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Peruvian Beach Ridges: Records of Human Activity and Climate Change

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PERUVIAN BEACH RIDGES: RECORDS OF HUMAN ACTIVITY AND CLIMATE CHANGE

by

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ABSTRACT

Among the many unusual features of the desert coast of northern Peru are the five major beach-ridge sets: Santa (9˚S), Piura (5˚30' S), Colán (5˚S), Chira (4˚50' S), and Tumbes (3˚40' S). These features of the landscape began forming after 5800 cal yr B.P., initiated by severe El Niño and seismic events. Archaeological remains on the beach-ridge sets of Santa, Colán, and Chira provide evidence of local prehistoric peoples. The extent of prehistoric occupation and utilization of beach ridges varied due to environmental limitations influenced by beach-ridge substrate material, local paleoenvironments, and climate-change events.

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CHAPTER ONE: INTRODUCTION

The desert coast of northern Peru from 3˚30' to 12˚ S is an extreme environment for the tropics. Human life in this region is possible only due to the combination of a rich ocean and the rivers that cut down to the shore from the adjacent Andes mountains. Among the many unusual features of this environment are the five major beach-ridge sets: Santa (9˚S), Piura (5˚30' S), Colán (5˚S), Chira (4˚50' S), and Tumbes (3˚40' S). Unlike most beach-ridge sets elsewhere in the world, the Peruvian ridges are relatively high relief and low frequency, and it is likely that their formation is driven by El Niño flooding combined with tectonic destabilization of the coastal catchment area (Sandweiss 1986; Sandweiss *et al*. 1998; Shafer *et al*. 2004). The ridges began forming in the mid-Holocene, after about 5800 cal yr BP.

Since they began forming, the ridges have provided local human populations with access to the shore and with platforms for habitation sites. Previous studies of the ridges have shown that some ridge sets were utilized much more intensively than others (e.g., Richardson 1983; Sandweiss *et al*. 1983; Sandweiss 1986). However, most research on the ridges has focused on geomorphology and paleoclimatology rather than archaeology. No one has done a comparative study of the ridges as settings for prehistoric (or modern) human activity.

The same processes that led to ridge formation would also have affected prehistoric peoples of the region. El Niño events in northern Peru drastically alter landscapes as well as reduce the availability of shellfish and fish, bring disease, rot crops, and destroy infrastructure. Investigations of the archaeological sites associated with the Santa, Colán, and Chira beach ridges (Figure 1.1) can contribute to resolving general questions about prehistoric peoples' responses to these events as well as more specific questions about use of the ridges through time.

Figure 1.1. Base map of study area showing the Santa, Colán, and Chira beach ridges.

Objectives

This investigation of the Santa, Colán, and Chira beach ridges has a number of major objectives drawing on an integration of archaeological and geological data. My first objective is to assess the archaeological sites associated with the Santa, Colán, and Chira beach-ridge sets. This is accomplished by analyzing the previous archaeological and geological literature of the study areas as well as field data personally collected during the 2006 and 2007 field seasons. The main research question is: how and to what extent did prehistoric peoples utilize the Santa, Colán, and Chira beach ridges?

A second objective is to reconstruct the paleoenvironments associated with the beach-ridge sets. The beach-ridge plains have been in a state of change since their geological formation. As no landscape is static, it is important to reconstruct the past environments associated with archaeological sites. By understanding past shorelines, ecosystems, and landscapes we can better interpret the coastal peoples occupying and utilizing the Peruvian beach ridges.

The third objective is to evaluate the effects on local prehistoric peoples of climate-change and landscape alteration episodes related to beach-ridge formation. The same processes of tectonic events and El Niño/Southern Oscillation events which created the beach ridges were also experienced by local prehistoric peoples. Furthermore, with the formation of successive beach ridges, the coastal plains and previous ecosystems were drastically impacted.

A fourth objective is to evaluate the current conditions of the archaeological sites associated with the Santa, Colán, and Chira beach ridges with regard to preservation. Like many archaeological sites around the world, natural and anthropogenic changes to the environment can threaten archaeological evidence. Therefore, archaeological site preservation concerns and possible solutions are addressed.

Plan of Presentation

The beach-ridge sets of Peru are unique coastal environments. First, I discuss the scientific background of El Niño/Southern Oscillation events, which are thought to be the main driver in beach-ridge formation. Second, the formation processes of the beach ridges are presented.

The peoples inhabiting or utilizing the beach-ridge sets were not isolated groups of hunters and gatherers cut off from broader social groups and networks. Therefore, a brief geological and cultural background of the Santa, Colán, and Chira beach-ridge areas is presented to put the archaeological investigations into a larger regional context.

The field research is presented by methodologies of the archaeological field investigations. Furthermore, brief methods in reconstructing paleoenvironments are discussed, followed by the research results. Last, a discussion of the interaction between prehistoric peoples, environmental limitations, and climate-change events is presented along with current site preservation concerns and ultimate conclusions.

CHAPTER TWO: EL NIÑO/SOUTHERN OSCILLATION EVENTS

The Peru Current (also known as the Humboldt Current) is a cold-water current flowing northward between 15° and 5° South latitude. The winds that blow above this current upwell deep-water nutrients that support one of the world's richest marine ecosystems. The Peru Current also has a large impact on the coastal landscapes of Chile and Peru. As the humid sea winds move along the cold-water current, they are forced to release their moisture before reaching land, creating northern Chile and Peru's hyper-arid coastal desert. The mean annual precipitation of the coastal desert is less than 50 mm (Rauh 1985).

Each January, warm waters push southward into the normally cold Peru Current. Peruvians have named this ocean current El Niño because its time of onset is close to Christmas. Yet, on a cycle of 2-7 years, a catastrophic version of El Niño occurs, technically called an El Niño/Southern Oscillation (ENSO) event. During ENSO events, a combination of oceanic and meteorological shifts occur as the cold flow of the Peru Current weakens or ceases to exist. Every ENSO event varies in regards to amplitude, time of onset, duration, spatial extent, and biological consequences (Cane 1983). Irregularly, severely strong ENSO events (also termed mega-El Niños) occur such as the 1982-83 or 1997-98 events. Severely strong ENSO events can last anywhere from several months to two years, and have drastic effects on marine and terrestrial ecosystems (Cane 1983).

Marine Ecosystemic Effects

During normal years, the upwelling of the Peru Current provides a rich resource of nutrients for marine life. Thriving on oceanic nutrients are plankton which form the base of the marine food chain. The larger the resource of plankton, the more mollusks, fish, and, consequently, marine birds and mammals can be supported. For these reasons, Peru's fishing industry has historically been one of the world's largest. In 1970 alone the tonnage of anchovies harvested for food and fertilizer was 10 million metric tons (Caviedes 2001).

Yet, during ENSO events, the encroaching warm-tropical waters have disastrous effects on the rich marine resource zone. The normal upwelling effects are disturbed, salinity increases, and oxygen and carbon decreases. These oceanic changes reduce the number of phytoplankton and zooplankton on which many marine species subsist. To add further stress, many of the cold-water species cannot survive in the warm waters. As cold-water species die or migrate, warm-water species migrate farther south, changing the available assemblage of fish and shellfish (Arntz and Valdivia 1985). The alterations in available marine resources can be economically detrimental to the Peruvian fisheries, as witnessed during the 1982/83 ENSO event (Arntz 1986).

Flood-Related Effects

During El Niño events, terrestrial environments are also drastically altered. The warm waters that replace the colder Peru Current usher in hot and humid air masses that dump torrential rains on the desert coast. These rains create destructive flash flooding and landslides. There is even greater potential for landslides and massive sediment movement when seismic activity occurs before El Niño events. Seismic events such as earthquakes enlarge runoff channels in upstream portions of drainage systems. Seismic events also provide more available material for runoff by detaching vast amounts of loose material from hills and banks (Keefer and Moseley 2004). ENSO events have proven to be detrimental to humans through the loss of life in flash floods and landslides, and the destruction of infrastructure such as roads, irrigation systems, and agricultural fields.

Interdisciplinary studies suggest that El Niño is not a modern phenomenon. Geoarchaeological studies, marine faunal records, ice cores, coral records, and lake sediment records provide evidence of the onset of ENSO after 5800 cal yr B.P. after a hiatus of several millennia (Rollins *et al*. 1986; Sandweiss *et al*. 1996, 1998; Sandweiss 1999). Archaeological studies also show that the modern hardships of ENSO events had similar impacts on people of the past. Prehistoric ENSO episodes have even been linked to cultural adaptations of subsistence strategy, technology, and land use patterns as well as cultural collapse (Nials *et al*. 1979; Craig and Shimada 1986; Moseley *et al*. 1992; Satterlee *et al*. 2000; Reycraft 2000). Severe ENSO events also influence attributes of coastal morphology.

CHAPTER THREE: BEACH RIDGES

One result of landscape alteration during periods of tectonic activity and severe El Niño episodes is the formation of coastal beach ridges. A beach ridge is any coast-parallel deposit of sands, gravels, and debris, and is usually formed during the waning phases of storms (Mason 1993). The five Peruvian beach-ridge sets are Santa (9°S), Piura (5°30' S), Colán (5°S), Chira (4°50' S), and Tumbes (3°40’ S). This study investigates the cobble-beach ridges of Santa (Figure 3.1), the gravel ridges of Colán (Figure 3.3), and the sandy ridges of Chira (Figure 3.4).

Beach-Ridge Formation

The beach ridges are thought to represent massive pulses of sediment produced by seismic activity in the desert coast and slopes of the western Andes. This sediment remains relatively immobile on the landscape until it is flushed into local rivers and drainage systems by torrential El Niño rainfall, the only occasion when heavy rains occur in this environment. Seismic events such as earthquakes or uplift activity increase available material for transport, and enlarge runoff channels in upstream portions of drainage systems (Sandweiss 1986; Keefer and Moseley 2004). The rivers carry the sediment to the shore dumping it at the river mouths.

The output of massive amounts of sediment at a river mouth forms a temporary alluvial fan (Moseley *et al.* 1992; Shafer *et al.* 2004). When normal climatic conditions return, the longshore current transports and deposits the flood sediments north of the river mouth forming a beach ridge (Sandweiss *et al*. 1983; Sandweiss 1986; Moseley *et al.* 1992; Sandweiss *et al.* 1998; Shafer *et al.* 2004). Stratigraphic profiles of the ridges indicate a lower layer of poorly sorted material with an upper layer of well-sorted material (Sandweiss *et al*. 1983; Sandweiss 1986; Ortlieb *et al.* 1989). Successive tectonic and mega-El Niño events throughout time create a beach-ridge set. The Santa, Colán, and Chira ridge sets are all composed of eight to ten ridges, yet it is uncertain if they all represent contemporary ridge-formation episodes.

The Santa Beach Ridges

The Santa beach-ridge set is located on the central coast of Peru north of the modern city of Chimbote. The beach ridges are located north of the mouth of the Santa River, with the most active ridge creating the modern shoreline (Figure 3.1). Before the formation of the Santa beach-ridge set, the landscape looked much different. Prior to approximately 5800 cal yr B.P., the shoreline was situated five kilometers inland forming a curving bay at the base of an ancient sea cliff five to ten meters high (Sandweiss *et al*. 1983; Sandweiss 1986). Shoals between the open ocean and the sea cliff formed embayments before they were cut off by the formation of the first Santa beach ridge

(Figure 3.2).

The beach ridges of Santa are composed of large cobbles intermixed with marine sands. The ridges were formed by material being transported by the Santa River during severe ENSO events. When the material was deposited by the longshore current, smaller grain sediments were removed and the larger cobble clasts were thrown up on the shore as a lag desposit (Sandweiss *et al*. 1983; Sandweiss 1986).

The Colán Beach-Ridge Set

Four of the five ridge sets have formed north of the mouths of the rivers with the highest discharge on the Peruvian coast; the fifth set (Colán) is a different case. The beach ridges of Colán, located south of the Chira River, are composed of cobbles, gravels, and sand. This material is thought to have originated from a Quaternary sea cliff east of the beach ridges called the Talara Tablazo (Richardson and McConaughy 1987; Ortlieb *et al.* 1989; Shafer *et al*. 2004). The mode of transport of the eroded cliff material is thought to have been dry ephemeral stream valleys (quebradas), which become activated during ENSO events (Shafer 1999). The material that reached the ocean was then transported and deposited northward by the normal longshore current, creating a beach ridge.

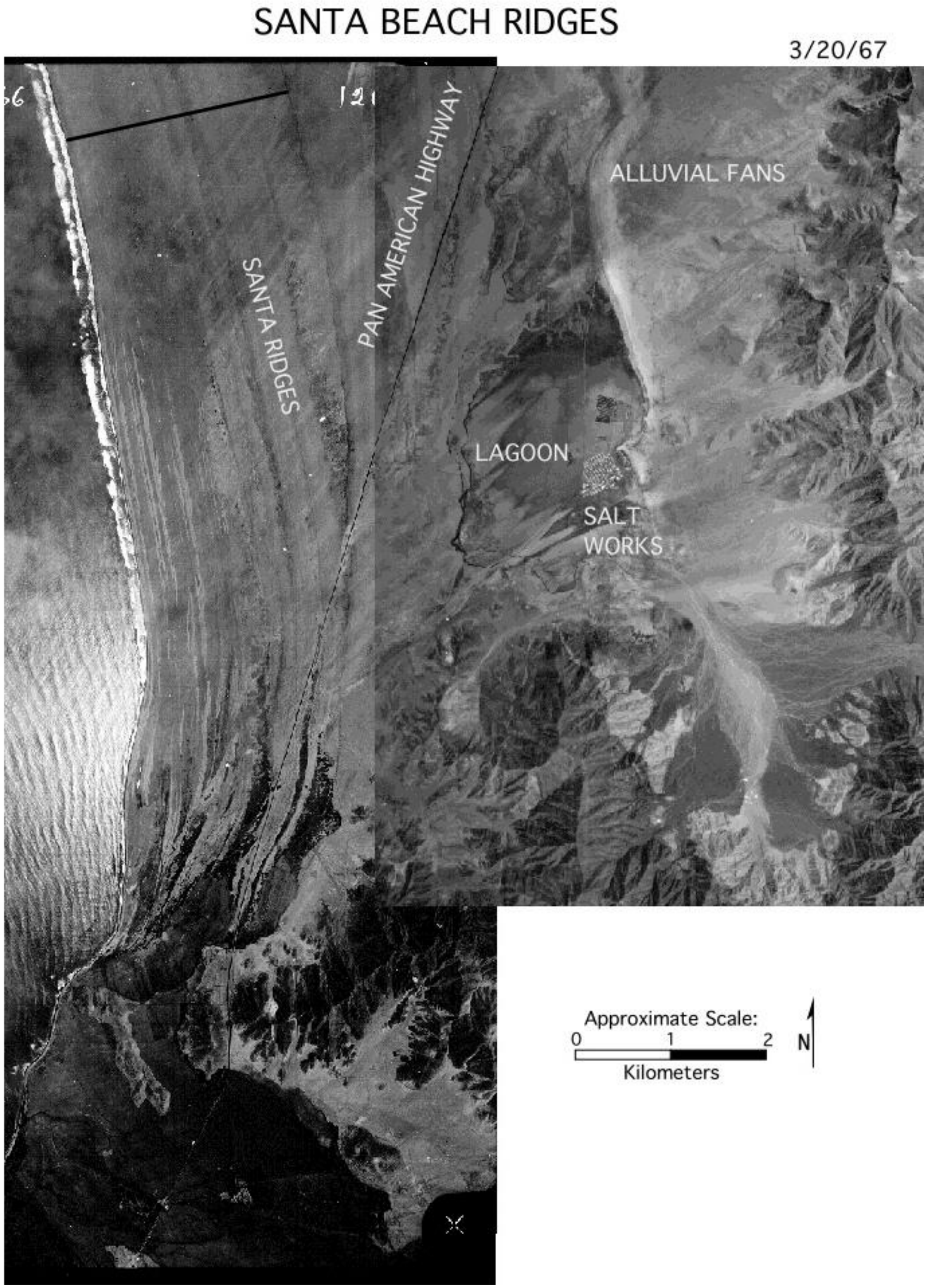

Figure 3.1. Aerial photograph of the Santa beach-ridge set (Image by Shafer 1999 from photographs by the Servicio Aerofotográfico del Perú).

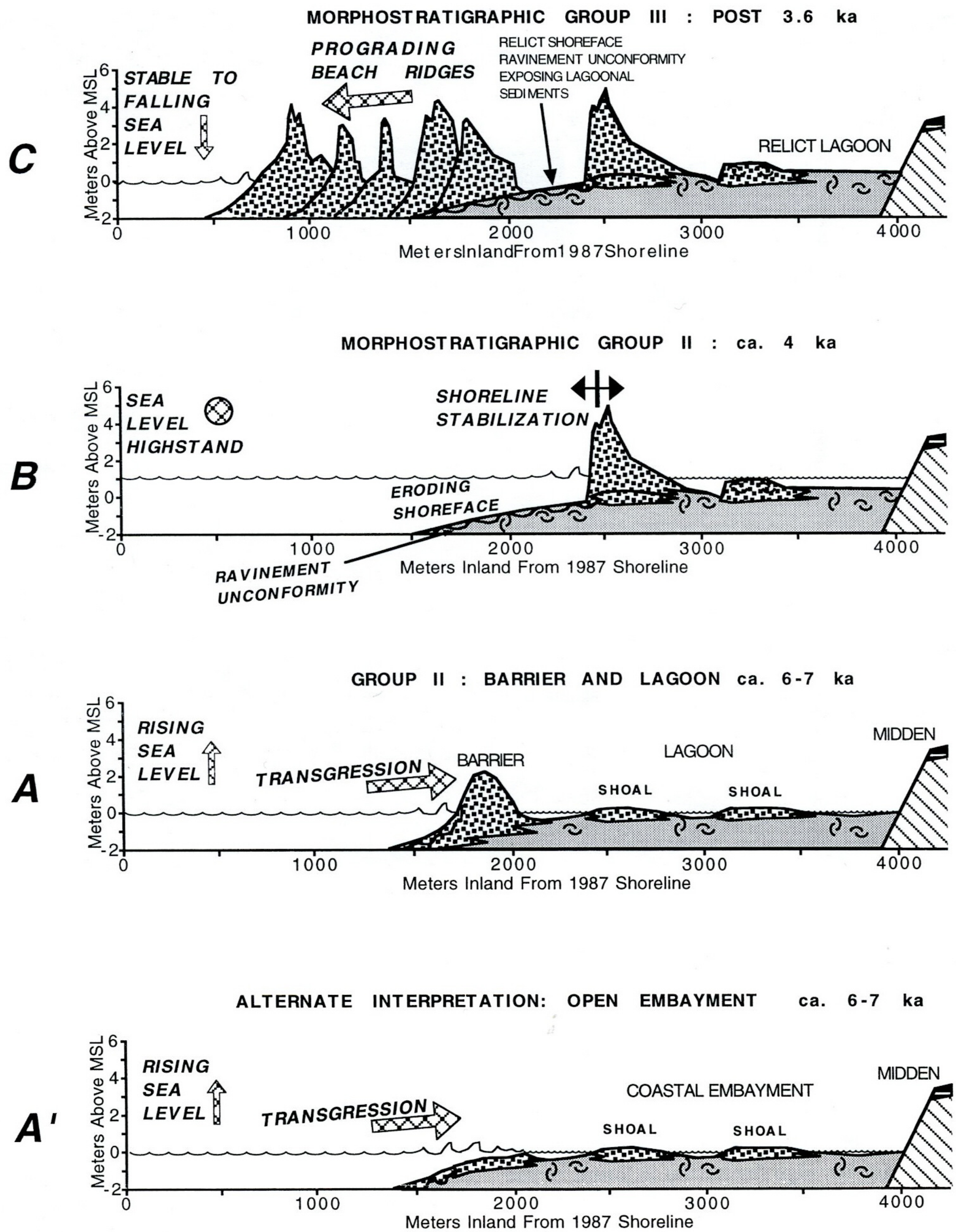

Figure 4.1. Scenarios for Santa beach-ridge formation processes (Figure adapted from Sandweiss *et al*. 1998).

Figure 3.3. Photomosaic of the Colán beach-ridge set (Image by Shafer 1999 from photographs by the Servicio Aerofotográfico del Perú).

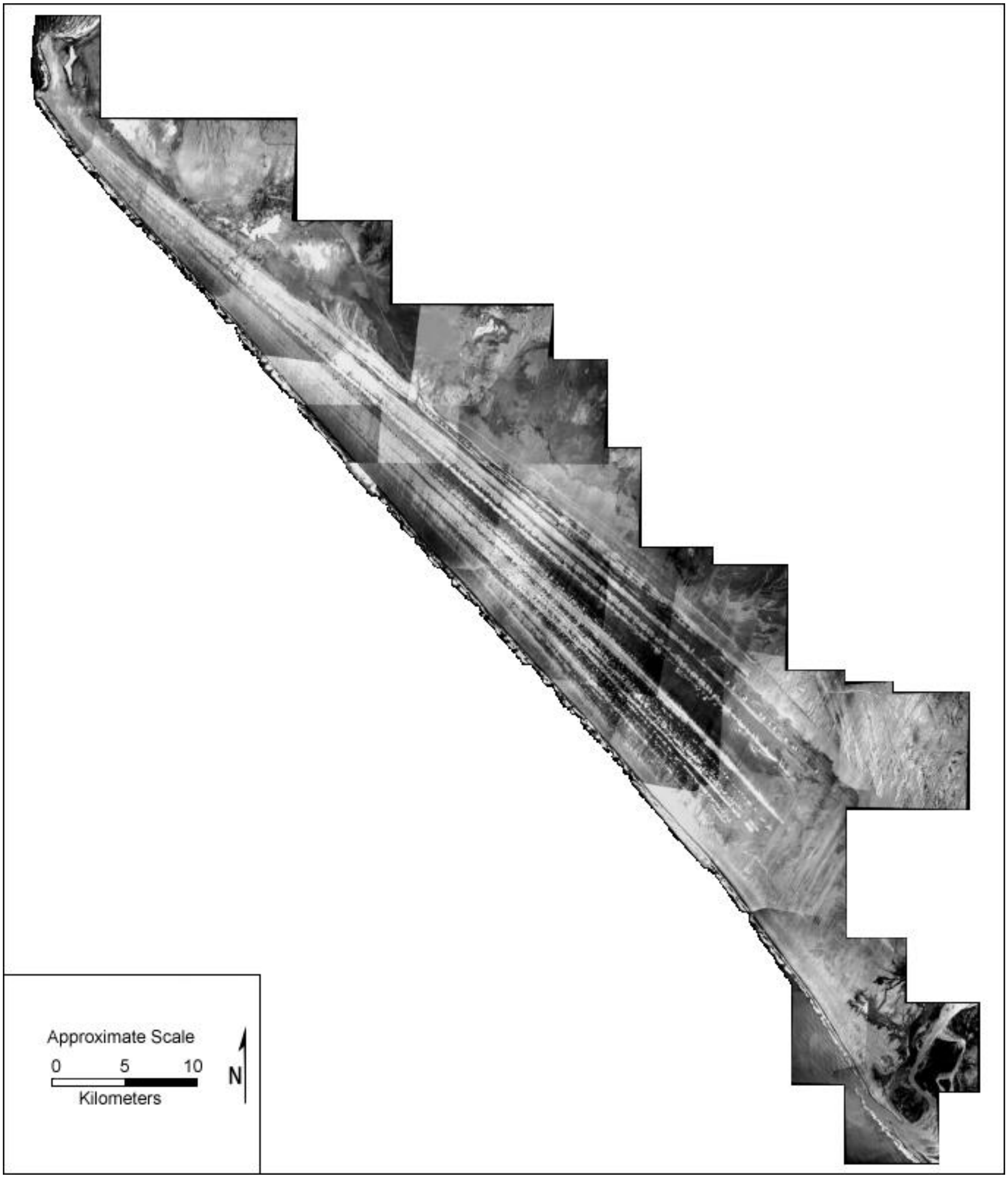

Figure 3.4. Photomosaic of the Chira beach-ridge set (Image by Shafer 1999 from photographs by the Servicio Aerofotográfico del Perú).

