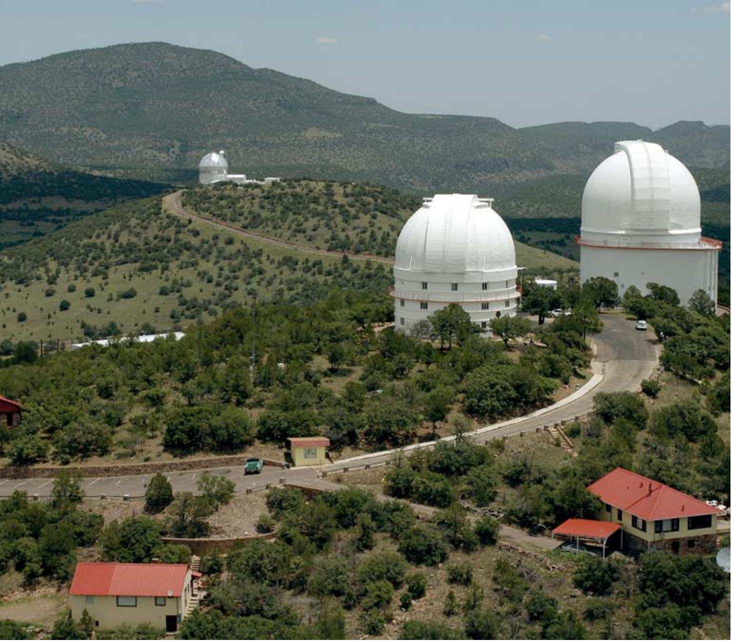
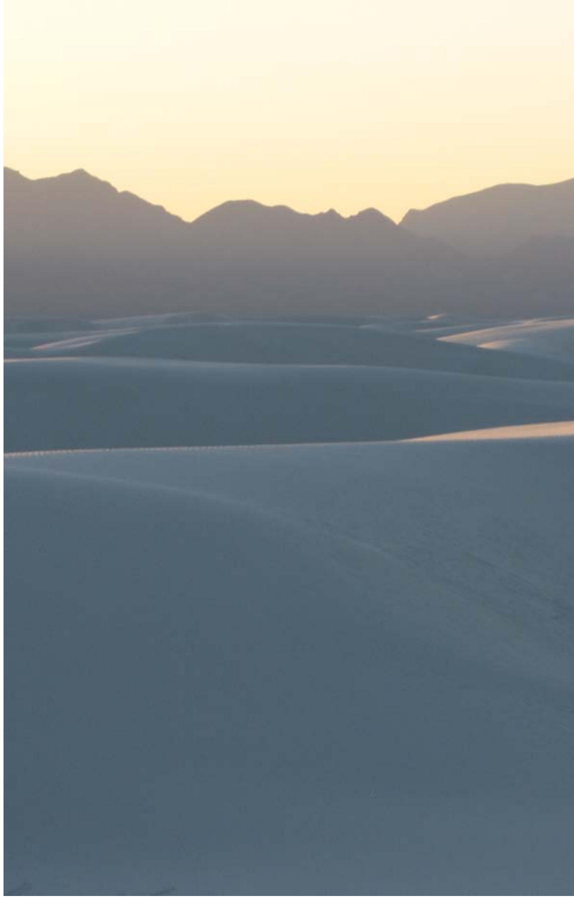




Undergraduate Spring Break Field Trip 2014
Western Texas and Southern New Mexico

DAVIS MOUNTAINS - BIG BEND - GUADALUPE MOUNTAINS - WHITE SANDS

Department of Geological Sciences, Brown University

Itinerary

Part One: Davis Mountains

Day 1: Friday, March 21

Early Morning:	Fly Delta Air Lines flight 1263 from PVD to ATL (duration 2 hours 49 minutes)
Morning:	Fly Delta Air Lines flight 2136 from ATL to ELP (duration 3 hours 28 minutes)
Midday:	Claim checked baggage, obtain rental cars, and shop for food at Walmart
Afternoon:	Drive 3.5 hours to Davis Mountains State Park
Evening:	Set up camp at Davis Mountains State Park and eat dinner
Evening:	Attend the McDonald Observatory Star Party (2 hours) *The Star Party takes full advantage of the dark night skies of Western Texas. Constellations and celestial objects will be viewed through numerous telescopes at the observatory.*

Day 2: Saturday, March 22

Morning:	Hike the 2.4-mile Madera Canyon Trail (2 hours) *The Nature Conservancy's Davis Mountains Preserve hosts the 900 ft.-deep Madera Canyon. Springs and volcanic dikes are noteworthy features.*
Morning:	Attend the McDonald Observatory daytime tour *This 2 hour 30 minute guided tour includes a 45-50 minute solar viewing and 90-100 minute tour of the facilities.*
Afternoon:	Drive 20 minutes to Fort Davis National Historic Site, have lunch, and explore
Afternoon:	Visit the Chihuahuan Desert Nature Center *This nature center is located in the foothills of the Davis Mountains and has a desert botanical garden and short walking trails to explore.*
Afternoon:	Drive 2 hours 30 minutes to Big Bend National Park *We will stop at the Fossil Bone Exhibit on the way into the park.*
Evening:	Arrive at Chisos Basin Campground and set up camp

Part Two: Big Bend

Day 3: Sunday, March 23

Morning:	Hike 10.5-mile Emory Peak Trail (7 hours) *This mountain trail goes past spectacular vistas and leads to the highest peak in the park. The last 25 feet requires a scramble up an exposed rock face.*
Evening:	Hike the 0.3-mile Window View Trail (5 minutes); enjoy sunset at 8:05pm *This easy stroll offers excellent views of the mountain peaks surrounding the Chisos Basin.*

Day 4: Monday, March 24

Morning:	Drive to the Ross Maxwell Scenic Drive (45 minutes) *This scenic drive showcases some of the most historic and geologic features of Big Bend.*
Morning:	Hike the 3.8-mile Mule Ears Spring Trail (3 hours) *This hike leads through the foothills of the Chisos Mountains, skirts Trap Mountain, and crosses several arroyos. An old rock corral is near an overgrown spring with shrubs, ferns, and cattails.*
Midday:	Drive to Tuff Canyon and hike through the gorge
Afternoon:	Visit the Castolon Historic District Visitor Center *Castolon was established as a cavalry camp in the early Twentieth Century.*
Afternoon:	Hike the Santa Elena Canyon Trail (1 hour) *The trail follows the Rio Grande upstream and then drops down to the canyon floor of this 1,500-foot vertical chasm. The right wall of the canyon is in Texas, while the left wall is in Mexico.*
Afternoon:	Hike the 0.5-mile Burro Mesa Trail (30 minutes)
Evening:	Make brief stops at the Sotol Vista Overlook and Blue Creek Ranch Overlook (time permitting) *The Sotol Vista offers views of the entire western side of Big Bend National Park, including Santa Elena Canyon. The Blue Creek Ranch Overlook provides views of the headquarters of the Homer Wilson Ranch, which used to be one of the largest in the region.*

Day 5: Tuesday, March 25

Morning: Hike the 4.8-mile Lost Mine Trail (3.5 hours)
This trail is a great way to witness the flora and fauna of the Chisos Mountains. The trail climbs steeply in and out of juniper, oak, and pine forest. The ridge offers superb views of Pine Canyon and the Sierra del Carmen in Mexico.
Afternoon: Drive 1 hour to the Terlingua ghost town; explore the ghost town
The ruins of the Chisos Mining Company are the backdrop of this unique stop.
Afternoon: Visit the Barton Warnock Environmental Education Center
Self-guided tours go through the Interpretive Center and two-acre desert garden.
Afternoon: Drive 1 hour 15 minutes to the Grapevine Hills Trail
Afternoon: Hike the 2.2-mile Grapevine Hills Trail (1 hour)
This trail leads hikers to a balanced rock formation.
Evening: Drive back to camp

Day 6: Wednesday, March 26

Morning: Pack up camp and drive 2 hours to Big Bend Ranch State Park
Morning: Hike the 1.4-mile Closed Canyon Trail (1 hour) and 1-mile Hoodoos Trail (1 hour)
Closed Canyon is a narrow slot canyon. The Hoodoos Trail descends to the Rio Grande river.
Afternoon: Drive 2 hours to Marfa, TX; shop for food
Evening: Drive 2 hours 15 minutes to Guadalupe Mountains National Park; set up camp at Pine Springs Campground

Part Three: Guadalupe Mountains

Day 7: Thursday, March 27

Morning: Guided and self-guided tours of Carlsbad Caverns
The 2-hour Left Hand Tunnel tour begins at 9:00am and the 1.5-hour Kings Palace tour begins at 10:30am. Both cave groups will also take the Big Room self-guided tour.
Afternoon: Hike the 0.9-mile McKittrick Canyon Nature Trail
Trailside exhibits describe common plants. This is also a great opportunity to learn about Permian Reef geology.
Afternoon: Hike the Permian Reef Geology Trail (3 hours)
This is a trail for serious geology buffs. There are excellent views looking down into McKittrick Canyon from the top of Wilderness Ridge. The trail is 8.4 miles round-trip, but turn around after hiking 1 hour 30 minutes.
Evening: Hike the short Pinery Trail before dinner
This short hike from the Pine Springs Visitor Center goes to the ruins of the old Pinery Station, once a favored stop on the original 2,800-mile Butterfield Overland Mail Route. Trailside exhibits describe Chihuahuan Desert vegetation.

