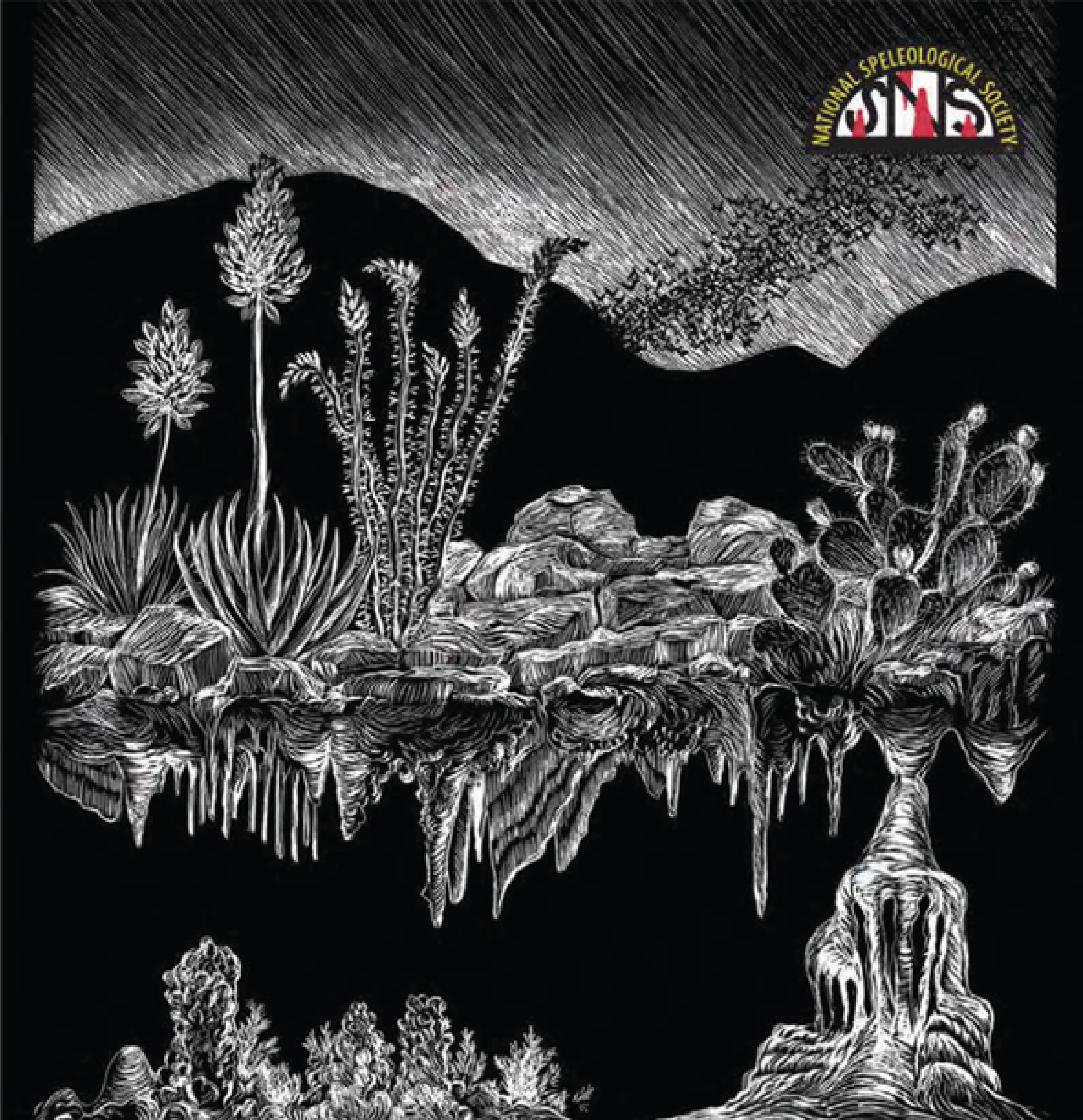

Red or Green 2017

74th Annual NSS Convention Guidebook

Rio Rancho, New Mexico

2017

NSS Convention Guidebook

Rio Rancho, New Mexico

74th Annual

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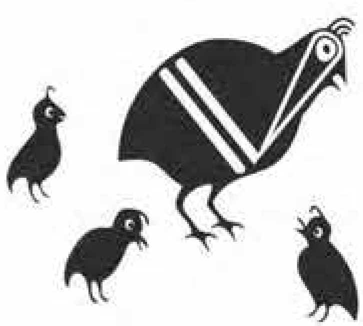
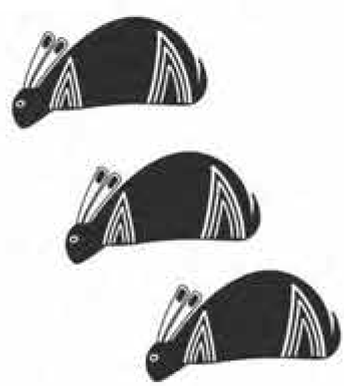


Edited-

Compiled by

Linda Starr



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This editor/compiler greatly appreciates all the help and contributions from everyone who has given effort to this extraordinary publication. I will try to name specifically some of the many who supported me in my efforts to compile a superior Guidebook to the 2017 NSS Convention in Rio Rancho, New Mexico.

Sam Bono was the first to contribute numerous articles describing caves in the Guadalupe Mountains, caves in the Sandia Mountains, local attractions and the surrounding towns close to our expected grand NSS event, the 2017 74th Annual NSS Convention.

Andy Komensky was one of the first to send a few of his original paintings that provide spice to the publication. Lois Manno is our outstanding cover and back cover designer. Michelle Wilson created our friendly Red or Green bat logo. Ron Maehler designed the Title Page art.

Then, Dave Decker generated an Annotated Geology Field Trip Guide. Gerald (Jerry) Atkinson gently adjusted Sam's cave accounts to add dimension to the descriptions with elevation, distance to travel, measurements and other elements and coordinated the maps. Carrin Rich and Garrett Jorgensen helped gather maps and descriptions of caves as well. Carrin also smoothly copy edited the entire production and helped keep me sane throughout this project. Gary Soule provided his historical collection of patches, postcards and brochures.

Certainly, it takes a village of cavers to put together a convention guidebook and this publication could not have happened without many hands. An attempt to list everyone I can think of who helped in some way to make this work possible is provided below. Any negligence to list someone is completely regretted.

Happy Trails – Linda Starr, Editor and Compiler

Photography
Sam Bensonhaver
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Geology Field Trip
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Artistry
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Lois Manno

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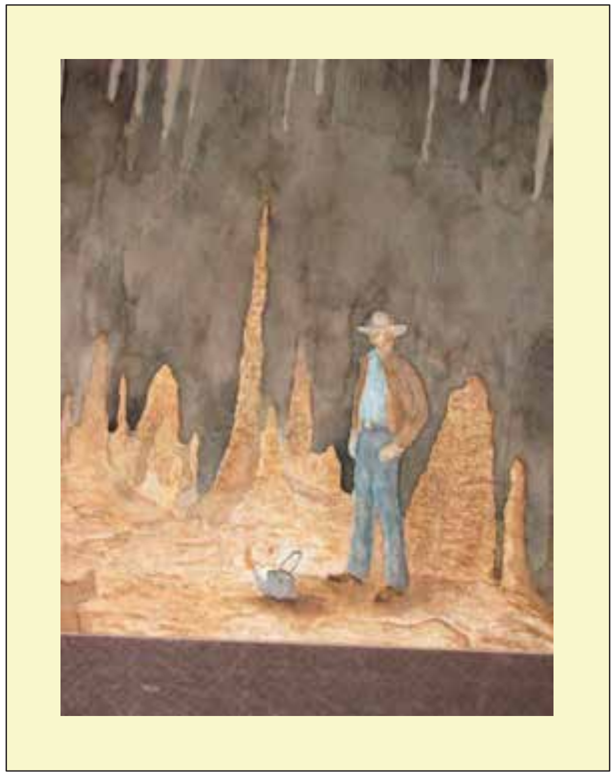
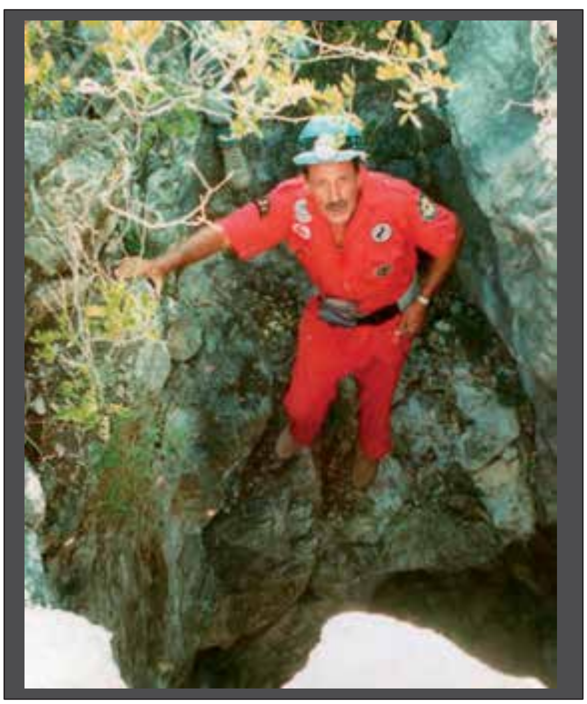


This 2017 NSS Convention Guidebook Is Dedicated to the Memory of Andy Komensky – Cave Artist Extraordinaire Mentor, Park Ranger, Friend & Curmudgeon



The "Mad Russian of New Mexico" at the entrance to KFFC, Komensky's Fantastic Fabulous Cavern. Photo courtesy of Peter Jones.

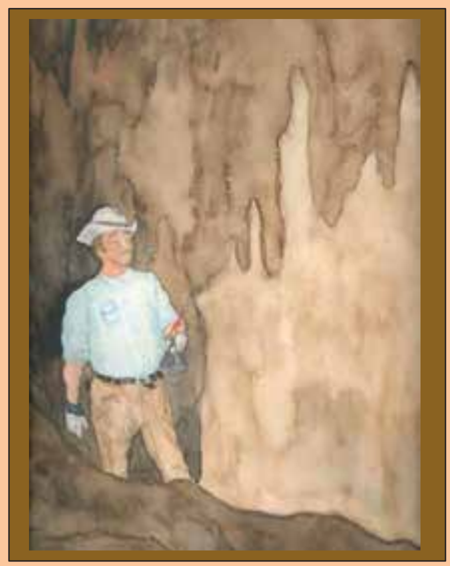
Watercolor Gallery by Andy Komensky

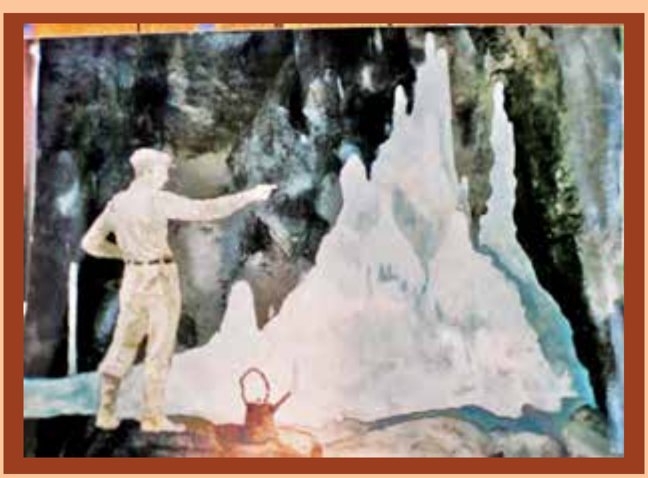
Harvesttime

Hawk Hole, a Carlsbad vicinity gypsum cave

High Lead in the Guads

Guano miner, Permanent collection, Carlsbad Cavern National Park



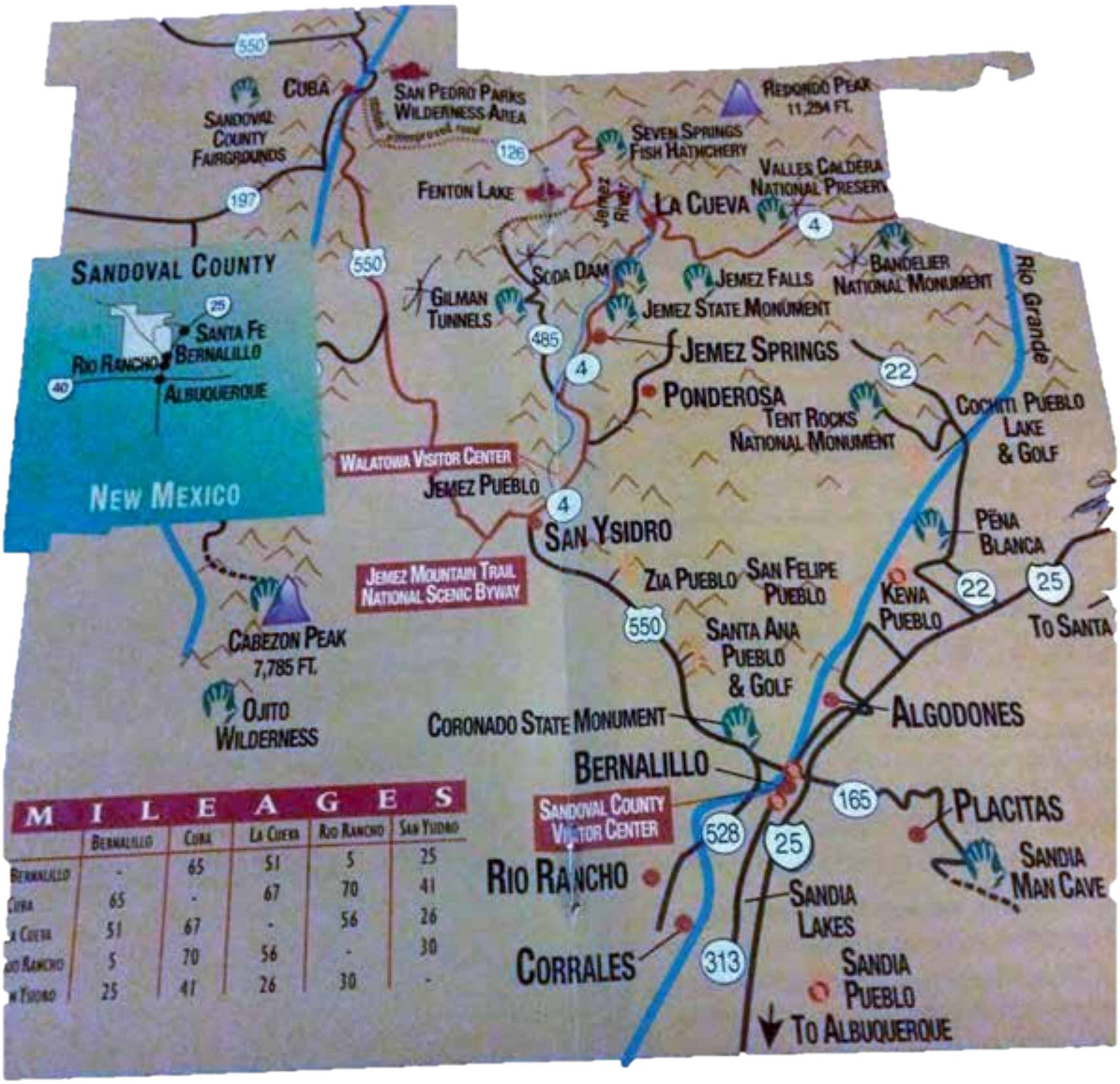


Andy passed away on March 29, 2017, before he was able to respond to an e-mail asking for titles on the many pieces of art he submitted for this Guidebook.

Albuquerque Skyline. Photo courtesy media.photobucket

Local Flavor

East side, Santa Ana Star Center, Rio Rancho from the air. Photo courtesy of RRCVB



	Bernalillo	Cuba	La Cueva	Rio Rancho	San Ysidro
Bernalillo	-	65	51	5	25
Cuba	65	-	67	70	41
a Cueva	51	67	-	56	26
io Rancho	5	70	56	-	30
n Ysidro	25	41	26	30	-

Historic Route 66

By Linda Starr

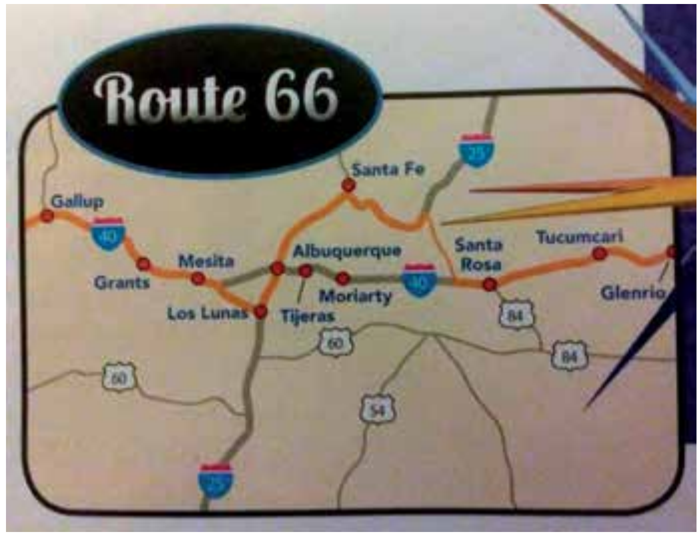


Photo courtesy of AAA *New Mexico Journey*

From the Texas/New Mexico state line just west of Glenrio and then to Tucumcari, billboards beckon Route 66 travelers to explore. On through to Albuquerque and west to Gallup (once a 400-mile journey), travelers can take advantage of the opportunity to follow the "Mother Road," as John Steinbeck christened Route 66 in his novel, *The Grapes of Wrath*. Part of the 1940 movie of this title was filmed along Fifth and Central Avenue in Albuquerque, as well as along the Pecos River in Santa Rosa to the east.

Santa Rosa is a spot that has risen from the ashes of a fire in 1994, when the Comet Drive-In burned down. Today the Comet II Restaurant serves a blue-plate special loaded with heritage chile from nearby Puerto del Luna. They say, "Hatch chile is no match."

In Moriarty, a futuristic retro rotosphere can be found in front of a shuttered El Comedor de Anaya's. The sphere is powered by a Model A car engine.

Along Route 66/NM 333, 2 miles west of Tijeras, rumble strips were cut into the eastbound lane. When vehicles drive at 45 mph, the tires rumble out the tune of "America the Beautiful." This was funded by the National Geographic Channel's "God Bless America" campaign for obeying speed limits and is one of a few "singing roads."

Highway 333 turns into Central Avenue at the eastern gates of Albuquerque and neon signs from the 1950s still advertise motels and restaurants along a 17-mile stretch. You will see La Puerta Motor Lodge and Kelly's Brew Pub (occupying a former 1939 Jones Motor Company building). The Route 66 Diner is known for its thick malts and chile cheese fries. After a couple more miles, park and stop downtown at the NW corner of 5th and Central to take in the astounding artistry of the Pueblo Deco-styled historic Kimo Theater, where movies and concerts still entertain locals of all ages. Visitors to downtown Albuquerque will find fascinating murals and sculptures galore throughout the Route 66 corridor. Albuquerque is currently considering a Route 66 renovation of the El Vado Motel, a 1937 Spanish Revival auto court, with a public-use space of restaurants, a tap room, a boutique motel and an amphitheater.

Continuing 25 miles west of Albuquerque, visitors come to Exit 140 along I-40 and will see the 1933 Rio Puerco Bridge with a section of Route 66 that still spans the dry bed below. The 66 Pit Stop gas station offers a $5 half-pound green-chile-cheese Laguna Burger, said to be one of the best in the state.

At Mesita, an eye-popping stretch of road winds through red rock cliffs. Then, at Dead Man's Curve, look for the bird of Owl Rock. In Grants, there's the New Mexico Mining Museum, where visitors can enjoy an underground tour and learn about uranium mining done here during the Cold War's Atomic Age.

Get more Kicks on Route 66 in Gallup, the gateway to Native America, where Navajo, Zuni and Hopi artwork is abundant and where movie stars of the '40s stayed at the El Rancho Hotel, which housed casts for the many Westerns filmed in the area.

Route 66 Red Rocks near Gallup, considered to be one of the entryways to "Indian Country." Photo courtesy of PhotographyLife.com.

Albuquerque

By Sam Bono

New Mexico's largest city was founded on April 23, 1706 as a farming community along the Rio Grande, and named after Don Francisco Fernandez de la Cueva, who at the time was the Viceroy of New Spain (1702-1711) and the 10th Duke of Alburquerque.

Note: the first "r" in Alburquerque went missing sometime in the 19th Century and it has never been returned. According to Wikipedia, in Western folklore the name Albuquerque is traced to the Galician word albaricoque, meaning "apricot." The apricot was brought to New Mexico by Spanish settlers, possibly as early as 1743. As the story goes, the settlement was established near an apricot tree, and became known as La Ciudad de Albaricoque. Frontiersmen couldn't correctly pronounce the Galician word, so it became corrupted to "Albuquerque." Interestingly, apricot blossoms in Albuquerque are usually hit by the last freeze and fail to produce fruit.

Native American/Puebloan artists market their wares in the shade of Old Town square.

This city of almost 550,000 spreads out from the base of the Sandia Mountains west across the Rio Grande and to the horizon above the mesa. The Sandia Mountains are laced with hundreds of miles of trails and top out at 10,678 feet, over 5,000 feet above the valley floor. "Sandia" is Spanish for "watermelon" and the name was inspired for the conquistadores of Coronado's expedition in the 1550s by the beautiful Southwestern sunsets that often cast a pinkish glow over the almost cave-less, limestone-capped mountain.

You can drive to the top of the Sandias by way of I-40 East, NM 14 North and then NM 536, the Crest Road. Or, you can take the very popular Sandia Tram (one of the world's longest) from the west side of the mountain and hike a half-mile or so farther north along the Crest Trail to the high point of the mountain. A third, highly scenic route NM 550 east through Bernalillo, which turns into NM 165 through Placitas and becomes a rough, narrow, graded, dirt road that connects to the Crest Road. Along the way, you pass the small parking lot for Sandia Cave.

One thing is certain in Albuquerque: because of the Sandias you always know which way is east! The volcanoes above the western skyline serve as a west orientation.

Central Avenue (Route 66) is the dividing line between north and south Albuquerque, and the Rio Grande mostly separates east and west.

As with any large city, the Duke City, or Burque as some call it, has all the modern amenities we've grown accustomed to: museums, malls, about 60 micro-breweries, and restaurants for all appetites. For a distinctive shopping and dining experience, visit Albuquerque's Old Town, where all began in 1706. Old Town has frequent summertime concerts at the town square or gazebo.

For an authentic New Mexico lunch or dinner while exploring Old Town, dine at the Church Street Café located in a thick-

Full moon rising over the Sandia Mountains, Albuquerque city lights and the ribbon of the Rio Grande.

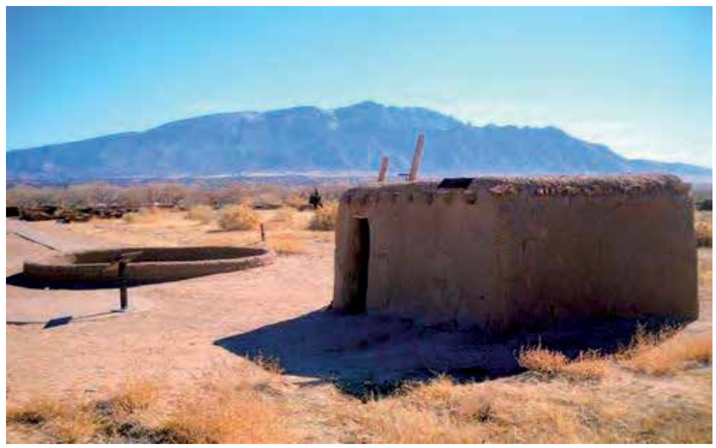
walled 18th century adobe. Remember our Convention's theme: Red or Green in 2017, and enjoy some of New Mexico's delicious red or green chile. Be bold and ask for Christmas! June is a great time to enjoy your chile-laced meal on one of the restaurant's delightful patios.

Post-convention, the largest hot air balloon event in the world is held in Albuquerque in early October. Now limited to 750 balloons, in some years past, the attendance maxed out at an unwieldy 1,000-plus balloons. In September, Albuquerque hosts the New Mexico State Fair, one of the most popular and well attended Fairs in the country.

Bernalillo

By Sam Bono

The small town of Bernalillo (burn-a-LEE-oh), founded in 1695, has a population of less than 9,000. It is located nine miles north of Rio Rancho's Santa Ana Star Center, headquarters of the 2017 NSS Convention, and is just to the west of I-25.



Some of the restored ruins at Coronado Historic Site with the Sandia Mountains in the background.

Along busy state highway 550, that cuts west across the northern half of the town from the interstate, you will find many popular local and national fast food restaurants, other eateries, gas stations, motels, and a Home Depot. Most of these restaurants are closer to the Star Center than similar services in Rio Rancho.

Bernalillo describes itself as the "The City of Coronado" because the Spanish conquistador, Francisco Vazquez de Coronado y Lujan (1510–1554) spent the winter of 1540-1541, close to Bernalillo with his 400 mostly-Spanish, men-in-arms and over 1,300 Mexican Indian allies. Coronado had traveled north from New Spain searching for the mythical Cities of Cibola, also known as the Seven Cities of Gold.

Much of the early charm of Bernalillo was the river crossing of the Rio Grande, which goes back 1000 years as a trading point among Pueblo people. Those peoples

Coyotes on local Bernalillo wall mural. Courtesy of Living Rootless, American Tourism.com

Canoeists and kayakers ply their skills along the cool water of the Rio Grande.

in Jemez, Santa Ana and Zia pueblos traveled down the Jemez River to cross the Rio Grande for trading among the Comanche. It was a crossroads of commerce.

Unfortunately, in the process of the search for new territories, the Spanish conquistadores destroyed numerous pueblos (Spanish for "village") along the Rio Grande and killed hundreds of Native Americans. Many others died from starvation and disease, a result of Coronado's persistent demands for food and other supplies from the pueblo's limited resources.

While Coronado never found the Seven Cities of Gold, members of his expedition were the first Europeans to visit the Grand Canyon and the mighty Colorado River.

To learn more of this tragic period in New Mexico history, visit the 98-acre Coronado Historic Site, located just north of NM 550 on the west side of the Rio Grande. The site is open Wednesday through Monday and closed on Tuesdays. Call (505) 867-5351 for details.

In 1695, Don Diego de Vargas founded modern-day Bernalillo close to the river crossing with a settlement along a floodplain that since washed away. Bernalillo continued as a trading center with El Camino Real running through its center. Around 1847, Americans came to Bernalillo and soon the railroad followed. Camino del Pueblo was the central artery in the 1920s.

For an easy and fun way to visit Santa Fe, 40 miles to the north, or downtown Albuquerque to the south, take the New Mexico Rail Runner from one of its two Bernalillo stations.

If a fun place for a casual lunch or dinner is part of your plan, try the Range Café, one of the author's favorite dining options, especially after visiting nearby Sandia Cave. The Range, noted for its American favorites, homemade desserts and, of course, traditional New Mexican cuisine, is located at 925 Camino del Pueblo, west of I-25 and south of NM 550.

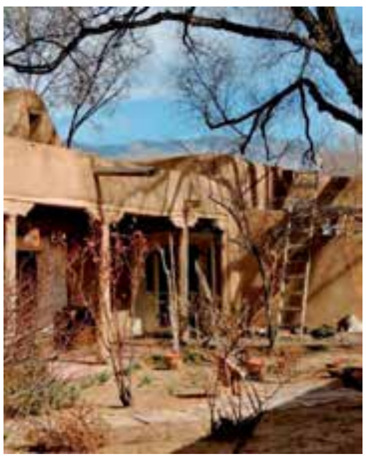
Acequia, vineyards and winery in Corrales.

Corrales

By Sam Bono

Tucked between the rapidly growing city of Rio Rancho and the west side of the Rio Grande, just north of Albuquerque, the Village of Corrales is a rural community of about 8,400 folks, many of whom are artists, writers, and or artisanal farmers.

Along the village's narrow, winding dirt roads you can find Spanish adobe (sun dried clay bricks) haciendas dating back to the early 1700s alongside modern adobe casas. Numerous examples of Spanish Revival, Pueblo, Santa Fe and other architectural styles, many of adobe, can also be found along the tree-lined lanes.



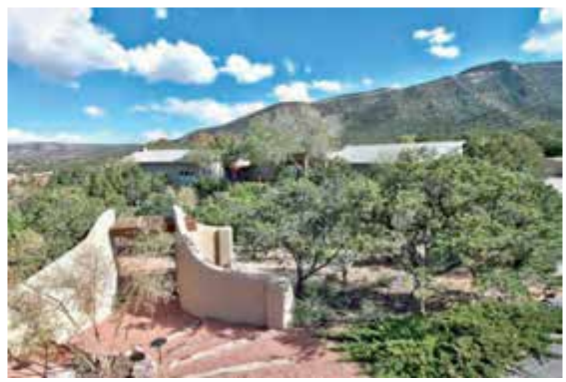
Casa San Ysidro Gutierrez-Minge House. Photo courtesy of Trip Advisor.

Hundreds of acres of village farmland and lush pastures are watered by over 17 miles of an 18th century acequia (irrigation ditch) crisscrossing the village.

For a close look at a local Spanish rancho from the 1700s visit Casa San Ysidro located at 973 Old Church Road just off NM 448, Corrales Road. Now a part of the Albuquerque Museum, the fully restored adobe home features Spanish Colonial furnishings, hand-woven floor coverings, and other authentic 19th century artifacts. Call (505) 897-8828 for tour information. Corrales is also known for its fine restaurants, and its numerous wineries and vineyards. We hope to arrange a vineyard tour and tasting field trip during the 2017 NSS Convention.

Photo courtesy DriveSlow. www. terrariums .net

Rural Corrales is a refreshing change from the urban sprawl, car dealerships, and the crowded malls of nearby Rio Rancho and Albuquerque.



Placitas and Sandia Mountain. Photo, media.photobucket.com

Placitas

By Sam Bono

When driving east on New Mexico 550 through Bernalillo, you will cross over Interstate 25 and 550 turns into NM 165. NM 165 then passes through Placitas, old and new. The paved road turns into a narrow, rough dirt road after about eight miles and runs past Sandia Cave (and others) along Las Huertas Creek. This creek is one of the few perennial streams in the Sandia Mountains.

Eventually, the road goes up the north end of the Sandias – without any guard rails to speak of – to connect with the Crest Road, NM 536, just north of the Sandia ski basin.

Placitas is a mixture of historic and modern, Hispanic and Anglo, a mountain village surrounded by hundreds of high-end, pseudo-adobe homes on acre lots that belong to mostly non-Hispanic folks. Much of the populace commutes daily south on I-25 to jobs in nearby Albuquerque.

Sunrise over Placitas. Photo, J. Fowler, *Lonely Planet*

The old Hispanic village, however, dates to the mid-18th century and was originally located in a nearby location with a different name, Las Huertas. The village sits on part of the San Antonio de Las Huertas Land Grant that was created in 1750.

Of note, during the 1960s, the village was home to four short-lived communes: Lower Farm, Towapa, Sun Farm, and Drop City South. These hundreds of counter-culture advocates, "hippies" living in the communes, mostly got along with the Hispanic villagers. The hippies were attracted to some of the same values and lifestyle of the local Hispanics.

Rio Rancho

By Sam Bono

Rio Rancho, Albuquerque's largest suburb and the home of the 2017 NSS Convention, can trace its European roots back to 1710. Captain Francisco Montes Vigil (1651-1730) petitioned King Philip IV of Spain for a 100,000-acre land grant as a reward for his service to King and country during the 1692 reconquest of New Mexico after the 1680 Pueblo Revolt.

For whatever reason, the Spanish King granted the good Captain only 89,000 acres across the Rio Grande from the recently established (1706) villa of Alburquerque, which would grow into New Mexico's most populous city. Two years later, Captain Vigil sold his 89,000 acres, known today as the Alameda Land Grant, to a Juan Gonzales Bas for all of 200 pesos (about $2,400 U.S. today).

Rio Rancho Badlands. Photo, Tourideas-usa.com

Leaping forward 250 years, the Grant, which had been used over the decades for marginal grazing, farm land, and a small part as an airport well into the 20th Century, was now mostly owned by the controversial land developer, the AMREP Corporation of New York City.

In the early 1960s, AMREP heavily promoted the Grant along the East Coast and in the Midwest as a retirement haven and an excellent short-term investment opportunity, especially during the east's usually cold and snowy winter months. The Grant was renamed Rio Rancho Estates by AMREP for marketing purposes in the New York City metro area,

Entrance sign along Highway 528. Courtesy of RRCVB.

Today, Rio Rancho is the third largest and fastest growing city in New Mexico with an estimated 2017 population of almost 96,000. No longer is it just the home of East Coast and Midwest retirees. It is now, because of lower taxes and more reasonable housing costs, the home of thousands of old and young families who have moved across the river from Albuquerque and from all over the United States to the sunny Southwest.

Anticipating Rio Rancho's continued rapid growth, city planners in 2007 established a Civic Center on the far north edge of town.

Looking East to Albuquerque from Rio Rancho. Courtesy: Smartgrowthusa.files.wordpress.com.

The Center includes a modernistic City Hall, three large hospitals, the University of New Mexico (UNM) West building, and the Santa Ana Star Center, headquarters for the 2017 New Mexico NSS Convention. Additional session rooms and vendors will be located nearby in the UNM West building.

UFO sighting near Sue Cleveland High School (north of the Santa Ana Star Center). Photo courtesy alibi.com.

Close-by Encounters

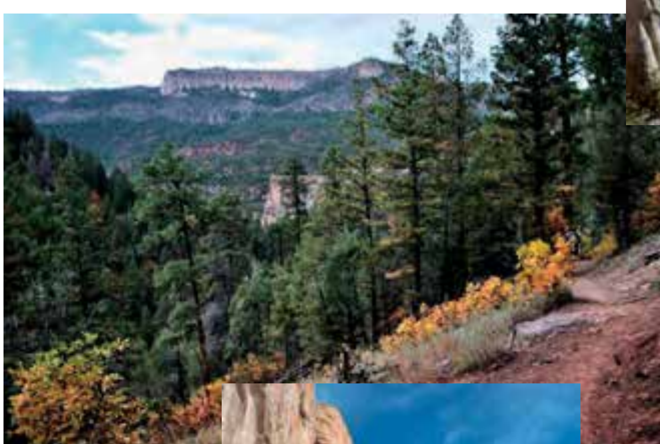
Pete Lindsley

Satellite Dish, Very Large Array, San Augustin Plains

Hydrothermal spring, Peñasco Springs, Zia Pueblo.
Photo by Pete Lindsley

Kasha-Katuwe National Monument (Tent Rocks)

Linda Starr

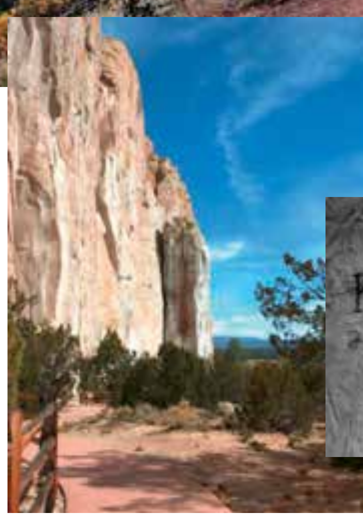


Kenneth Ingham

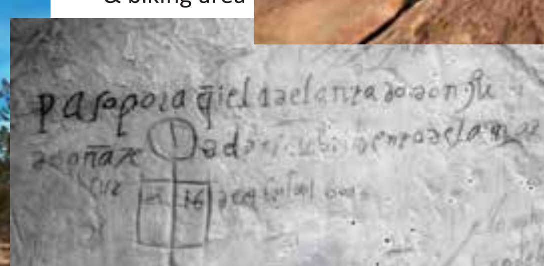
From Jemez Mountains trail to Battleship Rock

San Ysidro Trials, hiking & biking area

Kenneth Ingham



Along the visitor trail, El Morro National Monument.
Photos by Kenneth Ingham

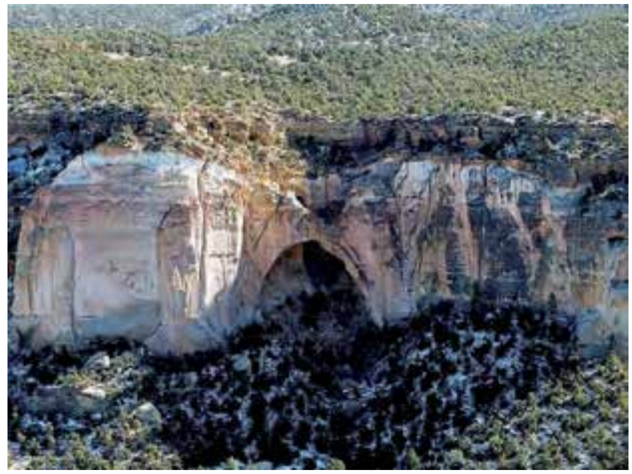


Historic Oñate inscription (ca. 1600): “I passed by here…”

Further Discoveries

Linda Starr

Arch and distant bluffs along Sandstone Bluffs Trail; El Malpais National Monument in the background



Todd Roberts

La Ventana natural arch (~100 ft wide) in BLM National Conservation Area, bordering El Malpais.

Taos Pueblo
Photo by Linda Starr

Linda Starr

Pueblo Bonito, Chaco Canyon National Cultural Center, from trail above.

Linda Starr

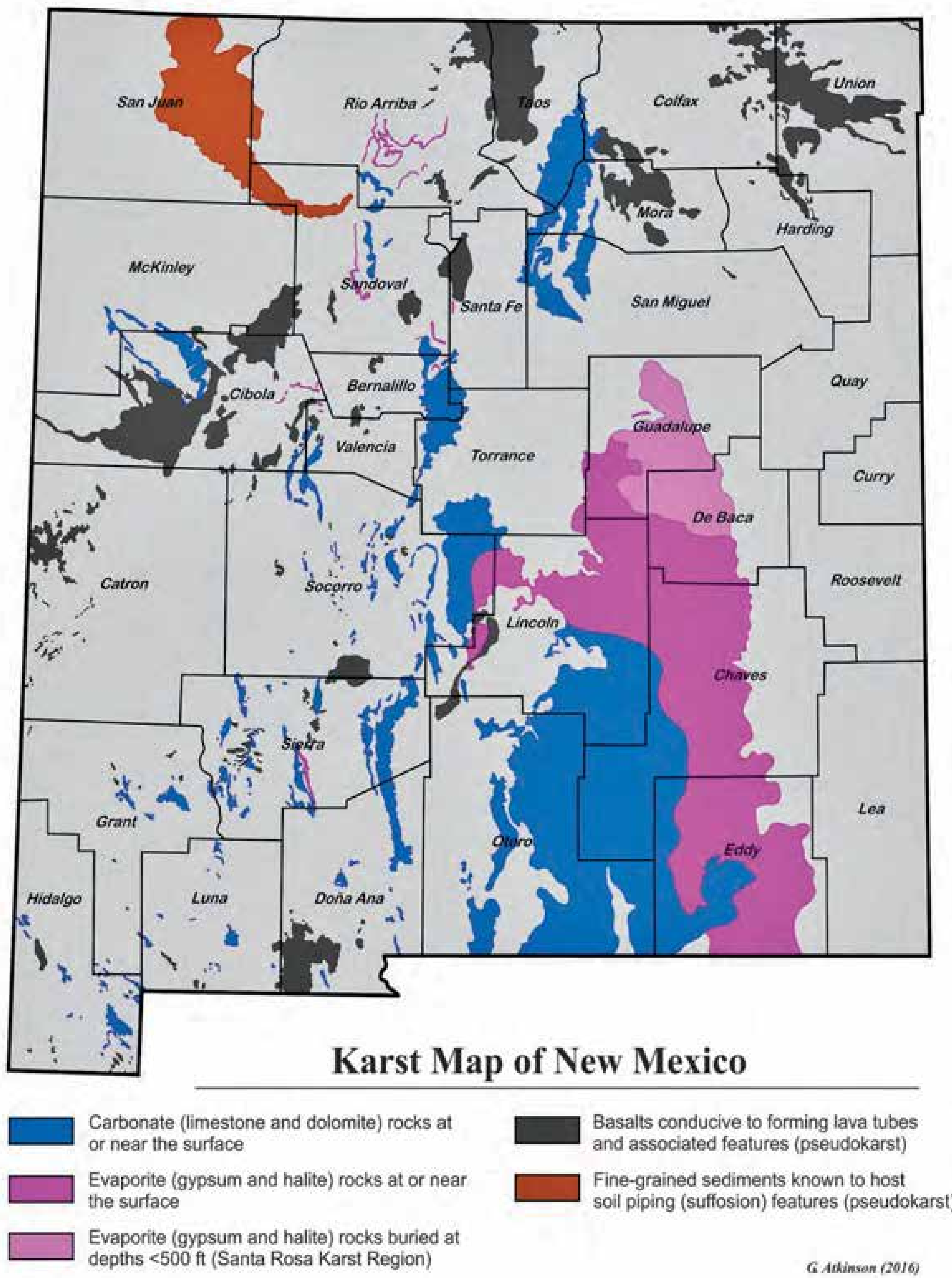
Los Volcanes Open Space

Valles Caldera National Preserve

Courtesy Nat. Park Service website

Cave & Karst Science

Previous Page – Bat Skeleton: Pink Panther Cave is probably most famous for its well-preserved short-faced bear skeleton, but a sharp eye can find this skeletal remnant of a bat in its final landing place in the same cave. Photo and caption by Peter Jones.



Bats of New Mexico

By Debbie C. Buecher
Buecher Biological Consulting, Tucson, AZ

Bats are the only mammal that can sustain true flight, allowing them to forage for hours across rugged terrains. There are currently over 1,300 bat species worldwide. Bats comprise approximately one-quarter of all extant mammalian fauna (Hill and Smith 1986), yet they are poorly understood due to their nocturnal lifestyle and elusive nature.

There are 27 bat species known from New Mexico (NM). Of these, four species are in the family Molossidae (free-tailed bats) and three are in the family Phyllostomidae (leaf-nosed bats). The remaining 20 bat species are in the family Vespertilionidae (evening bats). Of these, nine are in the genus *Myotis* (mouse-eared bats) and five are tree roosting bats (*Lasiurus* or *Lasionycteris*) (Table 1). Twenty-four NM bat species are insectivorous and are major predators of nocturnal insects (Table 2). Bats consume large quantities of insects nightly (>3/4 a bat's body mass) and many prey are insect pests, that have a negative impact on human health and productivity of agriculture, forests, and woodlands. Additionally, bats perform an ecological role through nutrient cycling across primary biotic communities within NM.

Table 1. List of bat species documented from NM. Includes general roosting associations and whether the species hibernates or migrates from the region during winter.

			Winter/Summer Habitat		
Scientific Name	Common Name	Hibernates	Caves/ Mines	Trees[1]	Crevices[2]
Family Phyllostomidae (leaf-nosed bats)					
*Choeroncycteris mexicana**	Mexican long-tongued	no	√		√
Leptonycteris nivalis[E]	Greater long-nosed	no	√		
Leptonycteris yerbabuenae[E]	Lesser long-nosed	no	√		
Family Vespertilionidae (evening bats)					
Antrozous pallidus	Pallid bat	yes	√	√	√
*Corynorhinus townsendii**	Townsend's big-eared	yes	√		
*Euderma maculatum**	Spotted bat	torpor?	√		√
Eptesicus fuscus	Big brown bat	yes	√	?	√
*Idionycteris phyllotis**	Allen's big-eared bat	yes	√	√	√
*Lasiurus blossevillii**	Western red bat	yes		√	
*Lasiurus borealis**	Eastern red bat	yes		√	
Lasiurus cinereus	Hoary bat	yes		√	
Lasionycteris noctivagans	Silver-haired bat	yes	rare	√	
Myotis auriculus	Southwestern myotis	yes	√	?	
Myotis californicus	California myotis	yes	√	√	√
*Myotis ciliolabrum**	Small-footed myotis	yes	√	√	√
Myotis evotis	Western long-eared	yes	√	√	√
*Myotis occultus**	Occult myotis	yes	√	√	√
*Myotis thysanodes**	Fringed myotis	yes	√	?	√
*Myotis velifer**	Cave myotis	yes	√		√
Myotis volans	Long-legged myotis	yes	√	√	√
*Myotis yumanensis**	Yuma myotis	yes	√		√
Parastrellus hesperus	Western canyon bat	torpor		?	√
Perimyotis subflavus	Tri-colored bat	yes	√	√	√
Family Molossidae (free-tailed bats)					
*Eumops perotis**	Western mastiff bat	no			√
Nyctinomops femorosaccus	Pocketed free-tailed	no			√
Nyctinomops macrotis	Big free-tailed bat	no			√
Tadarida brasiliensis	Brazilian free-tailed	no	√		√

The resources which limit distribution of NM bats are: adequate quantity of appropriate food resources, access to drinking water, and availability of roost sites with suitable temperatures and relative humidity (Hill and Smith 1986). Day-roosts for bats include: caves and abandoned mines, crevices,

Table 2. General insect prey consumed by NM bat species (Adams 2003).

Bat Diets	
Scientific Name	**General Diet**
Antrozous pallidus	beetles, moths, orthopteran, scorpions, centipedes, pollen, cacti fruit – can land on the ground to take prey
Corynorhinus townsendii	highly maneuverable – gleaning small bodied moths & other insects
Eptesicus fuscus	beetles, ants, flies, mosquitos, mayflies, true bugs and other insects
Euderma maculatum	mostly moths but may consume other insects
Idionycteris phyllotis	small moths, small beetles and flying ants
Lasiurus blossevillii	moths and other insects
Lasiurus borealis	moths, crickets, flies, mosquitos, true bugs and other insects
Lasiurus cinereus	moths, beetle, flies, grasshoppers, dragonflies, and wasps
Lasionycteris noctivagans	slow-flying after moths, true bugs, flying ants, beetles
Myotis auriculus	gleaning predator after small moths
Myotis californicus	small flying insects including flies, moths, beetles
Myotis ciliolabrum	small beetles, moths, lacewings
Myotis evotis	gleaning predator eating moths, beetles, flies, lace-winged insects and true bugs
Myotis occultus	often forage over water taking newly emergent insects and insect prey caught on the surface tension of the pond
Myotis thysanodes	moths, beetles, bees, lacewings
Myotis velifer	moths, flying ants, small beetles
Myotis volans	moths and soft bodies insects
Myotis yumanensis	often forage over water for beetles and soft bodied insects
Parastrellus hesperus	diversity of small insects
Perimyotis subflavus	diversity of small insects
Eumops perotis	aerial hawking larger insects including beetles cicadas, large hawkmoths
Nyctinomops femorosaccus	aerial hawking mostly moths, also small beetles, flying ants & flying termites, stink bugs, crickets
Nyctinomops macrotis	aerial hawking large moths, crickets, true bugs, flying ants and flying termites
Tadarida brasiliensis	aerial hawking moths and beetles, many are plant pests
Choeronycteris mexicana	fruits, pollen, nectar, probably some insect prey
Leptonycteris nivalis	fruits, pollen, nectar, probably some insect prey
Leptonycteris yerbabuenae	fruits, pollen, nectar, probably some insect prey

rock piles, bridge expansion joints, tree foliage, holes in trees and stumps, wood piles, exfoliating bark on tree snags, and both abandoned and occupied buildings which offer crevices (Adams 2003). Roosts are typically close to foraging areas but some NM bat species fly long distances between day-roosts and appropriate food resources. While western canyon bats, the smallest bat species in the NM, forage close to their day-roosts, the free-tailed bats have long narrow wings and are capable of flying 30-60 miles each way nightly to forage.

The topographic complexity of New Mexico (Figure 1) offers tremendous roosting and foraging opportunities, supporting its great bat diversity. The mean elevation in NM is 5,700 ft. (1,737 m) with the lowest point in the state at 2,817 ft. (859 m) along the southeast border with Texas. The highest point is Wheeler Peak at 13,161 ft. (4,011m) in the Sangre de Cristo Mountains of northern NM. Across this topographic spectrum are diverse biotic communities including: desert scrub, grasslands, chaparral, woodlands, conifer forests, and tundra found above the tree line. These reflect dramatic ranges in temperatures and relative humidity, offering bats tremendous habitat diversity. Bat species are often associated with a particular habitat or range of habitats. However, some bat species are very cosmopolitan in their distribution (Schmidly 1991). As an example, western red bats are considered a riparian obligate whereas big brown bats are found in every state of the continental U.S (Adams 2003). Roosting and foraging behaviors, diet choices, and flight behaviors are often species specific. Across NM, bat species are generally found in habitats for which they are best adapted. Most temperate bats species

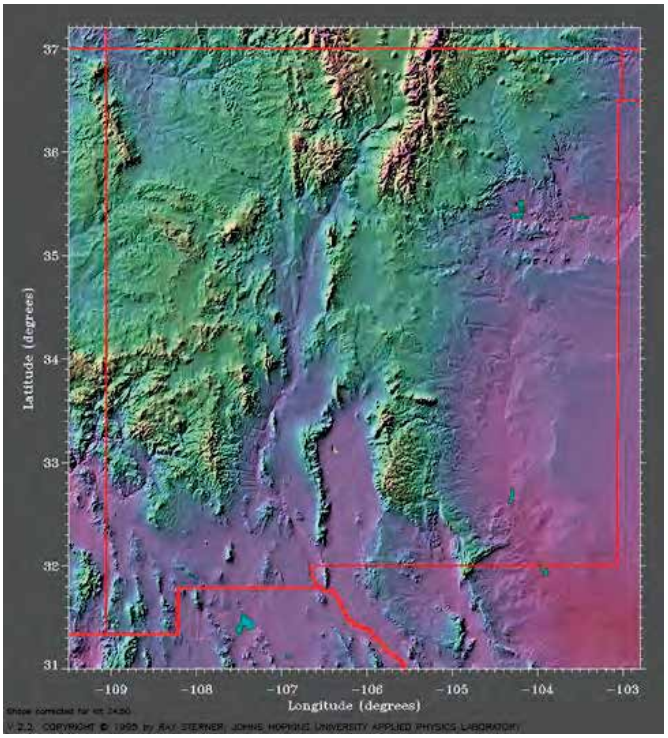


Figure 1. Color landform map of NM showing the broad elevational differences that influence biotic communities (R. Sterner). In turn, these biogeographic regions influence the distribution of bat species across NM by providing diverse temperatures and relative humidity.

A small footed *myotis (M. ciliolabrum)* found at El Malpais National Monument.

(28 out of 47 species) use caves or abandoned mines during specific periods in their life history. Bats need different microclimatic conditions (temperatures and relative humidity) across distinct seasonal periods. Summer sites chosen by reproductive female bats are generally warmer than typical caves and have higher relative humidity. These conditions ensure the rapid growth of the young neonates. On the other hand, winter hibernacula must be within species-specific cold temperatures and near saturation for the bats to survive months in hibernation, while living off accumulated fat

A Townsend's big-eared bat *(Corynorhinus townsendii)* captured in NM. New Mexico has a significant number of big-eared bat hibernacula.

reserves. Most NM bats hibernate during the winter but members of the leaf-nosed family and free-tailed family migrate seasonally to find food year-round.

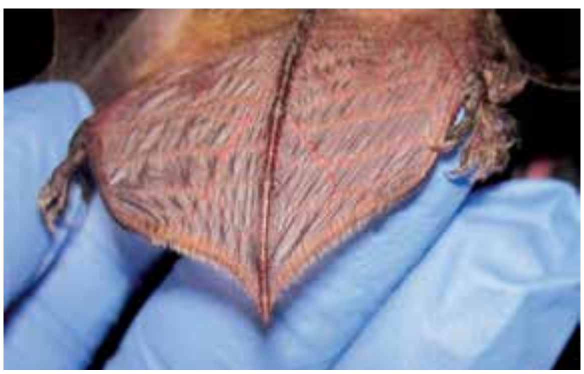
Though bats are surprisingly long-lived for their small size, they have a low reproductive potential (one young per year) exacerbated by high yearling mortality (Sidner, 1997). As a

A dead bat in a NM hibernaculum engulfed by fungal decay. This fungus is not *Pseudogymnoascus destructans,* but rather, a normal cave fungus that helps decompose larger organisms, thus recycling critical carbon back into the ecosystem.

result, bat population sizes are generally maintained when nothing adverse impacts their survival. Unfortunately, bat communities are negatively impacted by many anthropogenic

A fringed myotis *(M. thysanodes)* captured in a mist net along a creek in NM. This species is known in a number of habitats in the state.

activities. These include: wind turbines, mining, loss of habitat through urban development, timber industry or invasive species, and disturbance in their roosts. Most recently negative impacts from climate change and the



Detail of the fringed tail membrane (uropatagium) which gives the fringed myotis its distinguishing character.

emergent disease white-nose syndrome (WNS) are affecting US bat populations. Caves often reflect the mean annual surface temperatures (MAST) in which they are located and one might suspect that western bat species would be spared the ravages of WNS because of warmer regional temperatures and greater warmer regional temperatures and greater aridity. However, cave and mine passage geometry plays a significant role in roost temperatures. Cold air-sinks within a cave system can make a site much colder than the expected MAST. In addition, caves typically have higher humidity than the surface due to rainfall runoff flowing into cave systems, greatly increasing relative humidity (Perry 2013). It is generally thought that appropriate summer and winter roosts across a landscape may limit the distribution of bat species (Humphrey 1975). However, by choosing roosts seasonally across the geographic complexity of NM, bats are surprisingly successful.

Detail of a cave myotis *(Myotis velifer)* found in a NM cave. This is a strictly western bat species, so its vulnerability to WNS is unknown at this time.

One of the greatest concerns for resource managers across NM is that *Pseudogymnoascus destructans*, the psychrophilic pathogen responsible for WNS, will gain a foothold in a NM cave. Once introduced it could then be transferred between NM caves by human traffic or bat-to-bat between colonial roosts. New Mexico researchers, deploying data loggers to quantify cave microclimate, have determined that many NM bat hibernacula have appropriate conditions for the growth of *P. destructans.* Because of concern for possible WNS in NM winter hibernacula, bat biologists are conducting visual surveys during spring mist

Big brown bat *(Eptesicus fuscus)* found night-roosting under a bridge at Fort Stanton-Snowy River National Conservation Area. This handsome bat species is very cosmopolitan and can be found in every state of the continental U.S.

netting for evidence of *P. destructans* damage to bats' membranes. Research is on-going to investigate a possible safe biological control against *P. destructans* derived from NM bats. The fur and wing membranes of a subset of NM bats have been swabbed to inoculate culture plates that specifically grow *Actinobacteria* – the group from which we derive two-thirds of our natural antibiotics. Preliminary laboratory results show that some strains of *Actinobacteria* can inhibit the growth of *P. destructans*. This offers hope for naturally occurring cave and bat bacteria which could be developed as a biocontrol against WNS.

