Stratigraphic Investigations at Los Buchillones, a Coastal Taino Site in North-Central Cuba

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The authors present stratigraphic data from Los Buchillones, a now submerged Taino village on the north coast of central Cuba that was occupied from some time prior to A.D. 1220 until 1640 or later. Los Buchillones is one of the best-preserved sites in the Caribbean, with material culture remains that include palm thatch and wooden structural elements from some of the more than 40 collapsed structures. The purpose of this study was to investigate the environment and site-formation processes of the Taino settlement. Sediment cores were sampled from the site and its vicinity to permit integration of the geological and archaeological stratigraphies. The cores were analyzed for color, texture, mollusk content, elemental geochemistry, and mineralogy. The results of the stratigraphic work are consistent with regional sea-level data that shows relative sea level has risen gradually during the late Holocene, but has remained relatively stable since the time the Taino first occupied Los Buchillones. Of the two structures partially cleared, at least one appears to have been built over the water, supported on pilings. Site selection is likely to have resulted from a consideration of environmental factors, such as access to marine, terrestrial, and lagoonal resources, and proximity to freshwater springs. © 2006 Wiley Periodicals, Inc.

INTRODUCTION

Coastlines are complex and dynamic systems that have long been a focus for human settlement. The benefits of coastlines for human occupation are numerous and include marine and terrestrial (and, in some cases, estuarine and fluvial) resources within a limited geographic area; suites of organisms unique to the intertidal zone, such as crustaceans and edible seaweeds; relatively moderate climate regimes; and direct access to seaborne transportation and travel routes (Bailey and Parkington, 1988). Coastal environments are also sensitive to a wide range of modern human activities, which range from urbanization and coastal engineering (Chen et al., 2002) to the exploitation of resources, such as fish and vegetation, especially
mangroves (Hogarth, 1999, pp. 171–198). It is generally anticipated that coastlines will be profoundly affected by global warming through relative sea-level rise, which would result in flooding, erosion, and saltwater intrusion (Warrick et al., 1993). Given the often high population densities associated with coastlines in both the past and the present, current research into human–environmental interactions in such settings (e.g., Schmitt and Osenberg, 1996; NOAA, 2003) is clearly critical.

Contemporary studies of coastal environmental change have been accompanied by a growing appreciation of the importance of understanding how prehistoric societies adapted to and impacted coastal systems, partly because such studies add greatly to our knowledge of the chronology of environmental change. Archaeological research has focused on a number of areas, including subsistence (e.g., Anderson, 1988), settlement patterns (e.g., Parkington et al., 1988; Voorhies, 2000), climatic interaction (e.g., Sandweiss et al., 1996) and coastal-resource exploitation (e.g., Rippon, 2000). As a result of their location at the interface between marine and terrestrial environments, coastal archaeological sites generally provide a perspective on subsistence, trade, and other aspects of economy that cannot be gleaned from studies focusing exclusively on inland settlements. The study of coastal sites is, however, accompanied by unique difficulties. Many sites are now submerged because of the rise in sea level that followed the last deglaciation, tectonic upheaval, and other less dynamic geomorphological processes (Masters and Flemming, 1983; Johnson and Stright, 1992). Furthermore, site preservation is often problematic because wave activity during the period of submergence has led to the destruction of many near-shore sites (Flemming, 1983).

In the Caribbean, coastal prehistoric sites are numerous (Keegan, 1992a, 1992b; Watters et al., 1992; Watters, 1998; Keegan, 2000; Seidemann, 2001), but comparatively few have been subjected to intensive geoarchaeological examination. Many of the coastal sites in the Greater Antilles and the Bahamas were occupied by the Taino, a cultural group which emerged around 800 years B.P. from earlier pottery-making farmers who colonized the Caribbean by 2500–2200 yr B.P. These people and their successors, the Taino and the Island Carib, were horticulturalists who cultivated corn, manioc, and cotton (Keegan, 2000). Rouse (1992, p. 8) classifies the Taino into three groups: the Western Taino, who occupied the Bahamas, most of Cuba, and Jamaica; the “Classic” Taino, who occupied most of Hispaniola and Puerto Rico; and the Eastern Taino who occupied the Virgin and Leeward Islands. The population of Western Taino villages may have been in the range of several hundred occupants (Rouse, 1992, p. 17). In Cuba, the Caribbean’s largest island, estimates of the Taino population range from 150,000 to 1,000,000 inhabitants by the 15th century (Dobyns, 1966, p. 409; Dacal Moure and Rivero de la Calle, 1996, p. 20). By the mid-16th century, most of the Taino population under Spanish domination had disappeared or fragmented into small, isolated communities as a result of the combined effects of slavery, warfare, and disease (Rouse, 1992, pp. 150–161; Keegan, 2000).

