia. Segundas Jornadas de Arqueología de la Patagonia* (pp. 189–198). Puerto Madryn: Centro Nacional Patagónico.
- Borrego, J., Monterde, J., Morales, J. A., Carro, B., & López, N. (2003). Morfología de la piritita diagenética en sedimentos recientes de estuario del Río Odiel (SO de España). *Geogaceta*, 33, 99–101.
- Bronk Ramsey, C. & Lee, S. (2013). Recent and planned developments of the program OxCal. *Radiocarbon* 55, 3–4.
- Brown, A., Ellis, C., & Roseff, R. (2010). Holocene sulphur-rich palaeochannel sediments: Diagenetic conditions, magnetic properties and archaeological implications. *Journal of Archaeological Science*, 37(1), 21–29.
- Cartajena, I., & López, P. (2008). Análisis de Arqueofauna, in ARKA Consultores 2008. Evaluación Arqueológica Subacuática Sitio GNL Quintero 1, Proyecto “Terminal de GNL en Quintero”, Comuna de Quintero, V Región de Valparaíso. September 2008.
- Cartajena, I., López, P., Carabias, D., Morales C., & Vargas, G. (2011). Arqueología Subacuática y Tafonomía: Recientes Avances en el Estudio de Sitios Finipleistocénicos Sumergidos en la Costa Pacífica de Chile Central. *Antípoda*, 13, 201–225.
- Cartajena, I., López, P., Carabias, D., Morales, C., Vargas, G., & Ortega, C. (2013). First evidences of an underwater final pleistocene terrestrial extinct faunal bone assemblage from central Chile (South America): Taxonomic and taphonomic analyses. *Quaternary International* 305, 45–55.
- Davis, L. G., Jenevein, S. A., Punke, M. L., Noller, J. S., Jones, J. A., & Willis, S. C. (2009). Geoarchaeological themes in a dynamic coastal environment, Lincoln and Lane counties, Oregon. In J. E. O’Connor, R. J. Dorsey, & I. P. Madin (Eds.), *Volcanoes to vineyards: Geologic field trips through the dynamic landscape of the Pacific Northwest* (pp. 331–348). Geological Society of America Field Guide 15.
- Dillehay, T. (2000). *The settlement of the Americas: A New prehistory*. New York: Basic Books.
- Dillehay, T. (2009). Probing deeper into first American studies. *Proceedings of the National Academies of Science of the United States of America*, 106(4), 971–978.
- Dixon, E. J. (2001). Human colonization of the Americas: Timing, technology and process. *Quaternary Science Reviews*, 20, 277–299.
- Dunbar, J., Webb, D., & Cring, D. (1989). Culturally and naturally modified bones from a Paleoindian site in the Aucilla River, North Florida. In R. Bonnichsen & M. Sorg (Eds.), *Bone modifications* (pp. 473–497). Orono: Peopling the Americas Publications, Center for the Study of the First Americans, University of Maine.
- Easton, N. A., & Moore, C. (1991). Test excavations of subtidal deposits at Montague Harbour, British Columbia. *International Journal of Nautical Archaeology*, 20, 269–280.
- Encinas, A., Hervé, F., Villa-Martínez, R., Nielsen, S., Finger, K. L., & Peterson, D. E. (2006). Finding of a Holocene marine layer in Algarrobo (33°22’ S), Central Chile. Implications for coastal uplift. *Revista Geológica de Chile*, 33, 339–345.
- Erlanson, J. M., Moss, M. L., & Des Lauriers, M. (2008). Life on the edge: Early maritime cultures of the Pacific coast of North America. *Quaternary Science Reviews*, 27, 2232–2245.
- Fairbanks, R. G. (1989). A 17,000-year Glacio Eustatic sea level record: Influence of glacial melting rates on the younger Dryas event and the deep ocean circulation. *Nature*, 342, 637–642.

- Faught, M. K. (2004). The underwater archaeology of Paleolandscapes, Apalachee bay, Florida. *American Antiquity*, 69(2), 275–289.
- Faught, M. K. (2008). Archaeological roots of human diversity in the new world: A compilation of accurate and precise radiocarbon ages from earliest sites. *American Antiquity*, 73, 670–698.
- Faught, M. K., & Gusick, A. (2011). Submerged prehistory in the Americas. In J. Benjamin, C. Bonsall, C. Pickard, & A. Fisher (Eds.), *Submerged prehistory* (pp. 145–157). Oxford: Ox-bow Books.
- Fedje, D. W., & Christensen, T. (1999). Modeling Paleoshorelines and locating early Holocene coastal sites in Haida Gwaii. *American Antiquity*, 64(4), 635–652.
- Fedje, D. W., & Johsenhans, H. (2000). Drowned forests and archaeology on the continental shelf of British Columbia, Canada. *Geology*, 28(2), 99–102.
- Fladmark, K. R. (1979). Routes: Alternative migration corridors for early man in North America. *American Antiquity*, 44, 55–69.