Part Four: White Sands

Day 8: Friday, March 28

Morning: Hike the 2.3-mile Smith Spring Trail at Frijole Ranch (1.5 hours)
Enjoy the shady oasis of Smith Spring and the gurgling sounds of the tiny waterfall before continuing around to sunny Manzanita Spring.
Morning: Drive 2 hours 30 minutes to El Paso
Midday: Take the Wyler Aerial Tramway and have lunch at the top
The tramway offers panoramic views of the Franklin Mountains.
Afternoon: Drive 1 hour 45 minutes to White Sands National Monument
Afternoon: Explore White Sands
Potential activities include going on short hikes and sledding down the gypsum dunes. Hiking options include the Playa Trail, Dune Life Nature Trail, and the Interdune Boardwalk.
Evening: Drive 40 minutes to Oliver Lee Memorial State Park; set up camp

Return to Brown University

Day 9: Saturday, March 29

Morning: Eat a pancake breakfast; clean up the campsite and rental cars
Morning: Drive 1 hour 30 minutes to El Paso International Airport
Afternoon: Fly Delta Air Lines flight 2136 from ELP to ATL (duration 3 hours 12 minutes)
Evening: Fly Delta Air Lines flight 772 from ATL to PVD (duration 2 hours 25 minutes)
Night: Arrive at the Providence airport, claim checked baggage, and return to GeoChem

Undergraduate Students:
Jeff Baum
Jonah Berkowitz
Raquel Bryant
Chris Carchedi
Lena Champlin
Camera Ford
Adam Gilbert
Alan Gorchov Negron
Greg Jordan-Detamore
Lydia Joukowsky
Rachel Kaplan
Allison Lawman
Oliver McLellan
James Napoli
Nick O'Mara
Gene Robinson
Bekah Stein
Marina Stevenson
Conor Sullivan
Klara Zimmerman

Graduate Students:
Sam Bova
Tabb Prissel

Professor:
Steve Parman

This book was designed by Greg Jordan-Detamore and organized by Greg Jordan-Detamore, Klara Zimmerman, and Allison Lawman.

This trip generously received funding from the Rhode Island Space Grant Consortium.

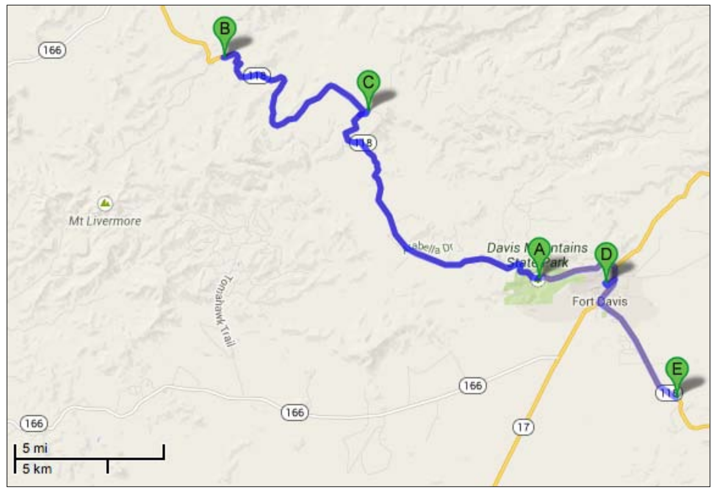
Saturday, March 22

Morning: Madera Canyon Trail (B)

The Madera Canyon Trail offers a glimpse into The Nature Conservancy's Davis Mountains Preserve, a unique sky island with plants and animals found nowhere else in the world.

The trail offers a moderate hike. Most of the trail is on sloping terrain. After crossing the Madera Creek, the trail winds through pinyon-oak-juniper woodlands to a scenic view of 8,378 foot Mount Livermore. The cliff tops in front of you offer a beautiful overlook of Madera Canyon. — *The Nature Conservancy*

Midday: McDonald Observatory (C)



The Visitors Center operates a set of specially filtered telescopes equipped with HD video cameras that allow us to bring live, safe views of the Sun into our multimedia theater. Your knowledgeable guide will discuss some interesting highlights about the history of the Sun, its formation, and what we expect the Sun to do over its expected 5-6 billion year remaining "lifetime". Assuming relatively clear skies, your guide will use the telescopes' remote controls to steer around a live view of the Sun showing and discussing various surface features typically visible. On not so clear days, video and stills from clear days as well as from the web are used. This is typically a 45-50 minute program. ...

Your guide for the Solar Viewing is also your guide for the Tour immediately following the Solar program.

The Tour typically begins at the overlook to the south of the 107" dome. From there, peaks over 80 miles way can be seen. At this location, your guide will typically discuss some of the history of the Observatory and why this location was chosen for an astronomical research facility. After pointing out some of the peaks in the area, the tour typically then proceeds to the ground floor lobby of the 107" dome where some of the history of that telescope is discussed. After a climb up four flights of steps (an elevator is available for those who shouldn't or can't take the steps .. your guide with discuss access to the elevator) the tour continues with descriptions of the parts of the telescope seen at the 5th floor level, demonstrations of the telescope motions, etc.

After visiting the 107" telescope, your guide will provide instructions for continuing with the tour at the summit of Mt. Fowlkes and the Hobby-Eberly Telescope. At the HET, you'll learn more about that telescope's unique, low-cost (for a world class telescope, at least) design and about new cutting-edge research projects for which the HET is currently being re-engineered.

— *McDonald Observatory*

Midday: Fort Davis National Historic Site (D)

A brief stop here will give us a chance to rest while taking in some of the local history.

"Fort Davis is one of the best surviving examples of an Indian Wars' frontier military post in the Southwest. From 1854 to 1891, Fort Davis was strategically located to protect emigrants, mail coaches, and freight wagons on the Trans-Pecos portion of the San Antonio-El Paso Road and on the Chihuahua Trail." — *National Park Service*

Afternoon: Chihuahuan Desert Nature Center (E)

In 1978, the board and supporters of the Chihuahuan Desert Research Institute purchased 507 acres of rolling grassland, oak-studded hills, and shady canyon springs in the foothills of the Davis Mountains. Here, they established the Chihuahuan Desert Nature Center. For over three decades, visitors have explored this tranquil and visually stunning site, taking the opportunity to reconnect with nature and discover the desert.

Highlights of the Nature Center include a desert botanical garden, 1400 sq. ft. cactus and succulent greenhouse, over 3 miles of hiking trails, and interpretive exhibits. Both formal and informal education programs for children and adults are offered throughout the year. — *Chihuahuan Desert Research Institute*

Afternoon: Drive to Big Bend

Our drive to Big Bend National Park will take approximately 2.5 hours. On our way into the park, we will stop at the Fossil Bone Exhibit.

We will set up camp at Chisos Basin Campground in the center of the park.

Big Bend

Sunday, March 23
Monday, March 24
Tuesday, March 25
Wednesday, March 26

Big Bend National Park is a Chihuahuan Desert Nature Preserve that will introduce us to Southwestern geology. We'll explore volcanism, rock deformation, dinosaur fossils, and landscapes modified by the erosive power of the Rio Grande River.

NATIONAL PARK SERVICE

Big Bend National Park

By National Park Service

The author Fredrick Gelbach describes these borderlands aptly when he calls them "a carpet of interacting plants and animals deftly woven on a geologic loom." This statement conjures up images of looming mountains, stark desert landscapes, and a ribbon of water slicing through it all. And, indeed, this is what Big Bend and the surrounding area is—a diverse natural area of river, desert, and mountains, and a land of extremes—hot and cold, wet and dry, high and low. To wander the shimmering desert flats, to ascend the rimrocks of the desert mountains, to float the canyons of the Rio Grande—to be "on the border"— is to experience sights and sounds and solitude unmatched elsewhere.

In the heart of Big Bend National Park lie the Chisos Mountains, mountains born of fire during volcanic eruptions and intrusions 40 - 60 million years ago and exposed by the incessant forces of erosion. As you ascend the slopes of the Chisos, the thorns of the desert give way to evergreens like pinyon pine and juniper, and oak trees appear. Some surprising species living at the very limit of their ranges can be found in the higher, moister areas—bigtooth maple, quaking aspen, and Douglas fir. Although only 2% of the park is woodland, this area draws people like a magnet—especially in the summer—as daytime temperatures are usually about 20 degrees cooler than by the river. Here, in this mountain island surrounded by a desert sea, one can find flora and fauna unique to the Chihuahuan desert and some unique to Big Bend.

Whether hiking to gain a glimpse of the colima warbler, a much sought after bird by birdwatchers which winters in Mexico but is only seen in Big Bend here in the U.S., or to get a coveted look at a mountain lion or black bear, or to see the towering displays of the century plants in bloom—whatever the reason, visitors to the Chisos are struck by the contrasts the mountains provide—prickly pear and pine tree side by side, snow-covered cactus, and a waterfall flowing through a feature called the "Window" to the desert below.

It's been said that if the Chisos Mountains are the heart of Big Bend, then the desert floor is its soul. Ninety-eight percent of the park is desert, and like the mountains, the desert is a land of contrasts—a place where you can touch 400 million year old rocks with one hand, and a day-old flower with the other, where extremes of temperatures of 50 degrees or more between dawn and mid-day are not uncommon.

