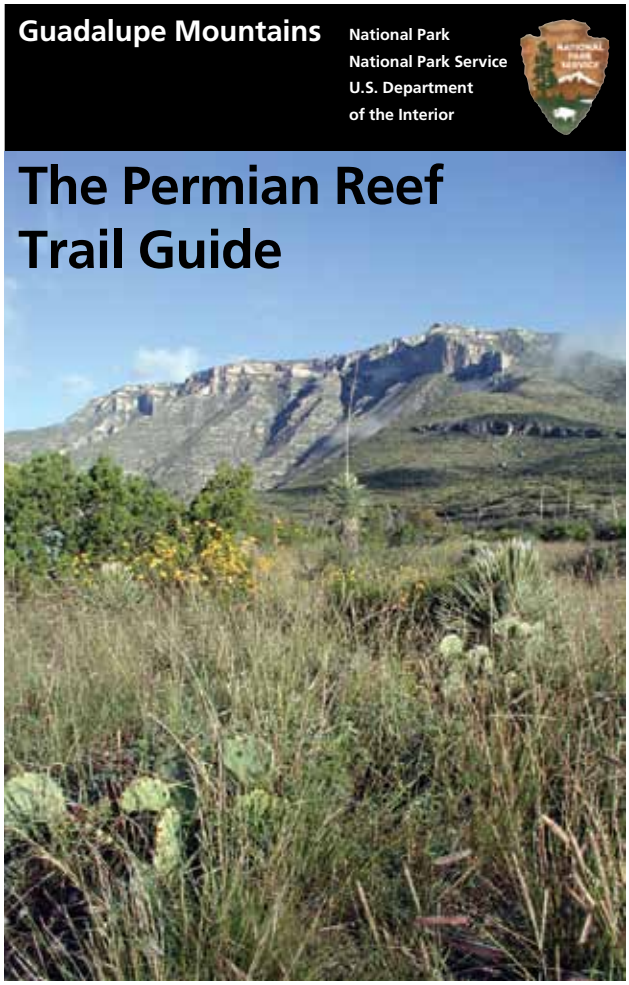
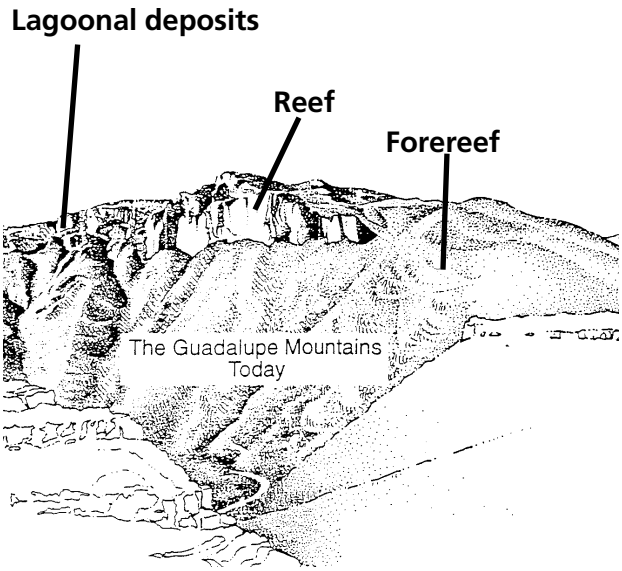
Marker 28

At this highpoint of the trail, you can find evidence that sea levels eventually rose and the reef front moved toward the basin center. The shallow lagoon that would have normally been behind the reef returned. Because evaporation rates were very high in the hot arid environment, the seawater had a high concentration of minerals. Mineral rich water permeated the limestone here, and replaced some of its calcium with magnesium, thus forming dolomite. Note that the reef has been eroded away here, but would have occupied a position a few hundred yards over the edge of the escarpment.

At this point you are 2,000 feet above the desert floor. You have encountered rocks formed on the seafloor and have seen evidence of the organisms that lived there. You have seen the forces of gravity and wave action working against the reef's upward growth, and you have found fossils of organisms frozen in the same position they were in millions of years ago. The clues found in the rocks preserved in Guadalupe Mountains National Park tell an unexpected story of life and death hidden in a remote corner of the Southwest.