NOTE: **All bat work in NM caves and on the surface strictly follows current US Fish and Wildlife Service WNS decontamination protocols for all scientific equipment and caving gear.**

Hoary bat *(Lasiurus cinereus)* captured during mist netting along the Rio Bonito Creek at Fort Stanton-Snowy River National Conservation Area. This NM species is a tree-roosting bat.

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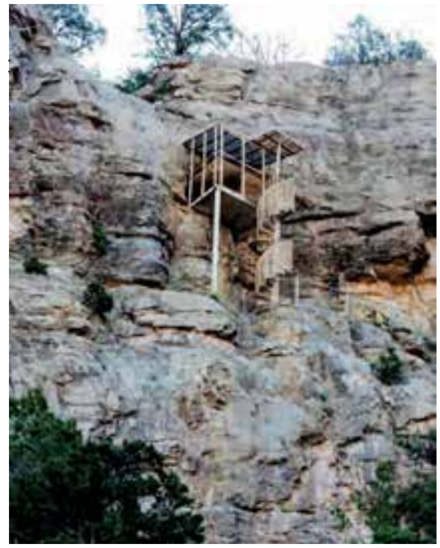
Sandia Cave Archaeology

By Michelle Wilson



Ron Maehler

US Forest Service trail and spiral staircase leads to entrance of Sandia Cave

Sandia Cave (also known as Sandia Man Cave) is a historic landmark located on the east side of Las Huertas Canyon, 15 miles northeast of Albuquerque. It has been designated as a traditional cultural property and is significant culturally for many Pueblo groups. This cave also played an important role in the history of how we think about the archaeological record in the Southwest during the Paleo-Indian period.

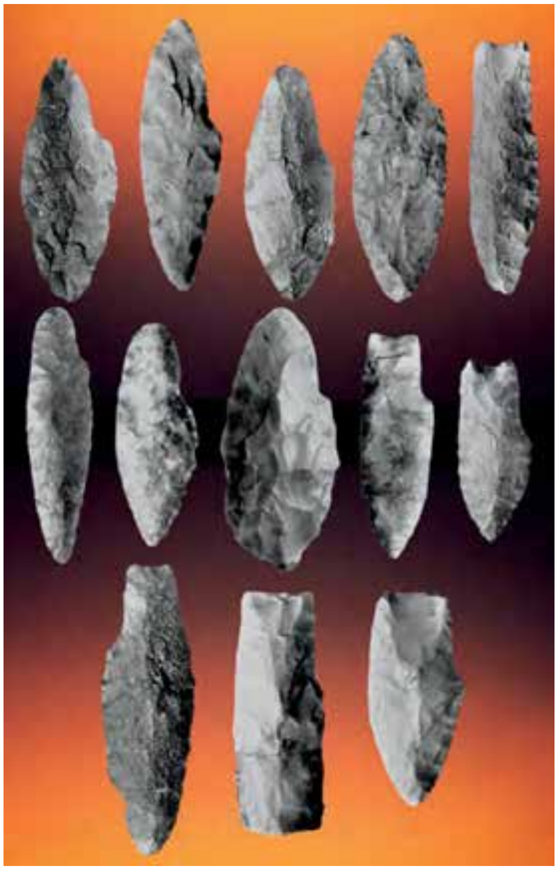
The late Frank Hibben conducted excavations inside of the cave from 1937-1941. Hibben divided the cave into seven layers. The top layer excavated was said to contain dust, guano, trash and potsherds consisting of Santa Fe black-on-white Pueblo III pottery and late glaze ware (Pueblo IV and V), dated to 1400-1600 AD. Potsherds were all found near the cave mouth and did not extend into the interior at this level. A crude, sandstone metate (but no mano) was also found near the front of the cave. Hibben indicated an Albuquerque Boy Scout troop was once in possession of a variety of artifacts from this level, including fragments of yucca cordage, feather cloth, and twill sandals, but these artifacts have been lost. Another local man retained a fragment of a coiled basket. Hibben concluded the artifacts found on this level indicated only sporadic and temporary occupations of the cave, probably by the Rio Grande pueblos (Hibben, 1941).

From the second layer (stalagmite layer), it was reported as chalky with a few stones present, along with the fall of blocks from the roof (Hibben, 1941). No artifacts were excavated at this level.

At the third layer (Folsom cultural layer), yellow ochre, fossil bone, artifacts, flint flakes and charcoal were recorded, but no hearths. This layer extended about 100 meters into the cave, although the artifacts were not evenly distributed across this distance. Additionally, this layer was identified as belonging to the Folsom culture due to the discovery of two intact, if poorly made, Classic Folsom points and two Folsom axes (Hibben, 1941).

Three other points were also found on this level and are similar to the Yuma points (Wormington, 1939, pp.22-26) found at Clovis, but with other characteristics reminiscent of Folsom points (Hibben, 1941). Hibben suggested these were perhaps created by a culture contemporaneous, but separate from the Folsom people. One other projectile point showing Yuma-point-style chipping (but no longitudinal grooves) was found, along with some lanceolate-type attributes sometimes found in the southern plains. Additionally, two complete large blades and three blade fragments were found on this level (Hibben, 1941). Five complete gravers – a flake/blade-tool with a sharp spur – were found and are said to be used in bone working to incise lines and grooves (Gramly, 1990, McDonald 1985). Also recorded were three varieties of scrapers – a type of utility blade/flake tool with a convex working edge at one or more margins (Bordes, 1973; Gramly.

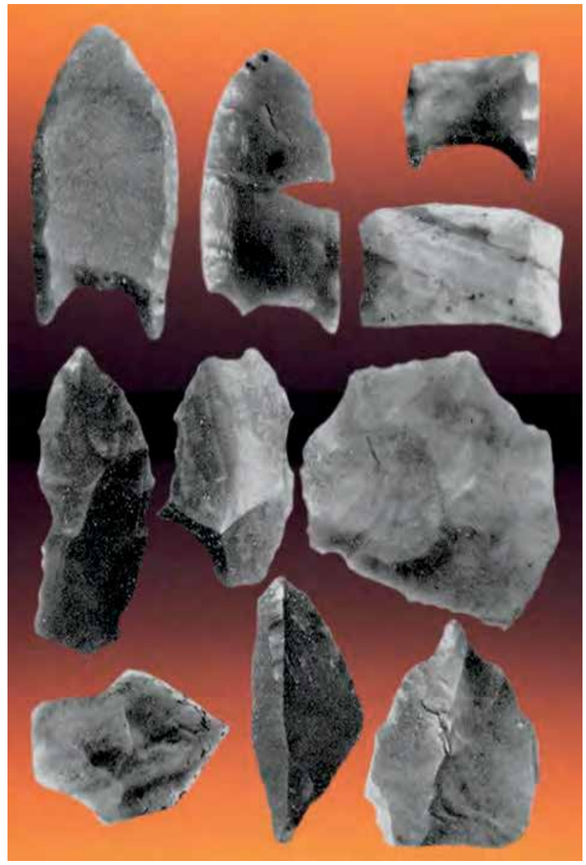
1990. Various sized, indefinite flakes that may have been used as tools, were found, and a few pieces of worked bone, including a remarkable ivory splinter (Hibben, 1941).



Sandia points found in Sandia Cave. Photo courtesy of *Smithsonian Report* vol. 99 no. 23.

The fourth layer also contained yellow ochre, but no artifacts, fossil bone or limestone were found in this layer (Hibben, 1941).

In the fifth layer (Sandia cultural layer), the record consisted of breccias, limestone, calcium carbonate and cultural deposits of fossil bone, artifacts, charcoal, charred bone and hearths within the first 1.5 meters (Hibben, 1941). Nineteen whole or broken points were recovered and fell into two main categories. In the lower levels the points were described by Hibben as "lanceolate or rounded in general outline. The base has a side shoulder or notch on one side, in what may accurately be described as a Solutrean manner." Hibben further described the Sandia points from the upper levels as "elongated with parallel sides and straight or slightly indented bases" and "with the typical Sandia side notch," (1941).



Folsom points and gravers from Sandia Cave. Photo courtesy of *Smithsonian Report*, vol. 99 no. 23

These diagnostic points were described by Wormington (1957) as single-shouldered points, some with basal fluting and wear patterns along one lateral side. Hibben argued two types of Sandia Points recovered during the excavation predated both Clovis (10,000-9000 BC) and Folsom (9000-8000 BC) cultures and proved the Sandia culture existed alongside extinct Pleistocene mammals, which were extant until about 11,700 years ago (Hibben, 1941).

In the same layer as the Sandia points, other tools were also found, such as blades, choppers, scrapers and points in the shape of leaves (Cordell, 1997). These tools may have been designed for the purpose of cutting out the limonite ocher, found in Sandia Cave (Haynes and Agogino, 1986). Three snub-nosed scrapers, numerous rough flakes, and two worked bone points were also recovered, as well as two clearly defined hearths. One of these was surrounded by a ring of rounded limestone boulders averaging 10 centimeters in diameter, probably brought up from the creek below (Hibben, 1941).

Basal clay and gray clay with loose crinoid stems and limestone fragments make up the sixth and final layer (Hibben, 1941).

No rock art was recorded in Hibben's excavation of Sandia Man Cave. Today the survey marks left by Hibben are considered historic. A handprint, red ochre lines and a few other drawings were noted in 2014 beneath the heavy graffiti in Sandia Cave, which may be prehistoric or historic rock art. Dr. Jannie Loubser, a specialist in rock art was contracted to restore Sandia Cave in 2015. With the help of many volunteers from multiple, interested organizations, modern graffiti was painstakingly removed and the cave restored to a more natural-looking state. Great care was taken in sensitive areas, where rock art may exist, to preserve the surfaces for further study.

The site was radio carbon dated in the range of 33,000 to 15,000 BC (Crane 1955, Hibben 1955). However, it has been suggested there were issues with this dating, such as whether the artifacts were actually associated with the fossil bone that was used as the sample (Bryan, 1965; Cordell, 1997). A variety of inconsistencies in regard to the dating, stratigraphy, interpretation of the geology, and even the artifacts themselves caused many to question the validity of Hibben's work (Bliss, 1940; Haynes and Agogino, 1986; Meltzer, 2009; Preston, 1995). A storm of controversy erupted, resulting in accusations that Hibben had seeded the cave with artifacts. Numerous academic reports question the veracity of Hibben's findings.

Debate about Sandia Cave and its place in Paleoindian history still continues into modern times, both in archaeology classrooms and in popular and professional articles.

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Late Pleistocene Vertebrate Fossils from Sandia Cave and Marmot Cave, Sandia Mountains, New Mexico

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New Mexico Museum of Natural History, Albuquerque, New Mexico

Sandia Cave and Marmot Cave are located in Las Huertas Canyon in the northern part of the Sandia Mountains, about 7 km south of Placitas and 20 km northeast of Albuquerque, in Sandoval County, north-central New Mexico (approximate latitude and longitude: 35º15'N, 106º24'W).

At an elevation of 2,208 m, Sandia Cave is one of the highest Pleistocene (Ice Age) cave fossil sites in New Mexico. Marmot Cave is slightly lower in elevation at 2,173 m. Sandia Cave is a well-known, late Pleistocene archaeological and paleontological site. It was one of the first sites in North America, where Paleoindian artifacts were reported to have been found in association with fossils belonging to large extinct species of Ice Age mammals, the "Pleistocene megafauna" (Hibben, 1937, 1941).

Marmot Cave has produced a diverse fauna of small vertebrates, especially mammals, but large extinct mammals are absent (Thompson and Morgan, 2001). Radiocarbon (14C) dates confirm a late Pleistocene age for the Marmot Cave fossils.

Sandia Cave is a solution cave about 140 m long, 2-4 m in diameter, and a maximum of three meters in height (see a detailed map of Sandia Cave by Jorgensen, this volume), with its opening in a vertical cliff on the east wall of Las Huertas Canyon (Figure 1). Frank Hibben (1936–1941), Vance Haynes and George Agogino (1961), and Richard Smartt and David Hafner (1984) conducted archaeological and/or paleontological excavations at this site. Nine extinct species of large mammals have been identified from Sandia Cave (Hibben, 1941; Thompson and Morgan, 2001; Thompson et al., 2008; Morgan and Harris, 2015): Shasta ground sloth *(Nothrotheriops shastensis)*, small horse *(Equus conversidens)*, large camel *(Camelops hesternus)*, two pronghorns or antilocaprids *(Capromeryx furcifer* and *Stockoceros conklingi)*, mountain deer *(Navahoceros fricki)*, extinct bison *(Bison antiquus)*, American mastodon *(Mammut americanum)*, and Columbian mammoth *(Mammuthus columbi)*. See Figure 2 for photographs of fossils from Sandia Cave representing most of these species.

The presence of Bison establishes a late Pleistocene age for the Sandia Cave vertebrate fauna and referral to the Rancholabrean North American, land-mammal age. The fossils of large mammals from Sandia Cave mostly consist of isolated elements, including teeth, ends of limb bones, toes, carpals and tarsals. They are similar in color and preservation to fossil teeth and bones of smaller mammals collected during Hibben's original excavations of Sandia Cave. There is no evidence that the fossils from Sandia Cave were derived from another Pleistocene fossil site in the Albuquerque area and later "salted" in Sandia Cave by Hibben, as has been suggested by some archaeologists (e.g., Stevens and Agogino, 1975).

Smartt and Hafner wet screened several hundred kilograms of sediment from Sandia Cave in 1984, which yielded 29 species of vertebrates, including salamander, toad, lizard, two birds, and 24 mammals. Their use of window screen (16 mesh/inch, 1.5 mm opening)

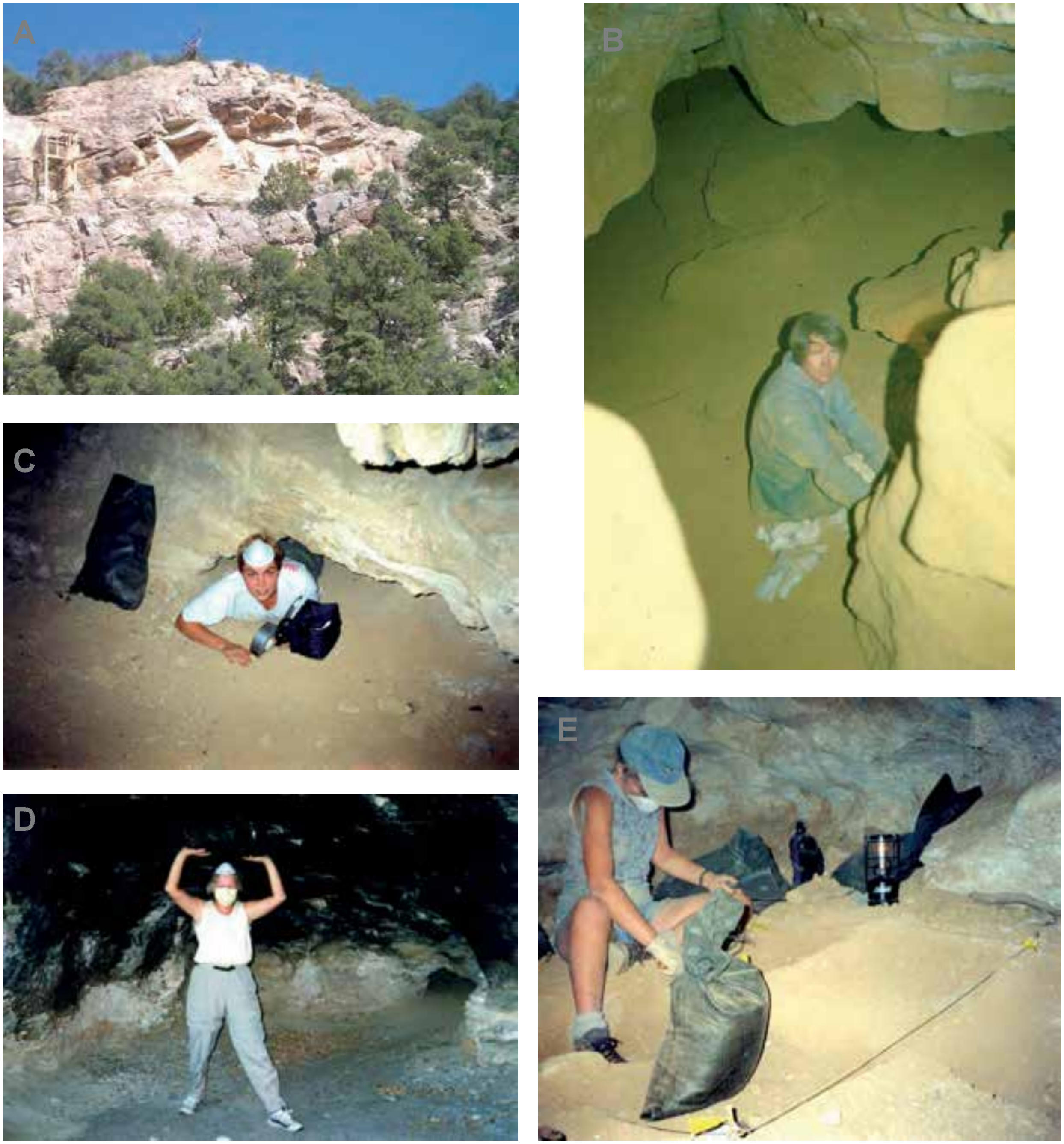

Figure 1. Photos of Sandia Cave and Marmot Cave (= Davis Cave), Sandia Mountains, Sandoval County, north-central New Mexico. A. Entrance to Sandia Cave on the east wall of Las Huertas Canyon. The cave entrance is located at the top of the steel staircase in the left-central portion of the photo. B–E, Paleontologists from the New Mexico Museum of Natural History working in Sandia and Marmot Caves. B. Richard Smartt excavating Sandia Cave. C. Jessica Thompson emerging from the inner chamber of Marmot Cave. D. Sandra Bruschini standing in the entrance shelter to Marmot Cave. The entrance to the inner chamber is in the right center of the photo. E. Susan Harris excavating a test pit in the inner chamber of Marmot Cave.

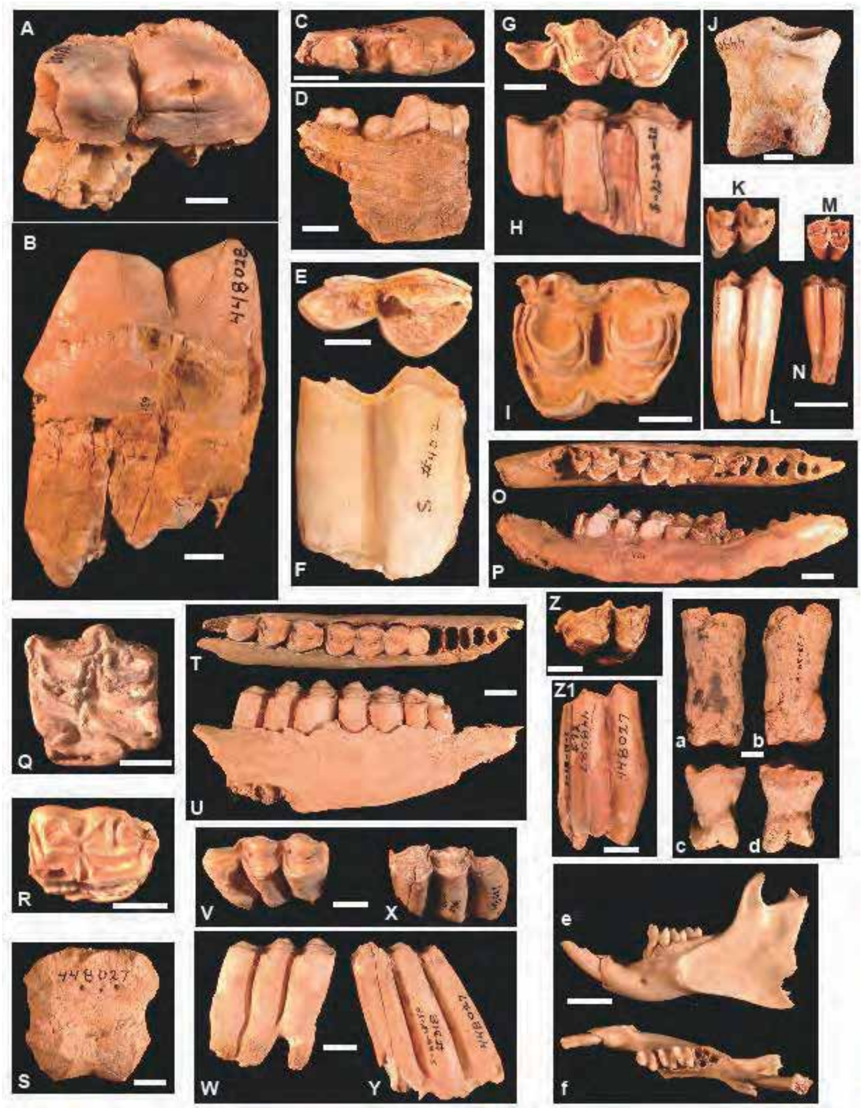

Figure 2. Photos of late Pleistocene mammals from the Sandia Mountains, Sandoval County, north-central New Mexico. All fossils are from Sandia Cave, except the mandibles in e and f, which are from Marmot Cave (=Davis Cave). All white scale bars are 1 cm in length. Partial tooth of an American mastodon (*Mammut americanum*) in A. occlusal view and B. anterior view. Right mandible with first and second lower molars (m1–m2) of gray wolf or lobo (*Canis lupus*) in C. occlusal view and D. labial view. Partial right lower third molar (m3) of giant llama (*Camelops hesternus*) in E. occlusal view and F. labial view. G–J, Fossils of extinct bison (*Bison cf. B. antiquus*): Right lower third molar (m3) in G. occlusal view and H. labial view; I. Left upper third molar (M3) in occlusal view; and J. medial phalanx in anterior view. Upper molar of Stock's pronghorn (*Stockoceros conklin*gi) in K. occlusal view and L. lingual view. Upper molar of dwarf pronghorn (*Capromeryx furcifer*) in M. occlusal view and N. lingual view. Right mandible with three molars (m1–m3) of mountain deer (*Navahoceros fricki*) in O. occlusal view and P. labial view. Q–S, Fossils of extinct Mexican horse (*Equus conversidens*): Q. Left upper premolar in occlusal view; R. Left lower premolar in occlusal view; S. Medial phalanx in posterior view (Note: vertical lines above catalog number are rodent gnaw marks). T-Z, Fossils of bighorn sheep (*Ovis canadensis*): Right mandible with three molars (m1–m3) in T. occlusal view and U. labial view; Right lower third molar (m3) in V. occlusal view and W. labial view; Left lower third molar in X. occlusal view and Y. labial view; Right upper third molar (M3) in Z. occlusal and Z1, lingual view. Proximal phalanx of extinct shrub ox (*Euceratherium collinum*) in a. anterior view and b. posterior view. Medial phalanx of *Euceratherium collinum* in c. anterior view and d. posterior view. Left mandible with incisor, 4th lower premolar, and first and second lower molars (I, p4, m1–m2) of yellow-bellied marmot (*Marmota flaviventris*) in e. labial view and f. occlusal view.

and fine screen (24 mesh/inch, 1.0 mm) ensured that even the smallest species were recovered. Hibben's more extensive excavations in the late1930s and early 1940s produced a much larger fossil sample, but the smallest vertebrates were not recovered because he used only coarse screens (4 mesh/inch, 6 mm) to dry screen the sediments.

The combined fossil sample from these two excavations documents the late Pleistocene vertebrate fauna from Sandia Cave, ranging from very small species (salamanders, toads, lizards, shrews, and voles) to the largest species (horses, bison, mastodons, and mammoths). The mammalian fauna from Sandia Cave consists of 39 species (Thompson et al., 2008). In addition to the nine, extinct species of large mammals listed above, the Sandia Cave fauna also contains five living species of small mammals that no longer occur (i.e., are extralimital) in the Sandia Mountains: snowshoe hare *(Lepus americanus)*, mountain cottontail *(Sylvilagus nuttallii)*, yellow-bellied marmot *(Marmota flaviventris)*, northern pocket gopher *(Thomomys talpoides)*, and bushy-tailed woodrat *(Neotoma cinerea)*.

There is also a diverse late Pleistocene bird fauna from Sandia Cave consisting of about 30 species, two of which are extinct and seven are extralimital (Brasso and Emslie, 2006). The most noteworthy of the locally extinct birds is the California condor *(Gymnogyps californianus)*, which was widespread throughout North America in the late Pleistocene, including New Mexico, but is now restricted to coastal California.

Hibben (1937, 1941) claimed that fossils of extinct mammals were directly associated with Paleoindian artifacts (called Sandia points) in Sandia Cave; however, that association has been questioned because of sediment mixing or bioturbation resulting from rodent burrowing (Haynes and Agogino, 1986). There are three radiocarbon dates on large mammal bones from Sandia Cave, ranging from 11,850 to 13,700 years before present (yrBP; Haynes and Agogino, 1986). Although radiocarbon dates indicate extinct mammals and Paleoindians may have been contemporaries in the vicinity of Sandia Cave during the latest Pleistocene, we cannot confirm that humans hunted the Pleistocene megafauna based on the fossils from this site.

An analysis of the surface features of large mammal bones from Sandia Cave did not provide definitive evidence that humans butchered bones from this site with stone tools during the late Pleistocene; most of the surface markings on the bones were caused by carnivore predation or rodent gnawing (Thompson et al., 2008). A recent reanalysis of the Paleoindian artifacts, surface modification of bones, and radiocarbon dates from Sandia Cave suggests that humans may not have used this cave until the time of the Folsom culture at about 10,000 yrBP (Thompson and Haynes, 2012), which is immediately after the extinction of the Pleistocene megafauna. Brasso and Emslie (2006) reported a radiocarbon date of 10,795 yrBP on a fossil bone of *Gymnogyps californianus* from Sandia Cave, establishing that condors survived in northern New Mexico until the end of the Pleistocene before disappearing from the state.

Marmot Cave (also known as Davis Cave; Hibben, 1941) has a shelter-like entrance room 10 m long and 3 m wide and a second enclosed room that is 12 m long, 3-5 m wide, and 1-2 m in height (see a detailed map of Marmot Cave = Davis Cave by Jorgensen, this volume). The enclosed room, which produced all of the vertebrate fossils described here, is accessed by a small opening less than 1 m in diameter in the back of the entrance shelter (Figure 1).

In 2000, a New Mexico Museum of Natural History (NMMNH) field crew under my supervision excavated four test pits in Marmot Cave to a maximum depth of 0.8 m (two of the test pits were 1 m^2 and two were 0.5 m^2). We collected and screenwashed over one metric ton of sediment from these test pits, using window screen and fine mesh screen to recover all fossils. The vertebrate fauna from Marmot Cave totaled 40 species, almost entirely consisting of small taxa, including: fish, toad, two lizards, two snakes, eight birds, and 26 mammals (Thompson and Morgan, 2001; Brasso and Emslie, 2006).

The most important difference from Sandia Cave is the absence of large extinct mammals. Marmot Cave was named for the abundance of fossils of the yellow-bellied marmot (*Marmota flaviventris*; Fig. 2), a member of the squirrel family, now found at higher elevations in the mountains of northern New Mexico but absent from the Sandia Mountains (Findley et al., 1975). Marmot Cave contains three of the five small mammals from Sandia Cave that no longer occur in the Sandia Mountains, *Sylvilagus nuttallii*, *Marmota flaviventris*, and *Thomomys talpoides*, as well as two additional extralimital species that are absent from Sandia Cave, golden-mantled ground squirrel *(Callospermophilus lateralis)* and heather vole *(Phenacomys intermedius)*.

A bone of *Gymnogyps californianus* from Marmot Cave yielded a radiocarbon date of 25,090 yrBP (Brasso and Emslie, 2006), and two limb bones of *Marmota flaviventris* produced radiocarbon dates of 16,290 and 24,050 yrBP (Thompson, pers. comm.; Morgan and Harris, 2015). The radiocarbon dates from Marmot Cave confirm a late Pleistocene age for the vertebrate fauna, despite the lack of extinct species of large mammals. These dates establish that the Marmot Cave vertebrate fauna is actually somewhat older than the Sandia Cave fauna, with dates ranging from 16,290 to 25,090 yrBP, during and slightly after the Last Glacial Maximum (LGM) at about 20,000 yrBP.

The vertebrate faunas from Sandia Cave and Marmot Cave provide significant evidence pertaining to extinction and climate change in New Mexico at the end of the Pleistocene. Two patterns of extinction are evident in the Pleistocene fauna from the Sandia Mountains: (1) the extinction of nine species of large mammals and two species of birds; (2) the disappearance (local extinction or extirpation) from the Sandias of seven species of small mammals and seven species of birds that still survive in other mountain ranges in northern New Mexico. Radiocarbon dates confirm that Sandia Cave documents fossils from the time period at the very end of the Pleistocene (11–14,000 yrBP), during which humans first arrived in North America and the majority of large mammals on the continent became extinct.

There are two competing theories for the extinction of the Pleistocene megafauna in North America at the end of the Ice Age, human overhunting and climate change. In a review of the theories for the extinction of the megafauna, Koch and Barnosky (2006) proposed that this event was primarily human-caused resulting from hunting – the so-called "Pleistocene overkill" – but that climate change was also a factor, in particular a period of rapid temperature decline at the end of the Pleistocene called the Younger Dryas (12–13,000 yrBP).

The climate in New Mexico and elsewhere in the American Southwest has changed dramatically over the past 25,000 years, from cooler and wetter conditions during the late Pleistocene glacial interval (10–25,000 yrBP) to warmer and drier conditions during the Holocene and continuing to the present (the last 10,000 years). Climate change was accompanied by changes in vegetation, which in turn led to changes in the geographic distribution of many species of birds and mammals.

Cooler and wetter conditions of the late Pleistocene allowed montane habitats, in particular various types of coniferous forests, to occur at lower elevations (up to ~600 m lower) and farther south than the areas where these vegetation zones are encountered in New Mexico today (Dick-Peddie, 1993). The current vegetation in the vicinity of Sandia and Marmot caves consists of a pinyon-juniper woodland, but during the late Pleistocene this area would have supported a mixed conifer forest with spruce and fir, now found at much higher elevations.

Pleistocene changes in vegetation zones led to the occurrence of certain living species of small mammals and birds outside their current geographic ranges. These changes in geographic distribution primarily involved species now found at higher elevations in the mountain ranges of northern New Mexico (Sangre de Cristo, Jemez, and San Juan Mountains) occurring farther south and at lower elevations in the late Pleistocene. Sandia Cave and Marmot Cave document late Pleistocene "disharmonious" or "nonanalog" faunas in which many species of mammals and birds now absent from the Sandia Mountains occur together with species that still inhabit this mountain range. Most of the extralimital species of mammals and birds identified from Sandia Cave and Marmot Cave now live above 2,500 m in montane coniferous forests in northernmost New Mexico, as well as in the Rocky Mountains of Colorado, Utah, and Wyoming.

Acknowledgments

I am grateful to the U. S. Forest Service for approving a special use permit for NMMNH field crews to conduct paleontological excavations in Marmot Cave. Jessica Thompson, Shirley Libed, Susan Harris, and Sandra Bruschini assisted with the Marmot Cave excavations. Garrett Jorgensen and Carrin Rich kindly provided copies of their maps of Sandia Cave and Marmot Cave (= Davis Cave). Linda Starr asked me to write this paper, and also helped with editorial questions.

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Present-day chipmunk, Sandia Mountains.
Photo by Pete Lindsley.

Geology of the Sandia Mountains

Sandia Mountains. Photo by Pete Lindsley

By Carol A. Hill

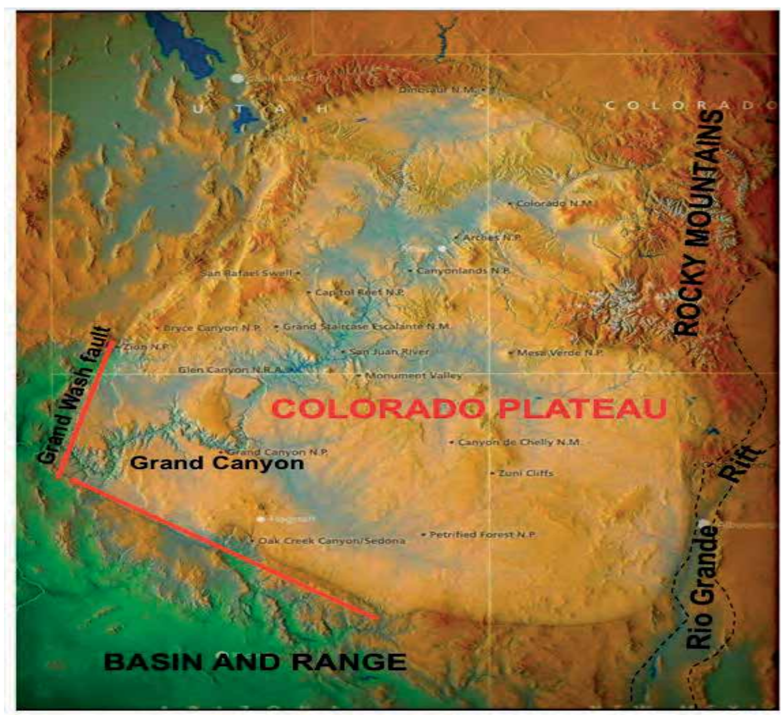

Figure 1. The Rio Grande Rift zone in relationship to the Colorado Plateau and Rocky Mountains. The Rio Grande Rift is part of the Basin and Range, not the Rocky Mountains. Google image.

The geologic provinces of the Four-Corners region of the Western United States consist of the Colorado Plateau, the Rocky Mountains, and the Rio Grande Rift (Fig. 1). Two main tectonic episodes have affected this region: (1) the Laramide (~80-40 million years previous) and (2) the Basin and Range (~20-0 million years past). The Laramide was a time of compression, or pushing together. This compression caused the Colorado Plateau to uplift to its present height, and since then it has acted like a single elevated tectonic block.

The Rocky Mountains on the northeast side of the Colorado Plateau also experienced a major episode of uplift in the Laramide, but with compression causing major faulting and folding. The Basin and Range was a time of extension, or pulling apart. This episode started when the Pacific Plate became subducted beneath the North American Plate. The Sandia Mountains are not part of the Colorado Plateau or Rocky

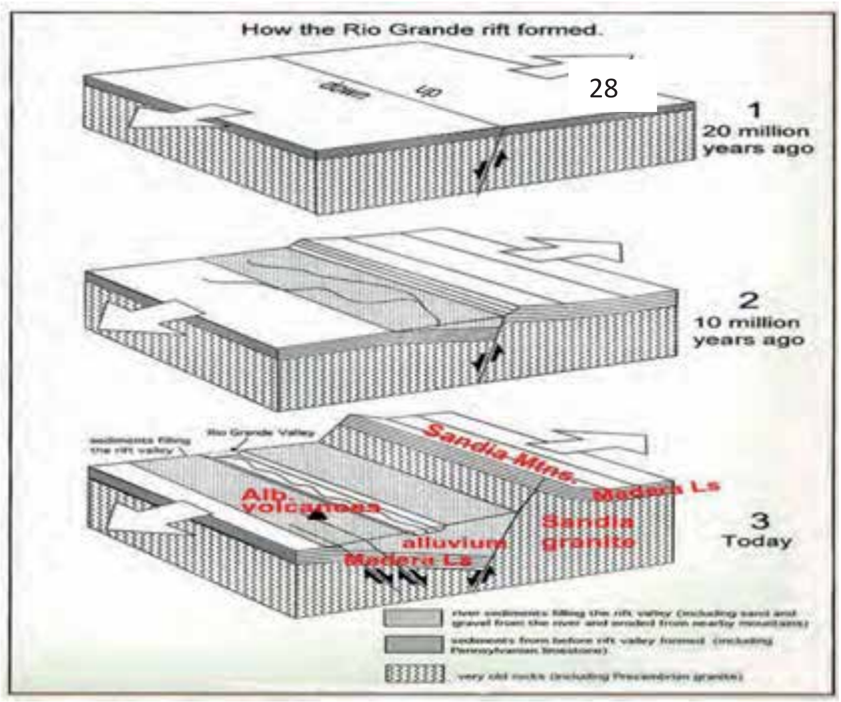

Figure 2. As the Rio Grande Rift pulled apart, the Sandia Mountains were uplifted and tilted to the east and molten lava came up fissures to form the Albuquerque volcanoes. After Aubele et al. (2005).

Mountains. They are part of the Rio Grande Rift, which is Basin and Range in age.

The Rio Grande Rift extends from Chihuahua, Mexico to Leadville, Colorado (Fig. 1). Rifting progressed as a series of rift basins aligned along normal faults, where mountains like the Sandias were raised, and fissures became pathways for ascending magma and volcanism (e.g., Albuquerque volcanoes), and basins became occupied by rivers such as the Rio Grande (Fig. 2). The Sandia fault – the main fault along which the Sandia Mountains were raised – has had about 20,000 feet of

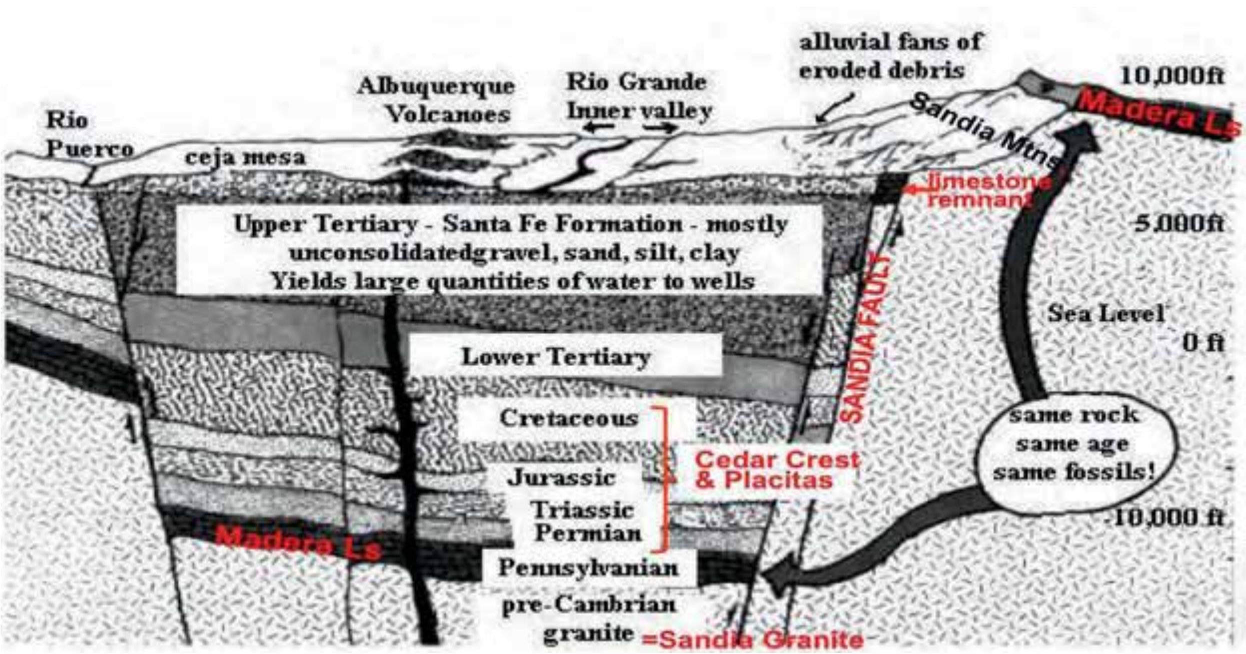

Figure 3. There have been over 20,000 feet of displacement along the Sandia fault! The Madera Limestone on top of the mountain at 10,000 feet elevation is also encountered in the Albuquerque Basin some 10,000 feet below sea level. Paleozoic and Mesozoic rock is exposed on the backside of the Sandia Mountains and also in Placitas. The Santa Fe Formation is the aquifer for Albuquerque. Note that the two main normal faults – the Sandia fault and Rio Puerco fault – make the Albuquerque Basin what is called a geologic graben.

displacement along it, so that its highest point, Sandia Peak, is now at an elevation of 10,678 feet (3255 m) (Fig. 3). However, the Sandia Mountains are also surrounded by the Tijeras fault on the south and smaller faults on its eastern Cedar Crest and northern Placitas sides. All of these faults have allowed the Sandia Mountains to be raised as a separate tectonic block. Normal faults exist along the entire Rio Grande Rift, all the way south to the Guadalupe Mountains of southern New Mexico, which were uplifted along the Border fault and tilted to the northeast. This uplift initiated the sulfuric acid speleogenesis of Carlsbad Cavern, Lechuguilla Cave, and other caves of the Guadalupe Mountains (Fig. 4; see Guadalupes section of this Guidebook).

The rocks of the Sandia Mountains consist of the massive Sandia Granite of Precambrian age (also called the Sandia Pluton) and the Sandia Sandstone/Conglomerate and Madera Limestone of Pennsylvanian age. On the Tijeras Canyon side of the Sandia Pluton are metamorphic rocks of Precambrian age, and on its backside and north side are rocks of Mesozoic age. The Sandia Granite has been radiometrically dated at 1.4 billion years old; from its fossil content the Madera Limestone is known to be about 300 million years old. Since the Sandia Conglomerate and Madera Limestone directly overlie the Sandia Granite, there is a 1.1-billion-year time gap between these units called the *Great Unconformity* (Figs. 4 and 5), which is about the same time duration as the

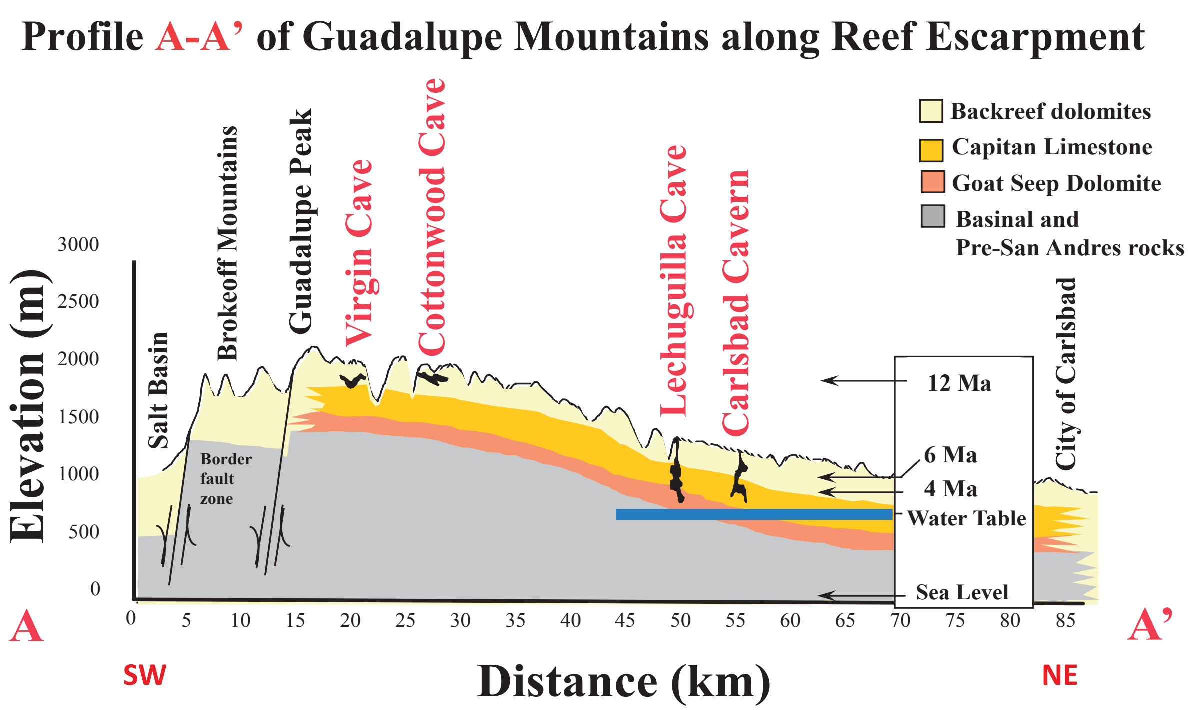

Figure 4. The Border fault zone, along which the Guadalupe Mountains were raised, are part of the series of faults along the Rio Grande Rift. The Guadalupe Mountain block began uplifting 12-15 million years ago, and with this uplift the Guadalupe caves began forming from southwest to northeast along the Guadalupe Ridge. After Polyak et al. (1998).

Great Unconformity in the Grand Canyon. The pebbles in the conglomerate indicate that a river once flowed over the top of the eroded surface of the granite about 300 million years past. Then, the ocean covered its surface and deposited the marine limestone with its contained fossils such as crinoids, brachiopods, and horn corals. The Madera Limestone is the unit in which the caves of the Sandia Mountains have formed. These caves will be the topic of a section later in this Guidebook.

Figure 5. Massive Sandia Granite overlain by the Sandia Conglomerate (covered by vegetation under the Great Unconformity) and topped by the horizontally bedded Madera Limestone. Photo by Roy Hill.

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Madera Limestone, along the road up to Sandia Crest. Fossils in the Madera include crinoids, horn corals, brachiopods, bryozoa, and gastropods. The Sandia Mountain caves are formed in the Madera Limestone. Photo by Alan Hill.

The Geological Story of the Albuquerque Area

By Jayne Aubele
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Geology combines science and history. The rocks and the landscape around us provide a record of the past if we can learn to read that record. In general, New Mexico's landscape represents primary geological processes. That means it is a relatively young, dynamic landscape that is still forming. The area around greater Albuquerque is a perfect example of this dynamic, young landscape; the mountains, river, and volcanoes are all a result of one specific geological feature – the Rio Grande Rift.

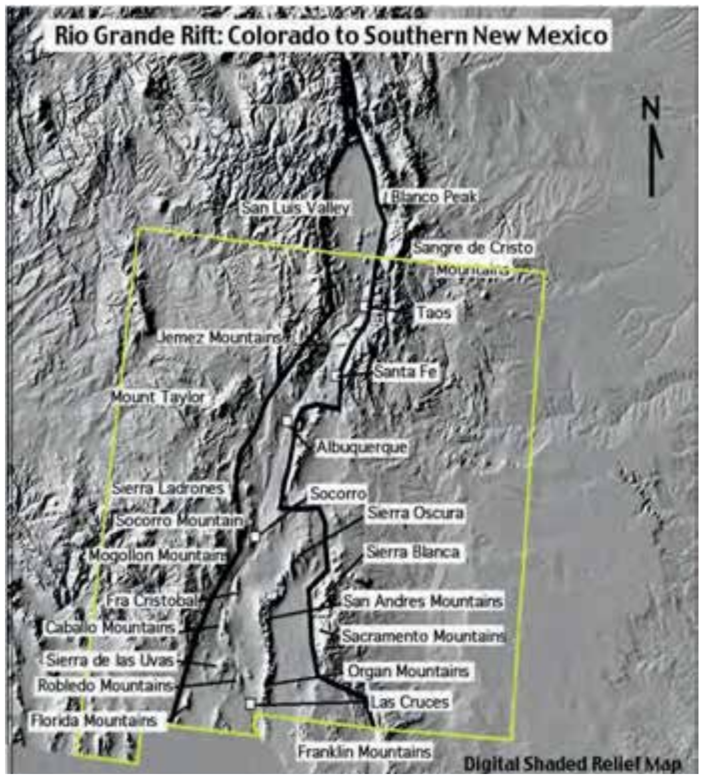

Figure 1. Digital, shaded relief map showing general topography. Yellow outline shows the boundary of the state of New Mexico. The black outline shows the margin of the Rio Grande Rift. The rift extends from southern Colorado to northern Mexico, and it defines most of the landscape throughout central New Mexico. This includes the central mountains, many of New Mexico's volcanoes, the location of the Rio Grande, and the location of many of New Mexico's largest cities.

Rio Grande Rift

The Rio Grande Rift extends from southern Colorado, through New Mexico, and into northern Mexico (Figure 1). Topographically, the rift is a broad, low area where Earth's crust is thinning and pulling apart and Earth's mantle is slightly closer to the surface. It is NOT a plate tectonic boundary; it is a continental rift located within the North American plate. Geologists believe that the rift began opening around 20 million years ago, which means it is geologically young, and it is still actively forming.

This rift is especially unusual. There are only five young, continental rifts on Earth and the Rio Grande Rift is one of them. Others are the East African Rift, the Rhine Valley in Germany, Lake Baikal in Siberia, and a recently discovered rift beneath the ice in Antarctica. In size, the Rio Grande Rift is similar to the East African Rift.

The Rio Grande Rift is not a single gash in the crust. It is a series of oval basins that are aligned north to south in en echelon or parallel patterns. Each basin has its own geological character.

The Albuquerque-Belen basin of the Rift is one of the larger basins. It is approximately 40 km wide at Albuquerque and extends 168 km from La Bajada north of Bernalillo to just north of Socorro at its southern end. It is filled with 20,000 feet of loosely consolidated sediment that eroded from surrounding highlands or was deposited by the river. The margins of the basin are defined by major boundary faults along which the crust has moved down in a trap-door movement, hinged on the west and forming a deeper basin to the east. As the basin has dropped down, the edges or margins of it have lifted up in a similar trap-door movement (Figure 2). This type of geological structure is called a "graben."

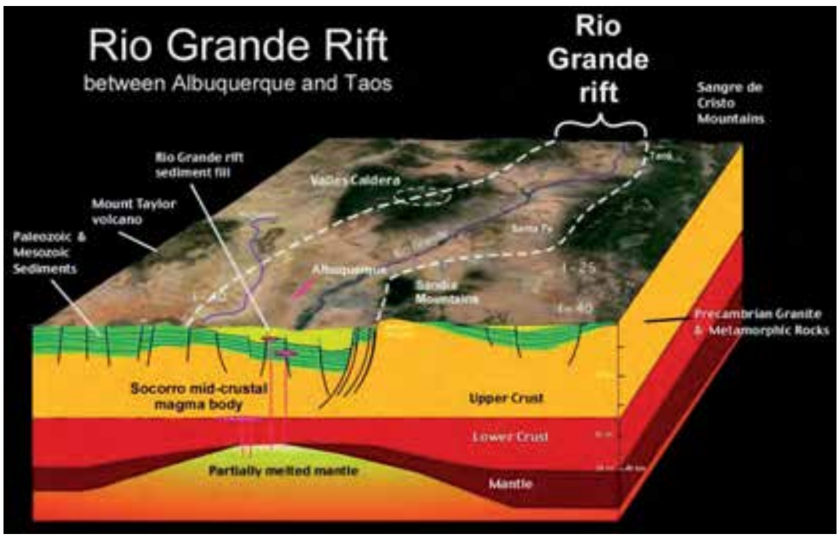

Figure 2. Cross-section of the Rio Grande Rift at Albuquerque along approximately the line of I-40 west to east. Dashed, white lines indicate the general margin of the rift. The Albuquerque basin of the rift shifted down in a trap-door movement that is hinged on the west and forms a deeper basin to the east. The green represents layered rocks that predate the rift. These rocks are thousands of feet beneath the city but outcrop at the crest of the Sandia Mountains. Pink represents magma beneath the surface of the rift and the location of the Albuquerque Volcanoes, marking the center of the rift.

The western margin of the Albuquerque basin is marked by a series of faults that step up to the west from the center of the basin to the Rio Puerco. A series of major faults along which the Sandia Mountains have lifted marks the eastern margin. The Sandia Mountains form the eastern margin of the Rio Grande Rift at Albuquerque.

Sandia Mountains

If you look at the Sandia Mountains from the Albuquerque area, they seem to be a steep vertical wall; but from the east or north they show a slope toward the east. The Sandias are an unusual type of mountain called a fault-block mountain. They formed as a block of rock layers was lifted up and tilted back toward the east; and this uplift occurred as a result of the formation of the rift. The Sandia Mountains are not part of the Rocky Mountains, which are much older and formed in a different way; the southernmost true Rocky Mountains end with the Sangre de Cristo Range east of Santa Fe. Geologically young, the Sandia Mountains are constantly lifting up as the rift continues to form. Geologists believe that they started lifting up only about 10 million years ago.

The Sandia Mountains have additional stories to tell. One important concept is that the age of a mountain may not be the same as the age of the rocks within the mountain. In this case, the rocks that have been lifted into view by the formation of the Sandia Mountains are exceedingly old, much older than the mountains themselves. In general, there are three major rock types in the Sandia Mountains: (1) granitic rocks (about 1.4 billion years old) that form the main mass of the mountains; (2) even older metamorphic rocks (about 1.6 billion years old) that outcrop in certain areas of the mountains; and (3) limestone (300 million years old) that forms the light-colored layers at the summit or crest of the mountains.

The limestone represents the classic situation of a seafloor on the top of a mountain; it was deposited as the floor of a sea that covered New Mexico 300 million years past and then was lifted up as the mountains formed. However, there is a mystery within these rocks. The 300-million-year-old limestone at the summit lies directly on top of the 1.4 billion-year-old granite (Figure 3).

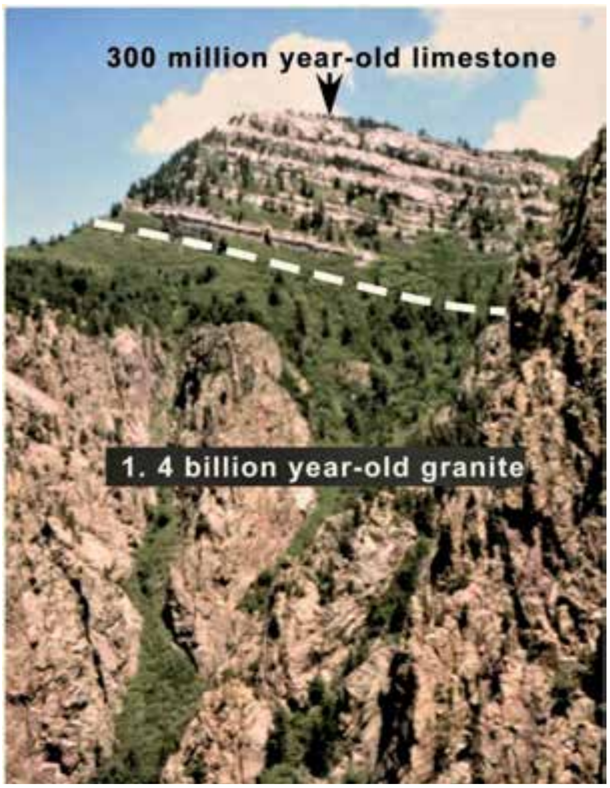

Figure 3. Sandia Crest, viewed from the south, shows the tilted aspect of the mountains. Also visible is the "Great Unconformity," shown by the dashed white line, between the 1.4-billion-year-old granitic rock and the 300-million-year-old limestone.