In this article, we have three objectives: (a) to present data on the environmental history and site-formation processes of Los Buchillones, a now submerged Taino village occupied from some time prior to A.D. 1220 until 1620–1640 or later.
(Pendergast, 1996a; Pendergast et al., 2002); (b) to discuss the implications of the environmental history for the understanding of the dynamics of Taino settlement; and (c) to build a database on human–environmental interaction from Los Buchillones that will provide significant underpinning for our understanding of long-term Caribbean coastal adaptations in general.

Dry-land excavation at Los Buchillones began in 1983 under the direction of Dr. Jorge Calvera (Calvera et al., 1996). The reconnaissance stage of the present project began in 1996, with the first excavations in 1997 followed by investigation of portions of two submerged structures in 1998 and 1999 (Pendergast, 1996b; 1997; Calvera et al., 2001; Pendergast et al., 2001, 2002, 2003). The work has revealed one of the best-preserved prehistoric sites in the Caribbean (Pendergast et al., 2001; see also Conrad et al., 2001). To date, investigations have been confined to mapping locations of offshore standing groups of posts, conducting test excavations in areas of secondary deposition, exposing but not removing the remains of two structures, and undertaking selected excavations in the terrestrial zone of the site. Because both the structural and the redeposited remains presently lie beneath the sea, excavations have required the construction of sandbag and polyethylene sheet dykes around the areas to be investigated, followed by removal of entrapped water with a gasoline-powered pump. Although continuing inflow of water beneath the dykes has limited the depth of the investigations, work proceeded, in large part, as if Los Buchillones were a dry-land site. Our investigation of the stratigraphy involved removal of sediment cores and their integration with stratigraphic data derived from the archaeological excavations. Here, we present a detailed geoarchaeological study of the Los Buchillones area, as well as new information on Taino settlement patterns that has resulted from our investigations.

BACKGROUND

Study Area

Los Buchillones (22°22'20"N, 78°48'10"E) is located on the north coast of central Cuba, in the province of Ciego de Avila (Figure 1). A shallow carbonate shelf extends far offshore. On its seaward edge lies an active coral reef, the Archipiélago Sabana-Camagüey. The reef is separated from the mainland by the shallow, hypersaline Bahía de Buena Vista. The maximum tidal range is only 30 cm. Despite relatively low-energy conditions, much of the north coast of Ciego de Avila, including parts of the Los Buchillones site, has eroded by over 40 m during the last several decades, probably, in large part, as the result of the construction of a breakwater roughly 3 km east of the archaeological site (J. Calvera, personal communication, February, 1997). This erosion has been possibly accelerated by the building of a causeway roughly 20 km to the east of the site that links the mainland to the offshore reef.

Three salt diapirs—named Punta Alegre, Turiguanó, and Cunagua—constitute the only significant relief in the region (Meyerhoff and Hatten, 1968). The Punta Alegre and Turiguanó diapirs consist of gypsum overlying halite, limestone, and dolomite (Iturralde-Vinent and Roque Morrero, 1982). Meyerhoff and Hatten (1968)
report that all three diapirs had pierced the surface by the Pliocene epoch, but there is no evidence to indicate significant vertical movement of the crust during the Holocene (Iturralde-Vinent and Roque Marrero, 1982).

The Los Buchillones site is situated east of the village of Punta Alegre, mostly within the Bahía de Buena Vista and partly within a lagoon (Figure 2). The lagoon is hypersaline and has a maximum length and width of 1.6 km and 300 m, respectively. It is deepest at the eastern end (70 cm) and shallows towards the western end. A chenier separates the lagoon from the Bahía de Buena Vista.

Hurricanes pass over the Los Buchillones area roughly once every 20 years; the most recent was category-3 Hurricane Michelle in November 2001 (National Hurricane Center, 2003). Despite the proximity of Hurricane Michelle, observations made in February 2002 indicate that little shoreline erosion occurred at the Los Buchillones site, although lagoons 5 km west of the site were breached some-
Figure 2. The Punta Alegre lagoon (top) and 2001 excavation area (bottom). In the top figure, transect A’–A was made in 1999; the resulting profile is shown in Figure 7. The thin solid lines on either side of A’–A represent the locations of the transects established in 2000. The main concentration of Taino structures lies between the dotted lines. In the bottom figure, the dark grey area represents where excavations occurred in 2001. The numbers (1–9, 11, 14, 17, 19–27) designate the excavation squares; the letters (A–E) represent coring sites. A large vertical wooden post (~30 cm diameter) is in square 22. The collapsed structure excavated in 1999 lies several meters to the northeast of excavation squares 3, 6, and 9.
time between May 2001 and May 2002, possibly as a result of this hurricane. While Hurricane Lili struck the western end of Cuba in October 2002, local residents claim that it had no effect on the northern part of the province of Ciego de Avila. Hurricane Georges was responsible for high winds and flooding in September 1998 on the seaward side of the Archipiélago Sabana-Camagüey, although the mainland experienced minimal damage.