The Chira Beach-Ridge Set

The Chira Beach ridges are located north of the Chira River. The ridges are composed of small sandy sediment. They were created by sediment discharged from the Chira River during severe ENSO events and carried northward by the regular longshore current. All nine ridges are composed of sediment similar in size and constituents to the Chira River alluvial deposits (Chigne 1975).

Beach-Ridge Chronology

Due to their formation processes, Peruvian beach ridges provide a paleo-record of severely strong El Niño events. Much is unknown about El Niño, such as the physical causes and predictability of the event. Therefore, understanding the history of El Niño, such as the onset and frequency in the past, is essential. Consequently, much attention has been paid to the beach-ridge sets in terms of dating and chronology.

The radiocarbon dates found in the literature were not all reported in a uniform manner. To be consistent in the manner I reported dates as well as to make accurate comparisons between sites and cultural histories I calibrated all radiocarbon dates using the program CALIB 5.10 (Stuiver and Reimer 1993). Dates that needed correcting were ones that did not account for the Southern Hemisphere calibration, and marine samples that were not corrected for the Marine Reservoir Effect. Also, to be completely consistent, even if a date was reported as "calibrated year B.P." I took the ^{14}C age and recalibrated it using the CALIB 5.10 program so there would be no error due to different calibration programs.

In Appendix B the ^{14}C age B.P. date is given as well as all lab numbers and references for each radiocarbon date cited in the thesis. All dates were calibrated to 1-sigma. A Delta R of 220 years and an Uncertainty in Delta R ratio of 50 years were used in the calibrations for marine samples according to Stuiver *et al*. 1986. Dates older than 11,000 cal yr B.P. cannot be calibrated using the Southern Hemisphere calibration data sets (McCormac *et al*. 2004). Therefore, dates older than 11,000 cal yr B.P. were calibrated using IntCal04.

A relative chronology of the beach ridges can be devised through the fact that the ridges represent a general progradation of the coast. Therefore, the ridge farthest inland is the oldest, and the ridges become progressively more recent moving to the active ridge (Mason 1993). A detailed chronology of ridge formation can be derived through radiocarbon dating of geological and archaeological material associated with the ridges.

During ridge-formation events, waves reworked and deposited gravels, sand, and shell material as well as anthropogenic material such as charcoal. Bivalve mollusks found as paired valves or rock-dwelling gastropod species with attached opercula were thought to be in living position during ridge-formation episodes (Sandweiss *et al*. 1983; Sandweiss 1986; Ortlieb *et al*. 1989; Shafer *et al*. 2004). Therefore, they are ideal as datable material, because they most likely lived shortly before or during the ridge-formation event.

Anthropogenic material has also been used to approximately date the beach ridges. This includes charcoal found embedded in the ridges and archaeological remains found in ancient hearths on top of the ridges. Yet, anthropogenic remains such as charcoal must be used with caution. Archaeological sites on top of the ridges post-date ridge-formation events, and anthropogenic material embedded in the ridges might be contemporaneous or pre-date the formation event. Nevertheless, at Chira, Richardson (1983) showed that coastal peoples utilizing each ridge moved seaward with the progradation of the coast by the formation of a new ridge.

Although there are questions still remaining as to the validity of the beach-ridge chronologies, they do exhibit the trend that the beach ridges get progressively younger moving towards the modern shoreline (Tables 1a and 1b). One limitation with the chronologies is that each ridge cannot be accurately dated closer than within one century. The marine reservoir effect makes shells appear older by 100-500 years (Ortlieb *et al*. 1993). Therefore, caution must be used when looking at site histories on a more detailed level than centuries.

The beach ridges have been numbered in the previous literature in two different ways. For this study the earliest beach ridge furthest inland shall be named Ridge 1 and the subsequent ridge as Ridge 2 and so on until the modern shoreline. Numbering the beach ridge plains in this manner looks to the future as new beach ridges will be created, as well as the identification of ridges or partial ridges that were not previously recorded. Also, the beach ridge identifications are analogous to ridge identification in the most recently published study on the Peruvian beach ridges (Shafer *et al*. 2004)

Table 1a. Absolute dates associated with the Chira beach ridges (Reproduced from Shafer 1999).

Ridge ID (this study)	Ridge (reference)	Measured C-14 age (B.P.)	Normalized C14 age (B.P.)	Cal yr B.P.	Source	Reference
1	9	4485 ± 90		5070 ± 200	charcoal	1,2
1	9	4255 ± 65		4730 ± 110	charcoal	1,2
1	9	3985 ± 80		4380 ± 140	charcoal	1,2
1	J	4210 ± 40	4630 ± 40	4580 ± 110	*Tivela*	3,4,5
1	J	4570 ± 50	4540 ± 50	5160 ± 120	charcoal	3,4,5

1	J	3230 ± 40	3640 ± 40	3290 ± 80	*Tivela*	3,4,5
2	8	3490 ± 80		3710 ± 120	charcoal	1,2
2	K	3310 ± 40	3720 ± 40	3390 ± 70	*Tivela*	3,4,5
2	K	3520 ± 50	3490 ± 50	3720 ± 100	charcoal	3,4,5
2	K	3060 ± 30	3480 ± 30	3090 ± 90	*Tivela*	3,4,5
-	inter-ridge	3410 ± 40	3840 ± 40	3520 ± 80	*Donax*	3,4,5
-	inter-ridge	3370 ± 40	3790 ± 40	3460 ± 80	*Tivela*	3,4,5
3	7	3500 ± 160		3110 ± 200	*Tivela*	1,2
3	L	3210 ± 35	3620 ± 35	3280 ± 70	*Tivela*	3,4,5
3	L	3190 ± 45	3160 ± 45	3320 ± 60	charcoal	3,4,5
3	L	2610 ± 35	3020 ± 35	3140 ± 70	*Tivela*	3,4,5
3	L	2600 ± 150	3030 ± 150	2530 ± 180	*Donax*	3,4,5
4	6	2685 ± 105		2680 ± 180	charcoal	1,2
4	6	2485 ± 70		2520 ± 170	charcoal	2
4	M	2540 ± 40	2950 ± 40	2430 ± 100	*Tivela*	3,4,5,
4	M	2760 ± 40	2730 ± 40	2800 ± 50	charcoal	4,5
5	5	1955 ± 100		1830 ± 120	charcoal	1,2
6	4	1550 ± 110	ca. 1990	1230 ± 120	*Tivela*	1,2
7	3	1405 ± 75		1260 ± 100	charcoal	2
7	3	1305 ± 100		1180 ± 100	charcoal	2
8	2	805 ± 60		700 ± 40	charcoal	1,2
9	R	460 ± 40	870 ± 40	320 ± 80	*Tivela*	3,4,5
9	R	380 ± 40	350 ± 40	380 ± 70	charcoal	3,4,5

(1) Analysis # of geochronology lab of ORSTROM-Bondy
(By) Cambridge, Mass. (GX) and Smithsonian Inst. (SI)

1. Richardson 1983; 2. Richardson and McConaughy 1987;
3. Ortlieb *et al*. 1989; 4. Ortlieb *et al*. 1993; 5. Ortlieb *et al*. 1995

Table 1b. Absolute dates associated with the Colán beach ridges (Reproduced from Shafer 1999).

Ridge ID (this study)	Ridge (reference)	Normalized C-14 age (B.P.)	Cal yr B.P.	Source	Reference
1	8N	3310 ± 45	3480 ± 80	charcoal	4,5
1	8N	3630 ± 40	3290 ± 80	*Tivela hians*	4,5
1	8N	3640 ± 50	3290 ± 90	*Donax* + spp	3,4,5
1	8	3130 ± 300	3240 ± 370	charcoal	3,4,5
1	8	3300 ± 250	2900 ± 320	several shell species	3,4,5
1	8	3450 ± 250	3050 ± 300	several shell species	3,4,5
2	7	3190 ± 210	2720 ± 280	*Donax* + spp	3,4,5
3	6				
4	5	2520 ± 490	2530 ± 610	charcoal	3,4,5
4	5	2920 ± 250	2420 ± 310	*Tivela hians*	3,4,5
EC-7	Y	2860 ± 240	2370 ± 300	*Donax obesulus*	4,5
EC-7	Y	2700 ± 200	2110 ± 250	*Tivela hians*	4,5

5	4	2560 ± 170	1960 ± 220	*Donax* + spp	3,4,5
6	3	2050 ± 540	2040 ± 660	charcoal	3,4,5
6	3	2010 ± 380	1880 ± 460	charcoal	3,4,5
6	3	2600 ± 300	1990 ± 370	*Olivella* + sp	3,4,5
-	3a	2090 ± 180	1450 ± 200	*Donax obesulus*	3,4,5
7	2	1880 ± 180	1190 ± 200	*Donax* + spp	3,4,5
8	1N	1390 ± 230	730 ± 210	*Donax* + spp	3,4,5
8	1S	1200 ± 210	570 ± 200	*Donax* + spp	3,4,5
-	flat	1150 ± 190	510 ± 170	*Donax obesulus*	4,5
-	shell line	590 ± 160 *		*Tivela hians*	3,4,5
M-?	site c	590 ± 290	480 ± 320	charcoal	3,4,5

(1) # of analysis from ORSTROM-Bondy geochronological laboratory
* Calibration of the sample was invalid due to impingement on the end of the calibration data set, because the sample was relatively recent in age (Stuiver and Reimer 1993).

Table 1c. Absolute dates associated with the Santa beach ridges.

Ridge ID (this study)	Ridge (reference)	C14 Age (B.P.)	Cal yr B.P.	Material	Reference
1	8	4235 ± 115	4030 ± 170	*Prisogaster niger*	Sandweiss *et al*. 1983
2	7				
3	6				
4	5				
5	4				
6	3				
7	2				
8	1				

The only radiocarbon date from the Santa beach ridges comes from Ridge 1, the first ridge that formed. An embedded shell sample (a *P. niger* with operculum) in the ridge dated to 4030 ± 170 cal yr B.P. (Sandweiss *et al*. 1983).

CHAPTER FOUR: BACKGROUND

To put the new archaeological data from the 2006 and 2007 field seasons into context, I first present the background of the Peruvian beach-ridge regions. Previous investigations of the beach-ridge sets not only provided information on paleo-ENSO events but also on prehistoric peoples. Evidence of prehistoric peoples utilizing the beach-ridge sets have been recorded at Colán, Piura, and Chira (Richardson 1983; Richardson and McConaughy 1987; Ravines 1988a; McConaughy 1993). It is important to place prehistoric peoples utilizing the beach ridges into a wider regional and cultural context, rather than interpreting the coastal groups as isolated. Therefore, a geological and cultural background of the Santa River valley and the far north coast will be briefly presented.

The Santa River Valley

Before the formation of the Santa ridges, the early Holocene shoreline (Early and Preceramic Periods) behind the Santa beach-ridge set was inhabited during the preceramic, or Las Salinas, period (Figure 4.1). The Las Salinas period sites date to approximately 7000-4000 cal yr B.P. (Alva 1986; Rollins *et al*. 1986; De Vries and Wells 1990). Coastal shellfish-collecting sites are located on top of the raised sea cliff and have been cause of debate concerning climate change and El Niño studies.

The Ostra Base Camp, the Ostra Collecting Station, and the fossil Ostra Beach contain warm-water mollusks, which form a thermally anomalous molluscan assemblage (referred to as a TAMA) (Sandweiss *et al*. 1983; Sandweiss 1986; Sandweiss 1996a; Sandweiss *et al*. 1996; Reitz and Sandweiss 2001). Most of the data comes from the Ostra Base Camp, which is located at the southern end of the paleoembayment near the early Holocene shoreline.

Today, the cold-water Humboldt Current restricts the presence of warm-water shellfish along most of the Peruvian coast including the Santa region. Under normal climate conditions, warm-water shellfish are found at the boundary between the warm Panamic Province and the cold Peruvian Province at around 5° S (Rollins *et al*. 1986). Therefore, the presence of warm-water shellfish at the Ostra sites have been a cause of contention.

One explanation for the presence of warm-water shellfish is that warm-water currents used to extend at least 500 kilometers further south from at least 9,000 cal yr B.P. to about 5800 cal yr B.P. (Richardson 1978; Rollins *et al*. 1986; Reitz 2001; Sandweiss 2003). Interdisciplinary evidence supporting this premise comes from archaeological sites, phosphorite distribution, timing of glacial retreat, sea level change, radiolarian, and diatom and fish scale distributions. A less well-supported hypothesis for the presence of warm-water mollusks at the Ostra Site is that solar warming of the paleo-embayment created sufficient conditions for the TAMA (De Vries and Wells 1990; cf. Sandweiss *et al*. 1996, 1998).

By the time modern climatic conditions stabilized (approximately 5800 cal yr B.P.) and the first Santa beach ridge formed, the Las Salinas sites associated with the paleo-embayment were abandoned. The abandonment of large parts of the coastline in the Santa River Valley is thought to be a response to the dramatic climate changes involved with ridge construction, such as the onset of El Niño, tectonic activity, and uplift events (Sandweiss *et al*. 1983).

The previous literature of the Santa region suggests that although prehistoric groups lived in the Santa region, the Santa beach ridges were never utilized or occupied (Sandweiss *et al*. 1983; Sandweiss 1986; Wilson 1988; Wells 1992). Wilson suggests that prehistoric people left the Santa region from approximately 4000-3000 cal yr B.P.

(1988). During this time period, people living in nearby valleys began to rely more upon irrigated agriculture (Alva 1986; Pozorski and Pozorski 1987). When people re-inhabited the region in great numbers, most centers were located further inland, as irrigation agriculture took root during the Cayhuamarca (3000-2300 cal yr B.P.) and Vinzos (2300-1950 cal yr B.P.) cultural phases.

Large settlements focused at the mouth of the Santa River were noted for the subsequent cultural phases of the Suchimancillo Period (1950-1550 cal yr B.P.), Guadalupito Period (1550-1300 cal yr B.P.), Tanguche Period (1300-800 cal yr B.P.), and Tambo Period (800-418 cal yr B.P.) (Note: the approximate ages for the Santa Valley cultural phases have not been recalibrated using the most recent Calib5.10 program like the other dates in the thesis. A recalibration of all the radiocarbon dates from the Santa Valley is beyond the scope of this project and is not necessary for this research; Rollins *et al*. 1986; Wilson 1988; Wells 1992). It is unlikely that prehistoric settlements at the mouth of the Santa River were occupied continuously throughout the cultural phases (Zeidler 1991). Yet, it is important to note that prehistoric people were located directly south of the Santa beach ridges.

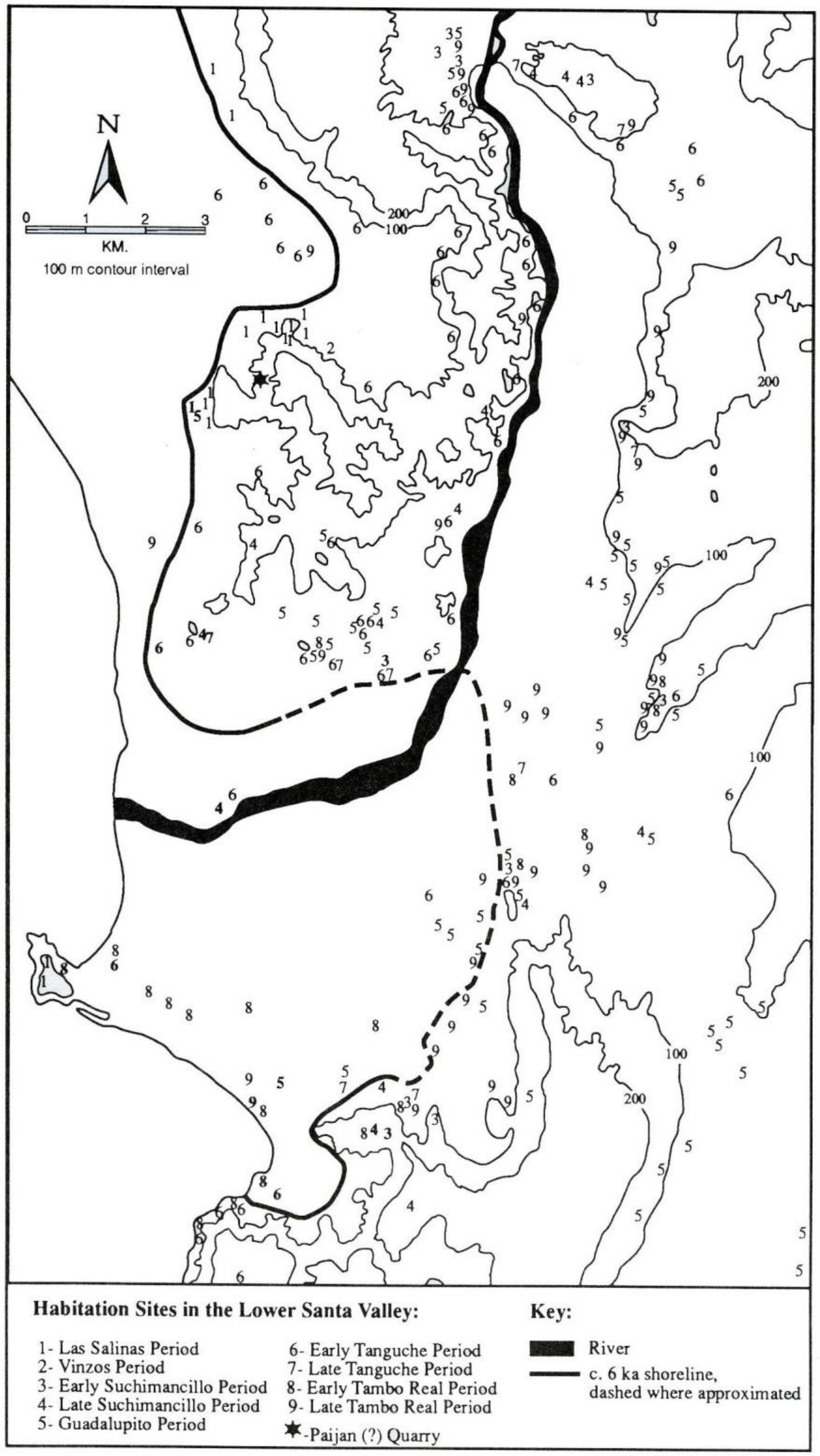

Figure 4.1. Map of archaeological sites of the lower Santa River valley, also showing location of the coastline at approximately 5800 cal yr B.P. (Adapted from Wells 1992).

The Far North Coast: Colán and Chira

The beach ridges of Colán and Chira are located on the far north coast of Peru. Prior to the end of the Pleistocene, a number of sea floors along the north coast were uplifted forming a series of raised sea cliffs. These 50-meter high *tablazos* (ancient marine terraces) are named the Mancora, Talara, and Lobitos (Bosworth 1922). The tablazos are composed of thick marine quartz sands, shelly and calcareous sands, marls, coquinas, and pebble beds (Richardson and McConaughy 1987). The tablazos are down-cut by the three major river valleys of the area: the Piura, Chira, and Tumbes. The Colán beach ridges are found at the base of the Talara Tablazo south of the Chira River mouth, whereas the Chira ridges have formed off the Lobitos Tablazo north of the Chira River mouth.

Before the mid-Holocene, the environment of the far north coast differed from the modern desert conditions. The best evidence comes from faunal and floral remains from the Talara Tar Pits. Radiocarbon dates from the tar-seeps dated to an average of 16,700 ± 230. Megafaunal and pollen evidence suggest a wetter habitat supporting a savanna environment of open grasslands interspersed with trees (Lemon and Churcher 1961; Churcher 1966; Campbell 1982). Preceramic age archaeological sites dating from approximately 13,000-6300 cal yr B.P. show evidence of mangrove mollusks, anomalous to today's region (Richardson 1973, 1978). Aridification and the retreat of the mangrove swamps north to Tumbes, Peru is thought to have occurred around 5800 cal yr B.P. when modern climate conditions stabilized.

Cultural Background

Before the Colán and Chira beach ridges began forming approximately 5000-4000 cal yr B.P., preceramic age peoples lived in the region (Orlieb *et al*. 1994). Three preceramic cultural phases have been identified along the northern coastal zone: Amotape (13,000-10,000 cal yr B.P.), Siches-Estero (10,000-6000 cal yr B.P.), and Honda (6000 to at least 4400 cal yr B.P.) (Richardson 1978; Richardson and McConaughy 1987; McConaughy 1993). The Amotape and Siches phase sites are predominately composed of middens with the mangrove shellfish *Anadara tuberculosa*, anomalous to today's region. When climate changed to its modern conditions, the mangrove swamps retreated north and conditions became more arid.

The Honda cultural phase shows the adaptation to modern conditions as people began exploiting colder-water shellfish such as *Donax obesulus* and *Tivela hians* in place of mangrove species (Richardson and McConaughy 1987). All three preceramic phases are similar in the utilization of unifacial chipped-stone tools as well as crude denticulates and scrapers (McConaughy 1993). Due to a lack of radiocarbon dates, we cannot more accurately define the cultural phase transition between the Honda preceramic and the Paita ceramic phases.

