White Sands National Park

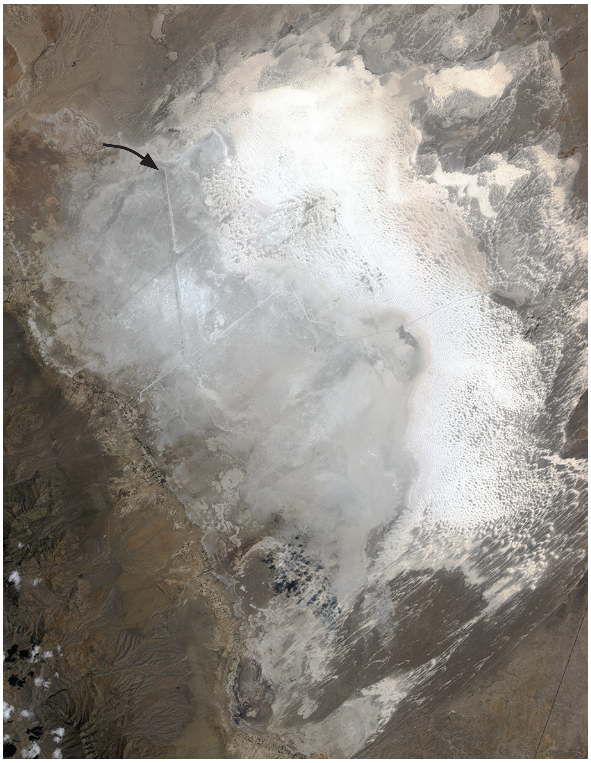
NATIONAL PARK SERVICE

America's newest national park (as of December 2019), White Sands is famous for its extensive sea of white gypsum dunes—indeed, it is the largest gypsum dune field in the world. Located in the southern Tularosa Basin, the park was established as a national monument in 1933 and encompasses nearly 176,000 acres (275 square miles, including 115 square miles of gypsum sand dunes). The park not only contains the large dune field but also a saline mudflat called Alkali Flat, a smaller ephemeral salt lake (or playa) named Lake Lucero, parts of the gypsum-dust plains east of the dune field, and alluvial fans from the surrounding mountains. The dune field and Alkali Flat extend more than 12 miles to the north of the park onto the White Sands Missile Range.

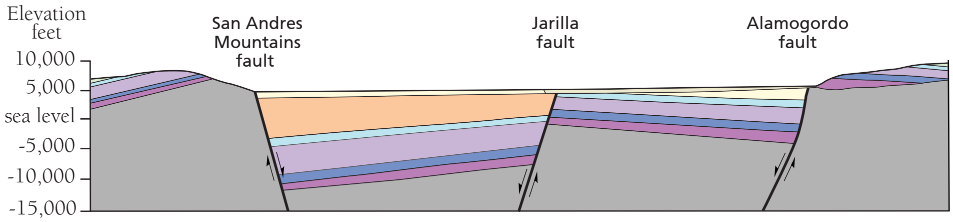
OPPOSITE: **Gypsum dunes and grasses in interdune flats with the San Andres and Organ mountains in the background.**

Six major factors account for the exceptional accumulation of gypsum sand in this area:

