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Terminal Pleistocene through Mid-Holocene archaeological sites as paleoclimatic archives for the Peruvian coast

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Abstract

Along the Peruvian coast, standard paleoclimatic archives such as pollen cores or corals are absent or undeveloped. However, anthropogenic deposits offer paleoclimatic information for the last 13 000 years at temporal scales ranging from centennial for long-term records to seasonal for short-term records. This paper summarizes archaeologically based paleoclimatic data for the Peruvian coast from the Terminal Pleistocene through the Middle Holocene. South of 12°S, coastal waters have been cool–temperate and terrestrial conditions have been hyperarid for the entire period. Between 8000 and 3600 cal BP, the highland precipitation supplying runoff to the south coast may have diminished sufficiently to restrict human occupation of ephemeral streams. North of ~10°S, sea surface temperatures were warmer and seasonal precipitation may have been greater from prior to 13 000 to 5800 cal BP. From 9000 to 5800 cal BP, El Niño was absent or very infrequent. After 5800 cal BP, the northern coastal waters cooled and El Niño was present but with a lower frequency than seen in the historical and instrumental record. El Niño frequencies in the modern and historical range were established ~3000 cal BP. Cultural changes correlate temporally with these major climatic transitions.

Keywords: Peru; paleoclimate; archaeology; molluscs; fish

1. Introduction

Archaeological sites are not perfect archives of past climatic and environmental conditions. In addition to the taphonomic factors and interpretative uncertainties that affect all paleo-archives, anthropogenic deposits have additional filters resulting from the human capacity for selection, or 'cultural imprinting' (Rollins et al., 1990; Sandweiss, 1996a). Nevertheless, properly interpreted archaeological remains can shed light on past conditions. This task becomes urgent for the coast of Peru during the span of prehistoric human occupation (~13 000 cal BP to AD 1532), as corals do not grow in Peru, arid conditions have so far frustrated the search for pollen archives, cores from the continental shelf have critical hiatuses (DeVries and Pearcy, 1982; DeVries and Schrader, 1981) and/or their Terminal Pleisto-

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cene–Holocene segments have not been published in detail, and few other sources of paleoclimatic information have been developed. In this context, biological materials from archaeological contexts and other archaeological data offer useful and unique insights.

Paleoclimatic data from anthropogenic deposits are often buried in archaeological reports that focus on other issues, so this information is rarely accessed by paleoclimatologists in other disciplines. To rectify the problem for the Peruvian coast, this paper offers a new synthesis of the archaeological data on regional paleoclimate from the Terminal Pleistocene (∼13 000–11 000 cal BP), Early Holocene (∼11 000–9000 cal BP), and Mid-Holocene (∼9000–3000 cal BP)[1]. The conditions and trends identified or suggested from these data are useful not only as a paleoclimatic archive but also in the attempt to understand climatic influences on prehistoric cultural development (e.g. Sandweiss et al., 2001). I therefore point briefly to relevant cultural trends, especially during the Mid-Holocene.

2. Interpreting the archaeological record of climate

All paleoclimatic archives suffer from problems of preservation and interpretation; anthropogenic deposits are no different. For the last 13 000 years on the Peruvian coast, the faunal remains that provide most insight into past conditions are well-preserved and appear to represent what was originally deposited at the sites. The problem with the archaeological record that differentiates it from other, natural, paleoclimatic archives is the difficulty of modeling the processes that affect what humans collect and where they deposit it. In short, the decisions people make may not always be what we would consider to be rational.

Human decision-making creates the archaeological record of climate-dependent plants and animals through a series of stages (Sandweiss, 1996a). First, past individuals and groups had to select which organisms to collect from those naturally available. Second, they had to choose which of the collected organisms would be transported to the sites that archaeologists eventually excavate. Third, they had to decide how to process the organisms (different processing methods affect preservation potential) and where and how to deposit the unconsumed portions. At this point, natural and cultural taphonomic processes come into play. Effects of human decision-making continue into the present, as the archaeologist must select which portions of which sites to excavate, decide how to recover samples (e.g. mesh size for sieving), and choose what fraction of the recovered remains will be analyzed.

Despite these problems, the archaeological record does contain useful paleoclimatic information if properly and cautiously approached using the following principles. First, presence means much more than absence: people never collect and deposit every species available in their proximal environment, and they may decide to ignore organisms that we would consider logical choices. Second, before mass transportation became available, those species that are abundantly represented at an archaeological site will usually have been drawn from the proximal environment. Therefore, the climatic parameters that determine the viability of these species must have been met in the region at the time the site was occupied, unless those parameters have changed since deposition (∼13 000 years for this study). Further, the skeletal remains of the marine fauna that form the core of this study often contain a geochemical record that can be used as an independent check on inferences drawn from habitat analogy.

Other kinds of archaeological data can provide climatic information. Settlement patterns – the distribution of archaeological sites across a landscape – depend in part on physical conditions. Sites may contain well-preserved and easily dated sedimentary or soil signatures of past conditions,

[1] For this paper, I have converted radiocarbon ages to calendar ages using Calib 4.3 (Stuiver et al., 1998a,b) and taking the approximate mid-point. With the exception of some of the dates from Siches and Quebrada Jaguay 280, all of the radiocarbon dates are published in the cited references. Dates on marine shells were adjusted using the regional mean of DR for Peru and central Chile from the online Marine Reservoir Correction Database compiled by P. Reimer (http://depts.washington.edu/qil/marine/).

