GPR identification of an early monument at Los Morteros in the Peruvian coastal desert

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ABSTRACT

Los Morteros (8°39′54″S, 78°42′00″W) is located in coastal, northern Peru, one of the six original centers of world civilization. The site consists of a large, sand-covered, isolated prominence situated on a Mid-Holocene shoreline, ~5 km from the present coast. Preceramic archaeological deposits (4040±75 to 4656±60 14Cy r BP or ~3600–5500 cal yr BP) cap this feature, which has been identified by prior researchers as a sand-draped, bedrock-cored landform or a relict dune deposit. Because neither explanation is geomorphologically probable, we used ground-penetrating radar (GPR) and high-resolution mapping to assess the mound’s interior structure. Our results indicate an anthropogenic origin for Los Morteros, potentially placing it among the earliest monumental structures in prehistoric South America. The extremely arid setting raises new questions about the purpose and the logistics of early mound construction in this region. This work demonstrates the value of an integrated Quaternary sciences approach to assess long-term landscape change and to understand the interaction between humans and the environment.

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Introduction

Los Morteros is a distinctive, mound-shaped landform on the desert coast of northern Peru. Long noted by archaeologists, prior investigators characterized the site as a sand-draped, bedrock-cored landform or as a relict dune deposit capped by human-emplaced midden material (Cárdenas Martin, 1995, 1999; Wells, [http://geoimages.berkeley.edu/geoimages/wells/geomorph/dune1.html]). We designed the research reported here to test these hypotheses and the alternative that the entire landform is in fact a structure built by ancient Peruvians. Our investigations do not support either the fossil dune or sand-draped bedrock hypotheses and instead suggest that Los Morteros may be one of the earliest monumental structures in South America. Because the site is located on a fossil shoreline in a desert setting, previous, more traditional archaeological efforts were theoretically and methodologically insufficient to understand this landform. Our work demonstrates the value of an integrated Quaternary sciences approach to assess long-term landscape change and to understand the interaction between humans and the environment.

As one of the six original centers of civilization (Service, 1975), coastal Peru plays an important role in understanding the development of complex societies. Monumental architecture, placed in climatic, environmental, economic, and social contexts, offers one of the most enduring and therefore available avenues to study this development. Coastal Peru has long been known for its early temple mounds, first built before or during the 5th millennium BP, prior to the introduction of pottery and nearly as early as the first Old World monuments (e.g., Burger, 1992; Moseley, 2001; Richardson, 1994; Shady Solís, 2007). Collaborative research between archaeologists and geoscientists has contributed to the recent recognition and dating of early temple mounds along the Peruvian coast, such as Caral (Shady Solís et al., 2001) and Bandurria (Chu Barrera, 2008), and suggests that other such sites remain to be discovered.

Location and Setting

Los Morteros is an elongate, elliptical landform ca. 225×200 m with a relief of 14.5 m at the highest point (Figs. 1–4). The site is situated on the edge of a paleo-bay containing the Salinas de Chao salt flats of northern Peru. From the seaward side, the former sea cliff adds an additional 3 m to the landform’s apparent height. The surface of the site is dominated by fine sand, shells from prehistoric middens (ancient garbage deposits), scattered stones (up to 0.5 m maximum dimension), many broken mortars (that give the site its name), and some human bone from looted burials. There are no pottery sherdos

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or around the site, nor were any discovered in Cárdenas’ twelve test excavations (Cárdenas Martin, 1995, 1999).

Isolated coastal mountains, up to 500 m relief, are located 1 km to the north, east, and south of Los Morteros. The mound sits on a broad, well-developed alluvial fan complex approximately 5 km from the current coastline (US Defense Mapping Agency, 1956). Many small channels dissect the alluvial fan, but no bedrock crops out through the fan for 5 km to the north or south, nor is bedrock exposed along the toe of the fan (Figs. 3 and 4). The toe of the fan is abruptly truncated by the former shoreline scarp, ca. 3 m in relief.