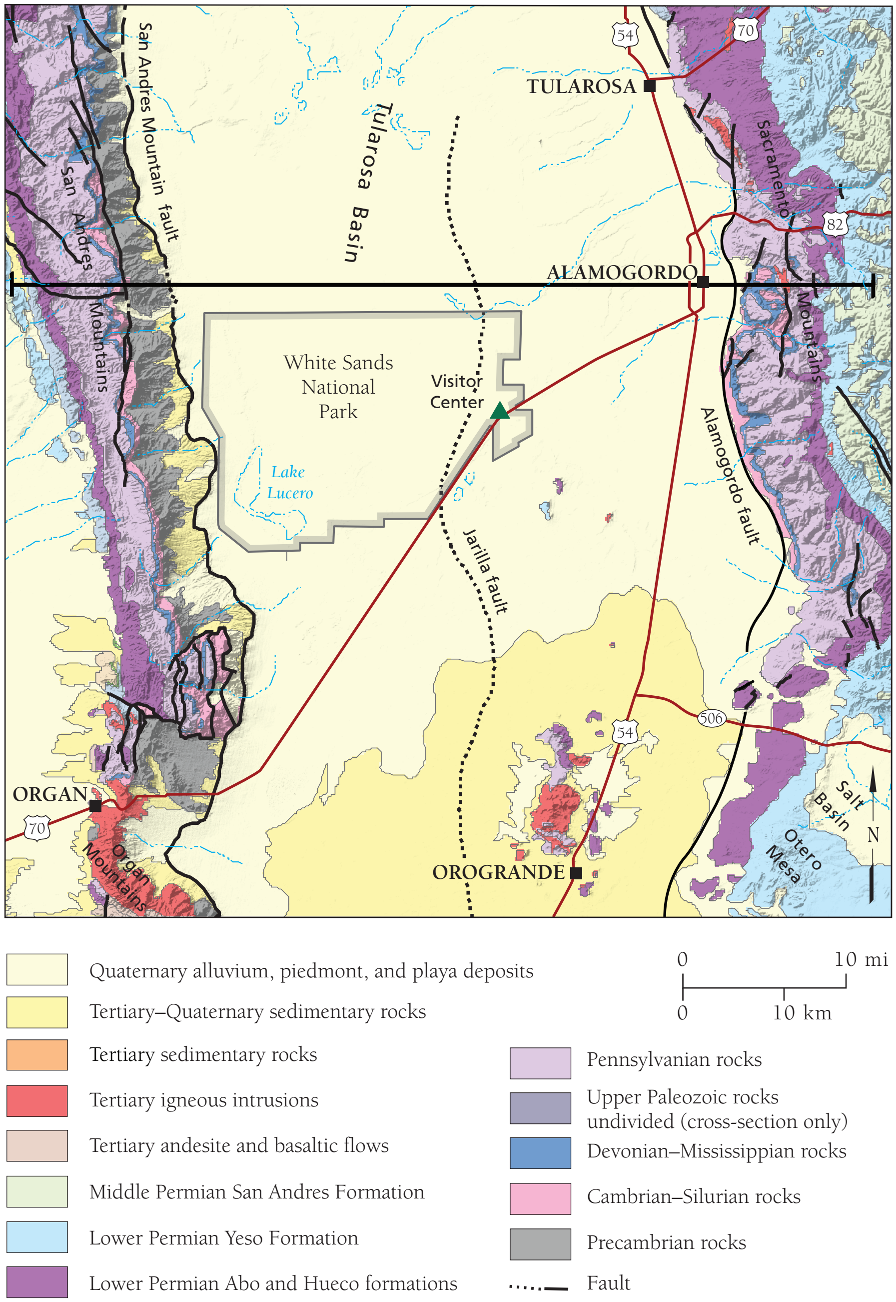
1. The area has **internal drainage** (there is no surface exit from the basin for water). In this respect, the basin is similar to the evaporitic Great Salt Lake of Utah.
2. The area has a **prolific source of calcium sulfate** (gypsum) from Permian rocks found in nearby mountains, especially to the north, as well as from equivalent rocks present beneath the Tularosa Basin. Those older gypsum deposits (mainly in the Yeso and San Andres formations) are easily dissolved and transported by surface and groundwater into the basin.
3. The **arid climate** of the region led to reprecipitation of gypsum following the last ice age (about 15,000 years ago) as Lake Otero dried up.
4. **Persistent southwesterly winds** erode gypsum from the exposed lake sediment and deposit it in dunes that migrate progressively to the northeast.
5. A very **shallow water table** (typically just 1 to 3 feet below the surface in interdune areas) maintains high soil moisture and helps to stabilize the wind-blown gypsum.
6. Dunes are further **stabilized by vegetation and soil crusts**, especially along the eastern margin of the dune field.