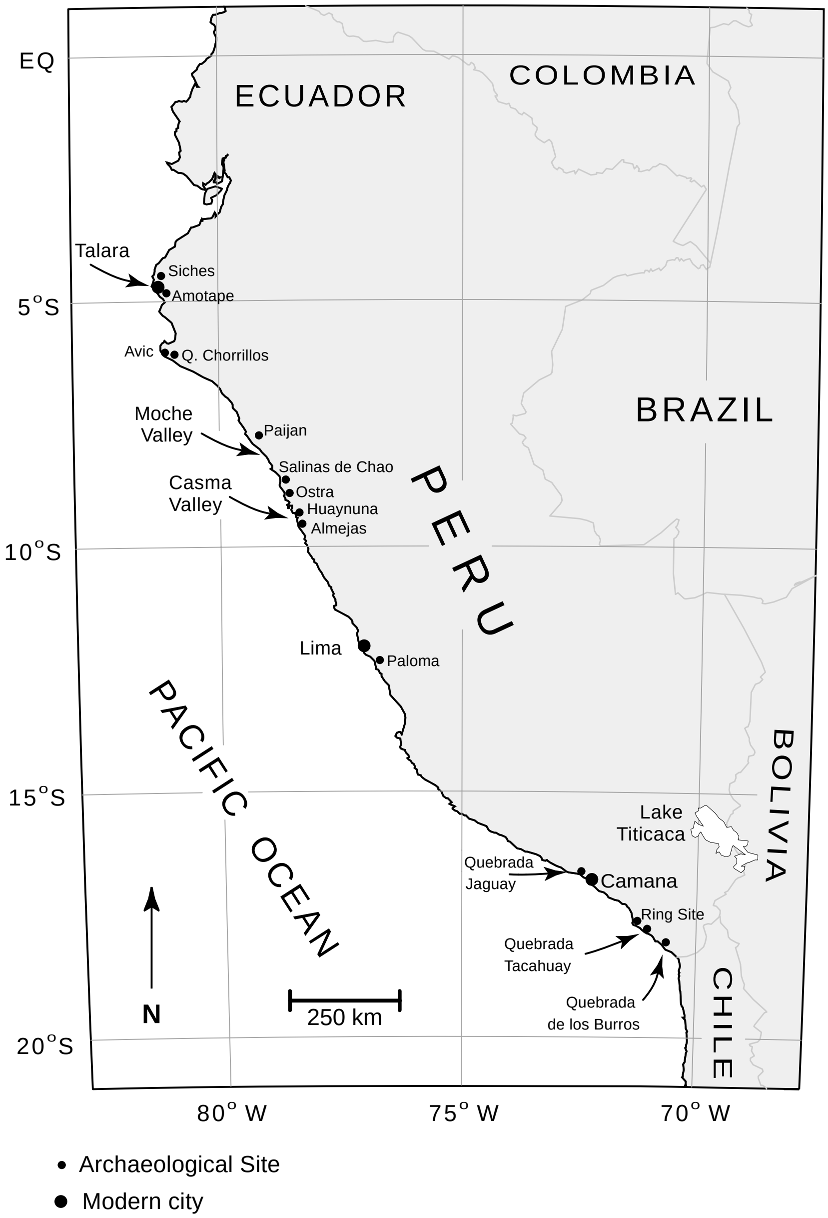

Fig. 1. Major sites and places mentioned in the text.

such as El Niño flood deposits. Finally, artifacts can indicate connections between peoples sharing similar environments and adaptations.

3. The Peruvian coast

The Peruvian coast lies entirely within the tropics but is far from a typical tropical shore (Fig. 1). Trending NW to SE from about 3°25′S at the Ecuadorian border to 18°20′S at the frontier with Chile, the coastal plain today is arid even in its northern reaches. Aridity increases with latitude, and southern Peru is an extension of the Atacama Desert. Desertic conditions result mainly from the influence of the cold Peru (Humboldt) Current to the west and the rainshadow effect of the Andes to the east. In the modern system, 'normal' dry conditions are interrupted at irregular intervals by pluvial episodes associated with El Niño Southern Oscillation (ENSO) events of varying intensity. Instrumental, historical (e.g. Quinn et al., 1987), and paleoclimatic (e.g. Sandweiss et al., 2001) records indicate that ENSO frequency has varied throughout the Holocene; since 1976, ENSO has had a short recurrence interval of 3–7 years.

In addition to the archaeological data discussed below (Sections 4–6), several records indicate that the Peruvian coast south of 12°S has been hyperarid for much longer than people have lived in South America. Noller's (1993) study of Quaternary soil development along the coast shows a major disjunction at 12°S. South of that point, the absence of significant soil development and the presence of soluble minerals and salts indicate long-term hyperaridity. North of 12°S, greater soil development and the absence of significant salt accumulations document periodic rainfall events. Noller's soil record is consistent with the patterns of endemism and adaptation in *lomas* (fog-based) plant communities in the western foothills of the Andes, overlooking the coast. Rundel and Dillon (1998; Rundel et al., 1991) identify northern and southern Peruvian *lomas*-flora units with a boundary at 12°S. The southern unit, with a high degree of endemism in each *lomas* stand, indicates long-term hyperaridity. The northern unit shows greater similarities between now-isolated *lomas* stands, suggesting periods of greater moisture in the past, when the *lomas* were continuous. North of 12°S, the archaeological record supports and adds detail to the indications of more humid conditions indicated by the soils and *lomas* plants, despite statements to the contrary by some authors (DeVries et al., 1997; Wells and Noller, 1997, 1999; Wells, 2001). Prior to 5800 cal BP, sites north of 12°S, and especially north of 10°S, do not have well-preserved soft organic tissues such as plant fibers, wool, hair, skin, or wood. In contrast, many Early, Middle, and Late Holocene sites south of 12°S have soft organic tissues, as do sites north of that point that date after 5800 cal BP (Sandweiss et al., 1997). Local rainfall would account for most destruction of such tissues, so the preservation record also points to increased aridity north of 12°S beginning at 5800 cal BP.

4. Terminal Pleistocene (~13 000–11 000 cal BP) and Early Holocene (~11 000–9000 cal BP)

Due to lower sea levels during the Terminal Pleistocene through Early Holocene and the presumed location of many early archaeological sites on the now-drowned continental margin, archaeological information on early Peruvian coastal climate is scarce. Furthermore, this period has not attracted the same research effort as later periods. However, recent site-survey strategies stressing areas of narrow shelf (Richardson, 1981) have led to the discovery of several maritime-adapted, Paleo-Indian (Terminal Pleistocene) sites on the Peruvian coast. Coupled with prior studies of sites in interior coastal plain settings, these new discoveries point to diverse lifeways and variable climate during the early human settlement of western South America. I review these sites from north to south. Here and throughout this paper, see Fig. 1 for locations of important sites and places. They are listed in Table 1.

4.1. Amotape (4°40′S)

In the early 1970s, near Talara in far northern Peru, Richardson discovered the Amotape campsites, with dates on molluscs between ~13 000 and 9000 cal BP. These campsites overlook a significant terrestrial hunting resource, the Talara Tar Seeps, but until a stratified Amotape site is discovered and excavated, we know little about these people beyond their limited lithic assemblage and the presence of marine shells in their middens (Richardson, 1978). The molluscs are a mangrove species (*Anadara tuberculosa*), suggesting warmer and wetter conditions along the adjacent shoreline. The Tar Seeps contain faunal remains recovered by the Royal Ontario Museum, Toronto, and dated on bone to around 16 700 cal BP. Identified species include mastodons, other large mammals, birds, and insects. The mammals

Table 1
Summary of archaeological sites and reconstructed climatic conditions discussed in the text for the Peruvian coast from the Terminal Pleistocene to the Mid-Holocene