Big Bend's desert landscape itself is a study in contrasts—mesas, mountains, and dikes formed by volcanic activity, limestone ridges and cliffs formed 100 - 200 million years ago when shallow seas covered the area, and ever-changing arroyos, dry most of the year, but subject to violent flash flooding during summer rains. Water is truly the "architect" of the desert, as its presence or absence determines the way the desert looks, its plant and animal life, and the way humans have been able to use it through time. Lest you feel a pang of pity for the roadrunners, coyotes, or javelinas you may encounter living in this harsh land, don't—the adaptations that allow these creatures to live here are no less than amazing, and, in fact, even allow them to thrive. Instead, think of the land not as burdened by its lack (or in some months, abundance) of water, but rather as blessed. It is this cycle of wet and dry, so unfamiliar to those from wetter climates, that allows us our spectacular display of bluebonnets, yucca blossoms, and other spectacular wildflowers. Our water, although paltry to some, is enough—for a desert. Any more, and this place would be something very different.

The one location where you can count on seeing water in Big Bend is along the Rio Grande—an oasis that's been called the "lifeblood" of Big Bend. To drift through the majestic canyons of the Rio Grande with your oars touching two countries at the same time is to span time and space. Although the river, as the boundary between the United States and Mexico, looks like a solid line on the maps of the area, it is always changing, always going somewhere, and it takes us along on its current opening our eyes to a panorama of towering cliffs, brilliant bird life, and grassy vegas or beaches. As you drift with the current, you may see both the expected and the unexpected—the black phoebe flitting to and fro, a turtle - a Big Bend slider, perhaps—perched on a rock slipping with a quiet "plop" into the water, swallows darting into their mud-nest "apartments", or a peregrine falcon stooping to its prey. And then, at night, the display of stars, connecting you to other parts of the world as well as to other worlds.

A visit to Big Bend provides opportunities for us to escape to isolation seldom found in daily life—a chance to experience unfamiliar creatures and plants, an endless expanse of stark desert and mountain scenery, and the vast space, heat, and silence that is the essence of the desert. Big Bend has been described as harsh, isolated, lonely, parched, and desolate, but for some people, in all of these adjectives—in the remoteness and isolation—lies the fascination of the Chihuahuan desert. From the earliest days of human occupation, people have recognized the value of this rugged land that the Spanish called "El Despoblado," and as a result, the people and the land have had a long partnership here.

Paleontology

By James Napoli

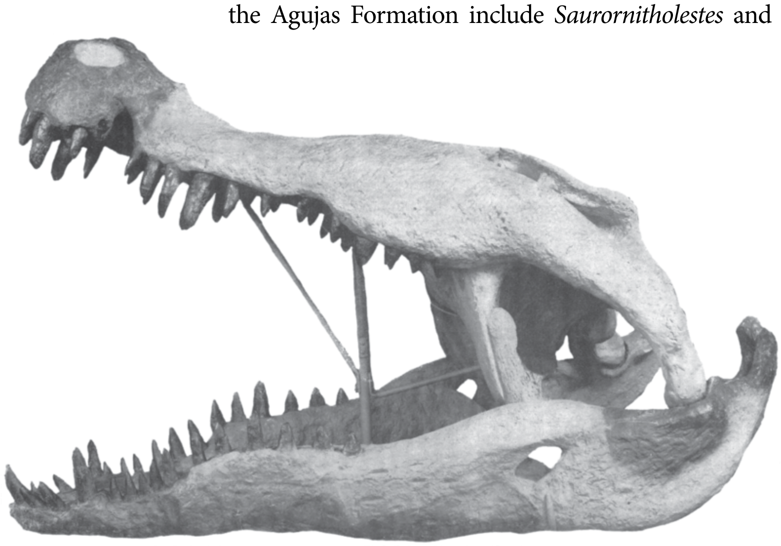
The state of Texas has three major Mesozoic fossil locations. The oldest remains, from the late Triassic 200 million years ago, are found in the Texas Panhandle, while the state's center contains rocks dating to the Middle Cretaceous, 100 million years ago. However, the most extensive and spectacular Texan Mesozoic fossil deposits come from Big Bend National Park, from Cretaceous formations in that span a time period of 35 million years.

Big Bend's Mesozoic fossils come from three rock formations. The oldest of these, the Boquillas Formation, is a shallow marine limestone approximately 100-95 million years old that formed when Big Bend was flooded by the Western Interior Seaway. One of the many fossils it has yielded is a 30 foot long sea-dwelling reptile called *Mosasaurus*, closely related to modern day varanid lizards such as the Komodo Dragon.

Skeletal diagram of *Tyrannosaurus rex*. The famous theropod is known from many fossil sites throughout North America, including Big Bend.

As the Western Interior Seaway retreated, the environment at Big Bend changed drastically. A warm and shallow marine environment gave way to humid coastal forests and swamps. This change is reflected in the region's stratigraphy - the Boquillas limestone transitions upward to the mudstones and sandstones of the Agujas Formation, which was deposited 80-75 million years ago. A relatively thin layer of marine shale, the Pen Formation, separates the two. Over 70 species have been discovered so far in this formation, including dinosaur remains. The most common Aguja dinosaur is the horned dinosaur *Chasmosaurus mariscalensis*, which was recovered in a bone bed of 10-15 individuals. Other dinosaur genera known from the Agujas Formation include *Saurornitholestes* and *Richardoestesia* (maniraptoran dinosaurs similar to *Velociraptor*), *Stegoceras* (a dome-headed dinosaur), *Edmontonia* (an armored dinosaur), and *Agujaceratops* (another horned dinosaur).

One of the most significant of the Agujas genera is not a dinosaur, but a giant crocodile known as *Deinosuchus riograndensis*. Known mainly from two-meter long skulls, it is estimated to have reached an adult size nearing 50 feet long and 5.5 metric tonnes in weight. Scars on Aguja dinosaur bones indicate that *Deinosuchus* preyed on them, likely using ambush tactics in a manner similar to Nile crocodiles hunting zebras and wildebeest.



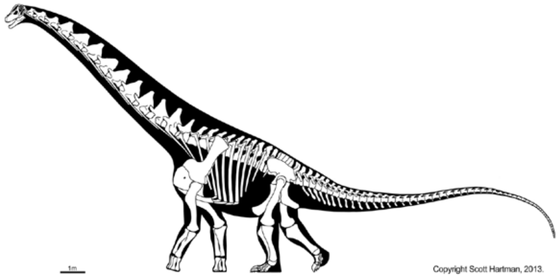
WIKIMEDIA COMMONS

Skull of *Deinosuchus riograndensis*, as exhibited at the American Museum of Natural History for 50 years. In life, the animal was 45 feet long and weighed approximately 4 metric tonnes.

Big Bend continued to dry in the Late Cretaceous. By 75-60 million years ago, the Western Interior Sea was completely gone from North America, and a semiarid floodplain environment had replaced the forests and swamps that had occupied Big Bend. This environment is preserved in the mudstones of the Javelina Formation. While its fossil yield does not match that of the Aguja Formation, the Javelina Formation has afforded over 20 species of dinosaur that lived in the time directly preceding the catastrophic impact that caused their extinction. Many of the species found in this formation, such as two species of horned dinosaur *Torosaurus* (*T. latus* and *T. utahensis*) and the famous *Tyrannosaurus rex*, represent the largest members of their clade to ever evolve.

Alamosaurus sanjuanensis, a long-necked sauropod dinosaur, is of particular significance to Big Bend and the Javelina Formation. While the first remains of the species were unearthed in New Mexico, they belonged to an individual of relatively small size for a sauropod - approximately 15 meters long. In 1999, a graduate student at the University of Texas at Dallas stumbled across some protruding bones while exploring Big Bend. Excavation revealed a partial pelvis and ten articulated neck vertebrae, which were so massive that they had to be airlifted from the dig site by helicopter. The Big Bend *Alamosaurus* has been estimated at 30 meters long, twice the size of the original New Mexico specimen.

Not all of the giant fossils from the Javelina



Skeletal diagram of titanosaur sauropod *Alamosaurus sanjuanensis*. An individual, discovered in Big Bend in 1999, measured 100 feet long and weighed nearly 50 tonnes.

Formation belong to dinosaurs, however. In 1971, a graduate student and his professor from the University of Texas at Austin discovered long, hollow arm bones exposed in a dry creek bed. After examining them, they concluded that they were the wings of an enormous flying pterosaur (a group of archosaurs closely related to - but distinct from - dinosaurs). They named it *Quetzalcoatlus nothropi*, after the Aztec snake god Quetzalcoatl. Although no body was found, later searches found a series of complete, though much smaller, members of the same species. The initial arm bones belong to an individual estimated to have a nearly 40 foot wingspan, making the Big Bend pterosaur the largest flying animal known in the fossil record.

Big Bend National Park has yielded an exceptional quantity and variety of fossil Mesozoic vertebrates, from marine reptiles to birdlike dinosaurs to immense soaring pterosaurs. The Aguja and Javelina Formations in particular have proved extremely valuable, giving an important insight into the composition of late Cretaceous terrestrial ecosystems, and both have been studied extensively. Few other locations have the ability to offer such a complete snapshot of life in the Mesozoic world.

