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Eolian Deflation of Holocene Playas and Formation of the White Sands Dune Field.

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Introduction

White Sands National Monument is the largest field of gypsum dunes in the world (Figure). Deposition in many of the desert basins of the region ceased during the Mid-Pleistocene. In the central part of the Tularosa basin, deposition continued through the late Pleistocene and Holocene, where pluvial Lake Otero extended across the basin (Seager et al., 1987; Blair et al., 1990; Buck, 1996)). During the latest Pleistocene the last Lake Otero shoreline formed at 1,216 m elevation (Seager et al., 1987), and was followed by desiccation .and the formation of the playa lakes and dune field.

The association of climatically constrained eolian deflation in the creation of the dunes is now being emphasized (Fryberger, personal communication, 2000; Langford, in press). The dunes lie downwind of a large deflation basin that has been incised into the sediments of Lake Otero (Figure). Modern, gypsum-crusted playa lakes, including Lake Lucero are found in the lowest parts of the deflation basin and are one source of gypsum sand for the dune field. Between the dunes and the playa lakes lies the Alkali Flat, a largely unvegetated expanse of blowing gypsum sand within salt flats that contain scattered Mesquite and salt brush.

Erosional Shorelines

An erosional shoreline surrounds modern Lake Lucero playa. Erosional shorelines are created by the erosive activity of waves when the playa is flooded. The base of an erosional shoreline marks the level of flooding of the playa. This shoreline is partially buried beneath aggrading playa mud and salt, but forms a well-defined escarpment around all except the northern end of the playa. The base of this erosional shoreline escarpment is the almost-horizontal playa surface. Over fifty measurements give escarpment slopes of 30˚ to 40˚ in poorly consolidated Lake Otero sediments.

Two similar erosional shorelines can be correlated on the slopes above the modern playa (Figure). The lowest of the shorelines occurs at approximately 1,191 m elevation (5.5 meters above the surface of Lake Lucero). A second shoreline is located at approximately 1,200 m of elevation (14.5 meters above the surface of Lake Lucero). These higher shorelines, mark elevations where playas formed between stages of deflation. The lower erosional shoreline (1191 m) is marked as the L-2 shoreline and the upper shoreline (1200 m), the L-1 shoreline. The L-2 shoreline is almost identical in morphology to the shoreline surrounding Lake Lucero. The upper, L-1 shoreline is a subtler feature that slopes 6˚ to 10˚ and is more gullied. Based on morphology the L-1 shoreline is older than the L-2 and Lake Lucero shorelines.

Older lacustrine sediments of Lake Otero are exposed by erosion within and between all the shorelines. These sediments, consisting of laminated carbonates and evaporites indicate deposition on the floor of a semi-permanent saline lake. Topographic profiles show the extent of deflation. Logged wells within the dunes indicate that the base of the eolian gypsum sand lies below the Lake Otero shoreline and slopes gently to the west. At the western edge of the dune field, the older lake muds are exposed, just above the L1 shoreline.

Source of the Dunes

The horizontal beds of lacustrine Lake Otero sediments are the key to understanding the history of the White Sands because they define a low-relief Pleistocene lake floor. Thus, the topography of the basin below the Lake Otero Shorelines is largely a product of Post-Otero erosion. Because the shorelines are preserved, deflation has deepened the basin, but not widened it. Most previous authors have noted that two sources of gypsum dune sand, Otero Sediments and Lake Lucero

(Allmendinger, 1972; LeMone, 1987). Allmendinger (1972) described a gypsum crystal-bearing layer in alkali flat up to 9m above the surface of Lake Lucero and suggested that deflation of these Pleistocene sediments produced most of the dunes. The main mass of the White Sands dune field begins abruptly near the L1 shoreline. However, several patches of parabolic dunes are forming by deflation of Lake Lucero and extend downwind from Lake Lucero, partially burying the L1 and L2 shorelines. Eolian sand was collected along a transect beginning near the L1 shoreline at the edge of the dune field. Samples near the shoreline include many angular unfrosted blades, indicating little transport. While 4 km into the dune field, the sands are equant and frosted, indicating that the source of the White Sands is probably the older lake sediments near the L1 shoreline.

Age of the Dunes and Association with Climatic Events.

The shoreline history described above implies, that while today, the dune field is actively migrating and is receiving a limited sand supply from the Alkali Flat, the majority of the growth of the White Sands dune field must have occurred during three short-lived arid climatic events, when the deflation basin was being deepened. One probably predated the dune field and occurred at the end of the Pleistocene resulting in deflation to the L1 shoreline. Two more events, the earliest circa 7,000 years BP formed the dune field and deflated to the L2 and Lake Lucero shorelines. Because the Pleistocene, Lake Otero Gypsum beds lie below the L1 shoreline, it is unlikely that a large dune field had formed until the deflation event between the L1 and L2 shorelines. No datable materials have been found yet on the L1 shoreline. However, searches of the archeological database at White Sands National Monument shows Folsom culture sites above the elevation of the L1 shoreline, but not within the L1 deflation basin (Eidenbach, Personal Communication, 2000). This suggests that the L1 shoreline can be dated to younger than the 9,800 to 10,800 BP range of Folsom activity (Ingbar, 1992).