Site	Terminal Pleistocene	Early Holocene	Mid-Holocene		Basic references
			Mid-Holocene I	Mid-Holocene II	
(S lat)	(~13 000–11 000 cal BP)	(~11 000–9000 cal BP)	(~9000–5800 cal BP)	(~5800–3000 cal BP)	
Siches (4°30′ S)	–	–	Warmer SSTs/seasonal precipitation/no ENSO	Cool SSTs (modern)	Sandweiss et al., 1996; Andrus et al., 2002
Amotape (4°40′S)	Warmer SSTs/less arid	Warmer SSTs/less arid	–	–	Richardson, 1978
Quebrada Chorrillos (6°S)	–	–	Warmer SSTs/no ENSO	–	Cárdenas et al., 1993
Avic (6°S)	–	–	–	Cool SSTs (modern)	Cárdenas et al., 1993
Paiján (8°30′)	Warmer SSTs/less arid	Warmer SSTs/less arid	–	–	Chauchat et al., 1992
Moche Valley Late Preceramic/Initial Period sites (8°10′S)	–	–	–	Cool SSTs (modern)/low frequency ENSO	Pozorski, 1979
Salinas de Chao (8°40′S)	–	–	–	Cool SSTs (modern)/low frequency ENSO	Sandweiss et al., 1996
Ostra (8°55′S)	–	–	Warmer SSTs/seasonal precipitation/high amplitude seasonal SST cycle/no ENSO	–	Sandweiss et al., 1996; Andrus et al., 2002
Huaynuná (9°30′S)	–	–	–	Cool SSTs (modern)/low frequency ENSO	Pozorski and Pozorski, 1990
Casma Valley Late Preceramic/Initial Period sites (9°30′S)	–	–	–	Cool SSTs (modern)/low frequency ENSO	Pozorski and Pozorski, 1987
Almejas (9°40′S)	–	–	Warmer SSTs/no ENSO	–	Pozorski and Pozorski, 1995
PV 35-106 (10°S)	–	–	Slightly warmer SSTs?	–	Bonavia, 1996
PV 35-6 (10°S)	–	–	–	Cool SSTs (modern)/low frequency ENSO	Bonavia et al., 1993
Los Gavilanes (10°S)	–	–	–	Cool SSTs (modern)	Bonavia, 1982
As8 (10°45′S)	–	–	Slightly warmer SSTs?	–	Feldman, 1980
Aspero (10°45′S)	–	–	–	Cool SSTs (modern)/low frequency ENSO	Feldman, 1980
Caral (10°45′S)	–	–	–	Cool SSTs (modern)/low frequency ENSO	Shady et al., 2001
Paloma (12°30′S)	–	–	Cool SSTs (modern)		Reitz, 1988
Quebrada Jaguay (16°30′S)	Cool SSTs (modern)/greater highland precipitation?	Cool SSTs (modern)/greater highland precipitation?	Very arid (reduced highland precipitation?) ~8100–3500 cal BP		Sandweiss et al., 1998
Ring Site (17°40′S)	Cool SSTs (modern)	Cool SSTs (modern)	Cool SSTs (modern)	–	Sandweiss et al., 1989
Quebrada Tacahuay (17°48′S)	Cool SSTs (modern)/ENSO floods	Cool SSTs (modern)	Cool SSTs (modern)/No ENSO floods	Cool SSTs (modern)/ENSO floods late	Keefer et al., 1998; deFrance et al., 2001
Quebrada de los Burros (18°00′S)	–	Cool SSTs (modern)	Cool SSTs (modern)/No ENSO floods	Cool SSTs (modern)/ENSO floods late	Fontugne et al., 1999; Lavallée et al., 1999b

The Basic references column lists the core publications providing data for each site; see text for further references and discussion.

would have required more water and vegetation than today, while the insects include species that live in pools of standing water (Lemon and Churcher, 1961; Churcher, 1966). Perhaps El Niño events periodically extended the range of these terrestrial species and the mangrove molluscs from some adjacent wetter place, but Campbell's (1982) analysis of the avifauna associated with the dated material suggests a climate marked by seasonal precipitation at the Tar Seeps locale at 16 700 cal BP. The location of the Amotape sites overlooking the Tar Seeps suggests that local conditions continued to sustain edible animals through the Terminal Pleistocene.

4.2. Paiján (8°30′S)

Excavated largely by Chauchat and associates (Chauchat, 1988; Chauchat et al., 1992), the Paiján sites of northern Peru offer information on Terminal Pleistocene people living in the interior coastal plain, a geographic setting that is not often found farther south. Because here the shelf is wide, no Terminal Pleistocene shoreline sites have been found in this area. Certainly such sites must have existed. The Paiján camps are 15 km or more from the modern shore, and they would have been over 25 km inland when first occupied. Still, these sites contain small quantities of marine fish bone, indicating contact with the shore. Given the distance, either the Paiján people spent time on the coast, or they were in contact with shoreline settlements.

The Paiján sites are part of an early hunting complex that dates between about 12 400 and 9000 cal BP (Chauchat, 1988, p. 59; see also Chauchat, 1992, p. 340). Wing (1986; see also Chauchat et al., 1992) identified the vertebrate remains from some of the Paiján sites excavated by Chauchat: 7% of the Minimum Number of Individuals (MNI)[2] are terrestrial mammals, 74% are lizards and snakes, 3% are birds, and 16% are fishes. The terrestrial mammals are primarily rodents. Chauchat (Chauchat et al., 1992; Pelegrin and Chauchat, 1993) recognizes the faunal assemblage as indicative of less arid conditions than present. At the Paiján site of La Cumbre, Ossa and Moseley (1972) found the remains of mastodons and horses, but in a stratum different from that containing the human artifacts (Chauchat, 1988). However, two dates on mastodon bone apatite, ∼12 600 and 14 300 cal BP (Ossa and Moseley, 1972), may indicate that megafauna survived in this region into the Terminal Pleistocene. Other Late Pleistocene megafaunal remains have been recovered from the area, but not in association with archaeological material (Chauchat, 1988; Pelegrin and Chauchat, 1993). Like the smaller animals recovered from Chauchat's excavations, these large mammals suggest wetter conditions than at present at least as far south as 8°S during the Terminal Pleistocene.

The terrestrial animals actually found at the Paiján sites are largely those that live in the area today. However, Reitz's analysis of the fish shows that tropical fishes constitute 97% of the fish MNI and temperate/Peru Current fishes constitute 3% (Reitz and Sandweiss, 2001; Sandweiss et al., 1996). Today, this section of the coast is dominated by Peru Current species.

4.3. Quebrada Jaguay (16°30′S)

Faunal remains or other reliable archaeological indicators of climate have not been reported for the Terminal Pleistocene and Early Holocene from the central Peruvian coast. In southern Peru, Quebrada Jaguay 280 is a Terminal Pleistocene and Early Holocene fishing settlement located 2 km from the modern shoreline on the banks of an ephemeral stream. The site was found by Frederic Engel (1981) in 1970 and excavated in 1996 and 1999 by teams under my direction. Twenty-five Terminal Pleistocene dates (23 conventional dates on charcoal and two AMS dates on wood) range from ∼11 200 to 13 250 cal BP, and seven conventional charcoal assays fall between 10 500 and 11 200 cal BP. These dates generally accord with site stratigraphy, as do six early Mid-Holocene dates between ∼8300 and 9000 cal BP (four conventional dates on charcoal and two AMS dates on gourd rind) (Sandweiss et al., 1998 and unpublished dates and notes).

Both the Terminal Pleistocene and Early Holocene deposits show an overwhelming emphasis on marine sources of animal food. For all periods, over 99% of the molluscs are *Mesodesma donacium*, a cool-water[3], Peru Current species. Ninety-seven percent of the identified fish remains are Sciaenids, or drums, also indigenous to the Peru Current, as are virtually all the other identified fish (Sandweiss et al., 1998; McInnis, 1999).