In 1963, Lanning published a ceramic sequence for the Piura and Chira coast. The sequence, later to be refined by Richardson (1974, 1978, 1983; Richardson *et al*. 1990), identifies three major cultural phases implied by dramatic changes in the ceramic typologies. These phases are Paita (3900-2700 cal yr B.P.), Sechura (2700-1250 cal yr B.P.), and Piura (1250 cal yr B.P. to present day) (Richardson *et al*. 1990; McConaughy 1993). The three ceramic cultural phases can be further split into sub-phases. Table 2 shows the radiocarbon dates reported by previous studies, which were then calibrated using CALIB 5.10 (Stuiver and Reimer 1993).

Ceramic Phase	Phase Cal yr (B.P.)	Site	C-14 Age (B.P.)	Calibrated yr (B.P.)	Dated Material	References
Paita 1	3900-3500	PV8-7	3610 ± 145	3860 ± 220	Charcoal	1
		PV8-7	3390 ± 125	3560 ± 160	Charcoal	1
Paita 2	3500-3200	PV10-23	3230 ± 70	3370 ± 100	Charcoal	2
Paita 3	3200-2700	Chira Ridge 4	2685 ± 110	2680 ± 180	Charcoal	2
Sechura 1	2700-2400	PV6-5	2535 ± 185	2550 ± 210	Charcoal	1
		PV10-48	2410 ± 70	2450 ± 230	Charcoal	5
Sechura 2	2400-1700					4
Sechura 3	1700-1250	PV7-18	1810 ± 70	1670 ± 110	Charcoal	1
		PV10-33	1780 ± 70	1630 ± 80	Charcoal	1
		PV7-18	1675 ± 85	1510 ± 100	Charcoal	1
		PV7-18	1445 ± 95	1290 ± 110	Charcoal	1
		Chira Ridge 6	ca. 1990	1230 ± 120	*Tivela*	2
Piura 1	1250-1100	PV10-30	1370 ± 80	1230 ± 80	Charcoal	3
Piura 2	1100-800					4
Piura 3	800-500	Chira Ridge 8	805 ± 60	700 ± 40	Charcoal	2
		PV7-4	640 ± 90	600 ± 60	Charcoal	1
		Near Huaca Rica	500 ± 85	440 ± 110	Charcoal	4
Piura 4	500-418					4
Piura 5	418-150	PV7-14	210 ± 60	190 ± 110	Charcoal	5
Piura 6	150-present					5

1. Richardson 1974; 2. Richardson 1983; 3. Richardson and McConaughy 1987; 4. Richardson *et al*.1990; 5. McConaughy 1993; 6. Ortlieb *et al*. 1993

Table 2. Dates of cultural sub-phases of Peru's far north coast.

During the Paita cultural phase (3900-2700 cal yr B.P.), peoples inhabited a number of sites on the coastline from the Paita Peninsula to north of the Chira River. Paita phase peoples were predominately coastal fishermen and shellfish collectors. Paita sites vary from shellfish collecting stations and small campsites, to the large Paita phase site (PV10-1) located above the modern town of Paita and the massive shell midden on the Chira beach ridges (PV8-7) (Richardson 1983; McConaughy 1993). Whether most sites were seasonal or annual is debatable, but it is thought that the large Paita centers with continuous ceramic styles are indicative of year-round settlements (McConaughy 1993).

Although a large number of people did not inhabit the area during the Paita phase, it is important to stress that these groups were not isolated entities. Paita ceramic styles and designs are similar to the contemporary Valdivia and Machililla cultures of Ecuador, the Cupisnique culture south of the Sechura Desert, and Encantada styles inland along the Upper Piura River (Meggers *et al*. 1965; Ravines 1988a; Richardson *et al*. 1990). These similarities suggest that some type of interaction and exchange of ideas occurred with cultures in surrounding regions.

The Sechura cultural phase (2700-1250 cal yr B.P.) marks larger settlements, evidence of copper smelting, and the occupation of inland as well as coastal sites. Inland sites along the Chira and Piura Rivers indicate a growing agricultural base for the peoples in the region. On the coast, fishing villages of five to twenty houses were located along the coast of the Paita Peninsula and at the mouth of Quebrada Pariñas (Richardson *et al*. 1990). Structures during this period became more complex with numerous rooms, such as the largest Sechura agricultural center PV7-18 with seventy-five rooms (Richardson *et al.* 1990; McConaughy 1993).

The prehistoric Piura cultural phase (1250-418 cal yr B.P.) marks dramatic changes with the rise of complex societies, the development of large ceremonial structures, and an adjustment of settlement pattern. During the transition from the Sechura to Piura Phases, long-term coastal sites along the Paita Peninsula were abandoned as shell collecting intensified along stretches of the Chira and Piura beach ridges. During Piura Phase 3, large inland agricultural centers rose with ceremonial *huacas* built of large adobes and associated walled compounds such as Huaca Rica and the associated Monte Lima Complex in the Chira River valley (Figure 4.2; Richardson *et al*. 1990). The ceramic styles of Piura Phase 3 indicate trade with Sicán and Chimú states south of the Sechura Desert. During Piura Phase 4, ceramics were heavily influenced by the Inca state (McConaughy 1993).

Figure 4.2. Huaca Rica and associated compounds of the Monte Lima complex (Piura Phase 3) in the Chira Valley (Photograph by Mark McConaughy).

When Francisco Pizarro landed on the north coast of Peru in 418 cal yr B.P., he ushered in significant change to the region. Settlements were reorganized to the modern day town of Paita during Piura Phase 5, marking the beginning of the Colonial Period. Piura Phase 5 ceramics continue with evidence of Spanish majolica at major sites (McConaughy 1993). During the 19th and 20th centuries A.D., the economy changed with the emergence of the whaling industry, the discovery of oil in the Talara region, and intensification of salt processing south of Paita (Richardson and Decima Zamecnik 1977; Ravines 1988b).

Site History of Colán

Archaeological investigations of the extensive prehistoric midden sites in the Colán region began with Lanning's (1963) ceramic sequence. A more detailed study was conducted by Ravines (1998a) as well as Richardson and McConaughy (1987) during the 1980's. The tablazo overlooking the Colán beach ridges was inhabited during Paita 2 and 3 phases based on ceramic surface collections and a sample of charcoal dating to 3090 ± 130 cal yr B.P. (Richardson and McConaughy 1987). Sechura phase pottery was also found in the tablazo middens as well as in a large midden on Colán beach Ridge 5. These sites represent the first occupation component of the Colán region.

During the late occupation component beginning in Piura Phase 3 (800-500 cal yr B.P.), extensive shell middens and occupation sites were located south of the main beach-ridge set. These sites were occupied through historical times, when the first Christian church in Peru, Iglesia de San Lucas, was built on top of the Piura sites in the early 16th century. Today, the modern town of Colán overlies parts of the Piura past with remaining portions of Prehispanic shell middens and artifacts in peoples' backyards.

Site History of the Chira Beach Ridges

Archaeological investigations of the Chira beach ridges began in 1965 in conjunction with using the beach ridges as potential indicators of climate change (Richardson 1983). The Chira beach-ridge set was the most extensively utilized compared with the other Peruvian beach ridges, with massive shell middens capping the long, sandy ridges.

Human occupation of the Chira beach-ridge area began before the first ridge formed during the preceramic Siches Phase (10,000-6000 cal yr B.P.). The Siches site PV9-31, south of the Chira River, dates to 7740 ± 130 cal yr B.P. The site is a shell midden composed of molluscan species from a mangrove swamp that developed behind a barrier ridge at the mouth of the river (Richardson 1983). When modern oceanic conditions stabilized and the first Chira beach ridge formed, preceramic peoples of the Honda phase used the ridge to exploit shellfish and fish (Richardson 1983).

As new beach ridges formed at Chira, prehistoric peoples moved up to the active shoreline, indicating that the Chira beach ridges were in continuous use since their initial formation. All the Chira beach ridges, except the most recent ridge, have extensive shell middens and associated hearths. On Ridges 1 and 2, lithic tools are abundant whereas ceramic sherds are abundant on Ridges 3-8. On Ridge 4, Paita Phase peoples occupied the region with abundant ceramic artifacts and the major site PV8-7 at the south end of the ridges. Ridge 5 has evidence of Sechura Phase ceramics with Ridge 8 being occupied by Piura Phase peoples (Richardson 1983).

Ceramics from the ridges helped refine the ceramic typology of the far north coast of Peru (Lanning 1963; Richardson 1983; Richardson and McConaughy 1987). Ceramics discovered include utilitarian wares, water storage jars, and a small percentage of cooking pots (Richardson and McConaughy 1987). Structure foundations discovered on the ridges include U-shaped features interpreted as short-term lean-to dwellings or windbreaks (Richardson *et al*. 1990). The previous archaeological investigations of the

Santa, Colán, and Chira regions set the background for the field investigations of 2006 and 2007.

CHAPTER FIVE: METHODOLOGY

Various methods of research were implemented to understand how and to what extent prehistoric peoples were utilizing the Santa, Colán, and Chira beach-ridge sets. The main methods of investigation were archaeological survey, molluscan analyses, and remote sensing image analyses. Field seasons took place in summer 2006 and winter 2007 for varying durations of time at each beach-ridge set.

Archaeological Investigations

The presence of prehistoric peoples on the beach-ridge sets of Santa, Colán, and Chira was previously investigated to different extents. The Santa beach-ridge set was surveyed by Sandweiss (*et al*. 1983) in 1980. The only anthropogenic evidence discovered that was possibly prehistoric were a number of windbreaks, yet without associated artifacts they are just as likely to be modern. The absence of prehistoric evidence on the Santa ridges was also corroborated by David Wilson, who surveyed the entire Santa River valley (Sandweiss pers. comm.; Wilson 1988). Archaeological sites associated with the Colán beach ridges have been noted in previous studies by Lanning (1963), Ravines (1988a), and Richardson and McConaughy (1987). Yet, no comprehensive study of these sites had been made in relation to the Colán beach ridges and the associated paleoenvironments. The Chira beach ridges have been extensively studied by Lanning (1963) and Richardson and colleagues (Richardson 1983; Richardson and McConaughy 1987; Richardson *et al*. 1990).

The extent of previous literature of the beach-ridge sets as well as a constricted time frame shaped the logistics of the archaeological survey. During the 2006 field season, we were only able to spend one day at each ridge set. Although we visited the Chira beach-ridge set, it was not necessary or practicable for field survey. During the 2007 field season we returned to the Colán beach ridges for an additional three days.

Archaeological Survey Logistics

During our field investigations, we surveyed the Santa and Colán beach ridges on foot. Although taking more time, conducting the survey by foot was much more efficient in site and artifact discovery than using a vehicle. When we located an archaeological site, we recorded the spatial coordinates using a Trimble GeoExplorer II Global Positioning System (GPS) handheld receiver.

At the Santa beach-ridge set, we conducted a transect from the oldest beach ridge to the most recent beach ridge that forms the present coastline. This survey transect focused on the southern portion of the ridge set. We also walked longer sections of the oldest beach ridges, compared to the more recent ridges, due to the discovery of artifacts.

During the 2006 and 2007 field seasons, we were able to survey almost the entire Colán beach-ridge set. The ridge set of Colán is spatially smaller than the Santa and Chira beach ridges, allowing for all the gravel ridges except the most recent ridge to be fully surveyed. Furthermore, archaeological sites previously recorded by Ravines (1988a) in the immediate area of the ridges were investigated.

Molluscan Analyses

After the 2006 field season, it became evident that to better understand the archaeological record at Colán, the paleo-shorelines and habitats needed to be identified. The types of shoreline (e.g., sandy substrate) and coastal habitats, such as marshes and lagoons, were important factors in prehistoric life (Moseley 1975). By reconstructing the paleoenvironments of the beach ridges, we can interpret how prehistoric peoples were utilizing the regions. A key in reconstructing the physical past is molluscan analyses.

Molluscan remains can tell us a great deal about past shorelines, because mollusks are often very habitat-specific. Mollusks are dependent on factors such as water temperature, salinity, the specific coastal littoral zone, and ecological systems they inhabit. Along the coast of Peru, numerous species of mollusks inhabit sandy littoral zones, rocky littoral zones, coastal lagoons, and river deltas (Moseley 1975; Sandweiss and Rodriguez 1991; Sandweiss 1996a). To reconstruct paleo-shorelines and habitats we can compare the molluscan species found in geological and archaeological contexts to their modern-day habitats. Through these analogs, molluscan species can inform us about past climatic conditions, oceanic changes in temperature, ecological niches, as well as the types of shorelines prehistoric peoples utilized for food gathering. When these data are considered in a regional context, the specific areas of the coast prehistoric peoples were utilizing can be determined (Sandweiss and Rodriguez 1991; Sandweiss 1996a).

Molluscan studies reconstructing coastal geomorphology have been incorporated into numerous archaeological investigations of the coast of Peru. Previous investigations of the beach ridges have applied molluscan analyses for radiocarbon dating and coastal littoral reconstruction (Sandweiss *et al*. 1983; Ortlieb *et al*. 1989; Diaz and Ortlieb 1991). During ridge-formation events, waves reworked and deposited gravels, sand, and shell material as well as anthropogenic material such as charcoal into beach ridges. Bivalve mollusks found as paired valves or rock-dwelling gastropod species with attached opercula were thought to be in living position during ridge-formation episodes (Sandweiss *et al*. 1983). In principle, these mollusks can inform us about the local shorelines and ecological habitats which existed just prior to or during ridge-formation events.

Molluscan remains can also be found in archaeological middens (refuse heaps) composed of shells that were once collected and processed for food by prehistoric peoples. Yet, solely using molluscan remains from the archaeological record to reconstruct paleoenvironments can be misleading. Shellfish asemblages from archaeological sites along the coast of Peru show that prehistoric peoples commonly preferred to collect shellfish from a variety of coastal environments. Case studies worldwide demonstrate that prehistoric gatherers can collect shellfish and transport them great distances to where they are finally discarded (Pozorski and Pozorski 1987; Rollins *et al*. 1990; Sandweiss and Rodriguez 1991; Sandweiss 1996a; Classen 1998). Consequently, it is important to take an interdisciplinary approach in understanding the complex interaction between coastal morphology, paleoecology, and prehistoric peoples.

<u>Molluscan Field Collection</u>

Shells were collected at the site of Colán to understand the littoral zones off the beach ridges as well as local ecological habitats. A surface collection was made from the major shell middens on the beach ridges. Shells were also collected from middens on top of the Quaternary sea cliff that looks out over the beach-ridge set. In order to do a detailed molluscan analysis, archaeological test pits would have had to be conducted at each midden site. Unfortunately, due to time and legal permitting, only surface collections were taken. The species of the mollusks, ecological habitat, and geographical range were then identified using modern analogs.

CHAPTER SIX: RESULTS

In this chapter, the results of the field investigations from the 2006 and 2007 seasons are presented. First, issues of preservation put the field investigations into context. Second, paleoenvironmental and archaeological data from the 2006 and 2007 surveys of the Santa and Colán beach-ridge sets are presented. Lastly, the Chira beach-ridge set is briefly discussed.

To understand the archaeological record of the Santa, Colán, and Chira beach-ridge sets, it is imperative to reconstruct the local past environments. Coastal landscapes such as the beach-ridge plains are dynamic features that have changed dramatically throughout time. The ridges have also been key geological components within various ecosystems which have fluctuated throughout time. Therefore, we cannot assume that the prehistoric environments were the same as today.

Reconstructing ancient coasts can provide great insight into the usages of coastal sites and areas. Moseley (1975) identifies six major types of coastal zones which prehistoric peoples of Peru utilized. The open-beach sublittoral zone is the deep-water zone beyond the sandy littoral zone. Resources of fish, birds, and sea mammals can be fished yet watercraft are needed. The resources of rocky-shore sublittoral zones are like open-beach sublittoral zones, but people can use hook-and-line-fishing-technology without the need for watercraft. Sandy littoral zones consist of sandy beaches with intertidal zones that contain mollusks, shore birds, fish, as well as driftwood and dead sea mammals that wash up on shore. Rocky littoral zones contain rich resources of birds, rookeries and roosts of sea mammals, and mollusks in the intertidal and subtidal zones. Coastal lagoons have grasses, sedges and reeds, small fish, birds, and mollusks. River deltas are marshy zones usually much like coastal lagoons. Due to the various resources that different coastal littoral zones and habitats provide to humans, it is essential to understand the paleoenvironments of the beach-ridge sets to interpret the archaeological remains.

Archaeological Preservation

The Santa, Colán, and Chira beach ridges are ideal sites for the recovery of archaeological data. The hyper-arid desert coast of Peru has conditions amenable to the preservation of archaeological remains. The coastal desert on average has little rainfall except during the periodic El Niño events. Associated with these arid conditions is the overall lack of vegetation outside the irrigated river valleys. Survey of the beach-ridge areas was made easier by the lack of vegetation that might have otherwise obscured artifacts and sites. Modern utilization of the ridges has occurred since pre-Hispanic times to varying extents and is discussed further in Chapter Seven.

Changes in the geological landscape have greatly impacted the preservation of the beach ridges themselves and overlying archaeological sites. The Peruvian beach-ridge sets are all located near major river mouths. Evidence at the Santa, Colán, and Chira beach ridges show the mouths of the Santa and Chira Rivers have migrated throughout time (Sandweiss *et al*. 1983; Sandweiss 1986; Shafer *et al.* 2004). Figure 6.1 shows the extent to which the Chira River has changed course, as seen in the meander cuts of the tablazo.

The Chira River and associated streams eroded the northernmost portion of the Colán beach ridges as well as the southernmost portion of the Chira beach ridges. Any sites associated with these sections would also have been eroded and later reworked northward by coastal processes (Shafer *et al*. 2004; Belknap pers. comm.). Geomorphological evidence of swales and paleo-inlets throughout the region are also indicative of a coastal landscape that has radically changed throughout time. Therefore, it is unlikely that intact or preserved archaeological sites lie in the vicinity of the Chira River mouth.

At Colán, two alluvial fans formed when sediment transported by El Niño floods was deposited at the base of two quebradas. The alluvial fans are composed of transported material that did not reach the shoreline to be reworked by regular oceanic processes, but rather slumped at the base of the tablazo cliff on top of previously formed beach ridges. The largest quebrada set in the region (the gravel and transport source for the cobble-beach ridges) was eventually cut off from depositing sediment into the ocean when the coast prograded to the extent of the eighth beach ridge (Shafer *et al*. 2004). After the quebrada was cut off from the shoreline, sediment that was transported in ENSO events formed an alluvial fan covering much of beach Ridge 8. A small quebrada to the north also created a small alluvial fan covering portions of the earliest ridges (Figure 6.2). It is unclear whether these depositional events covered up previous archaeological sites on those portions of the beach ridges.

Figure 6.1. Past boundaries of Chira River (Adapted from Google Earth).

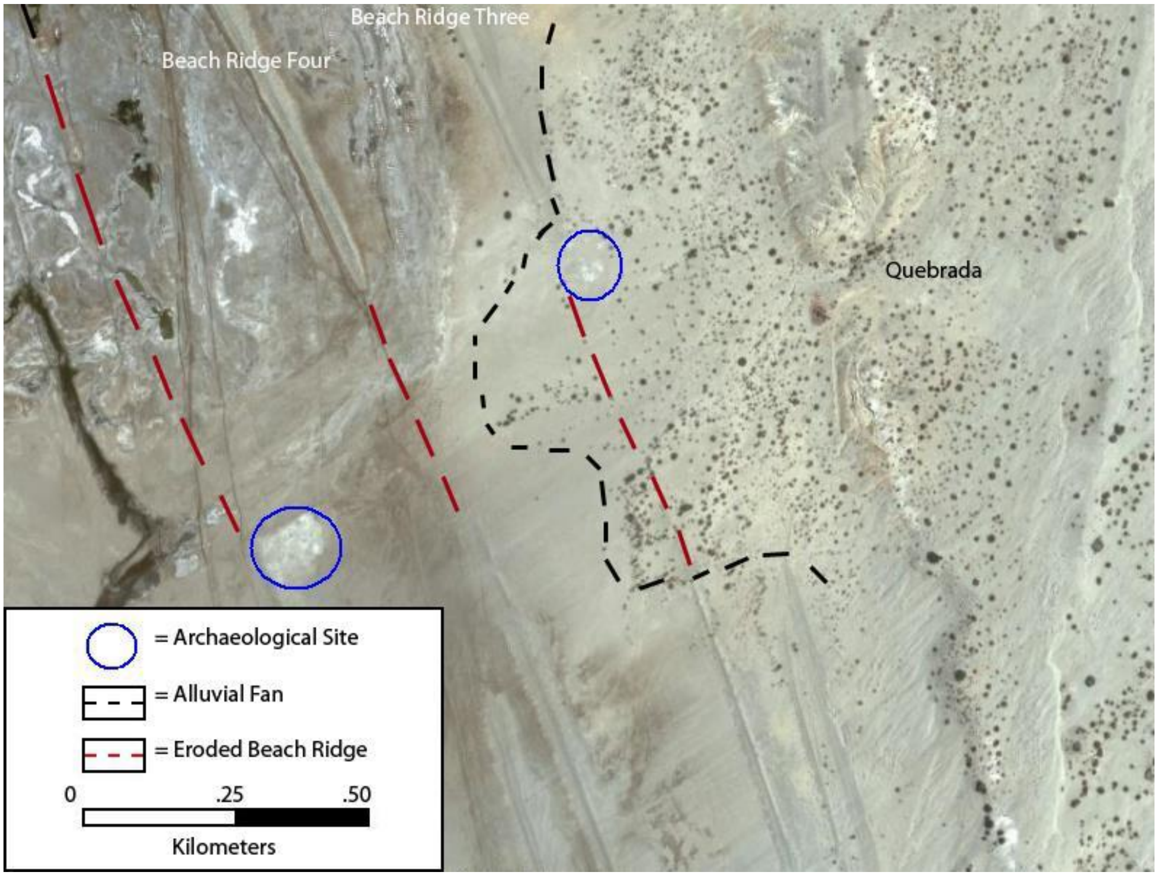

Figure 6.2: Northern quebrada and associated alluvial fan of the Colán beach-ridge set.

Paleoenvironments of the Santa Beach-Ridge Set

<u>Paleoshorelines</u>

The eight Santa beach ridges are located immediately north of the Santa River. The ridges are composed of cobbles and sands, supplied from the Santa River and carried north by longshore drift in the littoral zone. The stratigraphy of a borrow pit in Ridge 1 (the earliest ridge) exhibits a one-meter layer of poorly sorted fine material with a few poorly rounded large clasts, overlain by a well-sorted layer of rounded cobbles and pebbles (Sandweiss *et al*. 1983). The active beach ridge has a gravel substrate and experiences high wave action.