Archaeology at Los Buchillones

The Los Buchillones site (Pendergast, 1996b; Pendergast et al., 2001, 2002, 2003) covers an area at least 50 m wide and 500 m long, with its long axis obliquely oriented to the chenier (Figure 2). Marine, littoral, lagoonal, and terrestrial environments exist at the site. Artifacts have been recovered as far as 1 km west of the area shown in Figure 2, although some of this material may have been redeposited by recent erosion. Offshore submerged structural features extend along the shoreline of the Bahía de Buena Vista northeast of the excavation limits shown in Figure 2. The upper boundary of the cultural occupation zone underlies approximately 50 cm of water and 50–70 cm of sediment. Cultural material recovered from survey and excavation includes Amerindian stone, pottery, wooden artifacts, faunal and floral remains, and structural elements of wood and thatch (Graham et al., 2000; Pendergast et al., 2001, 2002, 2003). Twenty-three AMS dates on archaeological artifacts and structural timbers place the occupation of the site between some time prior to A.D. 1220 and 1640 or later (Pendergast, 1996a; Pendergast et al., 2002).

The evidence recovered from survey and limited excavations between 1997 and 2001 comprises structural material from, and basic plan data on, more than 40 collapsed Taino structures (some of which may be fish weirs or other nonresidential structures), all of which lie below present sea level. The offshore house locations are identified by groups of post butts made from lignum vitae (Guaiacum sp.), palm (Arecaceae), and other tropical hardwoods, possibly including poisonwood (Metopium sp.) (Newsom, personal communication, August 9, 2005). Based on the evidence, structures appear to have been of several forms, including round, rectangular, and possibly oval (Pendergast et al., 2002, p. 79). The structure partially cleared in 1998, which lies partly offshore and partly beneath the present shoreline (~50 m northeast of the sandbagged zone shown in Figure 2) was round, whereas the structure uncovered in 1999 in the Punta Alegre lagoon was rectangular.

The spatial organization of the archaeological remains suggests that relatively little lateral postsettlement disturbance has occurred. The remains of the structure cleared in 1999 include rafters and other structural debris, such as thatch, the main elements of which are oriented in a common direction (Figure 3). Although no structural elements were removed by the excavators, excavations around and beneath selected support posts, rafters, and other structural remains revealed that the sediments burying the elements were water-laid and accumulated under conditions of low energy. The absence of terrestrial sediments and stones trapped beneath even the heaviest posts indicated that the structures had not collapsed
on dry land and were then submerged at a later time. Wave activity strong enough to remove such evidence would also presumably have been strong enough to displace the thatch that was encountered in association with the stringers on which it was originally suspended; many of the collapsed house posts would likely have shifted as well.

Evidence suggests that the force of impact upon collapse was weak and that disturbance to collapsed material was minimal. The structural elements seem to have been protected from forces such as high winds and rain that would have been damaging had the house collapsed on dry land; strong currents or wave activity would also have been expected to displace or destroy evidence. Our best explanation for this level of preservation is that the structure excavated in 1999 once stood on pilings in water under protected conditions and collapsed in situ.
Good preservation and lack of disturbance are indicated across all shoreline areas of the site investigated thus far. It, therefore, appears that the village formed by the buildings was built over shallow water; when the settlement was abandoned, the structures collapsed into a relatively low-energy system that fostered preservation. Further archaeological excavation, both extensive and intensive, will be necessary to define fully the depositional matrices of all structures and structural elements and hence to confirm the shallow-water habitation hypothesis. Furthermore, the chemistry of the Los Buchillones lagoonal and near-shore sediments will need to be carefully examined because their locally recognized curative properties may indicate that they played a role in preservation of the archaeological remains.

The results of the research reported here constitute a step towards the clarification of premodern environmental conditions. Our investigations of the overall site stratigraphy thus far have allowed us to infer the depositional environments of the sedimentary units associated with the archaeological remains and to determine patterns of past sea-level change in the area.

Coastal Geomorphology at Los Buchillones

Kraft and Chrzastowitz (1978) developed stratigraphic models for transgressive and regressive lagoon-barrier systems. In the transgressive model—which, as will be shown, is most applicable to the situation at Los Buchillones—the lagoon and barrier migrate upward and landward in response to a rise in relative sea level. As long as the rate of sediment deposition within the lagoon, the rate of relative sea-level rise, and the slope of the coastal plane remain constant, the configuration of the lagoon-barrier system will remain unchanged. The resulting stratigraphy is characterized by overlapping facies that lie roughly parallel to the coastal plane.

The preservation of coastal facies depends largely on wave energy; wave energy affects the depth of erosion across the shoreface (Fischer, 1961). High wave energy causes deep shoreface erosion, which on a transgressive coast may result in a loss of earlier offshore sediment. However, sediment composition, shoreline orientation, tidal range, topography, and the rate and direction of relative sea-level change also influence facies preservation. Belknap and Kraft (1981) also suggest that a slowly rising sea level will increase the potential for erosion, because waves will be concentrated along the shoreface for a greater period of time. Conversely, if sea-level rise is rapid, wave action will be temporary, limiting erosion and possibly allowing a greater portion of the offshore stratigraphy to be preserved.

