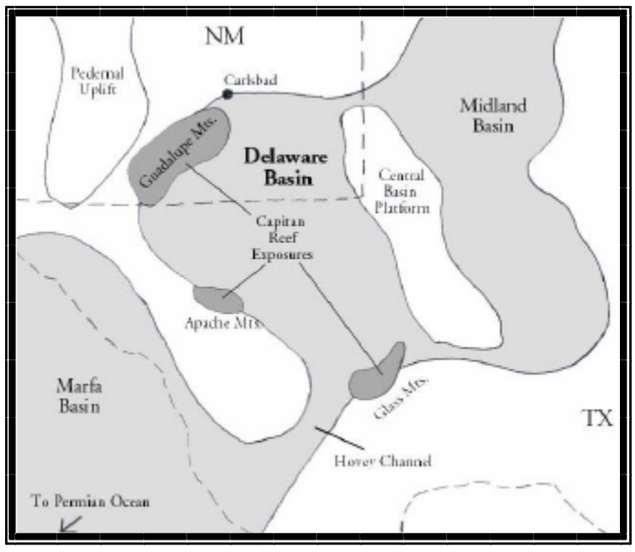
SURFACE GEOLOGY: From living reef to desert mountains.

The dramatic landscape of Carlsbad Caverns National Park would not have existed without a distinguishing series of geologic events and processes. It is a landscape where the world famous caves are not the only attraction. People from all over the world come here to study and discover the remarkable geologic story of the Guadalupe Mountains area. Two national parks, Carlsbad Caverns and Guadalupe Mountains, are located in this limestone mountain range. These national parks provide a unique window to the world's best outcrops of a preserved ancient reef where a 250- million year geologic story is exceptionally exposed in the desert landscape.

The Ancient Landscape

An important chapter in the development of Carlsbad Caverns National Park occurred during the Permian period of geologic time about 230- 286 million years ago. During this time, the world's continents were fused into one supercontinent known as Pangea with this region located near the equator on Pangea's western edge. An inland sea about 1800 feet deep, 150 miles long, and 75 miles wide inundated a region known as the Delaware Basin. A complex and diverse reef grew and fringed the basin almost completely for 400 miles. Although the reef's dimensions changed throughout the Permian period with sea level fluctuations, it left behind billions of skeletons and ocean sediments that combined to form the rock formation that is now the Capitan Limestone.

The Permian climate of the region is likely to have been hot and dry, much like today's Persian Gulf. By the beginning of the Permian period, life on earth was already quite diverse. Conifers and ferns were dominant among plants and trees. New insects such as beetles and cicada were evolving. Although large dinosaurs had not yet appeared, many types of reptiles and amphibians were common. The Permian seas hosted an even greater variety of life. Sponges and algae were the main reef inhabitants. This reef supported clams, flower- like crinoids, trilobites, bryozoans which resembled lacy moss fans, and ammonoids (related to squid). Single- celled fusulinids, snails, and algae populated the backreef area. The end of the Permian witnessed one of the greatest mass- extinctions of all time, wiping out the majority of earth's species (including most of the reef- builders).



Uplift & Exposure of the Reef

How did a submerged reef become imposing mountain peaks almost two miles above its original position? Geologists infer that by the end of the Permian period the growth of the reef ceased due to a restriction of water flow through the Hovey Channel. As the sea dried, evaporite salts (halite and gypsum) filled the basin, reef, and lagoon, remarkably preserving the entire reef complex. At the end of the Cretaceous period 65 million years ago, tectonic movement of this region occurred as a result of distant mountain- building episodes that formed the Rocky Mountains. Extensive uplift of the ancient reef to its present position did not occur until the late Tertiary period (about 6 million years ago) with the widespread Basin and Range block faulting that took place in the western United States. Tectonic uplift and weathering is responsible for the exposure of the reef complex which can be seen today as the Guadalupe, Apache, and Glass Mountains of the Delaware Basin. The same slow processes of uplift and erosion that exposed this ancient reef are still sculpting the landscape today.

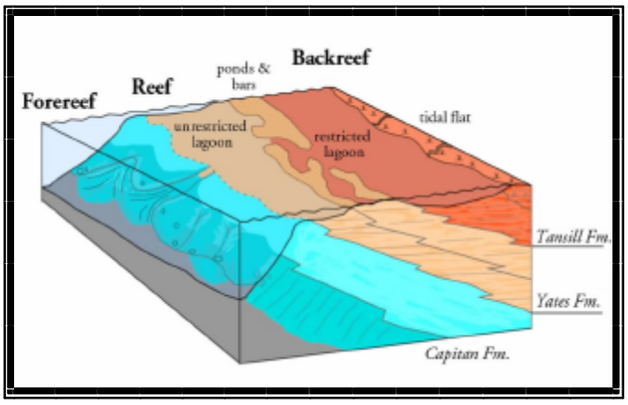
What do you think this fossil- filled mountain range will look like after another 250 million years?

