

Quaternary Stratigraphy of the La Playa Archaeological Site (SON F:10:3), Northern Sonora, Mexico

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Abstract The La Playa archaeological site is located along the Rio Boquillas, north of Trincheras in northern Sonora, Mexico. The site contains an extensive record of human occupation beginning during the Paleoindian period with the most intense utilization of the site during the Early Agricultural period (3,700–1,900 cal BP). This work focused on detailed mapping and description of the stratigraphic units across the site. The oldest exposed stratigraphic unit is a reddish, sandy paleosol. The paleosol grades laterally into gravels that contain cobble-size clasts of diverse compositions. Overlying the paleosol is a tan-brown, homogenous silt (Holocene?) that lacks sedimentary structures and is consistently 98% silt and clay and 2% very fine sand. The paleosol and associated gravels were deposited during relatively wet conditions. The gravels are evidence of alluvial channels traversing the landscape and the composition of these gravels indicates significant transport distance based on the occurrence of nonlocal lithologies. The paleoenvironmental interpretation for the overlying silt has been considered a cienega deposit, but the silt has many characteristics in common with eolian deposited loess. An alluvial floodplain interpretation

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is feasible if the channel of the Rio Boquillas was stable and did not frequently avulse, allowing deposition of these fine-grained deposits.

Keywords La Playa • Sonora • Paleosol • Quaternary • Silt • Early Agricultural period • Alluvial • Pleistocene • Mexico

Introduction

The relationships between environmental change, landscape evolution, and human activities is a complex web of interactions that have been a focus of various geoarchaeological studies (Butzer 1978; Ferring 1986; Haynes 1991; Bintliff 1992; Davis and Shafer 1992; Van Nest 1993; Holliday et al. 1994; Freeman 2000; Waters 2000; Stafford and Creasman 2002; Hill 2004; Eitel et al. 2005; Bubenzer and Riemer 2007; Wright et al. 2007; Huckleberry and Duff 2008; Nials 2008). In the context of modern environmental change, geoarchaeological studies are increasingly informative about the long term effects of landscape and climate change on human populations. Human responses to environmental variation often relate directly to subsistence and the effects on the availability of food (Mabry 1998). Subsistence-based responses can significantly alter settlement patterns, initiate demographic changes, and stimulate the adoption of new technologies. A critical initial step in studies of human–environment interaction is creation of a stratigraphic and paleoenvironmental framework to understand the overall landscape change through time. With a model of landscape evolution firmly established, a more refined examination of these changes on human activity can be evaluated.

The goal of this study was to define a basic stratigraphic and paleoenvironmental framework for the La Playa archaeological site located in northern Sonora, Mexico. This site contains an archaeological record that spans 12,000 years and has provided a wealth of artifacts and human skeletal remains. Much of the previous work at La Playa has focused on the documentation of cultural features that are being destroyed by modern erosion of the landscape. As a result, little work has been done to understand the depositional history of the site. While many studies in the Desert Southwest have examined human–environment interactions within systems that are alluvial, sections of the La Playa stratigraphy do not possess the geomorphological and sedimentological characteristics typically observed in alluvial systems.

Intensively studied alluvial systems, such as the Gila River drainage basin in southern Arizona (Waters 2008), record considerable deposition of gravels and sands, rapid facies changes, terrace formation and multiple episodes of channel incision and aggradation. The La Playa stratigraphy lacks these indicators of alluvial deposition; therefore, previously developed models of those systems are not necessarily applicable. Assessment of the Quaternary stratigraphy involved characterization of the soil and sediment types at La Playa and compilation of a surficial map of the site that addresses distribution of the sediment types, surfaces, and cultural materials. While this study addresses aspects of the stratigraphy and sedimentology,

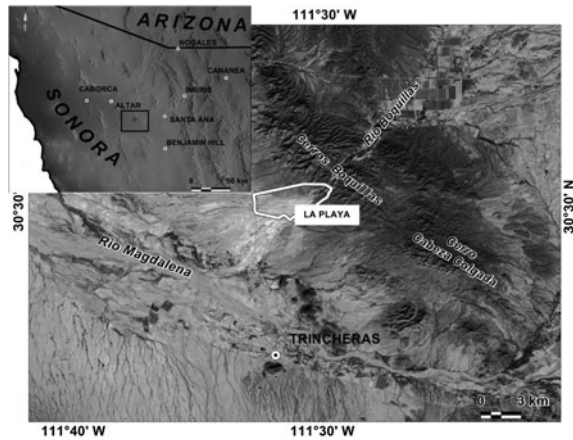


Fig. 1 Location map illustrating the location of the La Playa archaeological site within northern Sonora. The site lies adjacent to the Cerros Boquillas south and east of the Rio Boquillas

development of a chronological framework is in progress and consists of a combination of ^{14}C and OSL dating techniques.