Initiation of the White Sands Dune field coincided with deflation to the L2. Radiocarbon dates collected from the sediments below Lost River playa provided dates of 1,750 and 5,840 years BP (Monger and Gallegos, 1997). The dated sediments filled a basin dammed by the dunes suggesting that the growth of the White Sands dune field, and incision to the L2 shoreline occurred after 9,000 and before 5,840 BP. Two deflation events, dated at 7,000 and 4,000 ybp are increasingly identified with playa basin and eolian sand generation in the region (e.g. Allen, 1991; Buck 1996).

Several recent authors have noted the influence on climate change on playa hydrology (Jacobson, 1988; Doremus et al., 1989; Rosen, 1994; Fan et al., 1997). These authors emphasize that deposition of evaporates on playas only occurs when there is a balance between an influx to the playa and discharge of dense brines plume beneath the playa. When inflow is greater than discharge a lake forms. When discharge exceeds inflow, the groundwater table beneath the playa subsides and deflation may occur. The implications of these studies to the White Sands are twofold. First, generation of gypsum from the playa surface will be episodic and associated with climate fluctuations. Second, the deflation events are probably associated with longer-term arid climatic event that result in a lowering of the water table beneath the floor of the deflation basin.

Figure. Composite aerial photograph of Lake Lucero and the White Sands dune field. Dashed lines show the Lake Lucero, L2, and L1 shorelines. Posted elevations mark sites of GPS measurements of shoreline elevation. (Aerial photograph supplied by White Sands National Monument and prepared by ESRI, Albuquerque, NM). Inset—Location map showing the relationship of the gypsum dunes to Lake Lucero and the alkali flat. Cross section A to A’ shows the elevations of the Lake Lucero, the L 1 and L 2 shorelines and the Lake Otero shoreline. Photos are of gypsum grains collected along the transect.

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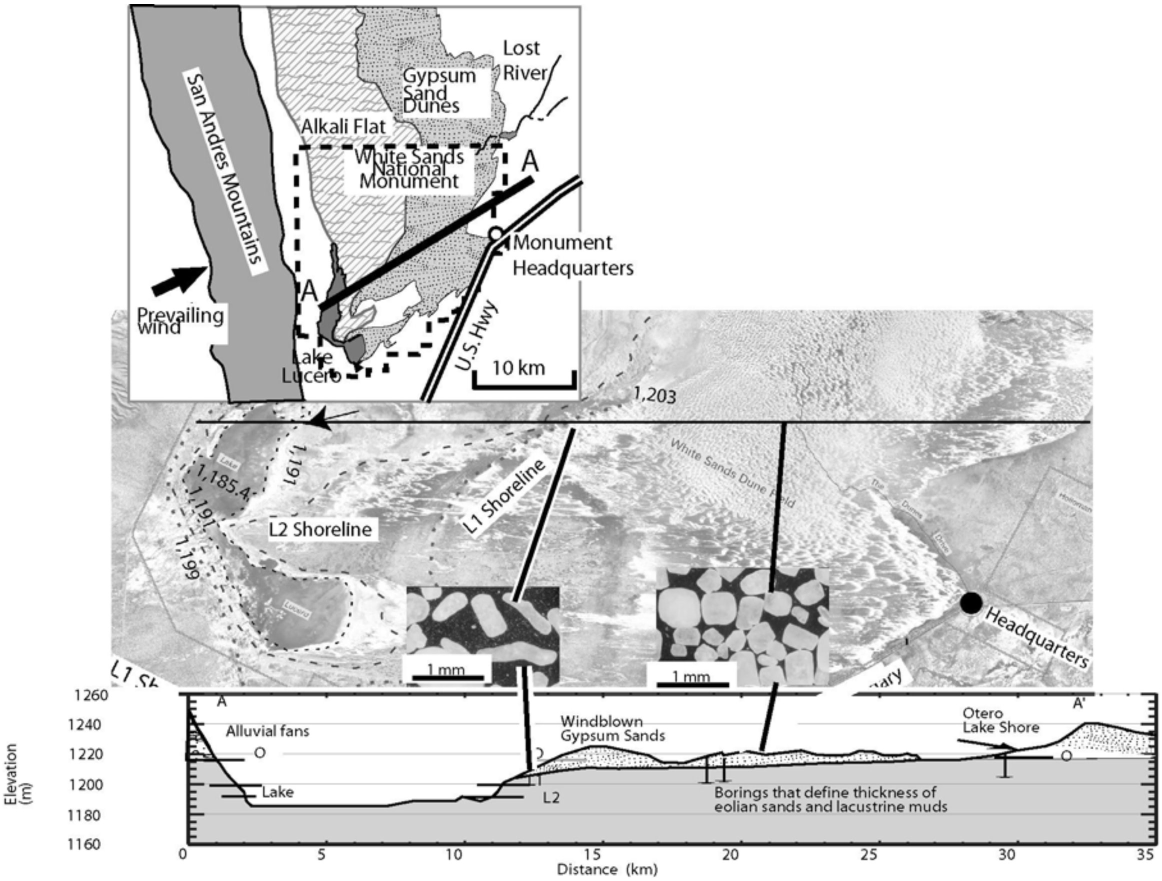

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