The paleoshoreline in the Salinas de Chao is a smoothly curving embayment shaped by waves refracted by the rock headlands 5 km to the SW and 6 km to the NW. There is no indication of a local rock outcrop distorting the shoreline’s curvature near the mound (see Fig. 3). To the west (seaward) of the site, modern dune fields are located on the relatively flat former marine embayment surface, which is up to 7 m above modern sea level at the scarp toe. Barchan dunes range from 2 to 5 m in height and occur in well-developed trains extending downwind for several kilometers to the northeast. Barchans typically have crescentic shapes and are elongated roughly northwest to southeast in this area, while longitudinal dunes, also found nearby, are far more elongated and trending northeast. The orientation and size of the Los Morteros landform are unlike either of these natural dune types.

Whitford (2002, p. 47) characterized the coast of Peru as one of the most arid regions of the globe, as measured by the Oberlander (1979) index. In the Salinas de Chao, vegetation is almost completely absent, with no surface expression of water or indications of intermittent springs. El Niño events of varying intensities occur at intervals of ∼3–5 years, and the stronger events create large rainfall episodes that produce gully flooding, slope wash, and debris flows in the area surrounding the site.

Previous Work

Though visited by other archaeologists, only Cárdenas has dug at the site (Cárdenas Martin, 1995, 1999; Cárdenas Martin and Vivar Anaya, 2002). In 1977, she excavated twelve test pits up to 1.8 m in depth into the deposits on the top of the mound (see Fig. 2). Two charcoal samples from Cárdenas’ Pit B (at 0.4 and 1.2 m depth) gave an age range of 4560 ± 60 (PUCP-27) and 4656 ± 60 (PUCP-26) ¹⁴C yr BP (5390–5051 and 5462–5072 cal yr BP, Calib 5.0.2, Stuiver and Reimer, 1993) (Cárdenas Martin and Vivar Anaya, 2002; see Table 1). These
dates fall early in the Late Preclassic Period (Table 2), when the earliest known monumental architecture was constructed on the Peruvian coast (e.g., Moseley, 2001; Shady Solís, et al., 2001; Haas et al., 2004). In her publications, Cárdenas describes the excavated deposits as primary midden, and the two dates are specifically associated with diverse midden materials (Cárdenas Martin, 1995, 1999; Cárdenas Martin and Vivar Anaya, 2002:45). Cárdenas interpreted her dates as a maximum age estimate for human occupation of a natural landform. Dates on two shell samples from the site surface gave ages of 4040±75 (SI 4959A) and 4380±75 (SI 4959B) \(^{14}C\) yr BP (3857–3623 and 4340–4080 cal yr BP, Calib 5.0.2, Stuiver and Reimer, 1993; shell dates were corrected for the marine reservoir using Hughen et al., 2004 and \(\Delta R = 243\ \sigma = 49\) from Reimer, http://intcal.qub.ac.uk/marine/]) (Sandweiss et al., 1983). A charcoal date from a surface sample returned an age of 4010±85 (SI date, number unreported) \(^{14}C\) yr BP (4523–4250 cal yr BP, Calib 5.0.2, Stuiver and Reimer, 1993) (Sandweiss et al., 1983). These surface dates (Table 1) fall in the second half of the Late Preclassic Period (Table 2), providing a minimum age estimate for human occupation of the mound surface. See the Discussion for further consideration of the site chronology.

**Methods**

In 2006, we conducted reconnaissance-level GPR studies to identify the composition of the landform and better understand the location of the archaeological site. GPR was selected because it

![Figure 2. Plan of Los Morteros; 50-cm contour interval. Heavy lines indicate location of GPR profiles. Squares show the location of Cárdenas Martin (1995, 1999) excavation units (A-L).](image_url)
provides a non-invasive method of examining subsurface stratigraphy and features. The system is highly portable, allowing data collection in challenging terrain and at walking speed. The electrical properties that lead to the creation of reflective horizons or anomalies are largely controlled by geological properties, such as grain size and composition. Sand-covered bedrock or bedded dune sands were deemed appropriate targets for this technique (Conyers, 2004).