As mentioned earlier, the type of barrier that separates the Punta Alegre lagoon from the Bahía de Buena Vista is a chenier. A chenier is a long, narrow, low-lying, shore-parallel ridge, which overlies a muddy substrate and is usually separated from the mainland by a mudflat or lagoon (Otvos and Price, 1979; Waters, 1992, p. 259). Cheniers are geologically ephemeral features, with sizes and positions influenced by factors such as relative sea-level change, sediment availability, and storm activity (Augustinus, 1989). The chenier at Los Buchillones most likely formed by the reworking and winnowing of offshore sediment, which produced
a shell lag that was transported landward and concentrated in a low-lying ridge (Waters, 1992, p. 260). Shells are easily incorporated into cheniers because their low specific gravity promotes landward transport into the supratidal zone (Cangzi and Walker, 1989). Winnowing may have been an episodic (e.g., during storms) or a continuous process.

METHODS

Field Methods

Geoarchaeological fieldwork at Los Buchillones began in 1999. That year, 11 sediment cores (numbered 1 to 11) and two soil pits (1 and 2) were sampled along a ~500-m northwest–southeast trending transect intersecting the main artifact concentration. The sediment cores were recovered with a Livingston piston corer (Wright, 1967). The positions of the cores and soil pits were recorded with a Garmin GPS 12. In May 2000, two new transects were established: one 100 m east and the other 150 m west of the 1999 transect. The locations of these cores, along with a description of each, were documented in the field. The excavations in May 2001 included areas in the lagoon and in the Bahía de Buena Vista, which were connected by a trench, approximately 1 m deep and 1 m wide, excavated perpendicular to the chenier (Figure 2). The purpose of the trench was to identify the stratigraphy underlying the chenier and to determine whether archaeological material lay beneath it. Five cores (designated A–E) were also sampled from the base of the trench.

Laboratory Methods

The first objective of the study was to generate a shore-perpendicular stratigraphic profile by identifying and describing the stratigraphic units and correlating them among adjacent cores. Color and texture were the primary criteria for identifying the units. Wet colors were recorded with a soil color chart (Oyama and Takehara, 1970). Texture (proportion of sand, silt, and clay) was estimated qualitatively. Subsamples were then taken from the center of each sedimentary unit in the cores and soils pits for more detailed analyses, as described below.

To assist in the correlation of the units among the cores, we attempted to determine if individual stratigraphic units had unique geochemical and/or mineralogical signatures. The elemental composition of each subsample was determined on the < 2 mm fraction by instrumental neutron activation analysis (INAA). The INAA determined the total concentration of selected major (Al, Ca, Cl, Fe, K, Mg, Na) and trace (As, Ba, Br, Co, Cr, Cs, Ga, Hf, Mn, Ni, Rb, Sb, Sc, Ta, Ti, Th, U, V) elements.

In terms of mineralogy, the relative abundance of primary minerals was determined using a Philips X-ray diffractometer (Philips Electronics, The Netherlands). Samples of bulk sediment were air-dried and disaggregated with a mortar and pestle before analysis. Each sample was X-rayed for 60 minutes. Mineral identification was made using X-pert system software (PANalytical, Almelo, The...
Netherlands) and a searchable powder diffraction file database. The relative abundance of the secondary (clay) minerals was determined with a Toshiba ADG-301H X-ray diffractometer (Toshiba, Tokyo, Japan). To separate the clay fraction, the subsamples were disaggregated and thoroughly mixed in distilled water in hydrometer jars. After 24 hours, the suspended clay slurry was siphoned out and centrifuged onto ceramic tiles, air-dried, and X-rayed for 60 minutes. The tiles were then saturated in ethylene glycol vapor at 60°C for 24 hours and X-rayed for 15 minutes each. Each tile was then heated for 2 hours at 300°C and X-rayed for 15 minutes. This procedure was repeated at 500°C and 550°C. Interpretation of the diffractograms was made by reference to several manuals (Carroll, 1970; Moore and Reynolds, 1989).

The proportion of organic matter, carbonates, and silicates in each subsample was estimated by loss on ignition, following Dean (1974). Our assumption was that units with relatively high silicate content were more likely to be of terrestrial origin, whereas high carbonate values would likely represent shell material and be indicative of sediments deposited in marine or lagoonal settings.

To determine molluscan ecology, mollusks were identified to genus or species level in cores 3 and 5. Sediment samples were wet-sieved through a 63-µm stainless steel sieve and all identifiable mollusks were retained and air-dried. Reference manuals were used for identification (Warmke and Tucker Abbott, 1961; Tucker Abbott, 1974).