NASA EO-1 satellite image of the White Sands gypsum deposits in the Tularosa Basin. The large X (arrowed) visible on the Alkali Flat west of the dunes is a 10-mile-long backup landing strip for Space Shuttle missions. It was used only once for Columbia in 1982.



West-east cross section through the Tularosa Basin showing fault blocks that underlie the basin. Down-dropped Precambrian, Paleozoic, and Cenozoic rocks are overlain by younger basin-fill deposits.



Geologic map of the White Sands National Park region. The line through Alamogordo marks the location of the cross section above.

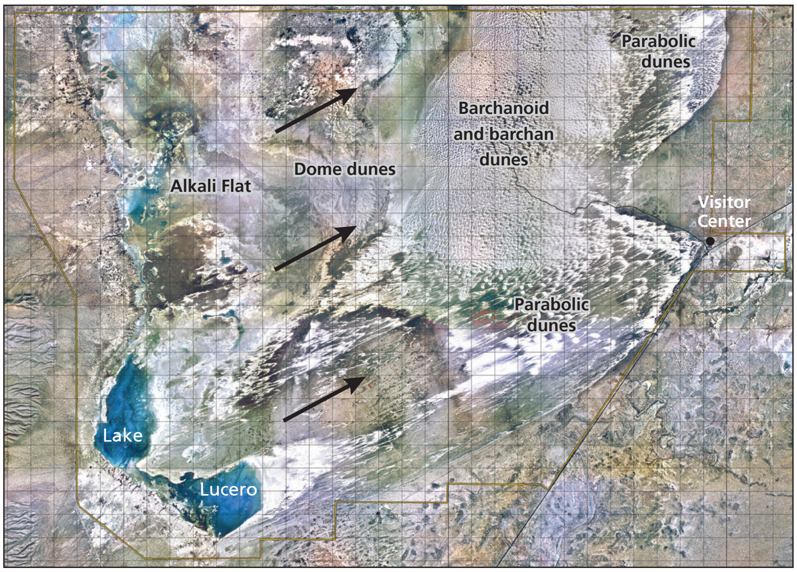
Geologic Province and Geography

The White Sands dune field is located in the southern part of the Tularosa Basin, a major down-dropped part of the Rio Grande rift. The basin was formed by sunken and tilted fault blocks that were subsequently buried by sediments eroded mostly from the nearby San Andres and Sacramento mountains.

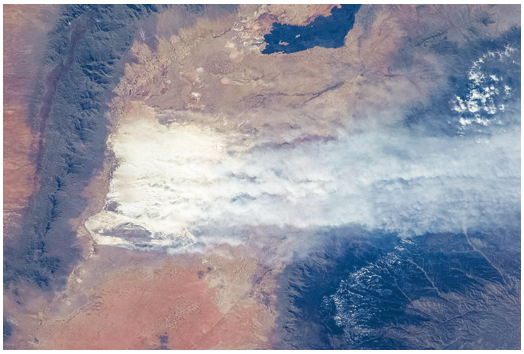
Today, the basin has no surface water discharge, and inflow either evaporates or infiltrates and ultimately leaves the basin via groundwater transport. Lake Lucero (elevation 3,890 feet) is an ephemeral lake (commonly termed a playa) near the southern end of Alkali Flat. Accumulations of gypsum sand increase downwind (northeast) from Alkali Flat and Lake Lucero, with the main dune field rising about 100 feet in elevation above the playa. Individual dunes typically are 15 to 35 feet high and advance downwind as much as 40 feet per year near Alkali Flat. This dune movement requires continual plowing of the roads and parking areas.

White Sands National Park lies in the semiarid northern Chihuahuan Desert, with high temperatures in the summer reaching 110°F and temperatures in the winter as low as -25°F. Although average annual precipitation is only about 10 inches, monsoonal summer rains and decadal rainfall events can produce short-lived flooding in the region. Prevailing winds are from the southwest, and gusts exceeding 55 miles per hour are relatively common.