Background

Geological/Geomorphic Setting

The La Playa archaeological site is located near of the town of Trincheras in northern Sonora, Mexico approximately 100 km southwest of Nogales, Arizona (Fig. 1). The site covers 9 km² along the Rio Boquillas east of its confluence with the Rio Magdalena. The site is situated below the low hills of the Cerros Boquillas where the river emerges from a narrow valley (Fig. 2). The Cerros Boquillas are a northwest–southeast trending ridge of Late Cretaceous metasedimentary fluvial deposits of the Pozo Duro Formation (McLaurin 2008). The site slopes gently to the southwest from an elevation of 526 m adjacent to the Cerros Boquillas to 506 m nearing the confluence of the Rios Boquillas and Magdalena. The surface of much of the La Playa site is characterized by a light-colored silt capped by a mantle of fire-cracked rock derived from deflated roasting pits, dispersed prehistoric human remains, and locally dense artifacts including flaked stone debitage, projectile points, marine shell jewelry and manufacturing debris, pottery sherds, and grinding stones.

Surface deposits at La Playa are characterized by a tan, homogenous silt that typically lacks internal stratification or sedimentary structures. On the flanks of the Rio Boquillas, this unit is reworked and is locally interbedded with sandier deposits exhibiting ripples and cross-laminations. Rapid, recent arroyo formation is heavily dissecting the silt and extensively exposes buried archaeological

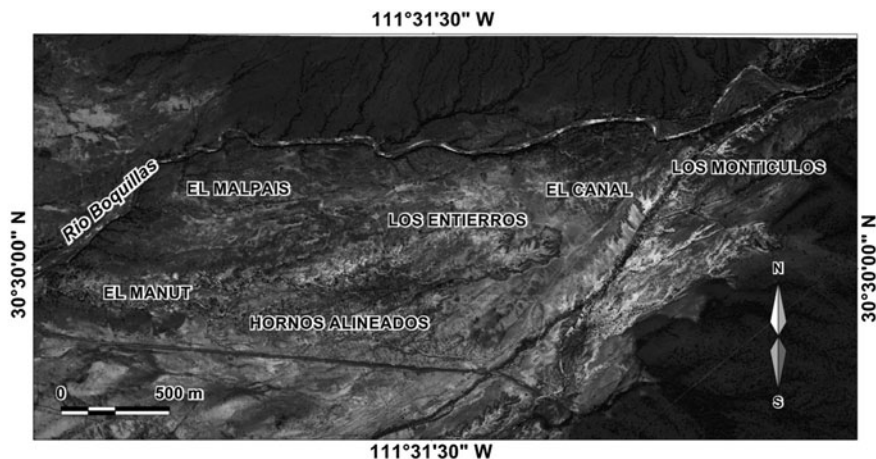


Fig. 2 Quickbird satellite image of the La Playa site with the major areas of the site labeled. Satellite image source: DigitalGlobe

remains. Drake (1961) examined gastropods from the silt, and identified genera suggesting moist conditions prevailed. This supported Johnson's (1960, 1963) proposal that La Playa was a *ciénega* or marsh-like setting prior to rapid incision and subsequent arroyo formation in the early twentieth century. The exposed thickness of this silt is approximately 2 m, and it unconformably overlies a red, sandy paleosol with calcareous root casts. The upper parts of the paleosol occasionally contain imbricated and rounded fluvial gravels. The paleosol also contains diverse Rancholabrean megafauna including mammoth, bison, camel, horse, deer, peccary, and tortoise (Carpenter et al. 2005). Although the development of the paleosol dates broadly to the Pleistocene based on the fossil assemblage (Carpenter et al. 2005), its exact age and that of the overlying silt have yet to be determined.

Archaeological Setting

Over 3,000 archaeological features have been recorded and 580 of these have been excavated during the last 14 years of archaeological investigation at La Playa. The earliest occupation of the La Playa site was during the Clovis tradition (13,500–13,000 cal BP) of the Paleoindian period (14,000–12,000 cal BP) (Fig. 3). During the Early Agricultural period (3,700–1,900 cal BP), occupation and utilization of La Playa intensified and as a result, artifacts and human burials date primarily to this period. Followed by the Early Ceramic period and Trincheras traditions, use of La Playa diminished, but a notable presence of humans continued at this locale until about A.D. 1950.

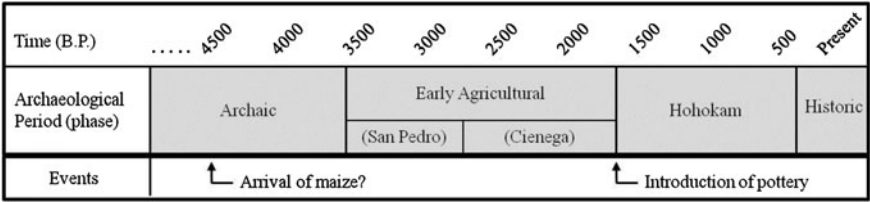


Fig. 3 Cultural chronology for Arizona and northern Mexico from Watson (2010). Used with permission of the author. Dates are calibrated radiocarbon years before present (BP)

Twelve thousand years of human history is documented by thousands of roasting pits, hundreds of human burials, dozens of activity areas, dozens of canine burials, a possible boarded field system, hundreds of projectile points, and thousands of pieces of flaked stone, ground stone, shell, and pottery (Carpenter et al. 2005). Consistently, the lack of discernable stratigraphy and extensive modern erosion that characterizes the silt at La Playa has made it difficult to understand the relative chronology of features and samples, and in turn the geomorphic and environmental contexts of the archaeological remains.