RESULTS

Stratigraphy

Based on similarities in color and texture, six sedimentary units were identified (Table I), and the resulting stratigraphic profile is illustrated in Figure 4. At the base of the section is unit 1, a silty to pebbly unit that extends at least 300 m offshore and continues onshore south of the lagoon. The cores sampled in May 2000 confirm that this red-brown unit also extends east and west of the 1999 transect, at roughly the same slope and depth below mean sea level. Overlying unit 1 is unit 2, a grayish-brown silty-clay that underlies the back-barrier. A lens of fine, light-grey sediment lies within unit 2 but has not been assigned to a separate sed-

<table>
<thead>
<tr>
<th>Unit</th>
<th>Color (7.5Y 4/4)</th>
<th>Texture</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Red-brown</td>
<td>Silty to pebbly</td>
<td>Stiff and dry; shell and roots rare</td>
</tr>
<tr>
<td>2</td>
<td>Grey-brown (7.5 Y 4/2)</td>
<td>Silty-clay</td>
<td>Moist and slightly plastic, no shell or roots</td>
</tr>
<tr>
<td>3</td>
<td>Olive-gray (5Y 5/1)</td>
<td>Clayey</td>
<td>No shell; poorly preserved turtle grass (Thalassia testudinum) roots are common</td>
</tr>
<tr>
<td>4</td>
<td>Light-gray (5Y 4/3)</td>
<td>Silty-clay</td>
<td>No shell or roots</td>
</tr>
<tr>
<td>5</td>
<td>Light-gray (5Y 6/1)</td>
<td>Silty-clay</td>
<td>Abundant shells and roots</td>
</tr>
<tr>
<td>6</td>
<td>Olive-gray (5Y 5/1)</td>
<td>Sandy</td>
<td>Abundant shells and shell fragments</td>
</tr>
</tbody>
</table>
Figure 4. Stratigraphy along transect A-A'. Cores and soil pits are represented by the vertical black bars. Archaeological material is concentrated within the dashed area, although extends downward into unit 3. The vertical exaggeration is 64X.
imimentary unit at this time. Unit 3 is clayey and olive-grey. It lies offshore and does not extend into the present lagoon. Unit 4 underlies the back-barrier and has a silty-clay texture with yellow-mottles. Unit 5, also consisting of silty-clay, is directly associated with the Punta Alegre lagoon. Unit 6, dominated by shell fragments and turtle grass (*Thalassia testudinum*) roots, represents the most recent marine deposit. The lateral relationship between units 5 and 6 is unclear, but the two units seem to grade into each other beneath the chenier. Based on the overlapping positions of the facies, the relative age of these units from oldest to youngest is unit 1, unit 2, unit 3, unit 4, unit 5, and unit 6.

The chenier consists of well-sorted mollusks, in particular *Cerithium eburneum* and *Chione cancellata*, with smaller amounts of *Modulus modulus*, *Polinices lacteus*, and *Anomalocardia auberiana*. The shells of the chenier grade into shelly mud at ~30 cm below the surface that buries wooden Taino structural material located ~70 cm below the surface of the chenier.

**Elemental Geochemistry**

The concentrations of select major and trace elements for each sample are shown in Table II. A correspondence analysis was performed on these data to display the relationship between the subsamples in a two-dimensional scattergram (Figure 5). Individual subsamples are plotted by sedimentary unit membership. The samples form distinct clusters, indicating that each unit has a relatively homogenous and distinctive elemental composition.

When the subsamples are seriated by unit membership along the first dimension of the correspondence analysis (Baxter, 1994, pp. 118–123), the ordering of the units is identical to their relative chronology. This indicates a progressive change in the elemental composition of successive facies, with the two end-members of this sequence—units 1 and 6—representing the most dissimilar environments (terrestrial and marine, respectively). The positions of the intermediate units—2, 3, 4, and 5—indicate that the marine environment has had an increasingly important influence on the compositions of the facies. The reason for the concordance between relative chronology and elemental composition can be explained with reference to the pronounced arch evident among the sample points. This arch effect often occurs when samples are measured along an environmental gradient (Legendre and Legendre, 1998, p. 465); in this case, the gradient is elemental composition over time.

**Mineralogy**

Results from the mineralogical analysis of the < 2 mm fraction show that quartz and calcite, with some gypsum, constitute the bulk of the material in each unit, with roughly equal abundances (Peros, unpublished data). The presence of gypsum is not surprising given the proximity of the Punta Alegre diapir. Individual units are distinctive, however, when the mineralogy of the clay-sized (< 2 µm) fraction is considered (Table III). Unit 6 is distinguished by the presence of smectite and high illite-
| Unit Sample | Al% | Ca% | Cl% | Fe% | K% | Mg% | Na% | As | Ba | Br | Co | Cr | Cs | Hf | Mn | Rb | Sc | Ta | Th | U | V |
|-------------|-----|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1           | 4.35 | 5.20 | 3.81 | 1.47 | 1.57 | 0.24 | 1.98 | 1.60 | 33  | 23  | 151 | 1.78 | 3.83 | 741 | 51.1 | 19.1 | 1.40 | 6583 | 3.33 | 2.02 |
| 2           | 3.45 | 4.95 | 3.86 | 1.55 | 1.89 | 0.35 | 4.08 | 1.69 | 35  | 38  | 252 | 2.65 | 2.32 | 543 | 86.6 | 22.0 | 1.41 | 7495 | 3.17 | 2.06 |
| 3           | 2.45 | 3.95 | 3.67 | 1.75 | 2.11 | 0.47 | 3.68 | 1.81 | 171 | 171 | 1.59 | 3.56 | 877 | 40.7 | 22.0 | 1.41 | 4915 | 3.11 | 2.06 |
| 4           | 1.45 | 2.95 | 3.46 | 1.96 | 2.32 | 0.58 | 3.70 | 1.83 | 152 | 189 | 1.82 | 2.00 | 320 | 41.0 | 18.8 | 1.41 | 6495 | 3.11 | 2.06 |
| 5           | 0.45 | 1.95 | 3.27 | 2.17 | 2.52 | 0.69 | 3.71 | 1.85 | 132 | 211 | 1.72 | 2.22 | 318 | 41.2 | 18.9 | 1.41 | 7100 | 3.11 | 2.06 |