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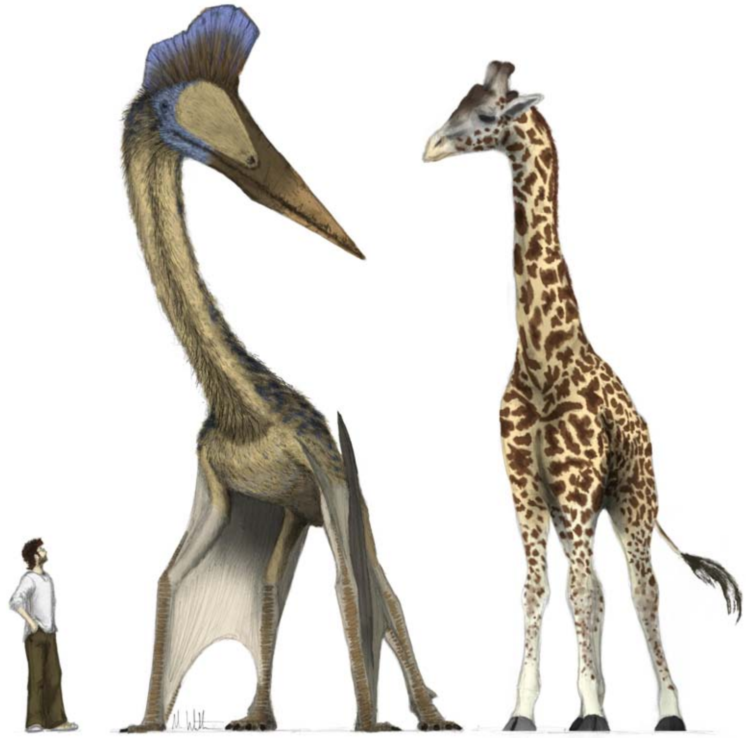
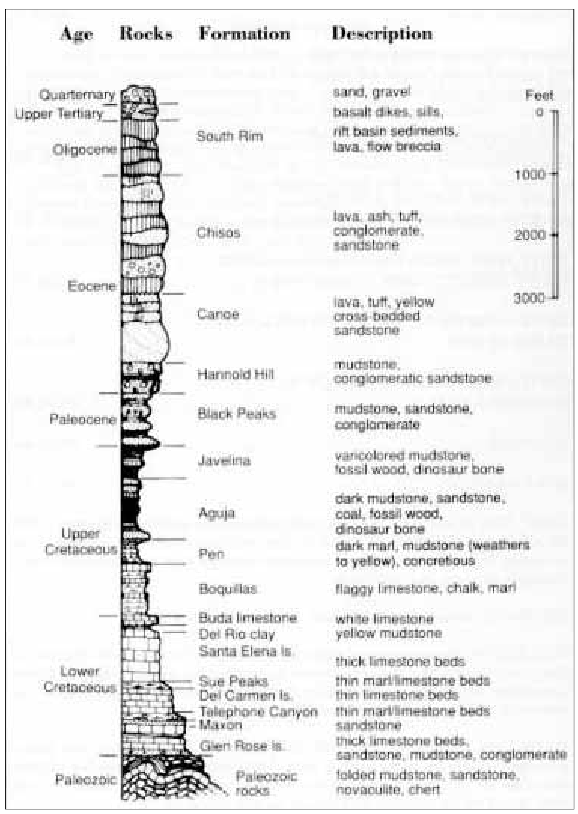


HOPKINS MEDICINE

***Quetzalcoatlus nothropi*, the Big Bend pterosaur, with a giraffe and a human for scale. *Quetzalcoatlus* is the largest known flying organism in the history of the Earth.**



UT DALLAS

Stratigraphic column of Big Bend, showing extensive unconformity from the Paleozoic to the Lower Cretaceous.

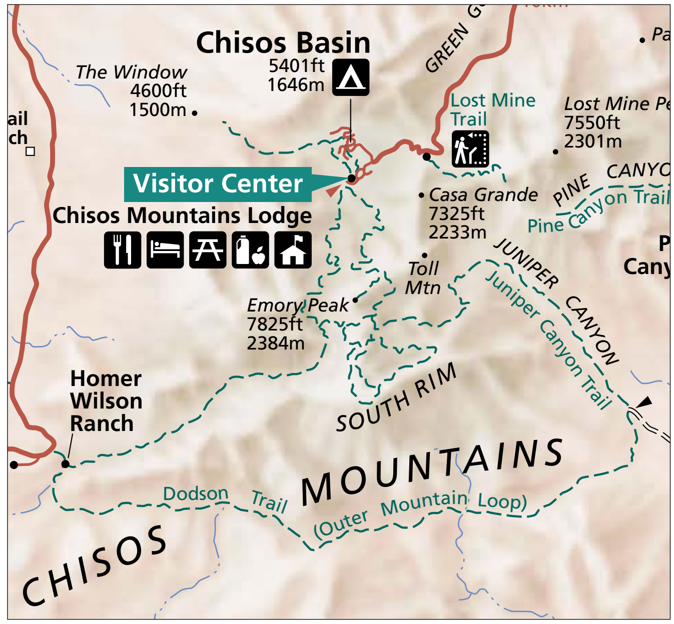
Big Bend

Sunday, March 23

Morning: Emory Peak Trail

This mountain trail goes past spectacular vistas and leads to the highest peak in the park. The last 25 feet requires a scramble up an exposed rock face.

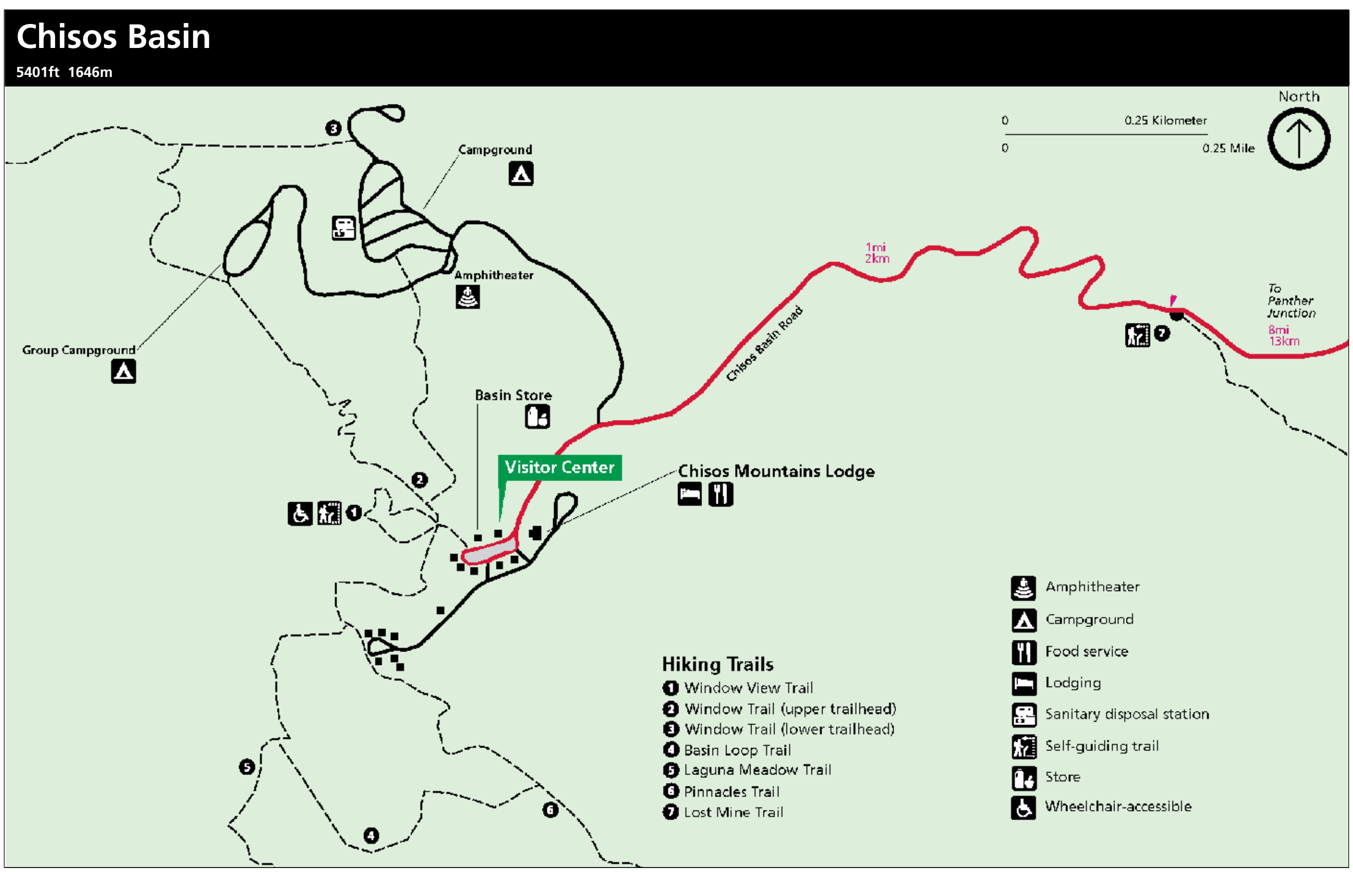
"A hike to the summit carries you through layers of Cretaceous formations embedded with an assortment of snail, clam, and oyster shell fossils; higher up only lava and extrusive rocks appear. Once upon the summit proper, you are standing on a cap of lava that cooled so quickly it appears glassy. Here, jointing occurred, breaking the rock into large vertical blocks. Once of these is the informally named 'water tower,' a remnant of rock that remained after erosion weathered the adjacent rock away." — *E. Dan Klepper ("100 Classic Hikes in Texas")*



Evening: Window View Trail

After eating dinner, we will head to the 0.3-mile Window View Trail, which offers great views of The Window.

Sunset is at 8:05pm.



