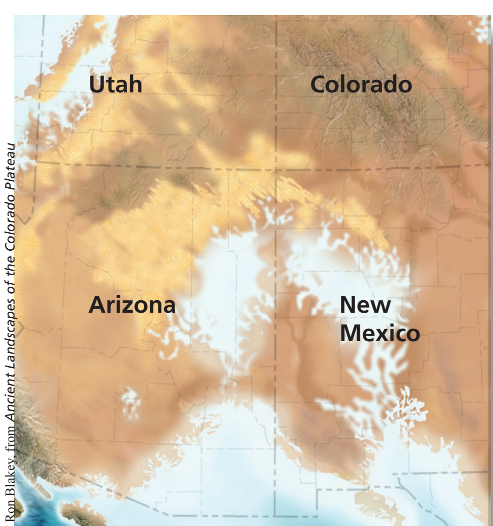
White Sands

National Park Service
Department of the Interior

White Sands National Monument

Overview of the Geology of White Sands National Monument

Within the Tularosa Basin lies a unique geological creation. It is here that the world's largest gypsum dunefield can be seen for hundreds of miles as a thin shimmering line across the base of the San Andres Mountains. This overview is intended to elaborate on some of the major geological factors set in place for such an exceptional place to exist.



Extent of the Permian Sea 280 million years ago

The Permian Sea

The unique geologic creation of the world's largest gypsum dunefield has been a project in the making for over 250 million years.

During the Paleozoic Era (570-245 million years ago), a supercontinent known as Pangaea accounted for almost all of Earth's landmass. Major portions of North America, predominantly across the western half, lay beneath a shallow body of water called the Permian Sea.

Throughout the Permian period (290-245 million years ago), sea levels rose and fell on numerous occasions. It was at this point that prominent gypsum deposits began to occur.

Gypsum is an evaporative mineral. During times of low sea levels and higher rates of evaporation, calcium (Ca_2+) and sulfate ($SO_4$2-) ions inevitably became concentrated enough for gypsum rock ($CaSO_4 \cdot 2H_2O$) to develop. The gypsum rock was then deposited on the sea floor which is now evident within the Yeso Formation found in the surrounding mountains.

"Yeso" is Spanish for gypsum. The Yeso Formation is a 1,500-foot thick deposit of gypsum rock that expands throughout much of the San Andres and Sacramento mountain ranges. This formation can be seen in patches along the Sacramento Mountains.

The Laramide Uplift

Approximately 70 million years ago, toward the end of the Cretaceous Period, the same compressional forces that developed the Rocky Mountains uplifted marine rocks within what is now the Tularosa Basin. Known as the Laramide Orogeny, this process has thought to have been primarily influenced by tectonic activity.

Earth's surface is comprised of seven continuously moving plates. Collision and diversion of these plates often results in common geologic features including mountain ranges and rift zones.

When a thin dense plate collides with a thicker but lighter plate, the thin plate will descend beneath the thick plate through a process known as subduction. (Figure 1) A well-referenced example of the subduction process is the Andes mountain range in South America.

Towards the end of the Cretaceous Period, the angle of subduction beneath the United States became increasingly shallow. This in turn transferred compressive forces from a westward direction into an eastward one.

The eastward shift of compression is believed to be responsible for the formation of the Rocky Mountains (Figure 2). The Laramide uplift affected a very broad region, including the White Sands area.

Formation of the Tularosa Basin

The geologic development of the Tularosa Basin began approximately 30 million years ago with the formation of the Rio Grande Rift. The rift is a north-trending continental rift zone that extends from central Colorado in the north all the way to the state of Chihuahua, Mexico in the south.

The Rio Grande Rift formed during a time of geological stress caused by crustal extension. During this time, the San Andreas Fault began to form as continental plates moved away from each other. As the plates pulled apart, the Earth's crust thinned until it finally separated.

This separation of the crust caused enormous gushes of magma to push upwards from the Earth's mantle. These upwellings stretched large areas of the southwestern United States into a massive formation known as "Basin and Range." The Basin and Range formation extends from southern Oregon down to northern Mexico, while a linear branch of the province extends from southern New Mexico into central Colorado.

As the crust continued to pull apart in the Basin and Range area, numerous fault zones developed, uplifting the yeso formation. Large blocks of crust also dropped thousands of feet along these faults, forming basins in between fault-bounded mountain ranges.