View from McKittrick Canyon Contact Station

The massive cliff at the top of the northeast wall of McKittrick Canyon is a fossil reef that formed approximately 260-270 million years ago. The Capitan Reef grew from the remains of billions of marine animals and plants cemented together by calcium carbonate.

Limy sands and muds were deposited in warm, quiet lagoons behind the reef. These "backreef" layers form horizontal rock beds visible to the left of the reef cliff. A narrow shoal, perhaps consisting of a line of small islands when sea level was low, restricted water circulation between the shallow lagoons and those above and oceanward of the reef. This allowed rapid evaporation of lagoon waters often leading to hypersaline conditions.

Fragments of the growing reef edge often broke off and rolled down slope into deep water, mixing with shells, sand, and other sediments to create thick "forereef" deposits. Generations of reef creatures then grew seaward on top of the remains of the old.

Water at the base of the forereef deposits was over 1500 feet deep. Fine windblown sand and floating organic debris sometimes crossed the shoal and barrier into the deep, cold water of the Delaware Basin. The organic debris eventually became the source of vast petroleum deposits of the Permian Basin of West Texas.

How to Use This Guide...

The photos on the following pages were taken near the numbered markers, but not necessarily right next to them, so some searching may be involved.

Each stop highlights an aspect of the reef's story or a fossil from the reef community that will give the user a broad understanding of the Capitan Reef.

Fossils are rare, non-renewable resources. Please do not damage or take fossils.

Numbered markers not featured in this guide are described in a technical work, written by professional geologists, called **Guide to the Permian Reef Trail, McKittrick Canyon, Guadadalupe Mountains National Park, West Texas**. This book is available for loan at the McKittrick Canyon Contact Station or for purchase at the Headquarters Visitor Center (Pine Springs).

Marker 27

You can find another clue that sea levels dropped at this stop. Sheet cracks and teepee structures (tent-like folds in the rocks) are evident along the trail here. Teepee structures may have formed by the expansion of hardening rock between softer layers of unconsolidated sediment. Today, teepee structures are seen in areas around the Persian Gulf in peritidal areas where sediments would be alternately submerged and exposed to the air during tidal cycles.

Sheet crack filled by sediments

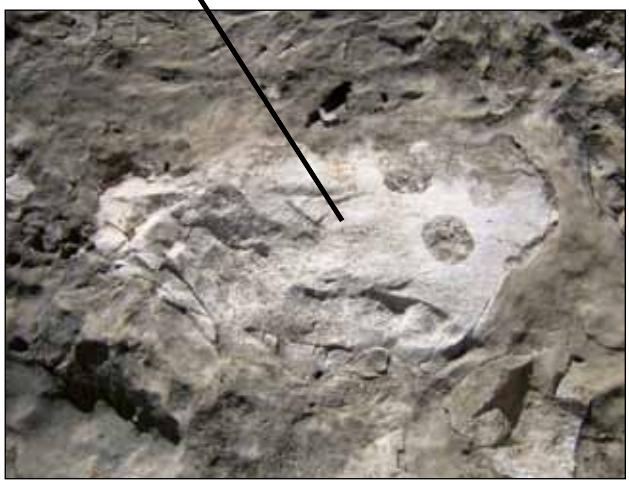
Marker 24

Stromatolites, structures formed by communities of algae, grew only in intertidal areas and they are featured at this stop. Stromatolites are characterized by alternating layers of algae and minerals that formed in mounds. They are an indication that sea levels were somewhat lower for a period of time.

Stromatolites can be seen on the trail. Look for light gray stromatolites and darker gray columnar deposits.