NATIONAL PARK SERVICE

After hiking the Pinnacles Trail for 3.5 miles, the Emory Peak Trail proper splits off as a 1-mile spur.

Wildlife of Big Bend

By Jonah Berkowitz

There are 4 chief communities of vegetation (biomes) in Big Bend:

1. Chihuahuan Desert scrub: Occupies the largest proportion of the park, and is characterized by creosotebush as well as yucca, agave, and candelilla (used for wax production in the early 1900s). The desert bursts into spectacular bloom twice a year, with the annual monsoon season in late summer and again during the spring after minimal winter precipitation. The spring will feature the cactus, yucca, and ocotillo blooms. *Cactuses* represent an especially good adaptation to the desert's harsh living conditions, growing with no leaves and sharp protective spines. Big Bend hosts the greatest diversity of cactuses of any National Park; look for everything from pricklypear to pineapple and strawberry cacti. Despite their extremely spiny bases, *agaves* are not cactuses because they have leaves. Some agaves are known as century plants because it takes them 100 years to reach maturity and flower. When agaves reach maturity, they die and the next generation sprouts from around the dead one, so look out for agaves in circular groups! The *lechuguilla* agave is unique to the Chihuahuan Desert, and was heavily used by Native Americans, especially for making soap.

Sotol resembles the agaves but has flattened, barbed leaves at its base.

The ocotillo in bloom.

2. Desert Grassland: Occupies mid-level elevations (3000ft-5000ft); low areas of the high mountains or the high areas of low mountains *Chinograss* and stotol are the 2 dominant species, although overgrazing has heavily altered grass diversity; invasive species like Bermuda are now common. Chinograss used to cover the hills of Big Bend country but became the primary food source for settlers, tradesmen and their livestock. It is still common, but not in its previous grandeur.

A stand of giant dagger yuccas, unique to the Big Bend area; they can reach a height of 25 feet. Yuccas are closely related to lilies and are ubiquitous in the southwest. Native Americans utilized the entire plant, from the roots to the fruit, for everything from basket making fibers to tequila production.

3. Pinyon-juniper-oak woodland: Occupies most of the Chizos mountain slopes, interspersing with grasslands at around 3500 ft. and becoming denser at greater heights.

4. Ponderosa pine-Douglas fir-Arizona cypress forest: Occupies the upper reaches of the Chizos mountains. This biome is not particularly common in Big Bend and is only found near peaks where ideal soil content and moisture exist. It is greatly endangered by current global warming and drought. *Ponderosas* have a wonderful vanilla, cinnamon smell so you'll know if they are nearby.

Animals

Because of its various biomes, Big Bend is host to a fantastic diversity of animal life. For example, at least 450 bird species inhabit—or migrate through—the park, more than in any other National Park. Black and turkey vultures are common, often mistaken for golden eagles and several other large hawks which are also present. Peregrine falcons thrive in the high cliffs of the Chisos Mountains and Rio Grande. Reptiles are common in Big Bend, and include 31 *snake* species and 22 *lizard* species. Rattlesnakes, bullsnakes and patchnose snakes are common. Lizards play an important role in keeping insect populations under control, while they themselves are an important food source for birds. The greater roadrunner, a type of cuckoo that feeds on lizards, can often be seen racing down roads in front of cars before jumping off into the brush. Collard and leopard lizards

Creosote bush. This shrub is characteristic to the desert floor; it grows very slowly, and can take a decade to reach a height of a couple feet. In addition, its circle of roots excretes a substance that is poisonous to other plants, so that it can protect all the available water for itself.

Greater Earless Lizard. Males are generally larger with more vivid colorations.

can measure over a foot in length, and are known to feed on small snakes! The yucca night lizard inhabits dead, moist yucca plants for shelter.

Mammal species found in Big Bend include 20 species of bats, including the *Mexican Long-nosed Bat*, an endangered species key to cactus pollination. This species is only present in the United States at Big Bend, where there is a colony in the Chisos Mountains. Black bears, mountain lions, javelinas, and coyotes are also present. *Black bears* became extinct in the park but returned in the 1980s and exist in small numbers in the Chisos. *Javelinas* are found throughout South and Central America, but are common in Big Bend country. They resemble wild pigs but are actually very different, possessing 3 toes instead of 4, a short tail, and a complex stomach system. They are herbivores, relying on pricklypear pads during the dry seasons, and herds of 10-20 are often seen around campsites in Big Bend. They are known to be quite adept at intruding campers' food supplies. In the early 1900s, their hides were shipped to New England and Europe for gloves and hairbrushes. *Mountain lion* sightings are rare at Big Bend, and 90% occur along park roads. Animals such as pronghorn, prairie dogs, wild turkey, Mexican gray wolf, and bighorn sheep were more common before the ranching and settlement in the Big Bend country.

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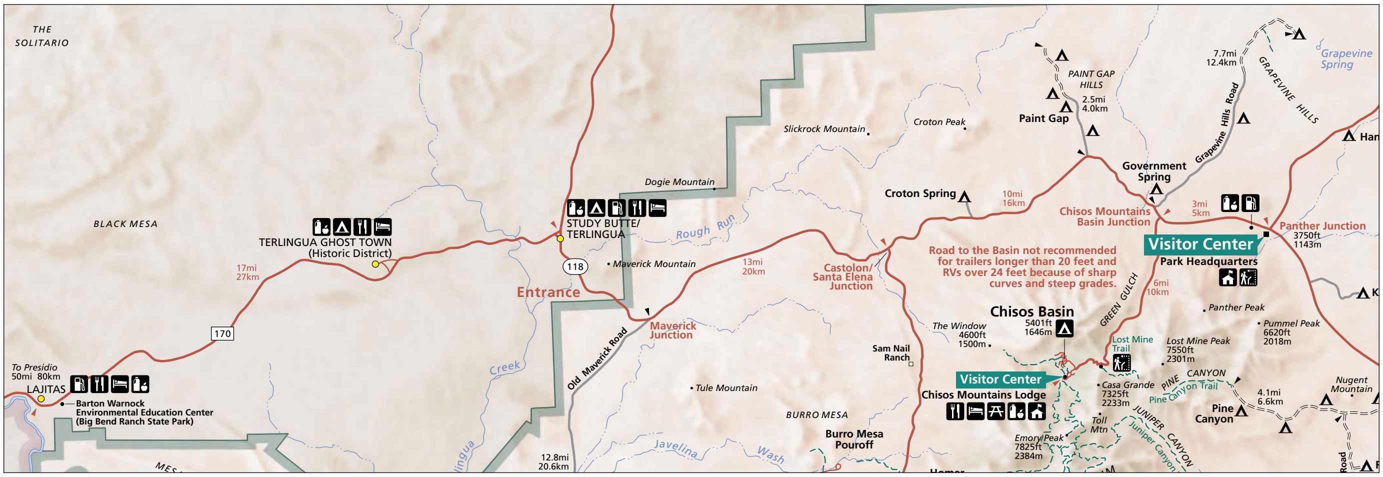
The non-poisonous Red Racer is the most commonly seen snake in Big Bend. You might see it stretched across an entire road lane.

Tuesday, March 25



Morning: Lost Mine Trail

Early Spanish explorers of the Southwest discovered and developed many mines. That we know of, no mine exists here today, but legend tells of a rich mineral deposit, kept so secret that those who worked the mines were prisoners, blindfolded on their way in and out each day. The trail is moderately strenuous and has beautiful views.

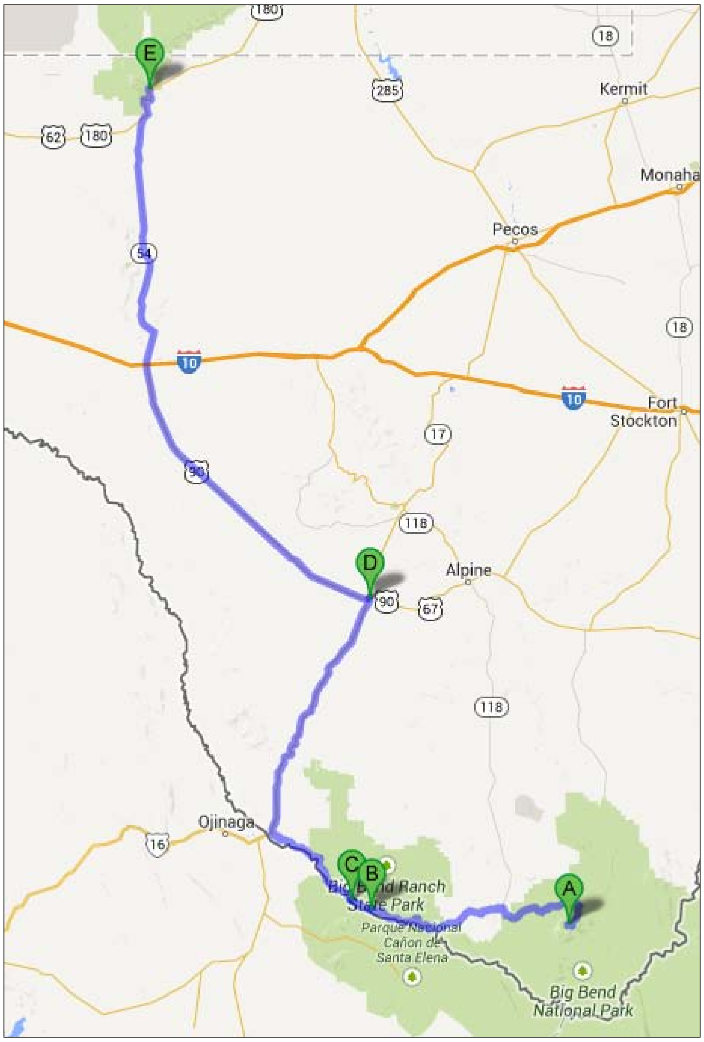
Afternoon: Terlingua Ghost Town and Barton Warnock Environmental Education Center

At Terlingua, we will walk around and explore the old ghost town. The Environmental Education Center has self-guided tours and a two-acre desert garden.