Molluscan remains come from geological contexts, as no archaeological middens have been discovered associated with the Santa beach ridges. The molluscan remains observed in geological deposits embedded in the ridges suggest a rocky substrate throughout ridge history (e.g., *Prisogaster niger* and *Tegula atra*). Due to the cobbles and high wave activity of the shoreline, mollusks are not abundant at the Santa ridges. Table 3 lists the molluscan species embedded in the Santa beach ridges with associated geographical distributions from Alamo and Valdivieso (1987).

Species	Habitat	Geographic Distribution	Source
Prisogaster niger (turban shell)	Rocky	Peru to Chile	Sandweiss *et al.* 1983
Tegula atra (top shell)	Rocky	Peru to Chile	Sandweiss *et al.* 1983
Xanthochorus buxea (gastropod)	Rocky	Peru to Chile	Diaz and Ortlieb 1991
Thais chocolata (dye shell)	Rocky and Sandy	Ecuador to Chile	Diaz and Ortlieb 1991
Semimytilus algosus (mussel)	Rocky	Peru to Chile	Diaz and Ortlieb 1991

Table 3. Molluscan species from geological contexts from Santa beach-ridge set.

Reed Marsh Habitats

The terrain between the ridges on the southern portion of the Santa beach set has attributes different from those of the northern half. The southern portion is located near the mouth of the Santa River, and it is affected by the higher water table in this area. Consequently, the depressions between the ridges have a variety of plant species. The extent of the reed marshes can be seen in Figure 6.3. During the survey, we were hindered by large stretches of marsh comprised of standing water, totora reeds (*Scirpus tatora*), and shrub grasses (Figure 6.4). In Sandweiss' 1980 survey of the beach ridges, he observed small fish in one of the same stretches of standing water (Sandweiss pers. comm.).

Figure 6.3. Vegetation between the Santa beach ridges (Adapted from GoogleEarth).

Figure 6.4. Modern reed marsh between two ridges on southern portion of the Santa beach-ridge set (Photograph by David Reid).

Natural Salt Deposits

Other features of the landscape between the ridges are wide expanses of a thin caliche surface layer. Caliche deposits are typically composed of sand or clay impregnated with crystalline salts such as sodium nitrate or sodium chloride (Figure 6.5). It is likely that these salt deposits would also have been present during prehistoric times, perhaps providing another resource for prehistoric peoples to exploit.

Figure 6.5. Caliche layer between two of the Santa beach ridges (Photograph by David Reid).

Archaeological Investigations of the Santa Beach-Ridge Set

Prior to this study it was thought that prehistoric peoples did not utilize the Santa beach ridges (Sandweiss *et al*. 1983; Wilson 1988). The only anthropogenic evidence observed during previous investigations was a number of windbreak foundations. These windbreaks are slightly curved lines of stones with an opening facing away from the prevailing southwesterly winds that come off the ocean (Sandweiss *et al*. 1983). They most likely served as a foundation for woven reed panels that would have served as walls. No artifacts were discovered with the windbreaks, therefore they are just as likely to be modern as prehistoric.

Yet, our 2006 field investigations led to the first conclusive evidence that prehistoric peoples utilized the Santa beach ridges. The archaeological evidence was not directly associated with the windbreaks, therefore it is still unclear if the foundations are prehistoric or modern. Prehistoric evidence included lithic remains of use-groundstone artifacts (used to grind materials and identifiable by a flattened and smooth surface), a quartzite cobble tool (an objective piece that shows signs of detached flake removal), and chipped-stone debitage (detached pieces discarded during the tool making process).

On Ridge 1, we discovered chipped-stone debitage, a quartzite cobble core with associated flakes (Figure 6.7) and a groundstone tool (Figure 6.8). On Ridge 2, we found volcanic use-groundstone (Figure 6.9) as well as an abandoned windbreak structure with no associated artifacts. The windbreak is similar to the ones observed by Sandweiss *et al*. (1983). It is semi-circular in design, has low walls of the same cobble material that forms the ridge, and is oriented to block the southwesterly winds (Figure 6.6). Yet, like the windbreaks previously recorded, it is just as likely to be modern as ancient since no artifacts were directly associated with it.

Our survey did discover evidence of prehistoric people on Ridge 3 a short distance from the windbreak. On Ridge 3, we discovered rosy quartzite flakes, some with obvious striking platforms (the surface area on a detached piece that was the point of applied force during tool production); thermally altered rock (possibly fragments of groundstone); and burned quartzite flakes.

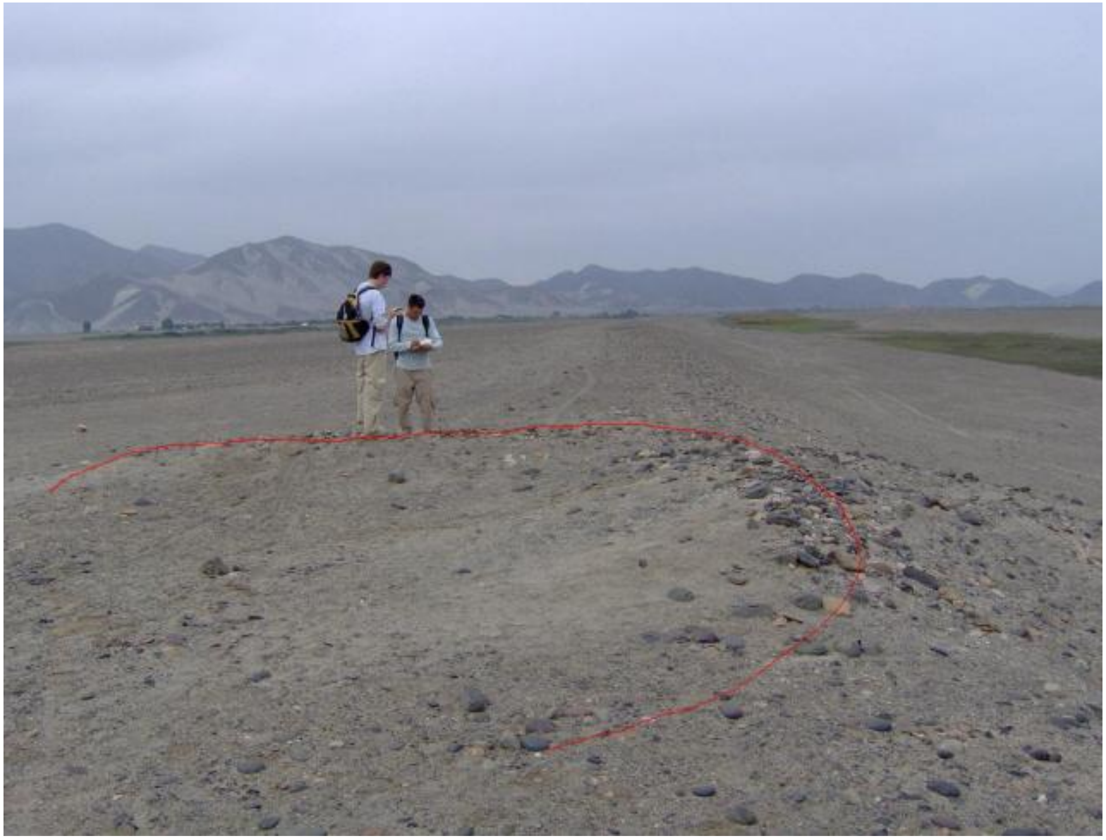

Figure 6.6: Windbreak structure on Santa beach-ridge set (Image by David Reid).

It is also important to note what we did not find on our survey. We did not find any evidence of habitation sites, shell middens, ceramics, or artifacts other than lithics. We did not find any evidence of prehistoric peoples on the more recent Ridges 4, 5, 6, 7, and 8. Due to the natural shattering of rock on many of the ridges, it is likely that more chipped-stone artifacts are present, yet obscured on the beach ridges. Due to the extensive amount of shattered rock, we took extra precautions when identifying chipped-stone artifacts. Another caution is not to automatically assume the lithics as prehistoric. Since the lithic artifacts are not temporally diagnostic, the people utilizing the Santa beach ridges might have lived during the Conquest or Colonial time periods (418-150 cal yr B.P.).

Figure 6.7. Cobble core discovered on Santa Beach Ridge 1 (Photograph by D. Reid).

Figure 6.8. Use-groundstone tool discovered on Santa Beach Ridge 1 (Photograph by D.Reid).

Figure 6.9. Use-groundstone tool discovered on Santa Beach Ridge 2 (Photograph by D.Reid).

Paleoenvironments of the Colán Beach Ridges

The Colán beach ridges located south of the Chira River are composed of gravel and sand. The Colán beach ridges are unique in that a major river did not contribute to their formation. During El Niño events, flood waters eroded conglomerate beds of the Quaternary age tablazo (sea cliff) and transported the material through a set of quebradas south of the Colán ridges (Richardson and McConaughy 1987; Ortlieb *et al.* 1989; Shafer *et al*. 2004). This material that was transported to the base of the quebradas was carried north by the longshore current and deposited as the Colán beach ridges. As littoral currents sorted the ridge material, larger clasts such as cobbles were deposited closer to the quebrada source. Therefore, as the ridges progress north, the ridge material is composed of smaller gravels and sand.

Over time, the progradation of the Colán coastal plain separated the quebrada mouths from the coast, cutting off the source of the gravel material, which might have been reworked into new beach ridges. Therefore, we do not have an active gravel beach ridge at Colán as a modern analog, as we do at the beach-ridge sets of Santa and Chira. The shoreline off the Colán beach ridges would have been a composite of large to small clasts of rock largely intermixed with sand, which the molluscan evidence suggests. The beach ridges are also of less relief, being 1.5 to 3.5 meters high above the coastal plain, providing an ideal platform to access the ocean and launch watercraft (Woodman and Polia 1974).

The molluscan remains from Colán exhibit a wide variation in habitats, such as sandy littoral zones, rocky littoral zones, lagoonal habitats, and even mangrove swamps (Table 4). The most abundant species, found in the geological cuts of the beach ridges, were the sand-dwelling *Donax obesulus* and *Tivela hians* (Ortlieb *et al*. 1989). *Donax* and *Tivela* are also the most abundant mollusks for each archaeological shell midden in the Colán area. Although the Colán beach ridges are largely composed of cobbles and gravels, sufficient amounts of sand built up fronting the ridges to provide sandy beaches.

Although sandy littoral zones seem to be dominant, other molluscan remains suggest a variety of smaller habitats. Ridge 1, proportionately contains the most rocky littoral zone species embedded in the ridges, including the species *Pseudochama corrugata* and *Anomia peruviana* (Diaz and Ortlieb 1991). Before Ridge 1 formed, the ocean would have bordered the tablazo, to provide a habitat for rocky species. During ridge formation the rocky littoral zone species would have been reworked into Ridge 1.

Based on midden surface collections, species of rocky littoral zones were in low abundance in the archaeological record at Colán. The molluscan species *Anomia peruviana* and *Crucibulum spp.* were found in the shell midden draping Ridges 4 and 5. These were most likely collected from nearby rocky habitats immediately south of the ridges by prehistoric peoples and transported to the midden location.

Geomorphological and molluscan evidence also indicates the presence of an intertidal lagoon (Figure 6.11). Strong geomorphological evidence for this lagoon is provided by the opening in Ridge 6, which appears to be an inlet with associated recurved spits. The intertidal attribute of the lagoon was further supported by ground penetrating radar (GPR) investigations performed in 2006 (Belknap pers. comm.; Orltieb *et al*. 1989; Shafer *et al*. 2004).

Molluscan evidence of a protected environment, such as a lagoon, was also found in geological and archaeological contexts. Embedded in a ridge associated with the paleolagoon was *Trivia radians* and *Protothaca columbiensis* (Diaz and Ortlieb 1991). During the 2007 field season, I collected shells of *Malea ringens* and *Anadara tuberculosa* from the midden sites located around the paleolagoon (Figure 6.11). Four of the molluscan species are specific to mangrove habitats, indicating that the intertidal lagoon once accommodated a remnant mangrove stand. The presence of mangrove habitats this far south is anomalous for the time period (Richardson 1995), and is further discussed in Chapter Seven.

Molluscan Speices	Habitat	Geographic Distribution	Source
Donax obesulus (clam)	Sandy	Ecuador to Chile	this study
Tivela hians (clam)	Sandy	Punta Telegrafo to Pimentel, Peru	this study
Semele corrugata (clam)	Sandy	Ecuador to Chile	this study
Olivella columellaris (olive shell)	Sandy	Nicaragua to Pimentel, Peru	Diaz and Ortlieb 1991
Trachycardium procerum (clam)	Muddy, Sandy	Mexico to Chile	this study
Conus fergusoni (cone shell)*	Muddy, Sandy	Mexico to Cherres, Peru	this study
Turritella broderipiana (snail)	Muddy, Sandy	Puerto Pizarro to Muelle Promar, Peru	this study
Sinum cymba (snail)	Muddy, Sandy, Rocky	Ecuador to Chile	this study
Protothaca thaca (clam)	Muddy, Sandy, Rocky	Peru to Chile	this study
Polinices uber (snail)	Sandy, Rocky	Mexico to Pisco, Peru	Ortlieb *et al*. 1989
Crucibulum spp (limpet)	Rocky	Peru to Chile	this study
Anomia peruviana (oyster)	Rocky	Mexico to Sechura, Peru	this study
Pseudochama corrugata (oyster)	Rocky	Mexico to Huacho, Peru	Diaz and Ortlieb 1991
Malea ringens (cask shell)	Mangroves	Mexico Islas Lobos de Afuera, PE	this study
Anadara tuberculosa (ark shell)*	Mangroves	Mexico to Puerto Pizarro, Peru	this study
Protothaca columbiensis (clam)	Mangroves	Mexico to Pacasmayo, Peru	Diaz and Ortlieb 1991
Trivia radians (snail)	Mangroves	Mexico to Islas Lobos de Afuera, PE	Diaz and Ortlieb 1991

***** Normal southernmost distribution of modern species found north of Colán (Alamo and Valdivieso (1987).

Table 4. Molluscan species observed in geological and archaeological contexts of Colán.

Archaeological Survey of the Colán Beach-Ridge Set

During the 2006 and 2007 field seasons, Kurt Rademaker and I investigated the archaeological sites associated with the Colán beach ridges. Our archaeological survey supports the interpretation of the Colán area first published by Ravines (1988a) and the observations of Richardson and McConaughy (1987). Our investigations add to the previous research by presenting a more refined hypothesis of how the Colán area was settled and utilized during prehistoric times.

The previous literature of the prehistory of Colán suggests that the region was inhabited and utilized in two settlement phases. The earliest component is a series of shell middens located on top of the tablazo (or ancient marine terrace) and associated middens on portions of the earliest beach ridges. The late component is a group of sites under the modern town of Colán, as well as a group of shell middens between Ridge 8 and the modern shoreline (Figure 6.10).

To make the recent archaeological investigations clearer, I have renamed the sites originally named by Ravines as seen in Table 5 (1988a). This is because of the discovery of new sites as well as new interpretations of settlement chronology. Early Component sites have the prefix EC, the Late Component sites near the modern town of Colán have the prefix LC, and the Late Component middens to the north between ridge 8 and the shell line were assigned the prefix M.

This Study	Ravines 1988a
EC-1	P4-2
EC-2	P4-4
EC-3	P4-1
EC-4	P4-5
EC-5	
EC-6	P4-6,7,8
EC-7	
EC-8	
LC-1	C1-9
LC-2	C1-2
LC-3	C1-5
LC-4	C1-4
LC-5	C1-7
LC-6	M2-1
M-1	L3-9
M-2	L3-8
M-3	L3-6
M-4	L3-7
M-5	L3-5
M-6	L3-4
M-7	L3-1,2
M-8	L3-3

Table 5. Colán archaeological site names.

Early Occupation Component: The Tablazo Sites

During the 2007 field season, we investigated the previously recorded archaeological sites on the tablazo (EC-1,2,4 and 6) (Ravines 1988a). The shell middens are separated into a distinctive northern area composed of EC-1 and 2, and a southern area composed of EC-4 and 6. These two midden areas differ in overall size and archaeological composition. The areas are separated by a dead-zone of quartzite gravels and rocky terrain, approximately half a kilometer long. Our survey of the tablazo did not recover any anthropogenic evidence in this dead-zone.

The two shell midden areas are significant in that they are both located at access points to the beach-ridge set below. The northern area consists of small middens with few lithic artifacts and ceramic artifacts located near a small quebrada that cuts down to the earliest beach ridges. The southern midden area is a large and complex site of thick deposits of shell middens, large shell rings, lithic and ceramic artifacts, and at least one structure foundation composed of rock. The southern midden area is also located near a slope in the tablazo that serves as a gentle route down to the beach-ridge plain. In both distributions the most abundant shellfish are the sand-dwelling *Donax obesulus* and *Tivela hians*.

The ceramics recovered from the tablazo middens correspond to Paita Phase 2 (3500-3200 cal yr B.P.) and Paita Phase 3 (3200-2700 cal yr B.P.) (Ravines 1988a). Ceramics of the subsequent Sechura Phase (2700-1250 cal yr B.P.) were also observed on the tablazo and in sites on the beach ridges themselves (Richardson *et al*. 1990). In the previous studies both midden areas were considered contemporaneous, although that may not be the case.

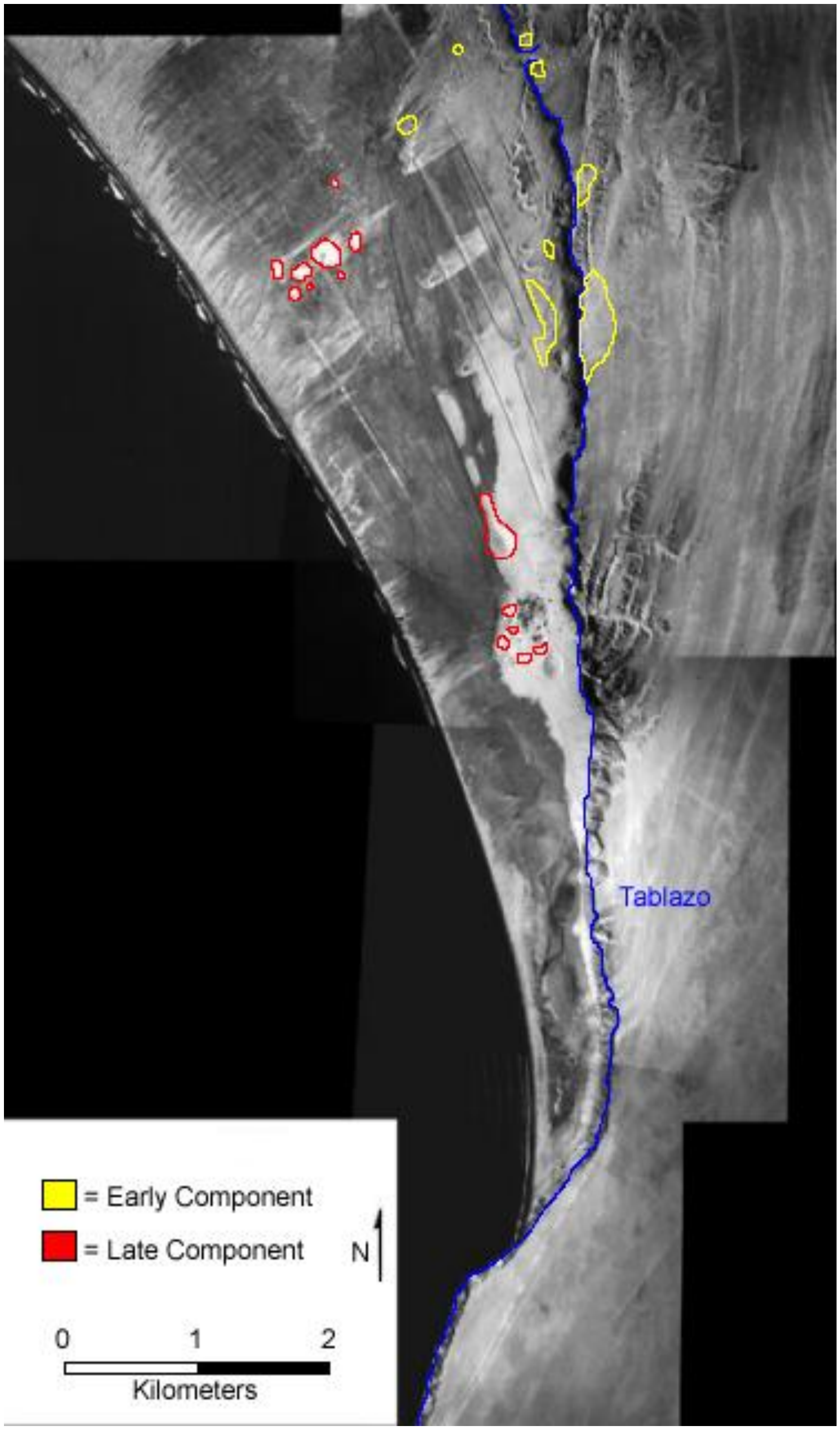

Figure 6.10. Distribution of archaeological sites of the Colán region (Image adapted from Shafer 1999).