Botanical data from Quebrada Jaguay 280 are limited. For the Terminal Pleistocene deposit, Cano (pers. commun. and Sandweiss et al., 1999b) was able to identify the majority of macrobotanical remains only as dicots or monocots. However, he did find several fragments of prickly pear seeds (*Opuntia* cf. *ficus-indica*), which suggest

[2] MNI refers to the lowest possible number of individual animals necessary to account for the skeletal elements recovered in a given context (Reitz and Wing, 1999, p. 194). For instance, three left valves and two right valves of a bivalve mollusc species would signify a MNI of 3.

[3] In this paper, 'cool-water' refers to warm–temperate conditions, while 'warm-water' refers to warm–tropical conditions (Reitz and Sandweiss, 2001).

interaction with higher elevations where *Opuntia* occurs naturally today. Prickly pear seeds were far more common in the Early Holocene deposits, which also yielded small quantities of other plant macrofossils. Analyzing site-sediment samples for microbotanical remains, Piperno (pers. commun.) found only one starch grain in the Terminal Pleistocene deposits; phytoliths were present but in poor condition and mixed with marine diatoms, presumably wind-blown. Pollen has yet to be analyzed.

Terminal Pleistocene strata in Sector II at Quebrada Jaguay 280 contain coherent posthole patterns, hearths, a final-reduction-stage lithic assemblage, and a possible storage unit. These data indicate that this sector was once the locus of a domestic structure, rebuilt on the same spot several times during the millennium just prior to the Holocene. The Early Holocene occupants of the site also built a house, though of a different pattern. Because house building suggests extended occupation of the site, this raises the issue of water, a critical resource in this desert setting. Today, Quebrada Jaguay flows only for a few days to weeks during the austral summer. The nearest modern springs are over 5 km from the site. Was the flow greater or more regular during the Terminal Pleistocene and Early Holocene, or did the site's inhabitants access some other source of water? Our archaeological survey of the immediate region indicates that Quebrada Jaguay was the only site occupied during the Terminal Pleistocene, when obsidian indicates contact with the highlands. This pattern suggests that water was limited to the Quebrada bed and that the site's inhabitants may have spent part of the year in the adjacent highlands. In the Early Holocene, there was a sudden explosion of small sites in the hills around the Quebrada, at a time when sedimentary analyses farther south at Quebrada de los Burros indicate intensified winter fog (Fontugne et al., 1999; see Section 6.5) that would have enhanced *lomas* growth and perhaps the accumulation of surface water. Just prior to 8000 cal BP, however, the region was apparently abandoned until around 3600 cal BP (Sandweiss et al., 1998). This hiatus coincides with the so-called 'archaeological silence' of northern Chile that some have blamed on a decrease in available water (e.g. Grosjean et al., 1997; Núñez et al., 2002; cf. e.g. Betancourt et al., 2000) (see Section 6.2).

4.4. Ring Site (17°40′S)

Located just south of Ilo in southern Peru, the Ring Site is a deep, well-stratified shell midden originally topped by a large ring of shells and other debris removed by local mining prior to our research. (Subsequently, the entire site was destroyed by road building and garbage deposition.) During the 1980s, test excavations by Richardson and I in the surviving lower strata produced seven radiocarbon dates ranging from ~11 200 to 5900 cal BP (Sandweiss et al., 1989). From the earliest stratum upward, the faunal remains indicate an overwhelming emphasis on maritime food sources: fish, shellfish, echinoderms, crustaceans, marine mammals, and birds (mostly seabirds). Of a total MNI of 436 for the identified bones from Unit C at the Ring Site, only 4 (all small mice) represent terrestrial mammals. Only 2.5% of the vertebrate faunal remains by MNI are from tropical species; in other words, the fish, sea mammals, and birds suggest coastal conditions much like today during the occupation of the site. The molluscs, too, are cool-water species typical of the Peru Current (Sandweiss et al., 1989; Reitz and Sandweiss, 2001). Uncharred plant remains were not preserved at the site, and charred plant parts did not include identifiable macrofossils. Microbotanical analyses were not done.

4.5. Quebrada Tacahuay (17°48′S)

Just south of the Ring Site, Keefer et al. (1998) have found Terminal Pleistocene archaeological deposits exposed in profiles along the Quebrada Tacahuay. Charcoal dates range from ~12 000 to 12 900 cal BP (deFrance et al., 2001). The excavations have produced a substantial vertebrate faunal assemblage emphasizing fish and seabirds, as well as some molluscs. The species are typical of the Peru Current today. No information is yet available on plant use. A substantial flood deposit overlies the Terminal Pleistocene archaeological deposits, suggesting ENSO-like conditions shortly before 11 000 cal BP.

4.6. Summary of Terminal Pleistocene–Early Holocene paleoclimate

This brief survey of information on the Terminal Pleistocene–Early Holocene human occupation of the Peruvian coast points mainly to the large gaps still existing in the archaeological record. Some of the problems, such as the lack of shoreline sites in the Paiján region, are largely beyond remedy. Others, such as the paleohydrology of southern Peru, can potentially be resolved. From the existing evidence, several patterns do emerge.

Subsistence systems evidenced in the coastal sites range from mixed hunting–gathering–fishing economies in the north to ones focused on fishing alone in the south. This apparent latitudinal gradient may respond to changes in vegetation and the size of the coastal plain from north to south. However, minimal evidence for plant use may well result from problems of preservation – shells and bones tend to preserve much better than plant macrofossils. More attention to microbotanical remains may help with this problem. We are also hampered by the lack of a complete set of sites (coast and interior) from a single seasonal round (that is, sites occupied by a single group as it moved seasonally between different resource zones).

Like human subsistence, climate shows diversity along a marked latitudinal gradient. This is hardly surprising. Northern sites indicate greater coastal precipitation and probably warmer sea surface temperatures (SSTs) than today, while southern sites indicate SSTs in the modern range and perhaps greater seasonal flow from the adjacent highlands. Flood events at Quebrada Tacahuay and Quebrada de los Burros (Fontugne et al., 1999) may signal ENSO-like phenomena in the Terminal Pleistocene and Early Holocene.

5. Mid-Holocene climatic transitions in northern Peru (~9000–3000 cal BP)

Coastal populations in Peru grew through time (e.g. Rick, 1987) and consequently created more and larger archaeological sites. Combined with the stabilization of sea level during the Mid-Holocene, this demographic trend resulted in an increasing number of sites preserved for analysis.

5.1. ENSO onset (~5800 cal BP)

The most significant climatic change recorded in archaeological deposits along the Peruvian coast is the shift at about 5800 cal BP from warmer mean annual SSTs and, presumably, greater seasonal precipitation north of ~10°S to conditions more closely resembling modern. My colleagues and I have suggested that this change reflects the onset (or at least a marked increase in frequency) of ENSO after a hiatus of at least three millennia (Rollins et al., 1986; Sandweiss et al., 1996). This interpretation accords with many other paleoclimatic archives and some modeling exercises for the tropical Pacific (see references in Sandweiss et al., 1996, 1997, 2001). More recently, we have noted another climatic change around 3000 cal BP, from less to more frequent ENSO events (Sandweiss et al., 2001). Both of these climatic changes are correlated with important cultural modifications.