In general, rock layers are laid down by geological processes, one on top of another, over time. This means there is a large section of rock missing between these two units and the missing rock represents about one billion years of Earth's history. This gap in the rock record is called the "Great Unconformity" by geologists and it occurs all over central and northern New Mexico. What happened? One possibility is that there was a highland or mountain here sometime during that billion years, and it was eroded to a flat plain before the ancient ocean covered New Mexico. Geological processes continue throughout time and the landscape is continually changing.

Volcanoes

As a rift forms, the crust thins and pulls apart, the mantle warps upward, and faults are formed in the crust. It is a perfect situation for volcanoes. New Mexico has abundant volcanoes of different ages and different types. Not all of them are related to the rift, but many are. Albuquerque is a good example of a city that is surrounded by volcanoes; the closest volcanoes to the city are the "Albuquerque Volcanoes" and they are directly connected to the rift.

Albuquerque Volcanoes

You may notice a line of small hills west of Albuquerque that seem to form a straight line along the horizon. These hills are not old and eroded. They are young volcanoes of a type that geologists call cinder-spatter cones. They erupted in a fissure eruption, a line of fire similar to recent eruptions in Iceland or Hawaii, and a style of eruption that is not common in the western U.S. The straight line along which the volcanoes have formed marks the center of the rift at Albuquerque.

The Albuquerque Volcanoes erupted between 150,000 and 200,000 years past. As they erupted, basalt lava flows moved down gradient toward the river to the east and piled one on top of another forming a cap on top of the easily eroded sediments of the rift basin. Over the past several hundred thousand years, the edge of the lava flows eroded and formed what is now called the "west mesa" of Albuquerque. These eroded basalt blocks became a perfect canvas for ancestral Puebloan petroglyphs. The Albuquerque Volcanoes are only a few of many that have erupted within the Rift throughout its formation. (See the article by Crumpler in this volume for more information about New Mexico volcanism.)

Figure 4. The Sandia Mountains, viewed from the northwest. In the foreground are volcanic rocks that erupted within the rift. Clearly visible is the steep west face and the eastern tilted slope of the mountain. Also in view is the current Rio Grande channel and the young bosque (riparian forest) along the river.

The Gift of the Rift

There is one more major feature of the Albuquerque-area landscape that is directly related to the rift. The Rio Grande (our "Great River") forms a life-giving thread that extends throughout the state and has enabled humans and other species to live and survive in New Mexico. Prior to the development of the Rift, small rivers entered the Albuquerque area from the west. Once the Rift was established, snow melt and runoff from the Rocky Mountains and other highlands to the north followed the ready-made series of interconnected basins of the Rift rather than carving a large, extensive river valley. The Rio Grande became an integrated river about 4 million years in the past. For most of that time, the river has carried eroded sediment and deposited it within the pre-existing basins of the rift, filling those basins with sediment. Only occasionally, when stream flow increased, has the river eroded sediment and formed small channels. The current inner valley at Albuquerque, the bosque (riparian forest), was carved by the river as recently as 10,000 years before now (Figure 4).

The rift also provides the region with its aquifer. However, that aquifer is much more limited than once thought. Only the top layers of the basin's sediment fill contain the Albuquerque area's limited resource of potable water.

Welcome to a Great Rift!

You are in the middle of one of the very few great rift valleys on Earth, surrounded by abundant volcanoes, very young mountains, and a river that is the gift of the Rift.

Welcome to New Mexico!

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Overview of the Volcanoes of New Mexico

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Introduction

Volcanologists identify many different types of volcanoes, defined by differing structure, abundance of lava versus pyroclastic material, and overall shape. Many of the differences derive from differing conditions of volcanic eruption, and variations in composition, volatile content, and the environment and rate of magma transport through the crust. New Mexico is somewhat unusual in that there are youthful examples of every principal type of volcano (Crumpler, 2009), all of which contribute to the unique landscape that distinguishes New Mexico from much of North America. In this article, we review a few examples from the thousands of volcanoes in New Mexico. Also given is an extremely abbreviated discussion of why they are unusual and represent a valuable scientific and natural heritage resource.

Ages and Distribution of Volcanoes

Volcanoes occur throughout the state, but the more recent eruptions have been along an east-northeast trend across the northern part of the state known as the Jemez Lineament (Fig. 1) and in areas where there has been late Cenozoic crustal fracturing. The Jemez Lineament does not have a strong physiographic expression and appears to be related to deep lithospheric structure. The areas of late Cenozoic crustal fracturing generally include the Rio Grande Rift and those parts of southern New Mexico within the Basin and Range province.

A Few Examples of the Range of Volcano Types in New Mexico

New Mexico has a youthful example of almost every type of volcano, but there are a few

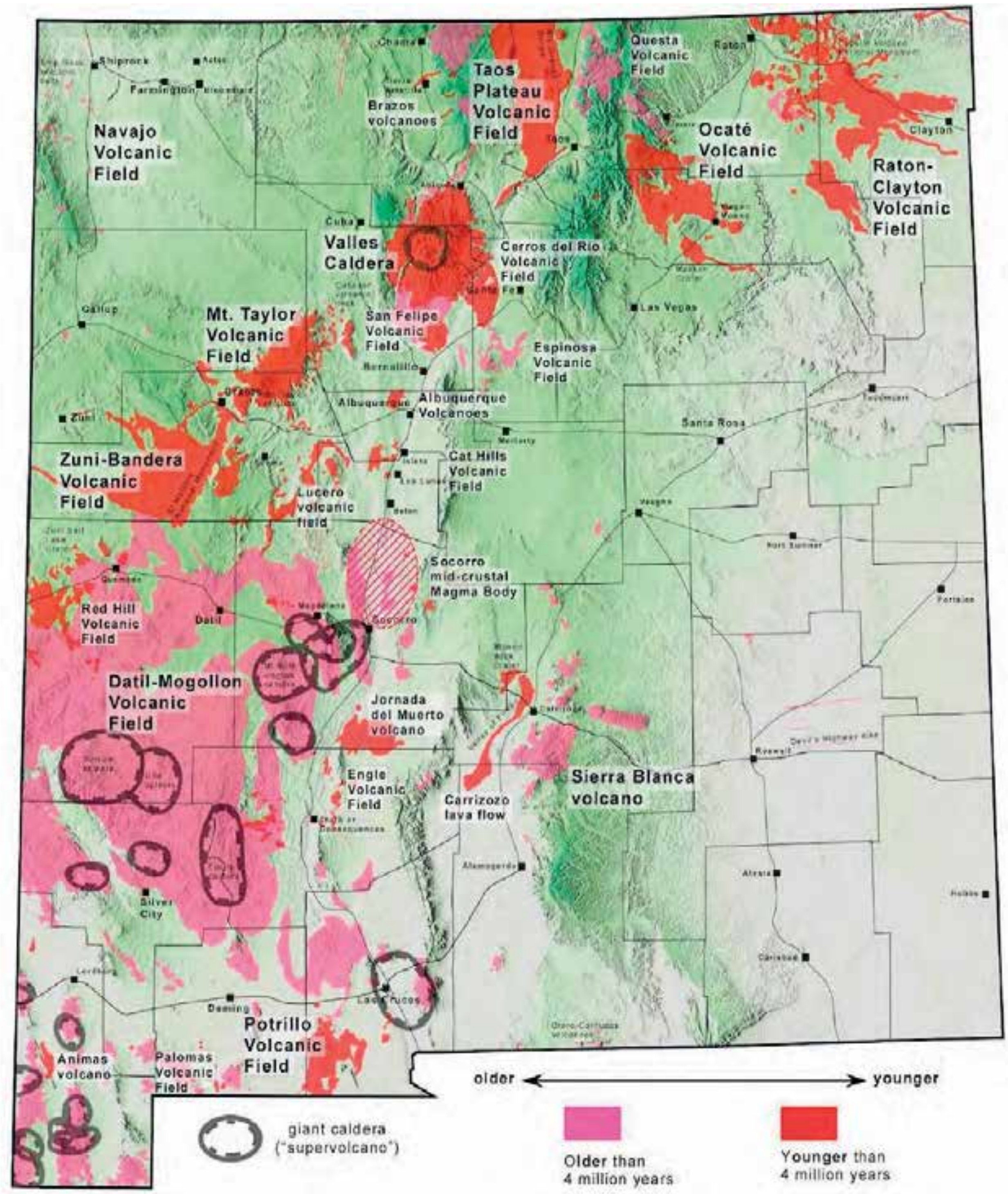

Figure 1. Distribution of volcanoes in New Mexico. L. Crumpler.

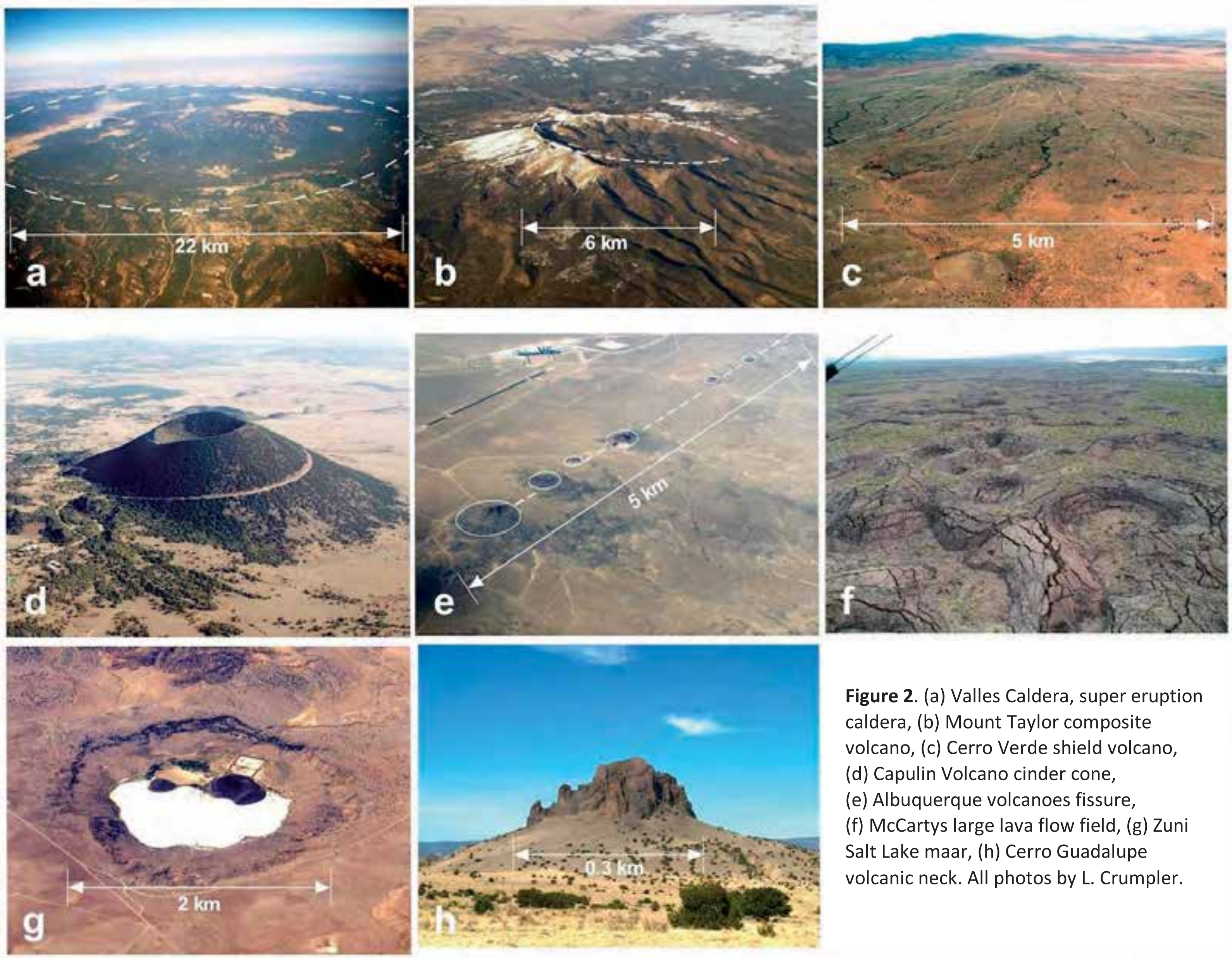

Figure 2. (a) Valles Caldera, super eruption caldera, (b) Mount Taylor composite volcano, (c) Cerro Verde shield volcano, (d) Capulin Volcano cinder cone, (e) Albuquerque volcanoes fissure, (f) McCartys large lava flow field, (g) Zuni Salt Lake maar, (h) Cerro Guadalupe volcanic neck. All photos by L. Crumpler.

notable types: (1) large caldera (sometimes referred to as "supervolcano"), (2) composite or strato-volcano, (3) shield volcanoes, (4) cinder cones, (5) fissure eruptions, (6) great (large volume) lava flow fields, (7) maars or magma-water, steam-blast explosion craters, and (8) volcanic necks.

Large Caldera: The Valles Caldera (Fig 2a). The type example of a large explosive caldera, the Valles Caldera formed by super eruptions (> several hundred cubic kilometers) of rhyolite ash and ash flows about 1.12 million years ago (Goff, 2009). The ash flows today form massive cliffs of welded tuffs lining radial canyons around the caldera rim. The latest eruptions occurred in the Valles Caldera about 40,000 years ago, were thick rhyolite lavas on the caldera floor and are responsible for a thick series of pumiceous ash that may be seen in road cuts throughout the caldera today.

Composite Volcano: Mount Taylor Volcano (Fig 2b). This is the second largest young volcano in New Mexico and was active from about 4 mya to 1.5 mya (Crumpler and Goff, 2013). The volcano consists of a sequence of several different types of lava flows, beginning with rhyolites formed from crustal melting, various early alkali basalt eruptions from scattered vents, and later hybrid magmas of trachyandesite and trachydacite composition. This volcano has a classic sweeping and truncated volcanic cone profile when viewed from the south, north, or west. From Albuquerque, it appears as a three-peaked mountain on the horizon. The three peaks are actually the far wall of the summit depression, possibly widened by erosion from an original summit crater. The plateau extending north is part of the field and includes some exotic alkali basalt and trachyte domes (Crumpler, 1980), as well as many pre-served maars.

Shield Volcanoes: Cerro Verde (Fig 2c). Youthful shield volcanoes are scattered throughout New Mexico. However, as a result of their low slopes, they are naturally easy to miss. They have complex vent regions and each is distinct, yet there are some broad characteristics. Cerro Verde, part of the Lucero volcanic field (Baldridge, et al., 1987), is a well-developed, mature example. It consists of overlapping, digitate lava flows radiating from a summit region dominated by three cinder cones. The flanks slope uniformly between 4 and 10° to a distance of 3 km radius from the summit, except in the direction down the regional gradient, where the lava flows extend for several kilometers. Other examples in which the flanking slopes are shallower and the edifice much less developed are dominated in the vent region by perched lava ponds, in many cases characterized by variable degrees of inflation.

Cinder cones: Capulin Volcano (Fig 2d). As elsewhere on Earth, cinder cones are the most common type of volcanic vent edifice in New Mexico. Two scenic examples occur in the Zuni-Bandera field (Bandera Crater-Ice Caves) and Raton-Clayton volcanic fields (Capulin Volcano) (Stormer, 1987; Aubele and Crumpler, 2001). Capulin Volcano is a classic cinder cone, the eastern-most young volcano in North America, one of the first national monuments, and one of the few volcanoes with a paved road winding to the summit crater. It erupted approximately 56,000 to 62,000 years ago (Stroud, 1996). It is similar in size, morphology, and eruption to Paricutin volcano, which erupted in Mexico in 1943.

Fissure Eruptions: Albuquerque Volcanoes (Fig 2e). Almost all volcanoes begin as short fissures from a few meters to several hundred meters long, from which eruptions commence and quickly confine to a more central conduit. In some cases, the regional crustal strain is such that an initial eruption fissure is several kilometers long, as are the cases of Iceland, Hawaii, and the Albuquerque Volcanoes. The resulting curtain of fire can deliver large volumes of low-viscosity basalt. The Albuquerque volcanoes fissure is over 6 km long and the source of lavas that make up the escarpment of the Petroglyphs National Monument (Crumpler, 1999; Smith et al, 1999; Kelly and Kudo, 1978). The most recent dates (Chan et al, 2016) imply an age of about 190 ka. Although older than many New Mexico volcanoes, if you know what to look for, you may see many fine details of the eruption process not visible in many other even younger volcanoes.

Large volume lava flow fields: McCartys and Carrizozo flow fields (Fig 2f). Two of the largest young lava flows in the western hemisphere occur in New Mexico. The McCartys flow is a 7 km^3 tholeitic lava field within El Malpais National Monument in western New Mexico near Grants, with a cosmogenic exposure age of 3.9±1.2 kya (Dunbar and Phillips, 1994). The Carrizozo flow (Keszthelyi and Pieri, 1993) is a 75-km-long and ~4.3 km3 transitional, composition lava flow in the Tularosa Valley (Zimbelman and Johnston, 2002) and is slightly older at 5.2±0.7 kya (Phillips et al, 1997). Both lava flows are dominantly pahoehoe.

Both lava flows erupted into relatively low slopes of valley floors. Recent research and mapping (Crumpler et al, 2013) has shown how large volume lava flows tend to undergo endogenous growth or “inflation” in areas of shallow slope, and both the McCartys and Carrizozo flow fields are prime examples of the phenomenon. The inflation process has resulted in few occurrences of lava tubes in both flows. Inflation has enabled identification of flow unit sequences and corresponding ability to estimate the rate at which the 7 km^3 of basalt were emplaced. This estimate is important in establishing some of the environmental consequences of large volume lava flow.

Maars: Zuni Salt Lake (Fig 2g). Maars are craters, usually about a kilometer in diameter, the floors of which lie below the current surface elevation. A maar forms when magma rising and erupting at the surface of the Earth encounters substantial water in the shallow subsurface. This usually happens in areas where the subsurface is saturated with water in river valleys, or within or adjacent to large bodies of water. That many examples of maars exist in New Mexico (Aubele et al, 1976) probably reflects the fact that most obvious examples are from a time (the last 2 million years through roughly the Pleistocene) when New Mexico was relatively wet compared with today. Zuni Salt Lake (estimated at 22.9 kya ±1.4 kya, Bradbury, 1966) is approximately 1.6 km in diameter. The walls consist of surge beds, accretionary lapilli, and infrequent blocks of sedimentary basement rocks (Elston and Wohletz, 1987), as well as fragments and mixed blocks of juvenile basalt and scoria. Three small black cones occur on the shore of a small, interior saltwater pond.

Volcanic necks: Cerro Guadalupe (Fig.2h). While Shiprock is an iconic volcanic feature of New Mexico, one of the premier areas of volcanic necks is the Rio Puerco Valley between the Mount Taylor volcanic field (Mesa Chivato) on the west and Mesa Prieta on the east. Cabezon Peak is one of many massive dark volcanic necks scattered throughout the Rio Puerco valley, but there are dozens of others (Crumpler, 2010; Hallet, 1992). Cerro Guadalupe is a complex volcanic neck southwest of Cabezon (Hallet, 1992) and illustrates the complexity: Masses of scoria, agglomerate, and massive bas-alt sheets form vertical cliffs resting, where exposed on early hydromagmatic tuff breccias. Other volcanic necks are simply the expression of former lava ponds within the craters of small vents. Further examples around the south margin of the Mount Taylor field include half-sectioned volcanoes (Crumpler, 2003). In addition to their structural characteristics, many of the volcanic necks host a variety of mantle nodules and crustal xenoliths that have been studied by petrologists. (Schmidt et al, 2016).

For more information about New Mexico's volcano collection, visit the Volcanoes of New Mexico pages on the New Mexico Museum of Natural History and Science website.

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An Introduction to the National Cave and Karst Research Institute

By George Veni,
NCKRI Executive Director and NSS #17322L

What is NCKRI?

The National Cave and Karst Research Institute (NCKRI) was created by the U.S. Congress in 1998, which established NCRKI's mission as to:

1) further the science of speleology;
2) centralize and standardize speleological information;
3) foster interdisciplinary cooperation in cave and karst research programs;
4) promote public education;
5) promote national and international cooperation in protecting the environment for the benefit of cave and karst landforms;
6) promote and develop environmentally sound and sustainable resource management practices.

Initially, NCKRI was established as an institute within the US National Park Service, but it 2006 it changed to a non-profit 501(c)(3) corporation to increase its flexibility to meet its mission.

NCKRI's vision is to become the world's premier cave and karst research organization through its mission to promote and perform projects of national and international application, of the highest quality and integrity, through dedicated staff and partners.

Why is NCKRI located in New Mexico?

As Congress was creating NCKRI, it looked for states to partner in supporting the institute. New Mexico came out on top, offering matching funds and through the City of Carlsbad, which constructed NCRKI Headquarters with roughly 50 percent city, 25 percent State of New Mexico, and 25 percent federal funds. Due to this early and critical partnership, these three entities have permanent positions on NCKRI's Board of Directors. New Mexico is represented by the New Mexico Institute of Mining and Technology (aka New Mexico Tech or NMT), which administers NCKRI's state and federal funds. The federal government is represented by the National Park Service, and the City of Carlsbad by a designated employee or city councilor.

What projects is NCKRI involved in?

Some of NCKRI's recent and current projects include:

● World Karst Map. The first reports on this should appear in 2017.

● Karst Information Portal. Free, on-line international cave and karst library at www.karstportal.org.

● Geophysics. A wide variety project in diverse settings, including the first electrical resistivity surveys in bat guano under the world's largest bat colony.

● Hydrogeology. Focused so far in New Mexico and west Texas, fresh and brackish water resources have been studied through hydrologic, geochemical, and dye tracing techniques.

● **Lampenflora in Carlsbad Cavern**. "Algae" commonly grows under lights in show caves. NCKRI is conducting a two-year study of

John Corcoran and Lewis Land doing resistivity studies outside of Fort Stanton Cave. Photo courtesy of G. Veni.

such growth in Carlsbad Cavern under the new LED lighting system, using cutting-edge microbiological techniques.

● By Lantern Light. This documentary on Jim White, the lead explorer of Carlsbad Cavern, is in development with a 2017 or 2018 estimated completion date.

● National and international workshops and lectures. To date, NCKRI has taught workshops on caves and karst in five US states and six countries.

● Conferences. NCKRI manages the Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst (aka, "The Sinkhole Conference") which will next be held in Shepherdstown, West Virginia, and include the 3rd Appalachian Karst Symposium. NCKRI has also organized and partnered on several other conferences, the most recent being DeepKarst 2016 on hypogenic karst.

What's the relationship between the NSS and NCKRI?

Excellent! We have no formal MOU or other document to define our relationship, but we remain open and helpful to each other on many levels. NCKRI provides an activities report to each NSS BOG meeting. NCKRI doesn't want to compete with any cave or karst organization, but wants to cooperate with all of them. The needs of cave and karst exploration, research, education, and management are too great for any one organization to handle. We need to work together and build on each other's strengths.

Stop by and visit us at our headquarters in Carlsbad, New Mexico.

How can you get involved with NCKRI?

Contact me: George Veni, 575-887-5517, gveni@nckri.org, NCKRI's needs vary according to its current projects and the location of its volunteers. Let me know your interests and we'll see what we can come up with. Also, if you want to get occasional cave and karst news and announcements, let me know and I'll add you to NCKRI's e-mail list.

If you have any questions about NCKRI or wonder if NCKRI may be able to assist you or your project, contact me at any time.

The Hunt for Intraterrestrials in New Mexico Caves

By P.J. Boston and D.E. Northup

You Can't See Me!
Courtesy, R.D. Frederick
gus@marsunderground.org

The remarkable subterranean landscapes of New Mexico are justifiably famous for their geologic and mineralogic treasures, but another marvel is contained in these wonderlands – a vast array of microorganisms of many exotic varieties that are less widely appreciated. Together, the diversity of the geology and geochemistry of the caves and the diversity of their microscopic inhabitants create a menu of environments that are enriching our understanding of Earth biology, and may even give us important lessons about environments possible on other planets and moons.

We know there are volcanic caves, both deep pits and lava tubes, on the moon, Mars, Venus, Io (volcanically active moon around Jupiter), and even the planet Mercury. Of course, looking for our type of life restricts us to thinking about the possibilities on Mars in volcanic caves, but caves in sedimentary or evaporite rocks there may also be possible. Thinking outside of the box into the realm of so-called cryovolcanism (eruptive processes in icy terrains), some of the geologically active bodies in the solar system (e.g. Europa, Enceladus, and Titan) may have cave-like features. Perhaps, they are sites of extraterrestrial biology. But meanwhile, right here in New Mexico....

As you explore the amazing passages of New Mexican caves, trillions upon trillions of microscopic organisms are mining the walls for food, making more organisms, and excreting waste products that help make some of the speleothems you're seeing. This hidden world of intraterrestrials has been revealing its secrets to the scientists studying microbes in NM caves for the last 25 years. We've learned that tiny bacteria with long, tail-like appendages, that are 1/100th the width of one of your hairs, are responsible for mining forms of manganese and iron in the crystal lattice of limestone cave walls. In Fort Stanton Cave, the starkly contrasting, black-and-brown deposits that line the walls of the beautiful, white Snowy River Passage are inhabited by many extremophilic bacteria and archaea ("extreme condition lovers") that are transforming different forms of nitrogen to supply a critical nutrient for their communities. Other microbes are multiplying and making a slimy matrix in which they are embedded, and precipitate calcite and other minerals beneath the shelfstone of pools, helping make the pool fingers we see today in Guadalupe Mountain caves. Even more visually obvious are the sparkly microbial/mineral mats

Dennis Worthington surveying in Snowy River Passage, Fort Stanton Cave. Photo by K. Ingham with assistance from Kyle Uckert.

Microbes Doing Essential Ecosystem Jobs in Extreme Conditions

By Jason Kimble

While your eyes were probably drawn immediately to the beautiful white, calcite-lined Snowy River channel, my attention leaps directly to dramatic black and brown coatings (aka speleosols) found on the walls above and throughout Snowy River passage. I am a Ph.D. student at the University of New Mexico working on microbial data from Fort Stanton Cave. Some of my research findings have revealed that those speleosol deposits contain an untold number of bacteria and archaea (mainly known as extremophiles, "lovers of extreme conditions"). These fascinating microbial communities are doing critical biological engineering jobs that allow them to live in a hostile environment, where nutrients are scare.

Evidence of some of these processes are visible to the human eye, such as the occurrence of the speleosol deposits. My findings are showing that some of these microbes, with archaea playing a key role, are able to take different kinds of nitrogen, which is critical to all life (e.g. ammonium or nitrate), and make energy for themselves. Remarkably, the waste products generated from these processes transform nitrogen into many other different biologically available forms that other microbes in the community can use for both energy and nutritional needs. This keeps the important task of the cycling of nitrogen moving in the cave.

The ammonia oxidizing archaea found in the Snowy River ecosystem are completely different from their counterparts found in surface soils above sampling sites in the cave. Instead, they show similarities to other archaeal microbes previously identified in deep South African gold mines and also marine environments.

that festoon the walls of lava caves in El Malpais National Monument.

Speleosols – Microbes Making Underground Soils

When you explore Lechuguilla Cave or Spider Cave in Carlsbad Caverns National Park, you may get coated with what early explorers used to call "gorilla shit" – lovely, right? Because of early work by Kiym Cunningham, a Colorado cave explorer and scientist working at the U.S. Geological Survey, we began studying whether microbes could make these ferromanganese deposits that line the walls. Through our studies of the microbes, geochemistry, and mineralogy of the deposits, Michael Spilde concluded that these represent an underground soil-forming process. He named these sticky skin-staining deposits "speleosols", a true "cave soil" (Figure 1).

To test whether these speleosols are partly produced by microbes, we grew microbes (a process known as culturing) from these deposits and followed what happened over time compared to microbes that we grew and killed early on. We found that the highly crystalline minerals only formed in live cultures after significant periods of time. This supports our hypothesis that speleosols are microbial products. So, next time you're crawling through "gorilla shit," say hello to the trillions of microbes going about their daily business! The gorillas in this case are extremely tiny....

Frozen in Stone

Pool fingers (Figure 2) were first studied in New Mexico caves by Donald Davis and colleagues. These fascinating shapes intrigued Leslie Melim of Western Illinois University, who combined forces with the authors to study these extraordinary speleothems. What caught her attention was that mineral formations shouldn't necessarily grow vertically downward underwater; maybe "assistance" could come from our friends the microbes! Scanning electron micrographs

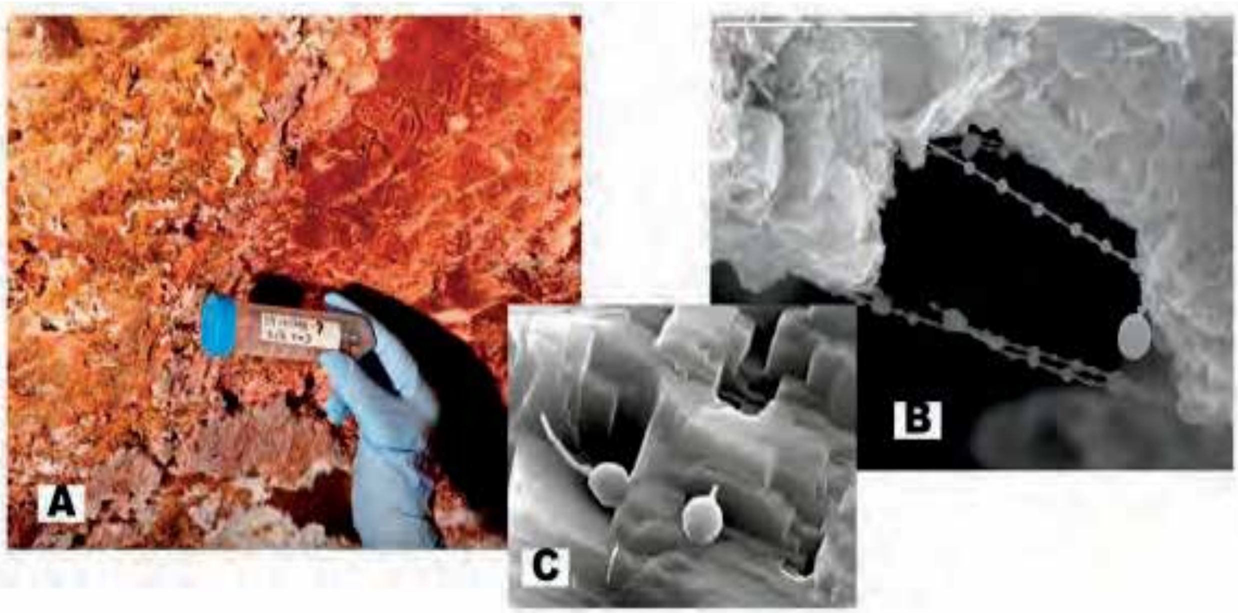

Figure 1: A. Ferromanganese deposits (speleosols) in Spider Cave. Photo by K. Ingham. B. Beads-on-a-string microbial shapes in Lechuguilla Cave. Scale bar is 5 micrometers (~1/20th the width of a human hair). C. Bead microbial shapes from Spider Cave speleosols. Scale bar is 2 micrometers (~1/50th the width of a human hair). Photos B and C by M.N. Spilde and D.E. Northup.

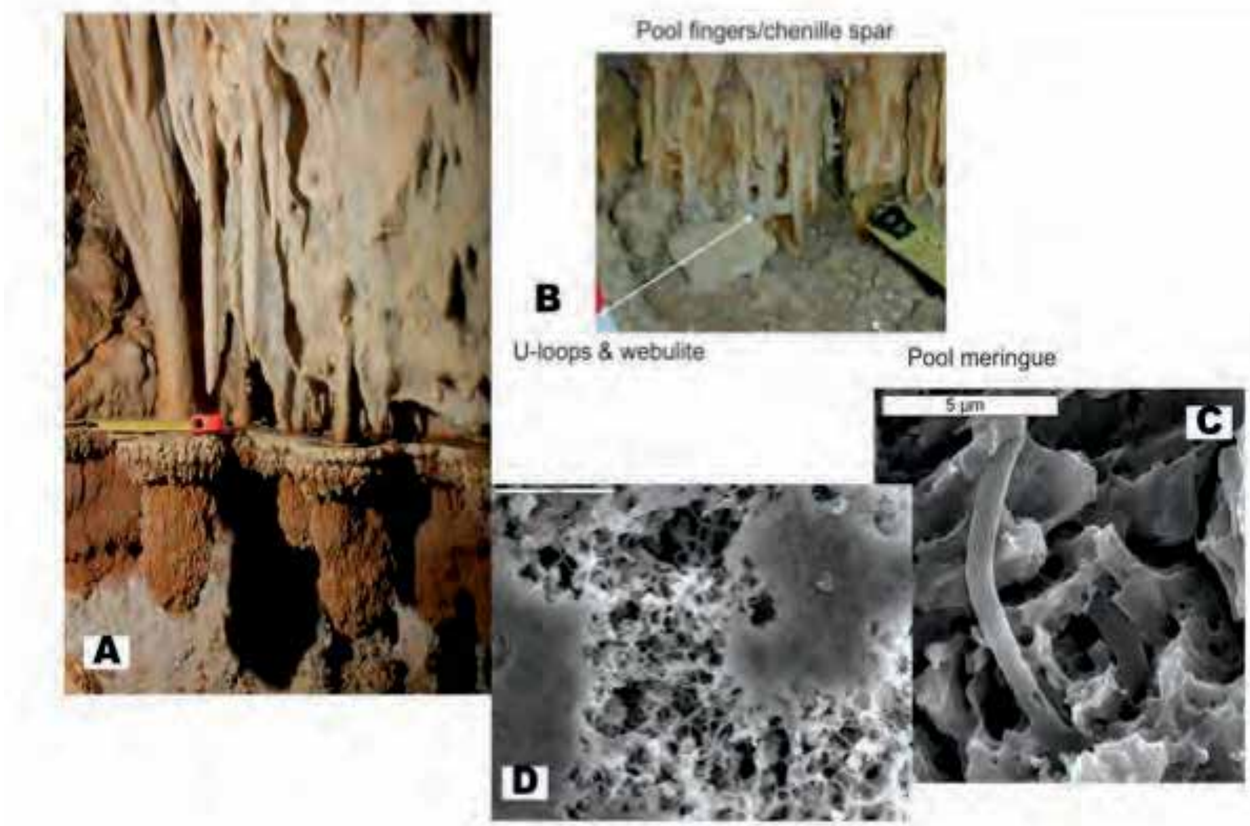

Figure 2: A. Pool fingers in Cottonwood Cave. B. Pool fingers, chenille spar, U-loops, webulite, and meringue in Carlsbad Cavern. C. Reticulated filament from Lechuguilla Cave pool finger. D. Microbes revealed after weak acid dissolution of carbonate speleothem. Photos A & B by K. Ingham. Photos C & D by L. Melim.

(Figure 2) revealed amazing morphologies preserved to a miraculous extent in these stone fingers. We would never have known this without a technique that Leslie used – applying a weak hydrochloric acid solution for a few seconds to the thin sections she made from the pool fingers. This revealed not only abundant preserved microbial filaments, but mineralized biofilm (a slimy matrix) in which they were originally growing. We have also learned that pool fingers in different caves have a range of microbial filament types. Depth below the surface seems to be one factor that affects this, plus possibly the presence of clays. These speleothems are a great feature to combine the study of geology and biology to really understand what's going on.

One of the most interesting microbial shapes that we have seen extensively in the pool fingers (and elsewhere in caves) is what we call reticulated filaments, or micro-cholla (Figure 2D). These filaments resemble the mesh-like cholla cactus skeleton that remains once a cholla dies. They are unique and we have not found microbial shapes like this in any of the microbiology encyclopedias, nor have they been seen by colleagues we consulted. We have observed these in many Guadalupe Mountain caves, in Carlsbad Cavern, Lechuguilla Cave, and numerous other caves worldwide. The hunt is still on to discover "who" these intriguing microbes are.

Bedrock Effects and Ancient Genes for Antibiotic Resistance

Examining the host rock geochemistry in Carlsbad Cavern, Hazel Barton has discovered the amount of biodiversity of the microbial community appears to be tied to the makeup of the bedrock on which the bacteria live. Bacteria living on the Yates Formation had a broader range of nutrients to support their rock-eating life-style than found in the Capitan limestone. Her studies revealed the importance of interdisciplinary studies that combine geological and biological aspects of a research topic.

Further, deep in the remote passages of Lechuguilla Cave, Hazel and her team sampled and grew bacteria that led to an exciting discovery. They found that the bacteria she had cultured in areas with little human contact were highly resistant to multiple antibiotics. This suggests that antibiotic resistance may have existed for a very long time in microbial genomes.

The Walls Are Alive with Sparkles Galore!

Often mistaken for mineral deposits on lava cave walls, microbial mats contain a wonderland of microbial diversity (Figure 3). During certain times of the year, water beads up on them as the microbes become water-repellent. When we shine our headlights on them, the walls appear to sparkle. Microbial mats, especially in El Malpais National Monument (ELMA), are usually white, tan, or yellow. Using genetic sequencing, we've learned at least 14 phyla of bacteria (very large groups of organisms) live in these mats across several different caves. For comparison, we're in the phylum that contains ALL animals, which shows that the bacterial diversity in ELMA caves is immense! One of the most common phyla is the Actinobacteria. This group provides two-thirds of our natural antibiotics. We know through studies testing for antibiotic production, that many of these microbes produce antibiotics that inhibit other microbes in lab studies.

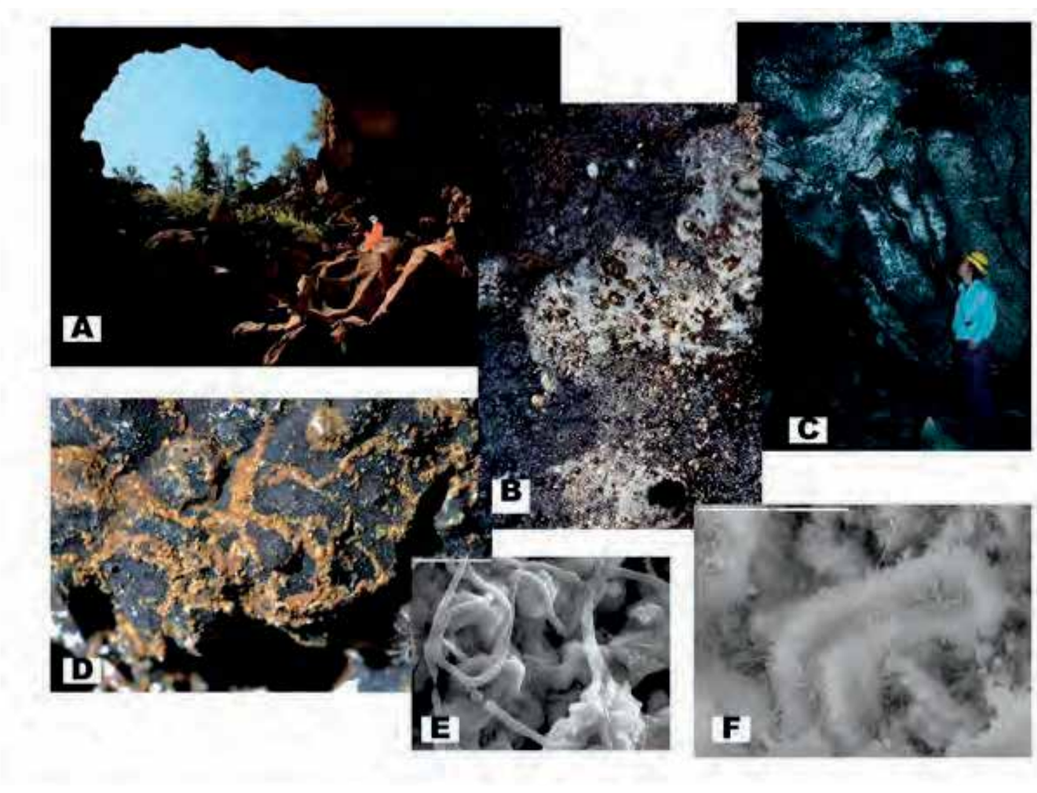

Figure 3: A. Entrance to ELMA Cave 12. B. Close-up of microbial mat on wall. C. Sparkly white microbial mats. D. Cryptic gold-colored minerals on wall. E. SEM image of microbes in D. F. SEM image of microbes in Cave 12 microbial mat. Macroscopic photos by K. Ingham.

Asking "who's home?", we find that communities differ from cave to cave. Why? By comparing NM communities with those in lava caves in Hawai`i, California, the Azores, and Iceland, we have learned the amount of surface precipitation, distance from an entrance, number of entrances and morphology of cave passages all make a difference in who and how many microbes we find. We've found that there are many microbes in the phylum Nitrospirae, nitrogen-recyclers, critical because biologically available nitrogen is critical to all life. Other microbes are called "chemolithotrophs" – a long word meaning that they're "rock eaters," getting their energy from sulfur, iron, manganese, etc. Others feed on the organic carbon slowly coming into the cave from the surface and other sources.

Another intriguing thing about lava caves is that they are especially rich in what we call cryptic minerals or microbes that masquerade as minerals (Figure 3). What looks like just a mineral can also contain a wealth of microbes – and different ones than we see in the microbial mats! These cryptic, biologically-influenced minerals can give us important clues as to how to know life when we see it in a lava cave here on Earth, on Mars, or some other extraterrestrial body! You can see that we have one of the most fun scientific playgrounds here in New Mexico, as we figure out basic principles that govern microbe life in our lava caves.

Figure 4: Bats being swabbed for DNA and microbes; isolating Actinobacteria from bat cultures.

New Mexico Bats—

Do They Hold the Answer to How to Control White-Nose Syndrome?

D.E. Northup

Southwestern bats are incredibly diverse with more than 28 species. Contrary to some assumptions, New Mexican caves are not warmer and drier than many eastern caves. Instead cave geometry and other factors often lead to caves being significantly colder than *(continued on next page)*

(continued from previous page)

the mean annual surface temperature of the region, as shown by bat biologist Debbie Buecher. Thus, the risk of white-nose syndrome (WNS) is not insignificant. Since 2010, a collaboration of researchers at the University of New Mexico, Western Illinois University, Buecher Biological Consulting, and the US Geological Survey has investigated who lives on bats (i.e. the microbiota, Figure 1). We are investigating whether the bacterial and fungal microbiota living on bats could provide a natural defense against WNS. Our studies have shown the identities of the microbiota on bats differ depending on whether the bat was caught in a cave or on the surface, suggesting that changes occur when the bats go out to feed or roost in a cave. The habitat or ecoregion where the bat resides also impacts the bat microbiota, as does the size of the bat.

Additionally, we cultured (grew) bacteria from the bats to test the bacteria's ability to kill *Pseudogymnoascus destructans*, the fungus that causes WNS. The dinner we feed to the bacteria selects for bacteria in the phylum *Actinobacteria*, the group from which we get two-thirds of our natural antibiotics. Nicole Caimi, at the University of New Mexico, has isolated over 3,400 different Actinobacteria and other bacteria from bats in New Mexico and Arizona (Figure 4). Many of these isolates have been tested for their ability to kill or inhibit *P. destructans* in the WIU lab. More than 80 different isolates have inhibited *P. destructans*. Southwestern bats are revealing some potential natural defenses that may help the bats if and when WNS arrives in this area of our country.

Guadalupe Bat Flight. Watercolor art by Andy Komensky.

Annotated Geology Field Trip

Geology of the New Mexico Pueblo Lands
2017 National Speleological Society Convention
Rio Rancho, NM, June 18th, 2017

By David D. Decker, dave.decker@caves.org
Gerald Atkinson, jerryatkin@aol.com
Kevin M. Madalena, kevin.m.madalena@gmail.com

Satellite view of the area covered by the 2017 NSS Geology Field Trip. Photo credit: Google Earth.

About the Guides/Authors

The guides, from left to right: Jerry Atkinson, Dave Decker, and Kevin Madalena.

Dave Decker

Dave retired from the U.S. Navy in 2010 after 25 years of service. While in the Navy, he. performed the duties of both Naval Flight Officer and Aerospace Engineering Duty Officer. Upon retirement, Lieutenant Commander Decker went in a different direction and began taking classes to fulfill a lifelong passion - geology.

Dave graduated in December, 2016 with his PhD in geology, concentrating in geochronology and geochemistry. His studies focused on, but were not limited to, constraining the uplift of the Guadalupe Mountains in southeastern New Mexico and west Texas. Dave is currently a Fellow and life member of the NSS and, as of the 2017 convention, is beginning his third year as a Director on the NSS Board of Governors. He has been a member of the Society since 1989.

Jerry Atkinson

Jerry worked for the USGS for several summers as a field geologist during college, graduating from the University of Texas in Austin with a Geology degree in 1983. From 1983 to 2013, Jerry was employed as an exploration and production geologist for Exxon Mobil working the Far East, Australia, Mexico, Canada, and USA. Jerry is currently the Director and of the Texas Speleological Survey and has been an officer since 1994. Additionally, Jerry has been the Chair of the Texas Speleological Association of the NSS and was a past director of the Texas Cave Management Association. Currently, he is serving as the editor for the TSS and is Chair of the Southwestern Region of the NSS. Jerry has authored approximately 60 articles, technical reports, and publications on the caves and karst of Texas. Jerry has also compiled most of the cave descriptions for this 2017 NSS Convention Guidebook.

Kevin Madalena

Kevin was born in Albuquerque and raised on Jemez Pueblo. A diligent and studious boy in a rural reservation in north-central New Mexico, Kevin's attention was captured early on by rocks, volcanoes, science fiction and dinosaurs. His passion culminated in a career as a geologist-sedimentologist and vertebrate paleontologist. Kevin enjoyed his education at New Mexico Institute of Mining and Technology in Socorro, NM and specializes in vertebrate paleontology and stratigraphic sedimentology.

As Kevin matured in his professional life, he had the honor and pleasure of working in the geosciences at the New Mexico Museum of Natural History and Science in Albuquerque, New Mexico Tech's Petroleum Research and Recovery Center, The Pueblo of Jemez

Natural Resources Department, TBA Power Incorporated and most recently as a paleontologist for the wonderful minority outreach program, Native Explorers, based at Oklahoma State University-Tulsa.

Kevin has the distinct pleasure of being the lead mapper in the recent push to thoroughly map the Pueblo of Jemez, which to date, has not had a proper geologic map completed. In his home life. Kevin recently served as an aide to the Fiscal Governor of Jemez Pueblo.

Figure 1. 2017 NSS Convention Geology Field Trip overview map. Yellow stars are field trip stops. Red dots are nearby Pueblos. Photo credit: Google Earth, 2016.

Road Log and Stop Descriptions

Meet at the Santa Ana Star Center upper parking lot, west of the building, at the VIP entrance to the arena (N 35 18.535 W 106 41.240). This location is between the building and the camping area. Coffee and donuts will be served at 7:00 AM. We will depart AT 7:30 AM SHARP.

- Depart Santa Ana Star Center (leave no later than 7:30).

45 minutes to White Mesa (arrive 8:15, depart 9:35; *1 hour & 20 minutes*)

0.0 Depart Santa Ana Star Center parking lot and turn right (north) onto Arena Dr. NE (service road).
0.2 Enter roundabout and depart on second exit (west) to stay on Arena Dr. NE.
0.6 Make a right turn (north) onto Unser Blvd.
6.2 Make a right turn (north) onto Loop Rd.
7.4 Make a left turn (west) onto SR-550.
10.0 Bus Talk 1: Introduction and Overview
21.5 Make a left turn onto Cabezon Rd. just after mile marker 21.
21.6 Continue straight (stay left) at "Y" junction.
25.9 Follow gravel road to Stop 1 parking area (9). (N 35 29.**900 W 106 50.475**)

Introduction (Bus Talk 1)

Geologic Overview

Welcome to the Geology Field Trip of the 2017 NSS Convention! This year's field trip theme is the geology of the pueblo lands of north-central New Mexico. New Mexico is nick-named the "Land of Enchantment," referring to its scenic beauty and rich history. It is also a land of contrasts – historically, culturally, and physiographically.

The region has a heritage of Native American, Hispanic, and Anglo cultures whose histories date back centuries and even millennia. The state is home to 23 Native American communities, each with its own language and traditions. The Spanish history of New Mexico has left an indelible mark on the region that can be seen in the food, customs, and familiar "Pueblo Revival" architecture of the state. Mountains form "islands in the sky" adjacent to vast plains, broad valleys, deep canyons, and mesas.

We hope that during the field trip, you will have the opportunity to experience some of the land and people that make New Mexico so unique.

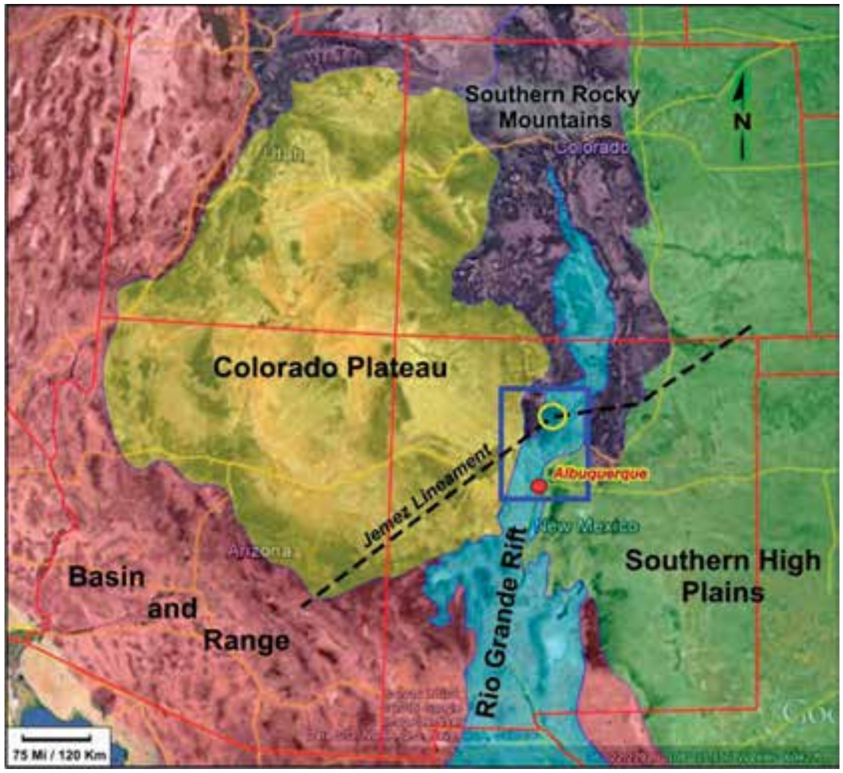

Figure 2: Physiographic provinces of the Southwest. Pink - Basin and Range, Yellow - Colorado Plateau, Purple - Southern Rocky Mountains, Blue - Rio Grande Rift, Green - Southern Great Plains. Black dashed line is the Jemez Lineament, blue square is the field trip area, and the yellow circle is the Valles Caldera.

Physiographic Provinces

Northern New Mexico encompasses four major physiographic provinces: the Rio Grande Rift, Colorado Plateau, Southern Rocky Mountains, and the Southern Great Plains provinces (Figure 2). During the field trip, we will be traversing two of these provinces (Rio Grande Rift and Colorado Plateau), and will hopefully enjoy dramatic views of the remaining two.

Rio Grande Rift

The Rio Grande Rift is a north-south trending zone of crustal extension and axial basins that stretches approximately 1100 km (700 miles) from central Colorado south to the state of Chihuahua in northern Mexico. The Rift is flanked by the Colorado Plateau to the west, the Great Plains to the east, the southern Rocky Mountains to the north, and merges with the Basin and Range province to the south (Figure 2). The northern part of the Rift is relatively narrow, consisting of a series of westward stepping, *en echelon* basins flanked by rugged mountains. The amount of extension increases to the south as the Rift broadens considerably south of Socorro and merges with the Basin and

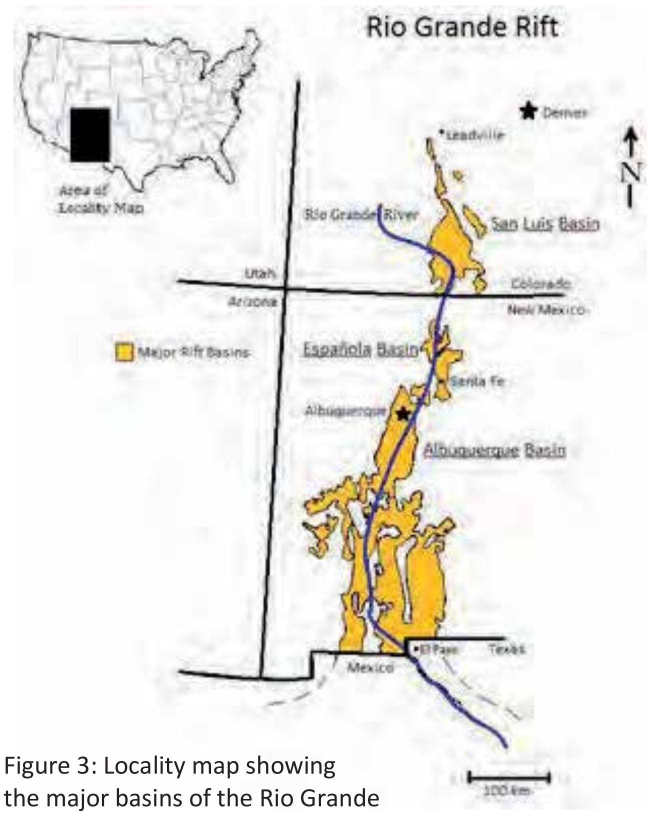

Figure 3: Locality map showing the major basins of the Rio Grande Rift extending from southern Colorado to Chihuahua, Mexico. The Rio Grande follows the Rift for much of its course. Image courtesy of Wikipedia public domain.