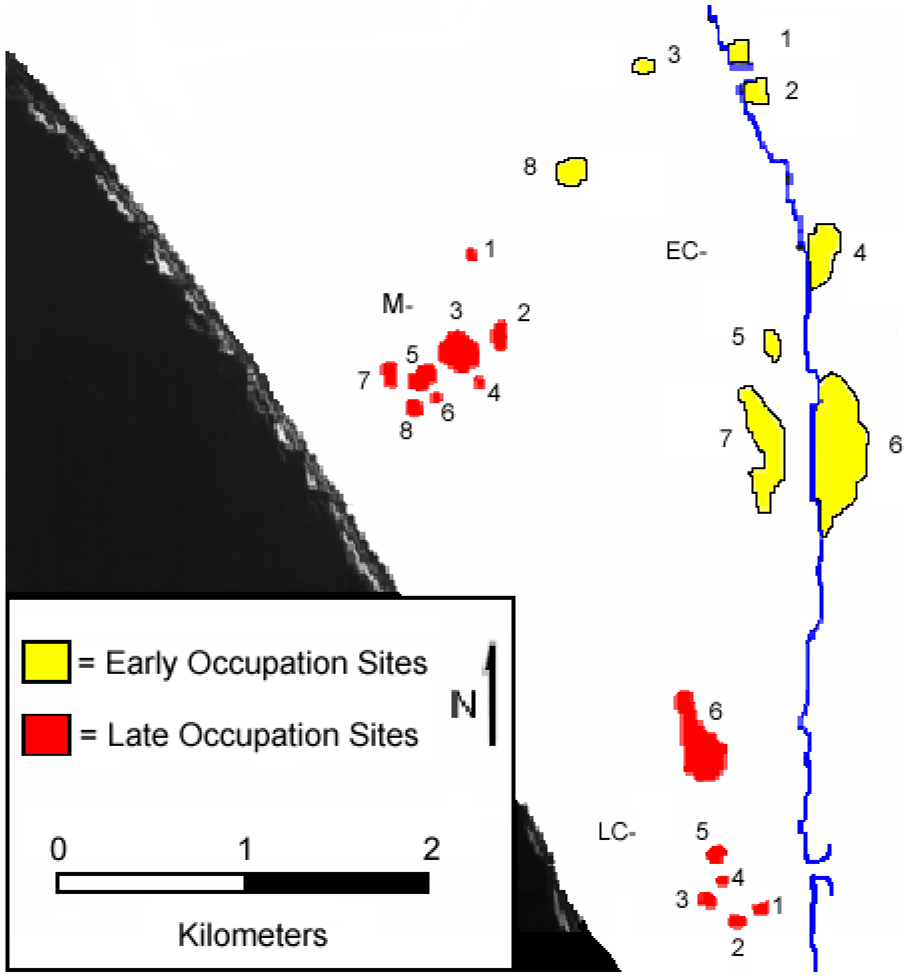

Figure 6.11. Site location and names for the Colán region.

During the 2007 field season, we discovered stylistically diagnostic ceramic sherds on the surface of the southernmost middens (EC-4 and 6). All the surface ceramics were unearthed by previous looting activity and were associated with major looters' pits. Using the ceramic sequences as described, drawn, and photographed in the previous literature, two sherds stylistically corresponded to either sub-phases Paita 2 (3500-3200 cal yr B.P.) or 3 (3200-2700 cal yr B.P.) and another sherd pertained to Sechura Phase 2 (2700-1700 cal yr B.P.) (Appendix A Ceramics 1- 3; Lanning 1963; Ravines 1988a; Richardson 1983; Richardson and McConaughy 1987; Richardson *et al*.

1990; McConaughy 1993). The Paita occupation of the tablazo is also supported by one radiocarbon date from an unknown provenience of 3090 ± 130 cal yr B.P. (Richardson and McConaughy 1987). The extensive tablazo middens overlooking the beach ridges and their location at major access points suggest the beach-ridge set attracted prehistoric peoples to the region.

Early Occupation Component: Beach-Ridge Sites

The earliest beach ridge at Colán (Beach Ridge 1) has no anthropogenic evidence, although the second beach ridge has extensive remains of lithic tool production. A large, rosy quartzite rock with associated debitage suggests the production of unifacial stone tools common for coastal peoples. This rock is much larger than the cobbles and pebbles of which the ridges themselves are composed, suggesting that the rock was moved to its present location by anthropogenic activity. Also, on the second ridge a ground-stone tool was discovered.

The third beach ridge was absent of prehistoric evidence except for a small shell midden near the eroded northern portion of ridge (EC-3; Figure 6.2). The past movements of the Chira River and associated streams washed out a large portion of the earliest ridges in close proximity to the site, therefore we do not know if associated nearby sites were destroyed. The EC-3 site is a small shell ring composed of mainly *Donax obesulus* and *Tivela hians* with unifacial lithic tools, ground stone, ceramics, and a small amount of bird faunal remains.

Since it is likely that the midden was created when Beach Ridge 3 was the active shoreline, we can relatively date the site from the beach ridges themselves. Although

Ridge 3 has not been radiocarbon dated, Ridges 2 and 4 have. Since the site is located on Ridge 3, it must post date Ridge 2 (2720 ± 280 cal yr B.P.) and predate Ridge 4 when the site was presumably abandoned (2530 ± 610 cal yr B.P.) (Ortlieb *et al*. 1989). Therefore, the EC-3 midden most likely dates between approximately 2800 cal yr B.P. to 2500 cal yr B.P.

This inference of age is also supported by the ceramics found on the surface of the midden EC-3. The majority of ceramics are sherds of orange utilitarianware blackened on one side, most likely a result from being set in hearths. Three of the sherds stylistically correspond to the Paita 3 ceramic phase (3200-2700 cal yr B.P.) (Richardson *et al*. 1990). The ceramics fit accordingly into the time frame of midden formation between 2800 cal yr B.P. and 2500 cal yr B.P.

The fourth ridge at Colán is much longer that the previous three ridges, and greatly expanded the area of available shoreline to exploit (Figure 3.3). Between Ridge 4 and the tablazo cliff are two natural dunes capped by shell middens. These sites named (EC-5) might be contemporaneous with a large midden area on the southern portion of the fourth and fifth beach ridges (EC-7) (Figure 6.12). These middens are composed of mainly *Donax obesulus* and *Tivela hians*, abundant chipped-stone debitage, use-groundstone tools, and ceramics. It is important to note that these sites are oriented around the geomorphic features of the paleolagoon (Figure 6.12).

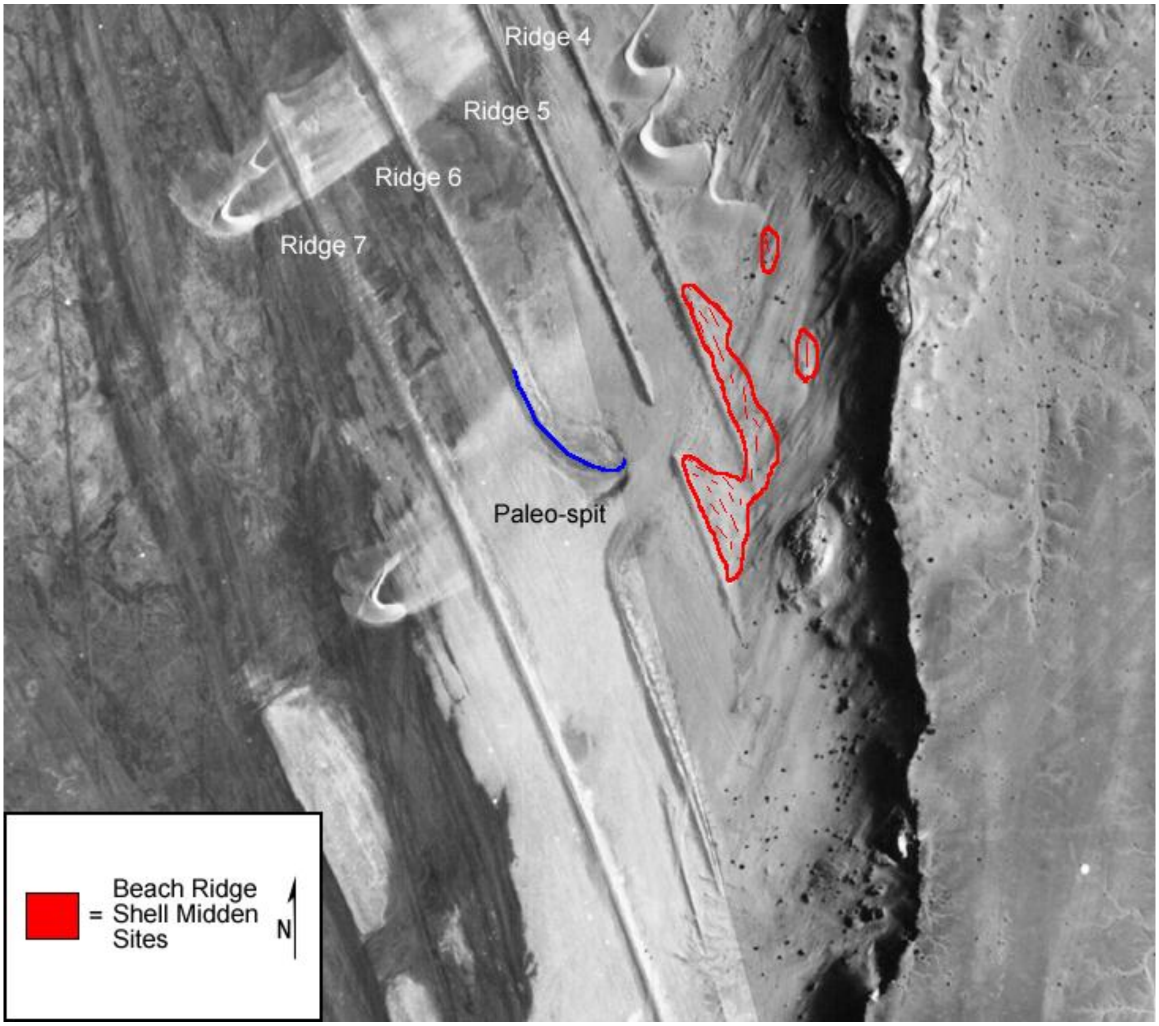

Figure 6.12. Recurved gravel spits at Colán indicating a paleo-lagoon and associated EC-5 and 7 shell-midden sites (Adapted from 1946 SAN airphoto).

Ceramics observed on the surface of the EC-5 and 7 shell middens pertain to the Sechura Phase (2700-1250 cal yr B.P.) (Richardson and McConaughy 1987). The ceramic artifacts observed in the field were mostly plain, orange/red utilitarianware blackened on one side by fire. One sherd discovered at EC-5, the armored dune behind Beach Ridge 4, stylistically corresponds to the Sechura 2 Phase (2400-1700 cal yr B.P.) (Appendix A, Ceramic 6). The sherd has a finely painted white on red, slipped ware design that began during the Sechura 2 phase (McConaughy 1993). The midden site EC-7 on Ridges 4 and 5 also has associated radiocarbon dates. Two samples of *Donax obesulus* and *Tivela hians* from the midden dated to 2370 ± 300 cal yr B.P. and 2110 ± 250 cal yr B.P. (Ortlieb *et al*. 1989). These dates confirm that the midden sites EC-5 and 7 correspond to Sechura Phase peoples, and they support the ceramic evidence that the occupation is in the Sechura Phase. It is also likely that the tablazo sites EC-4 and EC-6 correspond to these beach-ridge sites.

Another shell-midden site pertaining to the early settlement component is located on the slopes and behind Ridge 6 at its northernmost extent (EC-8). This shell midden was almost entirely composed of the sandy-environment shellfish *Donax obesulus* and *Tivela hians*. A small amount of lithic debitage and ceramic fragments was observed. The midden site most likely was larger as movements of the Chira River and associated streams eroded the northernmost portion of the ridge (Figure 6.2). Due to the midden's location it must post date Ridge 6 (1990 ± 370 cal yr B.P.) and predate Ridge 7 (1190 ± 200 cal yr B.P.). From these dates, the sites were likely created by peoples of the Sechura 3 phase (1700-1250 cal yr B.P.) (Ortlieb *et al*. 1989; Richardson *et al*. 1990).

After surveying the entirety of Beach Ridge 7, we did not find any evidence of prehistoric peoples. It is likely that before or during the formation of Ridge 7, the people of Colán abandoned the region. A sample of *Donax obesulus* embedded in Ridge 7 dates to 1190 ± 200 cal yr B.P. (Ortlieb *et al*. 1989). The hypothesis that Ridge 7 marks the abandonment period is corroborated by the previous ceramic studies of Ravines (1988a). Ravines did not find any ceramic evidence of the early Piura Phases. With the range of dating error of the beach ridges and the small number of associated radiocarbon dates with the ceramic typology, it is likely that abandonment of the area occurring during the transition from the Sechura Phase to the Piura Phase around 1200-1300 cal yr B.P. It is not until Piura Phase 3 (800-500 cal yr B.P.), that people returned to the Colán region (Ravines 1988a; Richardson *et al*. 1990).

Late Occupation Component

The modern town of Colán is located on top of late-occupation component sites. These shell-midden sites (LC-1-6) are located on an alluvial fan which formed on top of the eighth gravel beach ridge. The shell-midden sites on the alluvial fan contain evidence of the Piura Cultural Phase (1250 cal yr B.P. to the present). Ceramic artifacts stylistically pertain to the later sub-phases of Piura 3 (800-500 cal yr B.P.), Piura 4 (500-418 cal yr B.P.), and Piura 5 during the Colonial Period (418-150 cal yr B.P.) (Lanning 1963; Ravines 1988a; Richardson 1983; Richardson and McConaughy 1987; Richardson *et al*. 1990).

One stone artifact discovered at the group LC shell middens was a fish weight. This suggests that later-component peoples at Colán used fishing nets. This discovery also supports the evidence of technological changes from the Paita Phase hook-and-line technology to the cotton nets of the Piura (Ravines 1988a). Cotton fishing nets suggest that people were exploiting smaller types of fish, such as the anchovy which are abundantly found in the cold waters off the coast of Peru. Also, the use of cotton suggests ties to inland agricultural sites in the Chira and Piura River valleys, which markedly rose during the Piura phase (Richardson *et al*. 1990).

Unlike the other shell middens at Colán, a small amount of archaeological excavation occurred in association with the Church of San Lucas (part of the LC site grouping). Located in the modern town of Colán, San Lucas is claimed to be the very first Christian church in Peru, having been built in the early 16th century. The church is located directly on top of an archaeological site pertaining to the Piura phase. Ravines (1988a) excavated two tombs containing a young boy and an infant with ceramic offerings of bowls and jars. The decoration typology on a bowl fragment in one of the tombs corresponds to the Inca-Cusco type seen during Piura Phase 4 (500-418 cal yr B.P.).

At the northernmost extent of the beach ridges, between the eighth gravel ridge and the shell line, is a set of eight shell middens termed M1-8 (Ravines 1988a). The eight shell middens are likely not contemporaneous as previous shorelines separate the middens into at least two phases (Figure 6.13). A charcoal sample from one of the eight middens dates to 480 ± 320 cal yr B.P. (Ortlieb *et al.* 1989). The radiocarbon sample supports the hypothesis that the shell midden group M1-8 formed during the late Piura phases.

Figure 6.13. M1-8 shell-midden sites on paleo-shorelines (Adapted from 1946 airphoto).

The ceramics recovered from Colán indicate a shift from presumably local autonomy to the people of the far north coast being incorporated into ancient statehood networks. The Chimú State had a presence in the region during Piura Phase 3. It is also during this period that large ceremonial compounds were constructed in the Chira and Piura River valleys. During Piura Phase 4, the Inca state had a presence in the region incorporating the far north coast into its empire (Richardson *et al*. 1990).

It is important to stress that the people occupying Colán were not isolated from outside cultures and settlements, but were most likely an integral part in numerous systems. It is unclear without extensive archaeological excavation at Colán what role the sites played in these systems. Yet, due to the extent of the shell middens, funerary contexts, ceramic artifacts showing long-distance trade and interaction, as well as the Spanish construction of Peru's first Christian church on the site, Colán was probably more than just a small seasonal camp.

Coastal Progradation and Site Distribution

The formation of new beach ridges prograded the coastal plain of Colán, which had a large effect on site distribution. Prehistoric people who utilized shorelines tended to move up with progradations of the coast. When a new beach ridge formed people would utilize the new shoreline, creating new archaeological sites on or directly behind the contemporaneous ridge. This trend is observed in the archaeological remains at the Peruvian beach ridge set of Chira as well as Colán (Richardson 1983). Furthermore, this settlement and utilization trend is not exclusive to Peru, as it has been recorded at beach-ridge sets around the world (Mason 1993). Therefore, we can understand settlement patterns in relation to the ever-prograding beach-ridge plain.

The middens associated with the earliest three beach ridges are the small shell ring behind Ridge 3 (EC-3), and most likely the northern shell midden area on top of the tablazo (EC-1 and 2). The quebrada that leads down to the beach ridges in the north would have provided access to the coastline since the beach ridges began forming. People were probably occupying the top of the tablazo and were using the quebrada as a route down the cliff to access the marine resources off the first three beach ridges (Figure 6.14).

At least by the time that Beach Ridge 6 had formed, people at Colán had moved farther south on the beach-ridge set. This move is most likely to incorporate resources from paleolagoons located at this southern portion, as indicated by paleoinlets and intertidal spits. Also, mollusks from rocky littoral zones would have been available immediately to the south of EC-7 where the sandy beach had not yet prograded. The largest extent of shell middens on top of the tablazo (EC-6) in the southern area likely corresponds to the middens around the paleolagoon (EC-5 and 7) (Figure 6.15). A small path going up the natural contours of a slope in the tablazo cliff provides an access route from the middens on Beach Ridges 4 and 5 to the southern shell middens of the tablazo.

The late-occupation component demonstrates a large shift of people solely inhabiting the coastal plain and not the top of the tablazo cliffs (Figure 6.16). During the early component, people might have preferred to occupy the cliffs above the shoreline due to the presence of contemporaneous lagoons and marshes that grew between the early beach ridges. The tablazo would have lifted settlements out of the marshy conditions, and given people a good vantage point for observing the surrounding terrain.

By the late occupation, the coastal plain had prograded enough to provide sufficient area to occupy that was not marshy. Furthermore, the majority of late component sites are located at the base of a large set of quebradas, much like other large settlements along the Paita Peninsula (LC-1-8) (McConaughy 1993). This is likely due to the availability of fresh water, although more data are needed to substantiate this hypothesis. Another factor is the distance one would have to walk from the shoreline resources to the settlement area. By the late occupation component, the coastal plain had prograded to an extent that carrying shellfish longer distances to the top of the tablazo might have been undesirable.

The late-component shell-midden sites to the north (M1-8) most likely date after the initial Piura Phase settlement on the alluvial fan. The northern middens are located between Beach Ridge 1 and a major shell line close to the modern-day shore (Figure 6.17). This move north was probably due to nearby freshwater streams and associated vegetated marshy areas.

It is essential to first unravel alterations of the paleolandscape and environment to even begin to understand why past groups of people selected certain locations over others to occupy and exploit. Archaeological sites at Colán represent a myriad of spatial and temporal differences. The formation of the Colán beach ridges significantly influenced how prehistoric peoples interacted with their landscapes.

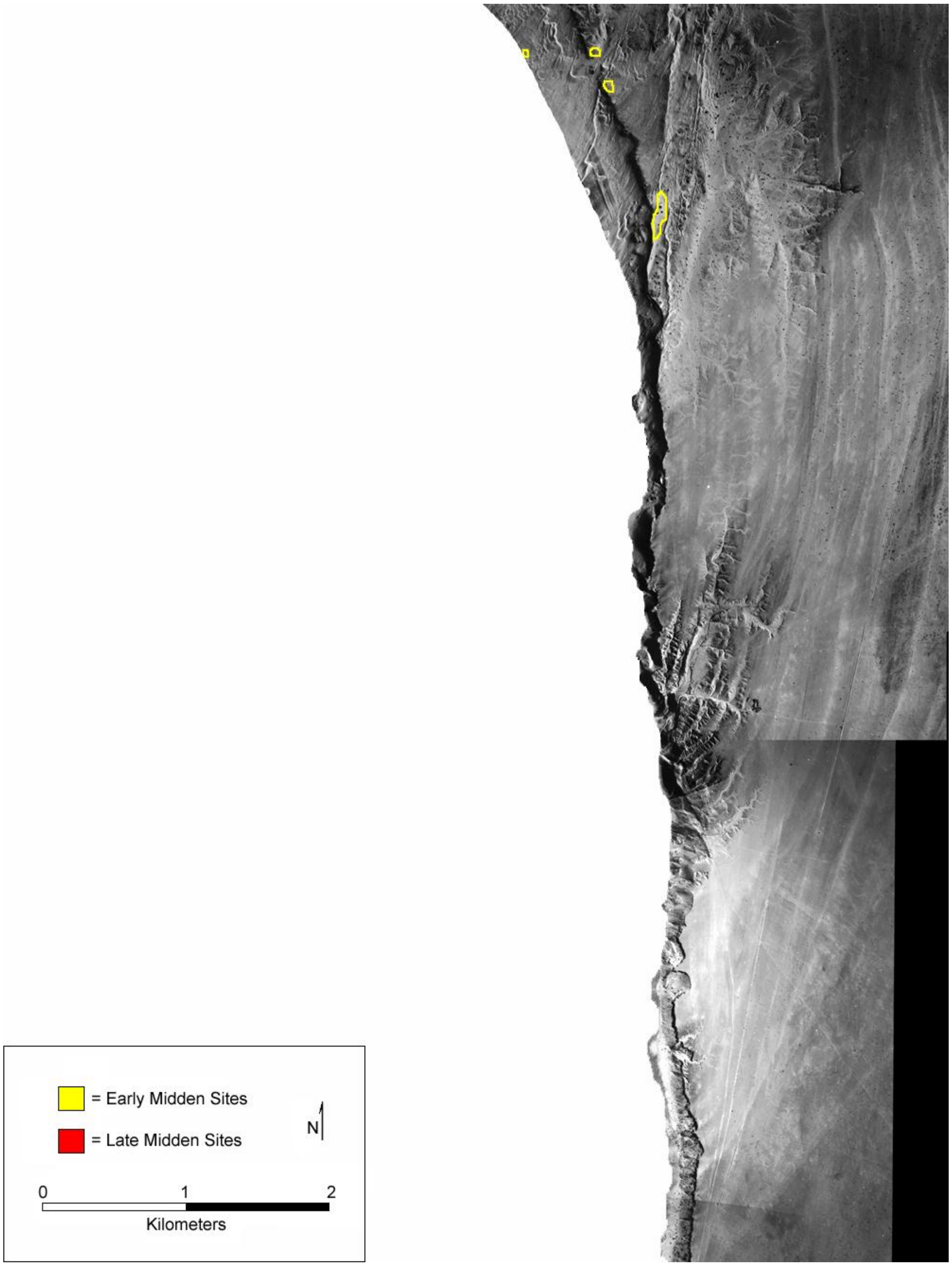

Figure 6.14. Likely initial settlement of Colán region (Adapted from Shafer 1999).