The most intensively investigated element of La Playa has been the human burials. Currently, a sample of 327 mortuary features has been excavated. Hundreds more are eroding out on the La Playa landscape, and hundreds more likely remain intact beyond the current erosional edge. Most burials are believed to date to the San Pedro (3,700–2,600 cal BP) and Cienega (2,600–1,900 cal BP) phases of the Early Agricultural period, and a sample of 40 bone collagen radiocarbon assays support this temporal assignment (Watson 2005).

Characterization of Soil and Sediments and Surficial Mapping

Since there is no detailed topographic model or mapping for the La Playa site, much of the surficial mapping effort utilized a Quickbird satellite imagery base. The Quickbird imagery consists of two imagery products. One is a four-band product that includes a near-infrared band and has a spatial resolution of 2.4 m. These bands cover the visible to near infrared range of wavelengths from 430 to 918 nm. The near infrared Quickbird imagery (bands 4-3-2) was particularly useful for defining areas of firecracked rock (linear and circular features in black), gravels and pavements (black to gray, smooth textured patches), the palesol (yellow) and dissected units (white). The second product is a panchromatic single band with a spatial resolution of 60 cm. The panchromatic image allowed examination of the surface geomorphology and sediment types at La Playa at a high spatial resolution which was used for accurately defining unit contacts. The surficial mapping integrated the Quickbird imagery with field examination of surface and cutbank exposures of the sediment types. GPS locations of specific

lithologies on the Quickbird imagery base within GIS allowed the delineation of map units and spatial distribution of depositional and cultural deposits.

The extensive erosion that serves to expose and destroy human burials and artifacts at La Playa also provides an opportunity to examine the site stratigraphy. When describing and classifying these sediments, it is critical to distinguish sediments that are naturally deposited with those that result from cultural processes including modern disturbances. The natural deposits that define the landscape of La Playa can be divided into eight units. A composite stratigraphic column illustrating the basic site stratigraphy is shown in Fig. 4. The age and exact stratigraphic relationships of these units are not yet clearly defined and are undergoing additional study. The surficial map of the La Playa site (Fig. 5) delineates both natural deposits and areas of cultural modification. The surficial units, described in more detail below, are: (1) Paleosol and associated sediments (Qp), (2) bajada deposits (Qbd, Qbdd), (3) alluvial gravels/pavements (Qg), (4) silt (Qs), (5) modern Rio Boquillas bar sands (Qrbbs) (6) modern Rio Boquillas channel deposits (Qrbcd), (7) fire-cracked rock concentrations (Qfcr), (8) minor channel sands (Qmcs), (9) dissected/reworked silt (Qdrs), and (10) modern disturbances (Qmd).

Paleosol and Associated Sediments: Qp

The paleosol at La Playa is the deepest exposed stratigraphic horizon and is primarily confined to localities west of Los Entierros and Hornos Alineados. It is considered to be Pleistocene in age based on the fossil assemblage of Rancho-labrean fauna (Carpenter et al. 2005). There is a small area of exposed paleosol adjacent to the Rio Boquillas in the northern part of El Canal/Los Entierros. In addition, in the channel of the Rio Boquillas, the transition between the paleosol and overlying silt is exposed along a ~400 m section. The paleosol is red in color and the maximum thickness exposed is approximately 4 m (Fig. 6). Upper intervals of the paleosol are sandy with minor gravel and a variable silt/clay content from 9 to 50%. The sand fraction is concentrated in the fine to medium-grained sizes. Early stage pedogenic carbonate formation is indicated by the presence of calcium carbonate nodules and root casts. Overall, the top of the paleosol is a planar surface with relief up to 50 cm. In several areas of the site, including the Rio Boquillas channel, deposits of gravels within the paleosol are observed. These gravel intervals are 4 m thick and occupy up to 30 m wide zones within the paleosol (Fig. 7). The gravels are calcite cemented with reddish sand and contain a diverse assemblage of rounded clasts of schist, gneiss, volcanics, plutonics, and sedimentary compositions. The clasts are in the cobble size range (up to 10 cm) although some clasts exceed 25 cm. Clast imbrications of the gravels indicates a west to southwesterly paleoflow direction.