I begin this section by reviewing data from sites that demonstrate the change from warmer than modern to modern SSTs that we have linked to the onset of ENSO at 5800 cal BP. I then discuss sites that show the increase in ENSO frequency at 3000 cal BP.

5.1.1. Siches (4°30′S)

Siches is the only site known from northern Peru that spans the climatic transition at 5800 cal BP. Though discovered in the 1920s by a petroleum geologist (Barrington Brown, 1926), it was Richardson (1973, 1978) who first recognized that the deposits record climatic change. In 1995 and 2001, Richardson and I excavated at Siches to recover samples of invertebrate and vertebrate faunal remains from well-dated contexts. Based on the 1995 results, Area I at Siches dates primarily between ~5200 and 5900 cal BP (the climatic transition), although one date from the basal level was ~6600 cal BP. Area II dates to ~7400–8400 cal BP, well before the 5800 cal BP climatic transition.

Siches is the type site for the phase of the same name, dated to 9000–5800 cal BP; the subsequent phase is labeled Honda and dates to 5800–3800 cal BP (Richardson, 1978, 1998). Sites of the Siches phase contain warm-water molluscs including the same mangrove species found in the Terminal Pleistocene–Early Holocene Amotape campsites in the same region (Section 4.1), while sites of the Honda phase have cooler-water species found in the region today. At the Siches site, molluscs from Area II and the basal level of Area I (Siches phase) are an unmixed warm assemblage. The upper levels of Area I that date around the climatic transition (early Honda phase) have a mixed molluscan fauna including tropical, eurytopic, and cooler-water species. Reitz's analysis of the vertebrate fauna from the Siches site also indicates a predominantly tropical assemblage throughout the occupation, with 83% tropical species (Reitz, 2001; Sandweiss et al., 1996). Recently, Andrus has analyzed $\delta^{18}O$ from seasonal growth increments in sea catfish (*Galeichthys peruvianus*) otoliths from Area II at Siches. Calibrated by reference to values recorded in modern otoliths from the same species in the same region, collected live in the 1990s, the results suggest that ~7400 years ago, mean annual SST near Siches was ~2–3°C warmer than at present but with a seasonal amplitude similar to modern (Andrus et al., 2002).

5.1.2. Quebrada Chorrillos and Avic (6°S)

Cárdenas et al. (1992, 1993) report a series of sites on the Illescas Peninsula at 6°S, on the west margin of the Sechura Desert. Quebrada Chorrillos 1 has dates of ~7750 and 8350 cal BP and contains a warm-water molluscan fauna very similar to that of Siches, including mangrove species (*Anadara tuberculosa* and *A. grandis*). Cool-water molluscs are absent. In contrast, Avic 2 dates between ~3950 and 5600 cal BP and contains a cool-water molluscan fauna typical of post-5800 cal BP sites in northern Peru (see Section 5.2). The investigators do not report data on vertebrate fauna, but the molluscs show the same transition as at Siches.

5.1.3. Ostra (8°55′S) and Salinas de Chao (8°40′S)

The Ostra complex sites lie on the shores of a now-dry embayment. In 1980, I first noticed that the sites contain a molluscan assemblage consisting of species characteristic of present-day Ecuador (more than 4° latitude farther north) and eurytopic species that tolerate a wide range of conditions. The same species of molluscs were found by colleagues Rollins, Richardson and me in living position in the former bay, indicating that the sites' molluscan contents came from the adjacent shoreline (Sandweiss et al., 1983; Rollins et al., 1986). We also visited another series of sites at Salinas de Chao, a second dry embayment some 20 km farther north. The earliest of these sites dates between ~3700 and 5350 cal BP and contains only cold-water molluscs characteristic of Peru and Chile today (Sandweiss et al., 1983). The similarity in the timing and nature of the changes seen at Ostra/Salinas de Chao and (in Richardson's earlier work) at Siches/Honda led us to publish the first version of the Mid-Holocene ENSO onset hypothesis (Rollins et al., 1986).

Subsequently, DeVries and Wells (1990) suggested that the presence of a warm-water molluscan fauna at the Ostra sites might be due to solar warming in a completely enclosed lagoon, rather than to a change in ocean circulation. The idea of anything living in a completely enclosed lagoon seems unlikely – at this latitude and in the absence of annual rainfall, such a lagoon would rapidly go hypersaline and then dry up completely. Today, rainfall is absent along this part of the cool-water Peruvian coast except during warm-water El Niño events, so the DeVries/Wells model precludes annual rainfall. Nevertheless, to test the idea of warm water only behind a barrier, with cold water immediately offshore of the barrier, I returned to the Ostra sites in 1991 to recover a more extensive and better-dated collection of fish as well as molluscs. The Ostra Base Camp site yielded well-preserved faunal remains and artifacts dated by associated charcoal to between ~6250 and 7150 cal BP. As the prior research had indicated, over 99% of the molluscan assemblage consisted of warm-water or eurytopic species, while over 60% of the vertebrate fauna was also tropical (Sandweiss, 1996b; Sandweiss et al., 1996; Reitz and Sandweiss, 2001). Non-carbonized plant remains were not preserved at this site; Cano and LaTorre (1992) analyzed the carbonized macrobotanical remains and found that the few identifiable specimens were almost all leguminous tree fruits, both huarango (*Acacia* spp.) and algarrobo (*Prosopis* spp.). These species shed little light on climatic change, as both taxa are widely distributed through tropical South America. Microbotanical remains from this site have not been studied.

Andrus has analyzed $\delta^{18}O$ in seasonal increments of *Galeichthys peruvianus* otoliths from Ostra, as at Siches; the Ostra results indicate a ~2–3°C warmer mean annual SST and a higher-amplitude seasonal cycle compared to today (Andrus et al., 2002).

At Ostra Base Camp, we found cultural evidence for interaction between the site's inhabitants and people to the north in warm–tropical Ecuador, rather than with human groups of the cool-water coast south of Ostra. After the cooling of the northern Peruvian coast at 5800 cal BP, most evidence for long-distance interaction in the Ostra area is with the inhabitants of the regions to the north and south dominated by the Humboldt Current (Sandweiss, 1996b).

5.1.4. Almejas (9°40′S) and Huaynuná (9°30′S)

Dated to ~7800 cal BP, Almejas is the only other known pre-5800 cal BP coastal site north of 10°S that contains an identified faunal assemblage. There, too, the molluscs and fish indicate warmer conditions than at present, although quantitative data have not been published (Pozorski and Pozorski, 1995). At Huaynuná, some 15 km to the north, deposits dated between ~4750 and 3650 cal BP contain typical cold-water species (Pozorski and Pozorski, 1987, 1990).

5.1.5. Sites between 10° and 12°S

The scant data available for the region between 10° and 12°S suggest generally cool but transitional SSTs prior to 5800 cal BP, while sites south of 12°S have the same suite of species that characterize the region today and are consistent with the presence of the Humboldt Current at those latitudes (and, consequently, with hyperaridity on shore; see Section 3). After 5800 cal BP, the faunal assemblages may vary but they remain representative of cool waters along the entire Peruvian coast.