We collected four GPR profiles on the Los Morteros landform with a Sensors and Software PulseEkko 100 system, using 100-MHz antennae to maximize energy penetration into the landform. Profile lines were oriented to examine the long axis of the landform (LM-1), the sides and floor of the upper depression (LM-2) and lower depression (LM-3) as well as an additional long axis profile oriented parallel to LM-1 (LM-4), but positioned to image the ridges separating the semicircular depressions (Figs. 2, 5–7). We collected elevation data every 5 m or at abrupt elevation changes along profile lines using hand leveling. Data produced as a result of the GPR survey of the Los Morteros landform were processed using IXterra software (Interpex International, 1999) to produce profiles expressed in terms of depth (based on a wave velocity of 0.15 m/ns in dry sand) and corrected for topographic variation.

In 2007, we completed a high-resolution topographic survey of Los Morteros to create a contour map (Fig. 2) and digital elevation model (DEM) (Fig. 4) of the landform. We used a Nikon DTM-322 total station with sub-centimeter precision to map 829 data points covering the mound surface and surrounding topography. We collected and post-processed site datum coordinates with a Trimble GeoExplorer handheld global positioning system (GPS) receiver and Pathfinder software. ESRI ArcGIS 9.1 Spatial Analyst raster interpolation tools were used to produce the DEM from our topographic data. A scanned and georeferenced 1962 Servicio Aerofotográfico Nacional del Perú (SAN) low-elevation air photo was draped over the DEM to create the depictions of Los Morteros shown in Figure 4.

The high-resolution topographic mapping allows quantitative estimation of the Los Morteros mound volume. We used the ESRI ArcGIS 9.1 Spatial Analyst cut/fill function to determine mound volumes.

Results

GPR assessment of Los Morteros

The GPR survey produced four profiles with strong radar penetration of 4–6 m below ground surface and weaker returns to twice that depth (Figs. 2, 5–7). All profiles showed a combination of parallel, horizontal, and inclined reflectors interspersed with hyperbolic returns characteristic of highly reflective objects. On each profile, reflectors fade in intensity with depth (see the Discussion for our interpretation of the GPR results).

GIS volumetric calculations for Los Morteros mound

We calculated mound volume as the difference between two elevation data set surfaces: the Los Morteros DEM surface and a modeled planar surface corresponding to the alluvial fan on which we believe the mound was constructed. The exposed alluvial fan and its presumed extension under the mound is level at its distal edge but exhibits minor topographic variability, so calculation of a mean basal elevation for the mound constitutes an uncertainty in the resulting volume estimate. Our topographic measurements were primarily limited to the close vicinity of the mound, and some of these areas have been affected by erosion during flood events. To provide the best possible estimate of the mean basal elevation for the mound, we used...
the georeferenced air photo to identify non-eroded and non-anthropogenic portions of the fan, sampled elevation values from these intact locations, and determined a mean elevation value of 10 m above sea level (masl). To test this value, we used a number of hypothetical mean basal elevation values until we achieved net-gain and net-loss polygons that best approximated the horizontal extent of the mound (see the Discussion section for the mound volume estimates).

Discussion

GPR-based interpretation of mound structure and paleogeography

Interpretation of the GPR profiles supports the hypothesis that the landform is not a natural feature. If the landform were underlain by a bedrock outcrop of significant size, a distinct, continuous reflector would mark the boundary between unconsolidated sediment and bedrock near the base of the landform (Conyers, 2004). Instead, reflectors uniformly fade in intensity with depth on all profiles (Figs. 2, 5–7). While a deeper, bedrock contact below the range of the GPR is possible, it is counter to geomorphic logic. A bedrock outcrop beneath the Los Morteros mound requires an erosion-resistant feature directly on the raised paleoshoreline spatially associated with the mound. Such an outcrop would form a headland and influence the shape of the paleoshoreline. The presence of an outcrop at Los Morteros would therefore result in the formation of a scalloped embayment anchored on each promontory. Instead, the Los Morteros paleoshoreline shows a smooth arc, a shape consistent with a coastline developed in unconsolidated sediments bounded by two rocky headlands (Fig. 3).