Afternoon: Grapevine Hills Trail

This trail leads to a group of balanced rocks in the heart of the Grapevine Hills. Initially, the trail follows a gravel wash, then climbs steeply for the last quarter mile into the boulders. Grapevine Hills is an exposed laccolith, with many giant, rounded boulders that are tempting to climb, but watch for snakes.

Wednesday, March 26



Morning: Travel to Big Bend Ranch State Park

After packing up camp we will drive 2 hours to Big Bend Ranch State Park.

Morning: Closed Canyon Trail and Hoodoos Trail (B, C)

The 0.7 mile (one-way) Closed Canyon trail leads to a narrow and deep slot canyon that cuts through the Colorado Mesa and the Rio Grande River. The canyon has been carved through welded tuff, a volcanic eruption of ash, liquid and gas. A small arroyo leads directly into the canyon. The Hoodoos Trail is an easy one mile loop that will take approximately one hour to complete. “Hoodoos” is defined as a uniquely shaped rock that has been formed over time by weathering.

Afternoon: Travel to Marfa, TX (D)

We will drive 2 hours to Marfa and do our second round of grocery shopping.

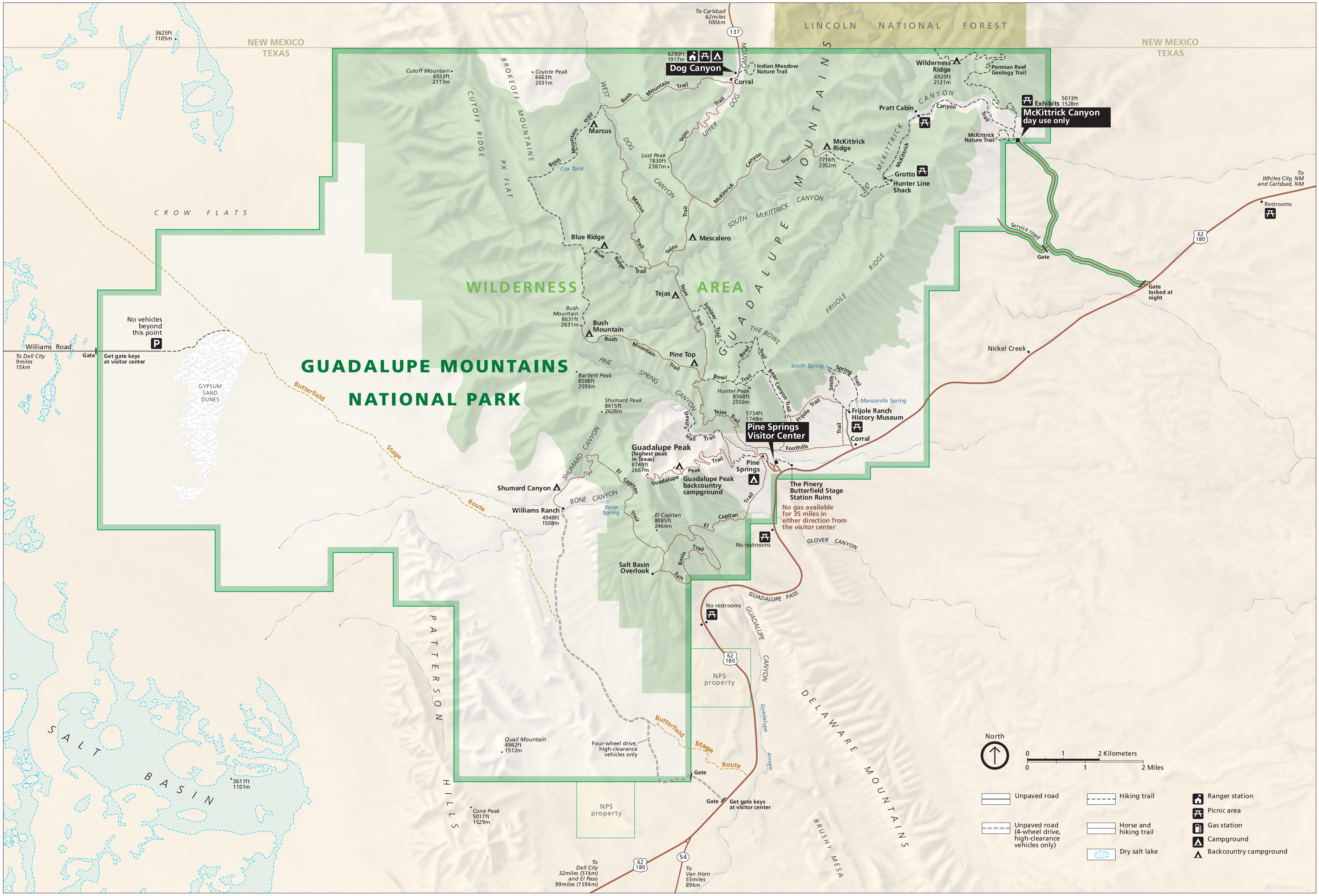
Afternoon: Travel to Guadalupe Mountains National Park (E)

We will leave Texas and drive 2 hours 15 minutes to Guadalupe Mountains National Park. We will set up camp at Pine Springs Campground.

Guadalupe Mountains

Thursday, March 27

The Guadalupe Mountains are the exposed remains of an ancient barrier reef that lined the perimeter of the Permian basin in modern-day eastern New Mexico and western Texas. Here we will hike the Permian Reef Geology Trail and check out Carlsbad Caverns, a limestone cave network with some of the largest and deepest caves in the world.


GUADALUPE MOUNTAINS NATIONAL PARK
WILDERNESS AREA
NEW MEXICO
TEXAS
LINCOLN NATIONAL FOREST
GUADALUPE MOUNTAINS
DELAWARE MOUNTAINS
BRUSHY MESA
PATTERSON HILLS
SALT BASIN
CROW FLATS
BROKEOFF MOUNTAINS
CUTOFF RIDGE
PX FLAT
GYPSUM SAND DUNES
Dog Canyon
6290ft 1917m
Corral
Indian Meadow Nature Trail
McKittrick Canyon day use only
Exhibits 5013ft 1528m
McKittrick Nature Trail
Permian Reef Geology Trail
Pratt Cabin
Grotto
Hunter Line Shack
Pine Springs Visitor Center
Pine Springs
Guadalupe Peak backcountry campground
Frijole Ranch History Museum
The Pinery Butterfield Stage Station Ruins
No gas available for 35 miles in either direction from the visitor center
No restrooms
Restrooms
Guadalupe Peak (highest peak in Texas) 8749ft 2667m
El Capitan 8085ft 2464m
Hunter Peak 8368ft 2550m
5734ft 1748m
Bush Mountain 8631ft 2631m
Shumard Peak 8615ft 2626m
Bartlett Peak 8508ft 2593m
Lost Peak 7830ft 2387m
McKittrick Ridge 7716ft 2352m
Wilderness Ridge 6920ft 2121m
Coyote Peak 6663ft 2031m
Cutoff Mountain 6933ft 2113m
Williams Ranch 4948ft 1508m
Quail Mountain 4962ft 1512m
Cone Peak 5017ft 1529m
3625ft 1105m
3611ft 1101m
Marcus
Blue Ridge
Mescalero
Tejas
Pine Top
Shumard Canyon
Salt Basin Overlook
Smith Spring
Manzanita Spring
Bone Spring
Cox Tank
Butterfield Stage Route
Williams Road
No vehicles beyond this point
Get gate keys at visitor center
Gate
Gate locked at night
Nickel Creek
Service road
Four-wheel drive, high-clearance vehicles only
NPS property
To Carlsbad 62miles 100km
To Whites City, NM and Carlsbad, NM
To Van Horn 55miles 89km
To Dell City 32miles (51km) and El Paso 99miles (159km)
To Dell City 9miles 15km
North
0 1 2 Kilometers
0 1 2 Miles
Unpaved road
Unpaved road (4-wheel drive, high-clearance vehicles only)
Hiking trail
Horse and hiking trail
Dry salt lake
Ranger station
Picnic area
Gas station
Campground
Backcountry campground

Thursday, March 27

NATIONAL PARK SERVICE

We will begin by driving from Pine Springs Campground to Carlsbad Caverns. After cave tours and lunch, we will head to McKittrick Canyon for two hikes, followed by a return to camp.

Morning: Carlsbad Caverns

We will go on both self-guided and ranger-led tours of the caves at Carlsbad Caverns National Park.

"The basic tour through Carlsbad Cavern is the Big Room route, a one-mile, self-guided underground walk around the perimeter of the largest room in the cave, the Big Room. An audio guide notably enhances the tour. Taking approximately 1½ hours, this circular route passes many large and famous features including Bottomless Pit, Giant Dome, Rock of Ages, and Painted Grotto. Highly decorated and immense, the Big Room should be seen by all park visitors." *— National Park Service*

There are two ranger-led tours available: Kings Palace and Left Hand Tunnel. The Kings Palace tour is a 1.5-hour tour that goes to the deepest part of the cave accessible to the public; it is the most popular tour at Carlsbad Caverns. For the more adventerous, the moderately strenuous Left Hand Tunnel tour lasts 2 hours and "is a historic candle-lit lantern tour through an undeveloped section of the cave on unpaved trails."