In the Huarmey Valley, at 10°S, Bonavia has excavated a series of preceramic sites. Only PV 35-106, at 7300 cal BP, dates before 5800 cal BP (Bonavia, 1996). Details of mollusc and fish identifications are not given except for a chiton said to be the most common species in the assemblage; this species (*Enoplochiton niger*) is found today from northern Peru (7°S) south through much of Chile (Alamo and Valdivieso, 1987). Late Preceramic sites are better reported. PV 35-6, dated about 4400 cal BP, has a fully cool-water molluscan assemblage in which the most abundant bivalve is *Choromytilus chorus* (see Section 5.2) (Bonavia et al., 1993). The identified fish from this site are also predominantly cool-water. At nearby Los Gavilanes (PV 35-1), dated between ~3400 and 4650 cal BP (using the dates accepted by the excavator), the molluscs were almost entirely cool-water: the one warm-water species (*Ostrea megadon*) identified constituted only 0.01% by weight of the molluscan assemblage from the final of three epochs and was absent altogether in the other epochs (Bonavia, 1982). Vertebrate remains include 15 species that can be assigned to the cool-water Humboldt Current, while four are tropical (Reitz and Sandweiss, 2001); the vertebrate data are not quantified in a way that would allow exact comparison with the other sites reviewed here, but the overall assemblage is clearly cool-water.

Located at 10°45′S, the Supe Valley also has several well-studied preceramic sites. The oldest is Site As8, with a date of ~6800 cal BP (Feldman, 1980). The molluscan assemblage is typical of the cool-water Humboldt regime, but two particularly warm sensitive species (*Mesodesma donacium* and *Choromytilus chorus*, see Section 5.2) are minimally represented (< 2% of identified shell remains by weight). In contrast, at the adjacent shoreline site of Aspero (~4300–5000 cal BP with one outlier at ~5600 cal BP) these two species account for over 50% of the identified molluscan remains in two of the three quantified samples, and *M. donacium* is the top-ranked species in all three samples. At the partially contemporary site of Caral (~4000–4600 cal BP), 23 km up the Supe Valley from the shore, the same two species were the most prominent of the abundant shells (Shady et al., 2001). The dramatic increase in abundance of *C. chorus* and *M. donacium* after 5800 cal BP suggests that in the millennia prior to that time the Supe sector of the coast was slightly warmer, or more frequently warmed, than it was later.

5.1.6. Summary of 5800 cal BP climatic change

The archaeological data for northern Peru between ~5800 and 9000 cal BP do not specifically address ENSO frequency, although they do indicate warmer annual SSTs than today that were probably associated with changes in ENSO. Since our initial publication of the El Niño onset hypothesis (Rollins et al., 1986), many paleoclimatic archives throughout the Pacific Basin have provided support for the inference of a significant climatic change at about 5800 cal BP, and/or a lack of El Niño-like variability for some millennia prior to that date (see references in Sandweiss et al., 1996, 1997, 2001; also Riedinger et al., 2002).

Whether ENSO actually shut down prior to 5800 BP or simply was much less frequent, something certainly changed in tropical Pacific climate at that time. Culturally, this transition is marked in the archaeological record by the first construction of large temple mounds along the Peruvian coast, and by other notable changes in many, though not all, of the Mid-Holocene societies ringing the Pacific Basin (Sandweiss et al., 1999a).

5.2. ENSO frequency change (~3000 cal BP)

After 5800 cal BP, the warm-adapted mollusc species at northern Peruvian sites were replaced by a temperate molluscan assemblage characteristic of present-day southern Peru and northern Chile; this assemblage continued during the Late Preceramic and Initial Periods (to about 3000/2800 cal BP). After this time, the most temperature-sensitive of these species (*Choromytilus chorus*, *Mesodesma donacium*) disappeared from middens between 9° and 7°S, and over the following centuries were largely replaced by the smaller, more eurytopic surf clam *Donax obesulus*. Modern behavior of *C. chorus* and *M. donacium* suggests that they would be present in northern Peru only under conditions of cool water and diminished frequency of strong El Niño events (see Sandweiss et al., 2001 for details). *M. donacium* and *C. chorus* are not reported north of Casma (9°30′S) in recent times.

The following subsections discuss the sequence of molluscan assemblages from archaeological sites in three north Peruvian coastal valleys. Identified molluscan assemblages from other north coast valleys show the same trend, but complete temporal sequences from these valleys are not yet available.

5.2.1. Moche Valley (8°10′S)

As part of her dissertation research, S. Pozorski (1979) identified faunal remains from a chronological cross-section of sites in the Moche Valley, spanning the Late Preceramic Period to the Late Horizon (~5800 to 400 cal BP). No Early or Middle Preceramic (13 000–5800 cal BP) sites are known from the Moche Valley proper, though some Early Preceramic sites are found inland on the valley margins.

Two sites in the Pozorski sample date to the Late Preceramic Period (5800–4100 cal BP) and two to the Initial Period (4100–2800 cal BP). *Choromytilus chorus* ranked number 1 among animals consumed at the Late Preceramic sites and 2 and 3, respectively, at the Initial Period sites. The sample does not include any sites of the subsequent period (Early Horizon, 2800–2150 cal BP), but by the Early Intermediate Period (2150–1300 cal BP) *C. chorus* was virtually absent and *Donax obesulus* had become noticeable although it was not dominant in the diet until later in the sequence.

5.2.2. Salinas de Chao (8°40′S)

The Salinas de Chao is a stranded embayment 75 km southwest of the Moche Valley. Los Morteros is the oldest site in this region, with dates between 5350 and 3700 cal BP (see above, Section 5.1.3) (Cárdenas, 1995, 1999; Sandweiss et al., 1983). The molluscan assemblage at this site is entirely cool-water. Although quantitative data are not available, *Choromytilus chorus* is present and *Mesodesma donacium* is abundant. Cárdenas (1999) reports several other sites in the same time range with similar molluscan assemblages, including the large, complex Late Preceramic site of Salinas de Chao (~3500–3800 cal BP) (see also Alva, 1986; Sandweiss et al., 1983).

In contrast to the assemblages containing *Choromytilus chorus* and *Mesodesma donacium*, we found one site (Site C in Sandweiss et al., 1983) with a surface assemblage lacking those species and consisting almost entirely of *Donax obesulus* and another sand-dwelling bivalve. In Sandweiss et al. (2001), we report Site C as Initial Period, based on the single date on a marine shell. However, we had failed to use the marine reservoir correction in our calibration, and the date is actually 2450 cal BP, squarely in the Early Horizon. This age is even more consistent with the interpretation of the disappearance of *C. chorus* and *M. donacium* as a result of increased frequency of ENSO after 3000 cal BP.