White Sands provides a natural laboratory for studies of the adaptation and rapid evolution of various gypsophile plants, animals (reptiles, amphibians, fish, insects, spiders, and mammals), and microorganisms. They all have undergone natural selection to survive in harsh conditions in terms of the semiarid climate, bright, hot sunlight with barely filtered ultraviolet rays, an uncommon gypsum substrate, and limited nutrients. Most noticeable are pale-colored insects and lizards, but other arthropods, reptiles, amphibians, and small mammals also are adapted to the blindingly white landscape. Some of the more uncommon plants that



Composite of aerial photographs, acquired on October 10, 1996, of White Sands National Park. The main gypsum source areas of Alkali Flat and Lake Lucero are labeled, as are three areas with distinctive dune types. The arrows indicate the direction of the predominant winds that transport gypsum from the source areas to the dunes.



are found in the gypsum are small (6 to 12 inches high) bushes with odd names such as "hairy crinklemat" (*Tiquilia hispidissima*) and "gyp moonpod" (*Acleisanthes acutifolia*). Although surface water is rare, scattered Rio Grande cottonwoods are found throughout the dunes. The gypsum crusts developed on some soils contain many active microorganisms as well. Visitors are referred to the White Sands National Park Visitor Center and webpages for more information about plants and animals.

Photograph taken from the International Space Station in late Feburary, 2012, shows that dust from White Sands can be carried as a visible plume for hundreds of miles, well into west Texas.

The Rock Record and Geologic History

Deposits exposed within the park are geologically young (less than 45,000 years old to only hours old). The only exception is a small outcrop of Permian limestone on the hill with the water tower east of the Visitor Center. Despite the recent formation of most of the features within the park, an important part of the geologic evolution of White Sands began over 270 million years ago, during Permian time. Southern New Mexico was then within 5 degrees of the equator and submerged beneath a shallow sea in which limestones, mudstones, sandstones, and, importantly, gypsum were deposited. These deposits were subsequently buried and preserved in the subsurface for hundreds of millions of years.

Development of the Rio Grande rift, including the Tularosa Basin and its bordering uplifts, began about 25 million years ago. As the crust was slowly stretched in a east-west direction, subsiding blocks became basins that eventually filled with thousands of feet of sediment eroded from the surrounding uplifts. In addition, the Rio Grande at one point

A windstorm carrying gypsum-rich dust northeast from White Sands National Park as seen from the crest of the Sacramento Mountains near Sunspot.

flowed into the southern Tularosa Basin through Filmore Pass, 40 miles southwest of the park. Between 2 and 3 million years ago, the river rapidly dumped nearly 1,500 feet of sands and gravels into the basin as a broad fan. The uplifted mountains surrounding the Tularosa Basin, and the buried rocks under the basin, contain Permian-age gypsum. The highly soluble gypsum is dissolved and transported by surface and subsurface water. Because the basin has no outlet for surface water, the dissolved materials accumulate in basinal waters and sediments.

During the ice age, a large lake (Lake Otero) occupied much of the southwestern part of the Tularosa Basin. The climate at that time is estimated to have been several degrees cooler with more precipitation. Locally, deposits of Lake Otero contain fossils of small and large mammals, fish, amphibians, gastropods, and microfossils of plants and other aquatic organisms. Tularosa Basin began to dry out about 15,000 years ago, eventually producing Alkali Flat and the modern playa of Lake Lucero. As the water of Lake Otero evaporated, gypsum was precipitated. Alkali Flat developed by wind erosion of dry lake muds on the floor of the basin. Sand-size gypsum crystals began to accumulate in dunes, downwind to the northeast of the playa. Formation of a large field of gypsum sand dunes was well underway several thousand years ago. The gypsum sand derives from older lake sediments as well as from modern gypsum crystals precipitated at the surface of Alkali Flat. A few factors limit the size of the gypsum dune fields of this area. Gypsum is both a very soft and a very soluble mineral. Dune migration leads to rapid