The internal stratigraphy of the landform does not support the interpretation of the feature as a large, relict dune. The continuous, stacked inclined reflectors (clinoforms) associated with dune construction (Bristow et al., 2007) were not observed on any of the GPR profiles, with the exception of surficial drapes of approximately 1 m in depth on the south flank and in the central depression. We interpret

Figure 4. ESRI ArcScene views of Los Morteros mound DEM with SAN (Servicio Aerofotográfico Nacional del Perú) air photo drape. A (top) is an overhead view showing the geomorphic setting of the landform. The Mid-Holocene seafloor arcs from the upper right to lower left, with the Los Morteros mound structure overlapping the scarp. The flood channels evident on the alluvial fan on the right side of the image have eroded the east side of the Los Morteros mound. B (bottom) is an oblique view of Los Morteros, facing southeast, showing the eroded eastern parts of the landform, the intact western portions of the mound, the atria, and the central access way. The viewer perspective is 153° azimuth and 20° from horizontal. Vertical exaggeration of the landform is 1.5×.
these isolated features, which are limited to the surface of the landform, as aeolian sand deposited after the mound was abandoned. In addition, numerous portions of the records show hyperbolic returns characteristic of isolated, dense features, such as rocks (Conyers, 2004) (Figs. 5–7). As dunes are constructed of sand by aeolian processes, the presence of rocks demonstrates that other processes were involved in the construction of the landform. In an effort to test our interpretation of dune GPR stratigraphy, we also surveyed one of the numerous, nearby barchan dunes and found the expected clinoforms and no isolated, dense features.

The interpretation of the landform as a human-constructed feature is supported by data on all GPR profiles. Hyperbolic returns, interpreted as rocks, show no apparent orientation in some portions of the profiles, while in others, they appear in linear arrangements. North-facing, topographically steep portions of the mound are associated with stacked, steeply dipping, near-vegetal reflectors that interrupt adjacent, gently dipping or horizontal reflectors (Figs. 5 and 7). We interpret these coherent, dense, linear features as standing or partially fallen walls. Additionally, similar reflectors are noted on the east and west sides of the upper depression (Fig. 6A–B). In this location, the reflectors may represent walls (e.g., cobble walls such as at the younger Bandurria site (Chu Barrera, 2008) or a steeply dipping coherent sediment surface). Clustered hyperbolic reflectors are also noted in ridge-top locations (Figs. 5–7) and are consistent with the observation of surface groupings of rocks arranged in linear or circular patterns in these locations. We interpret these groupings as the remains of structural foundations.

Many reflectors noted on the Los Morteros GPR profiles are parallel or sub-parallel to the surface. These reflectors vary in appearance from narrow, sharply defined returns to broader, more diffuse, but consistent reflectors (Figs. 5–7). We interpret the sharply defined reflectors as a consistent stratigraphic layer composed of fine-grained, potentially compacted material. The more diffuse, but consistent, near-surface horizons are interpreted to be composed of more poorly sorted material and may include stone clasts too small to be resolved by the relatively low-frequency radar waves used in this investigation.

Line LM-2 (Fig. 6A and B) also shows a series of “boxed” strong horizontal reflectors in the floor of the upper depression. These horizontal reflectors are adjacent to steeply dipping reflectors that we interpret as two sides of a well-defined structure that was subsequently filled. A similar, less distinct arrangement of reflectors appears on profiles LM-1 (Fig. 5) and LM-3 (Fig. 6C and D) in the area of the lower depression. These horizontal reflectors may represent filling by human or natural processes.

Profile LM-1 also has an isolated, strong reflector at ~3 m depth and approximately 2 m in length, paired with a similar strong reflector approximately 1 m above a lower reflector of similar size. These results suggest parallel hard surfaces, reminiscent of a ceiling and floor (see box, Fig. 5). The south-facing, steep, surface slope imaged in LM-1 shows a distinct interruption of stratigraphy, consistent with the eroded burials noted during a walkover survey of the site (Fig. 5B).