Stromatolites

Stromatolites (cross-section) in rocks next to trail



Marker 1

After crossing a rocky wash, you will notice beds of rounded rocks cemented together. These rocks pre-date the current downcutting cycle of the stream in McKittrick Canyon. Approximately 40,000 years ago during the Last Ice Age, floodwaters carried rocks to this location. Geologically speaking, the Pleistocene Epoch (11,500 to 1.8 million years ago) was not that long ago. However, the climate was very different than today: rainfall was higher and temperatures were cooler. Rushing streams transported the rocks eroded from the high country. Constant tumbling along the streambed rounded these rocks, and calcium cement in the water bound them together to form a sedimentary rock called conglomerate. Uplift of the mountains and erosion by the stream has exposed them.

Conglomerates

Marker 2

The limestone layers here are thin and fine-grained, because mud that settled on the ocean basin was relatively undisturbed by strong currents. In these layers and rising out of them you will see numerous orange chert nodules. They are made of silica and are more resistant to erosion. Iron present in these nodules gives them their orange color. These nodules may have formed from silica found within sponges when mud layers were buried and compacted. Notice also that this limestone is very dark in color. The dark color results from organic carbon and hydrocarbons trapped in small pores. Cold deep water here prevented completed oxidation (rotting) of organic remains of small animals. This type of limestone is a good source of petroleum. In the past, American Indians used chert to make tools and arrowheads.

Chert nodules

Marker 22

Organisms not found elsewhere help identify this area as the top of the reef. A type of algae, *Collenella*, that lived only near the reef's upper limit, is fossilized here. The reef top would have experienced tremendous force from waves crashing above it. The waves ground up animal skeletons and reef rock and washed it into low areas along the reef top. The type of sedimentary rock that resulted is called "grainstone" and it is very common here.

Collenella

Marker 21

The outcrops along this section of the trail are important for understanding diagenesis. Diagenesis refers to chemical and physical changes to the sedimentary rock after its formation. The large calcite crystals (called calcite spar) in the rock formed when the reef was buried during the Mesozoic Era (250-66 million years ago).

Marker 3

Every rock provides clues to the forces that have shaped the land. Geologists have studied thin cross-sections of this rock with microscopes and have found that some of the pebbles embedded in it are made of a type of limestone called boundstone which was formed by algae, growing around sponges. These types of organisms only grew on the reef, so it has been moved from its place of origin. The reef was made by billions of organisms and grew vertically until environmental conditions could no longer support continued upward growth. The reef community then started growing outwardly towards the ocean basin and became unstable. The force of wave-action and gravity tore off pieces of the reef. These pieces formed a steep slope of debris below and in front of the reef. Some particularly violent collapses carried debris all the way out into the deep sea floor where the pieces were buried and fossilized. Further up the trail near Marker 12, look for reef boulders six to nine feet in size.

Calcite crystals

Boundstone from the reef

Marker 4

Trace fossils are evidence of the past activity of organisms. At this stop the burrowing activity of a worm-like organism is preserved. In paleontology, trace fossils are named (*Planolites* in this case), but the organism that left the trace is not always known. The worm-like organisms that left these traces were burrowing through the seafloor millions of years ago in search of food. Only worms and a few animals could live in this cold, deep, dark, low-oxygen environment at the bottom of the sea. Now, in one of nature's great reversals, you can examine this record of an ancient sea preserved above ground in the Chihuahuan Desert.

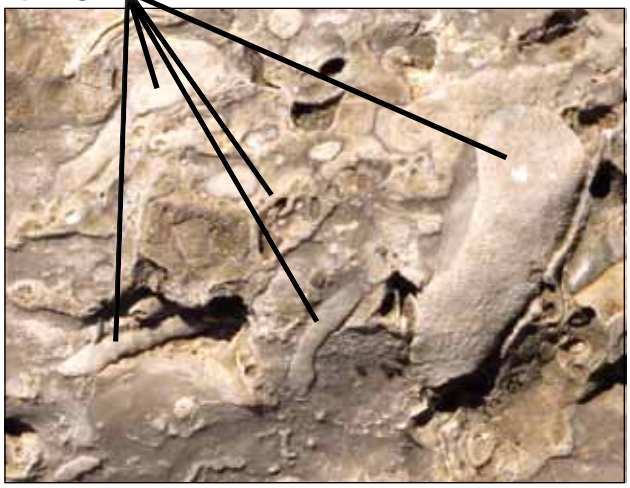
Worm burrows

Marker 16

This area of the reef was sponge paradise. Numerous types of sponge fossils can be found here as well as bryozoans. The various sponges were not restricted to specific zones because their filter-feeding habits allowed them to live in variety of environments. This is in contrast to modern day reefs where coral distribution is limited by the quantity of light available due to their symbiotic relationship with photosynthetic algae. Thus, ancient sponge reefs could grow in sea water hundreds of feet deep. Modern sponge reefs grow as deep as 500 feet.