- Goebel, T., Waters, M., & O'Rourke, D. (2008). The late Pleistocene dispersal of modern humans in the Americas. *Science*, 319, 1497–1502.
- Gusick, A., & Faught, M. K. (2011). Prehistoric archaeology underwater: A nascent subdiscipline critical to understanding early coastal occupations and migration routes. In N. F. Bicho et al. (Eds.), *Trekking the shore: changing coastlines and the antiquity of coastal settlement* (pp. 27–50). New York: Springer.
- Hamilton, D. L. (1998). Methods of conserving underwater archaeological material culture. Conservation files: ANTH 605, conservation of cultural resources I. Nautical archaeology program, Texas A & M University, world wide web. <http://nautarch.tamu.edu/class/ANTH605>. Accessed Oct 2012.
- Haynes, G. (1983a). A guide for differentiating mammalian carnivores taxa responsible for gnaw damage to herbivore limb bones. *Paleobiology*, 9(2), 164–172.
- Haynes, G. (1983b). Frequencies of spiral and greenbone fractures on ungulate limb bones in modern surface assemblages. *American Antiquity*, 48(1), 102–114.
- Inman, D. L. (1983). Application of coastal dynamics to the reconstruction of paleocoastlines in the vicinity of La Jolla, California. In P. M. Masters and N. C. Flemming (Eds.), *Quaternary Coastlines and Marine Archaeology* (pp. 1–49). Academic Press, London.
- Jackson, D. (2003). Evaluating evidence of cultural associations of Mylodon in the semiarid region of Chile. In L. Miotti, M. Salemme, & N. Flagenheimer (Eds.), *Where the south wind blows: Ancient evidence of Paleo South American* (pp. 77–81). Austin: Center for the study of the first Americans, Texas University Press.
- Jackson, D., Méndez, C., & De Souza, P. (2004). Poblamiento Paleoindio en el Norte-Centro de Chile: Evidencias, Problemas y Perspectivas. *Complutum*, 15, 165–176.
- Jackson, D., Méndez, C., Seguel, R., Maldonado, R. A., & Vargas, G. (2007). Initial occupation of the Pacific coast of Chile during late Pleistocene times. *Current Anthropology*, 48(5), 725–731.
- Johnson, L., & Stright, M. (Eds.). (1992). *Paleoshorelines and prehistory: An investigation of method*. Boca Raton: CRC Press.
- Josenhans, H., Fedje, D., Pienitz, R., & Southon, J. (1997). Early humans and rapidly changing Holocene sea levels in the Queen Charlotte Islands-Hecate Strait British Columbia, Canada. *Science*, 277, 71–74.
- Kim, J., Schneider, R., Hebbeln, D., Muller, P., & Wefer, G. (2002). Last deglacial sea-surface temperature evolution in the southeast Pacific compared to climate changes on the south American continent. *Quaternary Science Reviews*, 21, 2085–2097.
- Lambeck, K., Esat, T. M., & Potter, E. K. (2002). Links between climate and sea levels for the past three million years. *Nature*, 419, 199–206.
- Leonard, E. M., & Wehmiller, J. F. (1991). Geochronology of marine terraces at Caleta Michilla, Northern Chile; Implications for late Pleistocene and Holocene uplift. *Revista Geológica de Chile*, 18(1), 81–86.
- López, P., Labarca, R., & Núñez, L. (2004). Nivel Quereo I: una Discusión Acerca del Poblamiento Temprano en la Provincia del Choapa: Revista. *Werkén*, 5, 15–20.

- López, P., Cartajena, I., Olivares, G., López, O., Carabias, D., & Morales, C. (2012). Aplicación de Microscopio Electrónico de Barrido (MEB) y Espectroscopia de Energía Dispersiva (EDS) para Distinguir Alteraciones Termicas en Restos Osteofaunísticos de un Sitio Sumergido del Pleistoceno Final de la Costa de Chile Central. In A. Acosta (Ed.), *Estudios Tafonómicos y Zoológico-arqueológicos* (II), Temas de Arqueología 3. Instituto Nacional de Antropología y Pensamiento Latinoamericano.
- Mandryk, C. A. S., Josenhans, H., Fedje, D. W., & Mathewes, R. W. (2001). Late quaternary Palaeoenvironments of northwestern North America: Implications for inland versus coastal migration routes. *Quaternary Science Reviews*, 20, 301–314.
- Masters, P. M. (1983). Detection and assessment of prehistoric artifact sites off the coast of southern California. In P. M. Masters & N. C. Flemming (Eds.), *Quaternary coastlines and marine archaeology* (pp. 189–213). London: Academic Press.
- Masters, P. M. & Flemming, N. C. (1983). *Quaternary coastlines and marine archaeology: Towards the prehistory of land bridges and continental shelves*. London: Academic Press.
- Masters, P. M. (1985). California coastal evolution and the La Jollans. *Oceanus*, 28, 27–33.