Table 1
Radiocarbon dates from Los Morteros. Dates were calibrated using Calib 5.0.2 (Stuiver and Reimer, 1993): shell dates were corrected for the marine reservoir using Hughen et al. (2004) and ΔR = 243 ± 49 from Reimer (http://intcal.qub.ac.uk/marine/)

<table>
<thead>
<tr>
<th>Context</th>
<th>14C dates (1σ yr BP)</th>
<th>Calibrated age (1σ range)</th>
<th>Material</th>
<th>Lab no.</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>4040±75</td>
<td>3857–3623</td>
<td>Shell</td>
<td>SI</td>
<td>Sandweiss et al. 1983</td>
</tr>
<tr>
<td>Surface</td>
<td>4380±75</td>
<td>4340–4080</td>
<td>Shell</td>
<td>SI</td>
<td>Sandweiss et al. 1983</td>
</tr>
<tr>
<td>Surface</td>
<td>4010±85</td>
<td>4523–4250</td>
<td>Charcoal</td>
<td>SI-77</td>
<td>Sandweiss et al. 1983</td>
</tr>
<tr>
<td>Pit B, 0.40 m</td>
<td>4560±60</td>
<td>5290–5051</td>
<td>Charcoal</td>
<td>PUCP N° 27</td>
<td>Cárdenas Martin 1995, Cárdenas Martin and Vivar 2002, Anaya 2002</td>
</tr>
</tbody>
</table>

Table 2
Chronological chart for the Peruvian coast with emphasis on early periods.

<table>
<thead>
<tr>
<th>Period</th>
<th>Age (cal yr BP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Republican Period</td>
<td>129–present</td>
</tr>
<tr>
<td>Colonial Period</td>
<td>417–129</td>
</tr>
<tr>
<td>Ceramic Periods</td>
<td>2900–417</td>
</tr>
<tr>
<td>Initial Period</td>
<td>3600–2900</td>
</tr>
<tr>
<td>Late Preceramic Period</td>
<td>5800–3600</td>
</tr>
<tr>
<td>Middle Preceramic Period</td>
<td>9000–5800</td>
</tr>
<tr>
<td>Early Preceramic Period</td>
<td>13,000–9000</td>
</tr>
</tbody>
</table>
The maximum volume of the mound on top of the scarp, which is an underestimate of its overall volume, is 214,509 m$^3$ (Table 3). Three factors complicate this maximum volume estimate. First, our calculations include an unknown volume of aeolian deposits draping the mound surface. Since GPR work indicates that only small portions of the Los Morteros mound are covered by aeolian material, our volume estimates for the human-constructed portion of the existing mound would probably be only a slight overestimate. Second, the entire southeast corner and part of the northeast corner of the mound have been eroded by one or more flood events (Fig. 4A). Third, part of the mound is draped over the paleoshoreline scarp, requiring additional material to provide a base equivalent in height to the alluvial fan that underlies most of the mound and provided the base level for calculation. Both the second and third factors suggest that our maximum volume calculation is an underestimate.

We estimated two additional volumes for Los Morteros based on the actual volume of mound material imaged by our GPR transects above the alluvial fan surface: strong returns to 6 m below surface and weaker returns to 12 m below surface (Table 3). For both estimates, we assumed that our GPR transects are representative of the whole mound volume.
Interpretation of mound shape

The comparison of Los Morteros' surface morphology and sub-surface GPR results with excavated early mounds in coastal Peru (Burger, 1992; Haas et al., 2004; Moseley, 2001; Shady Solís et al., 2001; Shady Solís, 2007; Chu Barrera, 2008) offers insight into the mound's shape and possibly its function. Typical early mounds are rectangular, with central staircases joining atria at different levels; the sizes of the atria decrease with height. The mounds in Peru, as elsewhere, are often characterized by multiple construction events, each representing a finished structure used for some period of time before being encased in the next, larger version (e.g., Feldman, 1985).