Following the self-guided and ranger-led tours, we will eat lunch.

Afternoon: McKittrick Canyon Nature Trail

"An intermittent seep lies hidden within junipers, shrubs, and grasses that cling to this tiny ecosystem. Trailside exhibits describe common plants, reference wildland fire, and explain Permian Reef geology. The trail is 0.9 miles round trip, is rated moderate, but takes less than one hour to complete." *— National Park Service*

Afternoon: Permian Reef Geology Trail

"For serious geology buffs, this trail has stop markers that can be used with a comprehensive geology guide, available at the park's Headquarters Visitor Center. There are excellent views into McKittrick Canyon from the top of Wilderness Ridge." *— National Park Service*

Evening: The Pinery Trail

"Travel the short 0.75 mile path to the ruins of the old Pinery Station, once a favored stop on the original 2,800 mile Butterfield Overland Mail Route. Trailside exhibits describe Chihuahuan desert vegetation." *— National Park Service*

PETER JONES / NATIONAL PARK SERVICE

Speleothems are cave formations that form when surface water flows through cracks in limestone bedrock, drips into a cave opening and eventually evaporates, leaving a small calcite deposit behind.

Carlsbad Caverns

By Allison Lawman

The limestone bedrock of the Guadalupe Mountains in southeastern New Mexico hosts Carlsbad Caverns, a series of 118 caves which are 317 m deep and have a total length of over 48 km. The Caverns are among the largest and deepest in the world, and have resulted from millions of years of chemical weathering. Unlike the simple dissolution by acidic water that forms most caves, the process that formed Carlsbad Caverns is unique.

The vast Carlsbad Caverns cave network is situated within the 250 million year old Permian Capitan limestone. During this time, the Delaware Basin (which includes modern southeastern New Mexico) was closer to the equator and covered by a large and deep (549 m, 1800 ft.) inland sea. Over millions of years the accumulation and compaction of now extinct calcareous sponges, algae, bryozoans, and other marine microorganisms eventually became the thick (229 m, 750 ft) Capitan limestone. Once the inland sea dried up at the end of the Permian period, the reef was buried under other sediment layers until it was uplifted 20 million years ago when the Guadalupe Mountains started forming. The abundant oil fields below the Capitan limestone further indicate that the Delaware Basin was once a shallow marine environment.

Most caves form when rainwater and carbon dioxide from the atmosphere and soil combine to create carbonic acid. As acidic water moves down through soluble bedrock such as limestone, it enlarges fractures and faults and develops underground channels and cavities. However, geologic evidence indicates that Carlsbad Caverns formed in a different manner from the 'bottom up.'

Radioactive dating reveals that Carlsbad Caverns was one of the last caves to be dissolved in the Guadalupe Mountains. The last major uplift associated with the formation of the Guadalupe

PETER JONES / NATIONAL PARK SERVICE

Sulfuric acid dissolution formed the elaborate 48 km cave network of Carlsbad Caverns. The large chambers remained isolated from surface processes until approximately 1 million years ago when the natural entrance (above) formed.

Mountains occurred during the late Tertiary period 4-6 million years ago. During this period, sulfuric acid production occurred when hydrogen sulfide (H_2S) rich water migrated upward from the underlying oil-bearing strata and mixed with the oxygen in groundwater according to the following reaction:

$$H_2S + 2O_2 \rightarrow H_2SO_4 \rightarrow H^+ + HSO_4^-$$

Very large chambers developed in the Capitan limestone as sulfuric acid dissolved the carbonate along fractures and faults. Gypsum ($CaSO_4 \bullet 2H_2O$) is a byproduct of the sulfuric acid and calcium carbonate reaction, and thus the extensive deposits of this mineral in Carlsbad Caverns provide strong evidence of this unique cave formation process. Typical caves formed by carbonic acid dissolution are often characterized by the presence of lakes, waterfalls, and streams within their interior. However, the lack of flowing streams through Carlsbad Caverns further indicates that the sulfuric acid dissolution was not connected to surface processes. In fact, Carlsbad Caverns remained isolated from the surface until approximately one million years ago when the top of the cave collapsed and created the natural entrance.

In addition to the immense size of the chambers, the elaborate speleothems (cave decorations) are some of the most impressive features of Carlsbad Caverns. Air and water containing carbonic acid could readily circulate through the chambers following the formation of the natural entrance. When this acidic water reaches an open void in the cave it forms a drop and releases its carbon dioxide. The water becomes saturated with dissolved carbonate, so further evaporation causes a tiny amount of calcium carbonate to re-precipitate. Over time stalactites and stalagmites form on the cave ceiling and floor, and columns develop when these features meet. Other cave decorations include thin soda straws, sheet-like draperies, curved helectites, and bulbous protrusions called popcorn.

Guided and self-guided tours allow visitors to experience the ornate beauty of Carlsbad Caverns. Occupying 8.2 acres, the Big Room is the largest cave chamber in North America. The King's Palace and the Left Hand Tunnel tours further allow people to witness the elaborate speleothems and gypsum deposits. King's Palace goes through four highly decorated chambers and down 253 meters (830 ft) into the deepest portion of the cave accessible to the public.

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Speleothems as Climate Proxies

By Klara Zimmerman

Speleothems are cave deposits that form when groundwater drips into underground caverns and precipitates small amounts of calcite, which can eventually grow into large stalactite or stalagmite deposits. The drip formations that we will see on our trip to Carlsbad Caverns are not only beautiful, but also geologically interesting. The geochemical signatures, trace elements, and fluid inclusions in calcite cave formations can hold clues to past climates.

In order to understand the usefulness of speleothems, it is necessary to have a basic understanding of how stable isotope analysis of oxygen is used in paleoclimate reconstructions. Ocean water molecules that contain ^{18}O, a heavier isotope of oxygen, tend to stay in the ocean whereas ^{16}O, the lighter and more prevalent isotope, evaporates more readily. Some ^{18}O containing water does evaporate, but once in the atmosphere, it condenses and precipitates more readily than the lighter ^{16}O. Therefore, on its route from evaporation at the ocean near the equators toward the poles, atmospheric water vapor becomes relatively enriched in ^{16}O. Ambient temperature of an environment can be deciphered from the relative $^{18}O/^{16}O$ concentration in precipitation because water that condenses at colder temperatures will be relatively depleted of ^{18}O.

Although the $^{18}O/^{16}O$ relationship, commonly calculated as $\delta^{18}O$, is well-known in ice core paleoclimatology, it has more recently been applied to speleothems. There are many advantages of speleothem climate reconstructions compared to other climate proxies. First of all, they have the potential to provide long duration records because stalagmite deposits can date from thousands to millions of years ago. In addition, some speleothems can be accurately dated down to the calendar year or even the month using Uranium-Thorium decay. In some cases, speleothem lamina can even be counted like tree rings. Speleothems preserve relatively pure calcium carbonate (usually as calcite) precipitated from meteoric water and therefore are representative of surface environments. Finally, the caverns where speleothems are found have been protected from erosion and other potential causes of degradation for long periods of time.

However, like all climate proxies, speleothem stable isotope geochemistry has its weaknesses. Speleothem growth rates are not constant over the long term; they can vary considerably by season and can stop altogether when conditions are dry. Furthermore, variations in $\delta^{18}O$ values may be influenced by factors other than temperature including volume of rainfall, surface evaporation, and kinetic fractionation due to secondary evaporation in caves. Ideally, if uncertainties can be minimized, speleothems could serve as paleo-temperature proxies for long time period reconstructions. Due to the ambiguities mentioned, recent speleothem climate research has focused on minimizing uncertainty by measuring fluid inclusions that enable confirmation that the calcite was deposited in equilibrium with the source drip water.

New Mexico is one hotspot for speleothem climate research due to the prevalence of caves. Carlsbad Caverns, in particular, were the subject of a 2006 study, which took a core of a giant calcite column that contained a 164,000 year climate record. One advantage of Carlsbad Caverns as a study site is that the only water entering the caves percolates directly from the surface to groundwater to the cave, and moves a relatively short distance before it precipitates, minimizing errors associated with surface evaporation. Using the core, Brook et al (2006) were able to correlate the inferred temperature record with other Southwestern speleothem records and even far away ice cores that documented climate variations through several global glaciations. They found that global warm intervals were generally drier times for New Mexico, whereas wetter times were associated with global cooling. In sum, cave formations can link local climate to global climate events like glacial-interglacial cycles, and although many uncertainties still exist, efforts are being made to both increase precision of data collection and continually monitor present-day cave precipitation with local climate conditions to better understand the past.