- Méndez, C., Jackson, D., & Seguel, R. (2004). Narrowing the spatial range of Megafaunal distributions on the semiarid coast of Chile. *Current Research in the Pleistocene*, 21, 109–111.
- Méndez, C. (2011). Tecnología Lítica en Poblamiento Pleistoceno Terminal del Centro de Chile. Organización, Gestos y Saberes. PhD thesis, Universidad Católica del Norte, Universidad de Tarapacá, Chile.
- Morales, C. (2008). Conservación y Catalogación de Materiales. In ARKA Consultores 2008. Evaluación Arqueológica Subacuática Sitio GNL Quintero 1. September 2008.
- Myers, T., Voorhies, M., & Georde, C. (1980). Spiral fractures and bone Pseudotools at Paleontological sites. *American Antiquity*, 45(3), 483–490.
- Noakes, S., Garrison, E., & McFall, G. (2009). Underwater Paleontology: Recovery of a prehistoric Whale mandible offshore Georgia. In N. W. Pollock (Ed.), *Proceedings of the American Academy of Underwater Sciences 28th Symposium* (pp. 245–251). Atlanta: American Academy of Underwater Sciences.
- Núñez, L., Varela, J., & Casamiquela, R. (1987). Ocupación Paleoindia en el Centro-Norte de Chile: Adaptación Circunlacustre en las Tierras Bajas. *Estudios Atacameños*, 8, 137–181.
- Núñez, L., Varela, J., Casamiquela, R., Schiappacasse, V., Niemeyer, H., & Villagrán, C. (1994a). Cuenca de Taguatagua en Chile: el Ambiente del Pleistoceno Superior y Ocupaciones Humanas. *Revista Chilena de Historia Natural*, 67, 503–519.
- Núñez, L., Varela, J., Casamiquela, R., & Villagrán, C. (1994b). Reconstrucción Multidisciplinaria de la Ocupación Prehistórica de Quereo, Centro de Chile. *Latin American Antiquity*, 5(2), 99–118.
- Ota, Y., & Paskoff, R. (1993). Holocene deposits on the coast of north-central Chile: Radiocarbon ages and implications for coastal changes. *Revista Geológica de Chile*, 20(1), 25–32.
- Richardson, J. B. III. (1981). Modeling the development of sedentary maritime economies in the coast of Peru. *Annals of Carnegie Museum*, 50, 139–150.
- Saheb, M., Neff, D., Dillmann, P. H., Matthiesen, H., & Foy, E. (2008). Long-term corrosion behaviour of low-carbon steel in anoxic environment: Characterisation of archaeological artefacts. *Journal of Nuclear Materials*, 379(1–3), 118–123.
- Sandweiss, D. (2003). Terminal Pleistocene through mid-Holocene archaeological sites as Paleoclimatic archives for the Peruvian Coast. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 194, 23–40.
- Spada, G., & Stocchi, P. (2007). SELEN: a fortran 90 program for solving the ‘Sea-Level Equation’, *Computers and Geosciences*, 33(4), 538–562.
- Stewart, D. J. (1999). The formation processes affecting submerged archaeological sites: An overview. *Geoarchaeology: An International Journal*, 14(6), 565–587.
- Stright, M. J. (1990). Archaeological sites on the North American continental shelf. *Geological Society of America, Centennial Special Volume* 4, 439–465.
- Stright, M. J. (1995). Archaic period sites on the continental shelf of north America: The effect of relative sea-level changes on archaeological site locations and preservation. In E. A. Bettis

- (Ed.), *Archaeological Geology of the Archaic Period in North America* (pp. 131–147). Geological society of America special paper 297.
- Valero Garcés, B., Jenny, B., Rondanelli, M., Delgado-Huertas, A., Burns, S., Veit, H., & Moreno, A. (2005). Palaeohydrology of Laguna Tagua Tagua (34°31' S) and moisture fluctuations in central Chile for last 46,000 yr. *Journal of Quaternary Science*, 20(7–8), 625–641.
- Vargas, G., & Ortega, C. (2008). Contexto Geomorfológico y Análisis Sedimentológico Preliminar de Muestras de la Bahía Quintero, V Región. Proyecto Terminal GNL Quintero, in ARKA Consultores 2008, *Evaluación Arqueológica Subacuática Sitio GNL Quintero 1*. September 2008.
- Villagrán, C., & Varela, J. (1990). Palynological evidence for increased aridity on the central Chile coast during the Holocene. *Quaternary Research*, 34, 198–207.
- Villa-Martínez, R., & Villagrán, C. (1997). Historia de la Vegetación de Bosques Pantanosos de la Costa de Chile Central Durante el Holoceno Medio y Tardío, *Revista Chilena de Historia Natural*, 70, 391–401.
- Waters, M. (1992). *Principles of Geoarchaeology: A north American perspective*. Tucson: University of Arizona Press.
- Waters, M. R. & Stafford, T. W. (2007). Redefining the Age of Clovis: Implications for the Peopling of the Americas, *Science* 23 Vol. 315 (5815), 1122–1126.