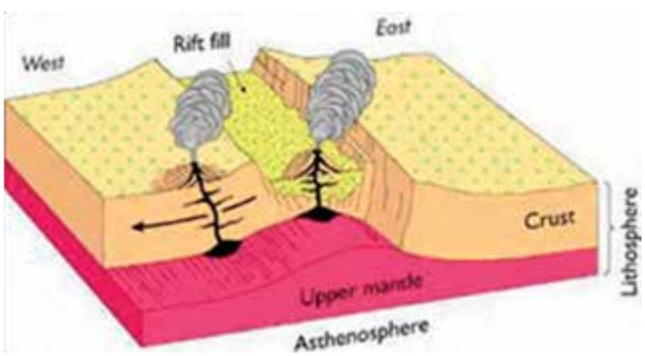

Figure 4: Diagrammatic cross-section of a continental rift. Image courtesy of the USGS.

Range province in southwestern New Mexico (Figure 3). Rift-related extension began earlier in southern New Mexico (~36 Ma) compared to northern New Mexico (~22-25 Ma), with extension peaking at 10 to 16 Ma (Read et al., 2010). Basin subsidence occurred along listric, normal faults that sole out at depths of up to 9 to 10.5 km (30,000 to 35,000 feet). Although the rate of extension has dramatically slowed in the last 5 Ma, motion on the Rift continues to the present (Lowry, 2012).

A consequence of this extension was a dramatic thinning of the crust within the Rift, producing higher heat flow and numerous volcanic features along the length and flanks of the Rift (Figure 4). An example is the chain of young volcanoes (~210 – 155 Ka) just west of Albuquerque at Petroglyph National Monument (Kelley, 2010c). Other examples of rift-associated volcanism will be seen during the course of the field trip, especially north of the Jemez Pueblo in the Valles Caldera area.

The axial basins form a series of half-grabens that are tilted strongly toward the east or the west, depending on the location of the master fault system on the margins of each basin (Pazzaglia et al., 1999). Approximately 6 to 7.5 km (20,000 to 25,000 feet) of rift sediments have accumulated in the axial basins of the Rift, forming important aquifers for some of the largest cities in the state. During the last 600 Ka, the ancestral Rio Grande system became fully integrated along the axis of the Rift, and today forms a central corridor for transportation and urban development (Pazzaglia et al., 1999; Read et al., 2010).

The city of Albuquerque is located within the Albuquerque Basin, a composite basin of the Rio Grande Rift system consisting of three half-grabens, or sub-basins (Connell, 2001; Keller et al., 1994) (Figure 5). Syn-rift sediments of the Santa Fe Group (25 to ~1 Ma) are over 4.8 km (16,000 feet) thick in the sub-basin depo-centers, and consist of a complex inter-tonguing of sandstones, mudstones and conglomerates deposited in playa lakes, fan deltas, eolian sand dunes, and mixed fluvial-alluvial fan environments (Russell et al., 1994; Lozinsky, 1994; Connell, 2001) (Figure 6).

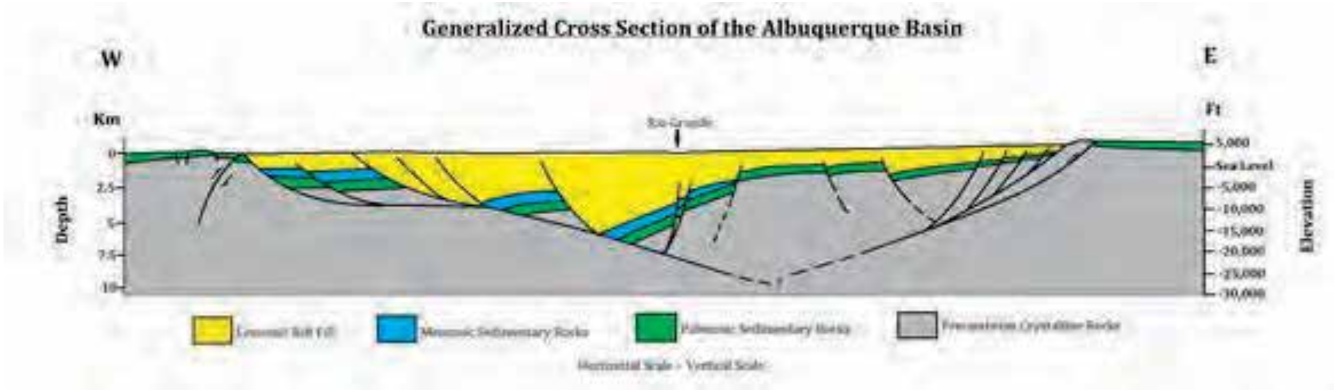

Figure 5: Generalized cross-section of the Albuquerque Basin. Modified after Russell et al. (1994). Image courtesy of Wikipedia public domain.

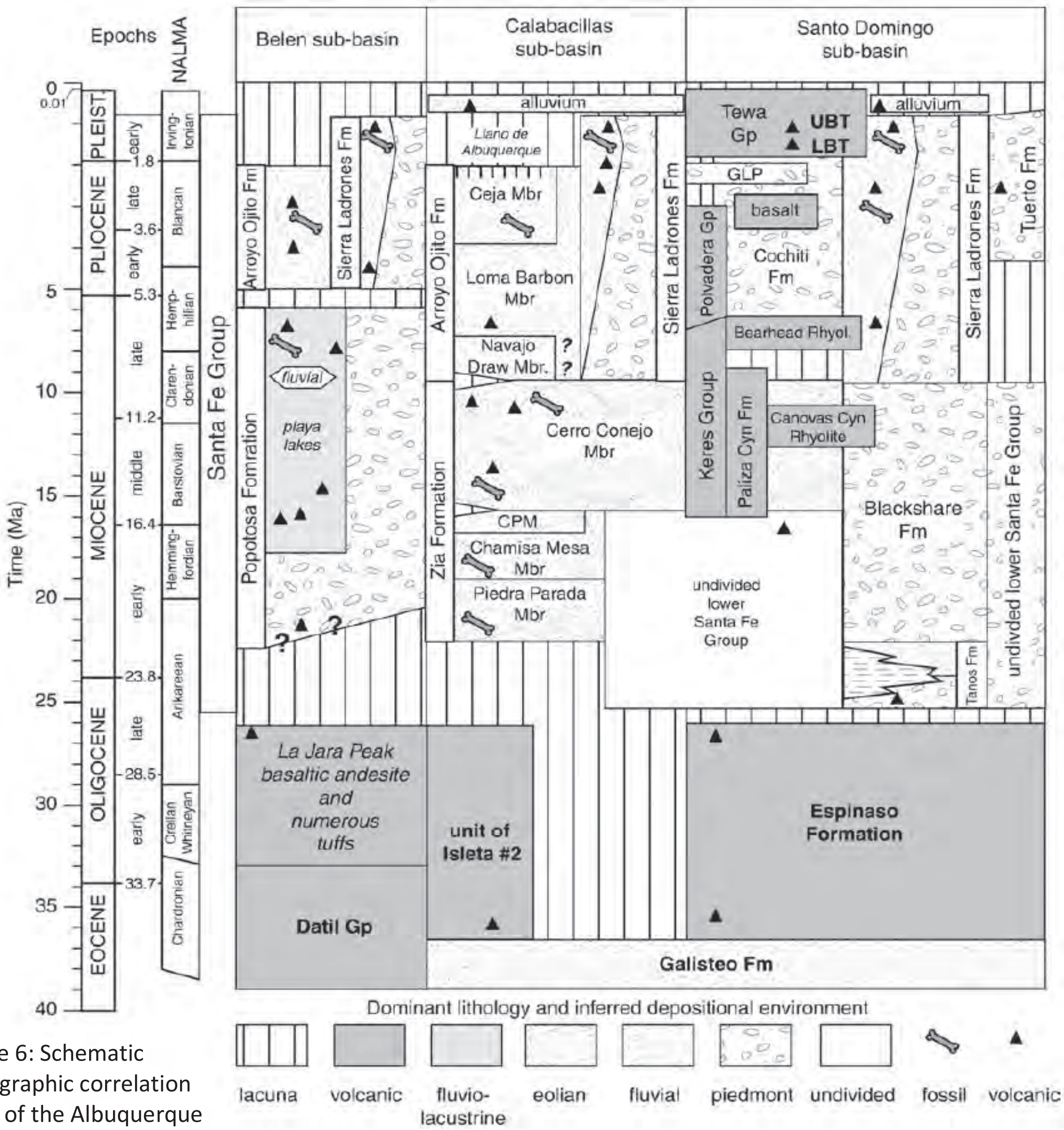

Figure 6: Schematic stratigraphic correlation chart of the Albuquerque Basin. From Connell (2001).

Colorado Plateau:

Figure 7: Major structural elements and points of interest of the Colorado Plateau described in the text.

The Colorado Plateau is a thick, high-elevation, crustal block of the North American craton that is located in the Four Corners region of northwest New Mexico. The province is unique in that it has undergone relatively minor deformation in the last 600 Ma, in contrast to the surrounding provinces (Kelley, 2010a). It is bounded to the west and south by the Basin and Range province and to the north and east by the Middle/Southern Rocky Mountains and Rio Grande Rift provinces. The major structural elements of note within the New Mexico portion of the Colorado Plateau are the San Juan Basin and Zuni Mountains (Figure 7), both formed by contraction and resultant crustal shortening during the Late Cretaceous-Eocene Laramide Orogeny (~75 to 40 Ma). We will be traversing the southeast edge of the San Juan Basin during the field trip.

The San Juan Basin (SJB) is a foreland basin encompassing approximately 11,900 K\km^2 (4600 mi^2). in a broad expanse of plains, canyons, and mesas at elevations ranging from about 1.5 to 2.4 km (5000 to 8000 feet) (Craigg, 2001). Over 4.2 km (14,000 feet) of Late Paleozoic, Mesozoic, and Tertiary clastic sediments were deposited in shallow marine, deltaic, coastal plain, eolian, and fluvial/alluvial environments. The basin is bounded on the west, north, and east by steep monoclines that are underlain by basement-involved reverse faults. The Nacimiento Fault system, a high angle reverse and thrust fault zone, separates the SJB from the Nacimiento Mountains uplift to the east and also marks the boundary between the Colorado Plateau and the Southern Rocky Mountains/Rio Grande Rift (Pazzaglia et al., 1999). We will observe this boundary during the field trip at Stop 1.

The SJB region is rich in cultural and natural resources such as the Chaco National Historical Park, Mesa Verde National Park, and Bisti/De-Na-Zin Wilderness area. Also note-worthy are the basin's large deposits of coal, uranium, and natural gas.

Volcanism during the Pliocene to Pleistocene (~3.7 – 1.5 Ma) overprinted portions of the southeastern SJB in the form of volcanoes (e.g. Mount Taylor composite stratovolcano, Cabezon Peak), fissure vents, maars, and associated basalt flows (Kelley, 2016). These are part of the greater magmatism occurring along the Jemez Lineament, a northeast trending line of eruptive centers that stretch from the Arizona-New Mexico border, through the Jemez Mountains, to northeast New Mexico

(Figure 2). The lineament is thought to represent a major Precambrian terrane boundary (~1.7 – 1.6 Ga) and is underlain by an anomalous low-velocity zone in the upper mantle, suggesting magmatic fluids are penetrating the lithosphere along an ancient suture zone (Karlstrom et al., 1998).

Southern Rocky Mountains

The Sangre de Cristo Mountains represent the extension of the Southern Rocky Mountains province into northern New Mexico, and stretch 360 km (225 miles) with peaks up to 4,370 meters (14,345 feet) high (Bauer, 2010). The San Luis and Española basins of the Rio Grande Rift bound the mountains to the west, and are responsible for the dramatic relief seen on the west flank of the Sangre de Cristo Mountains. To the east, the province is bounded by the Southern Great Plains. The mountain range has a long and complex history of multiple cycles of tectonism, erosion, and volcanic overprinting; the most recent being uplift and erosion during the Miocene-Pliocene. We will not be traversing the Southern Rocky Mountain province during the field trip, but the Sangre de Cristo range will be visible to the east during the late afternoon portion of the field trip.

Southern Great Plains

The Southern Great Plains are the easternmost physiographic province in northern New Mexico, and are a vast, low relief region of grassy plains, mesas capped by lava flows and sandstones, and steep canyons along the major rivers (Kelley, 2010b). We will not be traversing the Southern Great Plains during the field trip but portions of the plains may be visible to the east during the late afternoon portion of the field trip.

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For those interested in additional reading of a general nature, we recommend the following:

Price, L. Greer (ed.). 2010. *The Geology of Northern New Mexico's Parks, Monuments, and Public Lands*. New Mexico Bureau of Geology and Mineral Resources, Socorro, New Mexico, 372 pp.

The New Mexico Geological Society hosts an annual geological field trip and guidebook with excellent articles and road logs. Each year's field trip focuses on a specific area or region. Their guidebooks can be purchased at: http://geoinfo.nmt.edu/publications/nmgs/guidebooks/home.cfml

General Overview of the Caves of New Mexico

As of November 2016, there were 2,918 documented caves in the files of the state cave survey, with several hundred additional caves known on federal lands that have not been released to the general public (Belski, 2016; Atkinson, 2016). New Mexico's caves are formed in a wide variety of lithologies with most caves being developed in gypsum, carbonates, basalt, and sediments (Figure 8). Approximately 41 percent (~1,274) of the known caves are developed in Permian Age gypsum in the east-central and southeast corner of the state. The

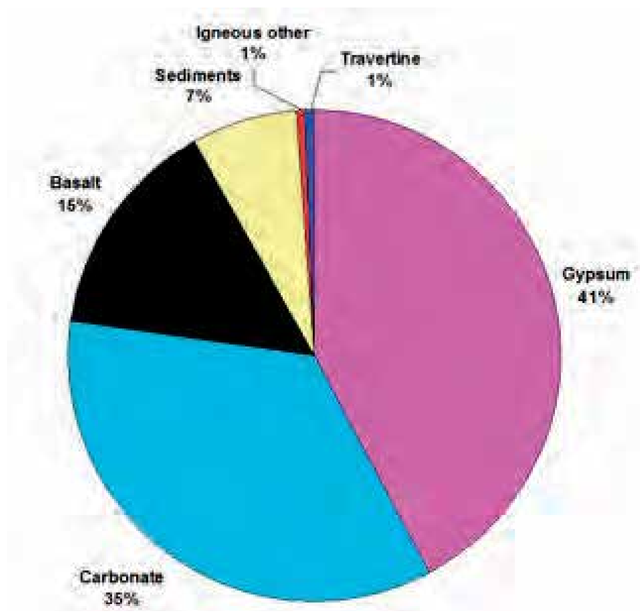


Figure 8: Bedrock lithology of New Mexico caves.

longest- known gypsum cave is Parks Ranch Cave, with a length of 6.6 km (4.1 miles) – the second longest gypsum cave in the U.S. and the 15th longest in the world (Gulden, 2016a). New Mexico gypsum caves are predominantly vadose in origin with dendritic map patterns and insurgence entrances that take intermittent runoff.

Carbonate-hosted caves comprise approximately 35 percent (~1,077) of the known caves, with the majority located in the Guadalupe Mountains and Lincoln County areas. They are predominantly hypogene in origin with some notable exceptions such as Fort Stanton Cave (50.8 km, 31.6 miles long), which appears to be a "conventional" epigenic cave, developed by descending meteoric water (Davis et al., 2006; Kendrick, 2016). The longest and deepest cave in the state is the world-famous Lechuguilla Cave at 227 km (141.1 miles) in length and 489 meters (1,604 feet) deep, formed in Permian Age carbonates (Lyles, 2016, Gulden, 2016b).

Lava tubes comprise approximately 15 percent (~440) of the known caves with most located in the El Malpais National Monument area, with lesser occurrences in the Valley of Fires Recreation Area and the northeastern-most corner of the state near Capulin Volcano National Monument. The longest lava tube cave in the state is Outlaw Cave with a length of approximately 2.5 km (1.6 miles) (Weaver, 2016).

Approximately 7 percent (~210) of the known caves are pseudokarst features developed in sediments such as mudstones and claystones, and are predominantly located in the San Juan Basin of northwest New Mexico. The San Juan Basin caves are formed in soils that swell when wetted and then shrink when they dry out, forming desiccation cracks. Water penetrating these cracks mechanically erodes grains of material via corrasion (suffosion piping) until passages are large enough for human entry. Many of the northwest New Mexico piping caves are developed in deep canyons, have high gradients, and contain narrow passages. Although these caves are generally only a few hundred feet long, the longest, B&B Caverns, has over 610 meters (2,000 feet) of surveyed passage and nearly 91 meters (300 feet) of vertical extent; possibly the longest and deepest piping cave in the U.S. (Medville, 2016). Another cave, Stairstep Canyon Cave, contains almost 243 meters (800 feet) of passage, extends upward for over 70 meters (230 feet), and still continues.

Land ownership in New Mexico is similar to many western states in that the majority of the known caves (~2550 or approximately 85 percent) are located on federal or state lands (Belski, 2016; Atkinson, 2016). Coordinating and maintaining access to the federally managed caves of New Mexico presents many unique challenges, which change with time, resource managers, caving ethics, political climates, and specific agencies (NPS, USFS, BLM, etc.). The recent WNS-related cave closures and additional decontamination protocols have been particularly difficult for both cavers and cave resource managers. **Please be respectful of the enormous time and effort that cavers have put into landowner relations by adhering to all decontamination procedures and other regulations while visiting the caves of our state.**

- *10.4 Point of Interest: (Right side of road) – Old Santa Ana Pueblo* – The Pueblo of Santa Ana (Tamaya) is a Keres speaking native pueblo civilization. The modern location of Santa Ana Pueblo is currently believed to have been settled in the late 1500s. The old and original location of the Pueblo is used by tribal members, and a more contemporary location with modern conveniences of electricity and facilities is located north of the Town of Bernalillo. The "new" Santa Ana Pueblo was established in 1693. (www.santaana.org). Santa Ana Mesa is a large section of basalt capped, Santa Fe Group strata. The large basalt fields are composed of basalt flows and cinder cones from the San Felipe volcanic flows (~2.5 to 3.0 Ma, [Crumpler and Aubele, 2001]). The Santa Ana Mesa basalt fields are located between the Rio Grande and Jemez River.

- *18.2 Point of Interest: (Right side of road) Zia Pueblo (Zia Symbol, owners of Alabaster Cave)* – The Pueblo of Zia (T'siya) is founded and built on a small bluff, east of the Jemez River. Zia Pueblo is also a Keres speaking pueblo civilization and was visited by the Spanish Conquistadores in 1541. The Zia Sun Symbol is the official insignia for the State of New Mexico's flag.

Low exposures of the Miocene Age Santa Fe Group, Zia Formation sands and recent Quaternary deposits are visible around the vicinity of Zia Pueblo. Mesa Blanca (White Mesa) is directly ahead on Highway 550. Mesa Blanca is capped by Late Jurassic Age Todilto Formation gypsum. The strata and sections below the Jurassic Todilto Formation are the early Jurassic Age Entrada Sandstone and the red and purple Late Triassic Age Chinle Group muds. The entire section lies unconformably on top of the Cretaceous Age Dakota Group and Mesa Verde Group marine deposits. New Mexico's largest commercial gypsum mine is located on top of Mesa Blanca. The top being excavated is the Tongue Arroyo Member of the Todilto Formation (Rogers et al., 1996).

A historical marker is also on the right, immediately west of Zia Pueblo on the highway:

> "Francisco Vasquez de Coronado, preparing to spend his second winter in New Mexico, sent out expeditions from Tiguex (an extinct Pueblo near Bernalillo), in the fall of 1541, to gather supplies. Captain Francisco de Barrrionuevo went so far west as Jemez Pueblo, then visited others as far north as the Rio Chama."

The east face and limb of the San Ysidro/ Nacimiento Syncline is prominent in exposure and can be directly observed ahead as we continue north. Permian and Triassic Age stratigraphy is exposed on the east limb of the syncline. The Permian Age exposures are as follows in ascending order: The red Abo Formation, the orange-red Yeso Formation, and the khaki-colored Glorieta Sandstone Formation. The Permian Age strata is overlain by the purple mud of the Triassic Age Moenkopi Formation. The light tan, and tabular Triassic Agua Zarca Formation sandstone caps the eastern face of the syncline. The Agua Zarca Formation is extremely fossiliferous in the sections belonging to the Pueblo of Jemez.

Figure 9: The trail from the Tierra Amarilla Anticline parking area to the overlook is 0.5 km (0.3 miles) with an elevation gain of 26 m (85 feet). The trail is mostly even and could be considered a moderately good trail. Note the outcrops of Todilto gypsum along the way; gypsum is highly soluble in water and is only in outcrop here because of the arid environment. Also, take note of the crypto-biotic soils. ***Please do not wander off the trail, these soils take thousands of years to form and can be destroyed in seconds.*** Last but not least, look for Ephedra, also known as Mormon Tea. This plant was used to make a bitter tea that would substitute for coffee and caffeinated tea, neither of which is allowed to be consumed by the Mormons. Photo credit: Google Earth, 2016.

Stop 1: White Mesa – Tierra Amarilla Anticline

The Sierra Nacimiento Uplift is a prominent north-striking mountain range and the eastern boundary of the San Juan Basin. It is located in lands belonging to the Pueblo of Jemez. The Sierra Nacimiento was a highland during the Mississippian Period until the Early Permian Ancestral Rocky Mountain deformation (~319 to 285 Ma; Woodward, 1987). Pennsylvanian to Permian structures in the Sierra Nacimiento were later reactivated during the beginning of the Late Cretaceous Campanian Age (~75 ma), forming a basement-cored uplift during Laramide transpression; most of the Laramide deformation in the Sierra Nacimiento occurred during the Eocene (55 – 50 Ma), (Baltz, 1967; Pazzaglia and Kelley, 1998; Cather, 2004). The southern Sierra Nacimiento and areas to the east of the mountain range were subsequently cut by north-striking normal faults associated with Rio Grande Rift extension, starting in the Oligocene Period (30 - 25 Ma), (Kelley and Gardner, 2010).

The Tierra Amarilla Anticline is a southwest plunging section and is cored by the Late Triassic Age, Chinle Group, Petrified Forest Member. The folds developed within the Chinle Group are complex in structure due to subsequent deformation. The plunging folds are capped by the Jurassic Age Todilto Formation along the western edge of the Mesa Blanca (White Mesa).

The Nacimiento Fault acts as a conduit for fluids flowing southwest from the Valles Caldera catchment area and allows these carbon dioxide-rich fluids to flow to the surface along the fault as carbonate springs (Figure 9). The Jemez Lineament also dissects the area and is

Figure 10: Looking north along the axis of the Tierra Amarilla Anticline and Nacimiento Fault. Todilto Gypsum stands high in relief in this arid environment. The Nacimiento Fault extends north along the west side of the Sierra Nacimiento, a Precambrian-cored uplift visible on the horizon just right of center. Carbonate springs deposited travertine mounds along the fault trace, visible in the center of the photo. Jerry Atkinson contemplates the gypsum caves located along the west limb of the anticline. Photo credit: Dave Decker.

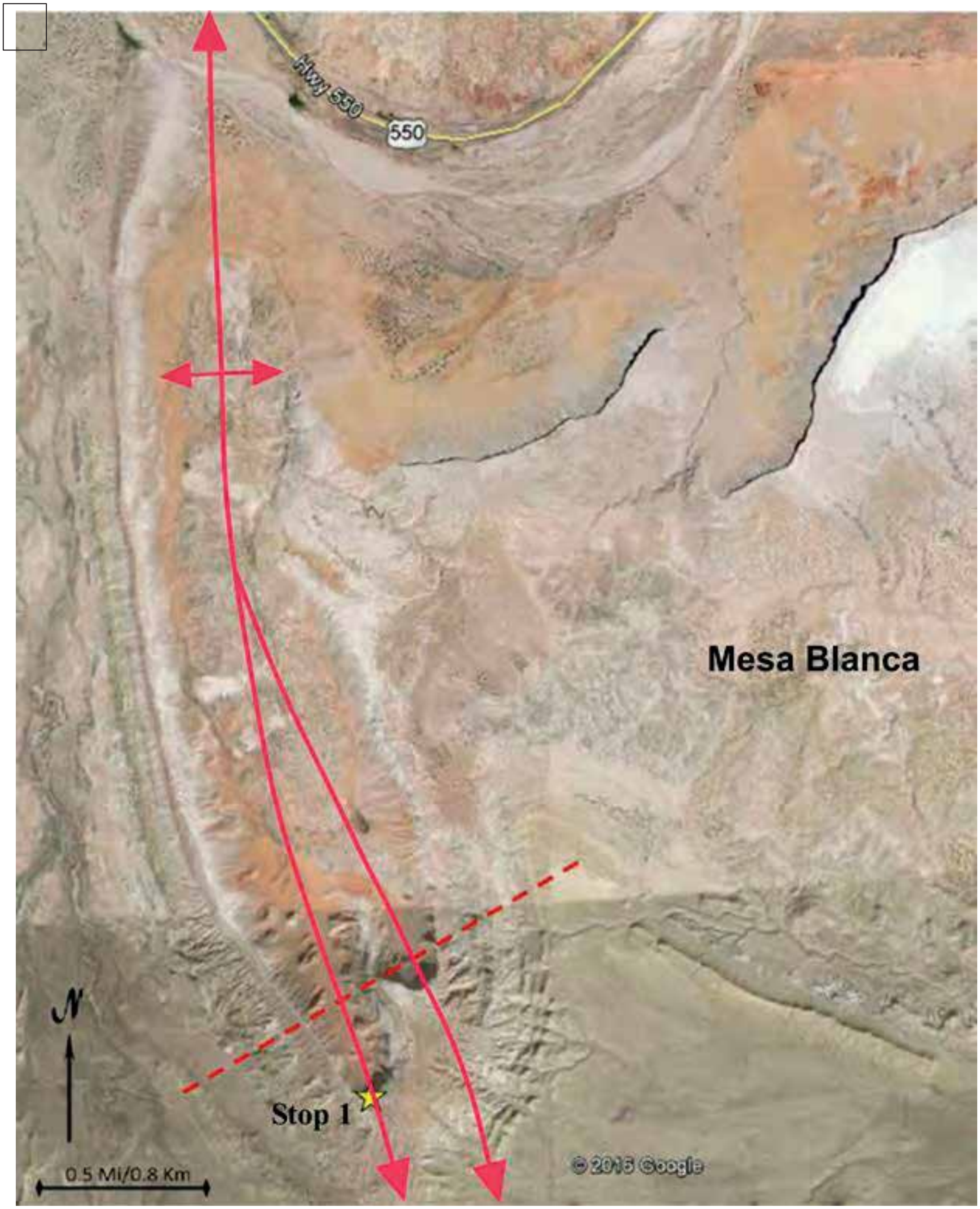


Figure 11: Satellite view of the Tierra Amarilla Anticline. This is a doubly-plunging anticline with three limbs exposed. Several carbonate springs mark the hinge trace to the north. Yellow star marks the position of stop 1. Red dashed line is the cross-section in Figure 12. Photo credit: Google Earth, 2016.

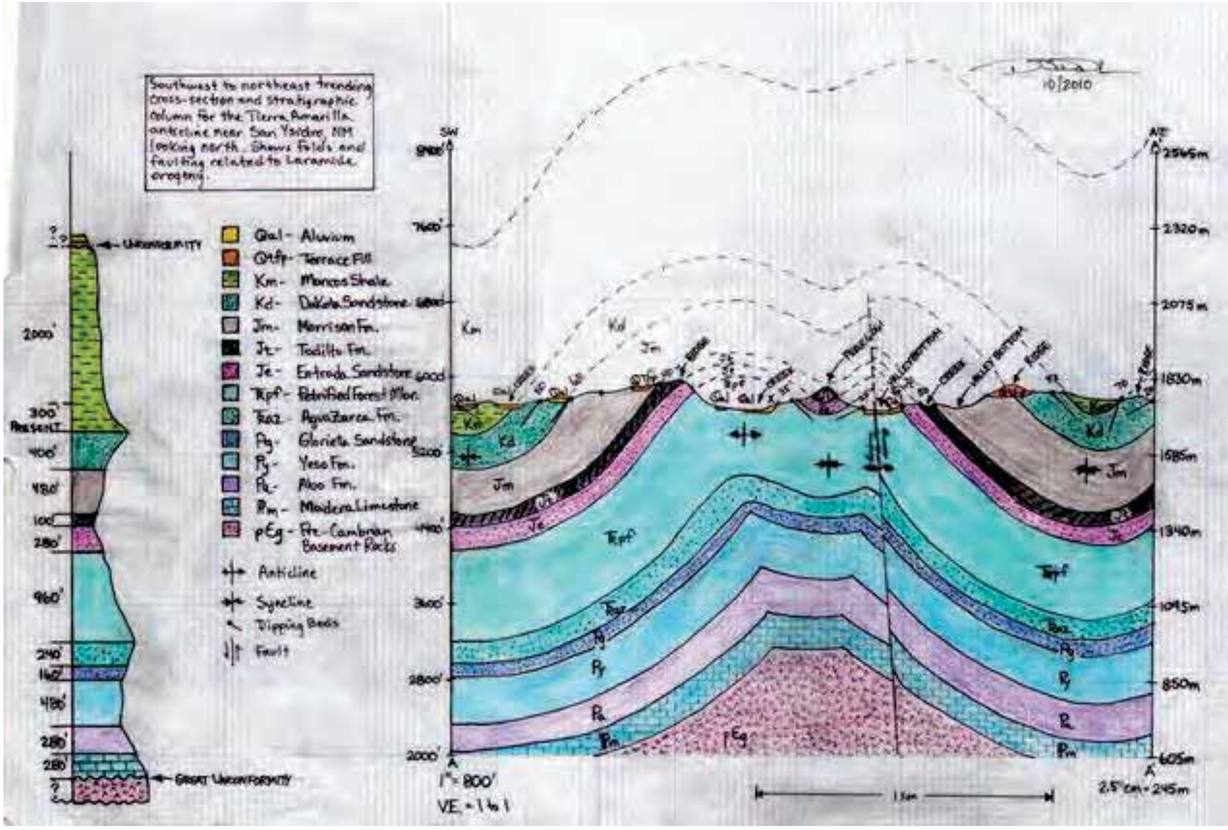


Figure 12. Southwest to northeast trending cross-section and stratigraphic column for the Tierra Amarilla Anticline near San Ysidro, NM. View looking north. Sketch by Dave Decker during an undergraduate field course.

believed to be the reason the caldera is located here. The Jemez Lineament bisects the Rio Grande Rift in this location providing a weak spot in the crust for upwelling magma to accumulate. Currently, there is a magma chamber less than 5 km (3 miles) from the surface.

Caves near Tierra Amarilla Anticline:

The caves in the Tierra Amarilla Anticline area are highly diverse in their lithologies and speleogenesis. They are developed in the gypsums of the Jurassic Todilto Formation, the mudstones of the Jurassic Morrison Formation, and the carbonates of Quaternary travertine deposits related to paleo-springs.

The gypsum caves of the Todilto Formation are vadose in origin, and with the exception of Alabaster Cave (~1.4 km long, ~0.85 miles), are relatively small and shallow. Alabaster is a horizontal, wet-weather stream cave developed on two levels with a total of five entrances.

The caves developed in the Morrison Formation are small pseudokarst caves formed by suffosion (soil piping); the longest surveyed cave being Ojito Cave (~40 meters long, ~140 feet). Other caves in the Morrison remain essentially unexplored.

The caves found in the Quaternary travertine deposits are rather unique. They are the remnants of paleo-springs that have been eroded, and in some cases, partially collapsed. The largest of these paleo-springs is Natural Bridge Cave (~70 m long, 12 m deep; ~230 feet and 38 feet), with two pit entrances leading to a large solutional room that is partially collapsed (Figure 13).

Figure 13: Natural Bridge Cave. View looking south along the axis of the Tierra Amarilla Anticline and Nacimiento Fault. Photo credit: Dave Decker.

25 minutes to Walatowa Visitors Center (Yeso Red Beds)
(arrive 10:00, depart 11:00; *60 minutes*)
(Bio Break: Snacks available for purchase)

NOTE: Jemez Pueblo is still an active and vibrant society. Please DO NOT pick up any rocks or artifacts while at this stop. No rock hammers, picks, or chisels - please leave them on the bus.

25.9 Retrace route to SR-550.
30.4 Make a left turn (west) onto SR-550.
32.7 Make a right turn (north) onto SR-4 toward Jemez.
40.2 Stop 2 is at the Jemez Pueblo Rest Area and Visitors Center (**N 35 38.600 W 106 43.475**).

The road log continues north on U.S Highway 550 and exits north on N.M State Road 4 toward the Village of San Ysidro, the Pueblo of Jemez, and the village of Jemez Springs. The village of San Ysidro is named after Saint Isadore, a Spanish prelate and the patron saint of farmers within the Catholic Faith. San Ysidro was settled by the Spanish in 1699.

- *36.0 Point of Interest: (Right side of road) Jemez geothermal well*

- *38.1 Point of Interest: (Left side of road) Jemez Pueblo and stratigraphy beyond – NO photos please* – The current location of Jemez Pueblo was settled permanently in 1702 (Sando, 2002). The large bluffs north of Jemez Pueblo, and located in Jemez Springs, are the original location of Jemez Pueblo. Vast ruins are located on top of the Guadalupe, Holiday, and San Diego mesas. In 1838, the Pueblo of Pecos fled their ancestral home lands northeast of Santa Fe, due to continued famine, disease and warfare with the Conquistadors and the Plains civilizations. Jemez and Pecos Pueblo descendents live together in present day Jemez Pueblo (Sando, 2002). The Sierra Nacimiento Uplift, a north-striking mountain range and the eastern boundary for the San Juan Basin (Figure 1), is located in lands belonging to the Pueblo of Jemez. The Sierra Nacimiento was a highland during the Mississippian Period to early Permian Period Ancestral Rocky Mountain deformation (~ 285 and 310 Ma; Woodward, 1987). Pennsylvanian to Permian structures in the Sierra Nacimiento were later reactivated during the beginning of the Late Cretaceous Campanian Age (75 Ma), forming a basement-cored uplift during Laramide transpression. Most of the Laramide deformation in the Sierra Nacimiento occurred during the Eocene (50-55 Ma; Baltz, 1967; Pazzaglia and Kelley, 1998; Cather, 2004). The southern Sierra Nacimiento and areas to the east of the mountain range were subsequently cut by north-striking normal faults associated with Rio Grande Rift extension, starting in the Oligocene Period (25-30 Ma), (Kelley et al., 2010a).

- *38.9 Point of Interest: (Right side of road) Ponderosa Winery*

Figure 16: Red beds of the Abo Formation. Photo looking south. Composed mostly of rounded quartz grains with hematite cement, these massively cross-bedded aeolian dunes represent a time of drier climate, much like today. Photo credit: Dave Decker.

Stop 2: Jemez Pueblo - Abo Red Beds (Bread Stands)

Figure 17: Cross-bedding. Photo looking east. Jerry Atkinson and Kevin Madalena examine the cross-bedding and gypsum nodules. Photo credit: Dave Decker.

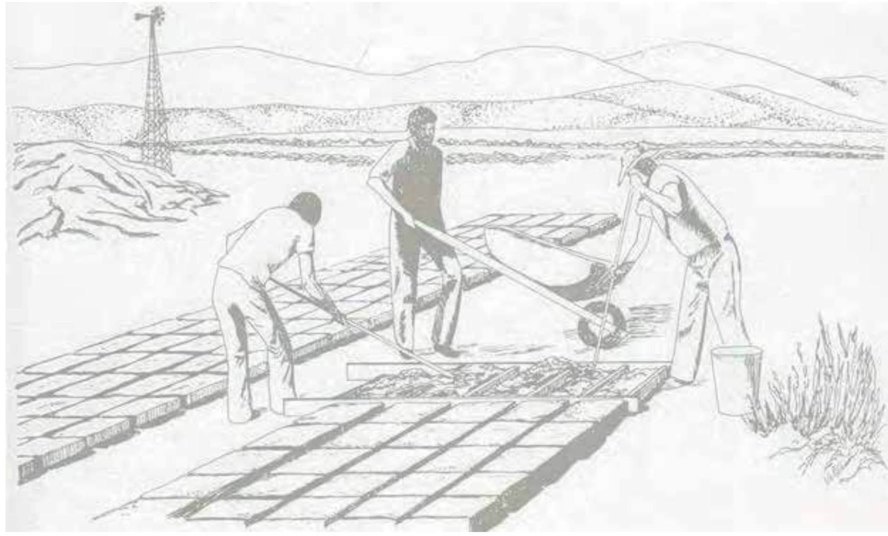
Here we examine the large and red eolian Permian Age sandstones. The Permian Age Yeso Group section is located north of Jemez Pueblo and the sections are behind the bread stands. The Meseta Blanca (DeChelly Sandstone) Formation is over 80 meters thick. The Yeso Group at the Jemez Red Rocks are exposed as large-scale, eolian sand dune cross beds. The intense red coloring of the rocks is due to an extremely thin coating of hematite (Fe_2O_3). Overlying the Meseta Blanca Formation is the San Ysidro Formation. The San Ysidro Formation is a gypsum-rich sandstone with a thin layer of siltstone and clay. The gypsum-rich sandstones clearly indicate a large scale drying trend in the American Southwest during the Permian Period. (Madalena et al., 2007). The type sections of the Meseta Blanca and San Ysidro Formations are located in the Jemez Red Rocks. (Wood and Northrop, 1946). Fossil root casts (rhizoliths), tree stumps and insect burrows are present in the large-scale sandstones (Lucas et al., 2005).

20 minutes to Soda Dam (arrive 11:20, depart 12:00; 40 minutes)

40.2 Remain on SR-4 heading north.
52.0 Stop 3 is at the road side parking area for the Soda Dam (N 35 47.550 W 106 41.220).

- *44.1 Point of Interest: (Left side of road) Bandelier Tuff - Abo Sandstone contact*
- *46.8 Point of Interest: (Right side of road) Spanish Queen Mine*
- *50.6 Point of Interest: (Left side of road) Jemez Hot Springs* (Figure 16).
- *51.0 Point of Interest: (Right side of road) Jemez Mission - San José de los Jemez (1621 AD)* - Also known as the Giusewa Ruins, this area is an ancestral home to Jemez Pueblo, in Jemez

Figure 16: Stalagmite beneath pressure relief vent at Giggling Springs in the village of Jemez Springs. Photo credit: Dave Decker.



Springs. A large church was constructed with forced labor by the Spanish Conquistadors in 1621 and named San Jose de los Jemez. The village and church were destroyed by the Jemez Pueblo natives during the 1680 Pueblo Revolt and was never occupied again. (Sando, 2002). A seven-acre national monument, Giusewa National Monument, is present at the ruins along with a museum.

An important geologic locality behind the ruins of the Guisewa church is the Pennsylvanian-Permian boundary and contact. The Pennsylvanian-Permian transition can be observed in the lithology on the contact horizon, marked by a fossiliferous limestone.

Stop 3: Soda Dam

Soda Dam is a small part of an impressive travertine apron that has been deposited along faults in San Diego Canyon over the past one million years. The oldest travertine, located approximately 130 meters above the level of the present day Jemez River, is between 1.0 and 0.5 Ma and contains nearly 3 million cubic meters of

Figure 17: Soda Dam. View looking north where the Rio Jemez has broken through the dam creating a waterfall and plunge pool. Just left of center, a small cave contains a hot spring with cascading travertine and micro-gours. Photo credit: Dave Decker.

calcium carbonate. The middle fissure ridge travertine, located approximately 40 to 45 meters above the river, is between 107 to 58 Ka and contains approximately 410,000 m^3 of travertine. Soda Dam proper contains nearly 24,000 m^3 of travertine and is thus the smallest of the deposits along the river. It has been deposited from 5,000 years ago to present. Movement along the fault since the travertine began forming is approximately 15 meters down to the east and is therefore related to the Rio Grande Rift. Down cutting of the Jemez River has been dated by use of U-Th dating techniques of both the travertine and of calcium carbonate that cements together river cobbles at different strath levels within the canyon (Tafoya, 2012). The dam was breached sometime in the 1960s (an exact date is not available) by the New Mexico Highway Department during road construction, which cutoff the main flow of water to the dam. Since then, the spring mound has started to rebuild from the west side of the road. There is also a small spring within the dam – a beautiful grotto you shouldn't miss seeing.

The San Diego Canyon Fault runs from the Nacimiento Fault through San Diego Canyon and into the Valles Caldera. It is part of the Jemez Fault Zone which is the western edge of the Rio Grande Rift. Many hot springs issue forth along the fault. Precipitation that falls within the caldera is heated by the magma chamber less than 5 km below the floor of the caldera as it travels down slope through the Madera Group, a Pennsylvanian-aged limestone that outcrops further up canyon (Goff et al., 2011).

On the west side of the road, Precambrian granitic gneiss (1.7 Ga) outcrops along the fault. Directly above it lies the Great Unconformity where more than one billion years of Earth's history is missing (Tafoya, 2012).

Also on the west side of the road is Jemez Cave, a large shelter cave that has produced significant archeological material. The entrance is about 7 m wide, varying in height from a meter to about 11 meters, and extends approximately 15 meters into the cliff. Jemez Cave has restricted public access due to an altar

Figure 18: View out of Jemez Cave looking east across San Diego Canyon, before it was closed. Photo credit: Dave Decker.

utilized by holy societies from the Pueblo of Jemez and a burial site in a midden located inside the cave. Geothermal waters from the springs and the river were used to bathe and for health benefits.

10 minutes to Battleship Rock (arrive 12:15, depart 13:15; 60 minutes)
(Bio Break, Lunch)

52.0 Continue north on SR-4.
55.9 Stop 4 is the Battleship Rock Picnic Area (N 35 49.700 W 106 38.645).

Stop 4: Battleship Rock

Battleship Rock (Figure 19) is a 66-meter erosional remnant of the most recent eruption in the Jemez Mountains – the Banco Bonito flow. The Banco Bonito flow is part of a rhyolitic ring fracture eruption within the Valles Caldera, which erupted approximately 40 Ka. The Plinian-style eruption that occurred deposited an ash fall tuff with large pumice fragments that can be seen throughout the cliff face in front of you. This is a welded tuff, which means that it was still very hot when it returned to the ground, so hot that the pumice fragments were easily deformed into "fiamme" (flame structure) and the entire formation was welded together by the intense heat. After the explosive part of the eruption was over, an effusive silica-rich eruption continued and created several obsidian lobes that will be visible at mile 63.9. Visible across the canyon near the top is the San Diego Canyon tuff (Figure 20), a 1.85 Ma ash fall tuff that filled in the paleo-canyon present prior to the eruption. The original river valley can be seen in several areas along the canyon wall. When examined closely, river cobbles can be found at the base of these u-shaped valleys that have been in-filled with the eruptive materials.

Figure 19: Battleship Rock looking east from SR-4. An erosional remnant of the 40 Ka Banco Bonito flow. Photo by Dave Decker.

Figure 20: Looking west across SR-4 from Battleship Rock at the 1.85 Ma San Diego Canyon Tuff. Note "tent rocks" near center of photo. Photo credit: Johanna Decker.

30 minutes to Valles Caldera (arrive 13:45, depart 14:15; *30 minutes*)

56.0 Continue north and east on SR-4.
72.9 Stop 5 is a road side pull-out overlooking the Valles Caldera
(**N 35 50.300 W 106 28.900**).

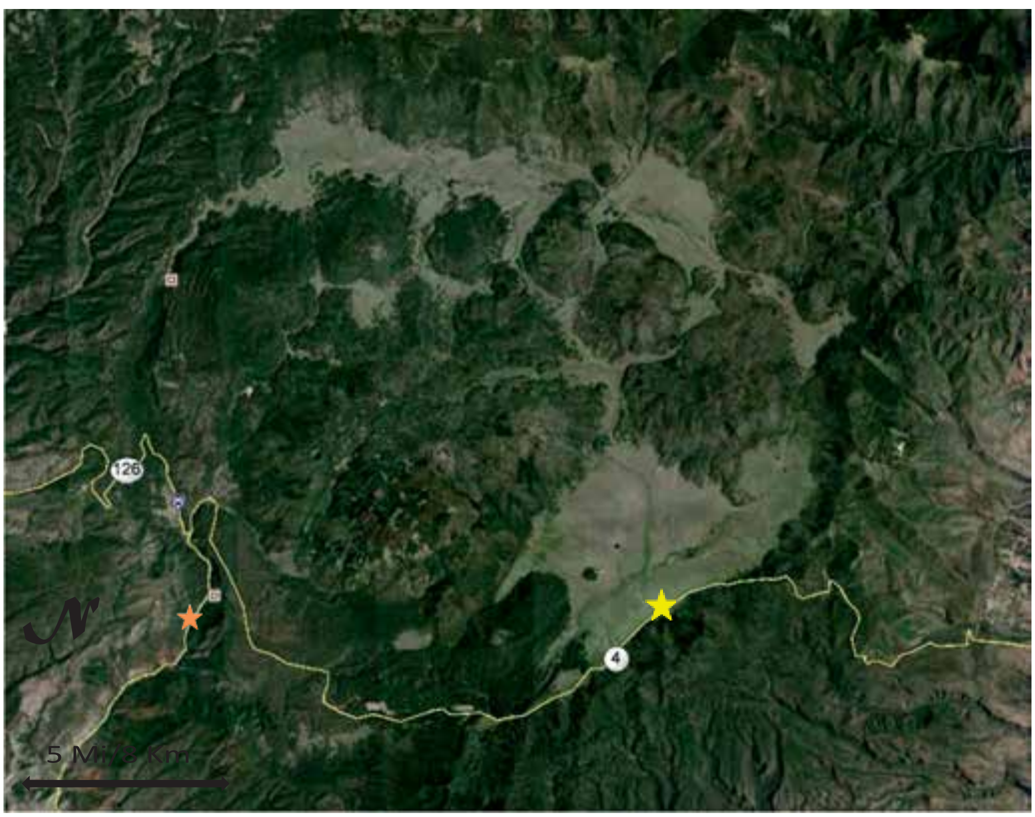
Figure 21: Pyroclastic flow structure in pumice. Photo credit: Dave Decker.

- *57.6 Point of Interest: (Right side of road) Spence Hot Springs*

- *59.1 Point of Interest: (Left side of road) Hummingbird Cave, fracture cave in Bandelier Tuff* - Hummingbird Cave is tectonic in origin and formed in the Quaternary (early Pleistocene) Lower Bandelier Tuff (~1.6 Ma). Although small (~40 m long), the cave is quite attractive, as the high, arched, and sculpted walls resemble a cathedral with light streaming in from the two entrances.

- *63.9 Point of Interest: (Left side of road) South Mountain rhyolite and obsidian flows (~0.52 Ma).* One of several sources of obsidian for spear points and arrow heads. Another is the Bearhead Rhyolite "Apache Tears" found in Paliza Canyon just to the south (Shackley et al., 2016).

- *64.8 Point of Interest: (Left side of road) Pyroclastic flow structure in road cut (Figure 21)*



Stop 5: Valles Caldera

Figure 22: Satellite view of the Valles Caldera. Notice the moat rhyolites ringing the caldera. Orange star marks Stop 4 (Battleship Rock), Yellow star marks Stop 5, Valles Caldera Overlook. Photo credit: Google Earth, 2016.

Figure 23: Valles Caldera. View looking northwest from view point. Resurgent dome Redondo Peak (left, background) and moat rhyolites (South Mountain, left, foreground) visible rising through Pleistocene lakebed sediments.
Photo credit: Dave Decker.

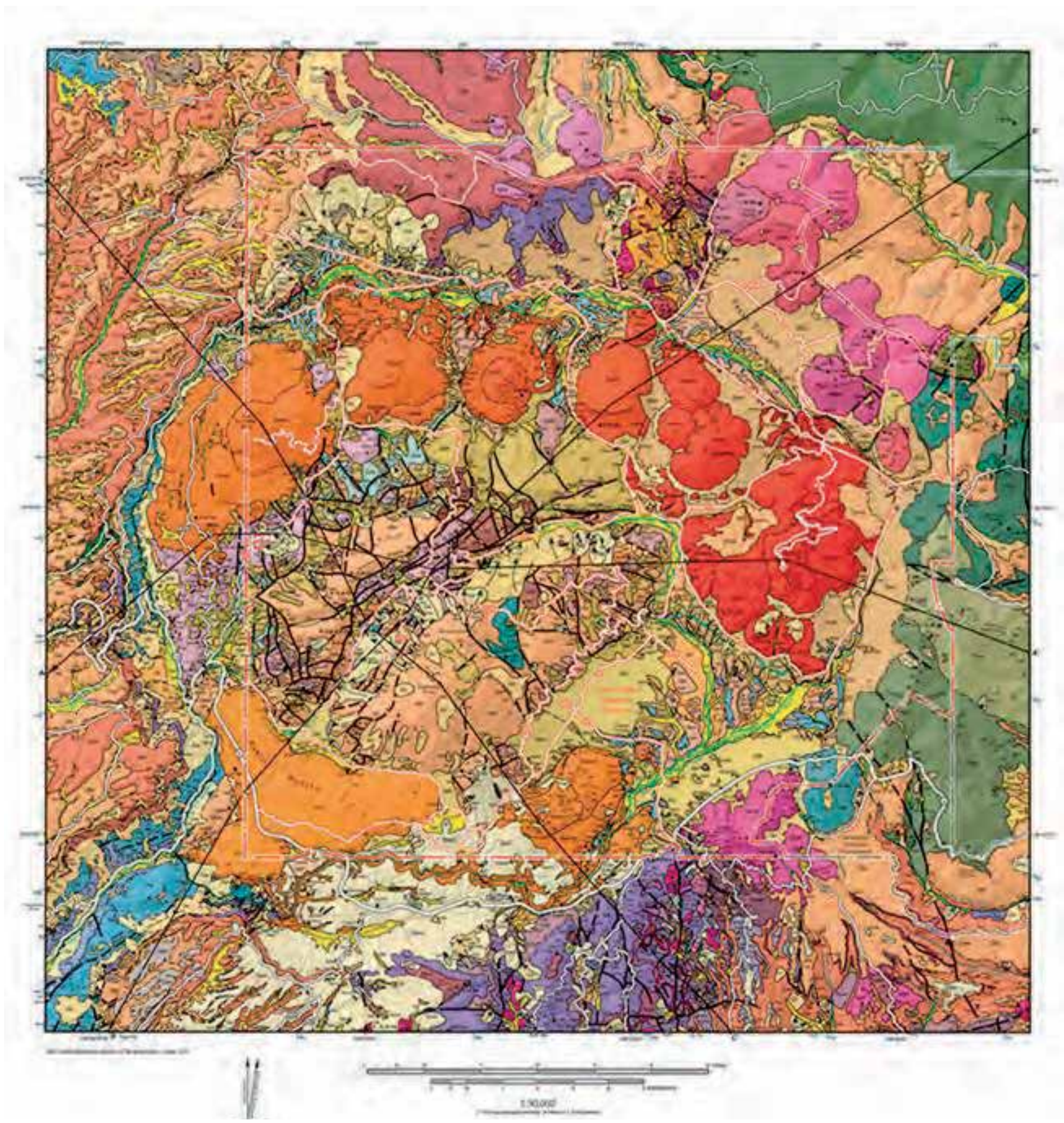


Figure 24: Geologic map of the Valles Caldera showing ring moat rhyolites and resurgent dome (Redondo Peak - peach color). Oldest moat eruption is the Cerro del Medio (red) at 1.2 Ma. Youngest is the Banco Bonito at 40 Ka (light orange). Yellow star is location of Stop 5. Image courtesy of the New Mexico Bureau of Geology and Mineral Resources.

The Valles Caldera was first described as a resurgent volcanic caldera by Smith and Baily in 1968. Since that time, it has become the type locality for caldera forming eruptions with resurgent dome and ring fracture eruptions. The Valles Caldera is located at the junction of two major crustal weak spots – the Rio Grande Rift, a nascent rift valley, and the Jemez Lineament, a Precambrian suture zone where the Yavapai (1.8 Ga) and Mazatzal (1.7 Ga) (Whitmeyer and Karlstrom, 2007) terranes have been sutured together. Valles Caldera is approximately 22 km across and is actually composed of at least two and probably three calderas (Baldridge, 2003). The oldest caldera, at 1.85 Ma, erupted the San Diego Canyon Tuff and is completely obliterated by the two younger caldera forming eruptions – the Lower Bandelier Tuff (Otowi Member) eruption at 1.64 Ma from the Toledo Caldera and the 1.25 Ma Upper Bandelier Tuff (Tshireg Member) eruption from the Valles Caldera (Goff et al., 2011). Together, the last two eruptions disgorged approximately 2000 km3 of ash and rhyolitic lava (Tafoya, 2012) Since the last caldera forming eruption, the resurgent dome called Redondo Peak (3,435 m, 11,267 feet) has risen from the caldera floor and is currently 1000 meters (3,280 feet) above the floor of the caldera. At least eight ring fracture volcanoes have erupted around the perimeter of the caldera. The oldest, erupting almost immediately after the latest Plinian style eruption, is the 1.2 Ma Cerro del Medio, and the youngest, at 40 Ka, is the Banco Bonito eruption that formed Battleship Rock (Figure 24).

San Diego Canyon has been around in many forms since before the San Diego Canyon Tuff erupted 1.85 million years ago. It is the western-most expression of the Jemez Fault Zone (JFZ) which marks the western boundary of the normal faults of the Rio Grande Rift. The canyon has been draining caldera lakes that have formed intermittently through both climate change in the region due to glacial-interglacial wet/dry spells and also damming of the caldera outlet by rhyolite flows (the latest being the Banco Bonito flow) for at least two million years. The valley floor of the caldera is still quite marshy in many areas from these paleo-lakes and is difficult to walk on. The JFZ extends north through the center of the caldera floor and provides routes for many hot springs to emerge within the caldera as well as allowing flow from the caldera to hot springs farther down canyon, most notably at the town of Jemez Springs.