Understanding the Modern Landscape

The extensive ancient reef complex now reveals itself in the escarpments, cliffs, and canyons of the Guadalupe, Apache, and Glass Mountains. Rock formations of the Guadalupes indicating the backreef, reef, and forereef environments can be seen by looking west from the Visitors' Center towards the mountain peaks.

The lagoonal backreef located on the landward side of the reef contains two different formations—the Tansill and Yates. The sediments that form the *Tansill* were the furthest landward of backreef deposits and consist of sandstone and siltstone with dolomite and thin clay layers. These semi- impermeable clay layers today prevent rainwater and snowmelt from easily percolating further downward to lower layers, causing water to accumulate above the clay layers. This water then moves horizontally until it emerges in springs or seeps along canyon walls. An example of this is Big Hill Seep, which can be viewed across from a pull- out along the Walnut Canyon drive. Distinctive features of the Tansill are aggregates of round carbonate- coated particles with a concentric structure called pisolites. These form in waters with a high calcium carbonate content with plenty of wave energy or agitation. Pisolites range in size from a few millimeters to 5 centimeters and are easily seen in outcrops by the old guano trail accessible near the cave entrance. The backreef was subjected to periodic drying of its sediments which concentrated minerals in the water, making it very saline. Many reef and marine organisms could not survive in this water, but snails and certain algae were able to thrive.

Permian Reef Environments of the Delaware Basin



The *Yates* formation contains dolomite and sandstone from the marine lagoon, which was on the ocean side of the Tansill deposits. This area was shallow, quiet, and relatively still. The dry episodes in the backreef produced characteristic structures in the Yates called mudcracks formed by the buckling of sediments as they partially dried. The flat ceiling in the cave near the Bat Cave sign exhibits these preserved polygonal structures which form a honeycomb pattern. Larger interpretations of the drying effect can be found in the upside- down V- shaped tepee structures found throughout the park. A good example is near the bottom of the bat flight amphitheater where the trail into the cave begins. Lagoons similar to those of the Permian period occur off the coast of Florida today.

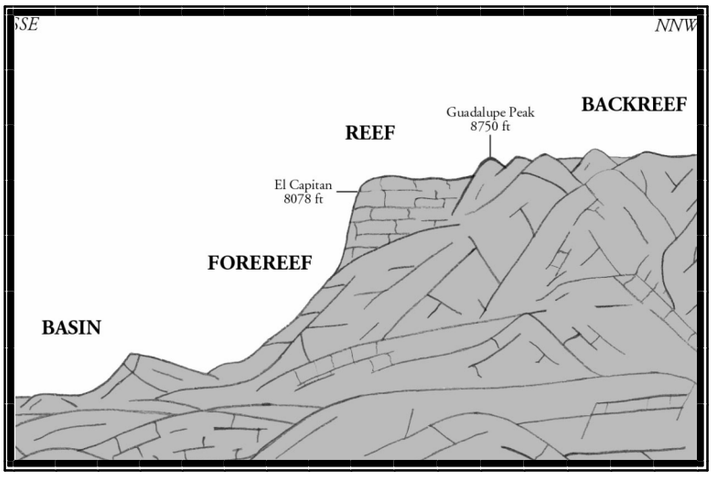
The *Capitan* formation includes massive, unbedded limestone reef deposits approximately 750 feet thick. This rock was formed by the buildup of the skeletal remains of calcareous reef- building organisms over millions of years. This Permian reef was quite different from modern reefs that are composed mainly of coral. The ancient reef contained sponges, algae, bryozoans, and various other microorganisms (most of which were extinct by the end of the Permian). As the Delaware Basin subsided, the reef was able to build on top of itself to increasing vertical heights while remaining in the zone of life- sustaining sunlight. The skeletal deposits of dead organisms were bound by encrusting organisms and natural calcite cement which filled any pore spaces. Fossils of the reef- building sponges and algae are easily visible in the formation today. Similar living reefs today fringe the coastline of modern Belize in Central America. The sheer cliff of El Capitan starkly reveals the massive Capitan Limestone and most of Carlsbad Caverns itself has been formed within the same rock formation.

The *Capitan forereef* environment is represented by sloping reef debris on the ocean side of the reef. As the reef grew upward, large house- sized blocks of it collapsed or were broken off by waves and fell into deeper water. This action created a poorly sorted debris pile at the base of the reef composed of lime mud, fossils, and reef fragments.

There are no significant outcrops of the deepwater basin deposits of limestone, gypsum, and sandstone in Carlsbad Caverns park boundary, but they are found in the flat plains below the steep escarpments.

Compare today's view to the diagram of the Permian reef environments. Now can you imagine the desert basin is filled with water teeming with Permian marine life as waves gently break on an ancient coastline?

View of the Guadalupe Mountains looking southwest from the visitor center →



Remember that collecting fossils, rocks, or minerals of any kind within the National Park is prohibited.