Table II. Concentrations of major and trace elements.
smectite, whereas unit 3 contains relatively high quantities of illite, chlorite, illite-smectite, and kaolinite. Units 1, 2, 4, and 5 have similar clay-mineral compositions; this finding suggests that many of the materials that constitute these units are derived from the same terrestrial source. The smectite in unit 6 may represent an authigenic marine clay, such as glaucony (Weaver, 1989, p. 372), although more detailed analysis is required to confirm this hypothesis. Thus, the results show that unit 6 has a unique mineralogy when the $<2\mu m$ fraction is considered, although the other units are difficult to differentiate on the basis of mineralogy alone.

Figure 5. Correspondence analysis (top) and seriation (bottom) of the elemental data in Table III. The dashed arrow shows how samples are seriated from the correspondence analysis.
Organic Matter, Carbonates, and Silicates

Loss-on-ignition results for two representative cores are shown in Figure 6. Among all cores, unit 3 contains the most organic matter at ~12%, whereas unit 1 has the least at ~6%. In all six units, carbonate constitutes 20–40% of the sediment and generally decreases in abundance with depth, whereas silicates constitute the bulk of each core (> 60%) and generally increase in abundance with depth. These results are consistent with the visual descriptions of each core; the units dominated by shell (5 and 6) contain the highest carbonate values, whereas unit 1, with almost no shell, yields the highest amount of silicate, consistent with its classification as a terrestrial unit.

**Table III.** Mineralogy of clay-sized fraction.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Sample</th>
<th>Clay Minerals</th>
<th>Primary Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Smectite</td>
<td>Illite</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>—</td>
<td>×</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>—</td>
<td>×</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>—</td>
<td>×××</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>—</td>
<td>×</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6</td>
<td>31</td>
<td>××</td>
<td>××</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>—</td>
<td>×××</td>
</tr>
<tr>
<td>8</td>
<td>14</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>9</td>
<td>19</td>
<td>—</td>
<td>×××</td>
</tr>
<tr>
<td>10</td>
<td>25</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>11</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Note. ××× = abundant; ×× = moderate; × = trace; — = not present.
**Figure 6a.** Loss on ignition and mollusk analysis results. The loss-on-ignition data are expressed as a percentage of the total dry weight of the sample. The mollusk results are total number of mollusks counted per taxon for each sample interval. Core 3 (nearshore).
Molluscan Ecology

The total number of each identified mollusk was plotted against the stratigraphy for cores 3 (Figure 6a) and 5 (Figure 6b). The bivalves (*Anomalocardia*, *Chione*, and most of the unknown examples) almost always exist in halves, and to maintain whole numbers, each half was counted individually, with the result that the bivalves are overrepresented. Mollusks are associated only with units 5 and 6. In order of abundance, they are *C. eburneum*, *A. auberiana*, *M. modulus*, *C. cancellata*, *Marginella apicina*, and *Urosalpix* spp. All are common in shallow marine conditions in the northern Caribbean (Warmke and Tucker Abbott, 1961; Tucker Abbott,
The proportions of each taxon are consistent down each core. Although only cores 3 and 5 were studied, a visual examination of the other cores indicates that patterns found in these units are consistent throughout the profile.

DISCUSSION

Environments of Deposition

Unit 1 is a buried soil. This is evidenced by its red-brown oxidized appearance, its relatively coarse texture, its lateral continuation onto the present-day surface, and its relatively high silicate content. Unit 1 predates the Taino settlement and does not appear to have been an occupation surface. In terms of soil classification, this unit has physical properties consistent with the Ferralsol group of the Food and Agriculture Organization (Bridges, 1997, pp. 128–130). It is also similar to the Cuban Ministry of Agriculture’s Francisco series soil, which is brownish-red and fine textured with occasional coarse particles (Suelos de la Provincia Ciego de Avila, 1983, p. 127).