The interior portion of the Valles Caldera was privately owned until recently and known as the Baca Ranch. In 1821, the land was deeded to Luis Maria Cabezon de la Baca and was deeded to his heirs in 1860. The ranch was private property and a working cattle ranch until 2000 when the federal government purchased the property for $106 million and created Valles Caldera National Preserve. There have been several challenges to the purchase, not the least of which was from Jemez Pueblo whose ancestral lands encompass the caldera. As of February 2016, theit challenge has been abandoned because the claim was not made within the 12-year statute of limitations.

30 minutes to Bandelier National Monument (arrive 14:45, depart 16:15; *1 hour 30 minutes*)
(Bio Break, Snacks available for purchase)

72.9 Continue east on SR-4.
83.5 Junction SR-501 toward Los Alamos (continue straight on SR-4)
89.3 Turn right into Bandelier National Monument
89.9 Stop 6 is the shuttle parking area for Bandelier National Monument (**N 35 47.700 W 106 16.850**). Geology buses will be allowed to drive into the park. Others park at the shuttle stop and take shuttles down into the canyon. Shuttles run approximately every 20 minutes.

- *79.9 Point of Interest: (Right side of road) Jemez Canyon view*

Figure 27: View west through water gap at Bandelier National Monument. Maar volcano is on the right (north) side of the canyon. Photo credit: Dave Decker.

Stop 6: Bandelier National Monument

Bandelier National Monument is located in Jemez Canyon and is best known for the Puebloan ruins found within the sheer cliffs of the canyon walls. These cliffs are formed of the 1.6 Ma Lower Bandelier Tuff and the 1.2 Ma Upper Bandelier Tuff. In several areas within the park, these tuffs can be seen infilling paleo-valleys. A trailhead at the east end of the visitor's center parking lot leads down a path that has many interesting geologic features. Several of the valley fills can be seen along with "tent rocks" – areas where it is thought that fumaroles formed from heated water right after the eruptions. This hypothesis is challenged however, and many researchers believe the tent rocks are merely protected areas underneath the capping rhyolite. Near the end of the trail leading down to the Rio Grande river at the east end of the parking area, a maar volcano that has been dissected by the stream flowing through the canyon is visible in the north wall of the canyon, just to the east of the waterfall.

60 minutes to La Bajada Fault (Bus Talk 2) (N 35 29.990 W 106 13.900)

90.4 Continue east on SR-4.
98.8 White Rock Village.
102.3 Merge onto SR-502 and continue east.
114.3 Turn right (south) onto SR-285 toward Santa Fe.
127.9 Veer right (west) onto ramp for SR-599, Santa Fe bypass.
140.8 Right (south) onto I-25 toward Albuquerque.
152.4 **Bus Talk 2: La Bajada Fault**.

- *92.8 Point of Interests: (Right side of road) Tafoni in Bandelier Tuff*
- *108.8 Point of Interest: (Left side of road) San Ildefonso Pueblo*
- *114.2 Point of Interest: (Left side of road) Pojoaque Pueblo*

- *114.4 Point of Interest: (Left side of road) Nambé Oweenge Pueblo*
- *119.7 Point of Interest: (Right side of road) Camel Rock*
- *120.9 Point of Interest: (Right side of road) Tesuque Pueblo*
- *132.9 Point of Interest: (Right side of road) Buckman Cave and Yo-Yo Pit (aka Pankey's Crater)*

Buckman Cave is tectonic in origin, caused by a large block of Tertiary basalt calving off the mesa and sliding down approximately 30 meters, creating a series of fissures in the block. There are at least seven entrances to the cave – four skylights and three walk-in/ scramble entrances. The two uppermost skylight entrances are the more commonly known entrances and are often used by the mountain rescue groups for vertical practice as the longer of the two is about 37 meters deep. The lower entrance is a walk-in and leads to a series of down climbs, short crawls, pits, chimneys, and tall fissure passages. A couple 15-m- to 30-m-deep pits along the walking passage can be bypassed by down climbing to the bottom level of the cave. The cave is approximately 350 meters long and 70 meters deep, though it is incompletely surveyed.

Yo-Yo Pit (Pankey's Crater) is an abandoned volcanic fumarole in Quaternary Twin Hills basaltic andesite cinder deposits of the Cerros del Rio volcanic field with an age of approximately 2.53 Ma. The sides of the pit near the surface are covered by what appears to be a coating of melted rock, possibly melted during the vent's eruption and which flowed down the sides of the pit.

Yo-Yo Pit is a popular spot for vertical rope work as the 8-m- by 9-m-wide pit is a straight, free-fall drop of 39 meters that bells-out for the final 18 meters to the top of a large talus cone. The bottom of the pit measures 23 meters long by 16 m wide with a small, wet weather stream bed that flows along the west wall and sinks in a debris-filled pit on the south side of the pit floor. Total depth is 45 m. Unfortunately, visitors have thrown in a variety of trash which litters the bottom of the pit, including the remains of a small truck that was pushed into the pit in 2009. As of 2015-2016, there is an active beehive on the lip of the pit. They are not aggressive but caution should be exercised.

- *146.8 Point of Interest: (Left side of road) Cerrillos Hills –*

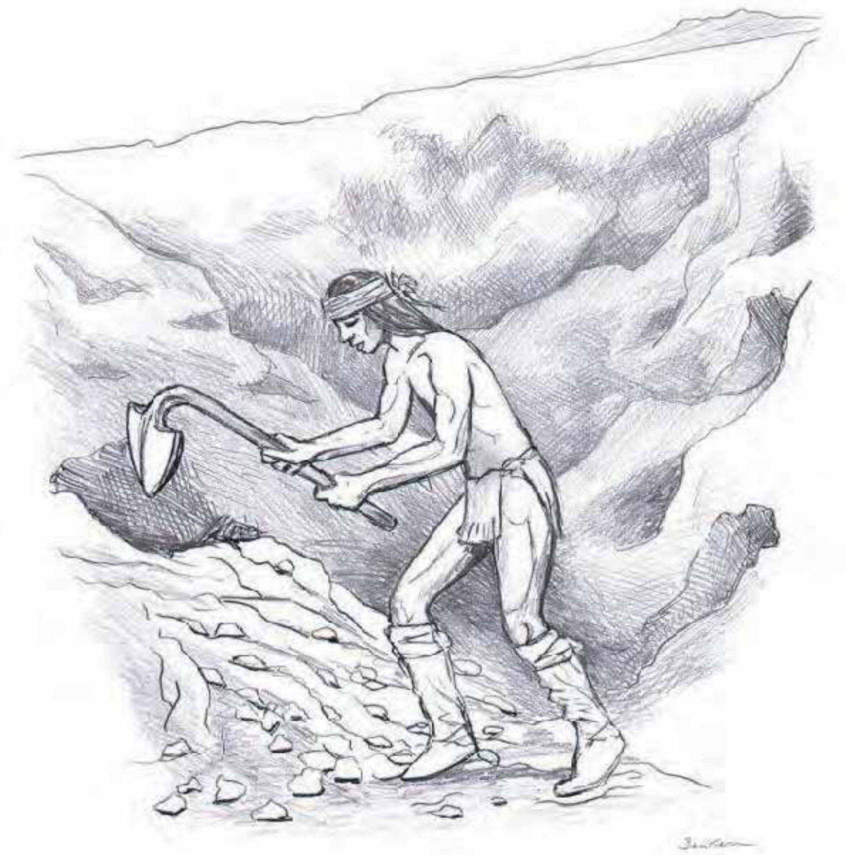
Mount Chalchihuitl, the oldest turquoise mine in New Mexico, is in the Cerrillos Hills mining district in north central New Mexico. Early Pueblo cultures began mining the district around 900 AD. Over a period of roughly 700 years, the native miners removed an estimated 100,000 tons of turquoise and rock to create a pit 130 feet deep and over 200 feet in diameter. Most of this turquoise was traded with the Navajo and the Chaco Canyon cultures (Milford, 1995) for use in jewelry and religious implements.

The Spanish arrived in the early 1600s and promptly took over the mines which also contained galena, a lead sulfide that contains silver in small quantities. They shut down the turquoise mines and concentrated solely on the galena to get silver for coins and lead for bullets. Many of the Puebloans were enslaved to mine the ore (Milford, 1995). During the Pueblo Revolt of 1680, the Spanish were "evicted" and the indigenous peoples filled in the mines so they could not be exploited again.

1879 was the year historic mining began in the region. An official mining district was set up and lands were parsed out. Within a few years, Cerillos Hills Mining District went defunct. Before it failed however, not only silver, but gold and copper were also recovered from the ore deposit.

Total yield of turquoise from these mines is unknown, but estimated to be several thousand tons (Cerillos, 2016).

The porphyry, which contains copper, lead and zinc along with trace amounts of gold, is related to the Ortiz Mountains (Espinosa volcanics), which erupted between 34 and 30 million years ago. The fluids which emplaced the ore are thought to be the last gasps of this volcanic episode, sometime around 28 Ma (Maynard, 2002). The turquoise, a later supergene event which occurred approximately 3 to 4 million years ago, was created by the oxidation of pyrite near the water table, which created sulfuric acid, and the remobilization of phosphorus from apatite (Maynard, 2002).



- *149.5 Point of Interest: (Left side of road) Ortiz Mountains*

Bus Talk 2 (Stop 7): La Bajada Fault
(This stop is optional and may be omitted for time.)

La Bajada Fault is a north-trending accommodation fault that begins near the Ortiz Mountains and marks the eastern edge of the Santo Domingo Basin of the Rio Grande Rift. This fault is the northern-most of a series of right stepping faults that accommodate the opening of the Rift from south to north. On the east side of I-25, the fault trace is visible along the cliffs that are marked by the Galisteo and Espinosa formations. This is a down-to-the-west normal fault. At the top of the cliffs to the west of I-25, 2.8 Ma basalt tops the Santa Fe Group, notice outcrops of Mancos shale and Morrison mudstones. A close look at the basalt reveals columnar jointing – a result of differential cooling of the flow. Farther to the south, mesas capped by similar basalts show fantastic examples of inverted topography, where the upland areas now covered by basalts were river valleys in the past, as evidenced by river cobbles at the base of many of the flows. These river valleys provided ideal flow paths for the fluid rock which flowed in and solidified, thereby armoring the ground beneath. As the region was uplifted and eroded, the basalts provided protection for these areas, while the sediments around them were carried away by the Rio Grande.

This part of the Rio Grande Rift began opening approximately 28 Ma when the North American plate overrode the eastern side of the Pacific Plate and intercepted the East Pacific Rise. Translational movement between the two plates began rotating the entire western United

States forming the Basin and Range, rotating the Colorado Plateau, and tearing the continental crust along the eastern side of the Colorado Plateau and the Great Plains region. The Rift is still in motion today, though this movement is not as prominent as in the past (Ricketts et al., 2014). The Rift is filled with the Santa Fe Group sediments, in some places consisting of over 6 km of sand, gravel and ash that were eroded from the surrounding, uplifted rift flanks, Cenozoic volcanics, and Rocky Mountains.

20 minutes to Sandia Overlook (Bus Talk 3) (N 35 18.245 W 106 29.170)

152.4 Continue south on I-25.
167.7 Bus Talk 3: Sandia Mountains
175.3 Exit I-25 at SR-550 exit (Bernalillo) and turn left (east) to cross the Interstate.

- *152.7 Point of Interest: (Right side of road) Cochiti Pueblo, Tent Rocks, Cochiti Reservoir*
- *154.8 Point of Interest: (Right side of road) Santo Domingo Pueblo*
- *165.0 Point of Interest: (Right side of road) San Felipe Pueblo*
- *170.3 Point of Interest: (Left side of road) Sand and gravel mines*
- *175.3 Point of Interest: (Left side of road) Sandia Pueblo*

Bus Talk 3 (Stop 8): Forest Loop Road Trailhead - Sandia Mountains
(This stop is optional; may be omitted for time)

The Sandia Mountains (elevation 3,244 meters, 10,640 feet) form a prominent landmark for the cities of Rio Rancho and Albuquerque (**Error! Reference source not found.**). The mountains are thought to be rift flank uplifts, areas of flexural uplift caused by the opening of the rift and warm mantle rock flowing in from below to "inflate" the area like a balloon. The Sandia Mountains began uplifting approximately 28 Ma along the Rincon Fault, a rift-bounding fault that runs along the base of the mountains through the Sandia Heights neighborhood and the eastern portion of the Sandia Pueblo. The word "Sandia" is Spanish for Watermelon, and describes well the color of the mountains at sunset.

The base of the Sandia Mountains is formed by 1.44 Ga Sandia Granite, which protrudes through the 1.66 Ga metavolcanic and

Figure 28: Sandia Peak, looking east across the Rio Grande River. The metamorphic Rincon Ridge is the lower peak in the foreground to the right. Notice the Madera limestones capping the Sandia Granite on the left. Photo credit: Dave Decker.

metasedimentary rocks of Rincon Ridge, just to the west of the sheer cliffs visible in front of you. Mantling the top of the mountains is the Madera Formation, a 300 Ma fossiliferous limestone that overlies the 360 Ma, Mississippian Arroyo Peñasco Group, a conglomeritic sandstone composed of the Sandia Granite, and the 325 Ma Sandia Formation, a Pennsylvanian sandstone. The Arroyo Peñasco Group is the remnants of an erosional surface that formed on the Precambrian section and was subsequently covered by the fluvial sands of the Sandia Formation, then finally the limestones of the Madera Group. The time between the cooling of the Sandia Granite and the deposition of the Arroyo Peñasco Group is 1.1 BILLION years! This is an area where the Great Unconformity is visible and touchable; a sign on the road to Sandia Peak marks an area on the side of the road where you can put your finger on it.

Fewer than 20 caves are known in the Sandia Mountains, and most are small caves developed in the carbonates of the Madera Formation of Pennsylvanian Age. They appear to be phreatic in origin and have strong stratigraphic and joint control. The longest known cave is Cooper-Ellis Cave with a length of 153 meters and a depth of 20 meters. Other significant caves include Sandia Cave (142 m long, 22 m deep) and Embudo Cave (115 m long, 16 m deep). These caves are available for day trips during convention.

20 minutes (arrive 18:00, but no later than 18:30)

175.3 Continue west on SR-550.
178.8 Turn left (south) on Paseo del Volcan.
184.8 Turn right (north) on Broadmore Dr. NE.
184.9 Turn left (west) onto Santa Ana Star Center Dr.
185.2 Turn right (north) to stay on Santa Ana Star Center Dr.
185.6 Return to Santa Ana Star Center.

- *176.9 Point of Interest: Rio Grande River*
- *177.2 Point of Interest: (Right side of road) Kuaua Pueblo and Coronado Historic Site (1540)*

Stop 9: Return to Santa Ana Star Center
(N 35 18.535 W 106 41.240)

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Notes on the Pueblos

Figure 17: Geographic distribution of the 19 Pueblos, 3 Apache reservations and the Navajo Nation in New Mexico. (NMIAD, 2016)

New Mexico has approximately 220,000 Indian citizens, which represent nearly 11 percent of the state's entire population. There are 23 Indian tribes located in New Mexico – 19 Pueblos, three Apache tribes (the Fort Sill Apache Tribe, the Jicarilla Apache Nation and the Mescalero Apache Tribe), and the Navajo Nation, plus a considerable urban Indian population (Figure 27). The 19 Pueblos are comprised of the Pueblos of Acoma, Cochiti, Isleta, Jemez, Laguna, Nambe, Ohkay Owingeh, Picuris, Pojoaque, Sandia, San Felipe, San Ildefonso, Santa Ana, Santa Clara, Santo Domingo, Taos, Tesuque, Zuni and Zia (NMIAD, 2016).

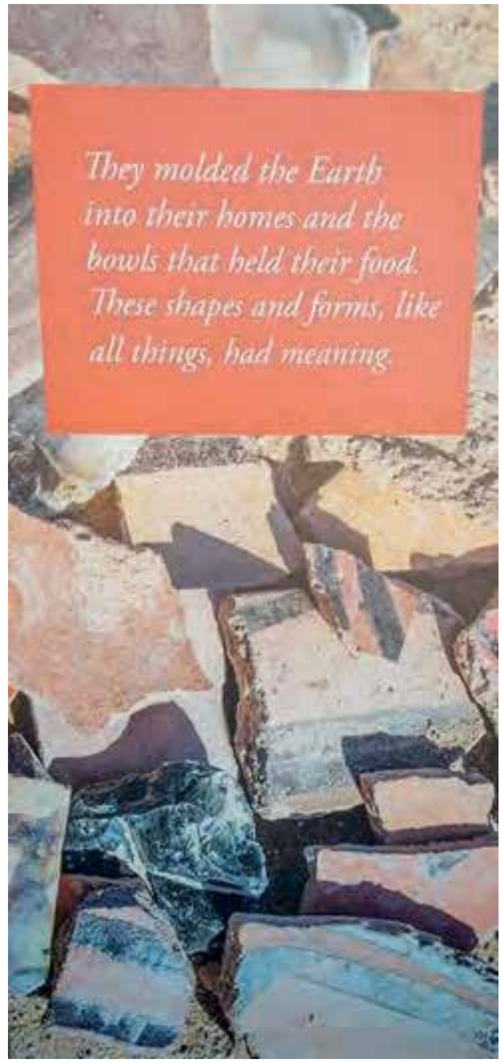
Each tribe is a sovereign nation with its own government, life-ways, traditions, and culture, and each tribe has a unique relationship with the federal and state governments. The 23 tribes in New Mexico are actively engaged in preserving their indigenous languages, religion, culture, the environment, and in promoting quality education and health care for all members.

Pueblos not passed during the field trip, and therefore not named in the text:

Acoma Pueblo	Isleta Pueblo
Laguna Pueblo	Ohkay Owingeh Pueblo
Picuris Pueblo	Santa Clara Pueblo
Taos Pueblo	Zuni Pueblo

Local rocks and minerals used by the Puebloans:

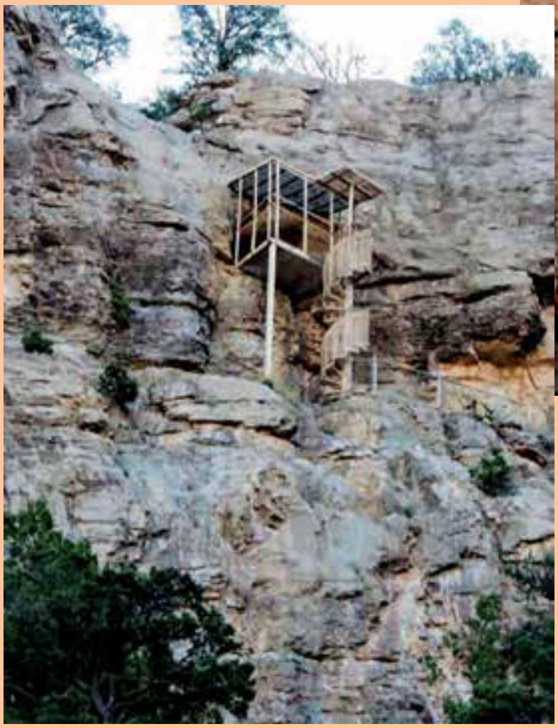
Basalt – as mano and metate, stone axes
Bentonite Clay – pottery
Chert from Sandia Formation – spear points and fetishes
Copper – in bells
Gypsum – a laxative historically; Plaster-of-Paris and wallboard currently
Hematite (Red Ochre) – pigment
Kaolinite Clay – pottery
Lead – as a pottery glaze and pigment
Limonite (Yellow Ochre) – pigment
Mica – pottery, also used by Puebloans for components of body paint for ceremonies.
Muscovite – a clear sheet mica, also utilized as windows.
Obsidian – as spear points and sometimes in jewelry and fetishes
Pumice – used to soften leather
Silver – in jewelry
Thermal waters – to bathe and for health
Turquoise – in jewelry and religious items
Fetishes for prayer and hunting are made from many different stones, not just those mentioned above.



Alabaster Cave

Ron Maehler

Sandia Cave Entrance



Ron Maehler

Regional Underground Features

Galena King Mine

Matt Thompson

Doug Medville

A Kutz Canyon cave

Sandia Grotto cavers headed into the North entrance of Alabaster Cave. Photo by Pete Lindsley.

More on Alabaster Cave (aka Dos Ojos or Ojo del Diablo)

By Dave Decker

Alabaster Cave is a fun, family friendly cave in the 150-million-year-old, Jurassic age, Todilto gypsum located near the village of San Ysidro, New Mexico on Zia Pueblo land. A permit from the Zia Pueblo is REQUIRED to enter the cave. Zia Pueblo Police patrol the area of Alabaster Cave along SR-550 and will ticket vehicles parked without a permit in the parking area.

WARNING: This cave has suffered two major rock falls in the past five years, albeit during the winter months. Please be careful where you grab a hold and ALWAYS let someone know where you are going and when you expect to return!

The cave consists of one main, nearly straight passage following a north-south trending joint; it has five known entrances. The North Entrance is found in a large sinkhole near the Rio Peñasco. The Slit Entrance is a narrow crevice along the face of the gypsum ridge that the cave is contained within. This ridge allows entrance or exit about one-third of the way through the cave (from north to south). The Foxhole Entrance is a sinkhole approximately 3 m (10 feet) in diameter, also at the base of the gypsum ridge, that allows entrance and exit about two-thirds of the way through the cave (from north to south). The South Entrance is essentially two entrances, where a small headward, eroding arroyo has collapsed both the upper and main levels of the cave.

Alabaster Cave

By Sam Bono

Alabaster Cave, located on 17,472 acre Zia Pueblo, is only about an hour northwest of the NSS Convention headquarters, and is just off New Mexico 550. The Pueblo, with a current population of 850, was first visited by Spanish Conquistadores in 1583. Their Zia Sun Symbol can be found everywhere in New Mexico, from our bright yellow-and-red state flag to the advertising of hundreds of local companies.

Long a favorite beginner's cave of the Sandia Grotto because of its five entrances/exits, dusty Alabaster was formerly known as Ojo del Diablo (Eye of the Devil).

NOTE: When caving almost anywhere in New Mexico, be aware of the potential for rattlesnakes. If you don't surprise them, they will gladly get out of your way. Walk with your head alternating between down and straight forward.

Kevin Lorms climbing into upper level. P. L:indsley

Throughout the cave there are equally-spaced cross-joints at about 60°. Some of these head to smaller, parallel side passages. These cross-joints are the result of normal faulting in the nearby Rio Grande Rift. In numerous locations in the cave, small scallops can be seen on the walls and ceiling, indicating rapid, bore-full water flow through the cave. These are paleo-scallops and the cave no longer floods to the ceiling since the water that formed the cave has been pirated by the nearby Rio Peñasco.

There are three levels in the southern half of the cave. The middle level is mostly walking passage averaging three meters wide and floored with breakdown. The lower level is generally crawlway with some very narrow squeezes and sandy floors. The lower level is prone to flooding during localized thunder storms directly above the cave. The upper level is a crawl except at the south end of the cave. This level can be entered at the South Entrance(s) by a short climb and can be traversed for about 90 m before a narrow breakdown crawl, called the Birth Canal, is encountered. The Birth Canal can be negotiated, even by larger cavers, with proper technique. Once through the Birth Canal, there are several opportunities to drop down to the main level of the cave.

Through-trips of the main part of the cave can be done in as little as 15 minutes by a fit caver that knows the system, but generally take about two hours for those wanting a more leisurely and fun trip. Trips of up to five hours can be done if the entire cave is explored. The known length of Alabaster is approximately 1,372 m (4,500 feet), with less than 15 m (50 feet) of elevation difference from the North entrance to the South entrance, and a linear distance from north to south of ~305 m (~1000 feet).

Recreational trips are usually started at the North Entrance and traverse a breakdown crawl and dry, sandy stream passage to the Slit Entrance. Look around carefully at the Slit Entrance. This is the only place in the cave

Paleo-scallops from rapid, bore-full water flow. Photo by Pete Lindsley.

where calcite speleothems can be seen. There are short, 5- to 8-cm (2- to 3-inch) soda straws hanging from the ceiling under a ledge. Also, keep a listen out for rattlesnakes; they like to come into the cave at this entrance to stay cool in the summer heat. Continuing from the Slit Entrance, the passage becomes an upper-level walking passage and lower-level crawl for about 15 m (50 feet) before merging into a narrow canyon passage. This passage makes a 150° turn, without being obvious, and leads to the Confusion Room, where a seeming dead end is encountered. Look to the left, a crawl into a passage that looks like it is going in the wrong direction is where you want to go. This is the main passage going south and continues to the Foxhole Entrance.

Solitary *Plecotus Townsendii* near the Water Passage. Photo by Linda Starr.

At the Foxhole Entrance, you can drop down into the lower passage and continue south in a sandy-floored, canyon passage, or pass directly under the Foxhole Entrance through a squeeze into the Green Clay Room. Here, again, you can drop down to the canyon passage or continue into an unstable area that eventually merges with the main level of the cave farther south in the Junction Room. Once beyond the Foxhole Entrance, the cave becomes cooler and wetter. This area is sometimes frequented by Townsend's Big-Eared bats, so watch where you are putting your hands! Also, this area of the cave is where multiple levels can be traversed. It is difficult to get lost and can be fun to explore all the different leads. If in the lower level, watch where you put your hands and knees as this area sometimes contains gypsum needles up to 2.5 cm (1 inch) long. Staying on the main level will bring you to the Water Passage, which contains floating gypsum rafts and putrid, anoxic mud. You can follow the water to the South Entrance if you don't mind being wet up to your waist (for some). There are several places to gain access to the upper level crawlway and the Birth Canal to exit at the South Entrance. If you decide not to go through the Birth Canal, you can turn around and exit at the Foxhole Entrance.

Clockwise from top: Jeff Kruse, Michele Wilson, Sam Bensonhaver during a rest stop. Photo by Todd Roberts.

Kenna Josephene enjoying the relief of exiting the Birth Canal. Photo by Linda Starr.

Sandia Cave

Sandoval County, New Mexico

By Sam Bono

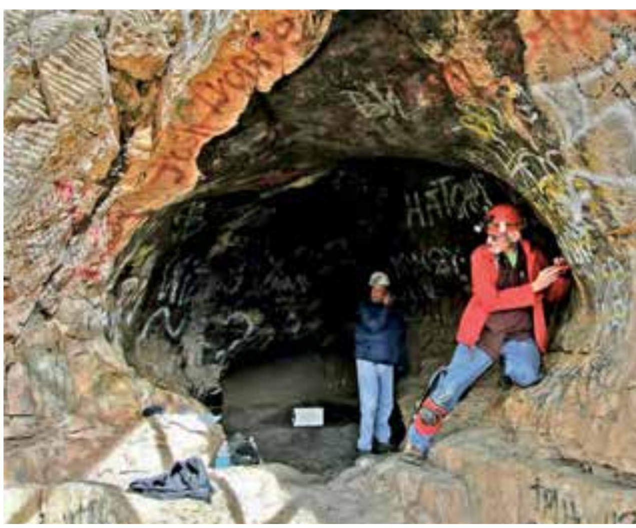
While only a little over 466 feet long, Sandia Cave is both a National Historic Landmark, and on the National Register of Historic Places. These prestigious designations are a result of archaeologist Frank C. Hibben's controversial discovery of artifacts from ancient people, who he named Sandia Man, that he claimed to have found in the cave.

Much of the floor of Sandia Cave is covered with a thick layer of yellow ochre – so much so that when Hibben dug off and on from 1936 until 1940, he considered calling it Sandia Yellow Ochre Cave. A dust mask or even two is highly recommended for anyone traveling to the end of this easy, mostly-crawling cave.

From the entrance, the single passage in the Madera limestone runs gradually downhill, with the bitter end of the cave sitting almost 72 feet below the walk-in entrance.

The entrance to Sandia Cave is at the top of a spiral staircase platform. Photo by Pete Lindsley.

Sandia Cave has long been known to local residents. It's on many maps, and there is even a sign on the road near the parking area. Unfortunately, as a result of its close proximity to an urban area, the site had graffiti on top of graffiti from the parking lot through the cave. In



The Entrance in June 2015 was covered with graffiti completely surrounding the entrance as well as the spiral staircase leading up to the cave. A massive restoration to remove graffiti began at this same time. Photo by Val Hildreth-Werker.

By July 1, Sandia Grotto, with the help of a U.S.F.S. grant and other volunteers, had nearly finished restoring the first two entrance chambers.
Photo by Pete Lindsley.

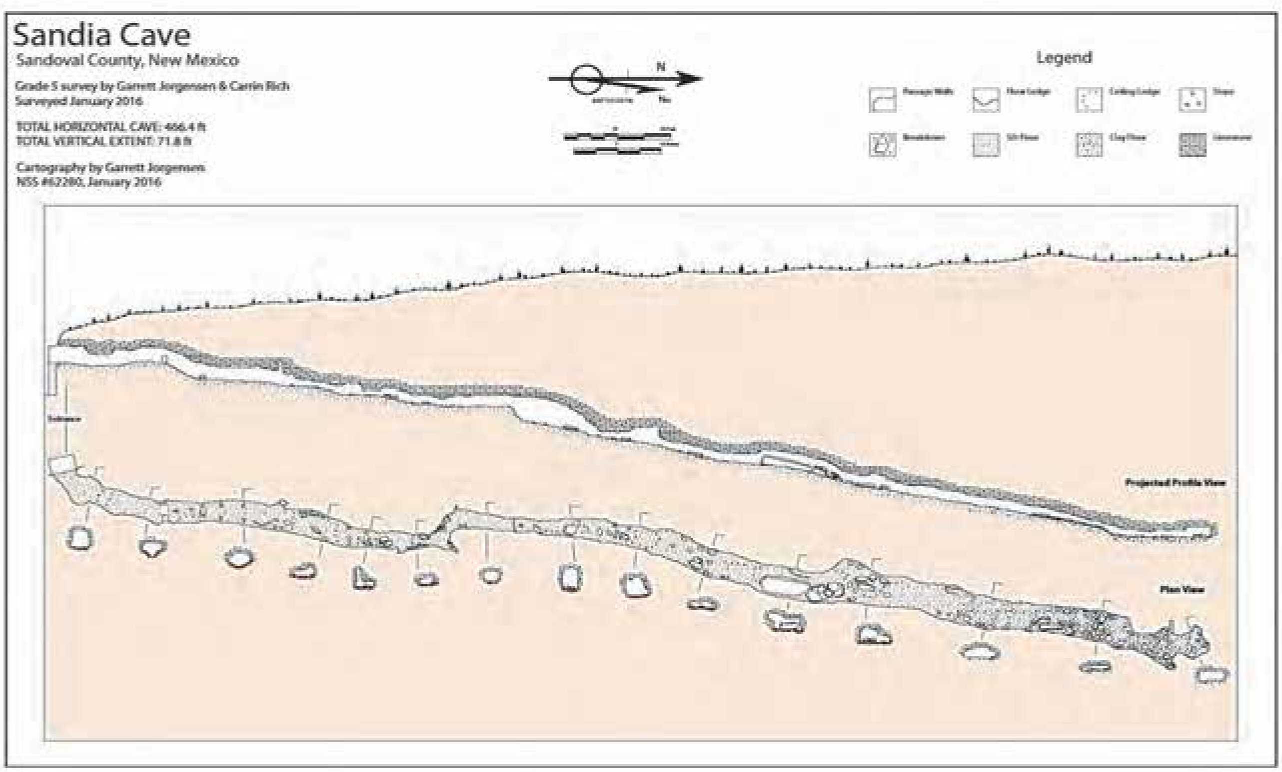
The wall in the foreground marks the end of the 2nd chamber and the beginning of the passage into the remainder of the cave. Photo by Pete Lindsley.

an attempt to keep the cave and the surrounding area clean, Sandia Grotto members have been removing trash from the cave, the steep cliff face below the cave, the trail, and the parking area since late last century and we adopted the cave and environs in a stewardship project with the U.S. Forest Service, its land management agency.

During the summer of 2015, Grotto volunteers, Forest Service personnel, and other volunteers cleaned an amazing amount of graffiti from the two front rooms of the cave, from the spiral staircase and platform, and from the trees, rocks and cliffs along the trail with the guidance of a professional rock art conservator. Today, the Grotto maintains the improved appearance by removing graffiti as it occurs.

While gearing up in the parking lot, you can often hear one of the few year-round streams in the Sandia Mountains, nearby Las Huertas Creek, merrily running down the canyon. Beware of poison ivy in this area.

See this same map in Cave Descriptions, this volume.



Sandia Cave

By Jack H. Speece

Jewel and Jeanette Baker in entrance of Sandia Cave, 1950s

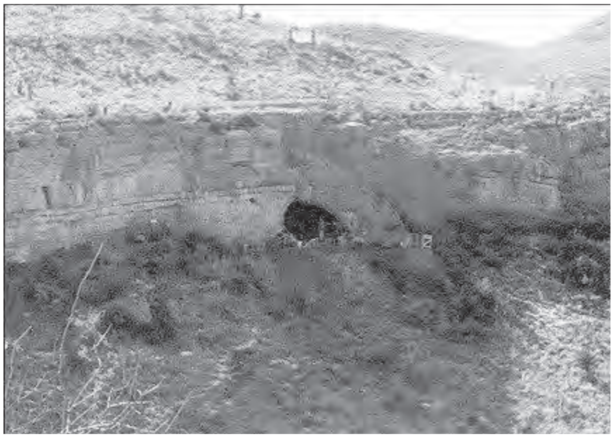
Sandia Cave is an archaeological site near Bernalillo, 15 miles northeast of Albuquerque, New Mexico, within the Cibola National Forest. It is located in an escarpment on the north end of the Sandia Mountains, high up on the steep cliff walls of Las Huertas Canyon. The trailhead is off SR 165 and is marked with a sign. It is a 0.47-mile hike from the parking lot to the cave. The trail leads to a concrete staircase, then to a limestone ledge in the cliff, and finally to a metal staircase that spirals up to the mouth of the cave. Sandia is a Spanish word that translates to watermelon.

Some say the cave was first discovered by Boy Scouts in 1929, while others give the credit to Kevin Davis from the University of New Mexico in 1936. Davis took a dusty cigar box full of pottery fragments from the cave to archaeologist Frank C. Hibben (1910-2002) at the University. Hibben then visited the site and organized several of his students to investigate.

Wesley Bliss and Chester Stock started the excavations here and discovered the now-famous Sandia points under the direction of Frank C. Hibben, professor of Anthropology, who became the principal investigator of the site. Based on Hibben's interpretation of data from the deposits, he proposed a new theory of Solutrean origins for New World cultures. This gave new support for the land-bridge-from-Asia theory.

In 1934, as a graduate student, Hibben was already a shining star of the archeology program at the University of New Mexico. He excavated the cave and discovered it contained artifacts from as far back as the Folsom culture, then considered the earliest inhabitants of the Americas. But Hibben didn't stop there. He kept digging, and soon found another cache of artifacts from what appeared to be a far older group of humans. He named the people of this group "Sandia Man," and estimated they had lived approximately 25,000 years ago, predating the Folsom culture by some 10,000 years. When the discovery was reported in the May 6, 1940 issue of *Time* magazine, Hibben, by then a full professor, was hailed as a revolutionary figure and the University of New Mexico became world-renowned for its archaeology and anthropology programs.

Prior to this time, the oldest known American Indian culture was that of Folsom Man. The artifacts found in 1926, at a site near Folsom, NM, by J.D. Figgins from the Colorado Museum of Natural History, included thin lanceolate stone projectile points with a distinct, deep concave base and remains of a giant extinct bison. Based on the best geological dating methods of the time, the archaeologists dated the relics at about 10,000 years old. Prior to the discovery, it was thought that the earliest Americans were only about 4,000 years old.



Radiocarbon dating on the bones at a later time placed the age at perhaps 12,000 years old. Similar points have been found throughout North America. Little is known about Folsom Man and human remains have not been found.

A similar site was discovered in 1929 near Clovis, NM. Its projectile points are similar to Folsom points but tend to be thicker in the middle. Clovis culture is believed to be of the Paleo-Indian period around 13,500 years ago. No human remains were found at Clovis. Similar points have been found over a large range throughout North America.

Pendejo Cave, in southern New Mexico, was first discovered in 1978, but archaeological excavations under the direction of Richard A. MacNeish were not begun until 1990. Clovis tools were discovered here along with bone awls and a bone knife, and a scapula of a horse. The claim of pre-Clovis human utilization of the site has made the cave and the interpretations of its contents controversial. Deposits uncovered in Ventana Cave in nearby Arizona have also become of interest.

The Sandia projectile points which Hibben claims to have found in a layer below (older) than the Folsom and Clovis points have a distinctly different appearance with one edge having a weak shoulder. They are similar to Solutrean points found in northwest Europe, which date back over 20,000 years. There were 19 points found at Sandia Cave and no broken samples or flakes. Only one other site in North America has been found to contain this type of point; it is controversial and discussed later.

It should be noted that the first discovery of human bones, including parts of two skulls, were confirmed by William A. Bryant of the Los Angeles Museum in 1929. The discovery was made by amateur archaeologist Roscoe P. Conkling in Conkling Cave (Bishop's Cave) in the Organ Mountains of New Mexico. An in-depth analysis of the find has not been published. No human remains were found in Sandia Cave; however, arrow and lance points, basket scraps, part of a woven moccasin and remains of Ice Age animals were discovered.

During the 1930s and early 1940s, New Mexico was hard hit by the Great Depression and prolonged drought. In November 1935, Dr. Brand of the UNM Anthropology Department applied for a permit to conduct excavations at Sandia and Davis Caves. Wesley L. Bliss (1905-1996) was in charge of the field work at the larger Davis site, and Frank Hibben at Sandia. Bliss dug at Davis Cave until March 1936, when it was determined to be sterile. Davis Cave, also known as Marmot Cave, is located about 300 feet north of Sandia Cave. The records from Sandia Cave are not clear, but it was reported that Bliss was working there prior to fall 1936. A lot of effort was required to build a trail to the cave, clean out the entrance, and install a door. Work was done on the weekends, mostly with undergraduate students. The excavation was tedious due to the poor candle lighting and the dusty conditions in addition to bagging all the dirt and hauling it to the bottom of the cliff to be screened.

Wesley L. Bliss was a graduate student at the University of New Mexico and earned his thesis by removing three large murals from a kiva at Kuaua and transferring them to the University in 1935. He completed a doctorate in anthropology and geology at the University of Arizona in 1952. Although Hibben gives no credit to any of the findings made by Bliss at

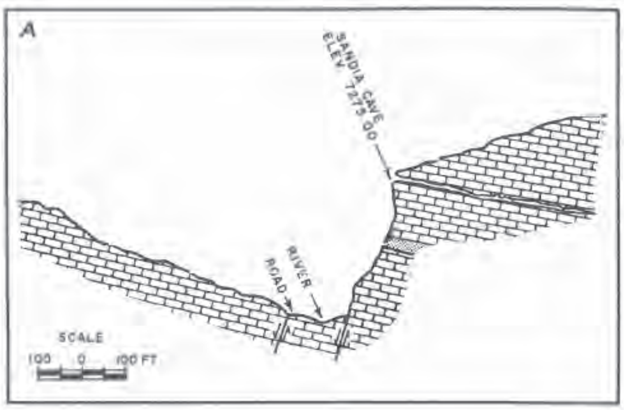
Sandia Cave, Bliss did work at the site during fall 1936 and spring 1937. That summer he headed a field party to Canada to survey evidence of early man in relation to glaciation and possible early migration routes from Asia. Upon his return, he transferred to the University of Pennsylvania.

Frank Cummings Hibben was quite a charming and witty individual. He married into money and enjoyed the good life, while other associates in his field struggled to maintain their careers. He toured the world and took pleasure in hunting big game. After graduation from Princeton in 1933, he earned his master's degree in zoology at the University of New Mexico and then attended Harvard for his doctorate in anthropology in 1940. In 1936, he married Eleanor (Brownie) Pack, the ex-wife of Arthur Pack (editor of *Nature Magazine*), who was financing his research for his master's thesis. Eleanor was 12 years older than Frank and quite wealthy. Most of his career was spent at the Maxwell Museum of Anthropology and as a professor at the University of New Mexico. He donated his home and assets of $10 million to build the Hibben Research Center, which was to support students as well as his professional allies. With his captivating personality, Frank knew how to tell a good story even if it somewhat stretched the truth. He enjoyed national fame and glory as a controversial archaeologist.

Hibben describes the Sandia Cave fill as stratified. In the mouth of the cave, modern material was present in the form of black and white potsherds of the Pueblo III period. Beneath this deposit extended a sheet of cave travertine representing a wet period. This calcium carbonate crust seems to represent the end of the Pleistocene. Beneath this cave crust lies the uppermost of the two main cultural horizons. The Folsom layer comprises a series of tools and implements, including Folsom points and other objects considered typical of Folsom times. This layer is characterized by loose debris cemented into breccia by calcium-charged waters percolating from above. Below the Folsom floor is a sterile, laminated stratum of yellow ochre representing another earlier wet phase. Farther below the yellow ochre is the Sandia layer, the earliest cultural stratum of the site. The Sandia layer is less consolidated than the Folsom and contained five areas or hearths, and the Sandia points. Hibben discovered 12 species of animals in his excavations. The Sandia stratum also contained horse, bison, camel, mastodon, and mammoth bones.

Sandia points are larger than Folsom points, not so well-chipped, and distinguished by a side shoulder or notch suggestive of Solutrean points, although no contemporaneity or connection between them and the Old-World forms is necessarily implied by such comparison. Sandia points are further divided into two subtypes, both possessing the side-shouldered feature. Type 1 is lanceolate and rounded in outline. Type 2 is straight-shafted with paralleling sides. Type 1 is apparently slightly older than Type 2. These points differ from those of the Solutrean collections in Europe in that they do not contain the fine ripple flaking and delicacy.

Prior to the 1950s when radiocarbon dating was introduced, archaeologists depended on stratigraphy for their estimations on dating. Stratigraphy has caused great controversy. It has been described different ways by different researchers. It has even been described differently by Hibben in his various publications. However there appears to be four distinct layers; 1) the latest disturbed layer; 2) the travertine layer; 3) the yellow ocher layer; 4) the undisturbed layer. The "unbroken" travertine layer is critical in authenticating the distinct Sandia Man theory. Also, the existence of the yellow ocher is significant but not mentioned in several reports.



It should be noted that in 1943 Hibben was traveling off the coast of Alaska and entered the Chinitna Bay. He claims to have made a remarkable discovery of several projectile points very similar to those found at Sandia Cave along with mammoth bones in cliff strata. Vicious storms prevented him from a more detailed evaluation. His conclusion on this find was that not only did it support the age of Sandia Man but also verified the land bridge at the early date of greater than 20,000 years from Asia to Alaska. – Quite a remarkable discovery! However, due to the impending storm, they had to leave quickly and nothing was documented. No one has since been able to relocate this site, and the geology of the area strata does not fit the correct geological time period. Hibben's findings and reports of the visit are no longer available.

In 1954, Hibben announced the discovery of a Sandia spear point along with mammoth bones at a site on the shore of a dry lake bed in the Estancia Basin, about 50 miles from Sandia Cave. His student, William Roosa, conducted these excavations at what became known as the "Lucy" site. This was an open site and not a cave. Although Roosa uncovered several additional points, he was suspicious of their origin and how easily Hibben had found the first one shortly after his arrival at the site. Hibben has been accused of planting these artifacts by most of the archaeologists that have worked in the area. No other Sandia points have ever been found.

An evaluation of the faunal remains in Sandia Cave has concluded that the cave, like most Great Basin caves, was used sporadically by the Native Americans. It is believed that carnivores introduced most of the bones discovered in the cave, including those from extinct Pleistocene species. Radiocarbon of modified bone fragments indicate there is no evidence of human use of the cave prior to the Folsom period.

Since the discovery of the Sandia points, no additional evidence of Sandia Man, except for the Lucy site, has been discovered in America. The Sandia Culture stands alone and only excavated by Hibben, and thus brings great controversy among other scientists in the field. The differentiation of Clovis and Folsom cultures has been verified over the years. The dating of the Sandia artifacts cannot be substantiated.

Vance Haynes and George Agogino in 1986 reported that the Sandia deposit is a rodent deposit created by bioturbation of the limonite ocher and contains material derived from most of the other deposits. They also report, the Sandia points discovered could be specialized Clovis or Folsom mining tools used by Paleo-Indians while digging the yellow ocher, making them less than 14,000 years old. The stratigraphic succession reflects both regional climatic variations and physical changes in the cave itself.

A few years later, Bruce Bradley from the Maxwell Museum examined the 13 points recovered from Sandia Cave. He remarked that it was unusual for a site to yield all complete points and no broken ones. Some looked fresh while others looked weathered. Two had modern alterations, one had metal markings, and some showed evidence of grinding. Also, there were different chipping techniques (percussion flaking and pressure flaking).

The inconsistencies among the various reports from Bliss and Hibben have added to the great controversy. Radiocarbon dating does not support an age earlier than the Folsom culture. There have been no additional discoveries to support the distinctive Sandia point fluting characteristics. The validity of mammoth ivory, tusks, and horse teeth samples that Hibben submitted for analysis has come into question. Preston (1995) describes the personal rivalry between Hibben and other colleagues, such as Bliss and Binford, as extremely abrasive and adding another variable to the misunderstandings.

The re-examination of the cave strata by Agogino and Haynes in 1986 could not support the original assumption that there were undisturbed layers sealed under a calcite deposit. The question has been asked, "Is this a hoax or just the result of sloppy work?"

Frank Hibben was well known in the Albuquerque area for stretching things a bit. He was frequently referred to as Fibbin' Hibben. He was an extraordinarily complicated figure, flamboyant, intelligent, and with a large ego. After a careful review of the deposits, few archaeologists today are willing to support Hibben's findings. It is the most controversial archaeological site ever excavated in the United States. The "discredited" findings are used today to teach students how not to do field work. That Sandia Man is the oldest finding in America is no longer taken seriously or even discussed.

Four other caves in the vicinity, including Davis Cave (Marmot Cave) and Guano Cave, have been excavated. Only Sandia Cave has shown evidence of early occupation. In 1961, Congress declared Sandia Cave a National Historic Landmark, and a bronze plaque was affixed below it, noting that the site possessed "national significance in commemorating the history of the United States of America."

Sandia Cave is located in the east wall of Las Huertas Canyon in Madera Limestone of Pennsylvanian age (circa 300 million years ago). The 466-foot-long by 6- to 12-foot diameter solution tunnel follows a tilted layer of limestone until it becomes too small to continue. The mouth is in a nearly vertical cliff some 300 feet above the valley floor. A talus slope 35 feet below the cave opening leads down to a creek. The approach to the cave is on a ledge along the cliff face, and the site can be reached via of a half-mile trail with spectacular views from a parking area along SR 165. A thrilling, 20-foot spiral staircase leads to the cave mouth.

During the past several decades the cave has been subject to a great amount of vandalism. Spray paint, fires, destruction of the metal gating and stairs, and litter have diminished the integrity of this historic site. Defacement has obscured the valuable historic and prehistoric markings throughout the cave.

In 2015, the Sandia Grotto began working with the Cibola National Forest on proper procedures to repair this gross devastation and return the cave to its natural condition. With the assistance of the University of New Mexico, a $16,777 grant was obtained from the New Mexico Historic Preservation Division. New techniques were developed to avoid further damage to the cave surfaces. After several years of painstaking efforts by numerous volunteers working along with specialists, the cave has been returned to a state that can be appreciated by the public, and by educators who can explain the significance of the site to visitiors. We can only hope others will respect this magnum effort.

See "Archeology of Sandia Cave," earlier in this volume.

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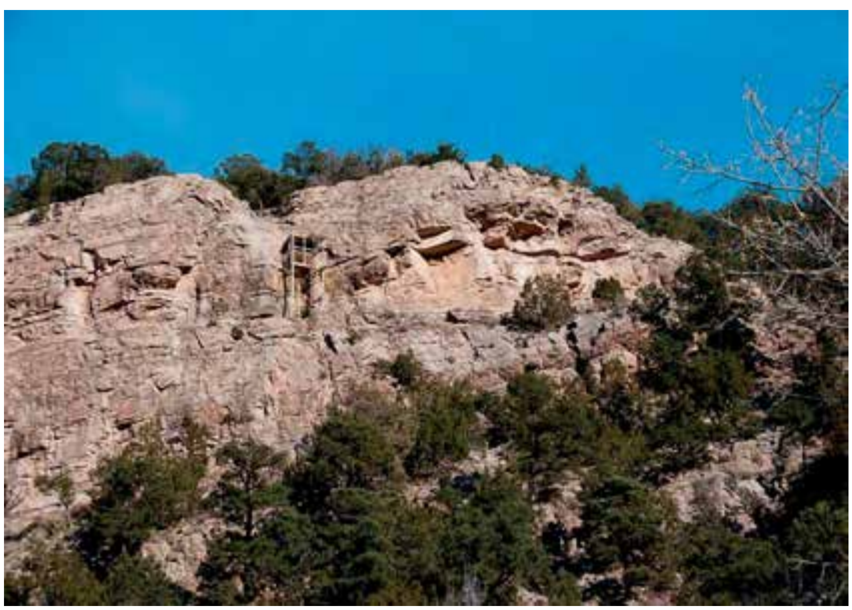


Sandia Cave, high up on the cliffs, and spiral staircase can be seen from Las Huertas Canyon below. Photo by Pete Lindsley.

Piping Caves in Kutz Canyon
San Juan County, NM

By Doug Medville


View of Kutz Canyon. Photo by Doug Medville.

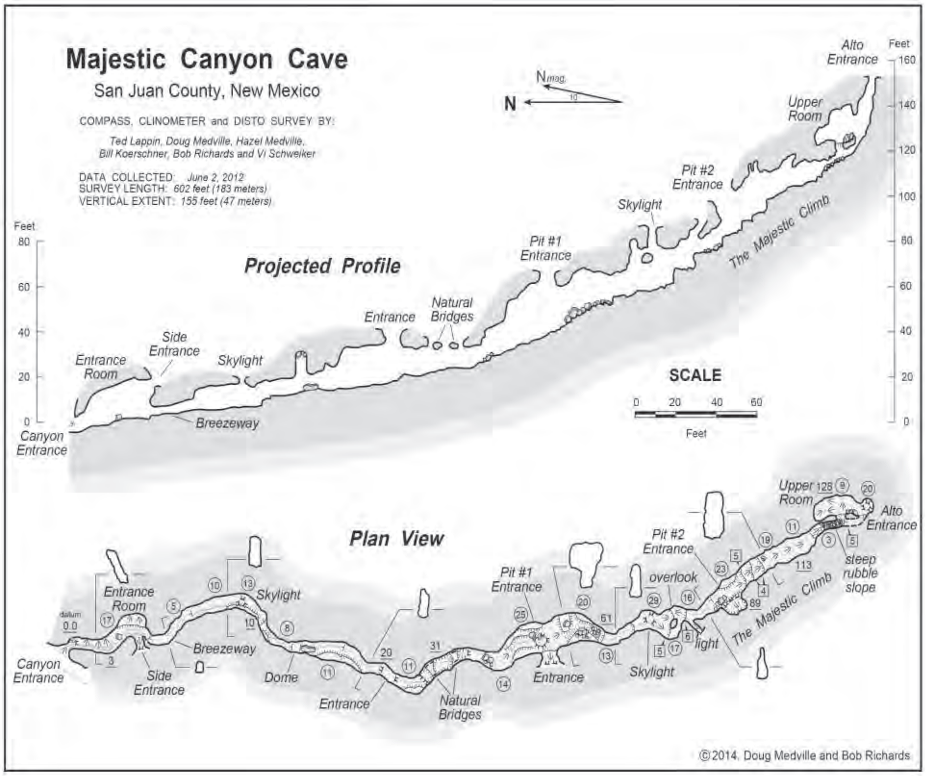
Kutz Canyon, in northwest New Mexico, is about 140 miles northwest of the Convention site. It's a 35,000-acre complex of canyons and badlands, formed on the 61-65 Ma Paleocene Nacimiento Formation. The canyon is a complicated maze of smaller canyons and narrow ridges spread out over four miles east to west and is 10 miles long. Vertical relief from the canyon rim to the canyon floor is in the 400-500-foot range. So, potential exists for caves in the canyon to have a substantial vertical relief.

Over the past five years, more than 170 piping caves have been found in Kutz Canyon with 70 having been surveyed. The caves tend to be small by limestone cave standards, they're usually only about 300-600 feet in length. The longest one has about 2,000 feet of passage and climbs over 300 vertical feet from its entrance. What the caves lack in length, they make up in the effort needed to explore them. Most of the caves have entrances that are at the bottoms of the canyons that they're found in and they go up steeply in high, narrow, and sometimes muddy passages that require numerous climbs, chimneys, and squeezes. Caving here involves a lot of body contact, and some of the caves will give you a workout!

Some of the caves, however, do have comfortable walking/climbing passages. These are suitable for people wanting a fairly east trip. A good example is the 602-foot-long Majestic Canyon Cave, climbing 155 vertical feet.

