Geology of a Gypsum Dunefield

A curious white line on the horizon, White Sands has long sparked wonder in people passing through the Tularosa Basin. Standing on top of a dune overlooking this sea of sand, it can be difficult to imagine where all the brilliant white sand came from. To understand the origins of the world's largest gypsum dunefield, we must look back over millions of years during which just the right geologic and climatic processes took place in just the right order. Many of these processes continue today, allowing us to witness the formation of these unusual sands.

Scan for a more in-depth explanation of the geologic story of White Sands and the Tularosa Basin.

A Source of Gypsum

The geologic story of White Sands began 250 million years ago when earth's continents were still joined in the megacontinent Pangaea. At this time much of the Southwest was covered by the shallow Permian Sea, including parts of present-day Arizona and New Mexico.

Over millions of years, sea levels rose and fell many times. In times of evaporation, concentrations of calcium and sulfate in the water increased enough to combine and form the mineral gypsum ($CaSO_4 \cdot 2H_2O$). Thick layers of gypsum were deposited in sedimentary rocks on the bottom of this sea.

Extent of the Permian Sea about 280 million years ago

Forming the Tularosa Basin

Beginning about 70 million years ago, pressure from colliding tectonic plates pushed up the land from Colorado to Mexico. These forces eventually formed the Rocky Mountain range.

The plates began pulling in the opposite direction about 30 million years ago, pulling the crust apart and forming mountains and low-lying basins along fault lines. The Tularosa Basin and its surrounding Sacramento and San Andres mountains formed at this time.

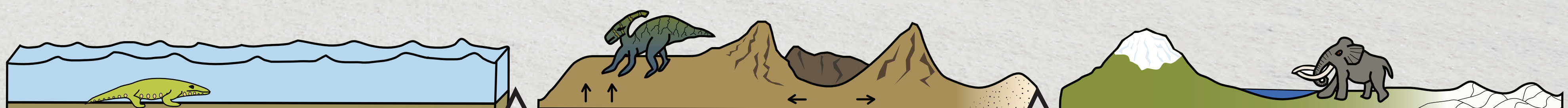
Two to three million years ago the ancient Rio Grande flowed along the southern edge of the Tularosa Basin. Sand deposits from the river blocked-off the southern edge of the basin, preventing snowmelt and rainfall from flowing out of it. This allowed for the formation of the 1,600-square-mile Lake Otero.

Lake Otero once covered much of the Tularosa Basin. When it dried, gypsum deposits were left behind on the basin floor.

An Ancient Lake

During the last ice age, 24,000 to 12,000 years ago, the climate in this region was considerably colder and wetter. A large cap of glacial ice was perched atop present-day Sierra Blanca. As the earth warmed approximately 11,000 years ago, ice melt and rain flowed down the mountains into Lake Otero. Water flowing down the mountains' sides dissolved gypsum in the surrounding rocks and carried it to the bottom of the basin.

Gradually, the climate became more arid and Lake Otero receded, leaving behind large deposits of gypsum on the floor of the Tularosa Basin. Lake Otero disappeared by about 10,000 years ago. Today, all that remains of Lake Otero is a small remnant called Lake Lucero at the foot of the San Andres Mountains in the southwest corner of the monument. The gypsum dunefield began to form shortly after Lake Otero dried up.



250 million years ago
Gypsum was formed and deposited in the Permian Sea.

70 million years ago
Tectonic forces pushed-up the land and the ancient seabed containing gypsum deposits

30 million years ago
The crust began pulling apart, creating Tularosa Basin.

2-3 million years ago
The Ancient Rio Grande River blocked off southern part of basin, allowing formation of Lake Otero.

24,000-12,000 years ago
Ice age conditions formed a glacier on Sierra Blanca. Rain and snowmelt fill Lake Otero.

10,000 years ago
Ice age ended. Lake Otero dried up. Dunes began to form.

Lake Lucero

Today, rainfall in the mountains still flows down the sides of the Tularosa Basin. Water dissolves gypsum in rocks as it travels and settles in low areas of the basin. Much of it settles in Alkali Flat and Lake Lucero. These areas are ephemeral lakes, or playas, that fill with water only parts of the year. On the surface of these playas, the final steps in the formation of rare gypsum sand can still be seen today.

Lake Lucero is a remnant of ancient Lake Otero. The same processes that formed crystals in Lake Otero continue today in this playa.

Water with dissolved gypsum in it flows to Alkali Flat and Lake Lucero during wet parts of the year, usually during July and August monsoons. There, the heat of the sun causes the water to evaporate, leaving the gypsum behind. Gypsum precipitates out of the water in the form of crystals. Smaller crystals form on the surface of these playas. Larger crystals form under the muddy surface of Lake Lucero and are shaped like long jagged spars and round segmented disks the size of bicycle tires. The crystal form of gypsum is known as selenite.

Although crystal growth continues in Alkali Flat and Lake Lucero, most of the sand in the dunefield came from crystals formed in ancient Lake Otero, which was much larger.

From Crystals to Fine Grains

Selenite crystals on the surface of Lake Lucero

Each year some of the crystals emerge from the protective mud surface of Lake Lucero as wind and rain remove sediments from around them. Once exposed, crystals begin the gradual process of erosion into smaller and smaller pieces.

Gypsum is a soft mineral—softer than a human fingernail—so it breaks down easily. Water seeps into cracks, freezes, and breaks fragile sheets of selenite apart. The process continues over time until large crystals become small shards.

When pieces become small enough that they can be picked up by the wind they are known as “cornflakes,” and this is when things really speed up. Grains of gypsum picked up by the wind bounce along the surface and leap-frog over each other, breaking down into smaller and smaller pieces.

As the soft grains collide with the ground and with one another their surfaces get scuffed. These scuffs reflect light rather than letting it pass through and give the gypsum sand its distinctive snowy appearance.

A Sea of White Sand

The dunes at White Sands probably began forming as late as 7,000 to 10,000 years ago, when Lake Otero started to dry up. The dunes are shaped by prevailing southwesterly winds, which pile the sand up and push dunes into various shapes and sizes. The different types of dunes depend on the amount of sand available, the power of the wind in a particular spot, and the vegatation anchoring sand in place.

Because of the consistent wind, dunes are evershifting. Some dunes in the heart of the dunefield can travel twelve to thirteen feet per year, keeping any thing but the occassional grasses from taking root. Others, on the edges of the dunefield, move only inches to a few feet per year and are firmly held in place by a variety of desert plants.

A Secret Key Ingredient

Gypsum is a common mineral in rocks all over the world. Basins are common too, even here in New Mexico. So, why is White Sands the world’s largest gypsum dunefield? Water!

Water is the secret ingredient necessary for gypsum sand to form. Although it is not obvious, White Sands is actually a very wet environment. These dunes are at one hundred percent humidity. Only a few feet under interdunal areas lies what is called a perched water table—water that is held by a barrier above the normal water table found in the rest of the basin, in our case a layer of impermeable clay. This shallow water table acts like a glue holding the dunes in place, preventing them from blowing away with the wind.

Heavy rain in 2006 flooded interdunal areas throughout the monument. Normally, White Sands has a perched water table that lies one to two feet below the surface of interdunal flats. During this storm, the unusually heavy rainfall raised the water table to the surface, which resulted in extensive flooding in the dunefield for six months.

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