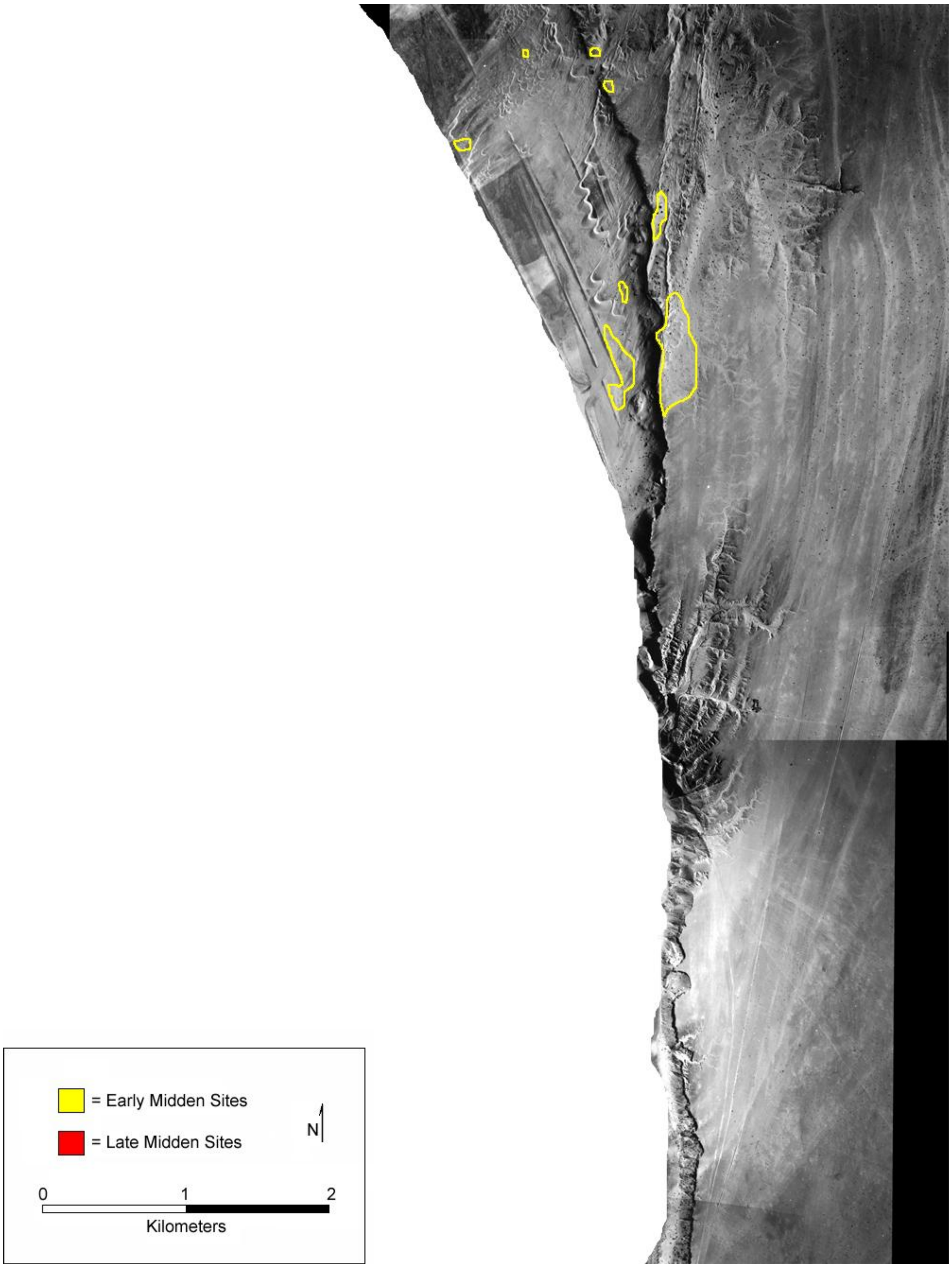

Figure 6.15. Extent of the early occupation component of the Colán region (Adapted from Shafer 1999).

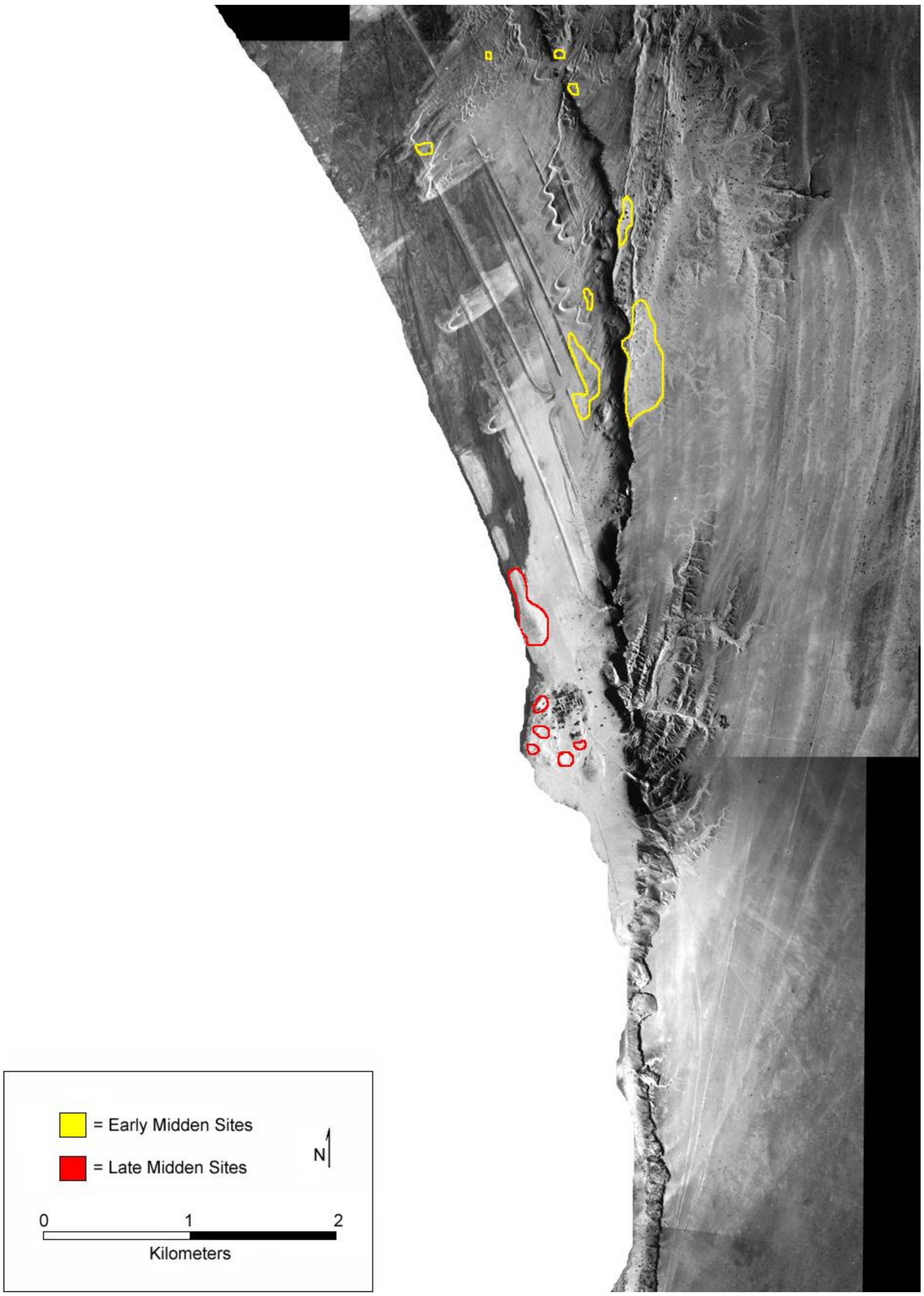

Figure 6.16. Initial sites of the late occupation component of the Colán region (Adapted from Shafer 1999).

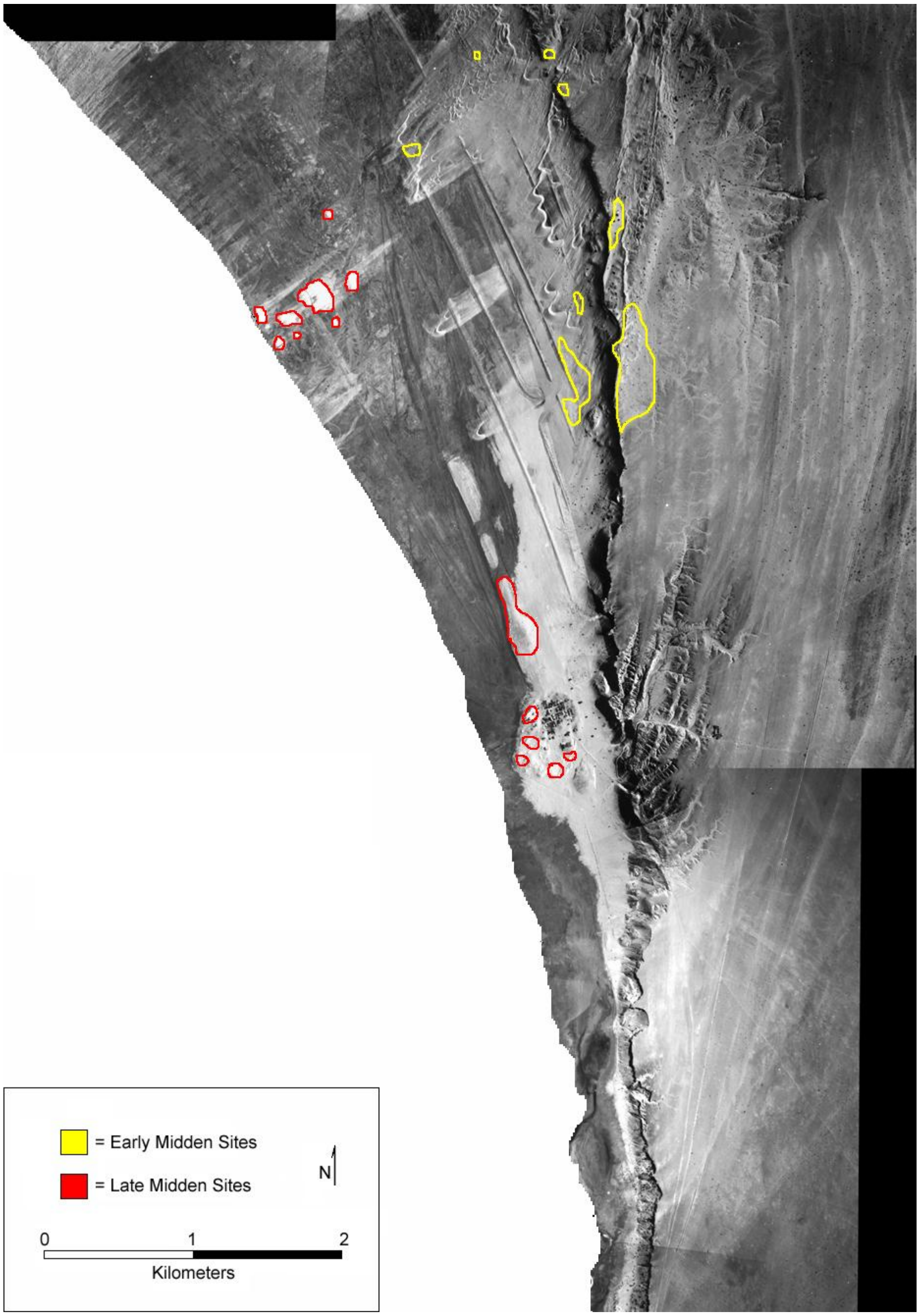

Figure 6.17. Extent of the late pre-Hispanic occupation of the Colán region (Adapted from Shafer 1999).

Paleoenvironments of the Chira Beach Ridges

The Chira Beach ridges, north of the Chira River, are composed of sand. The ridges were created by sediment discharged from the Chira River and carried northward. All nine ridges are composed of sediment similar in size and constituents to the Chira River alluvial deposits (Chigne 1975). The active ridge today is of a sandy substrate like the previous ridges.

The molluscan remains of the Chira ridges also inform us of the paleo-shorelines. All of the data concerning the Chira beach ridges come from archaeological contexts. The most abundant molluscan species throughout the archaeological record are *Donax obesulus* and *Tivela hians* (Table 6). These two species are still the most abundant mollusks found in the region today, and they are collected by local fishermen (Richardson 1983). In 2006, I observed *Tivela hians* in living context on the recent shoreline of the Chira beach-ridge set (Figure 6.18).

Species	Habitat	Geographical Distribution	Source
Donax obesulus (clam)	Sandy	Ecuador to Chile	Richardson 1983
Tivela hians (clam)	Sandy	Punta Telegrafo to Pimentel, Peru	Richardson 1983

Table 6. Molluscan species from archaeological contexts on the Chira beach ridges (Geographical distributions from Alamo and Valdivieso 1987).

Figure 6.18. *Tivela hians* in living context on the active Chira beach ridge (Photograph by David Reid). The coin in the photograph is the Peruvian Nuevo Sol with a 25.5 mm diameter.

Geomorphological evidence of paleolagoons is also found at the Chira beach ridges. The oldest ridge at Chira is discontinuous, with a series of paleoinlets and low-lying complexes of recurved spits. These inlets and associated spits suggest that when the first beach ridge was active, it formed a barrier fronting a lagoon (Richardson and McConaughy 1987; Shafer *et al*. 2004). At the southern end of the beach-ridge set, only scroll bars and remnant sections of the ridges remain due to past movements of the Chira River mouth (Shafer *et al*. 2004). It is likely that this southern portion of the ridges would have accommodated reed marshes and lagoons.

Archaeological Investigations of the Chira Beach-Ridge Set

During the 2006 field season, Kurt Rademaker and I walked a transect of the Chira beach ridges from the oldest ridge to the modern shoreline. Our observations matched previous studies of the extensive shell middens investigated by Richardson (1983). The sandy Chira beach ridges are capped with shell from anthropogenic and natural activity. The most abundant shell species are *Donax obesulus* and *Tivela hians*. An abundance of lithic debitage on the earlier ridges and the abundance of ceramics from Ridges 7 to 2 also correspond to Richardson and McConaughy's observations (1987; Richardson 1983).

The earliest ridge at Chira was occupied during the Honda Cultural Phase (6000 to at least 4400 cal yr B.P.) (Richardson 1978, McConaughy 1993). As the ridges prograded throughout time prehistoric peoples moved up with the active shoreline. The most recent Chira beach ridge does not have evidence of prehistoric peoples. It is thought that the extensive shell middens and natural shell that armor the previous Chira ridges protected the sandy ridges from wind erosion and sand movement (Richardson 1983; Shafer *et al*. 2004). Due to the lack of shells capping the ridge, the most recent ridge is noticeably much more hummocky than the previous ridges (Belknap pers. comm.).

CHAPTER SEVEN: DISCUSSION

When relating human culture to modern and past environments, it is important not to fall into the traps of environmental determinism. Yet, it is important in archaeology to understand the multitude of potential interactions of people and their environment. A part of this relationship between people and their surroundings are certain environmental limitations within which people must work. It is humans' responses to these limitations which are of interest to anthropology. Prehistoric peoples on the coast of Peru utilized the Santa, Colán, and Chira beach ridges in various ways and to different extents. What drew prehistoric peoples to the beach ridges? How do the different attributes of the ridge sets factor into differences in the archaeological record? From a human ecological approach, environmental limitations and climate-change events can help us understand the archaeological record left by prehistoric peoples.

Environmental Factors

Beach-Ridge Material

The beach ridges of Peru vary in composition from the cobble ridges of Santa to the cobble and gravel ridges of Colán and the sandy ridges of Chira. These varying beach- ridge materials have had a great impact on the coastal littoral zones and ecological habitats from the past to modern times. These platforms to the ocean were important for prehistoric peoples on the coast of Peru, because fish and shellfish provided a substantial portion of their diet (Moseley 1975).

The beach-ridge material played a crucial role in the availability of molluscan resources, because shoreline material can facilitate or impede the presence and abundance of different species of mollusks. Mollusks thrive in certain environments, such as sandy and rocky littoral zones, and do poorly in others such as cobble beaches. The archaeological investigations of the beach ridges must take into account these environmental limitations and factors.

The Santa beach ridges have very little evidence of prehistoric people. The environmental factors of the cobble-ridge coastlines limit the types of activities that could have occurred at Santa. The cobble substrate impedes shellfish that require sandy or muddy sediments, or shellfish that require rocky promontory littorals. The rounded cobbles are also in a constant state of motion, as the high wave action shifts and grinds them together. The high relief of the ridges combined with the high wave action would also make it difficult to launch a small boat for open-water fishing (Figure 7.1). Because of these ecological limitations, it is not surprising that shell middens or habitation sites have not been discovered along the 20 kilometer (12.5 mi) extent of the Santa beach ridges.

Figure 7.1. Active cobble-beach ridge at Santa (Photograph by David Reid).

The Colán beach ridges are composed of cobbles, gravels, and sand. Although the ridges consist of large cobbles like the Santa ridges, the presence of finer gravels and sands make the ancient shorelines distinct. Geological cuts in the Colán ridges contain sand-dwelling molluscan species such as *Donax obesulus* and *Tivela hians*. These two species are the most abundant in the extensive shell-midden sites of Colán.

The Colán shell middens are small in comparison to the extensive Chira beach-ridge middens. The Chira beach ridges stretch 30 kilometers (18.6 mi) north from the mouth of the Chira River. Unlike the ridges at Santa and Colán, there is evidence that since their early formation, the beach ridges of Chira were continuously utilized throughout prehistory. The shell middens are almost exclusively made up of *Donax obesulus* and *Tivela hians*, showing that the long sandy stretches of the Chira beach ridges were an ideal locale to collect and process shellfish.

The varying ridge material of cobbles, pebbles, and sand directly influenced the resources available to prehistoric peoples. At Santa, where the beach ridges impeded large quantities of shellfish, there is little archaeological evidence. With the opposite extreme at Chira, where abundant sandy-environment shellfish could easily be collected, there are immense shell-midden sites throughout the cultural phases. This suggests that in coastal areas where there is a ready abundance of food resources prehistoric peoples are more likely to utilize and inhabit those locales.

Coastal Marshes and Lagoons

We can begin to understand the relationship between prehistoric peoples and coastal marshes and lagoons by looking at the archaeological record. Marshes and lagoons occur along the coast of Peru, usually behind bars of sand. In Prehispanic times, people were drawn to these habitats for numerous reasons. Vegetation such as salt grasses, sedges, and reeds were woven into mats, baskets, panels used for shelter construction, and other small artifacts (Moseley 1975). Reeds were also used in the construction of *caballitos*, small one-person crafts used for off-shore fishing. Boat building is a very old craft, yet the earliest known evidence in Peru comes from ceramic artwork of the Moche Period approximately 1700-1100 cal yr B.P. (Wilson 1988). Marshy and lagoonal habitats also provide diverse wildlife such as birds, small fish, and crustaceans commonly exploited for food.

At the Santa beach ridges, the only archaeological evidence of past peoples are lithic artifacts of groundstone tools, cobble cores, and chipped-stone debitage (remains from tool production activity). The lithic artifacts were produced from beach-ridge cobbles, suggesting people were using the ridges as a source of raw material for stone tools. Prehistoric peoples visiting the Santa beach ridges were most likely taking advantage of the reed marshes that grow on the southern portion of the ridge set (Figure 7.2). The use-groundstone artifacts might have been used for processing food or plant materials collected from the marshes. Cobble windbreak foundations are also located on the southern portion of the ridges, suggesting they too might be related to prehistoric or modern activity concerning the marshes.

Geomorphological evidence also shows that the Colán and Chira beach ridges included marshy and lagoonal habitats that would have supported similar coastal vegetation. In the case of Colán, there is evidence that relict mangrove environments were present, providing an even greater variety of vegetation and biota to exploit. Coastal marshes, lagoons, and mangrove habitats would have all been factors in drawing prehistoric peoples to the beach-ridge sets compared to other stretches of the coast. It is important to note that the ecological habitats such as marshes and lagoons are also dynamic aspects of the environment and have changed dramatically throughout time.

Mangroves

The presence of mangrove specific shellfish at the Colán beach ridges is anomalous for what we know about the region after the mid-Holocene. Mangrove swamps or forests consist of shrub like vegetation and trees that grow in coastal habitats protected from high wave energy, such as lagoons. Mangrove habitats also support other biota, dependent on mangrove ecosystems, such as mollusks. The two major requirements for mangrove vegetation are: 1) sea-surface temperature with a monthly mean above 24° C (75° F) and 2) the influx of fresh water (Richardson 1995). The presence of mangrove species is surprising for the time period in which they appear to have lived.

It is thought that with the reorganization of the climate system approximately 5800 cal yr B.P., the colder waters of the Humboldt Current extended north. These colder waters would have made the mangrove stands recede north to warmer Ecuadorian waters (Richardson 1995; Sandweiss *et al*. 1996). Today, the southernmost extent of large mangrove stands is at Puerto Pizarro at the mouth of the Tumbes River in Peru near the border to Ecuador. Small remnant mangrove stands have been observed south of Tumbes, usually located at protected habitats at the major river mouths where there is an influx of fresh water.

The temporal discrepancies can be explained by two likely hypotheses: 1) mangrove environments were present at Colán due to the lagoonal attributes of the beach ridges or 2) prehistoric peoples collected shellfish from mangrove swamps off the coast of modern-day Tumbes and Ecuador, and brought or traded them down the coast to Colán.

Mangrove Evidence at Colán

The evidence of mangrove environments at Colán is habitat-specific mollusks from archaeological and geological contexts. The mollusks were discovered in contexts related to the paleolagoon and intertidal inlet of Beach Ridge 6. The midden oriented around the past intertidal inlet contained two habitat specific mangrove species: *Anadara tuberculosa* and *Malea ringens*. The mangrove mollusks *Trivia radians* and *Protothaca columbiensis* were discovered embedded in a geological trench associated with these geomorphological features. *Trivia radians* is a snail which inhabits intertidal, muddy substrates found under rocks commonly in mangrove environments, fitting for the cobble and sand matrix of the beach ridges (Keen 1971; Alamo and Valdivieso 1987). The species from the geological contexts are more indicative of mangrove habitats, as they were found in living contexts and could not have been brought to Colán through trade with regions to the north (Diaz and Ortlieb 1991).

Geomorphological evidence suggests that the requirements of fresh-water input to support mangrove environments were present at Colán in the past. A sequence of large gaps and swales in the northernmost part of the beach-ridge set suggests that in the past the Chira River flowed farther south, eroding these sections (Shafer *et al*. 2004; D. Belknap, pers. comm.). The Chira River, or associated streams at the northern end of the beach ridges, might have input enough fresh water into the paleolagoons that had formed behind the Colán ridges to allow mangroves to grow. Required warm waters might have formed behind the beach ridges through solar heat and the shallow lagoonal setting.