These processes resulted in the formation of several basins and valleys, including the Tularosa Basin. The Tularosa Basin is one of four basins that make up the Rio Grande Rift and lies at its southern end. Geologists believe that much of the basin formation associated with the Rio Grande Rift occurred within the last 10 million years.

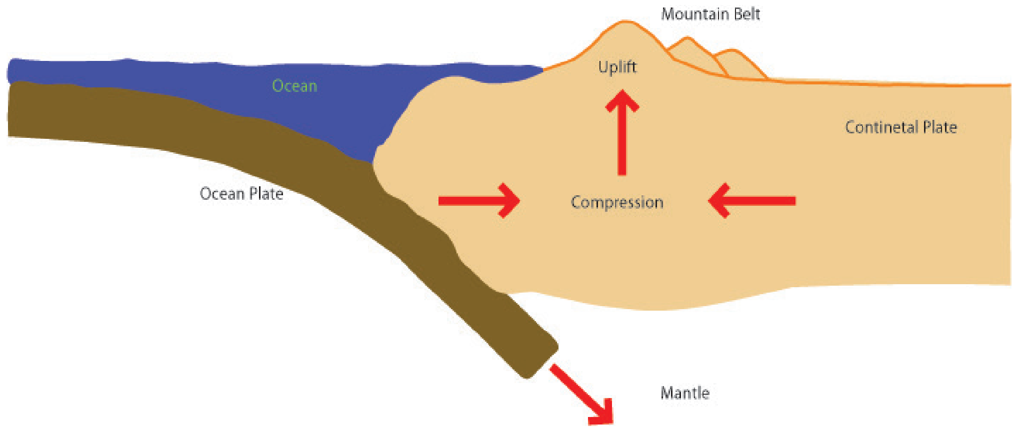


Figure 1: Normal subduction of an oceanic plate beneath a continental plate. Compression associated with subduction results in the uplift of a mountain belt near the plate boundary.

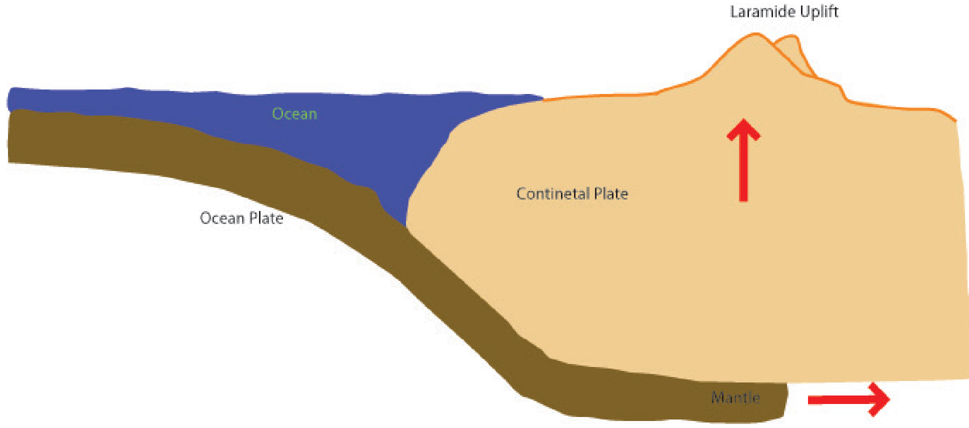


Figure 2: Shallow subduction beginning at the end of the Cretaceous Period. Change in the geometry of the subducting plate resulted in the Laramide uplift in the interior of the United States.

The Last Pleistocene Ice Age

The most recent ice age took place between 24,000 to 12,000 years ago. During this time the Tularosa Basin experienced a significantly cooler and wetter climate. In fact, the basin was predominantly filled with an enormous body of water called Lake Otero.

Higher levels of rainfall throughout the Pleistocene Ice Age extracted the gypsum that had been solidified within the ancient marine rocks high in the mountains. This gypsum laden water then collected in Lake Otero.

The high gypsum content in water flowing from the San Andres and Sacramento mountain ranges inevitably led to Lake Otero becoming saturated with dissolved gypsum.

Toward the end of the Pleistocene Ice Age, the climate began to change once again. The cool wet environment began to turn substantially more arid and Lake Otero dried up leaving behind enormous deposits of gypsum.