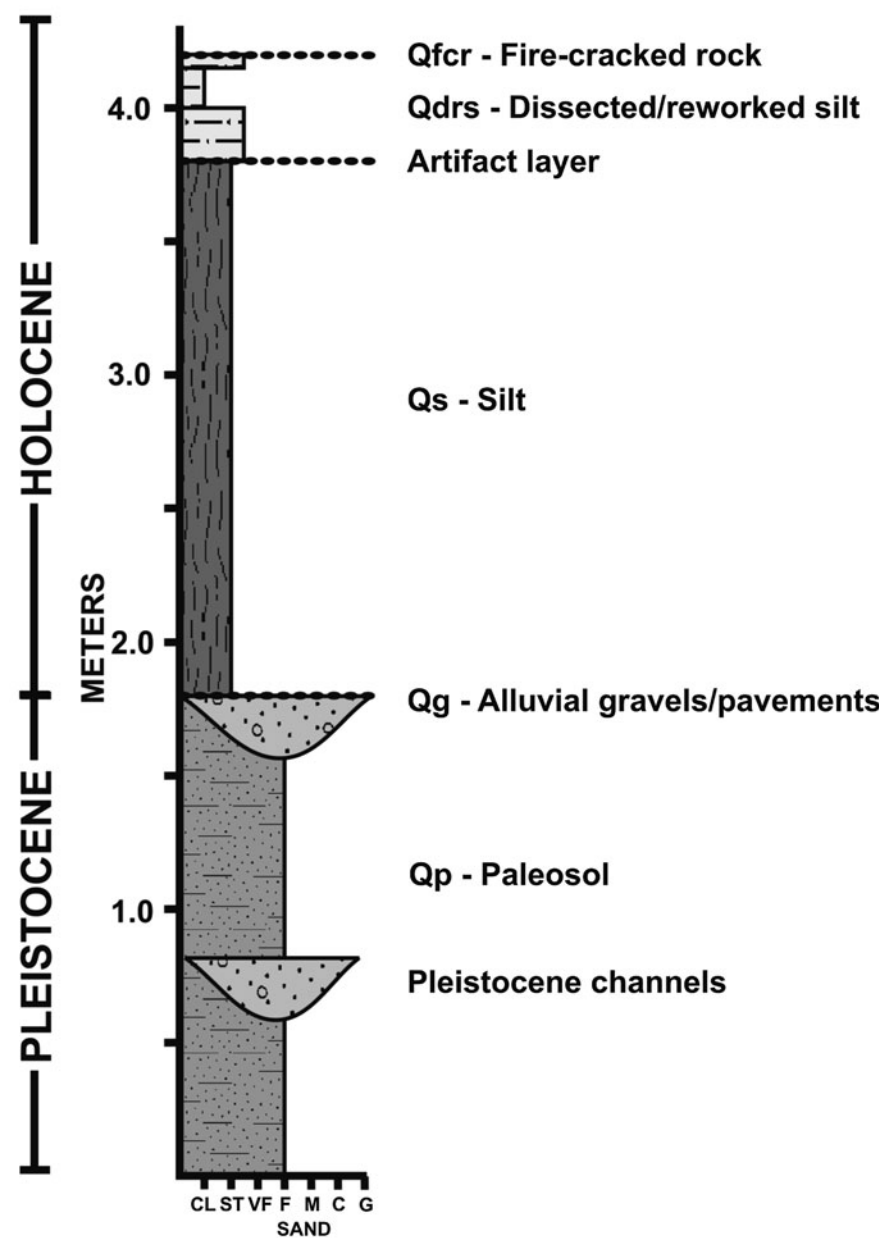


Fig. 4 Composite stratigraphic section of the La Playa Pleistocene and Holocene stratigraphy. Width of the stratigraphic section corresponds to sediment grain size. Grain size abbreviations on the section are as follows: *CL* clay, *ST* silt, *VF* very fine sand, *F* fine sand, *M* medium sand, *C* coarse sand, and *G* gravel