Temporal Context

An intertidal lagoon would have provided the conditions for mangrove vegetation and shellfish. Based on the available evidence, this lagoon would have existed between the dates of Ridge 6 (1990 ± 370 cal yr B.P.) and the cutting off of the lagoon to the ocean by the formation of Ridge 7 (1190 ± 200 cal yr B.P.). The dated midden site also corresponds to this period, providing dates of 2110 ± 250 cal yr B.P. and 2370 ± 300 cal yr B.P. (Ortlieb *et al*. 1989). An approximate time frame is 2000-1200 cal yr B.P. Contemporaneous evidence of mangroves can also be found for this time period further south at the Piura beach ridges.

The Piura beach-ridge set is composed of eight sandy ridges north of the mouth of the Piura River. A geological study by Diaz and Ortlieb (1991) discovered shellfish pertaining to mangrove habitats in a geological cut of the second most recent ridge. The mangrove specific species identified were *Cryptomya californica, Glycymeris inaequalis*, and *Cerithidea valida*.

The remains of mangrove mollusks at Colán most likely pertain to when Ridge 3 was inhabited. During the ENSO event that created Ridge 2, living mollusks would have been reworked with sand output from the Chira River to form the beach ridges. Although no radiocarbon dates have been performed on material from Beach Ridge 3, we can bracket the date of the ridge through archaeological remains on Ridge 4 and Ridge 2.

Dates for the Piura beach ridges are few in number and are from archaeological contexts. A small shell midden (PV10-75) on the fourth Piura ridge was dated to 3130 ± 120 cal yr B.P. The shell-midden site PV10-30 located on Ridge 2 dates to 1230 ± 80 (Richardson and McConaughy 1987). The time period of approximately 3000-1200 cal yr B.P. corresponds with the time frame of the paleolagoon and inlet at Colán.

On a wider regional scale, surface remains of *Anadara tuberculosa* have been discovered at Late-Holocene archaeological sites south of Colán. In his survey of the Paita Peninsula, McConaughy (1993) observed that every major Sechura Phase (2700-1250 cal yr B.P.) settlement contained the species *Anadara tuberculosa* as well as the normal cold-water species of *Donax obesulus* and *Tivela hians*. McConaughy does not mention the presence of *Anadara* at prehistoric Piura Phase (1250-418 cal yr B.P) sites. This suggests that if the source was local to the Paita Peninsula, the habitat requirements had disappeared by Piura times. If the source of *Anadara tuberculosa* for the region was indeed the paleolagoon at Colán, the remnant mangroves would have been destroyed with the closing off of the paleolagoon at 1190 ± 200 cal yr B.P. (Ortlieb *et al*. 1989). This would explain the lack of mangrove mollusks at the Piura Phase sites along the Paita Peninsula.

Modern Remnant Mangrove

The southernmost remnant mangrove stand in modern days is located at the mouth of the Piura River at the southern end of the Piura beach-ridge set. The most recent beach ridge creates a protected lagoonal environment supplied with the influx of fresh water from the Piura River. The remnant mangrove stand does not flourish like the northern mangroves located in warmer waters. The San Pedro mangrove sanctuary of Piura is 300 hectares (1.2 sq. miles) compared to the Tumbes mangroves, which cover 2972 hectares (11.5 sq. miles) (Peña and Vásquez 1985; Ravelo *et al*. 2005). The biota of the mangrove environments also differs to a great extent. The mangroves of San Pedro do not contain the major trees such as *Rhizophora mangle*, but they do contain the black mangrove tree *Avicenia germinas*. Also, modern species of *Anadara tuberculosa* have not been found south of the Tumbes mangroves (Richardson 1995).

Mangroves and El Niño

Mangrove environments greatly improve during El Niño events. The two habitat requirements of mangrove habitats are more easily met. With the influx of warm, tropical currents warm-water species and mangrove vegetation would be able to survive farther south on the coast of Peru. Also, during El Niño events, the unusual rains that pour across the coastal desert create an input of fresh water into coastal systems, especially at the mouths of rivers.

Interaction with Ecuador

The presence of *Anadara tuberculosa* represents either interaction such as trade with peoples in Ecuador or a mangrove source in the region. The remains of *Anadara tuberculosa* could very well have come from the coasts of Ecuador. The mollusk can remain alive outside of water for five days in warm periods (MacKenzie 2001). It is roughly 175 kilometers (108.7 mi) in a straight line from Tumbes to Colán over land, even a longer distance by boat. Despite the long distance, interaction between Ecuadorian cultures and the far north coast of Peru extends much further back than Sechura times (Sandweiss 1996b; Richardson *et al*. 1990).

The mollusk *Anadara tuberculosa* is a good microhabitat indicator because it has a very limited habitat. The mollusk, also known as concha negra, most abundantly lives in association with red mangrove vegetation (*Rhizophora mangle*) and to a much lesser degree in association with black mangrove vegetation (*Avicenia germinas*). *Anadara tuberculosa* inhabits level mud sediments among the aerial prop roots or canopies of mangles (MacKenzie 2001). It is unclear whether remnant mangrove swamps were healthy enough to support red mangrove vegetation and the popularly collected *Anadara tuberculosa*. Future research is needed to understand the extent of mangrove environments at the Colán and Piura beach ridges.

Climate Change and Cultural Response at Colán

The beach ridges represent brief periods of drastic climate change associated with severe El Niño/Southern Oscillation events coupled with previous seismic activity. The same extreme ENSO events which formed the beach ridges, also would have impacted prehistoric peoples of the region. I propose that the severe El Niño event which created Beach Ridge 7 at Colán drastically altered the previous ecosystems they were exploiting. In response, prehistoric peoples abandoned the Colán area. I first outline the abrupt change in the occupation patterns of Colán, the temporal relationship of site abandonment to climate-change events, the effects of El Niño, cultural responses to disaster events, and implications on a regional scale.

Studies which link disaster events to cultural change, as witnessed in the archaeological record, are increasingly focusing on the social sciences. This new emphasis incorporates recent ecological and geographical concepts that relate humans *in* the environment as opposed to two dichotomous notions (VanBuren 2001; Reycraft 2000). In other words, cultures have innumerable ways of reacting to disaster events that are largely based on their relationship with habitats, social institutions of the group and cultural history.

<u>Discontinuity in Site Occupation</u>

The human occupation and utilization of the Colán area was not continuous as at other coastal sites such as the Chira beach ridges. The sites at Colán can be divided into early and late components. Between the two components is a period of approximately 500 years with no human evidence.

Based on ceramic typologies, radiocarbon dates of sites, and the location of shell middens, the early component dates approximately from at least Paita Phase 2 to Sechura Phase 3 (3500-1250 cal yr B.P.) (Richardson *et al*. 1990). The early component consists of major midden sites on the tablazo as well as on the beach ridges. During this period, prehistoric peoples most likely utilized the Colán beach ridges to access the ocean for collecting shellfish and lagoonal and mangrove resources behind active ridges.

With the formation of Beach Ridge 7, the evidence of prehistoric peoples disappears until the late-prehispanic component of Piura 3 to Piura 4 (800-418 cal yr B.P.) (Richardson *et al*. 1990). This occupation component is mainly located on the alluvial fan directly on top of Beach Ridge 8. By this time, the formation of gravel beach ridges had ceased and the shoreline most likely resembled the sandy coastal plain of today. Middens associated with the late component are also found to the north near evidence of past fresh-water streams associated with the Chira River.

After the early component, there is a gap of approximately 500 years before prehistoric peoples returned to the area. Why did Sechura peoples leave the Colán region? Was the abandonment of Colán based on internal cultural factors? Did outside factors influence their decision-making? I suggest that the climate-change events that formed Beach Ridge 7 and the subsequent alteration of the coastal landscape were leading factors in the abandonment of the Colán region.

Relating Site Abandonment to Climate-Change Events

Dating problems are usually abundant when drawing connections between a single natural disaster or climate-change event and changes in human patterns. One problem with refining the prehistoric chronology at Colán is a considerable lack of radiocarbon dates from archaeological contexts. Another chronological problem is limitations inherent in the radiocarbon methodology. Due to the reservoir effect and upwelling, shells cannot be dated to within less than one century. Therefore, most of the

Colán dates have an error of one to three centuries. Yet, the radiocarbon dates of the beach ridges can inform us about the sites that overlay them.

Beach-ridge formation dates can aid us in approximately dating the end of the early occupation component. There is substantial evidence that humans utilized Beach Ridge 6 as a platform between the open ocean and the lagoon to collect shellfish and lagoonal resources. Theoretically, prehistoric people who gathered shellfish moved up with the progradation of the coast, thereby leaving evidence of utilization such as shell middens. Since no human evidence was found on Ridge 7, it indicates that by this time, people at Colán no longer inhabited or utilized the area when the new coastline was formed. Therefore, the date of Beach Ridge 7 gives us the maximum date that early component peoples were in the area.

Colán Beach Ridge 7 dates to 1190 ± 200 cal yr B.P. (Ortlieb *et al*. 1989). We can further temporally place the ENSO event that formed this ridge by looking at the Chira beach ridges. Ortlieb *et al*. (1995) determined that Colán Beach Ridge 7 correlated to Chira Beach Ridge 7, both being created by the same ENSO event. Chira Beach Ridge 7 was dated to 1230 ± 100 cal yr B.P. and 1180 ± 100 cal yr B.P. Therefore an approximate range for this event is 1200-1300 cal yr B.P.

Disastrous Effects of El Niño

The severe ENSO event that created Beach Ridge 7 would also have had three major effects to which people who either occupied or utilized the Colán area would have had to respond. These effects include floods and mudslides, changes in available marine life, and subsequent landscape and ecological alterations of the Colán coastal plain.

El Niño instigates the most severe flood-related events on the far north coast of Peru due to the region's normally hyper-arid climate. When intense rains fall on the desert, coastal people must respond to overflowing rivers, flash flooding, mudflows, landslides, bank erosion, and damages to structures, irrigation canals, and agricultural fields. There is no evidence of flood sediments on top of the archaeological sites on the tablazo or the middens on Ridges 4, 5, and 6. Yet, they would have witnessed the activation of the nearby quebradas, the overwelling of nearby streams, and the flooding of the nearby Chira River.

Severe ENSO events also affect available marine resources due to the influx of warmer tropical waters, which greatly disturb the normal cold-water marine food chain. Populations of anchovies are highly sensitive to the warmer ocean temperatures and either die or migrate beyond the reach of coastal fishermen to deeper waters or colder waters farther south (Arntz 1986). Due to the loss of anchovies and other small fish, coastal bird populations collapse. During the mega-El Niño of 1982-83, the bird population on Christmas Island was decimated from an estimated 14,000,000 to only 150,000 birds (Caviedes 1984). Due to the decline of small fish such as anchovies, there is also a high mortality of fur seals and sea lions (Arntz 1986). Key molluscan species are also severely affected, yet it is unclear what changes would have occurred at the site of Colán.

The two major species collected at Colán (and Chira) were *Donax obesulus* and *Tivela hians*. Studies from the 1982-83 El Niño show that while *Donax* populations have an increased mortality, they are better capable to survive warmer waters than most temperate-water mollusks (Caviedes 1984). It is unclear how ENSO affects the populations of *Tivela hians*. Therefore, although changes in marine life would have ensued during the ENSO event that formed Beach Ridge 7, it is unclear how much of an impact it would have had on the subsistence habits of people at Colán.

Without archaeological excavation and faunal analyses, we can only assume from surface remains that people at Colán subsisted mainly off shellfish. Yet, how much did people at Colán rely on fish or coastal birds? What are the taphonomic factors in what we see in the archaeological records? To understand the impact of an ENSO event on subsistence habits at Colán, one must first accurately define the prehistoric diet, which necessitates further archaeological investigations.

The third major effect of the severe El Niño event would have been the landscape and ecological alteration of the Colán coastal plain. The creation of Beach Ridge 7 would have cut off the previous intertidal lagoon and mangrove ecosystem from the ocean, consequently destroying the habitat. The intertidal lagoon appears to have been of importance, as the major early component sites on the beach ridges are oriented around it (Figure 6.12). Not only did prehistoric people most probably collect shellfish from this habitat (Table 4), but vegetation such as reeds and grasses as well as mangrove trees would also have been valuable resources. Coastal lagoons also offered a wide variety of wildlife, such as birds that could have been hunted. Therefore, the destruction of this ecosystem would have had a large influence on people's decisions to abandon the area.

Cultural Responses

The people at Colán would have had numerous choices to make concerning the disaster events associated with the severe ENSO dating to approximately 1660 cal yr B.P. To understand potential responses, we must first identify who was occupying the early component sites of Colán. In this respect, we are quite limited in identifying how many people inhabited the Colán area. Even though the shell middens are quite large and observed deposits are thick, we cannot precisely know if the middens represent a continuous habitation, how many groups created the archaeological sites, and if people were practicing seasonal migratory patterns. Yet, decision-making would most likely have been on a very personal level as compared to the large settlements and ancient states of the north coast, such as the Moche and Chimú.

Although the people at Colán might have been few in number, they were not an isolated group of hunters and gatherers. They were part of a larger cultural identity and distinction as seen in the cultural phases of the far north coast. It is possible that the people at Colán only utilized the area seasonally and might have been associated with other larger coastal sites or inland sites that practiced agriculture. Unfortunately, we do not know about systems of kinship and alliances within the Paita-Sechura phases. Yet, the decision to abandon the site of Colán might have been influenced by outside factors and obligations to larger social groups and networks.

By looking at historical responses to El Niño events on the north coast of Peru, we can begin to understand certain commonalities including relocation, replacement, and rebuilding coping strategies. A common theme during the massive flooding events brought on by the severe rains is people relocating to higher ground. Throughout historical El Niño disasters, such as the El Niño of 1578 up to the 1997/98 event, coastal peoples have had to flee to high hills and *huacas* (sacred high places) to escape the floods (Alcocer 1578; Quinn and Neal 1986; Pease 1992; Sandweiss 1999; Copson and Sandweiss 1999). Did people at Colán flee inland to higher ground or to inland agricultural sites?

Replacement coping strategies have also been historically noted. Due to the oceanic effects of ENSO during severe events, the normal coastal subsistence is greatly impacted. Historical sources report people going inland and into the mountains due to a lack of food on the coast (Pease 1992). Did people at Colán move inland to exploit other resources?

Rebuilding coping strategies are most important for inland agricultural villages. The floods and landslides can destroy irrigation canals, and flood sediments can cover agricultural fields making them unproductive (Alcocer 1578; Nials *et al*. 1979; Craig and Shimada 1986; Moseley *et al*. 1992; Satterlee *et al*. 2000; Reycraft 2000). One positive effect of the El Niño rains is that overall vegetation is enhanced. The input of unusual amounts of rainfall into the coastal systems sometimes lead to higher agricultural yields and the expansion of lomas zones which wild and domesticated animals can exploit.

What could these observed coping strategies potentially tell us about the coastal people at Colán? People might have moved inland during this time of stress to unite with larger social groups and kinship networks which inhabited nearby sites. Could the people occupying Colán have moved inland to merge with agricultural centers? Agricultural centers with irrigation would have needed as many people as possible to help rebuild canals and reclaim fields which were damaged during the severe El Niño. Also, after the El Niño episode, the influx of water might have improved agricultural yields making farming more attractive. One logistical problem which would have occurred if coastal peoples were drawn inland to help rebuild infrastructure would be that at a time of food crisis, there would be more mouths to feed. Previous studies have shown that prehistoric peoples adapting to severe El Niño conditions needed to remain flexible with regard to subsistence (Moore 1991). The abandonment of Colán might also provide much needed insight into regional settlement patterns.

Shifts in Regional Settlement Patterns

The abandonment of Colán occurred at the same approximate time period of the cultural transition from the Sechura 3 Phase (1700-1250 cal yr B.P.) to the Piura 1 Phase (1250-1100 cal yr B.P.). The cultural transition to the Piura Phase witnesses the most dramatic change in settlement and occupation patterns of the far north coast, since modern climate stabilized approximately 5800 cal yr B.P. (Richardson 1981). Sites along the Paita Peninsula are abandoned, shellfish collecting is intensified along the Chira and Piura beach ridges, agricultural sites become abundant in nearby river valleys, and cultural complexity develops in the valleys as seen in large monumental architecture (Richardson *et al*. 1990).

The abandonment of Colán is part of a wider abandonment of the coastal region to the immediate south, on the Paita Peninsula. During the Sechura Phase, coastal peoples intensively utilized the Paita Peninsula. Maritime specialists, who occupied long-term year-round settlements, exploited sea mammals found on the rocky headlands, coastal birds, fish, and shellfish (McConaughy 1993). Also, at these Sechura Phase sites evidence of the mangrove shellfish *Anadara tuberculosa* was discovered, which might have come from the nearby mangrove swamps of Colán. Surface remains of ceramics prove that these sites were abandoned during Sechura Phase 3 as no later styles pertaining to the Piura Phase were found at the sites. I propose that the abandonment of the Paita Peninsula during this time was also a result of the same El Niño episode that resulted in the abandonment of Colán.

During ENSO events the influx of warm waters that disturb the normal marine food chain negatively impacts populations of sea mammals, as mentioned above. During the 1982-83 El Niño event, scientists observed drastic reductions in sea lion (*Otaria byronia*) populations due to the lack of food such as the anchovy. Large numbers of dead sea mammals were discovered washed up on the Peruvian coast. In search of food, sea lions followed the migration of anchovies into southern and deeper waters, and abandoned rookeries on rocky headlands (Caviedes 1984). To cause further stress, pup mortality increased greatly and in the years following the ENSO event pup production in the breeding season was much lower (Arntz 1986). Using these modern analogs we can model the impact of prehistoric ENSO events on sea mammals.

The coastal peoples on the Paita Peninsula were specialized fishermen who exploited sea mammals such as sea lions (McConaughy 1993). During the severe ENSO event around 1200-1300 cal yr B.P., the sea lions populations would have been drastically reduced and the rookeries along the peninsula might have been abandoned. As witnessed after the 1982-83 event, the sea mammal populations would not have rebounded quickly (Arntz 1986). This loss of a main resource, like the loss of the mangrove habitat at Colán, might have influenced peoples' decisions to abandon sites on a large scale.

We also have evidence where these coastal peoples went. During this transitional period, Piura phase sites appeared immediately south of the Paita Peninsula on the sandy Piura beach ridges. Also the Chira beach ridges greatly intensified in shellfish collecting during this time. The maritime specialists at the sites of Colán and along the Paita Peninsula might have adapted their subsistence habits by exploiting the abundant sandy-environment shellfish along the Piura and Chira beach ridges. It is also thought that the Piura Phase beach ridge sites were collecting stations for inland agricultural sites, and mark intensification in shell collecting (Richardson 1983; Richardson *et al*. 1990; McConaughy 1993).

Although there are many possible explanations for the abandonment of the Colán region, the dramatic changes in the previously utilized landscape and ecosystems are likely the main causes. These changes also need to be put into the wider cultural and social context of the group of people living in the region and their circumstances at that particular time in prehistory. Consequently, much more research needs to be done for a better glimpse into these scenarios.

Current Preservation Conditions of the Beach Ridges

The greatest concern regarding the archaeological record of a particular site or region is that once it is destroyed, potential information is lost forever. An aspect of my study was to evaluate the current condition of the archaeological sites associated with the beach ridges. The present-day condition of the three beach-ridge sets varies in the degree of disturbance to the archaeological record.

The Santa Beach Ridges

The Pan-American Highway runs parallel with the oldest ridges at the Santa set. Due to access to the highway, modern construction on the beach ridges themselves has caused the most disturbance. The most recent construction on the ridges occur on the oldest ridges on the southern end. Private house construction, agribusiness construction of chicken farms, roadways across the ridge plain, and gravel mining of the ridge material are the greatest threats to archaeological remains.

Although there is not much evidence of prehistoric people at the Santa ridges, the lithic remains discovered in 2006 are located on the earliest ridges on the southern end of the ridge set. This is the area most heavily impacted by recent construction. In fact, the first lithic remains of the cobble core and associated flakes were found within 50 meters of a roadside restaurant. Furthermore, the chicken farm has designated a large portion of the earliest ridges as off limits due to biohazardous waste. Due to the overall lack of large archaeological sites, preservation issues at Santa are less of an emergency than at the Colán and Chira beach ridges.

The Colán Beach Ridges

The archaeological sites of the Colán region are the most endangered by modern anthropogenic activity. The sites pertaining to the late-occupation component have been most affected by site destruction, as the colonial and modern towns of Colán were built on top of the archaeological sites. As the town of Colán expands, with a revived focus as a tourist destination, more sites have been disturbed (Figure 7.2).

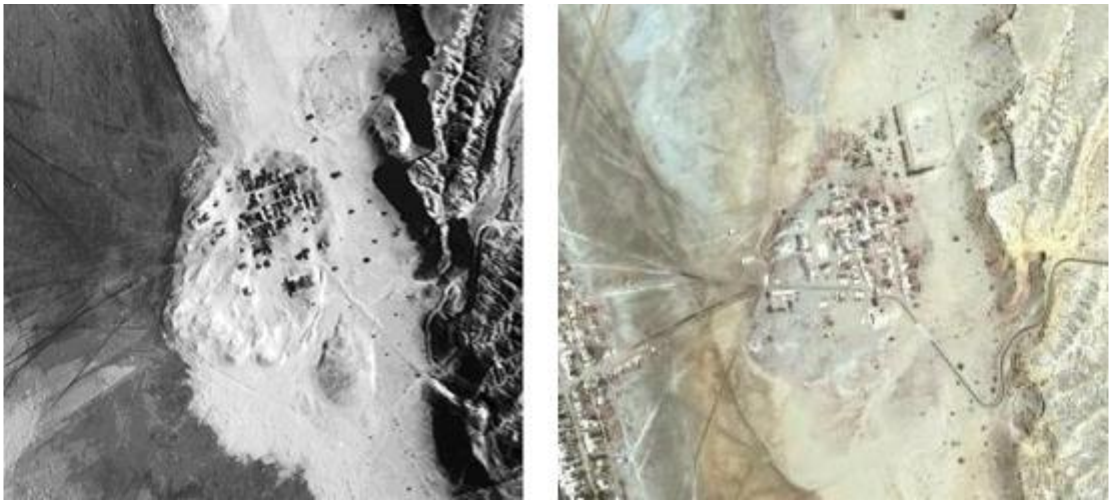

Figure 7.2. Aerial photographs of town of Colán from 1946 compared to 2007.

Another concern for preservation at Colán is looting. All the archaeological sites observed in 2006 and 2007 had evidence of looters pits. The early-component sites on the tablazo are the most heavily impacted. The extensively decorated and painted ceramics from the Paita, Sechura, and Piura cultural phases are most likely the major incentive for the looting.

The archaeological sites on the beach ridges associated with the paleolagoon and inlet features are also in danger from modern activity. A modern town dump is located just meters away. If this area is continued to be used, it will eventually begin to cover the archaeological evidence on Beach Ridges 5 and 4.