Though now long past, the Ice Age was essential in the development of dunefield today. It was also critical in flushing large quantities of gypsum from the mountains into the Tularosa Basin. The relatively slow rate of evaporation, combined with

Lake Lucero and the Alkali Flat are all that's left of Lake Otero

Selenite crystal blades at Lake Lucero

saturated, muddy conditions along the edges of the lake, allowed the dissolved gypsum to crystallize as selenite "discs" and bladed crystals.

The evaporation of Lake Otero left behind two playas, the only remainders of what was once an enormous body of water. These ephemeral lakes are now referred to as Lake Lucero and the Alkali Flat and together make up the source of the gypsum sand.

Neither playa holds standing water very often, but when they do it can often be contributed to the ever constant, shallow water table that sits directly below the surface. At Lake Lucero, as the water table rises, the ground often becomes marsh-like, while only a few inches of water covers the crystals.

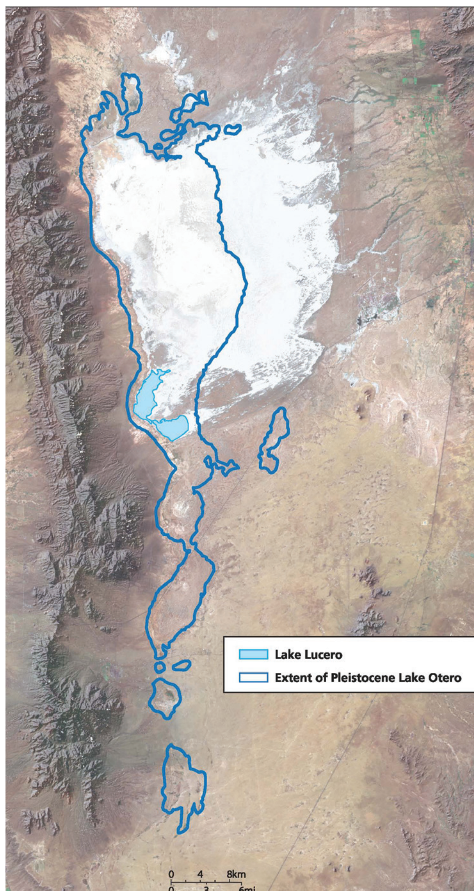
The crystals at Lake Lucero continue to form today, although the majority of the selenite developed as Lake Otero dried. Following the evaporation of this enormous lake, large stretches of the Tularosa Basin must have been littered with selenite crystals as Lake Lucero is today.

Dune Formation

Most of the gypsum sand in the dunefield was formed by the breakdown of selenite crystals. These crystals occur in a variety of shapes and sizes but common to all selenite crystals from the monument is that they are comprised of paper-thin layers similar to those found in mica or biotite.

Expansion and contraction caused by large temperature fluctuations and periodic freezing will break up selenite crystals along these planes. When crystal grains become small enough to be transported by wind, further breakdown will occur.

Gypsum is one of the softest minerals. Unlike hard quartz sand, gypsum sand will be ground down into smaller and smaller grains when moved by the wind. This grain size reduction can be seen when comparing coarse crystal grains near Lake Lucero to very fine sand near the eastern edge of the dunefield.



A map of Lake Otero and the current dunefield.

Geologically speaking, the dunefield has only existed for such a short amount of time and is a relatively young geologic formation. Exact dates regarding the dunefield's original development remain to be determined but research suggest that dunes were forming as far back as 18,000 years ago.

Many scientists find this baffling due to the fact that almost all of the basin lay beneath Lake Otero during this time. It is possible though that there was a local evaporative period roughly 16,000 years ago, allowing a small dunefield to form.

Fossil dunes can be found northeast of Lake Lucero and have been dated back to approximately 6,500 years ago. This date has shown to be much more typical of the dunes that had developed during the early, large scale evaporation of Lake Otero.The dunes we see today are significantly younger; most of them are only hundreds of years old and sit on top of over twenty-five feet of packed gypsum from years before.

The process of dune formation is still taking place today. As old crystals emerge from the protective mud surface of Lake Lucero and new ones form due to evaporation, the wind and weather gradually break them down into sand which is then blown into the dunefield. At the same time, however, the sand is being ground down into silt size particles that can be blown out of the Tularosa Basin. This endless cycle of creation and destruction feeds the dunefield at White Sands National Monument and helps to ensure that future generations will get to enjoy one of nature's greatest treasures.

75-mile dust plume from White Sands blowing over the Sacramento Mountains (NASA image).

Revised 3/7/16