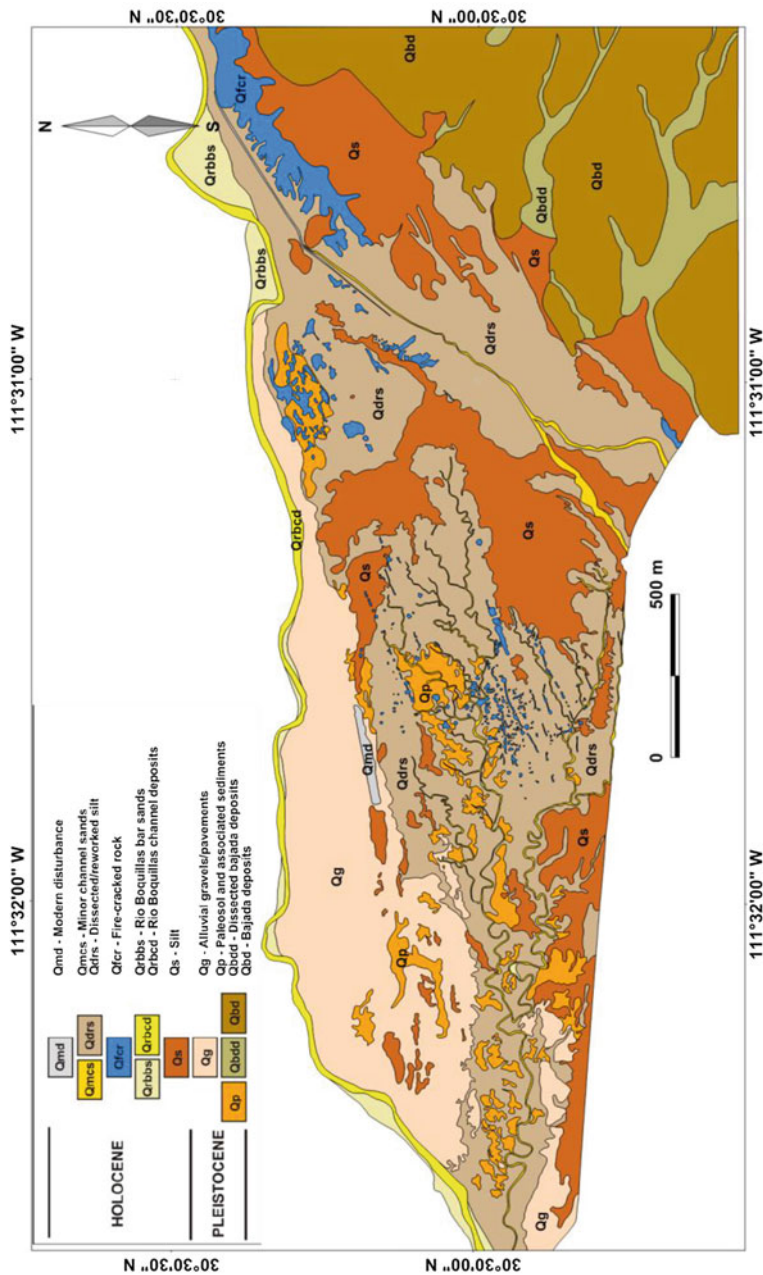


Fig. 5 Surficial map of the La Playa site showing the distribution of natural and cultural deposits across the site

Fig. 6 Photographs of the paleosol. **a** Here the paleosol is overlain by a thin interval of the reworked silt.

b Exposure of the paleosol in the channel of the Rio Boquillas. Beneath the interval of sandy paleosol are Pleistocene gravels and cobbles

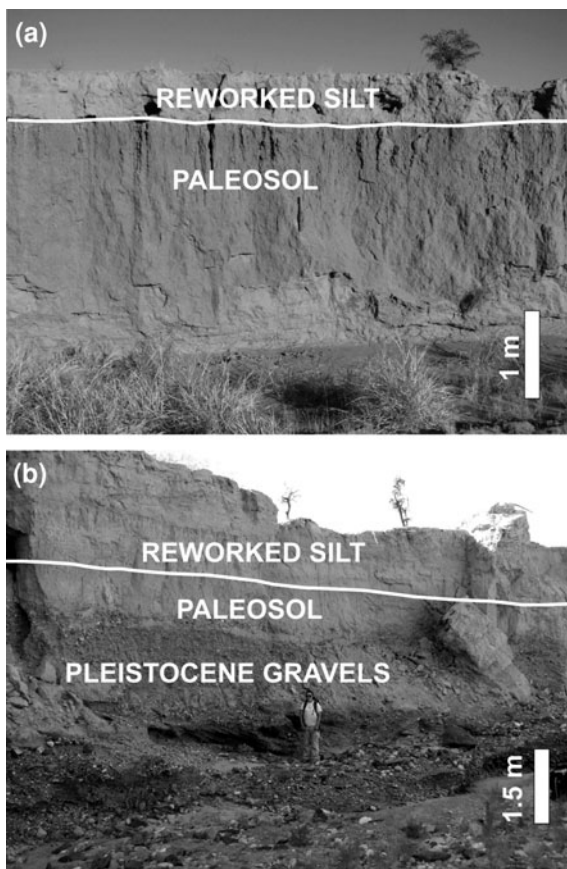


Fig. 7 Photograph of the Pleistocene cobbles, cemented with *red*, coarse-grained sands



Bajada Deposits: Qbd, Qbdd

Bajada deposits include colluvium derived from the adjacent Cerros Boquillas. These deposits occur on the north side of the Rio Boquillas (not mapped) and on the eastern side of the site. The slope in these areas is steeper and overall has higher elevations than other areas at the site. Slopes are covered by cobble-size angular clasts of Cerros Boquillas lithologies derived from the bedrock exposures. These deposits are a mixture of sandstone, siltstone and conglomerate clasts. In some areas, these Bajada deposits have been incised and dissected (Qbdd) by younger drainage systems. These drainages, depending on depth of incision, may expose some of the bedrock lithologies beneath the colluvial cover.