5.2.3. Casma Valley (9°30′S)

Pozorski and Pozorski (1987) report on the molluscan component of multiple sites in the Casma Valley spanning the Late Preceramic Period through the Early Horizon (~5150 to 2200 cal BP based on suites of radiocarbon dates from the sites). Throughout, the molluscs are typical of the cool-water Peruvian coast. However, during the Late Preceramic and Initial Periods, *Mesodesma donacium* and *Choromytilus chorus* were abundant, while in the Early Horizon sites these species were rare to absent. The most recent date for an Initial Period site in the sample (Pampa de las Llamas–Moxeke) is nearly indistinguishable from the oldest date from the oldest Early Horizon site (Las Haldas/Early Horizon component) at about 3100 cal BP.

5.2.4. Summary of 3000 cal BP climatic change

The archaeological record from northern Peru strongly suggests an increase in the frequency of El Niño at about 3000 cal BP (Sandweiss et al., 2001), a conclusion supported by other paleoclimatic archives, including the recently published Bainbridge Crater Lake (Galapagos) record (Riedinger et al., 2002) and lake and swamp forest records from mid-latitude Chile (Jenny et al., 2002; Maldonado and Villagrán, 2002). The change in ENSO frequency was accompanied by the abandonment of the monumental temples that had been built along the central and northern Peruvian coast throughout the Late Preceramic and Initial Periods – that is, since the onset of El Niño at 5800 cal BP. Burger has investigated three Initial Period temple complexes in the Lurín Valley (12°15′S), and the one that survived the longest is the only one that made a significant investment in El Niño mitigation (Sandweiss et al., 2001). I do not advocate a direct correspondence between climatic and cultural change; technology, history, cultural practices, religion, perception, and individual and group idiosyncrasies can all affect the way a society and its members respond to change. However, radical environmental change requires some response from the people who experience it. The close temporal correlation between the changing climatic regimes on the Peruvian coast and the construction and later abandonment of monumental religious structures in the same area certainly suggests a role for climate in these cultural developments.

6. Mid-Holocene (9000–3000 cal BP) climate in southern Peru

Various paleoclimatic records indicate a major break at about 12°S, with long-term hyperaridity south of that point and more variable regimes to the north (Section 3). In general, paleoclimatic data from archaeological sites concord with these other sources (Section 3 discusses the preservation record for soft organic tissues; below I cover faunal, flood deposit, and site-distribution data). However, for several millennia prior to 5800 cal BP, the major latitudinal break indicated by the archaeological record seems to have been at about 10°S, possibly with a transitional climate between 10° and 12°S (Section 5). In earlier publications, my colleagues and I have stressed the difference between the northern and southern segments of the Peruvian coast (Sandweiss et al., 1996, 1997), but I emphasize it again here, as some authors have missed that point and treated our statements about northern Peru as though they apply to the entire coast (e.g. DeVries et al., 1997).

South of 12°S, all studied sites contain cool-water molluscan and fish faunas indicative of SSTs in the modern range (i.e. presence of the Humboldt Current). Cool SSTs, in turn, support the hyperarid terrestrial conditions suggested by the soils, *lomas* formations, and preservation of soft organic tissues. During the later part of the Mid-Holocene and the Late Holocene, occasional catastrophic flooding accompanied strong El Niño events, as witnessed by flood deposits and erosional episodes at archaeological sites and natural catchments (Keefer et al., 1998; Fontugne et al., 1999; Satterlee et al., 2001).

6.1. Paloma (12°30′S)

With dates ranging between 5500 and 8450 cal BP, Paloma spans much of the time when the northern Peruvian coastal sites contain warm-water molluscan and fish assemblages and have poor preservation of soft organic tissues. Located a few km from the shoreline at 12°45′S, the contents of Paloma stand in marked contrast to the northern sites. Soft organic tissues ranging from diverse plant materials to human hair are well-preserved (Benfer, 1984, 1990; Quilter, 1989). The molluscs are typical cool-water, Humboldt Current species, including small numbers of *Choromytilus chorus* and *Mesodesma donacium* (Reitz, 1988). The most common molluscs are two small mussels (*Semimytilus algosus* and *Perumytilus peruvianus*) that remained important in faunal assemblages in this region throughout the prehispanic period (Sandweiss, 1992) and are still common today. The vertebrate fauna are 94–98% cool-water when compared only with those species that can be assigned to warm or cool, and 80–83% cool when all vertebrate remains are considered (Sandweiss et al., 1996; Reitz and Sandweiss, 2001).

6.2. Quebrada Jaguay (16°30′S)

The occupation of the Quebrada Jaguay sector of the Peruvian south coast (Section 4.3) continued from the Terminal Pleistocene and Early Holocene into the early Mid-Holocene, both at the major QJ-280 site and in the adjacent foothills (Sandweiss et al., 1998). Throughout this time the mollusc and fish remains are almost exclusively those of cool-water species; indeed, over 99% of the molluscs are *Mesodesma donacium*. Soft organic tissues (plant remains, bird feathers) are present but rare.

QJ-280 was occupied during the Jaguay (Terminal Pleistocene) and Machas (Early to early Mid-Holocene) phases. The most recent date from QJ-280 is ~8300 cal BP, while the most recent date for a site of the Machas phase is ~8100 cal BP. The Machas phase sites have a characteristic surface assemblage that includes low molluscan diversity and the presence of chipped but not ground stone. The succeeding Manos phase (late Mid-Holocene) sites display high molluscan diversity and ground stone tools including distinctive flat oval basalt grinders ('manos') (Sandweiss et al., 1998, 1999b). These sites are dated to about 3500 cal BP. Apparently the region was abandoned for over 4000 years of the Mid-Holocene, during the same time that Núñez and his colleagues (Grosjean et al., 1997; Núñez et al., 2002) call the 'archaeological silence'. During this period in northern Chile, surveys have found very few archaeological sites compared to the preceding and succeeding periods (see Section 4.3).

6.3. Ring Site (17°40′S)

Now totally destroyed by modern road construction (Wise, 1999), the Ring Site was once a massive shell ring up to 5 m thick and over 25 m in diameter, with extensive deposits surrounding the actual ring. The site is located about 5 km south of the Ilo River. When we began excavations, all but the base of the ring and much of the underlying deposits had been removed for use in smelting, but substantial early deposits remained. A radiocarbon date on shell from near the base of the deposit places the initial occupation of the site around 11 200 cal BP, at the end of the Terminal Pleistocene (Section 4.4), but the rest of the dates are Mid-Holocene (~5800–9000 cal BP) (Sandweiss et al., 1989). Stratigraphically, the 5800 cal BP date immediately precedes the construction of the ring, so presumably occupation of the site continued for sometime thereafter. The vertebrate and molluscan fauna recovered from all levels are typical of the cool-water Humboldt Current, with temperate (cool) species constituting 96.4% of all specimens that could be assigned to a specific temperature regime (Reitz and Sandweiss, 2001; Sandweiss et al., 1989). North of the Ilo River a series of Mid-Holocene sites are located adjacent to springs in quebradas (Wise, 1999), as was the case farther south at Quebrada Tacahuay; we found no evidence of a spring near the Ring Site. The density and extent of the deposits at the Ring Site suggest that it was occupied frequently if not continuously over at least four millennia, so the absence of a local water source is puzzling.