The fine texture of units 2, 3, 4 and 5, and their grayish color, indicative of reduced conditions, suggest these facies were deposited in a lagoon. The yellow mottles of unit 4 may have been caused by alternating reducing and oxidizing conditions from a period of fluctuating or low water levels (Birkeland, 1999, p. 134). The marine mollusk fragments in unit 5 indicate that there has been a nearly constant exchange of water between the Bahía de Buena Vista and the Punta Alegre lagoon. Despite this finding, thick mollusk layers, which would indicate washover fans from hurricane strikes (Liu and Fearn, 2000), are absent from the cores. This absence of thick mollusk layers suggests that hurricanes had a limited impact as a geomorphologic agent, possibly because the Archipiélago Sabana-Camagüey reef protects the mainland from storm surges. Until more cores are studied, however, the presumption of limited hurricane impact will remain tentative.

Unit 6 was deposited in a shallow marine environment. This is indicated by the presence of turtle grass (*Thalassia testudinum*), usually in growth position and a high abundance of marine mollusks. The coarseness of the sediment in this unit is consistent with the higher energy conditions of the Bahía de Buena Vista compared to the Punta Alegre lagoon.

Relative Sea-Level Change at Los Buchillones

The overlapping positions of the sedimentary units, as shown in Figure 4, can be interpreted using principles of sequence stratigraphy (Van Wagoner et al., 1988). Sequence stratigraphy uses the boundaries that separate sedimentary units to infer the direction and rate of relative sea-level change (Haq, 1991). The main unit of analysis in sequence stratigraphy is the sequence, which is a stratigraphic unit bounded at its top and base by unconformities (Van Wagoner et al., 1988). Such unconformities, or sequence boundaries, form during periods of low sea level when the shallow marine environment is aerially exposed and is subject to erosion.
sediments that make up the sequence are deposited during a period of high sea level occurring between two successive periods of low sea level.

Figure 4 represents the lower portion of a sequence. The contact separating unit 1, the buried soil, from units 2, 3, and 5 represents a basal sequence boundary and, therefore, a period of relative sea-level rise. There is no upper sequence boundary, because relative sea level has yet to fall, although the mottled, oxidized appearance of unit 4 may reflect a brief stillstand. The rise in relative sea level inferred from the stratigraphic sequence is strongly supported by the geochemical results (Figure 5), which indicate that the elemental compositions of lagoonal units 3, 4, and 5 are increasingly similar to the marine facies (unit 6)—a condition that would be expected during a sea-level transgression. A consequence of the relative sea-level rise would have been the landward migration of the lagoon, which can indeed be tracked in the profile by examining the overlapping positions of units 3, 4, and 5. This migration may have included a concurrent landward shift of the chenier, which is a typical response of such features during a rise in relative sea level. The presence of the chenier overlying Taino material culture indicates that the chenier reached its present location sometime since that portion of the site was last occupied.

The units in each core (with the exception of unit 1) show a sequence of finer sediment overlain by coarser sediment. This textural pattern represents a shallowing-upward sequence, indicating that until the recent period of erosion, sediment supply exceeded the rate of relative sea level rise in this area (Nichols, 1989), and hence the lagoon was deeper when it was farther seaward and that it has been gradually infilling as it migrated landward. In addition, the orientation of the shoreline appears to have changed as this migration occurred. Assuming the long axis of the Los Buchillones site was parallel to the shoreline (as was the case with many Taino sites in the Bahamas; Keegan, 1992a), the coastline had a slightly more north–south orientation when the site was occupied.

Figure 7 shows several published relative sea-level records from Florida and the Bahamas (Scholl et al., 1969; Boardman et al., 1988; Gelsanlitter, 1996). These data—obtained from 14C-dated mangrove peat—indicate that relative sea level in the northern Caribbean region was around 2 m below present level at 3000 14C yr B.P. and then rose at a decelerating rate to its present position—a pattern also consistent with recent Holocene sea-level observations from the Mississippi Delta (Törnqvist et al., 2004). Other research from Florida, however, based on geoarchaeological (Walker et al., 1994, 1995) and rhyzolith evidence (Froede, 2002), suggests that centennial-scale highstands of ~1 m occurred from 1000 to 2000 14C yr B.P. There is no evidence, such as raised beaches or wave-cut notches, for a Holocene highstand in the Los Buchillones area. Given the tectonic stability of the region (Iturralde Vincent and Roque Marrero, 1982), the stratigraphy from Los Buchillones appears to be largely consistent with the overall pattern and timing of relative sea-level rise shown in the sea-level curves in Figure 7.

Site Formation and Implications for the Taino Settlement

These investigations provide insight into the environmental setting of the Taino village. If relative sea level was 0.2–0.5 m lower during the Taino occupation of Los
Buchillones (Figure 7), most of the features represented by the archaeological material, which lie at least 1 m below present sea level, would have been associated with shallow-water conditions. The full range of environmental conditions contemporary with site formation are, at present, difficult to determine, although a lagoonal or nearshore system is likely. However, given the size of the village and the duration over which it was occupied, various components of the site may have been built in different settings; some houses, for example, might have been built on a chenier, whereas others may have been built in the lagoon. Alternatively, the site may have been initially settled on a dry surface, and as the population grew, or relative sea level rose, the Taino adapted by expanding the settlement over water. Nevertheless, the littoral zone at the Los Buchillones site appears to have had a complex history, and it is likely that the Taino were compelled to adapt their settlement patterns to an ever-changing coastal environment.