Alluvial Gravels/Pavements: Qg

A layer of thin gravel lies atop the paleosol in the northern and southwestern areas of the site (Fig. 8a). These gravels are dominated by clasts derived from the sedimentary rocks and quartz veins of the Cerros Boquillas. The gravels also contain clasts of granite, volcanic, and metamorphic rocks. These clasts are well-rounded and up to 9 cm in diameter and appear to have been reworked significantly. The gravels often form a pavement-like surface containing slightly varnished cobbles, particularly in the southwestern areas of the site (Fig. 8b).

Silt: Qs

The silt that covers much of the site, herein termed the La Playa silt, possesses sedimentological properties that are different from other archaeological sites in the southwestern U.S. and northern Mexico that are interpreted as alluvial. The silt stratigraphically overlies the paleosol and is often exposed in the cut banks of modern arroyos and channels that have incised into the landscape. The age of the silt is unknown, but is assumed to be Holocene in age. For mapping purposes the silt unit is considered undissected silt (Qs) and covers those areas where the silt has not yet been incised by gully formation. The silt is tan-brown in color and lacks definable stratigraphy or sedimentary structures (Fig. 9). The unit is largely barren of fossils compared to the underlying paleosol. However, terrestrial and aquatic gastropods were previously described within the La Playa silt by Drake (1960, 1961). The exposed thickness of the silt is at least 2 m thick, but there is no complete section that preserves the entire silt succession on top of the paleosol.

Grain size distribution within the silt is fairly consistent with no particles larger than very fine sand. Dry and wet sieve analysis of four samples of the silt show remarkable consistency in their grain size trends with each sample approximately 98% clayey silt and 2% very fine sand size. Additional grain size determination,

Fig. 8 Photograph of the gravel deposits (Qg). **a** View looking towards the west of the alluvial gravels overlying the reddish paleosol. **b** Weakly developed desert pavement from the southwestern part of the site



Fig. 9 Section of the La Playa silt with the overlying reworked silt

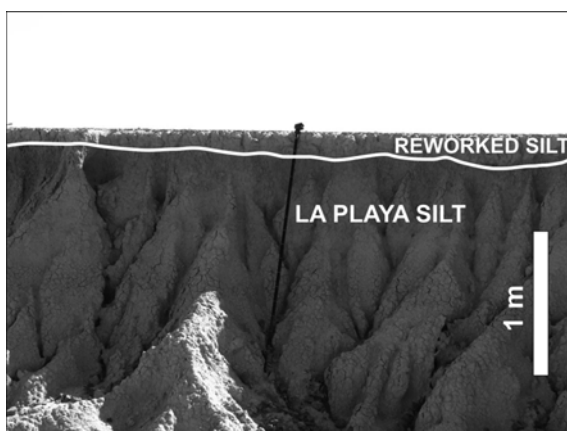
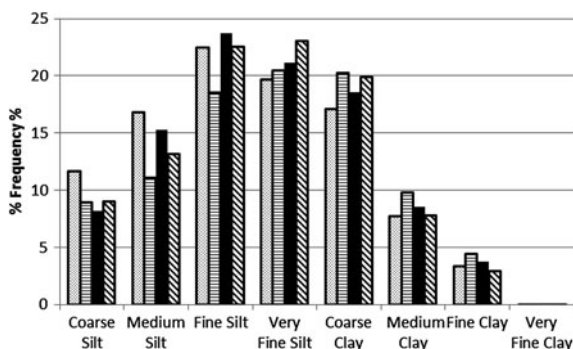


Fig. 10 Results of laser particle size analysis of the fine fraction from four samples of the La Playa silt. The fine fraction is dominated by very fine silt with clay



focusing on the fine fraction of those same four samples, were measured with a Malvern laser particle size analyzer. The results of that analysis indicate a median particle size of 6.7–8.5 μm (very fine silt). The clay content for the mud fraction ranges from 28 to 35% (Fig. 10).

Modern Rio Boquillas Bar Sands: Qrbbs

These fine to medium-grained sands within the deeply incised Rio Boquillas are adjacent to the coarser channel deposits (Qrbcd). They are distinguished from channel deposits by the lack of coarse clasts, the abundance of vegetation, and ridge and swale topography which reflects growth and migration of the laterally migrating barforms (Miall 2010).

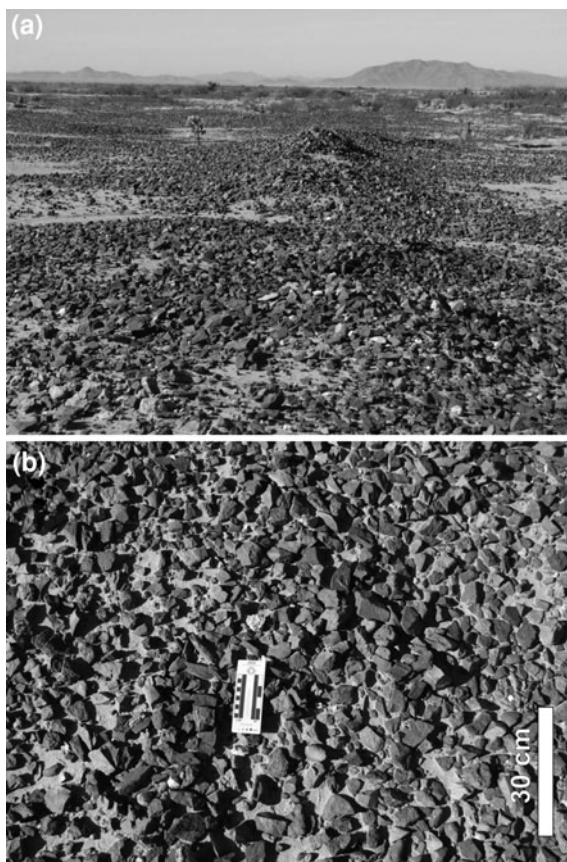
Modern Rio Boquillas Channel Deposits: Qrbcd