Sponges

Sponges



Marker 15

You are now at the base of the reef and will see numerous fossils along this section of trail including ammonoids, sponges, and bryozoans. Some of the sponges are fossilized in growth position. They grew hanging upside down by attaching themselves to the skeletons of bryozoans that were growing in holes in the reef. Eventually these areas were filled in with minerals call “marine cement”. The cement helped to preserve a moment of time in the reef’s life.

Ammonoid (cross-section)

Bryozoan (cross-section)

Marker 7

Along the slope beneath the reef, different forces transported material off the reef. You have already seen the force of wave action on unstable portions of the reef at the third stop. At this stop, evidence of a submarine debris slide is preserved in the rock. Numerous fragments of clam-like creatures called brachiopods are found here. They lived in an area higher up and closer to the reef.

Debris Slide

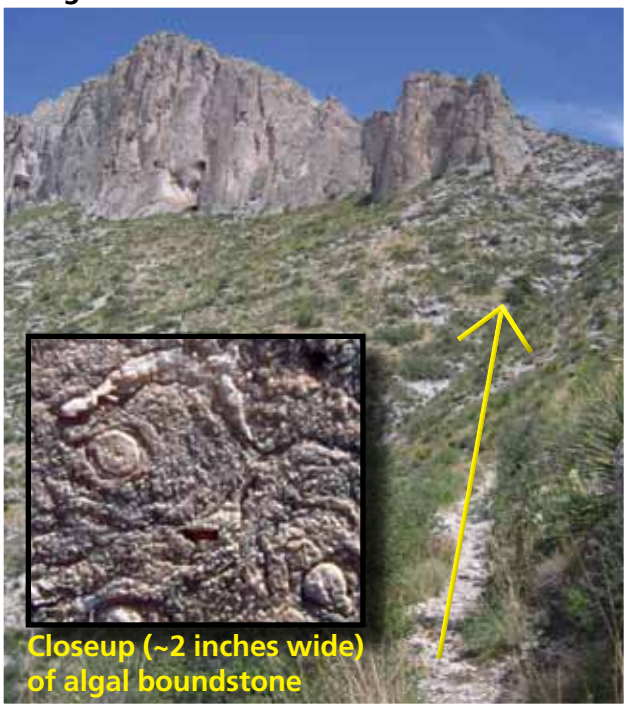
Brachiopods

Marker 9

The clues yielded by rocks help us build a picture of past environments and create a story of what occurred at a certain location. Unlike a photograph that represents one moment in time, the scene you encounter in the landscape is more like a painting that shows several moments in time as a progression from earlier to later stages. Sometimes there are gaps in the rock record due to the forces of erosion.

Geologists can recognize different portions of the reef and changes that took place within the community by the differing organisms found there and the types of mineral cements that filled the spaces on the reef. The youngest portions of the reef would be found on the crest of the ridge above if it were not for erosion or gravitational collapse. Some portions of the reef tumbled down slope and can be found at this stop as huge boulders up to 30 feet across.

Look for reef boulders (algal boundstone) along this stretch of the trail



Marker 14

At this stop you can see many rice-shaped grains within the rock. These are the fossilized remains of fusulinids, a type of single-celled organism that became extinct at the end of the Permian Period. They were similar to amoebas but they had a hard protective outer covering with holes in it. This allowed them to extend part of their bodies out of the holes to catch micro-organisms for food. Some fusulinids lived in the mud behind and on the reef. They could move, but the great numbers evident here were transported after the organisms died in mass. Possibly, this mass die-off was due to a change in environmental conditions.

Fusulinids