The vertical wood pilings are consistent with the idea that the Taino houses were raised above water. Pile dwellings are not uncommon archaeologically. The Lagunillas Phase (3000–1700 yr B.P.) for the Lake Maracaibo Basin in Venezuela is characterized by pile dwellings (Wagner and Tarble de Ruíz, 1975) and numerous pile dwellings have been documented from lakes in Germany and Switzerland.
(Hafner, 1995; Strobel, 2000). Indeed, modern pile dwellings can also be found in Southeast Asia and northern South America. In Belize, small structures are built over water to accommodate people during periods of intensive fishing activity. The motives for living over water in pile dwellings vary, but include efficient transportation and waste-disposal, coping with occasional high tides and flooding, adapting to long-term environmental change (e.g., sea- or lake-level change), ensuring structural stability on soft substrates, and architectural preference (Oliver, 1987). At Los Buchillones, ensuring structural stability in the mud may have been important in addition to coping with the wet substrate. Despite this, it is important to note that raised floors are a necessary requisite for raised houses, and, as yet, floors have not been identified archaeologically (Pendergast et al., 2001). In any event, pile dwellings would represent a unique adaptation among Taino settlements, as coastal Taino sites elsewhere are normally associated with sand beaches (Sears and Sullivan, 1978; Keegan, 1992a, 1992b).

Based on the results and discussion above, we have developed a preliminary model for the evolution of the coastline (Figure 8). During the time of Taino occupation (~A.D. 1220–1640), the Punta Alegre lagoon and chenier were seaward of their present position, with much, or perhaps all, of the Taino settlement located within the lagoon. By the mid-18th century, the village had been abandoned for at least 100 years and the structures had collapsed into the low-energy environment of the lagoon. The chenier began to transgress the site, changing its orientation and reaching its present position by the early 20th century. The western, shallower end of the lagoon was also inundated gradually during this time. Beginning in the 1950s, erosion of the coast had begun, and the chenier narrowed to its present width.

On a broader level, environmental considerations appear to have been critical for site selection. Nearby springs in the Punta Alegre diapir (Figure 2; Fagundo et al., 1993) would have provided potable water, as the next nearest source is the Rio Los Perros 7 km to the west. In addition, the summit of the diapir provides an excellent view of the region. The vast diversity of materials found in the excavations attests to the exploitation of a variety of micro-environments. Resources would have been immediately available from terrestrial, marine, and lagoonal environments, whereas estuarine (the Rio Los Perros estuary) and reef communities could be accessed. Furthermore, the location of the site inside the Archipiélago Sabana-Camagüey appears to have provided some protection from hurricane activity. Last, the late occupation of Los Buchillones (~A.D. 1640) is atypical (Rouse, 1992, p. 158). The Punta Alegre diapir and Archipiélago Sabana-Camagüey may have been sufficient physical barriers to hide the site from European contact until the first half of the 17th century (Pendergast et al., 2001).

CONCLUSIONS

Geoarchaeological research at Los Buchillones has revealed valuable information about the complex history of the coastal environment. The stratigraphy shows that relative sea level has gradually risen over the past several thousand years, and
there is no evidence to indicate that it has been above its present level during the Holocene. The rise in sea level appears to have been accompanied by a landward shift in the Punta Alegre lagoon and chenier. The geological and archaeological evidence suggests that the Los Buchillones site was built above a wet substrate—a settlement strategy unique among Taino sites elsewhere. Despite this, there is still a lack of important evidence, such as house floors, which would be expected in such circumstances, although future archaeological excavations will shed light on this. Furthermore, given the length of Taino occupation of Los Buchillones, it is not unlikely that the local environment—and consequently Taino settlement patterns—changed during the roughly 400 years the site was occupied.

Ongoing and future work is focusing on several areas. At the site itself, deeper excavations over a larger area are essential to fully reconstruct Taino house form.
Our intention is to drive semipermanent caissons into the sediment to allow excavations to reach archaeologically sterile sediment without flooding. In addition to providing valuable archaeological information, this method will allow us to examine the sediment directly underlying and overlying the houses to provide a more detailed picture of the depositional environments prior to, during, and following settlement. One of us (Peros) is also examining foraminiferal assemblages from the sediments at the site to determine whether lagoonal and marine facies can be easily identified on the basis of micropaleontological content. On a regional level, archaeological surveys have begun on the cays north of Punta Alegre and several small sites with ceramics identical to those at Los Buchillones have been found. We have taken sediment cores from mangrove swamps on many of these cays and on the mainland west of Punta Alegre to develop a well-dated relative sea level curve for the area and to reconstruct past vegetation communities. This work will better constrain the timing of inundation of the Los Buchillones area and provide a regional environmental framework within which the archaeology at Los Buchillones and its environs can be interpreted.

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