These deposits occupy the main channel of the Rio Boquillas. The channel is incised into Holocene and Pleistocene deposits and contains sand and cobble-size materials composed of multiple lithologies that include sedimentary, volcanic, plutonic, and metamorphic rocks. The in-channel deposits reflects a mix of bajada gravels, reworked Pleistocene gravels, and modern deposits. Comparison of aerial photography from May 1996 and the October 2008 Quickbird imagery show that the river channel is fairly stable and only exhibits significant lateral migration in areas where Rio Boquillas bar sands (Qrbbs) are present.

Fire-Cracked Rock: Qfcr

Fire-cracked rock or FCR is cultural material remaining from utilization and occupation of the site and may represent a palimpsest produced by deflation and winnowing of the finer-grained silt (Qs). Such a deposit would represent comingling of

Fig. 11 **a** View of linear piles of fire cracked rock.
b Close-up of typical fire cracked rock



FCR from successive occupations. Much of the landscape is littered with FCR and it is often concentrated in circular mounds 1–2 m in diameter or linear piles that can reach more than 200 m long. For mapping purposes FCR units were delineated where the concentration of FCR was the highest and could be easily identified on the Quickbird imagery, hence some surfaces with minimal FCR concentration are mapped as other units. The fire-cracked rock usually overlies silt or dissected/reworked silt and occurs as angular fragments that are larger than 5 cm (Fig. 11). The pattern of FCR distribution on the site is variable. Areas such as Los Monticulos, and El Canal contain the highest concentration of FCR. Hornos Alineados also preserves significant quantities of FCR arranged as mounds and linear piles.

Minor Channel Sands: Qmcs

Minor channel/bar sands are channels and associated features that are mapped within the site other than the main channel of the Rio Boquillas. These are small

ephemeral features that show a high degree of sinuosity and are responsible for producing much of the modern dissected landscape. They drain into the Rio Boquillas, west of the site and are over 2 km long. The channel widths average approximately 2 m. The small channels are slightly sandy, but primarily are composed of reworked silt. Barforms along the insides of channel meanders are dominantly sandy, but may also be reworked sandy silt.

Dissected/Reworked Silt: Qdrs

These areas are underlain by silt that has been dissected by modern drainages and reworked by fluvial processes. Many of the areas in Los Entierros and Los Monticulos have been extensively dissected. Dissected silt surfaces often contain more rock and fire cracked rock than the undissected silt. The localities where fluvial reworking is established include Los Monticulos, the northern parts of Los Entierros and western El Canal, and the areas immediately adjacent to the channels that flow through the dissected areas. Often these reworked deposits are difficult to distinguish from undissected silt. Some general characteristics for distinguishing reworked silt are (1) the reworked silt shows evidence of small ripples and other sedimentary structures, whereas non-reworked silt is homogenous, and (2) the reworked silt has a slightly higher sand content. Reworked silt is often present at the site as a “cap” that overlies the homogenous, undissected silt. In areas of extensive erosion where the silt and upper parts of the paleosol have been removed, reworked silt may directly overlie the paleosol.

Modern Disturbances: Qmd

Modern disturbances reflect historic modification of the landscape, with much of it during the twentieth century. This unit is represented by constructed features such as roads and canals.

Discussion

The landscape at La Playa is interpreted to reflect development during extremes related to climatic shifts from the Pleistocene into the Holocene. The diverse grain sizes present within its soils and sediments and the variety of compositions show that different styles of sediment transport and deposition were active. Within the paleosol, Pleistocene gravels that are present indicate significant transport by rivers draining an extremely large catchment. The size of this drainage basin is