We interpret the GPR results from Los Morteros as follows: vertical to steeply inclined reflectors are walls, hyperbolic reflectors are tops of walls or isolated stones, depressions with floors and surrounding walls are atria, and an alignment of walls and topographic lows marks a central staircase climbing the mound from north to south and connecting the atria (Fig. 4B). In addition, there are rectangular depressions near the top of the mound that we interpret as rooms.

Taking into account the substantial erosion of the southeast and northeast corners of the mound as well as diffusive smoothing, the overall morphology suggests that the mound was a symmetrical and possibly rectangular structure (see Fig. 4). The Los Morteros GPR profiles show evidence of the intentional placement of rocks to form now-buried structures and walls. The prominent, horizontal, parallel reflectors shown on line LM-2 (Fig. 6A and B) suggest multiple construction episodes, separated by either floor construction or surface trampling of sediments. Buried reflectors also hint at earlier walls or floors covered by subsequent construction.

Table 3

<table>
<thead>
<tr>
<th>Volume estimate method</th>
<th>Volume estimate (m³)</th>
<th>Labor–Reed et al. (1968) (1.42 person-days/m³)</th>
<th>Labor–Ravines et al. (1982) (5.3 person-days/m³)</th>
<th>Labor–Heizer (1960) (6.25 person-days/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>214,509</td>
<td>304,603</td>
<td>1,136,898</td>
<td>1,294,309</td>
</tr>
<tr>
<td>12 m penetration (99.7% total mound volume)</td>
<td>213,842</td>
<td>303,656</td>
<td>1,133,363</td>
<td>1,389,973</td>
</tr>
<tr>
<td>6 m penetration (77.9% total mound volume)</td>
<td>167,140</td>
<td>237,339</td>
<td>885,842</td>
<td>1,086,410</td>
</tr>
</tbody>
</table>
although this is not yet proven. The surface dates are similar to the earliest dates from large Late Preceramic mound centers such as Caral (e.g., Shady Solís et al., 2001; Haas et al., 2004; Shady Solís, 2007). An additional chronological problem concerns the relationship of the mound to the floor of the adjacent paleo-embayment. If built on both the scarp and paleo-embayment floor, Los Morteros must post-date the sea-level highstand that formed the scarp in the millennium prior to 5800 cal yr BP, by analogy to the morphology and timing of the Santa paleo-embayment 20 km to the south (Sandweiss et al., 2007). At least one third of the mound clearly overlaps the scarp, and there are no inflection points on the west profile of the mound that would indicate that the portion overlapping the scarp results from post-construction slumping. However, if the current mound structure encloses a smaller, precursor construction phase, the earlier phase may pre-date or be contemporary with the formation of the marine scarp.

Geoarchaeological implications

The location of a structure as large as Los Morteros in extreme desert conditions raises a number of issues. Where did inhabitants procure drinking water? Preliminary reconnaissance failed to identify any proximal modern or paleo-sources of water, either as springs or streams. Today, the nearest source of surface water is the Chao River, 6.5 km to the north. Archaeologists have not identified Preceramic wells in Peru, though wells are known in association with sites of later periods. Dillehay et al. (2005) found small-scale canals dating to the Late Preceramic Period in the western Andean foothills about 200 km north-northwest of Los Morteros, but no canals of this age have yet been identified any closer to the Salinas de Chao. The question of water remains unresolved.

Cárdenas’ excavations show utilization of marine mammals, mollusks, and fish. Charcoal, cotton textiles (associated with intrusive human burials), and the remains of reeds, gourds, squashes, Inga feuillei fruit, and other plants were also found in the excavations (Cárdenas Martin, 1995, 1999; Cárdenas Martin and Vivas Anaya, 2002). We saw no evidence of ancient agricultural systems in the Salinas de Chao, implying that the nearest source of domesticated plants was the Chao Valley. However, all these food remains were found in the post-construction, near-surface levels at Los Morteros. We do not know if the builders of the Los Morteros mound were resident at the site or elsewhere, nor do we yet know anything about their diet.