6.4. *Quebrada Tacahuay (17°48′S)*

Quebrada Tacahuay consists of cultural levels separated by flood deposits most likely associated with El Niño events. As Keefer et al. (1998) noted, flood deposits are absent at the site between ~8900 and 5700 cal BP, exactly the period of which we proposed that El Niño was absent.

Keefer et al. (1998; deFrance et al., 2001) interpret Quebrada Tacahuay as a specialized site for processing seabirds to which humans were sporadically drawn by nearby seeps and springs. Although the principal anthropogenic deposits date to the Terminal Pleistocene (Section 4.5), more ephemeral occupations in the Early Holocene (~10 200 cal BP) and early Mid-Holocene (~8900 cal BP) are indicated by marine mussel shell accumulations (deFrance et al., 2001; Keefer et al., 1998). Vertebrate species are not reported from the post-Pleistocene occupations, but the indicated molluscan species are cool-adapted (deFrance et al., 2001).

6.5. *Quebrada de los Burros (18°00′S)*

Since 1996 a multidisciplinary French–Peruvian team has been studying both human and natural deposits about 2 km inland from the modern shoreline at Quebrada de los Burros (Fontugne et al., 1999; Lavallée et al., 1999a,b; Usselmann et al., 1999). This narrow canyon heads below the altitude of seasonal rainfall, but its lower reaches contain a series of spring-fed ponds. During the austral winter, dense fog permits particularly productive *lomas* stands on the slopes surrounding the Quebrada, attracting a variety of fauna. Together with the rich marine resources of the adjacent ocean, these factors probably account for the presence of an important human occupation during the Mid-Holocene.

Sedimentary analysis shows that much of the Mid-Holocene was characterized by organic layers interpreted as indicators of 'a permanent water supply resulting from an increased condensation of fog at mid-altitudes' due to enhanced coastal upwelling (Fontugne et al., 1999, p. 171). The organic layers are inconsistent with El Niño activity in this region, and they are bracketed between two debris-flow units dated to ~9600 and 3400 cal BP, respectively, that likely resulted from torrential coastal rainfall associated with El Niño events (Fontugne et al., 1999; Lavallée et al., 1999a). This hiatus in extreme flood events is similar to that found at Quebrada Tacahuay and further supports the archaeological data from northern Peru and paleoclimatic records elsewhere indicating that ENSO was absent or much less frequent during the Mid-Holocene than before or after that time (see Section 5.1).

The archaeological deposits at Quebrada de los Burros date between ~10 150 and 4250 cal BP (Lavallée et al., 1999a). The molluscan assemblage is similar to that from contemporary deposits at the Ring Site, consisting entirely of cool-water species typical of the Peru Current. Lavallée et al. (1999a,b) report variations in frequency of certain species through time, noting in particular that *Choromytilus chorus* is abundant early and late in the sequence and almost absent in the middle. It would be interesting to know whether the absence of *C. chorus* is contemporary with the period of elevated SSTs in northern Peru (Section 5.1), but details necessary to evaluate this possibility have not yet been published. The majority of fish are Peru Current species, though a small number of tropical specimens are present. The rare plant macrofossils are also typical of southern Peru today (Lavallée et al., 1999a,b; Béarez, 2000).

6.6. Mid-Holocene precipitation patterns south of 12°S

Human survival on the arid Peruvian coast depends directly (via river flow) or indirectly (as a component of groundwater recharge) on rainfall in the adjacent highlands. Therefore, when coastal regions were abandoned for extended periods of time, decreased rainfall seems likely. Paleoclimatic records from the highlands of southern Peru and northern Chile offer conflicting evidence concerning the Mid-Holocene precipitation patterns (for a recent review, see Placzek et al., 2001). For the Central Atacama Desert of northern Chile, the point of debate is whether the higher groundwater tables in the Mid-Holocene occurred in the context of greater or lesser precipitation (Grosjean et al., 2001). Though far from conclusive, the archaeological settlement pattern data suggest that precipitation did decrease in the south-central Andes, at least regionally. Where human populations got their water from springs, as at sites on the Peruvian south coast such as those north of Ilo, Peru (Wise, 1999), and at Quebrada de los Burros (Fontugne et al., 1999; Lavallée et al., 1999a,b; Section 6.5), or at Quebrada Puripica in the central Atacama Desert (Grosjean et al., 1997), human occupation continued through the Mid-Holocene. Where people depended on seasonal streams or local precipitation, as at Quebrada Jaguay and in much of the Atacama Desert, Mid-Holocene sites are virtually absent. Farther north the situation is quite different (Section 5): sites were present throughout the Mid-Holocene, and prior to 5800 cal BP annual coastal precipitation was probably greater than today. The proposed decrease in precipitation in the south-central Andes and the occupational hiatus at Quebrada Jaguay and in the Atacama continue well past the 5800 cal BP climatic change; the hiatuses in flood deposits at Quebrada Tacahuay and Quebrada de los Burros bracket the 9000–5800 cal BP period of no or minimal El Niños documented for northern Peru, but the Burros hiatus continues even beyond the 'silencio arqueológico'. The relation between the changes in ENSO frequency at 5800 and 3000 cal BP and the archaeological and paleoclimatic records from southern Peru and northern Chile remains to be resolved; it is not clear at this time whether the inconsistencies relate to the low resolution of the records, problems with chronometric dating, asynchroneity in northern and southern climatic change, or some combination of these factors.

7. Conclusions

In the multiproxy effort to reconstruct past climates in Andean South America, paleoclimatic archives embedded in archaeological site contents and distributions can play a critical role. At the least, these data serve to generate hypotheses about climate and climatic change that can be tested through other archives and through modeling. Indeed, this has been the case with the hypothesis of an ENSO onset at 5800 cal BP. At the same time, archaeologists need to embed their understanding of prehistoric cultural change in the context of past environmental conditions and changing climate.

The archaeological record of the Peruvian coast supports the following hypotheses about the Terminal Pleistocene through Mid-Holocene climate in that region. Each of these points requires continued testing and refinement through further research in multiple archives.

(1) From the Terminal Pleistocene through the middle Mid-Holocene (13 000–5800 cal BP), SSTs north of 10°S were as much as 3–4°C warmer than at present, with an amplified seasonal signal at 9°S. Seasonal precipitation presumably occurred during this time. ENSO activity was minimal compared to at present, at least from 9000 to 5800 cal BP.

(2) At this time, the region between 10° and 12°S was climatically transitional, with slightly warmer annual SSTs or more frequent warm events than after 5800 cal BP.

(3) South of 12°S, SSTs have been cool (modern range) from the Terminal Pleistocene through to the present. However, there was millennial-

scale variation, for during the Mid-Holocene upwelling may have been enhanced while water resources fed by highland precipitation may have diminished.

(4) From 5800 to 3000 cal BP, ENSO was present but with low recurrence intervals.

(5) Modern climatic conditions and range of interannual variability were established along the entire Peruvian coast at about 3000 cal BP.

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