Besides anthropogenic activity, the natural movement of the Chira River and associated streams is also a threat. There is evidence that in the past, the movements of the river have destroyed sections of the beach ridges as well as parts of archaeological sites (Figure 6.2). The northern portion of the Colán beach-ridge set is the most in danger from fluvial erosion.

The Chira Beach Ridges

The Chira beach ridges have been preserved partly due to the oil and salt processing industries which use the area without greatly disturbing the large expanse of archaeological shell midden and associated artifacts on the beach ridges. Like the northern parts of the Colán ridges, the southern portion of the Chira beach ridges are also in danger from possible movements of the Chira River, as is evident in the heavily dissected southern end.

CHAPTER EIGHT: CONCLUSIONS

Project Summary

The geoarchaeological investigations of the Peruvian beach-ridge sets of Santa, Colán, and Chira have provided new data on the prehistoric peoples of coastal of Peru. Prehistoric peoples' decisions on how and to what extent they utilized the beach-ridge areas were largely influenced by environmental limitations. Beach-ridge material can facilitate or impede the presence of shellfish that comprised a large part of prehistoric diet. The Santa ridges were not intensively utilized as a platform for food gathering due to the large cobble material which impeded an abundance and variety of available mollusks. In contrast, the sandy Chira ridges were extensively utilized as platforms to access the ocean due to the abundance of mollusks that inhabit sandy littoral zones.

The paleohabitats of the beach-ridge sets also played an important factor in site settlement and utilization. Habitats such as lagoons, mangrove swamps, and reed marshes greatly attracted prehistoric peoples due to the various amount of resources. The only evidence of prehistoric activity on the Santa ridges is oriented around the southern portion where reed marshes are located. At Colán, one of the largest sites is oriented around an intertidal lagoon which also supported mangrove vegetation.

The beach ridges also signify changes in coastal landscapes. The progradation of the Chira and Colán beach ridges greatly influenced site-settlement patterns. Beach Ridge 7 at Colán dramatically altered the previous landscape, cutting off a previously utilized intertidal lagoon. This ENSO event likely explains the human abandonment of the Colán and Paita Peninsula region for a number of generations. To interpret the archaeological remains associated with the beach ridges, interdisciplinary research has proven invaluable.

Contributions to the Field

The data collected during the 2006 and 2007 field seasons contribute to our overall knowledge of prehistoric peoples on the coast of Peru. This study is indicative of how we can interpret the archaeological record with a greater interdisciplinary knowledge about paleoenvironments. The beach ridges of Peru provided rich habitats from the coastal littorals to the lagoons and marshes behind the ridges. The beach-ridge studies provide more information on regional prehistory as well as the themes of human ecology.

The Peruvian far north coast is a region understudied in many regards. The area has been a peripheral zone throughout prehistory for the trade of ideas and goods between Ecuador and Peruvian cultures. The mid-Holocene to late-Holocene sites associated with the beach ridges are part of this interaction as seen in the ceramic styles influenced by Ecuadorian cultures as well as the Peruvian cultures of the Chimú and Inca.

To understand the cultural development of the far north coast, data from smaller sites such as Colán and large coastal middens such as Chira are all essential pieces for reconstructing the past. Although archaeological investigations of large agricultural sites in the Piura and Chira River valleys are essential, we must also focus on the complex interaction between agricultural and coastal fishing groups.

The archaeological investigations presented in this thesis refined the understanding of past peoples occupying the region of Colán. Using the general principles of beach-ridge archaeology, the study provides more details on the abandonment and settlement of sites as the Colán coastal plain prograded. The study also raises questions about human responses to climate-change events such as periodically severe El Niños.

How did the disastrous alteration of landscape, which cut off the intertidal lagoon at Colán, impact the psychology of Sechura phase peoples at the site? Were there consequences in terms of religious concepts and themes or group power structures? Did the mega-El Niño event trigger inland and coastal settlement changes that occurred at approximately the same time during the beginning of the Piura cultural phase? The abandonment evidence at Colán might hold the key to understanding broader regional developments. Some questions may never be answered concerning the ancient past, but future investigations may provide valuable insight.

Future Research

The archaeological study of the Peruvian beach ridges of Santa, Colán, and Chira has yielded new data as well as new intriguing research questions. This study should be seen as preliminary to more in-depth analyses and investigations. Three main areas of future research include thorough investigations of the archaeological record at Colán, reconstructing paleohabitats at the Piura, Colán, and Chira beach ridges, and a wider investigation of the cultural transitions of the far north coast of Peru.

Unresolved Questions of Colán

The occupational prehistory of the Colán region can only be understood to a limited extent without archaeological excavation and radiocarbon dating of sites. The chronology of the numerous midden and occupational sites at Colán is largely based on ceramic typologies and radiocarbon dates of the beach ridges with which the sites are associated. A much more precise chronology could easily be obtained through excavation. Almost every shell-midden site in the region has evidence of looters' pits. A future research project would be to excavate and clean the profiles of the looters pits for charcoal and shell samples to be dated. Evidence of hearths with associated organics was observed in many of the looters' pits. One goal in refining the site chronology at Colán is to more precisely date the abandonment during the early occupation component to more accurately correlate the archaeological record with climate-change events.

Subsistence analyses through archaeological excavation could also provide a great level of detail about prehistoric life at Colán. It is important not to assume that people were living at Colán year round. Shell midden studies show that determining seasonality is difficult yet not impossible. Did people at Colán only collect marine resources as part of an annual round? Did they also practice agriculture? Through excavation, the presence of agricultural foods could be discovered, providing a link with inland agricultural sites. By reconstructing prehistoric diet at Colán we could also determine if lagoonal or mangrove biota were important.

Refining Cultural Transitions of the Far North Coast of Peru

The far north coast of Peru is an understudied region. Various investigators have done site surveys in the Chira and Piura River Valleys and along the coast, but archaeological excavation could provide valuable data to put site settlement patterns in context (e.g. Lanning 1963; Richardson 1983; Richardson and McConaughy 1987; Richardson *et al*. 1990; McConaughy 1993).

More radiocarbon dates from the Paita and Sechura cultural phases of the far north coast would also greatly contribute to refining the ceramic sequences first researched by Lanning (1963). In particular, many of the subphases have few or no radiocarbon dates from the same contexts. When relying on surface ceramics to temporally place sites in prehistory, a more reliable sequence is needed. Hindering this endeavor are the high costs of dating numerous samples, as well as a general lack of research in the far north coast of Peru.

Reconstructing Paleoenvironments

The anomalous discovery of mangrove mollusks at the Colán and Piura beach ridges requires future investigations. The beach ridges have proven to be ideal locales for remnant mangrove stands to survive. This is indicated by the present-day mangrove environment behind the most recent Piura beach ridge at the mouth of Piura River. Yet how extensive were the mangrove environments in the past?

The presence of the mollusk *Anadara tuberculosa* in archaeological sites from Colán to the Paita Peninsula is anomalous to our current understanding of the past coastal environments (McConaughy 1993). The southernmost locale of the species is in the mangroves of Tumbes, Peru. The remnant mangrove outcrops on the coast lack the red mangrove trees (*Rhizophora mangle*), which are essential for the presence of *Anadara tuberculosa*. Yet, were *Anadara tuberculosa* present in the paleo-mangroves at Colán or Piura?

Palynological investigations of the Colán and Piura beach ridges could potentially answer these questions. Previous studies in reconstructing past mangrove environments have been successful in identifying red mangrove (*Rhizophora mangle*) pollen (Ellison 1996). Samples from the sediment associated with the major paleolagoons at Colán and Piura could provide sufficient evidence in sourcing the remains of *Anadara tuberculosa* in the Paita Peninsula region. Although the archaeological investigations of the Santa, Colán, and Chira beach ridges have provided new information, there is opportunity for more refined research initiatives in the regions.

With climate change an ever-present issue in the modern world, studies dealing with ancient climate change events and consequent human adaptations are pertinent. The beach ridge sets of Peru and associated archaeological remains provide unique scenarios of how specific climate change events, landscape alteration, changes in resources, disaster events, and human culture intertwine.

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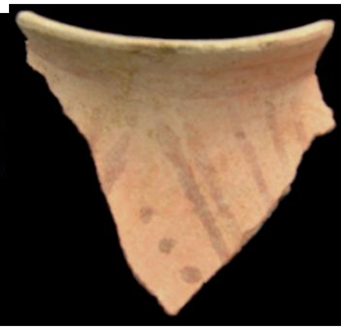
APPENDIX A: COLÁN CERAMIC ARTIFACTS FROM 2007 FIELD SEASON

Ceramic 1

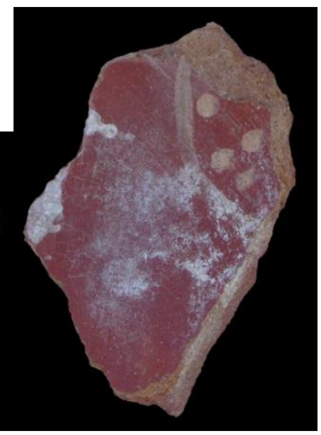


Ceramic 2

Ceramic 3

Ceramic 4

Ceramic 5



Ceramic 6

Ceramic 7

Shard	Provenience	Style
Ceramic 1	P4-8 tablazo	Paita 2-3
Ceramic 2	P4-8 tablazo	Paita 2-3
Ceramic 3	P4-8 tablazo	Paita 2-3
Ceramic 4	P4-1 third ridge	Paita 2-3
Ceramic 5	P4-1 third ridge	Paita 2-3
Ceramic 6	armored dune behind fourth ridge	Sechura 1
Ceramic 7	M2-1	Piura 3

APPENDIX B: CITED RADIOCARBON DATES

C14 Dates of the Chira Beach Ridge Set

1. Richardson 1983; 2. Richardson and McConaughy 1987; 3. Ortlieb *et al*. 1989; 4. Ortlieb *et al*. 1993; 5. Ortlieb *et al*. 1995.

Ridge ID (this study)	Ridge (reference)	Sample (field) #	Lab analysis # (1)	Measured C-14 age (B.P.)	Normalized C14 age (B.P.)	Cal yr B.P.	Source	Reference
1	9		SI-1450	4485 ± 90		5070 ± 200	charcoal	1,2
1	9		SI-1420	4255 ± 65		4730 ± 110	charcoal	1,2
1	9		SI-1456	3985 ± 80		4380 ± 140	charcoal	1,2
1	J	P.293	By 667	4210 ± 40	4630 ± 40	4580 ± 110	*Tivela*	3,4,5
1	J	P.294	By 693	4570 ± 50	4540 ± 50	5160 ± 120	charcoal	3,4,5
1	J	P.263	By 562	3230 ± 40	3640 ± 40	3290 ± 80	*Tivela*	3,4,5
2	8		SI-1421	3490 ± 80		3710 ± 120	charcoal	1,2
2	K	P.295	By 668	3310 ± 40	3720 ± 40	3390 ± 70	*Tivela*	3,4,5
2	K	P.296	By 648	3520 ± 50	3490 ± 50	3720 ± 100	charcoal	3,4,5
2	K	P.269	By 549	3060 ± 30	3480 ± 30	3090 ± 90	*Tivela*	3,4,5
-	inter-ridge	P.300A	By 671	3410 ± 40	3840 ± 40	3520 ± 80	*Donax*	3,4,5
-	inter-ridge	P.300B	By 672	3370 ± 40	3790 ± 40	3460 ± 80	*Tivela*	3,4,5
3	7		GX-1565	3500 ± 160		3110 ± 200	*Tivela*	1,2
3	L	P.298	By 669	3210 ± 35	3620 ± 35	3280 ± 70	*Tivela*	3,4,5
3	L	P.299	By 691	3190 ± 45	3160 ± 45	3320 ± 60	charcoal	3,4,5
3	L	P.268	By 670	2610 ± 35	3020 ± 35	3140 ± 70	*Tivela*	3,4,5
3	L	P.267	By 525	2600 ± 150	3030 ± 150	2530 ± 180	*Donax*	3,4,5
4	6		SI-1422	2685 ± 105		2680 ± 180	charcoal	1,2
4	6		SI-3184	2485 ± 70		2520 ± 170	charcoal	2
4	M	P.305	By 678	2540 ± 40	2950 ± 40	2430 ± 100	*Tivela*	3,4,5,
4	M	P.306	By 689	2760 ± 40	2730 ± 40	2800 ± 50	charcoal	4,5
5	5		SI-1423	1955 ± 100		1830 ± 120	charcoal	1,2
6	4		GX-1566	1550 ± 110	ca. 1990	1230 ± 120	*Tivela*	1,2

7	3		SI-1424A	1405 ± 75		1260 ± 100	charcoal	2
7	3		SI-1424B	1305 ± 100		1180 ± 100	charcoal	2
8	2		SI-1457	805 ± 60		700 ± 40	charcoal	1,2
9	R	P.301	By 673	460 ± 40	870 ± 40	320 ± 80	*Tivela*	3,4,5
9	R	P.303	By 647	380 ± 40	350 ± 40	380 ± 70	charcoal	3,4,5

(1) ORSTROM-Bondy geochronological lab (By).
(2) Cambridge, Mass. (GX).
(3) Smithsonian Inst. (SI).

C14 Dates of the Cólan Beach Ridge Set

1. Richardson 1983; 2. Richardson and McConaughy 1987; 3. Ortlieb *et al*. 1989; 4. Ortlieb *et al*. 1993; 5. Ortlieb *et al*. 1995.

Ridge ID (this study)	Ridge (reference)	Sample (field) #	Lab Analysis # (1)	Normalized C-14 age (B.P.)	Cal yr B.P.	Source	Reference
1	8N	P.393	By 688	3310 ± 45	3480 ± 80	Charcoal	4,5
1	8N	P.394	By 690	3630 ± 40	3290 ± 80	*Tivela hians*	4,5
1	8N	P.395	By 686	3640 ± 50	3290 ± 90	*Donax* + spp	3,4,5
1	8	P.176	By 316	3130 ± 300	3240 ± 370	Charcoal	3,4,5
1	8	P.174	By 331	3300 ± 250	2900 ± 320	several shell species	3,4,5
1	8	P.175	By 345	3450 ± 250	3050 ± 300	several shell species	3,4,5
Tablazo	Tablazo		SI-3178	2970 ± 75	3080 ± 125	Charcoal	2
2	7	P.187	By 380	3190 ± 210	2720 ± 280	*Donax* + spp	3,4,5
3	6						
4	5	P.189	By 324	2520 ± 490	2530 ± 610	Charcoal	3,4,5
4	5	P.190	By 350	2920 ± 250	2420 ± 310	*Tivela hians*	3,4,5
EC-7	Y	P.237	By 410	2860 ± 240	2370 ± 300	*Donax obesulus*	4,5
EC-7	Y	P.238	By 402	2700 ± 200	2110 ± 250	*Tivela hians*	4,5
5	4	P.194	By 382	2560 ± 170	1960 ± 220	*Donax* + spp	3,4,5

6	3	P.199	By 323	2050 ± 540	2040 ± 660	Charcoal	3,4,5
6	3	P.200	By 322	2010 ± 380	1880 ± 460	Charcoal	3,4,5
6	3	P.197	By 349	2600 ± 300	1990 ± 370	*Olivella* + sp	3,4,5
-	3a	P.209	By 381	2090 ± 180	1450 ± 200	*Donax obesulus*	3,4,5
7	2	P.202	By 379	1880 ± 180	1190 ± 200	*Donax* + spp	3,4,5
8	1N	P.207	By 351	1390 ± 230	730 ± 210	*Donax* + spp	3,4,5
8	1S	P.124	By 383	1200 ± 210	570 ± 200	*Donax* + spp	3,4,5
-	flat	P.235	By 441	1150 ± 190	510 ± 170	*Donax obesulus*	4,5
-	shell line	P.181	By 424	590 ± 160 *		*Tivela hians*	3,4,5
M-?	site c	P.170	By 320	590 ± 290	480 ± 320	Charcoal	3,4,5

(1) ORSTROM-Bondy geochronological lab (By).
(2) Smithsonian Inst. (SI).

C14 Dates of the Santa Beach Ridge Set

Ridge ID (this study)	Ridge (reference)	Lab Number	Location	C14 Age (B.P.)	Cal yr B.P.	Material	Reference
1	8	SI-4957	Embedded	4235 ± 115	4030 ± 170	*Prisogaster niger*	Sandweiss 1983
2	7						
3	6						
4	5						
5	4						
6	3						
7	2						
8	1						

(1) Smithsonian Inst. (SI).

C14 Dates of the Piura Beach Ridge Set

Ridge ID (this study)	Ridge (reference)	Lab Analysis #	Site	C14 Age (B.P.)	Cal yr B.P.	Material	Reference
1	9						
2	8	ISGS-1236	n.d.	4700 ± 70	4680 ± 120	*Donax obesulus*	McConaughy 1993
3	7						
4	6						
5	5						
6	4	ISGS-1238	PV10-75	3020 ± 70	3130 ± 120	Charcoal	McConaughy 1993
7	3						
8	2	ISGS-1233	PV10-30	1370 ± 80	1230 ± 80	Charcoal	Richardson and McConaughy 1987
9	1						

(1) Illinois State Geological Survey (ISGS).

C14 Dates for the Preceramic Sequence of Peru's Far North Coast

Cultural Phase	Phase Cal yr B.P.	Site	Lab Analysis #	C14 Age (B.P.)	Cal yr B.P.	Material	Reference
Ecological	Pleistocene	Talara Tar-seeps	SM-852-854	Average: 13994 ± 100	16700 ± 230	Wood	Churcher 1966
Amotape	13,000-10,000	PV8-29	SI-1415	11200 ± 115	13100 ± 110	*Anadara tuberculosa*	Richardson 1974
		PV8-26	SI-1414	8125 ± 80	8380 ± 100	*Anadara tuberculosa*	Richardson 1974
Siches	10,000-6000	PV10-43	ISGS-1237	9960 ± 80	10620 ± 120	*Anadara tuberculosa*	McConaughy 1993
		PV8-13	GX-1002	8000 ± 140	8800 ± 190	Charcoal	Richardson 1973
		PV7-19	GX-0997	7980 ± 130	8800 ± 190	Charcoal	Richardson 1973
		PV8-24	SI-1417	7840 ± 90	8080 ± 110	*Anadara tuberculosa*	Richardson 1974
		PV9-31	SI-1416	7485 ± 120	7740 ± 130	*Anadara tuberculosa*	Richardson 1974
		PV8-13	GX-1563	6655 ± 130	7470 ± 140	Charcoal	Richardson 1973
		PV7-19	GX-0998	5990 ± 120	6790 ± 150	Charcoal	Richardson 1973
		PV7-19	GX-1137	5605 ± 95	6330 ± 110	Charcoal	Richardson 1973
Honda	6000-4400	PV7-16	GX-0994	5185 ± 105	5870 ± 130	Charcoal	Richardson 1973
		PV7-16	GX-0995	5150 ± 105	5820 ± 160	Charcoal	Richardson 1973
		PV7-16	GX-0993	4820 ± 95	5460 ± 130	Charcoal	Richardson 1973
		PV7-19	GX-0996	4805 ± 130	5460 ± 140	Charcoal	Richardson 1973
		Piura Ridge 2	ISGS-1236	4700 ± 70	4680 ± 120	*Donax obesulus*	McConaughy 1993
		Chira Ridge 1	SI-1450	4485 ± 90	5070 ± 200	charcoal	Richardson 1983
		Chira Ridge 1	SI-1420	4255 ± 65	4730 ± 110	charcoal	Richardson 1983
		Chira Ridge 1	SI-1456	3985 ± 80	4380 ± 140	charcoal	Richardson 1983

(1) Cambridge, Mass. (GX).
(2) Smithsonian Inst. (SI).
(3) Illinois State Geological Survey (ISGS).
(4) Mobil Oil Corp., Dallas (SM).

C14 Dates for the Ceramic Sequence of Peru's Far North Coast

1. Richardson 1974; 2. Richardson 1983; 3. Richardson and McConaughy 1987; 4. Richardson *et al.*1990; 5. McConaughy 1993.

Ceramic Phase	Phase Cal yr B.P.	Lab Analysis #	Site	C-14 Age B.P.	Calibrated yr B.P.	Dated Material	References
Paita 1	3900-3500	GX-1136	PV8-7	3610 ± 145	3860 ± 220	Charcoal	1
		GX-1003	PV8-7	3390 ± 125	3560 ± 160	Charcoal	1
Paita 2	3500-3200	ISGS-1029	PV10-23	3230 ± 70	3370 ± 100	Charcoal	5
Paita 3	3200-2700	SI-1422	Chira Ridge 4	2685 ± 110	2680 ± 180	Charcoal	2
Sechura 1	2700-2400	SI-1418	PV6-5	2535 ± 185	2550 ± 210	Charcoal	1
		ISGS-1028	PV10-48	2410 ± 70	2450 ± 230	Charcoal	5
Sechura 2	2400-1700						4
Sechura 3	1700-1250	SI-1419	PV7-18	1810 ± 70	1670 ± 110	Charcoal	1
		ISGS-1031	PV10-33	1780 ± 70	1630 ± 80	Charcoal	1
		GX-1561	PV7-18	1675 ± 85	1510 ± 100	Charcoal	1
		GX-1562	PV7-18	1445 ± 95	1290 ± 110	Charcoal	1
		GX-1566	Chira Ridge 6	ca. 1990	1230 ± 120	Tivela	2
Piura 1	1250-1100	ISGS-1233	PV10-30	1370 ± 80	1230 ± 80	Charcoal	3
Piura 2	1100-800						4
Piura 3	800-500	SI-1457	Chira Ridge 8	805 ± 60	700 ± 40	Charcoal	2
		SI-3184	PV7-4	640 ± 90	600 ± 60	Charcoal	1
		SI-3180	Near Huaca Rica	500 ± 85	440 ± 110	Charcoal	4
Piura 4	500-418						4
Piura 5	418-150						5
Piura 6	150-present						5

(1) Cambridge, Mass. (GX).
(5) Smithsonian Inst. (SI).
(6) Illinois State Geological Survey (ISGS).

APPENDIX C: AUTHOR'S BIOGRAHPY

David A. Reid was born in Southbridge, Massachusetts July 27, 1985. He was raised in Woodstock, CT and graduated from Woodstock Academy in 2003. Majoring in Anthropology, David is a member of Phi Beta Kappa and various student and honors groups.

Upon graduation, David plans on returning to Peru on various archaeological projects, before returning to work on an advanced degree in anthropology and climate change studies.