A more strenuous cave is the 576-foot-long King Kutz Cave, containing crawls, narrow


Ascending passage in Majestic Canyon Cave. Photo by Ted Lappin)



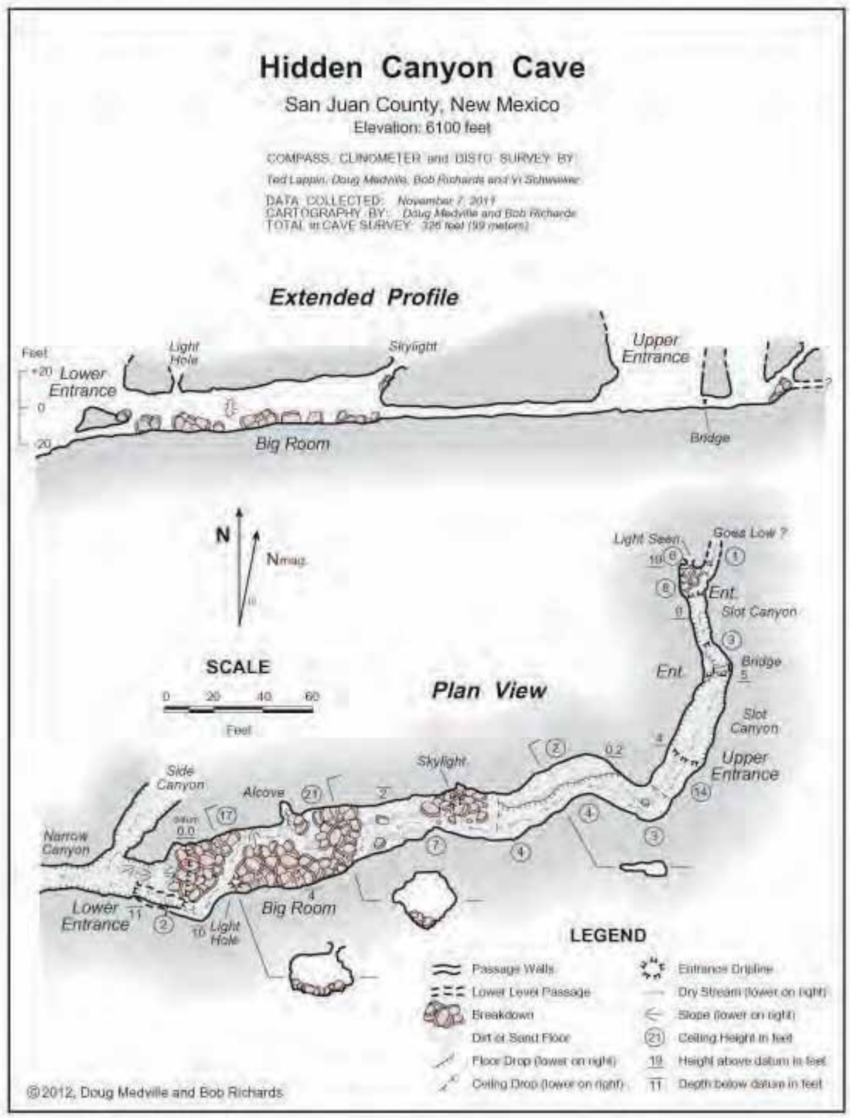
climbs, and large passages that ascend for 145 feet to an upper entrance with the possibility of more cave above. The specific caves to be visited will depend on people's interests (i.e., photography, survey, vertical work, and recreational caving.

A little geology: The material in which the caves are found is a mix of claystones and sandstones that swell when wetted by rainfall or snowmelt. The clays then shrink upon drying, resulting in desiccation cracks. With repeated swell/shrink cycles, the cracks deepen with sinkholes and pits forming. The process continues downward until a less permeable surface such as a sandstone bed is reached. Water then moves down gradient to an outlet, usually near the bottom of the local drainage, forming a conduit in the process. The moving water transports grains of sand and clay, gradually enlarging the conduit through mechanical means (corrasion) until passages are large enough for human entry, resulting in soil piping caves – also known as dirt caves, claystone caves, debris flow caves, suffosional caves, mud caves, and by other terms.

As the process continues, passage ceilings stope upward toward the surface and surface sinks deepen and intersect the ceilings. Both processes result in skylights as seen from inside the caves and pits when looking down from above. As the sand grains and claystones are washed away, some fairly large passages can form; for example, the entrance passage to the 450-foot-long Hidden Canyon Cave, as illustrated.

Passage in Hidden Canyon Cave. Photo by Ted Lappin.

The 140-mile trip to these and other caves takes about 2.5 hours going north on four lane U.S. 550 toward Bloomfield, NM. We'll make a stop at a lookout at the Kutz Canyon rim to look down into the canyon and admire the impressive badlands topography below. We'll then drive down into the canyon on a steep, high-clearance, dirt road to reach the canyon floor. Kutz Canyon is an active gas-producing area and contains a network of dirt roads leading to well pads, pumps, pipelines, and other infrastructure so it is not a wilderness by any means. These roads give us access to many of the side canyons containing the caves, so the walks to the cave entrances usually only take a few minutes. Since the caves tend to be short, we expect to visit several caves during the day.



The Galena King Mine
Bernalillo County, New Mexico

By Matt Thompson

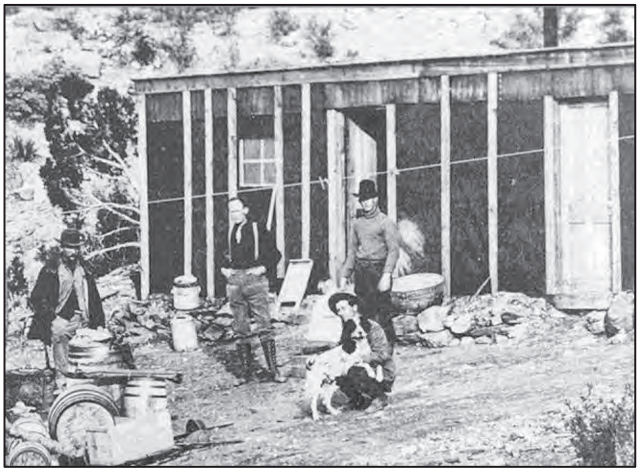
Many cavers look at mines with disdain; mines are man-made, empty, uninteresting holes in the ground. The Galena King is very much an exception to this, with its unusual circumstances and history. Approximately 110 years ago, the mine was opened and its brief operating life left us with a unique window to spectacular Neogene-period mineral deposits.

History

In 1907, A.G. Bateman and his brothers started to develop a claim on the side of a steep ridge in the Manzanita Mountains approximately 15 miles from "New Albuquerque." Following a seam of exposed fluorite and galena in the granite, they began mining a hard rock adit and shaft. Sinking about $4,000 into development, eventually the brothers shipped two loads of ore, getting about one-third of their money back on the lead. While they had discovered that the ore seam had widened 145 feet in the adit to a width of four feet, exposing hundreds of tons of new mineral deposits, by late 1911 they had run out of operating funds.

Then, in December 1911, the Galena King Mining Company was formed and took over the Octoroon Mine Group. Selling shares to raise capital, in August 1913, they began a second adit lower down on the ridge to ease ore extraction. The upper and lower adits were now connected by a 175-foot winze that ran through the middle of the mineral seam. The mine was patented as the Octoroon Group in 1922; the patent was signed by President Harding and there was even discussion of building a small mill on site to reduce ore processing costs. Even though interest in mining fluorspar was increasing in the United States, fluctuation in the metals market had stretched the finances of the mining company thin by 1928. In 1932, the Octoroon Mine was out of business and all production had stopped.

In 1940, with the clouds of war looming, the mine re-opened specifically to mine fluorite, which was needed for fluorescent light bulbs. A blacksmith shop, a powder magazine, and an oil house were all constructed along with a 300-ton ore chute to ease the loading of trucks. New

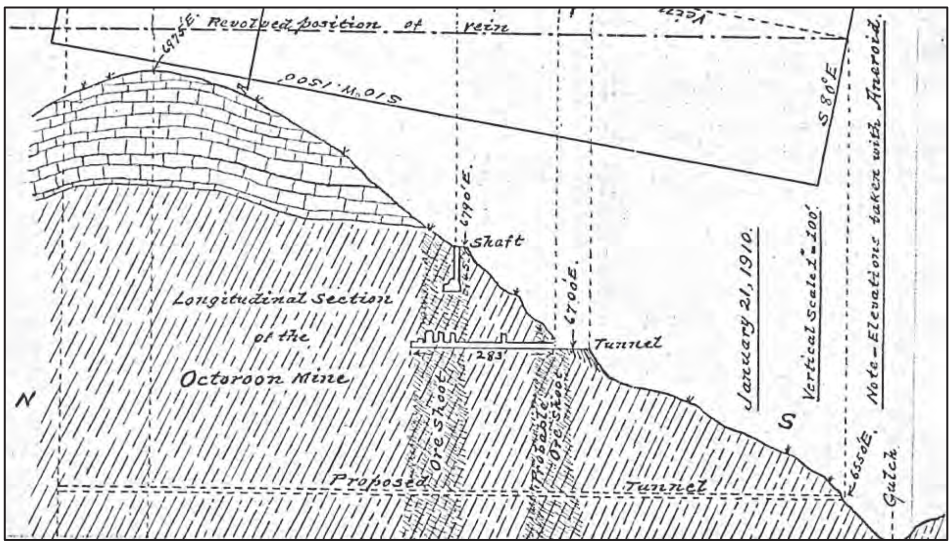


SEVENTEEN TONS NETS $653.39

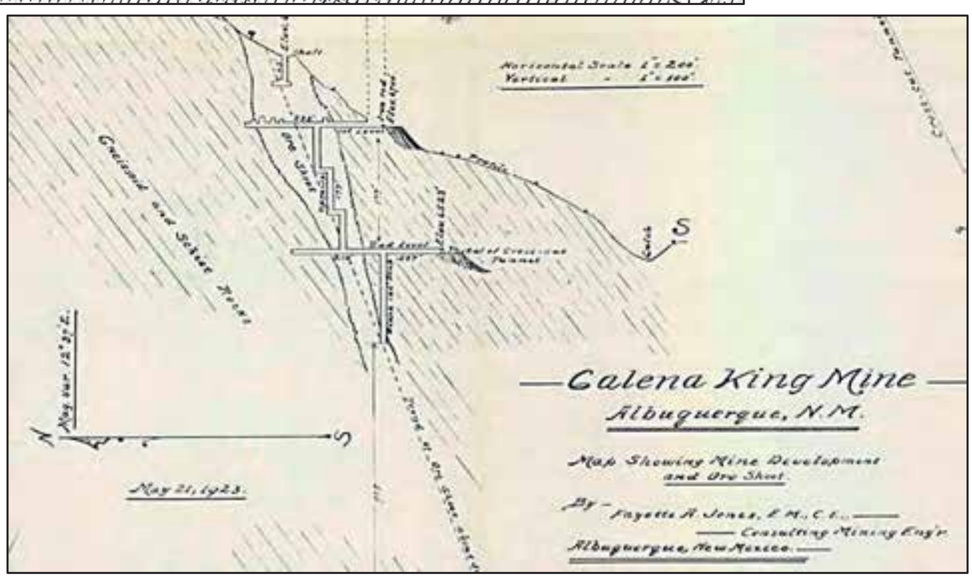
Sample Shipment of Lead Ore from Octoroon Mine Assays 68.3 Lead.

ASSEMBLES MACHINERY HERE TO DRILL TUNNEL AT OCTOROON MINE

Above Left: A.G. Bateman and his brothers at the Octoroon Mine Cabin. (Bill Bateman) **Above Center:** 22 December 1910, *Albuquerque Journal* article about the first shipment of ore from the Octoroon Mine. **Above Right:** 24 August 1913, *Albuquerque Journal* article about the digging of the lower tunnel; the mine is now also called the Galena King. (*Albuquerque Morning Journal*)



The 1910 cross-section survey of the Octoroon Mine with two ore seams shown. (New Mexico Bureau of Geology and Mineral Resources)



The 1923 cross-section survey of Galena King Mine with the completed lower tunnel, the connecting winze, and recognition that there is a single ore seam. (New Mexico Bureau of Geology and Mineral Resources)

Mexico Proving Ground (NMPG) took over the area just north of the mine in 1942, blocking access and shutting the mine back down. The NMPG set up a gun line to test the new proximity fuze, a technological marvel credited with helping to win the war. From 1943 to 1952, over 49,000 high explosive and inert rounds of various calibers were fired into this hillside to test fuzes before testing ceased. Several massive ordnance clearance sweeps have been conducted since 1953, but shells still can be found hidden in the rugged terrain. Ownership of the mine passed along through the family of one of its shareholders, but the mine remained dormant with all of the new military activity in the area.

Old Galena King Mine Reopened

Journal 2/11/40

Pittsburgh Company To Get Fluorspar

Mining operations in a fluorspar mine in the Manzana Mountains, about 15 miles east of Albuquerque, are scheduled to begin this week, according to W. R Mohney, in charge of production.

The mine, once opened as a lead mine, is owned by the Newalpitt Mining Co. of Pittsburgh, Pa. The company recently purchased the property from Louis Lowry of Coyote Springs.

Work of getting the mine in shape to begin taking out the ore has been in progress for the past two months, Mohney said. A 300-ton chute for storage and conveyance of the ore from the pit mouth to trucks is completed. A compressor has been installed and a blacksmith shop, powder magazine and oil house built.

Plan to Build Mill

Mohney said plans called for eventual erection of a processing mill of 100 tons capacity to separate the fluorspar from impurities. Output of the mill will be 99 per cent pure calcium fluoride.

The mine will employ 25 to 30 men in mining operations and will employ more after the erection of the mill, according to Mohney.

The Newalpitt Mining Co. recently was formed by a group of Pittsburgh business men to develop the property, according to Mohney. John Edmunds is president and E. Arthur Kerschbaumer, treasurer. Both men live in Pittsburgh, although Kerschbaumer has made several recent trips to Albuquerque in connection with the mine.

The company took its name from the words New Mexico, Albuquerque and Pittsburgh.

Here From Arizona

Mohney moved to Albuquerque recently from Arizona, where he

Continued From Page One

was in charge of a mine. He lives on the Atrisco Road, northwest of Five Points.

The property many years ago was operated as a lead mine and known as the Galena King mine. It is on the east slope of the Manzano Mountains, about eight miles south of Highway 66 and near Coyote Canyon.

Gordon Winter, county road superintendent, has surveyed a proposed road from the present Coyote Springs road to the airport after authorization by the County Commission. That body now is discussing possible construction of the road.

Reopening of the mine for fluorspar follows a recent rise in the price of that mineral, Albuquerque engineers said Saturday. It has long been used in the smelting of iron, and more recently has come into use in fluorescent lighting.

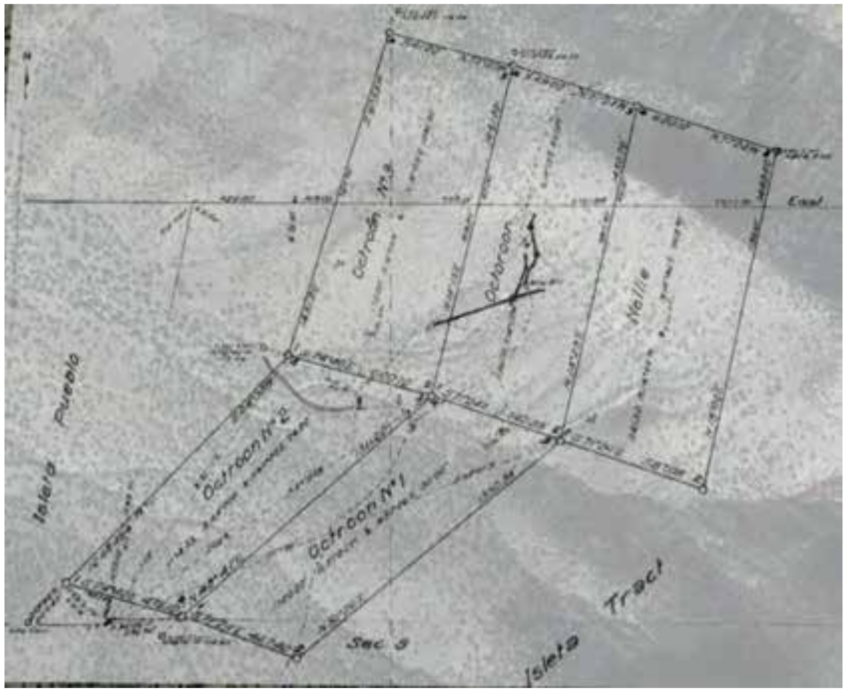
Above: 11 February 1940 article announcing the reopening of the mine to produce fluorite as the threat of war looms. (Albuquerque Journal)

Below: 1944-45 images of the New Mexico Proving Ground (NMPG) gun line and wooden towers designed to hold chicken-wire mockups of planes for proximity fuze testing. (Kirtland Air Force Base)

Over 100 years ago, miners working in this hard rock mine, originally by candle-light and oil lamps, left intact large sections of faceted fluorite and other minerals on the walls. The mineral-covered walls made sections of the mine appear like the inside of a geode, and the miners clearly chose to preserve these sections even in busy areas of the mine. Due to intermittent production over a relatively short period of time, large portions of the blue, purple and orange ore seam remain unmined along with these preserved walls. In 1963, the current owner, Mr. Max Evans, purchased the mine solely for the beauty of these intact mineral deposits. After extensive experience with mining and a variety of mines across the State, Mr. Evans and his head geologists knew the mine was unprofitable, but by 1963 he had fallen in love with the natural beauty left here.

Unfortunately, by the late 1960s rock collecting was a serious business and over the last several decades illegal collectors have systematically destroyed and removed large sections of preserved mineral from the mine. Relatively close to Albuquerque and tucked into a rarely trafficked corner of the

Manzano Mountains, thieves felt comfortable making regular trips to the mine. “No-Trespassing” signs and wooden barriers over the tunnels were removed by these thieves as they sought mineral specimens left by the original miners 100 years earlier.



Right: Mine survey from 1920 of the 82.5-acre property superimposed over a Google Earth landscape image. (Thompson)

Fluorite and barite deposits in the ceiling and walls of the upper tunnel. (Thompson)

The Minerals

The deposition of minerals in the Galena King began 15 million years ago, with hydrothermal activity pushing through fissures in the 1.63-billion-year-old granite found in this range. The minerals carried in superheated water began to first deposit out the galena (lead sulfide or PbS) and the fluorite (calcium fluorite or CaF_2). Fluorite forms octahedral crystals in higher temperatures and cubic structures in lower temperature fluid. In places, barite (barium sulfate or $BaSO_4$) with higher oxygen content, gradually formed out of the solution over these octahedral and cubic structures, forming barite “roses.” Usually these grew together as a series of layers forming a seam running from a few inches to a few feet wide. Where these layers did not grow together, the mineral structures remained unrecognizable until uncovered by the miners. Fluorite is fairly brittle and easily damaged, and illegal collectors broke off large chunks trying to get intact specimens.

Above: Mineral deposits in Galena King Mine today. (Foote, Maehler, Decker, Thompson)

Fluorite is the common name of the mineral, and fluorspar is the term for fluorite bearing ore. Most of the fluorite in the Galena King is dark blue with color variation based on impurities. Outside in the bright sun, fluorite loses its color and becomes clear in a matter of a week or two. These unique color and optical qualities make fluorite such an interesting material, and the term "fluorescence" comes from the mineral.

From the late 1940s to the early 1960s the United States was a leader in fluorspar production, until Europe, Canada, Mexico and China took over the market. Today, industrial fluorspar is still used as a metal flux for aluminum production but predominately as hydrofluoric acid to produce refrigerants, with almost half of the consumption occurring in China.

The Mine Today

While the United States no longer mines fluorspar, several mines remain of interest to mineral collectors. Trespassers continue attempting to loot the Galena King today. However, in 2014, a small group of volunteers formed Friends of the Galena King to work with the owner to better protect and preserve this mine. By January 2015, the partially buried upper tunnel was dug out and gated. With help from student volunteers on geologic field trips, over a ton of supplies was hauled up the ridge on foot and bat-friendly steel doors were anchored into the walls with concrete. The Friends of Galena King first met the Sandia Grotto through these geologic field trips with the University of New Mexico. In sharing similar preservation interests, as well as a strong desire to protect the remaining minerals left by the miners, a partnership evolved.

Above: The upper tunnel in February 2014 and after digging begins to make room for concrete and steel gate. (Thompson)

Above: Hauling the steel gate up the ridge to the upper tunnel on 12 October 2014, and the gate sitting on the concrete footer. (Thompson)

Above: January 2015, the upper tunnel is secured; work on preparing for the lower tunnel concrete footer begins. (Thompson)

With Sandia Grotto's help, work rapidly progressed to complete the lower tunnel steel door and concrete wall by July 2015. Locating and fencing open shafts on and near the mine is an ongoing project, with all materials provided by the owner and installed by volunteers. With the tunnels protected, new ladders and a bridge were installed allowing safer exploration. The last partial survey of the mine was completed in 1928, and since 2015 volunteers from Sandia Grotto have helped to update our understanding of this underground space. Using photogrammetry, a 3D model is starting to take shape. On 29 May 2016, the first people in over 74 years carefully descended the winze between the upper and lower tunnel and began to survey this poorly understood section of the mine.

Since 2014, over a dozen educational field trips have been hosted at the mine by the Sandia Grotto, the University of New Mexico, and Kirtland Air Force Base. It is the intent of the mine owner, Mr. Evans and the Friends of the Galena King to keep the mine preserved and accessible so future generations of students, researchers, and conservationists can enjoy this window into these mineral-rich hills.

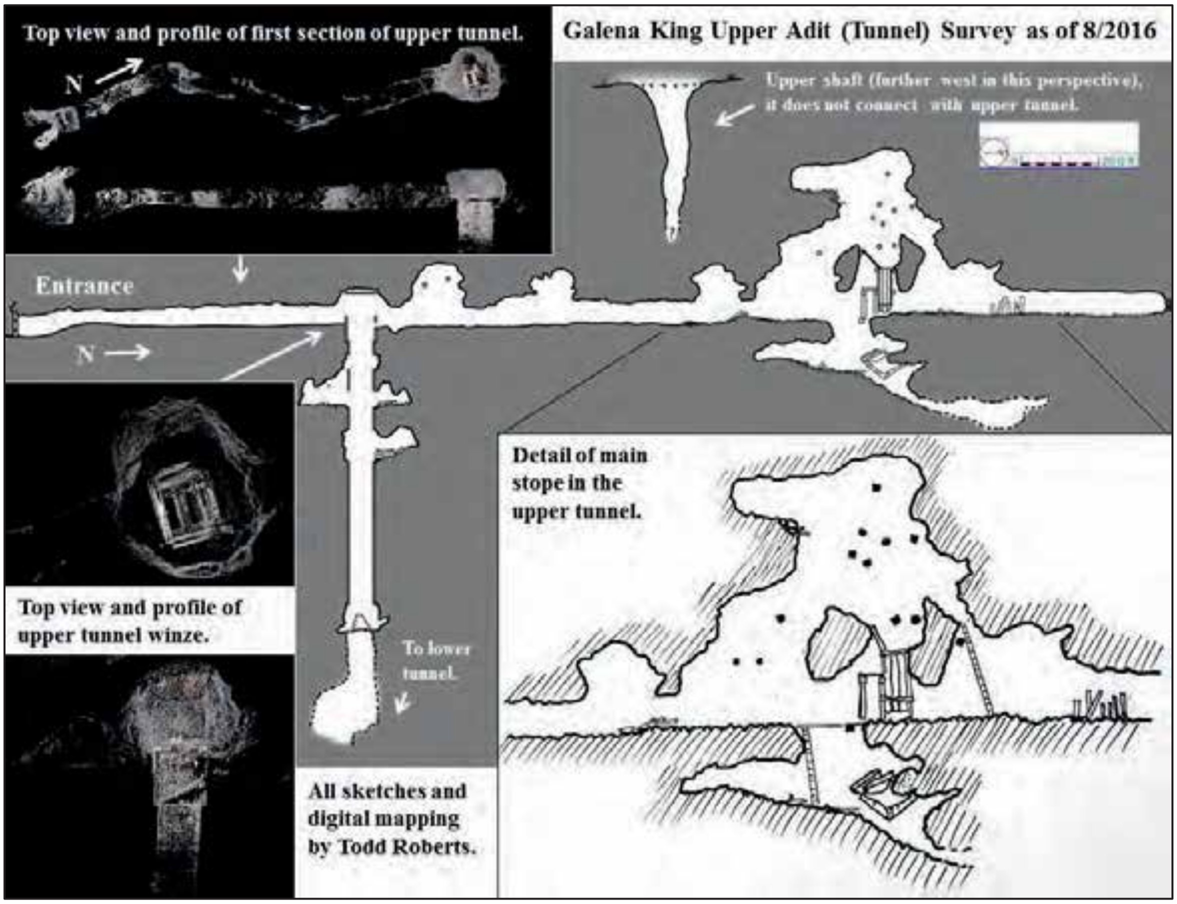
Above: Sandia Grotto helps work on the lower tunnel. By July 2015, the lower tunnel is secure, with gold paint added for flair. (Roberts, Thompson)

Above: In August 2015, the open shaft in the lower tunnel intersection gets a new timber cover. September 2015, Friends of Galena King and Sandia Grotto finish the upper shaft barb wire fence. Note the view of the Rio Grande valley. (Hodge, Thompson)

Above: New ladders and a bridge are added to improve safe exploration and study. (Thompson)

Left: Initial survey of the winze between the upper and lower tunnel, 29 May 2016. (Thompson)

Right: The Galena King Mine has a small bat population today and they are serious about protecting their home. (Thompson)



Above: Summary collage of Sandia Grotto survey work to date. (Roberts)

Lava Tubes of El Malpais National Monument

By Devin Scheid, Eric Weaver, and Laura Baumann

El Malpais National Monument (Figure 1) is located about 70 miles west of Albuquerque. Spanish for "The Badland," El Malpais is known for its rough and rugged lava flows. Elevation within the park ranges from 6,600-8,066 feet on the monument's east side at Lost Woman Crater. The monument contains over 116,626 acres of land, where over 85 percent is proposed wilderness. The vegetation at El Malpais has significant diversity. Lower elevation areas of the monument are mainly pinon-juniper savannah/woodlands and higher elevations are ponderosa pine forests, while the flow margins of the lava often contain aspen stands. The monument's property is shaped very much like an 'H' and many locations are best described as being on the east side (traversed by Highway 117) and the west side (traversed by County Road 42). County Road 42 is a maintained dirt road and a backcountry byway, which tours the Chain of Craters area and exits to the south onto 117. CR 42 also connects with Big Tubes Road, which is the main road into the monument. The Continental Divide Trail traverses and passes through the monument. Park trails include Lava Falls, Sandstone Bluffs, Zuni-Acoma, El Calderon, and Big Tubes.

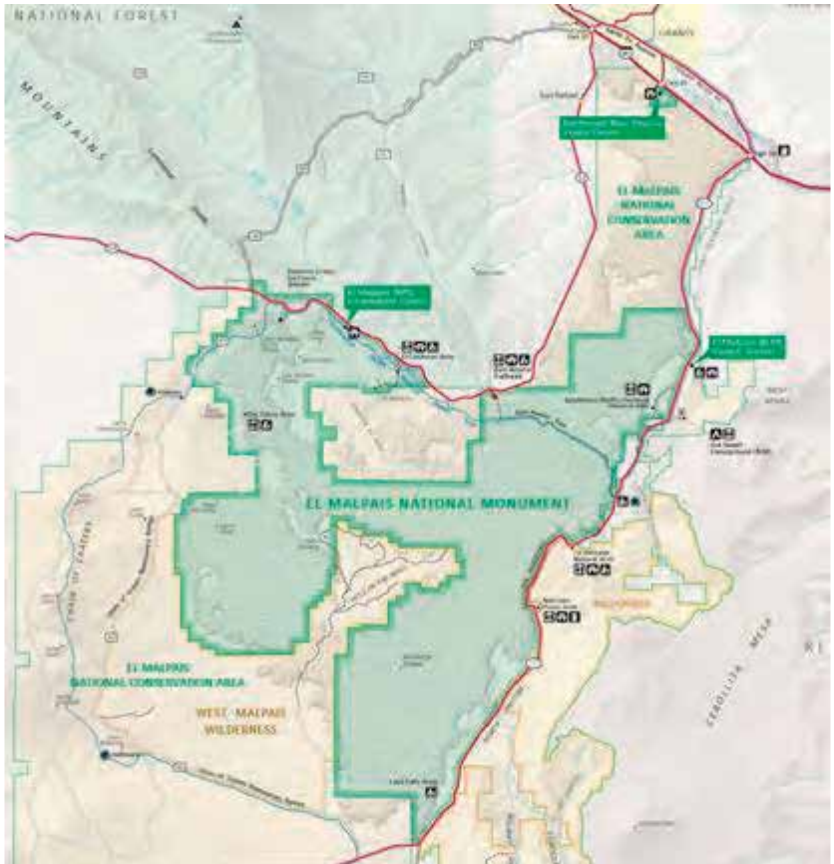


Figure 1. El Malpais National Monument

The oldest part of the rock record present in the El Malpais consists of 1.4 billion-year-old metamorphic and igneous rocks from the Proterozoic Eon. These can be seen while driving along NM Highway 53 on the way to the monument's caves. The next section of the geologic record consists of sedimentary rocks deposited 299 million to 65 million years ago or from the Permian to Cretaceous Eras. These are visible primarily along NM Highway 117, where large sandstone cliffs parallel the monument's eastern border.

The Zuni-Bandera Volcanic Field is a tectonic boundary between two Proterozoic cratons situated along the Jemez Lineament (Figure 2). The monument is situated near the center of the lineament where the craton blocks are colliding and creating a suture that allows for the upwelling of magma. These weak sutures are the root of the volcanic activity has been so prevalent in the El Malpais area. The Zuni-Bandera Volcanic Field began erupting approximately 700,000 years ago and contains

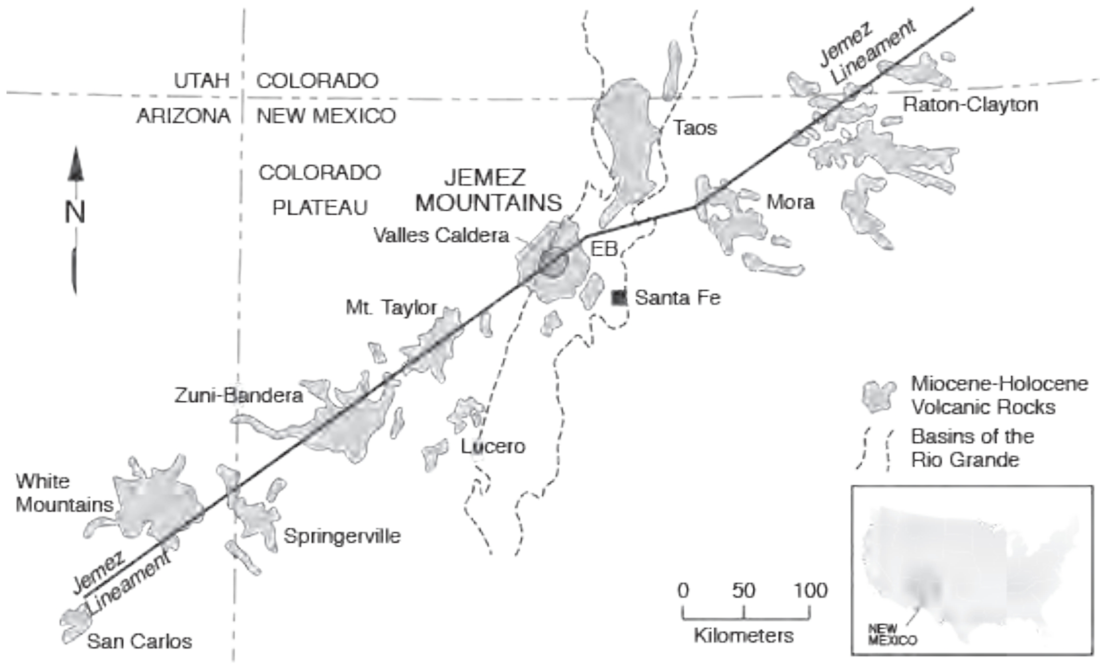


Figure 3. Map of the Jemez Lineament. (Image Credit: *Natural History of El Malpais National Monument*)

over 100 vents, shield volcanoes, and lava flows. Limburg suggests a 1 percent possibility of a volcanic event occurring in New Mexico by 2090 and a 10 percent chance one will occur within the next 1,000 years. Five lava flows occur within the monument. In order of youngest to oldest, they are the McCarty's Flow, Bandera Flow, Hoya de Cibola Flow, Twin Craters Flow, and the El Calderon Flow. Nearly all the volcanic rock at El Malpais National Monument is basalt that has erupted from various cinder cones around the monument. Most of the volcanic rocks present on the monument's landscape are younger than 60,000 years. The low viscosity of basalt in comparison to other magma compositions has resulted in the erupted lava to flow slowly across the landscape. These young basaltic lava flows, especially McCartys, are the best examples of Hawaiian-style lava flows in North America.

Lava tube caves begin as conduits for molten lava as the flow progresses the top of the lava solidifies and forms a roof while the lava below continues to flow for great distances forming lava tube caves. Structural collapses of the ceilings have created skylights and entrances to the tubes. Superficial collapses of the interior tube faces cause many of the caves to be covered in breakdown with very little primary floor and wall surfaces visible. The monument has documented over 300 lava tube caves and over 100 additional subterranean lava features such as surface tubes, alcoves, and tree molds. Many of these caves have been mapped and inventoried through the assistance of Sandia grotto and other cavers from the National Speleological Society and Cave Research Foundation. A large number of the monument's caves are found within the Bandera Flow, which is relatively young in geologic time at approximately 11,000 years old (Figure 3). It also contains one of the longest lava systems in North America which is 17 miles long. Only 20 percent of this system is uncollapsed and the longest single lava tube in the monument is over 1.06 miles (this has recently been connected to another lava tube which will likely extend this number by at least 1,000 feet).

Many lava tubes act as cold traps and the basalt composition acts as an insulator; their temperatures range from 30-40° F. This has

Flow	Age (years ago)
McCartys (Qbm and Qbd)	3,900
Bandera (Qbb)	11,000
Hoya de Cibola (Qbw)	Exact age unknown, but older than Bandera
Paxton Springs, south (Qbp)	15,000
Zuni (Qbz and Qba)	Exact age unknown, but overlie Oso Ridge flows in Zuni Canyon
Oso Ridge (Qbo)	Exact age unknown, but younger than Twin Craters
Twin Craters (Qbt)	18,000
Paxton Springs, north (Qbp)	20,700
El Calderon (Qbc)	<60,000
Basalt flows (Qbu) "Chain of Craters"	~150,000
Old basalt flows (Qb), e.g., Hole-in-the-Wall	~700,000
Basalt flows on Cebollita Mesa, Mesa Negro, and Horace Mesa (Tb) "Mount Taylor"	3.73 million to 1.57 million

Figure 3. Ages of the respective lava flows of El Malpais (Image Credit: ELMA Geologic Resources Inventory)

resulted in several lava tubes in the area having the southernmost ice in North America.

A variety of minerals can be found in the lava tubes of El Malpais (Figure 4), some of which are extremely rare, including a few that were the first known occurrences in caves. These minerals often have fragile forms like angel-hair or an encrusted cottage-cheese-like texture, sometimes forming small minarets that can reach up to a foot in height on the floor of the cave, making them especially sensitive to the impact of visitors. Many of the secondary mineral deposits, like gypsum, formed immediately after the initial eruption while others, such as mirabilite, are ephemeral and dissolve during the wet season then precipitate back out of solution during the dry season. Some common lava tube minerals can be distinguished by taste: mirabilite (slightly bitter and salty), epsomite (very bitter taste), and gypsum (no taste) (Hill and Forti 1997). Many lava tubes contain xenoliths which are inclusions that originated in the Earth's crust and mantle.

Likewise, numerous features unique to lava tubes can be found throughout the caves in El Malpais. Lava glaze is the smooth vitreous appearance that is often a primary feature on the walls of lava tubes. How it forms is a matter of dispute, but one possible explanation is the

Figure 4. Cave minerals present within the caves of El Malpais. (Image Credit: ELMA Geologic Resources Inventory)

Name	Chemical Formula	Speleothem Type	Occurrence
Amorphous silica glass	SiO_2	Bubbly, green, glass coatings on xenoliths	Rare (known only in Xenolith Cave)
Burkeite	$Na_4(CO_3)(SO_4)_2$	Crusts	Rare (known only in Outlaw Cave)
Calcite	$CaCO_3$	Flowstone, draperies, coralloids, and moonmilk	Common
αCristobalite	SiO_2	Coralloids	Uncommon
Epsomite	$MgSO_4 \bullet 7H_2O$	Hairs and crystals	Rare
Glaserite	$(K, Na)Na(SO_4)_2$	Constituent of mirabilite and thenardite "snowballs"	Rare (known only in Braided Cave)
Gypsum	$CaSO_4 \bullet 2H_2O$	Sugary crusts, stalactites, stalagmites, columns, flowstone, hairs, and powder	Common
Malachite	$Cu_2(CO_3)(OH)_2$	Green stains in xenoliths	Rare
Mirabilite	$Na_2SO_4 \bullet 10H_2O$	Hairs	Rare
Opal-A	$SiO_2 \bullet nH_2O$	Coralloids (e.g., "cave coral")	Common
Opal-CT	$SiO_2 \bullet nH_2O$	Crystals on xenoliths	Rare (known only in Xenolith Cave)
Thenardite	Na_2SO	Powder and coralloids (e.g., "snowballs")	Rare
Trona	$Na_3(CO_3)(HCO_3) \bullet 2H_2O$	Crusts	Rare (known only in Outlaw Cave)

presence of magnetite on the walls that gives off a silvery sheen. Another feature, known as a lava seal, forms when part of the magma solidifies and seals off the path along which the magma flowed. Consequently, the dam creates a backflow. A more aesthetically-pleasing feature is the lava rose, which forms as lava upwells or drips down from the ceiling, incrementally forming distinct layers of different sizes that give the appearance of a blooming rose.

Lava flows typically fall in a range between two lava types: Pahoehoe and A'a. Pahoehoe is a low-viscosity flow and cools more slowly forming a flat, ropey surface. A'a has a higher viscosity and is often highly vesicular and cools much quicker causing rough rocks to be pushed to the surface. Pahoehoe literally means "smooth," which quite accurately describes its texture. A'a, on the contrary, has a very jagged and rough texture that can destroy one's gear readily. A'a flows can produce lava tubes, but they are more commonly produced by pahoehoe. The McCartys lava flow is the best representation of a pahoehoe flow in the monument. Some of the fringes of the Bandera flow as you drive on CR42 are a good example of A'a lava.

History

Archaeological evidence of the use of the El Malpais lava tubes begins with the early Puebloans around AD 800. The caves in the area were heavily utilized during this time and continued through Contact. Human bones, charcoal, pictographs, petroglyphs, pottery fragments, and walls have been identified in the caves of El Malpais. Spanish conquistador Francisco Vazquez de Coronado arrived in the region in 1540 seeking control of the land and inhabitants, though his party made little to no use of caves because lava that must be traversed to access the caves was too rough. The Spaniards viewed El Malpais as an obstacle and tried to avoid the lava fields altogether, since their horses could not cross these badlands. Following the end of the 1846-1848 war with Mexico and the annexation of New Mexico, the United States government sent a scientific expedition to the region in 1849. Lieutenant James H. Simpson (USA), the leader of the expedition, referred to the Malpais as simply "some unseemly piles of blackened scoriaceous volcanic rocks." Almost no traces of Europeans from the times of Spanish colonialism and early American settlement have been identified in the caves. An exception is those caves which contain perennial ice. Extensive mining of the cave ice occurred in the early 20th Century. El Malpais became a National Monument in 1987. Thereafter, conservation work and research on the monument and its caves became more consistent and methodical.

Cave Ecology

Many of the geologic features have contributed to the development of the cave ecosystems. The ecosystems vary throughout the cave as a gradient, which follows the respective zones of the cave. The zones correspond to the level of diminishing light with less biota found as one travels deeper into the cave. El Malpais has many moss gardens in the

Moss garden at Big Skylight Cave.
Photo by Linda Starr.

entrances and twilight zones of the lava tubes and in skylights within the tubes. While the moss is still in the process of being inventoried, a few species have been identified as being the only occurrence in New Mexico and are more typical of northern alpine climates and the arctic. It is likely that these moss gardens are relicts from the early Holocene and have been supported by the cold and humid environment that many of the lava tubes support. These moss gardens also provide a habitat for many invertebrate species, several of which were previously unknown to science and have not been found outside of El Malpais. The twilight zone of lava tubes provide shelter for many vertebrate animals, including grey foxes, ringtails, pack rats, mountain lions, bobcats, owls, turkey vultures, and rock wrens. It is more difficult to observe life in the dark zones of most caves in El Malpais; bats are the most obvious inhabitant and they support a rich diversity of invertebrate and microbial life.

Research

Cave bacteria offer many opportunities for research. Actinobacteria, a common phylum in El Malpais, create stunning microbial mats. The hydrophobic bacteria cause water to bead up on the interior surfaces of the cave, resulting in shimmering silver and gold sheens that can be seen in many of the monument's lava tubes. These actinobacteria and other bacteria found in the cave are being studied for their natural antibacterial and antifungal properties. Some of these bacteria have been tested for use as a natural defense against the fungus that causes white nose syndrome. When cultured together a few bacteria found in El Malpais have created buffer zones around themselves that inhibit the growth of the fungus.

The monument's resources have provided substantial information to better understand our past climates. The oldest tree ring record in the Southwest was collected from a Douglas fir named "Yoda" at El Malpais that provided records dating back 2,129 years. This has helped to fill in gaps in the regional climate history and wildfire regimes. The ice caves at El Malpais and surrounding areas have also been used as a climate proxy. Much like tree rings, long standing ice such as glaciers can be cored to observe striations related to climate. The most famous and fruitful of these was conducted by Ohio State University at the privately-owned Candelaria Ice Cave, which is adjacent to the monument. Many discontinuities due to long-term human usage of the cave created difficulties in establishing a record, but stable isotope dating of a twig in a 13-foot ice bank indicated a date of 3,166 years old. Organic items trapped within the ice, such as tree bark and pollen, were able to be radiocarbon dated to help reconstruct the past climate. Recently, several lava tubes at El Malpais NM have been examined for potential coring of ice and guano with the hopes of adding to the climate record.

Stratigraphic ice. Xenolith Cave. Photo by Kenneth Ingham.

The lava fields and caves of El Malpais are considered to be analogous to formations on the Moon and on Mars, so much so that they have been used as a proxy for research on these extraterrestrial landscapes. They have even been used for field testing of NASA robots designed to explore lava tube caves on the Moon and Mars. El Malpais and these extraterrestrial bodies share a similar geologic history. Most Martian volcanoes have far more similarities with hot spot volcanism like ours, which is controlled by upwelling of lava in the form of a plume, than the more common plate margin volcanism. Studies of the McCartys flow have been particularly helpful in understanding the Martian landscape. Inflation pits found on this flow have helped to identify similar features on Mars.

Bats

El Malpais NM has 13 species of bats known to reside within the monument, with about half the species using the caves for day or night roosts. Ninety caves in the monument have been documented to be used as hibernaculum for bats during the winter months and at least three maternity colonies documented in the summer. One of the most prestigious maternity colonies at El Malpais is Bat Cave which contains a maternity colony of Brazilian free-tailed bats. The cave is closed to the public due to health risks; however, visitors are able to watch the outflights during the summer months. A good-sized outflight will have between 40-50,000 bats; however, outflights have been documented as high as 110,000 and as little as 5,000. Other species present in the monument's caves include, but are not limited to, Townsend's big eared bats, big brown bats, pallid bats, long legged myotis bat, and long eared myotis bats.

Currently the presence of *Pseudogymnoascus Destructans* (Pd) or White Nose Syndrome has not been found in New Mexico. However, there is an increasing concern as it continues to push toward the Western states. As of March 2017, Pd has been found as close as Texas. The monument is part of the New Mexico Interagency White-nose Syndrome Response Plan and supports the decontamination protocol established by the US Fish and Wildlife Service.

Visitation

Caves open to the public are limited to Junction Cave (closed during the winter), Xenolith Cave, Giant Ice Cave, Big Skylight Cave, and Four Windows. Caving permits are required for entry into the caves. These can be found at the El Malpais Visitor Center immediately off of I-40, the El Malpais Information Center on Highway 53, or the El Morro National Monument Visitor Center. A caving brochure along with maps and guides for each of the respective caves can found on the monument's website at www.nps.gov./elma/learn/nature/lava-tubes-and-caving.htm. Access to the caves in the Big Tubes area requires travel on a rough dirt road and a hike over difficult terrain on a trail designated by rock cairns. Dirt roads may be impassable during the wet-season (4WD and high clearance vehicles are recommended).

El Malpais Visitor Center off of I-40. (Image Credit: https://www.nps.gov/elma/planyourvisit/images/MAC_3_favorite.JPG)

Junction Cave is the easiest and most accessible of the monument's caves, located right off of Highway 53 near the El Calderon

Parking area. The cave is gated during the winter to protect bats during hibernation. The first half of the cave is largely breakdown and no longer contains the primary features; the second half of the cave is more representative of an intact lava tube and has a good example of a lava bench. The main passage terminates 980 feet

Dipluran found on mud at the back of Junction Cave, El Malpais. (Image Credit: *Natural History of El Malpais National Monument*)

from the opening into a room containing a mud floor. To avoid disturbing this area and possibly harming any of the endemic invertebrates, a trail of reflective markers has been built that avoids the mud floor at the cave junction and leads to a long effluent crawl tube. This side passage has many excellent examples of shark-tooth lavacicles, lava dribbles, and raised lava floor can be seen along the way before it terminates in a lava seal. Gypsum snow, hair, and needles have been noted in this section of the cave.

Cavers entering Xenolith Cave.
Photo by Kenneth Ingham.

for the many xenoliths contained in its walls. The initial portion of the cave is primarily breakdown, some of which has been welded in place by lava dripping down into the rubble. Past the breakdown is a ladder over lava falls, which leads to a room, where many visitors stop. Unfortunately, this is where the most interesting part of the cave begins. Several small crawls on the left-hand side of the wall leads to a smooth 30-foot-bellycrawl tube that opens into a large room with a massive rafted boulder at its end. The total length of the cave is 625 feet.

Big Skylight Cave, showing skylight, shelves, and moss garden. Photo by Linda Starr.

Big Skylight Cave is a half-mile across the Bandera lava flow from the Big Tubes parking area. The entrance of the cave is within a trench and is only accessible by a steep climb down, which often is not very obvious. The cave has an impressive entrance, large passage, and – as the name implies – a big skylight. A large moss garden underneath the skylight contains many bryophytes, including a species known primarily in Canada and Colorado, and provides habitat for many invertebrates that are likely to be relict species from the early Holocene era. Most of the cave has experienced some level of collapse; therefore, very few ceiling features are evident and many breakdown blocks are present. The floor of the cave shows evidence of inflation and has several areas where rafted plates are present. Well-preserved gypsum crusts are often present on the cave walls and are most likely speleogenetic crusts. Immediately in the entrance a large lava shelf and grooves can be seen. Lava glaze, drips, boxwork, and gutters can be seen as you progress through the cave. The walls of Big Skylight are often covered with driblets, coralloids, and helictites. Toward the back of the cave are examples of sulfate moonmilk.

Four Windows is a ¼- mile hike to the east from Big Skylight Cave and has a trail marked by cairns. A steep climb down into a trench and a scramble across large breakdown rocks is necessary to approach the large Four Windows Cave entrance. The moss garden near the entrance is one of the more impressive at El Malpais NM. Sunlight from the four skylights helps provide the necessary nourishment needed

Moss garden, Four Windows Cave.

to support the moss garden. Certain bryophytes and invertebrates contained within the moss garden are not known elsewhere in New Mexico and are likely relicts that the low temperatures of the cave (mid-upper 30s) and high humidity are able to support. Lava shelves are quite evident in the cave and are one the more impressive features. The west wall shows the flow units of the lava. The floor of Four Windows Cave presents many interesting features, such as a flat pahoehoe, lava levees, gutters, rafted boulders, and floor spots. A stacked tube marks the point where the cave is closed to protect sensitive resources.

Giant Ice Cave is on the other side of the trench of Big Skylight and has a massive entrance (88 feet wide and 30 feet high. Despite its namesake, Giant Ice Cave has very little perennial ice present throughout the year in comparison to other caves at El Malpais NM.

Jen Foote, Giant Ice Cave. Photo, Kenneth Ingham.

Access to the cave is via a steep climb down located on the East side of the trench a few hundred feet from the entrance and then a hike across breakdown blocks. A lava bench is present but not as spectacular as the one at Big Skylight Cave. Lava driblets, gypsum crust, and glaze are present on the cave's walls.

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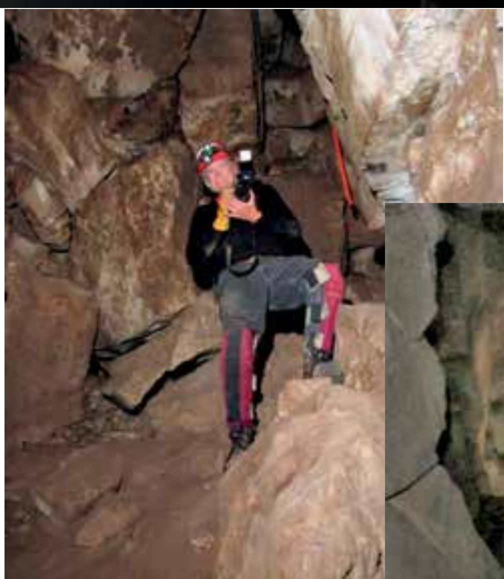
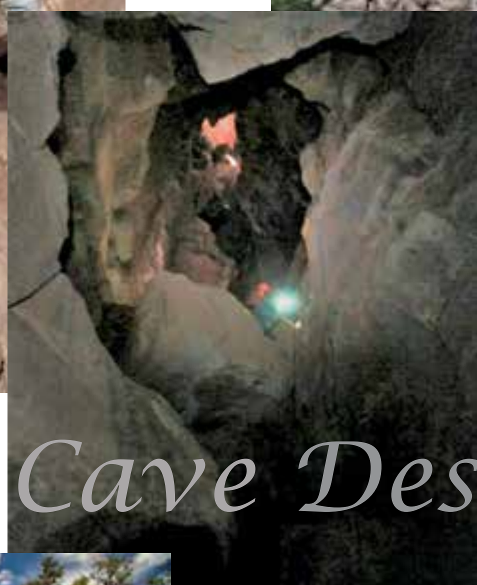
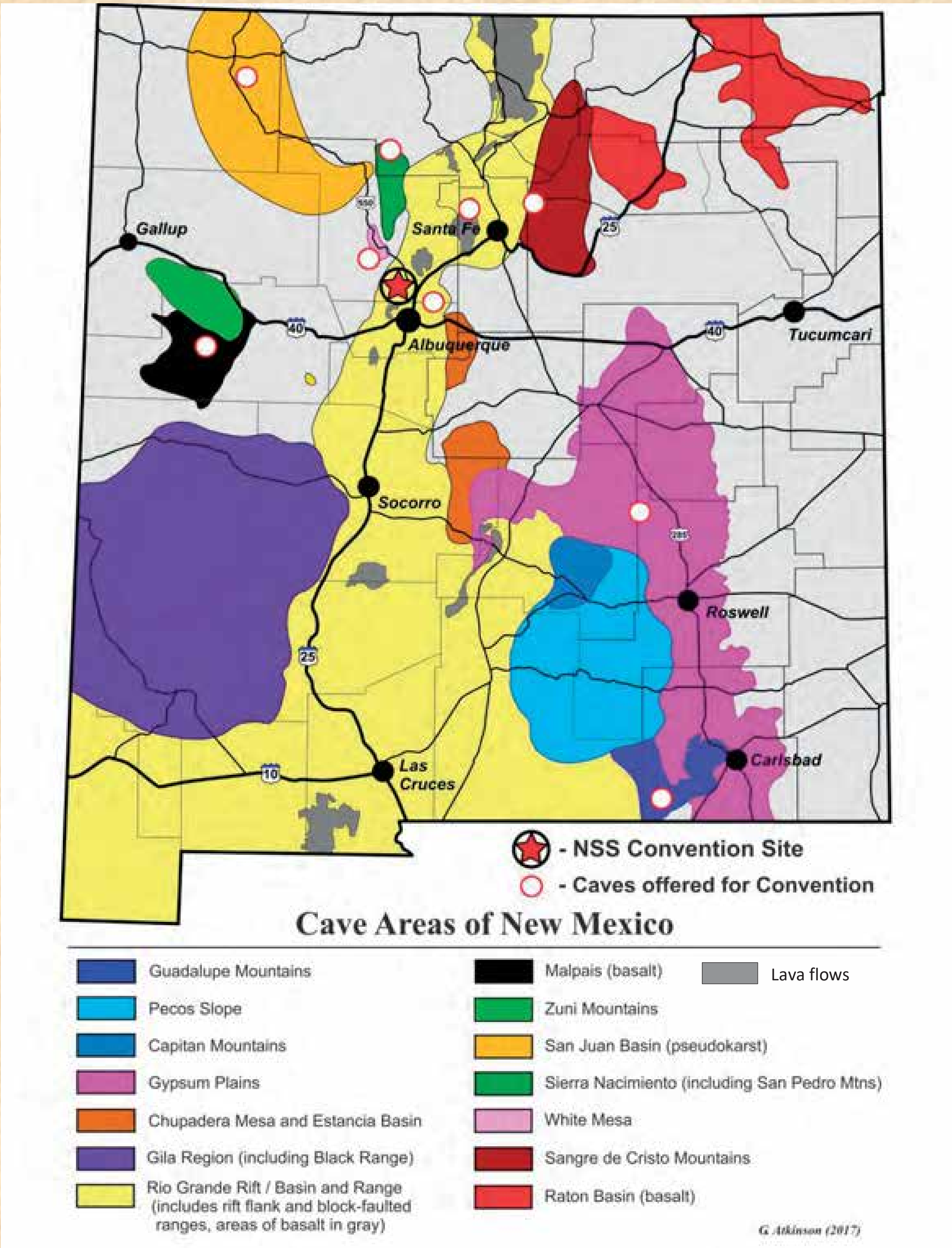




Cave Descriptions



Previous Page, clockwise from top left: Big Skylight Cave, El Malpais National Monument (Linda Starr); Sandia Cave Entrance and view north (Pete Lindsley); Yo-Yo Pit (Dave Decker); Minori Yoshida, survey in Alabaster Cave (Dave Decker); Water Drop in the Deep, Deep Cave, Carlsbad Caverns National Park (Peter Jones); New Year's Eve Gallery, Hell Below Cave, Guadalupe Mountains (Sam Bensonhaver); Hall of the Giants. Carlsbad Cavern (Tabitha Hall); Seven Bridges, El Malpais National Monument (Kenneth Ingham); Buckman Cave (Scott Christenson); Rodger Burt, Cooper- Ellis Cave, Sandia Mountains (Dave Decker).

Day Trips

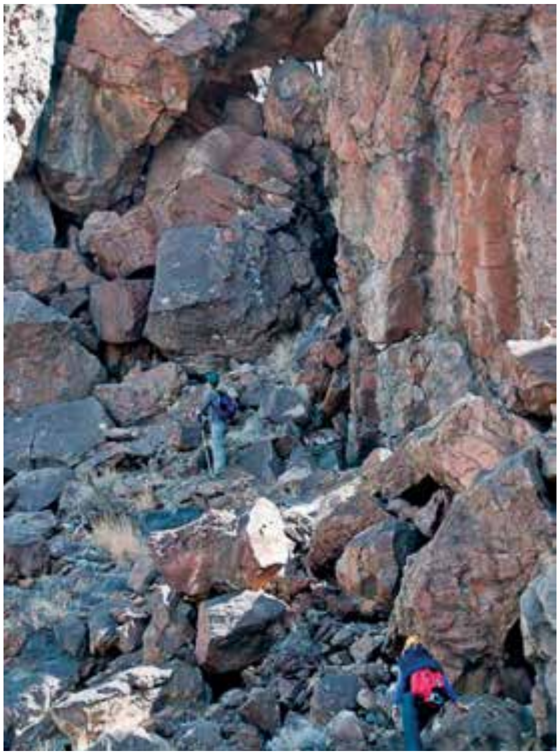
By Gerald Atkinson

Buckman Cave

Distance from NSS Campground: About 65 miles (105 km) to parking area for cave, 1½-hour drive one-way. Hike to cave is about 0.7 miles (1.1 km).