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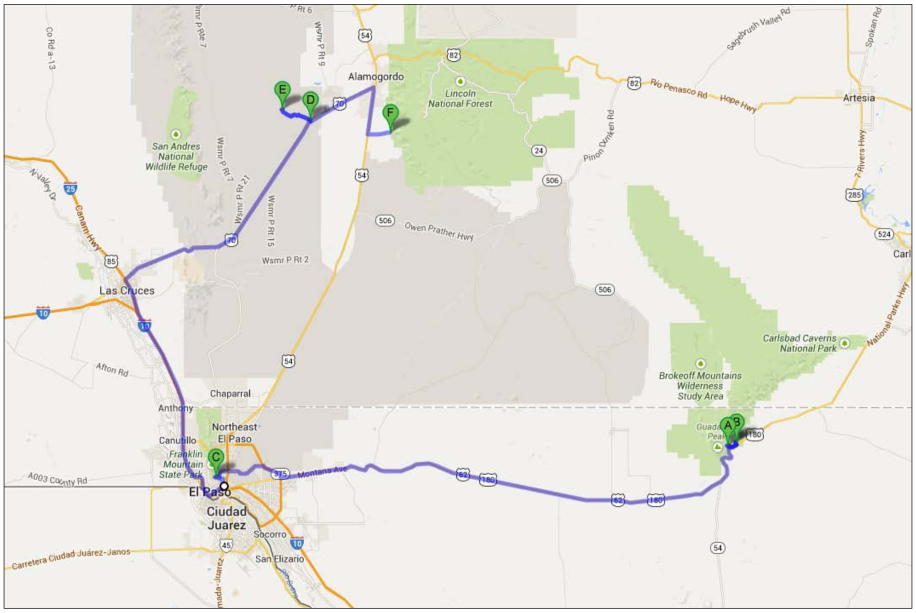
Friday, March 28



Morning: Smith Spring Trail (B)

Begin this hike at the trailhead sign. Look for birds, mule deer, and elk as you walk this loop trail to the shady oasis of Smith Spring. Take a break here and enjoy the gurgling sounds of the tiny waterfall before continuing around to sunny Manzanita Spring. Scars from wildland fires of 1990 and 1993 are evident along the trail. The trail is rated moderate, with a round-trip distance of 2.3 miles. Allow one to two hours.

— *National Park Service*

Midday: Wyler Aerial Tramway (C)

The Wyler Aerial Tramway at Franklin Mountains State Park features an aerial cable car situated on 195.742 acres of rugged mountain and rock formations on the east side of the Franklin Mountains.

Driving the paved road that snakes up the east side of the Franklin Mountains from the intersection of McKinley and Alabama streets is half the fun. The visitor arrives at a parking area that sits at an elevation of 4,692 feet. The view of El Paso, to the east, is magnificent. Here visitors can admire the beauty of cacti gardens or watch the tramway gondolas take off.

Visitors can purchase tickets at the tramway station to ride a gondola that will transport them to the top of Ranger Peak. The Swiss made gondolas travel on a 2,600 feet long, 1 3/8 inch diameter steel cable. While waiting to depart, the visitor can view part of the machinery and mechanism of the system through a window located on the south side of the base station. On the smooth ride to the top, the cabin attendant will describe the different cacti and rock formations along the way. Abundant wildlife, including reptiles, birds and insects, offer exciting viewing opportunities. The 4 minute ride soars above a vast canyon that is 240 feet deep in some places.

From Ranger Peak, 5,632 feet above sea level, the visitor can enjoy the view of 7,000 square miles encompassing three states and two nations. The tramway ride is a memorable experience offering a vista of the vastness and stark beauty of the southwest.

— *Texas Parks and Wildlife*

Afternoon: White Sands National Monument (D/E)

Potential activities include going on short hikes and sledding down the gypsum dunes. Hiking options include the Playa Trail, Dune Life Nature Trail, the Interdune Boardwalk, and the Backcountry Camping Trail.

— *National Park Service*

Evening: Oliver Lee Memorial State Park (F)

Located on the western edge of the Sacramento Mountains, this state park is where we will camp for our last night. There are showers!

WIKIMEDIA COMMONS

The steeper, West escarpment of the Sacramento Mountains, dipping towards the Tularosa Basin. We will have a similar view when we stay at Oliver Lee Memorial State Park

Sacramento Mountains

By Jeff Baum

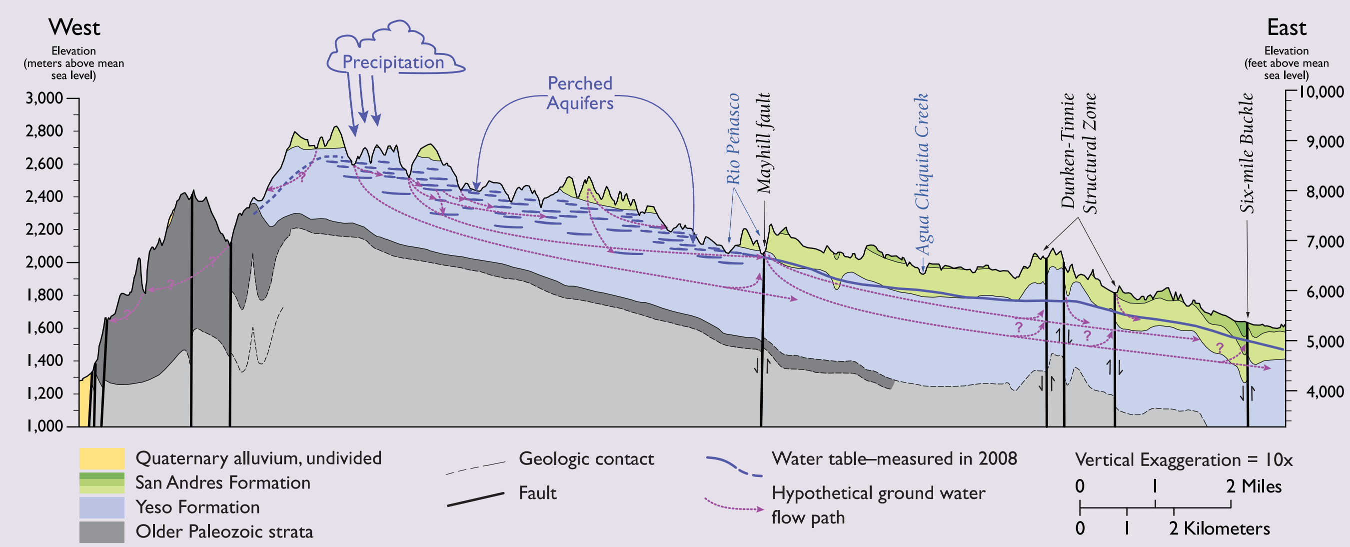
The Sacramento Mountains are located in southern New Mexico, directly east of Almogordo in Otero County. The range trends 85 miles north-south. The range forms part of the eastern border of the Tularosa Basin, which in turn is part of the Rio Grande rift valley. The mountains form a large cuesta. The western escarpment has a total relief of more than a mile and irregular topography typical of the Basin and Range Province. The shallow, 1-2 degree dipping eastern slope extends 80 miles from the crest to the Pecos River; this broad expansive terrain resembles the structures typically found in the Great Plains Province.

Stratigraphic history

The strata of the Sacramento Mountains have a composite thickness of 8,000 feet and range from Precambrian metamorphic rock to Cretaceous limestone. The exposed section consists entirely of Paleozoic rocks and has an average thickness of 5,000 feet. The Precambrian strata are slightly metamorphosed shales, siltstones, and quartzites that are intruded by igneous sills. These strata only outcrop towards the southern end of the range. An angular disconformity of approximately 10 degrees separates these strata from the thick, overlying Paleozoic sediments. These sediments are primarily marine carbonates deposited while the Permian sea covered the area. However, the Permian sea retreated and advanced periodically, leading to depositions of gypsum, shale and sandstone layers as well.

Formation of the mountains

Towards the end of the late Cretaceous, the Sacramento Mountains region was part of a large anticline composed of Paleozoic sediments. This anticline stretched across today's Tularosa Basin and San Andres Mountains. The Rio Grande Rift Zone led to the collapse of the anticline. The Tularosa block dropped over 5000 feet and the San Andreas and Sacramento Mountains were uplifted along normal fault zones. The Tularosa Basin has no drainage outlet; all of the sediment eroded from the Sacramento and San Andres Mountains is deposited



Cross section of the Sacramento Mountains from west to east, showing the steep west-facing slope and the broader, more shallow east-facing slope. Much of the ground water moves eastward toward the Pecos River and the Roswell Artesian Basin.

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in the basin. During the Pleistocene Ice Age, the region was significantly cooler and wetter; the basin was covered by Lake Otero. The water that drained from the San Andreas and Sacramento Mountains was rich in gypsum and other salts, so gypsum accumulated in the basin. The lake eventually dried up, leaving behind the massive gypsum deposits known as the White Sands National Monument.

Hydrology

The Sacramento Mountains receives most of the precipitation in Southern New Mexico. This precipitation seeps through fracture networks into shallow carbonate aquifers that supply water to several indigenous highlands communities as well as much of the industrial agriculture in the region.

However, there has been a marked decrease in groundwater levels and spring discharges over the past few decades attributed to both a change in climate and land use. Most of the groundwater in the Tularosa Basin originates as high-altitude snowmelt, but summer precipitation can contribute significantly to groundwater levels. Climate projections project both less future snowfall and more intense summer rainstorms. Thus, summer storms will become a progressively more important source of groundwater in the region.

As natural recharge rates continue to drop, artificial recharge techniques may be required for human withdrawal in the future. One technique being discussed in New Mexico is tree thinning. Tree thinning reduces the local canopy cover, increasing the amount of water that reaches the surface. Furthermore, the removal of some vegetation prevents excess water loss due to evapotranspiration. An ongoing study is analyzing whether tree thinning will actually increase groundwater levels in the Sacramento Mountains region.

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