Table 3 shows estimates of person-days of labor based on different published figures for mound construction labor costs (extracting and transporting raw material and incorporating it in the structure). We prefer Ravines et al.’s (1982) estimate of 5.3 person-days/m³ of constructed volume, as it is the only one based on a Peruvian site (Garagay, a 2800- to 3500-cal yr BP Initial Period mound complex near Lima). Ravines’ model assumes that all material came from within a 1-km radius; rock and sand are available within this range at Los Morteros. Using the different models, our estimates of the labor invested in building the mound range from a maximum of 1,394,309 to a minimum of 237,339 person-days of work (Table 3). Los Morteros was almost certainly built in stages, and the construction may have been spread across many years. Nevertheless, all of our estimates indicate a significant labor investment.

Construction of monumental architecture often requires a complex, hierarchical social organization. Unlike the pyramids of Egypt, which were meant to entomb the high status dead, all early mounds in Peru were built as bases for atria and room complexes connected by stairways. Some parts of these mounds are easily seen from below, while access to other areas was restricted and the interiors kept hidden from view (e.g., Feldman, 1985; Shady Solís, 2007). Following Roscoe’s argument (1993), such mounds could have been used as platforms for mass communication in pedestrian societies to make political manipulation more efficient.

Our interpretation of the GPR and GIS results and the available chronological data suggest that Los Morteros fits the early Peruvian mound pattern and thus may represent early social complexity in coastal Peru. At Los Morteros, mound construction pre-dates the near-surface levels excavated by Cárdenas, and so is most likely earlier than ca. 5500 cal yr BP. How much earlier? This age would place Los Morteros on equal chronological footing with any dated mound in coastal Peru (e.g., Caballete site, Haas et al., 2004). Was initial construction contemporaneous with the paleo-bay, in a temporal window between the highstand sometime in the millennium preceding 5800 cal yr BP (Sandweiss et al., 2007) and subsequent shoreline retreat from the scarp? If so, climatic reconstructions suggest seasonal rainfall in the region (Andrus et al., 2002; Sandweiss et al., 1996, 2007) for one or two millennia prior to 5800 cal yr BP and would help explain the apparent contradiction between a large artificial structure and the extreme aridity of the modern environment in the Salinas de Chao region.

Conclusions

The elongate, north-south oriented, elliptical landform at Los Morteros is not a natural, bedrock-cored feature or a relic dune, as previously described. The GPR investigation penetrated up to 12 m below the surface along our four sample transects without imaging bedrock, suggesting there is no bedrock core within the upper 213,842 m³ or 99.7% of the mound volume. Also, no bedrock is exposed anywhere on the alluvial fan or at its toe along the former shoreline, nor does the geomorphology of the paleoshoreline suggest the presence of a bedrock outcrop.

GPR profiles did not reveal stratigraphy consistent with dune formation processes. Instead, these profiles showed a series of reflectors that we interpret as walls and floors. We conclude that Los Morteros is a human-constructed mound, with a central access way connecting distinct upper and lower atria through openings in enclosing walls. Buried reflectors also hint at earlier walls or floors covered by subsequent construction, suggesting multiple construction episodes, as seen at other early mounds in Peru. Taking into account various post-construction formation processes, the overall morphology suggests that the mound was a symmetrical and possibly rectangular structure. Los Morteros thus replicates the form and possibly the construction history of other early mounds of the Late Preceramic and Initial Periods on the Peruvian coast (Feldman, 1985; Burger, 1992; Haas et al., 2004; Moseley, 2001; Shady Solís et al., 2001; Shady Solís, 2007; Chu Barrera, 2008).

The Los Morteros structure pre-dates the ca. 5500 cal yr BP, near-surface levels excavated by Cárdenas, an age which already places Los Morteros among the earliest mounds in coastal Peru. Initial construction may substantially pre-date this time. Further research is needed to establish the full chronology and sequence of mound construction, lifeways of the builders, and environmental setting of what may be ancient Peru’s first coastal monument.

Acknowledgments

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