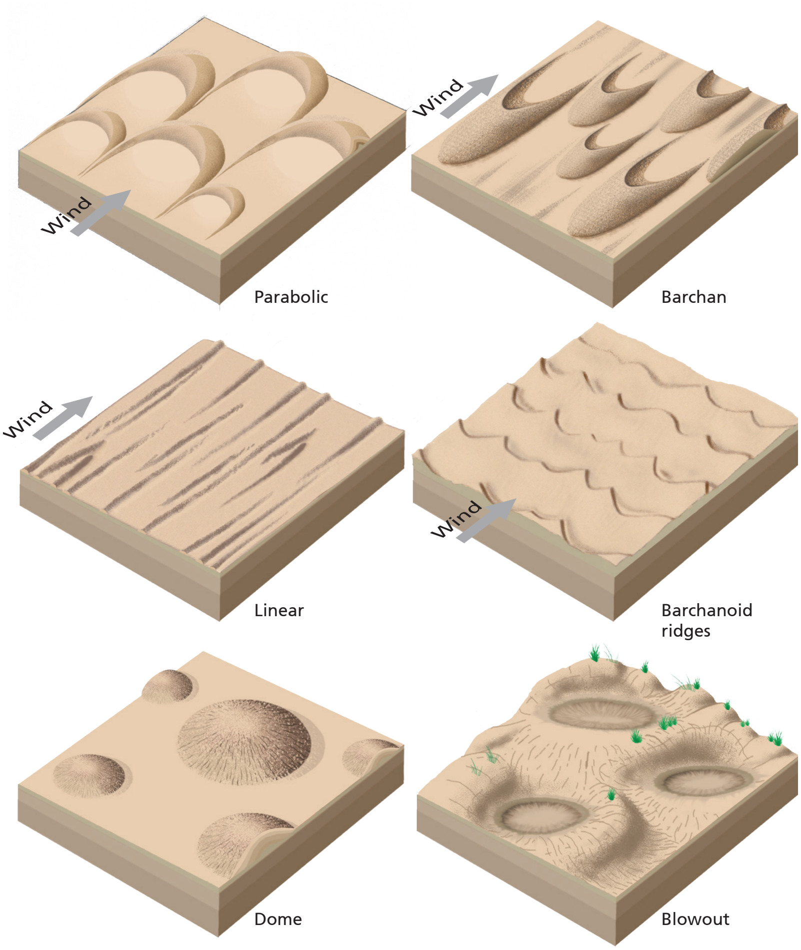
Large gypsum (selenite) crystals exposed in the Alkali Flat area are weathering out of Pleistocene Lake Otero deposits. These crystals are one of several sources for the White Sands dunes. Crystals shown are about 2 to 3 inches long.

abrasion of gypsum sands and eventual reduction of those grains to dust-size particles. The ultra-fine gypsum either leaves the basin during dust storms or settles as fine dust on the east side of the basin, where much of it is dissolved by rain and adds to the dissolved materials in regional groundwater.

Geologic Features

THE LOOP DRIVE AND ASSOCIATED HIKING AREAS—Large white gypsum dunes and associated interdune areas are the main geologic features visitors see along the loop drive in the park. They are part of the larger system of wind erosion, transport, and deposition across the southern Tularosa Basin. Eolian erosion mobilizes gypsum crystal fragments from Alkali Flat and the Lake Lucero playa and moves them to the northeast. Sand grains gather into small sand ripples and low dunes under vegetation. Larger dome dunes form farther downwind and, as they advance, they may form barchan dunes. The margins of barchan dunes form "horns" pointing downwind. Individual barchan dunes coalesce to form barchanoid ridges with sinuous crests. These are the most common and extensive features found along the loop drive in the "heart of the dunes." Straight-crested linear dunes are rare. In areas partially stabilized by vegetation, sand sheets and older dunes may remobilize to form parabolic dunes with long arms trailing from upwind margins. The dunes along the eastern margin of the dune field move very slowly, in large part because they have been stabilized by vegetation. Archaeological sites along the margins show that the past inhabitants took advantage of the diverse ecological environments that developed there.

Characteristic shapes of some dune types found in the White Sands area.