Alternate Names: Diablo Canyon Cave, St. Adams Cave, Devils' Cave
County: Santa Fe
Ownership: U.S. Government – Santa Fe National Forest

Length: ~353 m (~1160 feet)
Depth: 71 m (234 feet)



Ascent through tectonic basalt blocks to Buckman Cave. Photo by Pete Lindsley.

View toward Santa Fe from near Buckman Cave. Photo by Pete Lindsley.

Elevation: 6050 feet

Synopsis: A vertical, tectonic cave in basalt.

Description: Buckman Cave is tectonic in origin, caused by a large block of Tertiary basalt calving off the mesa and sliding down approximately 30 m, creating a series of fissures in the block.

There are at least seven entrances to the cave: four skylights and three walk-in/scramble entrances. The two uppermost skylight entrances are the more commonly known entrances and are often used by the mountain rescue groups for vertical practice, as the longer of the two is about 37 m deep. The lower entrance is a walk-in and leads to a series of down-climbs, short crawls, pits, chimneys, and tall fissure passages. Near the lower entrance is a 30-m-deep pit that has been the scene of several tragic accidents (Adam Blum Memorial Pit). The cave suffers from high, irresponsible visitation and has been trashed to a large degree with cans, glass, and graffiti. In places the floor is covered with about 10 cm of fine, gray dust and precautions should be taken to avoid stirring up too much dust. A couple 15- to 30-m-deep pits along the walking passage can be bypassed by down-climbing to the lower level of the cave.

Todd Roberts rappelling into one of Buckman Cave's entrances. Photo by Scott Christenson.

The cave is incompletely surveyed. It has been extended for at least another 200 m by other surveys that have not been tied into the main cave.

Special equipment or precautions: Rope and vertical gear for upper skylight entrances. Avoid stirring up dust; be careful of pits in the upper level.

Slitrock and Winnebago Caves

As similar caves in the same formation as Buckman's, the entrances to both these are 200 feet west of Buckman's main entrance. For Slitrock, an exposed climb at the entrance requires a 50-foot rope; for Winnebago, a 65-foot drop into the bottom chamber requires a 100-foot rope.

Yo-Yo Pit

Distance from NSS Campground: About 60 miles (95 km) to parking area for cave, 1¼-hour drive one-way. Hike to cave is about 0.3 miles (0.5 km).

Alternate Names: Pankey's Crater
County: Santa Fe
Ownership: U.S. Government – Santa Fe National Forest

Length: 71 m (234 feet)
Depth: 44 m (146 feet)
Elevation: 7125 feet

Synopsis: A deep, volcanic vent with archeological and paleontological significance.

Description: Yo-Yo Pit is an abandoned volcanic fumarole developed in the Quaternary Twin Hills basaltic cinder deposits of the Cerros

Garrett Jorgensen rappelling into Yo-Yo Pit, early spring, 2016. Photo by Dave Decker.

del Rio volcanic field, with an age of approximately 2.53 Ma. It is a popular spot for vertical rope work, as the 8- by 9-m-wide pit is a straight, free-fall drop of 39 m that bells out for the final 18 m to the top of a large talus cone. The bottom of the pit measures 23 m long by 16 m wide with a small, wet-weather streambed that flows along the west wall and sinks in a debris-filled pit on the south side of the pit floor. The sides of the pit near the surface are covered by what appears to be a coating of melted rock, possibly melted during the vent's eruption and which flowed down the sides of the pit. Total depth is 44 m.

Unfortunately, visitors have thrown in a variety of trash that litters the bottom of the pit, including a small truck that was pushed in. The remains of at least three humans and the bones of several animals were excavated from the talus cone at the base of the drop in 1967.

As of 2015-2016, there is an active beehive on the lip of the pit. The bees are not aggressive but caution should be exercised.

Special equipment or precautions: Rope and vertical gear for the entrance drop. Be careful of an active beehive at lip of pit.

Upper Cave Creek Cave

Distance from NSS Campground: About 95 miles (150 km) to parking area for cave, 2-hour drive one-way. Hike to cave is about 2 miles (3.2 km).

Alternate Names: Cave Creek Cave
County: San Miguel
Ownership: U.S. Government –Santa Fe National Forest – Pecos Wilderness

Length: 130 m (427 feet)
Depth: 9 m (28 feet)
Elevation: 8,850 feet

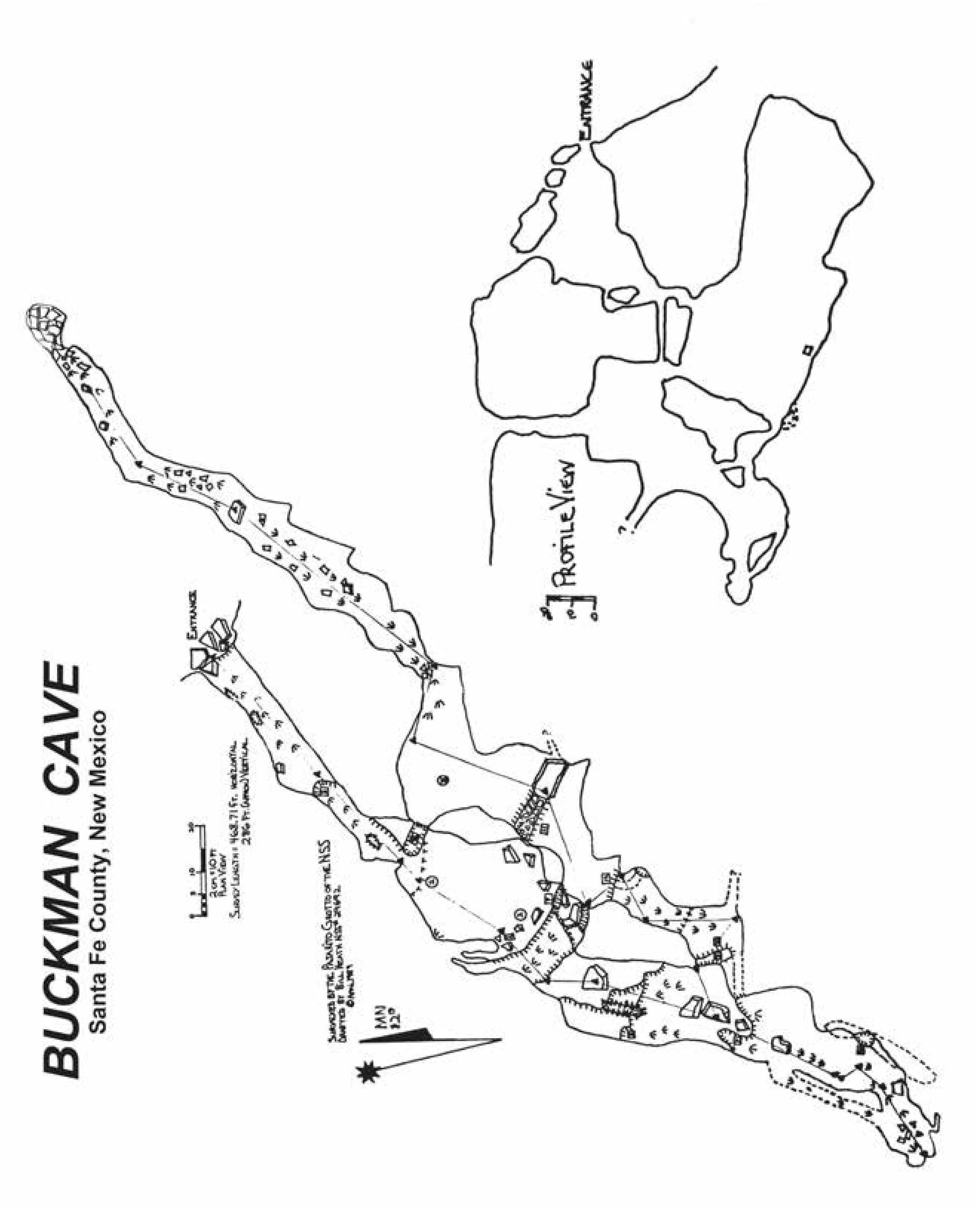
Synopsis: An active stream cave.

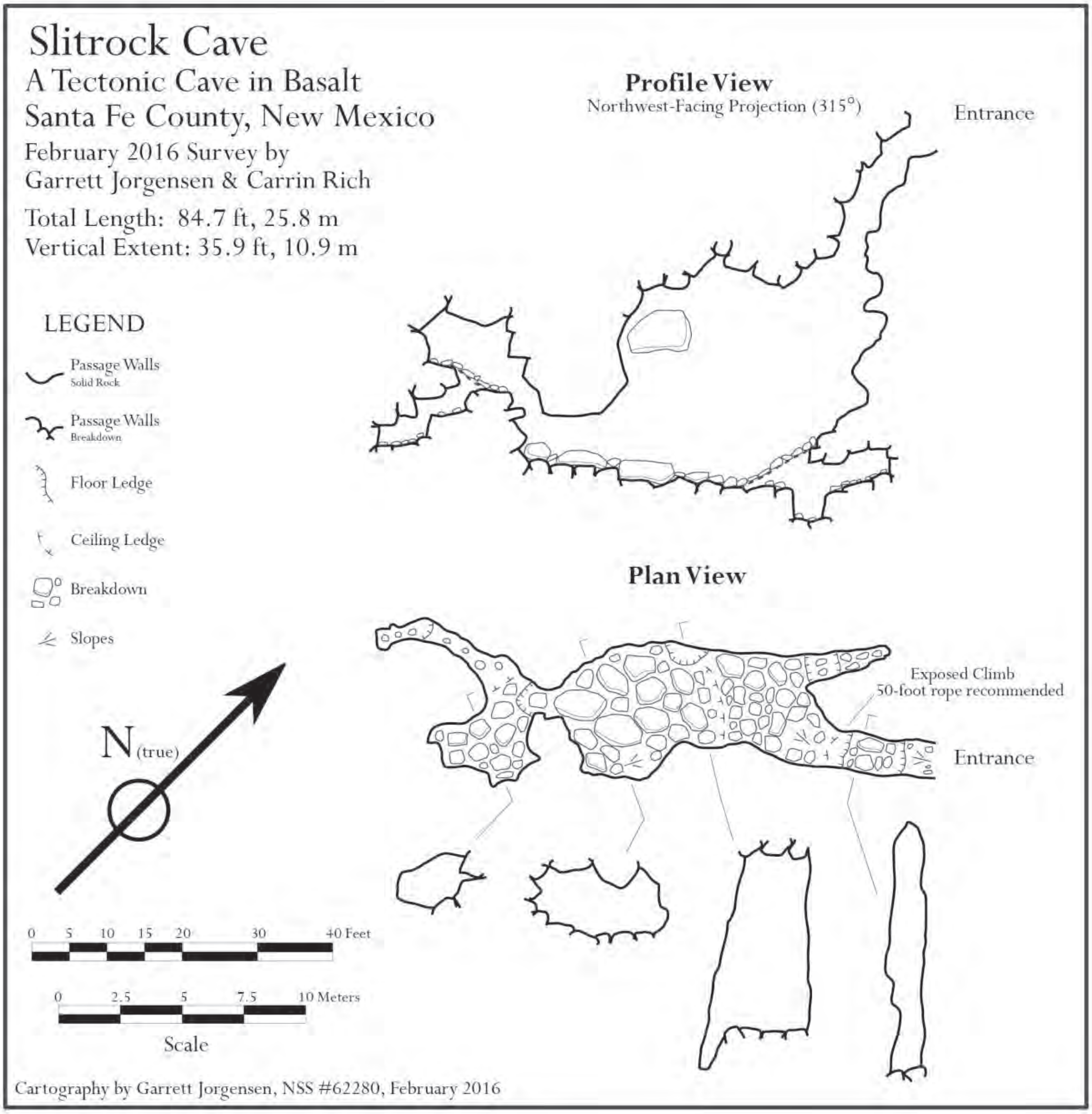
Description: The cave is a stream swallet for a large portion of the water flowing in Cave Creek. The four principal entrances are located in a cliff on the south bank of the creek and measure 1 to 2 m wide and from 1.5 to 4 m high. The entrances open into a rectilinear maze of strike and dip passages through which the stream flows.

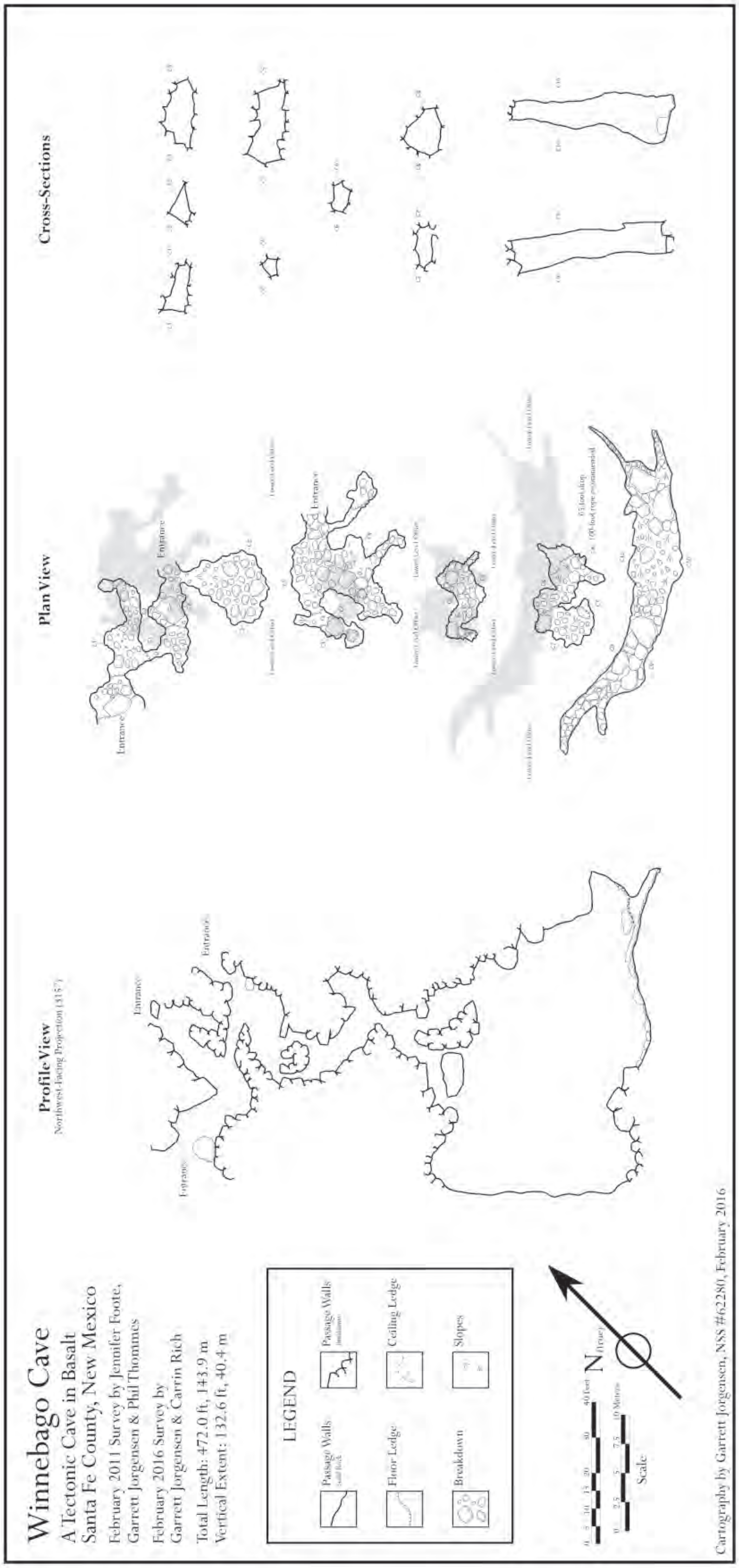
Cave Creek Cave entrance. Photo by Linda Starr.

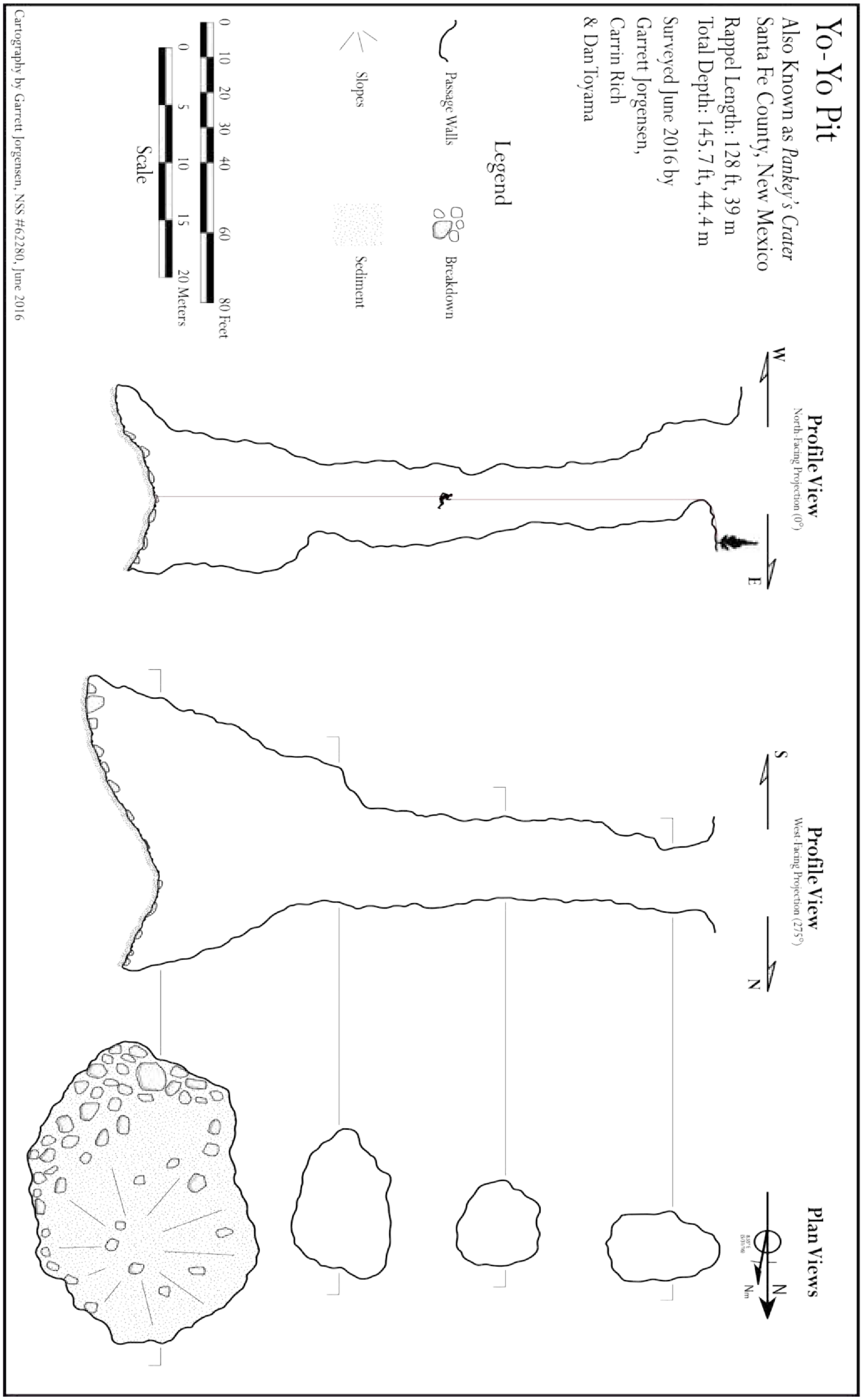
Most of the cave consists of 1.5- to 4.5-m-wide, 2.5- to 6-m-high canyon passages that carry a portion of the water flow in fast-moving streams. The stream passages eventually combine and drain into two, 3- to 4.5-m-deep waterfall pits. The passages at the bottom of the pits reportedly lead to sumps after a short distance. One stream passage to the east ends in a scum sump after about 10 m. There is one side passage to the west that is dry and continues for 45 m before ending in silt. The cave stream resurges approximately 180 m downstream from gravel and boulders at the base of a cliff. The cave is a popular destination for day-hikers.

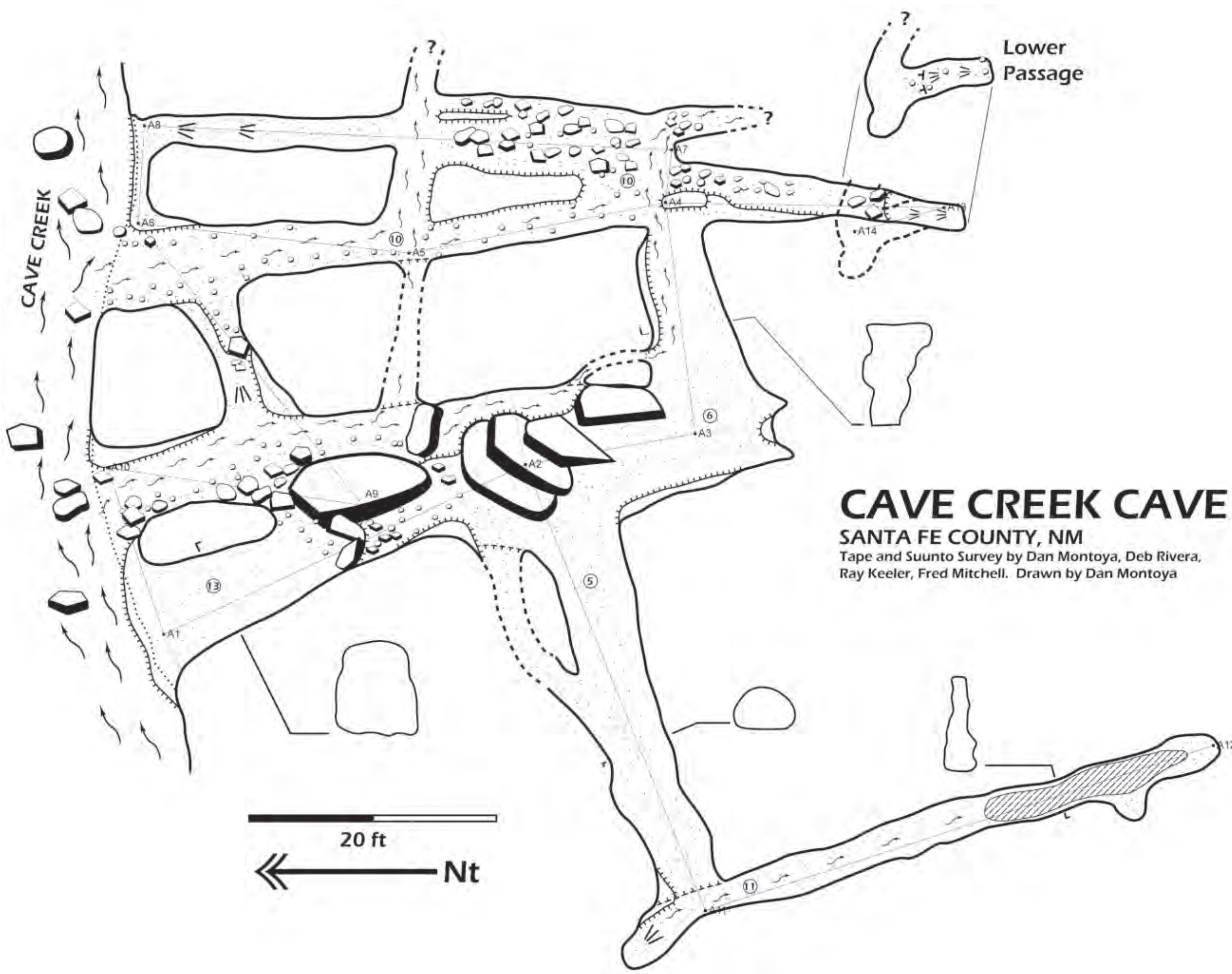
Special equipment or precautions: This cave is dangerous if the creek is flooding. Avoid descending the waterfall pits if water levels are high. Entering these pits requires a wetsuit, rope and vertical gear, and low water conditions.


BUCKMAN CAVE
Santa Fe County, New Mexico
ENTRANCE
PROFILE VIEW
ENTRANCE
MN


Slitrock Cave
A Tectonic Cave in Basalt
Santa Fe County, New Mexico
February 2016 Survey by
Garrett Jorgensen & Carrin Rich
Total Length: 84.7 ft, 25.8 m
Vertical Extent: 35.9 ft, 10.9 m
LEGEND
Passage Walls Solid Rock
Passage Walls Breakdown
Floor Ledge
Ceiling Ledge
Breakdown
Slopes
N (true)
0 5 10 15 20 30 40 Feet
0 2.5 5 7.5 10 Meters
Scale
Profile View
Northwest-Facing Projection (315°)
Entrance
Plan View
Exposed Climb
50-foot rope recommended
Entrance
Cartography by Garrett Jorgensen, NSS #62280, February 2016


Winnebago Cave
A Tectonic Cave in Basalt
Santa Fe County, New Mexico
February 2011 Survey by Jennifer Foote,
Garrett Jorgensen & Phil Thommes
February 2016 Survey by
Garrett Jorgensen & Carrin Rich
Total Length: 472.0 ft, 143.9 m
Vertical Extent: 132.6 ft, 40.4 m
LEGEND
Passage Walls
Floor Ledge
Breakdown
Passage Walls
Ceiling Ledge
Slopes
Scale
N
Cartography by Garrett Jorgensen, NSS #62280, February 2016
Profile View
Entrance
Entrance
Entrance
Entrance
Plan View
Entrance
Entrance
Entrance
Cross-Sections


Yo-Yo Pit
Also Known as *Pankey's Crater*
Santa Fe County, New Mexico
Rappel Length: 128 ft, 39 m
Total Depth: 145.7 ft, 44.4 m
Surveyed June 2016 by
Garrett Jorgensen,
Carrin Rich
& Dan Toyama
Legend
Passage Walls
Breakdown
Slopes
Sediment
0 10 20 30 40 60 80 Feet
0 5 10 15 20 Meters
Scale
Cartography by Garrett Jorgensen, NSS #62280, June 2016
Profile View
North-Facing Projection (0°)
W
E
Profile View
West-Facing Projection (275°)
S
N
Plan Views
N
Nm


CAVE CREEK CAVE
SANTA FE COUNTY, NM
Tape and Suunto Survey by Dan Montoya, Deb Rivera, Ray Keeler, Fred Mitchell. Drawn by Dan Montoya
Lower Passage
CAVE CREEK
20 ft
Nt

Alabaster Cave

Looking at the Alabaster Cave area (in white) as seen from Red Mesa, overlooking NM 550. Photo by Linda Starr.

Distance from NSS Campground: About 30 miles (50 km) to parking area for cave, ½-hour drive one-way. Hike to cave is about 700 feet (200 m).

Alternate Names: Ojo del Diablo
County: Sandoval
Ownership: Zia Pueblo

Length: 1396 m (4580 feet)
Depth: -12 m (-40 feet)
Elevation: 5620 feet

Synopsis: A significant and family-friendly gypsum cave with a lower stream passage.

Description: Alabaster Cave consists of one main, nearly straight passage following a north-south trending joint and has five known entrances (see map). The North Entrance is found in a large sinkhole near the Rio Peñasco. The Slit Entrance is a narrow crevice along the face of the cliff. (See earlier description, this volume, by Dave Decker.)

Sandia Grotto cavers entering the north-facing sinkhole entrance of Alabaster Cave. Photo by Pete Lindsley.

Special equipment or precautions: Do not enter the cave if there is a significant chance of rain, as the lower level passage floods. Watch out for rockfalls, as the walls and ceiling are unstable in places.

Permissions: Permission is required from the Zia Pueblo. Please check with cave trip coordinators regarding access.

Ojito Cave

Distance from NSS Campground: About 31 miles (50 km) to parking area for cave, 3/4-hour drive one-way. Hike to cave is about 0.7 miles (1.1 km).

County: Sandoval
Ownership: U.S. Government – BLM

Length: 42.6 m (140 feet)
Depth: 5.5 m (-18 feet)
Elevation: 5760 feet

Synopsis: A small, pseudokarst cave.

Candle Cave Entrance area. Photo by Pete Lindsley.

Description: The cave has two walk-in and two skylight entrances. The southern, or upstream entrance, is 2 m wide by 1 m high, and after a 1.3 m climb-down just inside the entrance, opens to a meandering, wet-weather stream passage averaging 1 to 3.5 m wide by 0.5 to 2.5 m high (see map). A small skylight entrance is located approximately 10 m down the passage in a small room to the left. After about 30 m, the main passage opens to a 5-m-wide by 5-m-long room with a skylight 5 m above the floor. The passage continues another 5.3 m to the northern, or downstream entrance that is 2 m wide by 2 m high.

The cave is developed in clastics of the Morrison Formation and is a pseudokarst feature due to soil piping (suffosion) of the sediments by flowing water. Ojito Cave is located in the bottom of an arroyo that had been covered by collapsed material from a cliff face composed of sandstones and mudstones. This rockfall likely formed a dam over the arroyo, causing water to erode the bottom of the collapse pile, forming an underground stream through the rubble. (See map in this volume.)

References:

Jorgensen, Garrett. 2016. Ojito Cave, Sandoval Co., NM, January 29, 2016. *Southwestern Cavers,* 54(2):14 (March-April).

Special equipment or precautions: Do not enter the cave if there is a significant chance of rain as the cave floods. Watch out for rockfalls, as the walls and ceiling are unstable in places.

Permissions: As of December 2016, no permit was required. Please check with cave trip coordinators regarding current access.

Candle Cave

Distance from NSS Campground: 26 miles (41.8 km) to White Ridge Bike Trails parking area, 30-minute drive one-way. Hike to cave is 2.5 miles (4.0 km) with fantastic views.

Troy Fisher looking up through the fissure entrance, Candle Cave. Photo by Sean Lewis.

County: Sandoval
Ownership: U.S. Government –
Bureau of Land Management

Length: 41.0 m (134.5 feet)
Depth: 4.1 m (13.3 feet)
Elevation: 5,900 feet

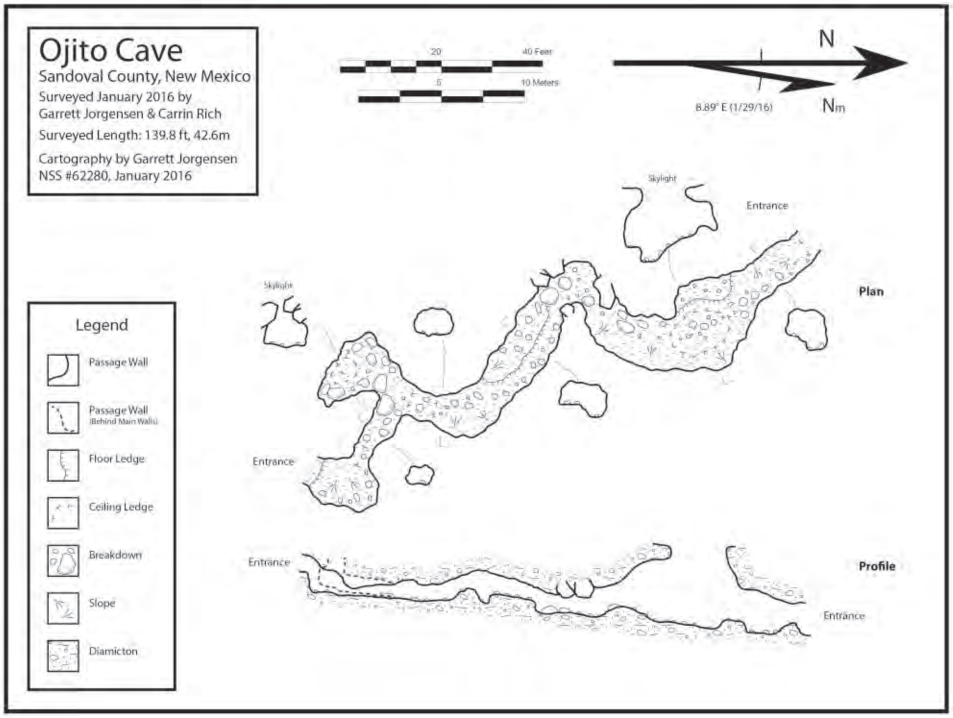
Synopsis: A fissure cave in travertine.

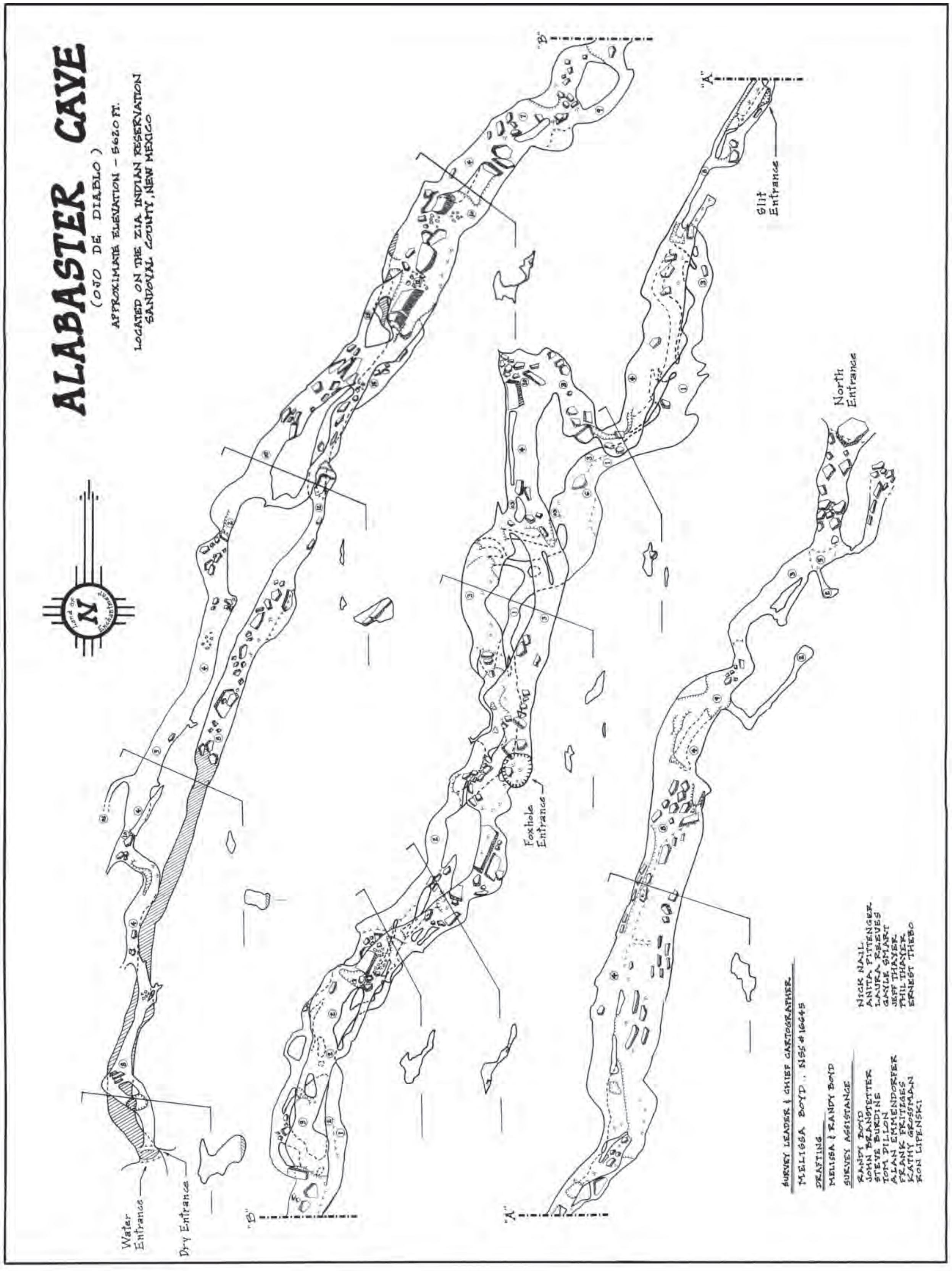
Description: Candle Cave is a fissure cave formed in Quaternary travertine deposits along the Nacimiento Fault. The cave was formed as large blocks of travertine broke apart and were pulled down slope to the west gravitationally. The back of the cave was used in the past as a place to stash and smoke marijuana. There are a number of candles in the small room at the back of the cave where people have hung out to smoke, hence the name "Candle Cave." An altar with a tiny, ceramic pair of shoes and displays of colorful, hanging, beaded jewelry has made this cave someone's sanctuary. Nearby, there are several spring mounds, one still quite active, along the hike to the cave.

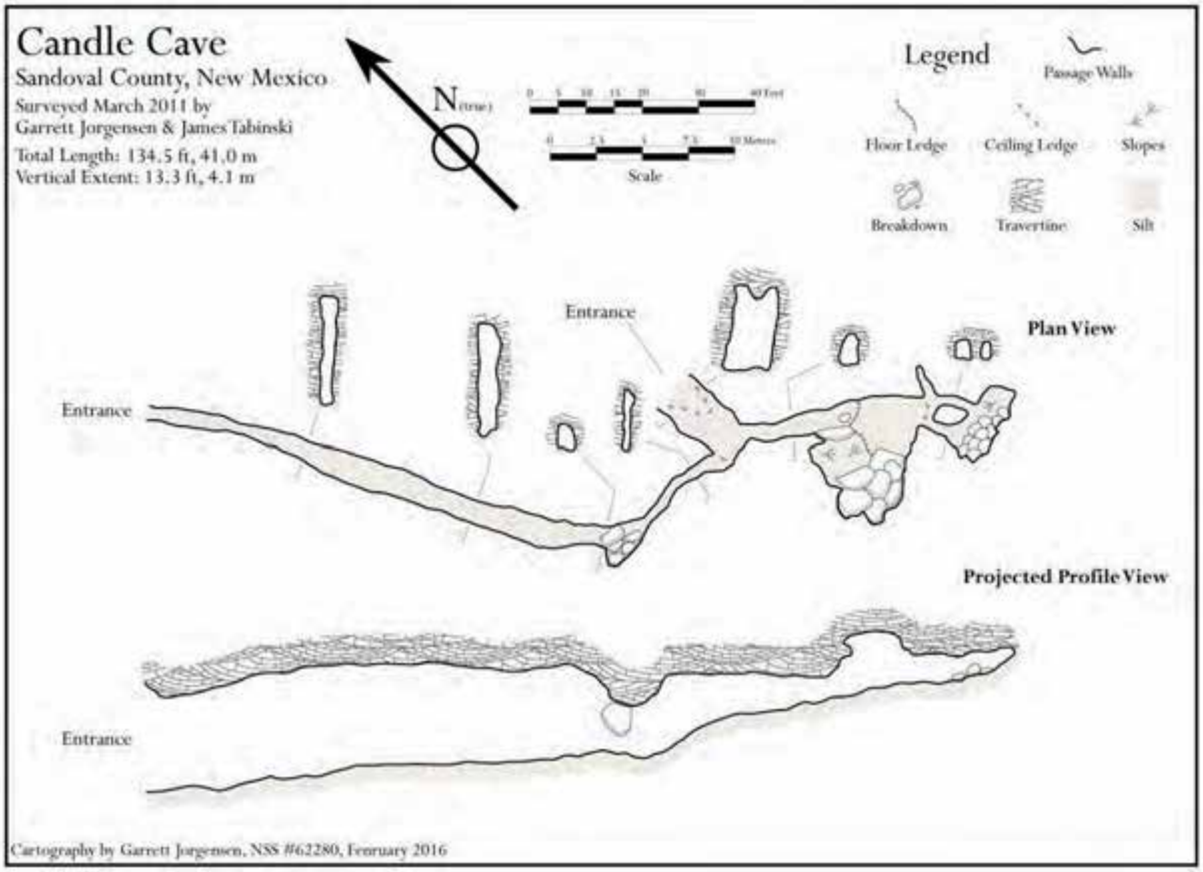
Sandia Grotto cavers exploring springs and seeps in the Candle Cave area. Photo by Pete Lindsley.

Recommended: There are several small slot canyons in the area surrounding Candle Cave as well as "travertine mazes." The entire area is fun to hike and explore, and extremely scenic.

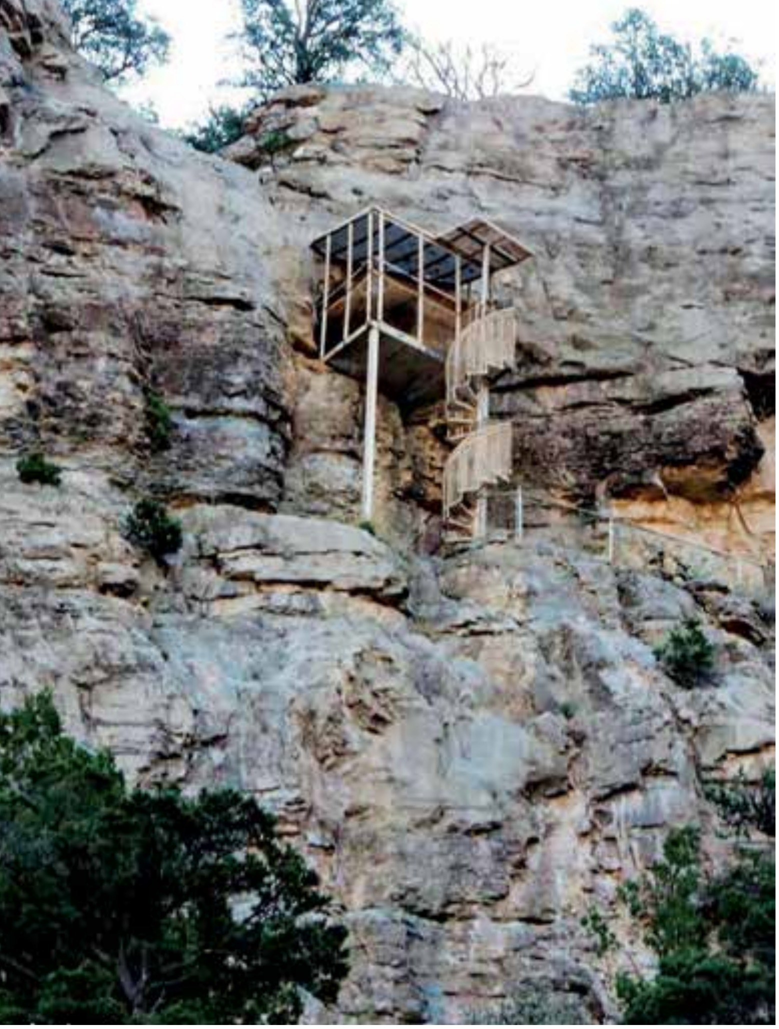
Special equipment or precautions: The hike is completely exposed; bring sunscreen, hat, shade and water.




ALABASTER CAVE
(OJO DE DIABLO)
APPROXIMATE ELEVATION - 5620 FT.
LOCATED ON THE ZIA INDIAN RESERVATION
SANDOVAL COUNTY, NEW MEXICO
"B"
"A"
Water Entrance
Dry Entrance
Foxhole Entrance
Slit Entrance
North Entrance
SURVEY LEADER & CHIEF CARTOGRAPHER
MELISSA BOYD, NSS #16645
DRAFTING
MELISSA & RANDY BOYD
SURVEY ASSISTANCE
RANDY BOYD
JOHN BRANSTETTER
STEVE BURDINE
TOM DILLON
ALAN EMMENDORFER
FRANK FRITZGES
KATHY GROSSMAN
RON LIPENSKI
NICK NAIL
ANITA PITTENGER
LAURA REEVES
GAYLE SMART
JEFF THAYER
PHIL THAYER
ERNEST THEBO



A hydrothermal spring deposit in Ojito-Candle Caves area. Photo by Pete Lindsley.



Sandia Cave entrance and spiral staircase leading up. Photo by Ron Maehler.

Sandia Cave

Distance from NSS Campground: About 20 miles (32 km) to parking area for cave, ½-hour drive one-way. Hike to cave is about 2640 feet (805 m).

Alternate Names: Sandia Man Cave
County: Sandoval
Ownership: U.S. Government – Cibola National Forest

Length: 142 m (466 feet)
Depth: 22 m (72 feet)
Elevation: 7180 feet

Synopsis: A significant archeological and paleontological cave site.

Description: Sandia Cave is a dry, phreatic cave consisting of a single, descending passage with an average width of 3 m and a height from 0.6 to 3.5 m (see map below). There are no pits nor side passages, and the floor is predominantly composed of silt. The cave is a National Natural Landmark and is open to public access without a permit.

Donald G. Davis passing through the first of many low spots in the cave. Photo by Pete Lindsley.

The site was excavated from 1936 to 1941 by Frank Hibben and others from the University of New Mexico. Found in the cave were stone arrow and lance points, basket scraps, bits of woven yucca moccasins, and the skeletal remains of Ice Age animals such as mammoth, mastodon, sloth, horses, and camels. No human remains were discovered. Both Folsom and Sandia hunting points were recovered, with the hitherto unknown Sandia points, interpreted by Hibben as being much older than any other evidence of man in North America. Later studies of the stratigraphy and recent radiometric dating have since corrected some serious, earlier misinterpretations, leaving "Sandia Man" as definitely younger than earlier claimed.

The cave became quite famous due to Hibben's claims, and a spiral staircase to the entrance was subsequently installed to allow public access. Sandia Cave was registered as a National Natural Landmark in 1961, and it was added to the National Register of Historic Places in 1966. Unfortunately, it has been heavily vandalized by locals over the years. In 2015, the Forest Service (Cibola National Forest), in conjunction with the Sandia Grotto and New Mexico SiteWatch, sponsored a remarkable project for the restoration and conservation of Sandia Cave.

Sam Bono works his way through stubborn spray-painted graffiti during the 2015 restoration. Photo by Pete Lindsley.

Sandia Grotto's Adopt-a-Cave-and-Trail sign. Photo by Pete Lindsley.

Sandia Grotto adopted the cave and endeavors to maintain two front rooms and the trail to the cave as free of graffiti and trash. (See article on Sandia Cave elsewhere in this volume.)

Special equipment or precautions: It helps to have a dust mask if you are crawling all the way through to the back of the cave.

Permissions: As of December 2016, no permit was required. Please check with cave trip coordinators regarding current access.

Davis Cave

Distance from NSS Campground: About 20 miles (32 km) to parking area for cave, ½-hour drive one-way. Hike to cave is about 400 feet (121 m).

Alternate Names: Marmot Cave
County: Sandoval
Ownership: U.S. Government – Cibola National Forest

Length: 16 m (52 feet)
Depth: 3.5 m (11 feet)
Elevation: 7100 feet

Synopsis: A small, two-room cave near Sandia Cave.

Description: Davis Cave is a small, horizontal two-room cave and was the site of an archeological dig in 1936. The entrance measures 7 m wide by 3.5 m high and opens to a room 9 m long that gradually becomes narrower towards the back. A 2-m-long, hands-and-knees crawlway at the back leads to a terminal room measuring 10 m long, 2.5 to 7 m wide, and from 1 to 3 m high. The floor consists of fine silt and gravel. (See map below and article on Sandia Cave elsewhere in this volume.)

Special equipment or precautions: none

Permissions: As of December 2016, no permit was required. Please check with cave trip coordinators regarding current access.

Guano Cave

Distance from NSS Campground: About 20 miles (32 km) to parking area for cave, ½-hour drive one-way. Hike to cave is about 3840 feet (1170 m).

County: Sandoval
Ownership: U.S. Government – Cibola National Forest
Length: 22 m (73 feet)
Depth: 7 m (22 feet)
Elevation: 6960 feet

Synopsis: A small cave near Sandia Cave.

Description: The cave has a large entrance measuring 12 feet wide by 18 feet high that opens to a steeply ascending passage about 75 feet long. There is recent litter in the cave that needs to be removed.

Special equipment or precautions: none

Permissions: As of December 2016, no permit was required. Please check with cave trip coordinators regarding current access.

Cooper-Ellis Cave

Distance from NSS Campground: About 25 miles (40 km) to parking area for cave, ½-hour drive one-way. Hike to cave is about 0.2 miles (0.3 km).
Alternate Names: Ellis Cave
County: Sandoval
Ownership: Private

Length: 153 m (502 feet)
Depth: 20 m (64 feet)
Elevation: 8130 feet

Synopsis: A relatively small, multi-level fissure cave with airflow.

Description: The entrance to Cooper-Ellis Cave is a vertical crack at the bottom of a limestone cliff. The passages are primarily aligned along a NE-SW direction parallel to the cliff face and consist of solution-enhanced fissures (see map below). There are three main rooms, inter-connected by crawlways and vertical chimneys. No special equipment is required to climb the vertical sections, with the exception of one lead

A winter Sandia Grotto survey trip into Cooper-Ellis Cave. Photo courtesy of Evan Hubbard on the left.

in the roof of the Swimming Pool Room. There are a few speleothems present, although the north walls of the Big Room and several other rooms and passages are covered with a plaster-like flowstone layer averaging 1.5 to 2.5 cm thick. Historic graffiti is present.

Rodger Burt, photo mode in Cooper-Ellis Cave's Big Room. Photo by Scott Christenson.

Compared to the other known caves in the area, Cooper-Ellis Cave is much more complex and is one of the few caves that has rooms large enough to stand up in. Despite the small size of the cave, there is often a strong breeze observed in the Big Room and in some of the lower passageways, which suggests the possibility of an extension of the known cave by digging. It is also possible that there are other entrances that have not been found.

Special equipment or precautions: none

Permissions: The cave is privately owned. Trips will be led by a designated trip leader.

Embudo Cave

Distance from NSS Campground: About 28 miles (45 km) to parking area for cave, ¾-hour drive one-way. Hike to cave is about 0.4 miles (0.6 km).

County: Bernalillo
Ownership: U.S. Government – Cibola National Forest – Sandia Peak Ski Area

Length: 115 m (377 feet)
Depth: 16 m (53 feet)
Elevation: 8935 feet

Synopsis: A short cave with large passage.

Description: Embudo Cave consists of a single, large, descending passage measuring 55 m long, 7 to 11 m wide, and from 1.5 to 4.5 m high, with a smaller side passage that bifurcates into several smaller passages that end after 20 to 25 m (see map below). Speleothems include dripstone (stalactites, stalagmites, columns), flowstone, draperies, boxwork, a conulite, rimstone dams (microgours), calcite rafts, and popcorn coralloids. The calcareous boxwork is exposed in the ceiling of the main passage with fins up to 2-3 cm deep. The main passage follows the ~18° bedding dip of the Pennsylvanian-age Madera

Selfie, Photo by Ron Maehler in Embudo Cave.

Formation. Almost the entire cave is formed in shaley beds at a shale-limestone contact within the Madera. A prominent bedding plane defines the ceiling of the main passage. The cave is about 115 m long with a constant temperature of 13° C (55° F).

Rodger Burt in Embudo Cave. Photo by Ron Maehler.

In the spring of 1965, the University of New Mexico Physics Department installed a meson telescope in the cave to measure and track cosmic rays. The telescope measured pulses of light caused when cosmic rays penetrated the Earth and struck film plates that had been placed in a special shelter built in the cave. The experiments at the cave ended in 1995, and the telescope equipment was subsequently removed. The cave currently has a solid steel door that seals the entrance, and a hand crank is needed to open a covering that allows access to the lock. Sandia Grotto is currently in negotiations with the U.S. Forest Service to make improvements on gating and protecting access to this cave resource.

Special equipment or precautions: none

Permissions: Permission required for access. Please check with cave trip coordinators regarding access. Trips may be led by a designated trip leader.

References:

Hill, Carol. 1996. "Mineralogy of Embudo Cave, Sandia Mountains, Cibola National Forest, New Mexico." Unpublished report submitted to the National Forest Service, 7 pp.

Pronoun Cave Complex

Whut Cave

Distance from NSS Campground: About 70 miles (113 km) to parking area for cave. Cave is located within a short walk from the road.

Alternate Names: What Cave
County: Cibola
Ownership: U.S. Government – BLM

Length: ~187 m (~613 feet)
Depth: 19 m (62 feet)
Elevation: 6705 feet

Synopsis: A travertine cave and paleo-spring.

Description: Whut Cave is a relatively small and tight cave, extending only about 100 m west-northwest and about 50 m east-southeast of the present pit entrance, which measures 61 cm in width and 1.5 m long. The entrance tunnel is vertical and drops 4.5 m to a ledge, then 4.5 m more to the bottom of the cave. At this point, the passage remains relatively level with fill material and extends both east and west as a narrow fissure passage with several tight squeezes.

Just below the base of the present entrance is a man-made shaft that extends about 9 m vertically into the cave fill. The nature of this mining activity is not clear, though it is thought to have been an attempt to recover manganese ore from the sediments. Based on preliminary mineral analyses, the black material at the bottom of the shaft appears to consist of a mixture of pyrolusite (MnO_2), psilomelane ($BaMn_9O_{16}(OH)_4$), and perhaps other poorly defined oxides of manganese and iron. Speleothems are restricted to popcorn along the passage walls. The cave is also a significant paleontological site.

The cave developed in Late Pleistocene travertine deposits dating back to at least 760 Kya. It is almost certainly the throat of an ancient, extinct spring vent. This cave appears to have developed as a linear travertine-precipitating spring, built with progressively higher "walls" on either side of the central fissure-like spring vent. Continued precipitation of calcite along the vent led the orifice to become plugged over time, causing the water to seek another exit. At certain times, the water may have emerged only from a few small holes, and the present entrance to Whut Cave appears to be just such an extinct, circular spring vent. Erosional pockets (corrosion domes) in the ceiling just inside the entrance appear to record where upwelling spring water flowed against the older travertine, redissolving it in places.

Special equipment or precautions: Rope and vertical gear for entrance drop.