suggested based on the variety of clast compositions present in these gravels and cobbles. The composition of the rocks in the adjacent Cerros Boquillas is clastic sedimentary and includes sandstone, siltstone, and conglomerate (McLaurin 2008). The presence of igneous and metamorphic clasts demonstrates that an ancestral Rio Boquillas was transporting bed load from the north at a minimum distance of 30 km. Furthermore, the rounded nature of the gravels is indicative of transport in water, whereas locally sourced bajada gravels would be more angular in clast shape. The Pleistocene gravels exposed in the modern Rio Boquillas show that modern river is following the course of an ancestral Pleistocene channel. Other gravels identified in other areas of the site suggest that frequent channel avulsion allowed an ancestral Rio Boquillas to move across a broad floodplain or there were multiple channels active simultaneously, such as in a braided river system. The large clast size and diverse clast compositions suggest a wetter climate in which materials from distant sources could be easily transported by high energy rivers. These rivers reflect a climate that received more rainfall than the present Sonoran Desert. This is supported by paleoclimatic studies (Metcalf et al. 2000) that indicate conditions during the last glacial maximum to around 9,000 years ago were characterized by abundant rainfall during the winter months. The development of desert pavement surfaces above the paleosol may be attributed to stabilization of the landscape perhaps associated with a drying of the climate into the early to middle Holocene (Mabry 1998).

The tan-brown La Playa silt was deposited under conditions quite different from the underlying paleosol. The clayey, very fine silt-size is consistent throughout the unit. The lack of definable stratigraphy, coarser sandy sheetflood deposits or coarse gravel lags make a floodplain or cienega-type interpretation (Johnson 1960, 1963) worth further examination. Another possible interpretation could be that the silt is an eolian loess or loess-like deposit. Comparison of the La Playa silt with diagnostic criteria used to define loess (Pécsi 1990; Pye 1995) shows the grain size, composition, weathering characteristics, and stratigraphic context are all consistent with other described loess deposits. Although the concept of “desert loess” remains controversial (Tsoar and Pye 1987; Wright 2001), an eolian origin for the La Playa silt is a reasonable interpretation based on characteristics defined by Pécsi (1990) and Pye (1995). If the La Playa silt was deposited in a subaqueous environment, it would have required isolation from Rio Boquillas flooding and channel switching. The very fine silt size would need deposition under very low energy conditions and the lack of coarse interbeds would mean that the Rio Boquillas would have been relatively stable in its floodplain, distant from the deposition of the silt (Miall 2010). Mabry (1998) suggests that middle Holocene drying would have encouraged channel downcutting and the establishment of extensive flood plain sediments.

The modern erosive processes that are cutting into the La Playa landscape and exposing its stratigraphic and sedimentological story represents a shift to a drier climate and involves the impact of human activities on the desert landscape. Watson (2005) relates that the Rio Boquillas was a perennial stream prior to the 1960s. Overgrazing and modern disturbances throughout the twentieth and early

twenty-first century have served to initiate arroyo cutting and the gradual destruction of the La Playa site.

Conclusions

The paleoenvironmental and depositional history of the La Playa site reflects the climatic shift from the terminal Pleistocene into the Holocene. Wetter conditions were present during the last glacial maximum to around 9,000 years BP in northern Mexico (Metcalf et al. 2000). At La Playa the paleosol reflects depositional conditions that were fluvially dominated as suggested by poorly sorted, rounded cobbles within channel fill of a sandy floodplain. The cobbles were transported by high energy river systems. These cobbles are composed of diverse lithologies from a large drainage basin that tapped source areas of volcanic, plutonic, and metamorphic rock. Gravel imbrications show that the paleoflow in the Pleistocene was westerly and consistent with the direction of modern flow of the Rio Boquillas. These rivers that traversed the La Playa area either were a single, frequently avulsing channel, or possibly a multi-channel braided system. Individual channels were at least 30 m wide. Climatic conditions during the Pleistocene were clearly adequate to support a diverse biota as suggested by the Rancholabrean fauna (Carpenter et al. 2005). The transition to the overlying silt records a period of landscape stabilization as indicated by the gravel sheet and desert pavements that overlie the paleosol. This period of stability possibly records a climatic shift from a much wetter environment capable of supporting high energy fluvial systems to one that is drier. The La Playa silt was previously described as a cienega or swamp-type depositional system, but many of the characteristics of the silt seem more typical of the eolian deposition of loess. The tan-brown clayey silt is extremely fine-grained and does not exhibit sedimentary structures that are consistent with alluvial deposition. For the silt to have been deposited in such an environment would have required very quiet depositional conditions where the environment was isolated from major flooding events. If La Playa represented a typical alluvial floodplain, there should be coarser channel deposits and crevasse splay sands that are interbedded with the silt and are a result of flooding events or avulsion. A floodplain interpretation for the silt that can explain the lack of alluvial features would depend on a stable river system that was incising rather than frequently meandering across its floodplain. Clearly, more detailed studies are necessary to answer this question.

The description and mapping of the surficial units at La Playa provides a fundamental stratigraphic framework for understanding landscape changes within the larger context of climate change. The striking differences between the paleosol and overlying silt are due to the highly variable nature of their depositional systems. This model of significant shifts in climate during the Pleistocene–Holocene transition at La Playa may, in the future, prove to be

accompanied by documented changes in the nature of the archaeological record. However, the lack of a detailed temporal framework for much of the depositional history of La Playa currently prevents such correlations between climatic change and shifts in human activities.

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