A dune field has two major zones—one of material transport represented by the dunes themselves and one of material storage in the interdune areas. Roadcuts through dunes, exposures beneath vegetation-protected pedestals, and eroded interdune areas reveal that dune interiors have complex cross-laminated sands with cross-cutting features related to constant erosion and redeposition of dune sands.

Crest of a typical barchan dune (at sunrise) with its steep downwind face showing "scars" of many small avalanches of gypsum sand.

The dunes migrate by wind blowing grains up the gentle, hard-packed backsides of the dune that then cascade as small avalanches down the sheltered lee side of the dune. That forms slopes of loosely packed sediment, typically with slope angles of about 30 degrees (termed the "angle of repose"). Differences in slope angle and packing account for the variations in effort needed to walk across the dune landscape.

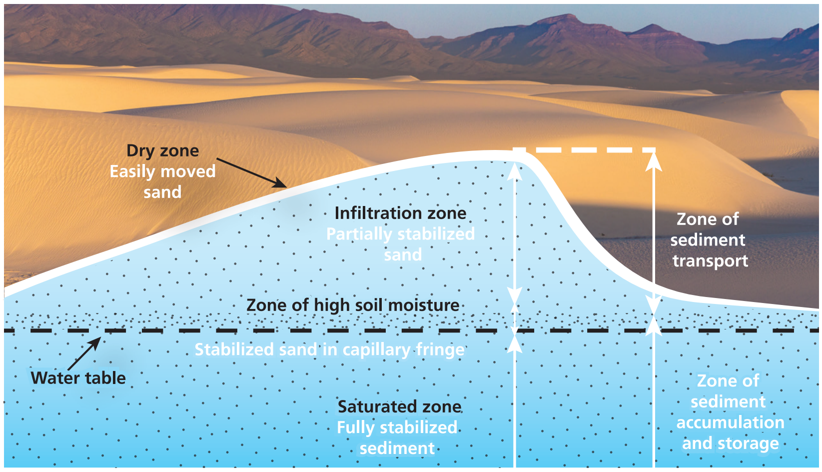
Dune interiors commonly are partially saturated with water, derived from precipitation, that is held by capillary forces and slowly percolates downward to the shallow water table. The remaining water makes dune interiors cool to the touch, although the dry surfaces may be quite hot.

Aerial view of closely spaced barchanoid sand dunes with narrow, brown, sparsely vegetated interdune areas.

In interdune areas, zones of sediment accumulation, or storage, are largely stabilized by a zone of dampness above the very shallow (1–3 feet deep) water table. Variations in rainfall lead to fluctuations in the elevation of the water table that can trap sediment, accounting for the sometimes spectacular "scrollwork ridges" in eroded interdune flats. These ridges reflect small differences in grain size of sediment layers formed by avalanching of sediment down the lee slopes of dunes. The curvature of the ridges results from the cusp shapes of the common barchan, barchanoid, and parabolic dunes that deposited the sand.

On rare occasions, interdune areas may receive enough precipitation to make ephemeral ponds that can be extensive enough to flood the main loop drive. Water in both dunes and interdune flats or ponds seeps downward and then moves laterally, evaporating near the surface and undergoing evapotranspiration by plants. Much of the shallow groundwater is perched above impermeable clay layers. Regional groundwater slowly flows southward toward the Rio Grande. Because

Diagram showing the distribution of interstitial water in dunes and its effect on sediment mobility versus sediment stability. Background photo shows sunrise on the dunes with the San Andres range in the distance.



Flooded interdune areas following an exceptionally intense late summer rainstorm in 2006. The flooding forced closure of the main road into the park for nearly six months.

the exceptionally shallow groundwater plays a vital role in the formation and stabilization of dunes in this area, there is great concern that increased use (including desalination) of groundwater in the region will affect the future of the dune field.

Because groundwater beneath much of the park is saturated with dissolved gypsum and other minerals, it is not potable. Fresh water for human use is piped into the park area from wells near the Sacramento Mountains.

OTHER PARK AREAS—Although most visitors will only visit the main dune area, infrequent (once a month in January, February, March, April,

November, and December) National Park Service-led tours to Lake Lucero and Alkali Flat reveal a very interesting and different landscape. During times of wet weather, Lake Lucero is flooded and large areas of Alkali Flat contain standing water. Under more common, drier conditions, the wind-eroded sediments of ice-age Lake Otero are exposed, revealing large gypsum crystals (up to 4 feet in length) that grew in the lake muds, as well as many fragments of the mineral as it weathers. Accumulations of gypsum fragments have produced odd mounds and pinnacles on Alkali Flat. Additional evaporite minerals precipitated in the area include halite, thenardite, mirabilite, hexahydrite, dolomite, and others. As the wind erodes Alkali Flat, 12- to 20-feet high, prow-like "mesitas" are carved from the resistant beds of Lake Otero to form features called "yardangs" that point into the predominant wind direction.

Along the margins of Lake Lucero and on Alkali Flat, numerous fossil tracks of mammoths, camels, sloths, and rare predators (dire wolves and saber-tooth cats) are briefly exposed before being eroded. One east-west camel trackway, with individual tracks filled with resistant dolomite, was traced across Alkali Flat for more than 1.5 miles. In addition, footprints have been found of humans interacting with megafauna, and throughout the park, there are thousands of fossilized human prints from adults and children—the greatest concentration of Pleistocene fossil footprints in the Americas.

The Lost River flows into the park along incised drainages coming from La Luz Creek and the foothills of the Sacramento Mountains to the northeast. The path of Lost River within the park is westward into the dune field, reaching a small playa before being overrun by dune sand. It deposits red mud on the playa that contrasts with the

Artist Karen Carr's rendering of the Late Pleistocene environment and now extinct megafauna at White Sands National Park.

Vegetation-stabilized dunes at the eastern edge of the White Sands dune field.

A vegetation-stabilized erosional remnant of a dune (called a pedestal). The steeply inclined layering is typical of the internal structure of dunes. It is formed by sand avalanches on the lee (downwind) side of dunes. The non-native tamerisk tree seen at the top of the pedestal can transpire over 100 gallons of water per day.

white gypsum sand in surrounding dunes. A rare and endangered fish, the White Sands pupfish (*Cyprinodon tularosa*, up to 2.5 inches long), was apparently introduced into the Lost River in the late 20th century and has established itself in the perennial reach of the creek.

—David W. Love, Bruce D. Allen,
Peter A. Scholle, and David Bustos

Additional Reading

White Sands National Monument, Rose Houk, Michael Collier, and Sandra Scott, Southwest Parks and Monuments Association, 1994.

White Sands National Monument Geologic Resources Inventory Report, National Park Service, 2012.

If You Plan to Visit

The entrance to White Sands National Park is on the north side of US 70, 15 miles southwest of Alamogordo and 52 miles northeast of Las Cruces, New Mexico. The park may be closed for unusual conditions, such as extreme weather, flooding, or missile tests on the adjacent White Sands Missile Range. US 70 can also be closed for an hour or more during missile tests. Check the park web pages for scheduled closures.

The main access to the park is a 16-mile loop drive into the heart of the dunes. Along the drive, several nature trails start from parking lots. Because the park is open during the daylight hours, entrance and exit times vary during the year. In addition, moonlight hikes are scheduled monthly and special escorted visits to Lake Lucero require prior registration. Check the park website for hours and to sign up for special tours.

White Sands can be a harsh environment, so please follow all National Park Service safety rules concerning appropriate clothing and sunscreen. Take plenty of water and food. In an environment where each dune looks similar to the previous one, it is easy to become disoriented—so a charged cellphone, GPS device, and compass are all essential for longer hikes. For more information:

An eroded interdune area with scroll-work patterns that reflect the preserved "toes" of former barchan dunes, now removed by the wind. The dune toes are retained by capillary water associated with the shallow, underlying water table.

White Sands National Park
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For Lake Lucero tour information:
www.nps.gov/whsa/planyourvisit/lake-lucero-tour.htm