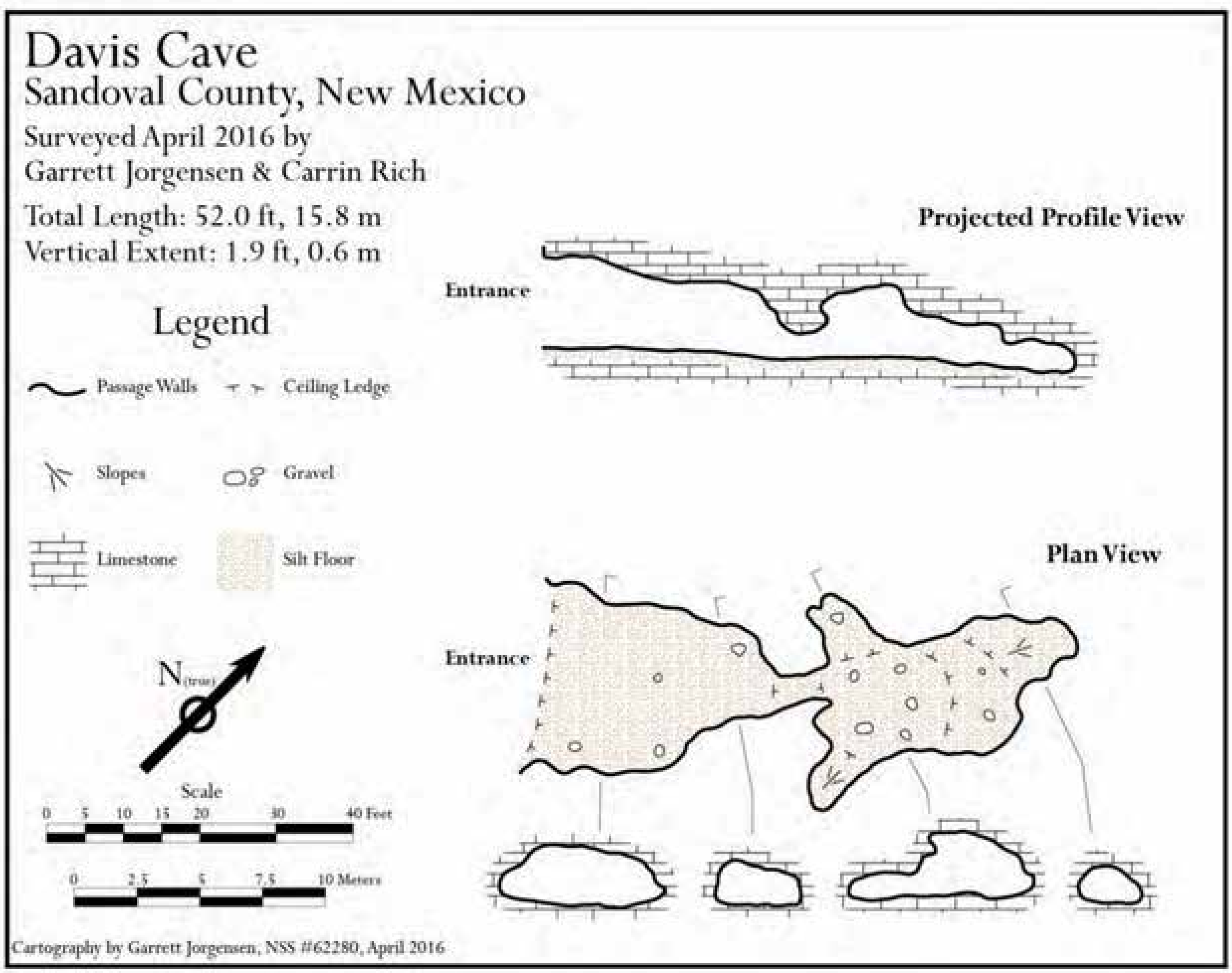
Permission: ACCESS NOT AVAILABLE.

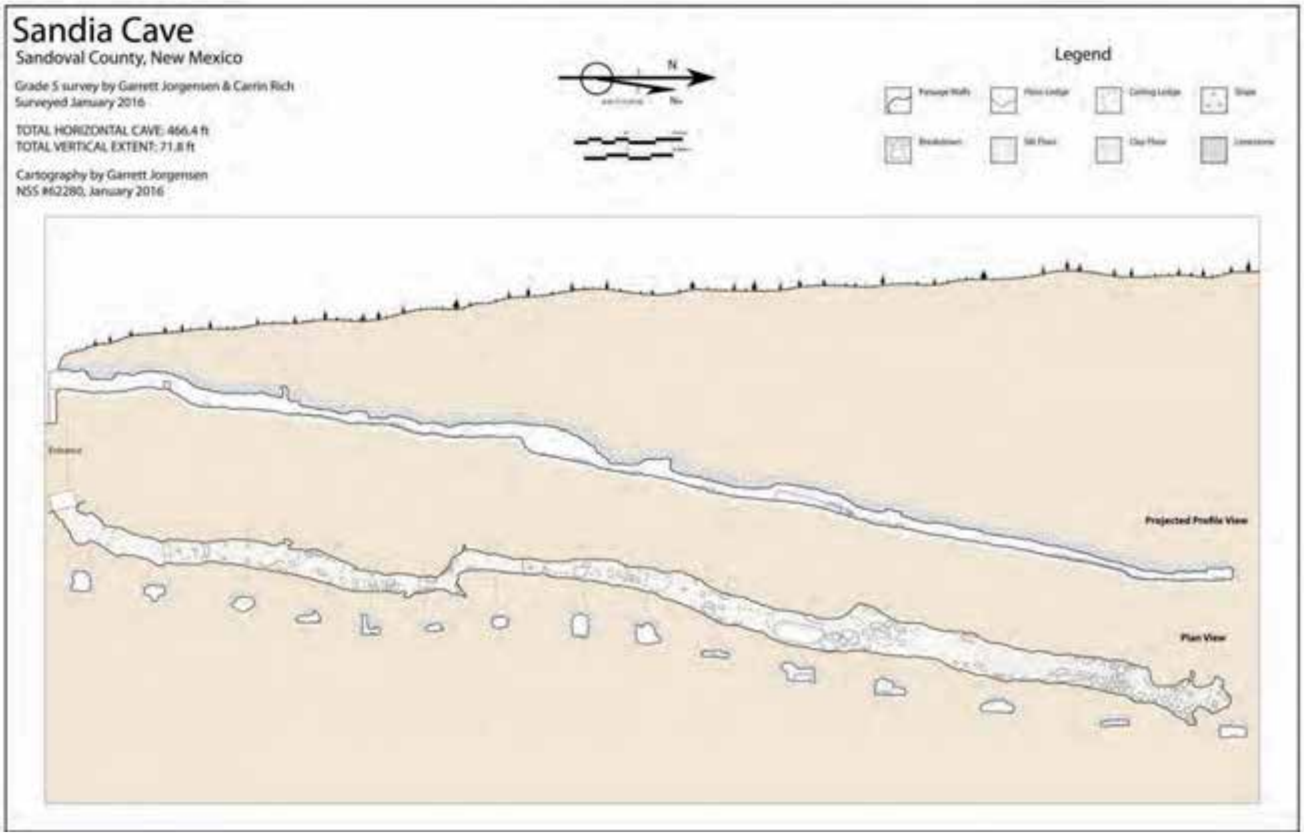
Bibliography:

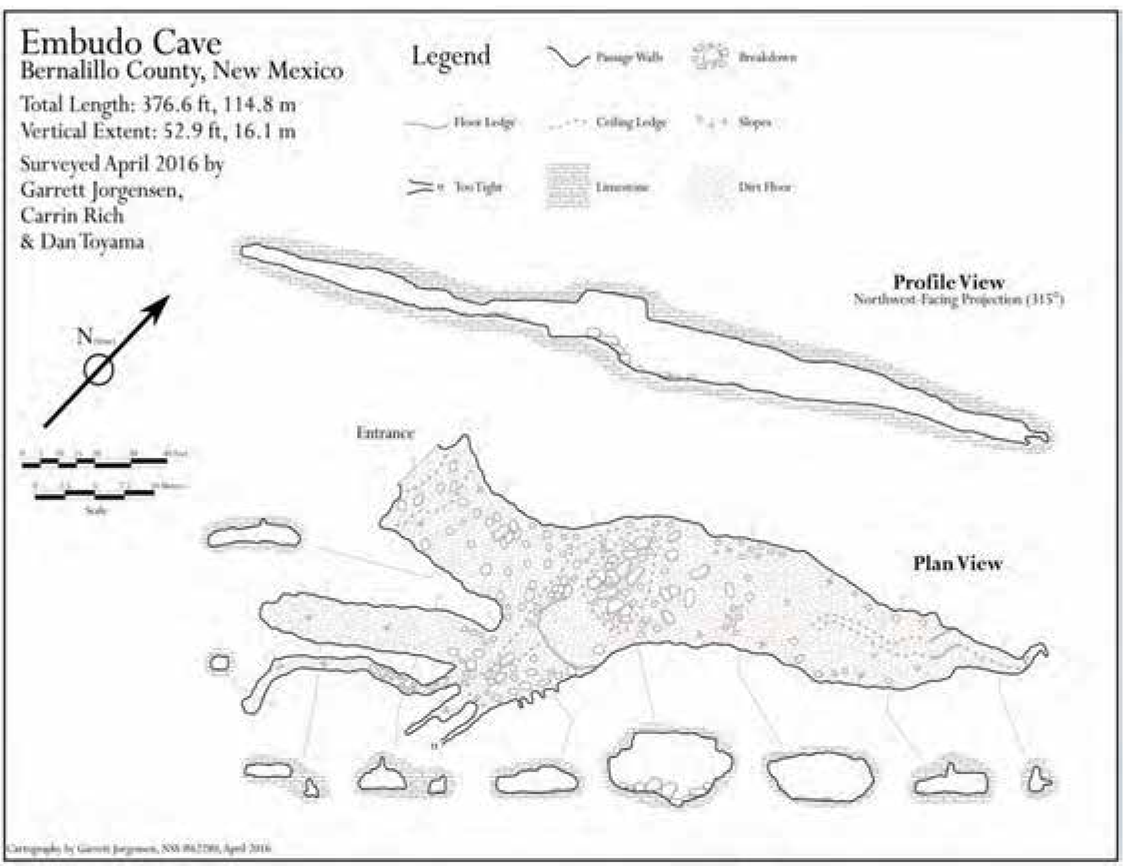
Forbes, Jeffrey. 1993. "Geologic introduction to the caves of Mesa del Oro travertine." Unpublished report for the Fall 1993 meeting of Southwestern Region of the NSS, 5 pp.

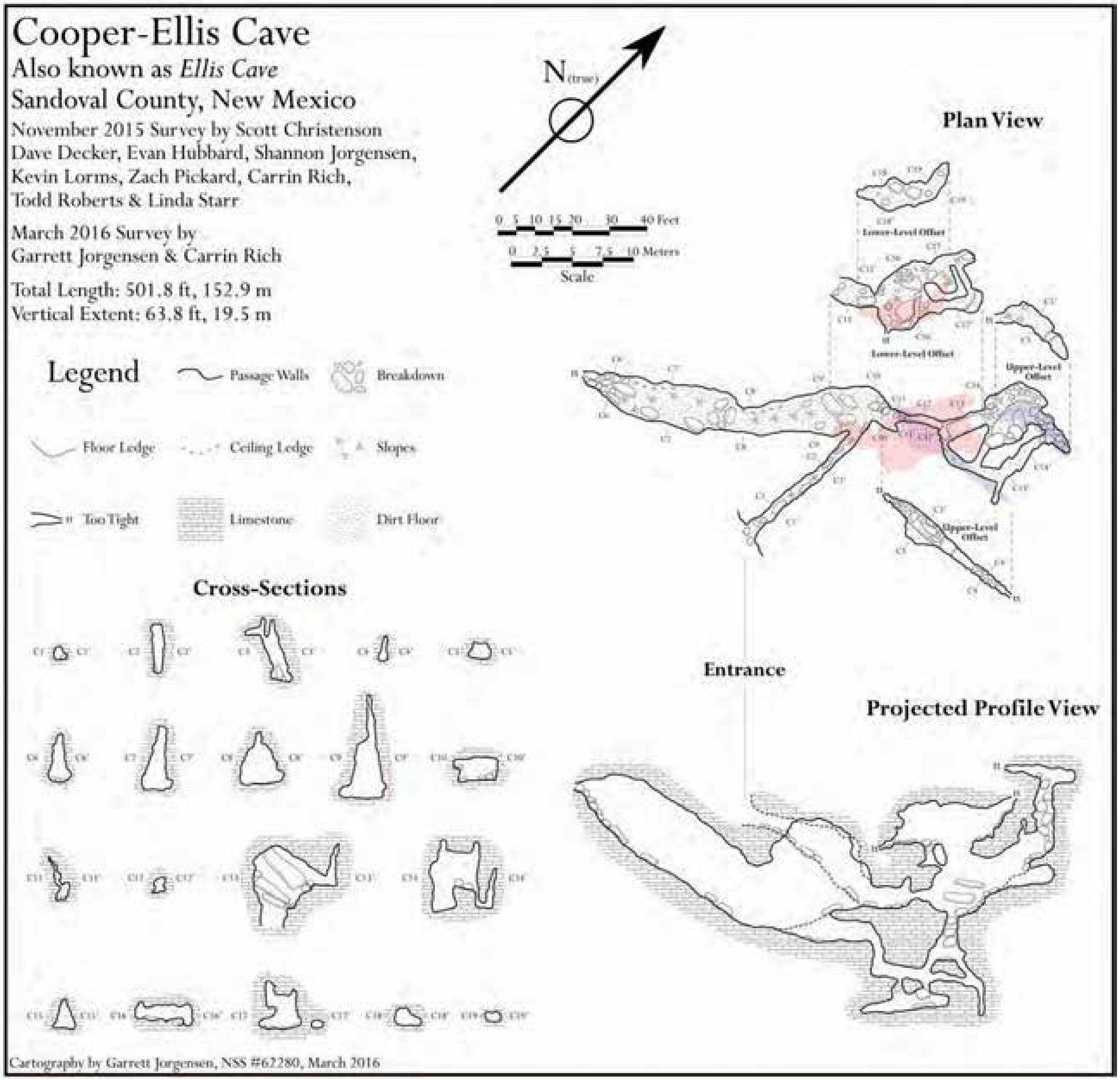
----- and D. Stephens. 1994. Caves of the Mesa del Oro travertine, New Mexico, U.S.A. Pp. 18-20 in: *Breakthroughs in Karst Geomicrobiology and Redox Geochemistry*, Ira D. Sasowsky and Margaret V. Palmer (eds.), Karst Waters Institute, Special Publication 1, xiv + 111 pp.

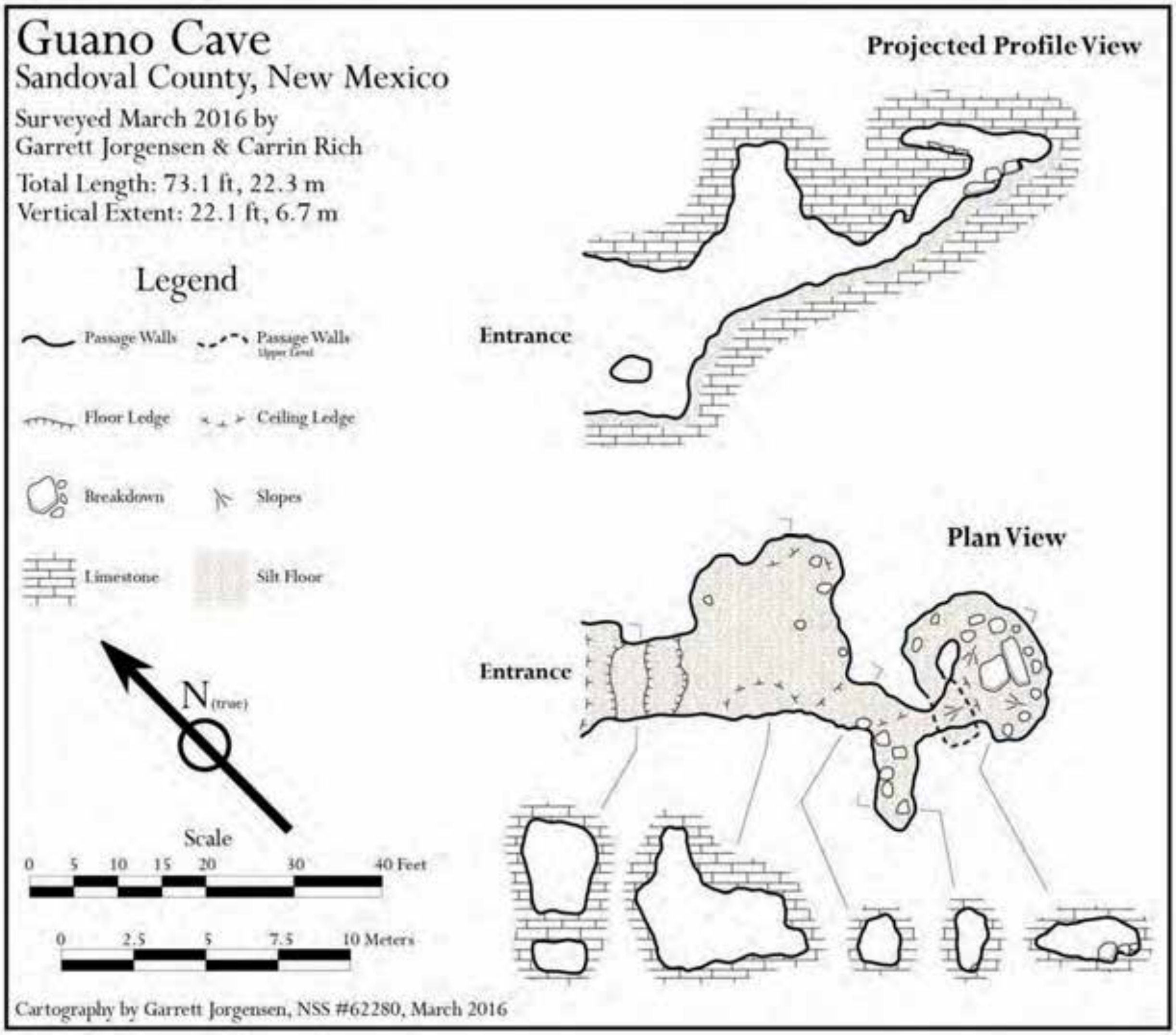
Priewisch, A., L. J. Crossey, and K. E. Karlstrom. 2013. U-Series Ages and Morphology of a Quaternary Large-volume Travertine Deposit at Mesa Del Oro, NM: Implications for Paleohydrology, Paleoclimate, and Neotectonic processes. Pp. 229-237 in: *Geology of Route 66 Region: Flagstaff to Grants*, Kate Zeigler, J. Michael Timmons, Stacey Timmons, and Steve Semken, (eds.), New Mexico Geological Society Guidebook, 64th Field Conference, 237 pp.




Sandia Cave
Sandoval County, New Mexico
Grade 5 survey by Garrett Jorgensen & Carrin Rich
Surveyed January 2016
TOTAL HORIZONTAL CAVE: 466.4 ft
TOTAL VERTICAL EXTENT: 71.8 ft
Cartography by Garrett Jorgensen
NSS #62280, January 2016
N
Legend
Entrance
Projected Profile View
Plan View

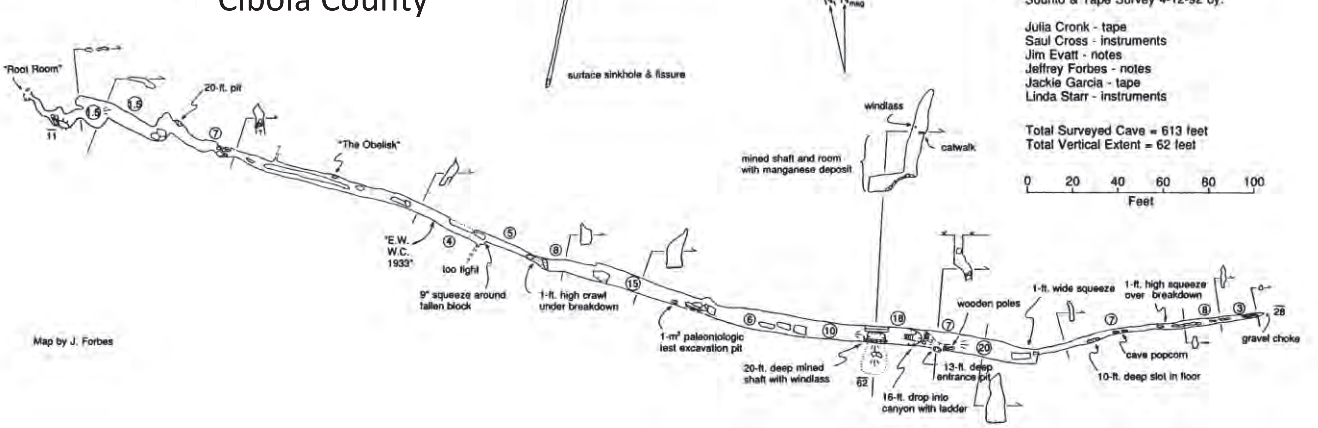

Embudo Cave
Bernalillo County, New Mexico
Total Length: 376.6 ft, 114.8 m
Vertical Extent: 52.9 ft, 16.1 m
Surveyed April 2016 by
Garrett Jorgensen,
Carrin Rich
& Dan Toyama
Legend
Passage Walls
Breakdown
Floor Ledge
Ceiling Ledge
Slopes
Too Tight
Limestone
Dirt Floor
Profile View
Northwest-Facing Projection (315°)
N
Entrance
Scale
Plan View


Cooper-Ellis Cave
Also known as Ellis Cave
Sandoval County, New Mexico
November 2015 Survey by Scott Christenson
Dave Decker, Evan Hubbard, Shannon Jorgensen,
Kevin Lorms, Zach Pickard, Carrin Rich,
Todd Roberts & Linda Starr
March 2016 Survey by
Garrett Jorgensen & Carrin Rich
Total Length: 501.8 ft, 152.9 m
Vertical Extent: 63.8 ft, 19.5 m
N(true)
0 5 10 15 20 30 40 Feet
0 2.5 5 7.5 10 Meters
Scale
Plan View
Legend
Passage Walls
Breakdown
Floor Ledge
Ceiling Ledge
Slopes
Too Tight
Limestone
Dirt Floor
Cross-Sections
Entrance
Projected Profile View
Cartography by Garrett Jorgensen, NSS #62280, March 2016



Whut Cave

Cibola County



Caves of El Malpais National Monument

A cave in El Malpais National Monument. Photo by Kenneth Ingham.

Junction Cave

Distance from NSS Campground: About 110 miles (180 km) to the Visitor Center, 1.75-hour drive one-way. A 3-mile (5 km) drive from the Visitor Center to the parking area for the cave. Cave is about 100 yards (91.5 m) from parking area.

County: Cibola
Ownership: U.S. Government – El Malpais National Monument

Length: 581 m (1907 feet)
Depth: 31 m (102 feet)
Elevation: 7270 feet

Synopsis: A large lava tube and bat hibernaculum.

Description: Junction Cave is one of El Malpais' most frequently visited caves due to its easy accessibility, but also contains the largest-known Townsend's Big-Eared bat hibernaculum in the park. The cave is located about 100 m from El Calderon parking lot. It is a 581-m (1,907-ft)-long lava tube that averages 8 m wide and 5 m high (see map). Like many other caves at El Malpais, Junction Cave contains a cold air trap and the temperature of the cave is in the low 40s F. The cave entrance requires a brief scramble down into a trench. A small moss garden is present in the twilight area of the cave. While the first half of the cave is largely breakdown and no longer contains many primary features, the second half of the cave is more representative of an intact lava tube and has a good example of a lava bench.

The main passage terminates ~300 m (~980 feet) from the entrance at a room containing a mud floor. A waterline beginning almost halfway through the cave and into this room suggests that standing water of about 11-m depth once filled the area. Invertebrates have been found in the room containing the mud floor, including a troglobitic bristletail known only to exist in this area of this cave. To avoid disturbing this area and possibly harming any invertebrates, a trail of reflective markers has been built that avoids the mud floor at the cave junction and leads to a long effluent crawl tube. The effluent tube has many excellent

Jack Hathaway in Junction Cave. Photo by K. Ingham.

examples of shark-tooth lavacicles and lava dribbles, and a raised lava floor can be seen along the way before it terminates in a lava seal. Gypsum snow, hair, and needles have been noted in this section of the cave.

Junction Cave was gated in 2015 due to its significance as a bat hibernaculum and concerns that its close proximity to El Calderon parking area posed a threat to the bats during the winter hibernation period. The cave has the largest diversity of bats at El Malpais National Monument. A map and short guide to the cave can be downloaded at: https://www.nps.gov/elma/learn/nature/upload/Junction-Cave.pdf.

Special equipment or precautions: Wear clothing appropriate for cold temperatures in the cave.

Permissions: Visitors must obtain a permit at the Visitor Center prior to entering the cave. The cave is closed during the winter.

Xenolith Cave

Distance from NSS Campground: About 110 miles (180 km) to Visitor Center, 2-hour drive one-way. A 3-mile (5 km) drive from Visitor Center to parking area for cave. Hike to cave is about ¾ mile (1.2 km).

County: Cibola
Ownership: U.S. Government – El Malpais National Monument

Length: 191 m (625 feet)
Elevation: 7290 feet

Synopsis: A geologically interesting lava tube.

Description: Xenolith Cave is located 1.2 km (¾ mi) down El Calderon loop trail at the western end of a 15-m-long and 3-m-deep

Cavers descend into Xenolith Cave. Photo by Kenneth Ingham.

subsidence collapse. Within this same collapse is Bat Cave, which is closed year-round due to its use by a maternity colony of Brazilian free-tailed bats. Throughout the summer, visitors can watch the bat flight at sunset.

Xenolith Cave is named for the many xenoliths (pieces of non-volcanic rock found embedded in the lava flow) exposed in its walls. The initial portion of the cave is primarily breakdown, some of which has been welded in

Water drop in Xenolith Cave.

Photo by Kenneth Ingham.

place by lava dripping down into the rubble (see map). Past the breakdown is a 2.5-m-long ladder over lava falls, which leads to a room where many visitors stop. Unfortunately, this is where the most interesting part of the cave begins. Several small crawls on the left-hand side of the wall lead to a smooth, 10-m-long belly crawl tube that opens to a large room with a massive, rafted boulder at its end. A map and short guide to the cave can be downloaded at: [https://www.nps.gov/elma/learn/nature/upload/Xenolith-Cave.pdf.](https://www.nps.gov/elma/learn/nature/upload/Xenolith-Cave.pdf)

Special equipment or precautions: Wear clothing appropriate for cold temperatures in the cave.

Permissions: Visitors must obtain a permit at the Visitor Center prior to entering the cave.

Caves of the Big Tubes Area

The Big Tubes Area is located in the Bandera lava flow. This flow is the second youngest volcanic event at El Malpais, with an age of approximately 11,000 years. The parking area is found on Big Tubes Road off County Road 42. These roads are maintained but may be difficult to impassable when wet.

Seven Bridges Trench, Big Tubes Area. Photo by Kenneth Ingham.

High clearance and 4-wheel drive are recommended during periods of wet road conditions.

Big Skylight Cave. Photo by Linda Starr.

Big Skylight Cave

Distance from NSS Campground: About 110 miles (180 km) to the Visitor Center, two-hour drive one-way. An 11-mile (18 km) drive from Visitor Center to parking area for cave. Hike to cave is about one-half mile (800 m).

County: Cibola
Ownership: U.S. Government – El Malpais National Monument

Length: ~240 m (~780 feet)
Elevation: 7620 feet

Synopsis: An immense lava tube with many volcanogenic cave features.

Description: Big Skylight Cave is an 800 m (1/2 mi) walk across the Bandera lava flow from the Big Tubes parking area. The entrance of the cave is within a trench and is only accessible by a steep climb-down, which often is not obvious. The cave has an impressive entrance (15 m high by 18 m wide), large passage, and—as the name implies—a big skylight. A large moss garden underneath the skylight contains bryophytes (non-vascular plants like mosses) known primarily in Canada and Colorado, and provides habitat for many invertebrates that are likely to be relict species from the late Pleistocene to early Holocene epochs. Immediately within the entrance, a large lava shelf and grooves can be seen. Lava glaze, drips, boxwork, and gutters can be observed as you progress through the cave. The walls of Big Skylight are often covered with driblets, coralloids, and helictites.

Most of the cave has experienced some level of collapse; therefore, very few ceiling features are evident and breakdown blocks are common. The floor of the cave shows evidence of inflation and has several areas where rafted plates are present. Well-preserved gypsum crusts are often present on the cave walls and are most likely speleogenetic crusts. Toward the back of the cave are examples of sulfate moonmilk. The temperature in Big Skylight Cave is in the upper 30s F and the relative humidity varies significantly by area (30-70 percent). A map and short guide to the cave can be downloaded at: https://www.nps.gov/elma/learn/nature/upload/Big-Skylight-Cave.pdf.

Special equipment or precautions: Wear clothing appropriate for cold temperatures in the cave.

Permissions: Visitors must obtain a permit at the Visitor Center prior to entering the cave.

Giant Ice Cave

Distance from NSS Campground: About 110 miles (180 km) to Visitor Center, two-hour

Entrance of Giant Ice Cave. Photo by Kenneth Ingham.

County: Cibola
Ownership: U.S. Government – El Malpais National Monument

Length: 73 m (240 feet)
Elevation: 7620 feet

Synopsis: A relatively short but large lava tube.

Description: Giant Ice Cave is located on the other side of the trench from Big Skylight Cave and has a massive entrance (27 m wide and 9 m high). Despite its name, Giant Ice Cave has very little perennial ice in comparison to other caves at El Malpais National Monument. Access to the cave is via a steep climb- down located on the east side of the trench about 100 m from the entrance, then a hike across breakdown blocks. The cave is relatively short and there is little of the cave that is out of the twilight zone (see map). The floor is primarily composed of breakdown. A lava bench is present but not as spectacular as the one in Big Skylight Cave. Lava dribblets, gypsum crust, and glaze are present on the cave walls. A map and short guide to the cave can be downloaded at: https://www.nps.gov/elma/learn/nature/

upload/Giant-Ice-Cave.pdf.

Special equipment or precautions: Wear clothing appropriate for cold temperatures in the cave.

Permissions: Visitors must obtain a permit at the Visitor Center prior to entering the cave.

Four Windows Cave

Distance from NSS Campground: About 110 miles (180 km) to Visitor Center, 2-hour drive one-way. An 11-mile (18 km) drive from Visitor Center to parking area for cave. Hike to cave is about 0.7 mi (1.0 km).

County: Cibola
Ownership: U.S. Government – El Malpais National Monument

Length: ~275 m (~900 feet)
Elevation: 7640 feet

Synopsis: A lava tube with many volcanogenic cave features.

Description: Four Windows Cave is a 250-m (0.2 mi) hike to the east from Big Skylight Cave and has a trail marked by cairns. A steep climb-down into a trench and a scramble across large breakdown blocks is necessary to approach the entrance. The cave was named for the four skylight openings near its entrance. The main entrance to Four Windows Cave measures 15 by 15 m and leads to approximately 275 m (900 feet) of passage. The moss garden near the main entrance is one of the more impressive at El Malpais. Sun through the four skylights helps provide the light necessary to support the moss garden. Certain bryophytes (non-vascular plants like mosses) and invertebrates contained within the moss garden are not known elsewhere in New Mexico and are likely relicts that the low temperatures of the cave (mid-upper 30s F) and high humidity are able to support.

Passages in Four Windows. Photos courtesy of Ron Maehler.

From the entrance, the cave descends to the north, down a slope of breakdown to the original floor level, where flow patterns from the pahoehoe lava in the Cauliflower Passage can be seen. The cave then changes to small rubble in the One-Foot-in-the Gutters Gallery. Lava shelves are quite evident in the cave and are one of its more impressive features. The flow units of the lava can be seen in the west wall of the cave. The floor of Four Windows Cave presents many interesting features, such as a flat pahoehoe floor, lava levees, gutters, rafted boulders, and floor spots. A stacked tube marks the point where the cave is closed to protect sensitive resources.

Special equipment or precautions: Wear clothing appropriate for cold temperatures in the cave.

Permissions: Visitors must obtain a permit at the Visitor Center prior to entering the cave.

Sam Bono at a small moss garden at main entrance of Hummingbird Cave. Photo by Victor Polyak.

Caves Near El Malpais National Monument

Hummingbird Cave

Distance from NSS Campground: About 110 miles (180 km) to parking area for the cave, 2-hour drive one-way. Hike to cave is about 1.2 mi (2.0 km).

Alternate Names: Rubble Cave, Lava Falls Cave
County: Cibola
Ownership: U.S. Government – BLM

Length: 752 m (2468 feet)
Depth: 10.8 m (35 feet)
Elevation: 7020 feet

Synopsis: A lava tube with volcanogenic cave features.

Description: Hummingbird Cave was named Rubble Cave first and renamed for two hummingbirds zipping around the entrance on a September day in 2003. It is an easy, walking passage, over breakdown for the most part. It has three entrances: a walk-in entrance, a scramble entrance that is quite unstable, and a skylight entrance. The cave is part of a braided lava tube system of significant length. Ice stalagmites occur on the floor of the passage near the main entrance, and several large (0.5 to 7 feet high) ice stalactites, stalagmites, columns, and draperies occur along the north wall of a small breakdown room near Entrance No. 2. These ice speleothems appear to be seasonal, as previous reports state they were not present during spring and summer trips.

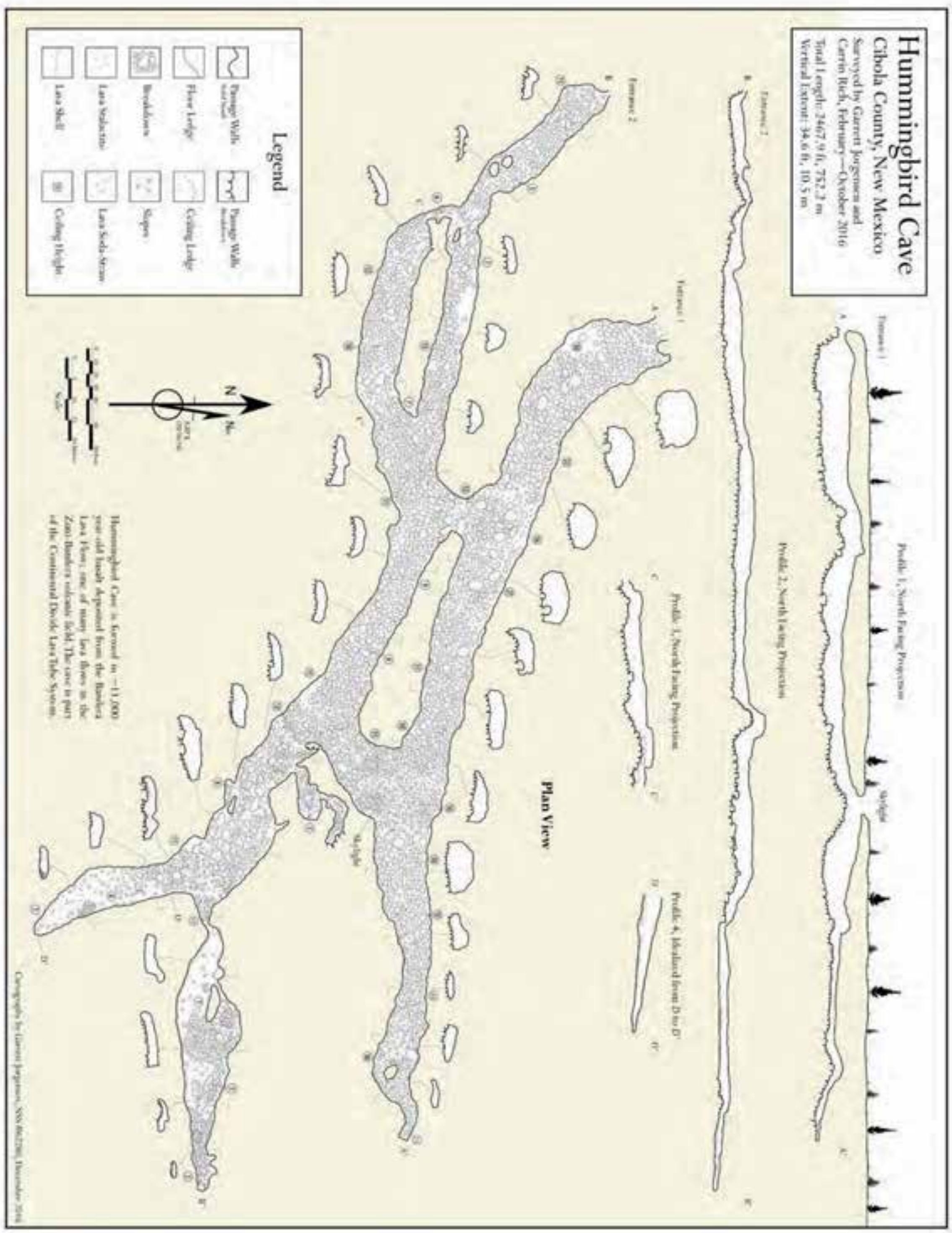
The cave contains areas with small lavacicles, lava benches, pahoehoe floors, microbial mats, and 8-feet high lava falls.

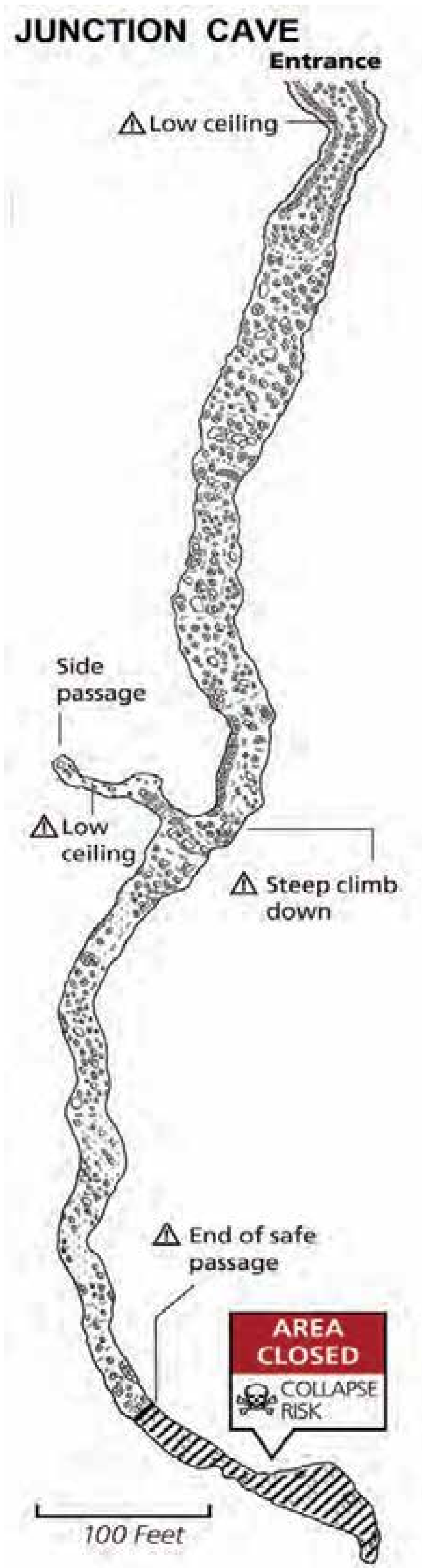
Starburst moonmilk in Hummingbird Cave. These are probably microbial in origin. Photo by Victor Polyak.

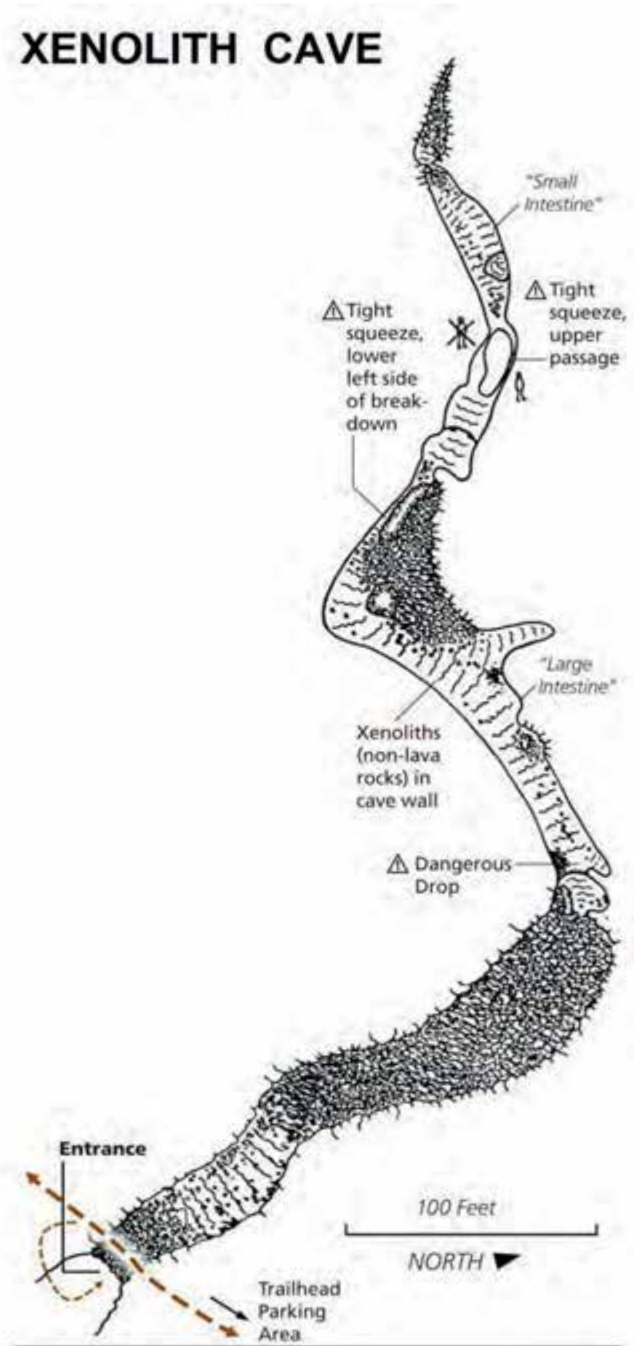
Xenoliths composed of sedimentary rocks can be found in sections of the cave. A small moss garden is located under the skylight entrance. These mosses are unique, in that they have been identified as relict habitats of the last glacial maximum (approximately 20,000 years ago,) and support invertebrate species now restricted to similar environments in both El Malpais and in Oregon.

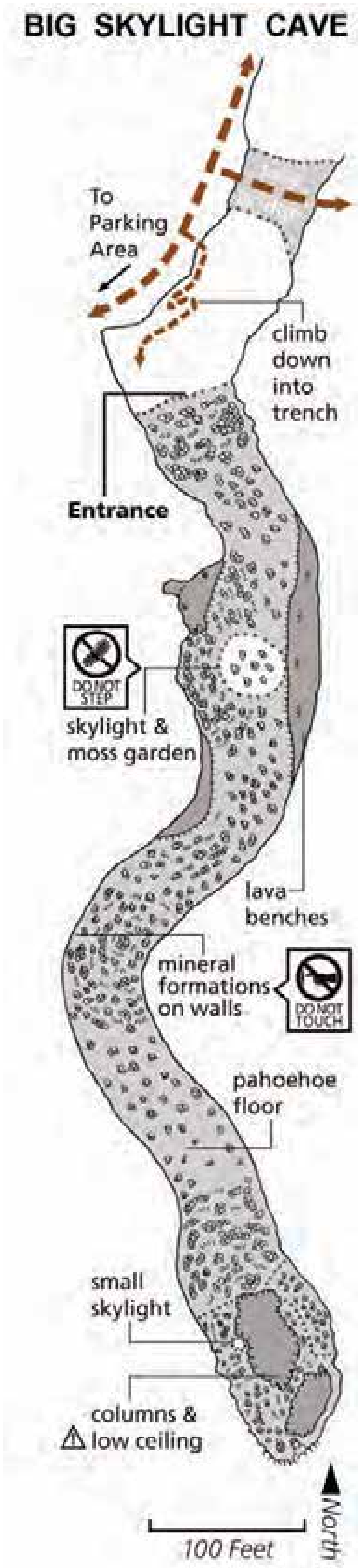
Special equipment or precautions: Do not use the scramble entrance (Entrance No. 2 on the map), as it is unstable. Wear clothing appropriate for cool temperatures in the cave and sturdy boots for hike to cave.

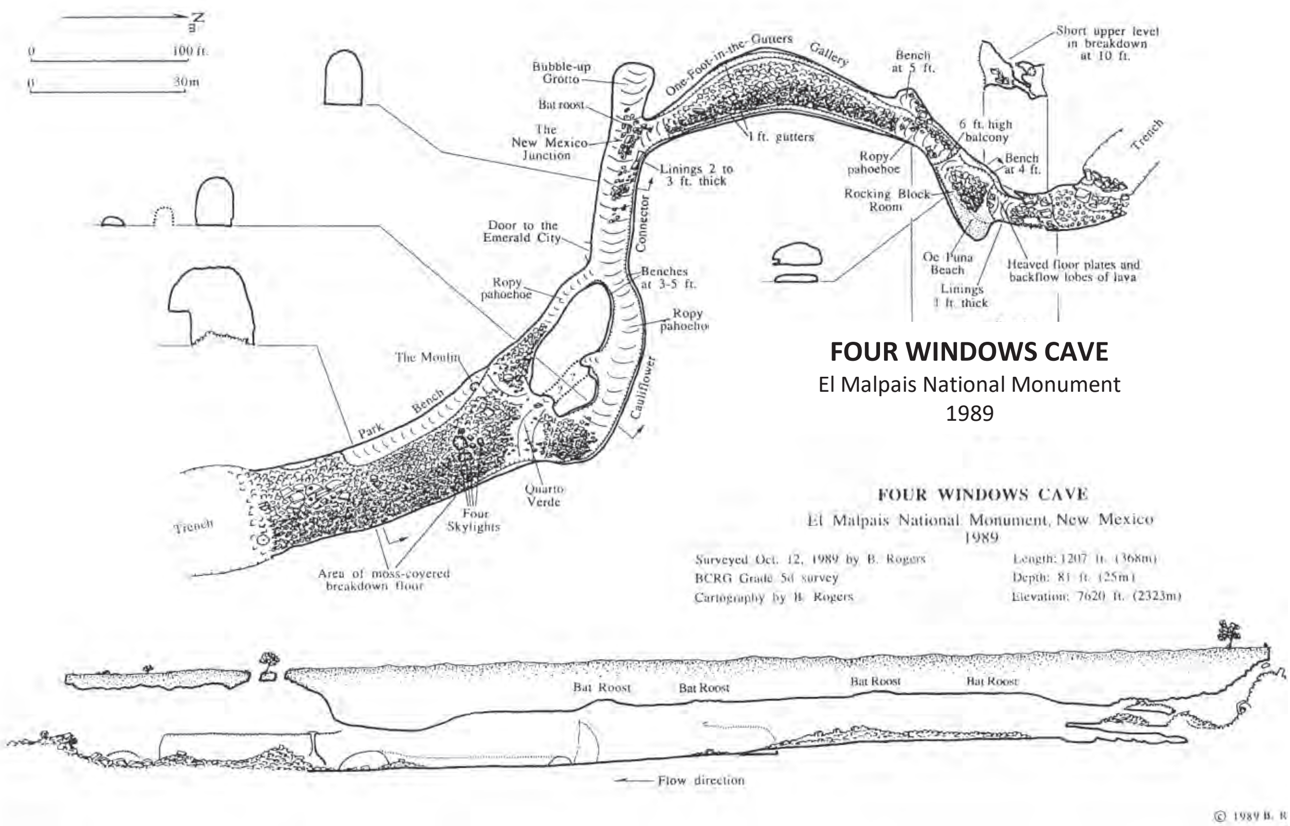
Permissions: No permits required.




JUNCTION CAVE
Entrance
Low ceiling
Side passage
Low ceiling
Steep climb down
End of safe passage
AREA CLOSED
COLLAPSE RISK
100 Feet


XENOLITH CAVE
"Small Intestine"
Tight squeeze, upper passage
Tight squeeze, lower left side of break-down
"Large Intestine"
Xenoliths (non-lava rocks) in cave wall
Dangerous Drop
Entrance
100 Feet
NORTH
Trailhead Parking Area


BIG SKYLIGHT CAVE
To
Parking
Area
climb
down
into
trench
Entrance
DO NOT STEP
skylight &
moss garden
lava
benches
mineral
formations
on walls
DO NOT TOUCH
pahoehoe
floor
small
skylight
columns &
low ceiling
100 Feet
North



FOUR WINDOWS CAVE
El Malpais National Monument
1989

Inaccessible Area Caves

Edgewood Caverns

By Garrett Jorgensen

Edgewood Caverns is an extensive network-maze cave located on private land on the flanks of the Estancia Basin in north-central New Mexico. The cave is formed entirely within the Wild Cow Formation of the Madera Group and contains no natural entrance.

Speleogenesis of the system is uncertain, but is likely related to inundation of the karst system corresponding to rising water levels in Pleistocene Lake Estancia during periods of wetter climate. These water fluctuation events also resulted in the formation of subaqueous and water-level speleothems. Additionally, Edgewood Caverns contains an abundance of world-class Pennsylvanian-aged fossils. The temperature in the cave is ~60°C and relative humidity is 99 percent. CO_2 levels average 8000 ppm.

The existence of the Caverns was first hypothesized in 1906 when a water well intersected a void at a depth of 130 feet. In subsequent years, other voids were encountered by drilling and rumors spread of a large cave system beneath the town of Edgewood. Finally, in 1973 efforts were made to drill a human-sized entrance into the cave. By the end of that year, the shaft was completed and the cave system was discovered and seen for the first time. A large survey effort was conducted and by 1977 the cave was mapped to a length of 3.04 miles.

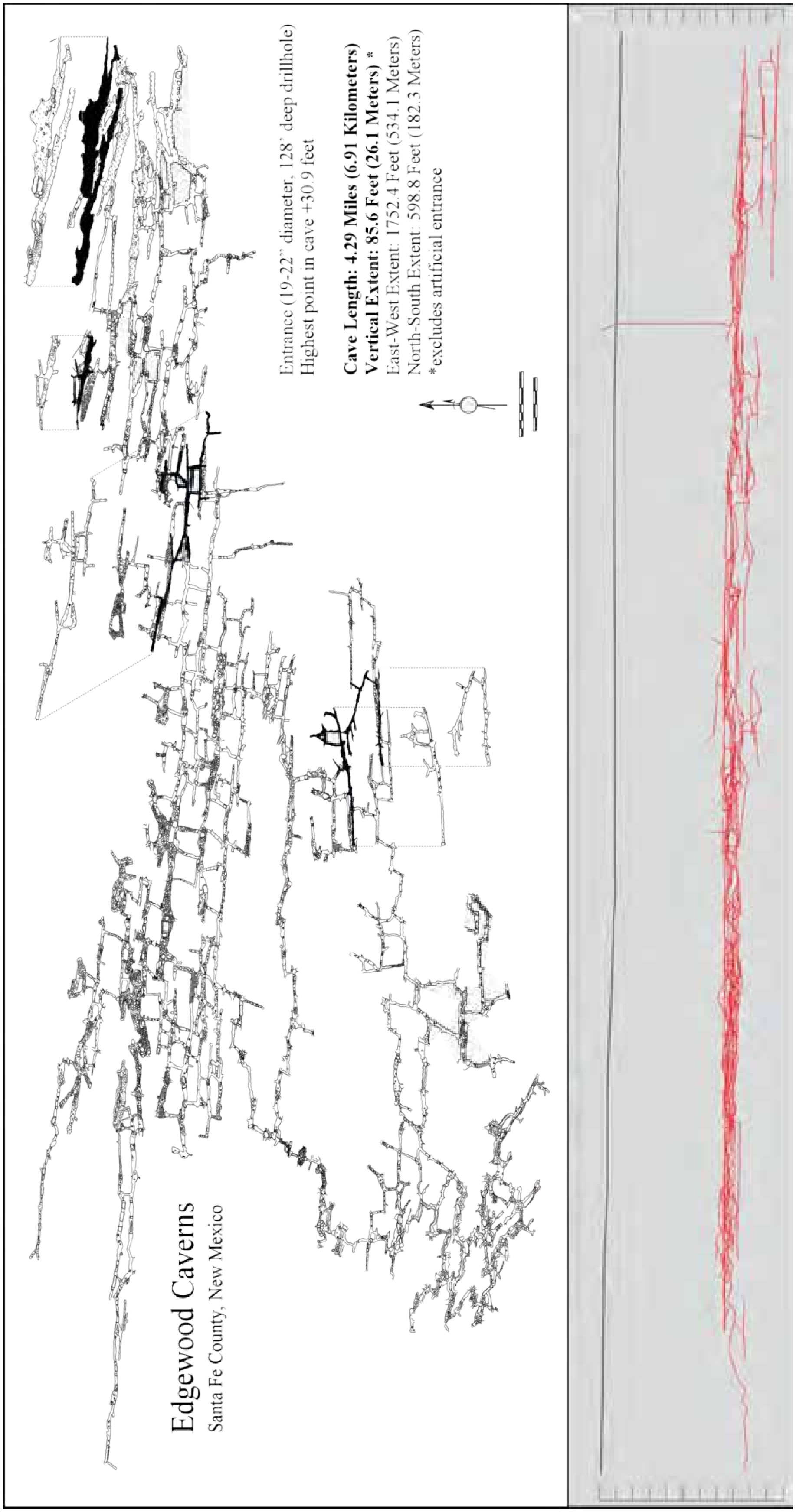
Access to the caverns was lost in 1977 due to complications between cavers and the landowner. Access was regained from 2011-2013 and a complete resurvey was started, mapping a total of 1.46 miles before access was again suspended.

Survey efforts resumed in December 2015 and continue to this day, with over five miles expected on the next map. Access to the cave is restricted due to sensitive, private landowner relations.

Nautiloid and brachiopod at Nautilus Junction. Photo by Garrett Jorgensen.

Calcite raft mound. Photo by Garrett Jorgensen.

Crinoid stem about 10 inches long in Fossil Flats. Photo by Garrett Jorgensen.



Surveyed November 2011— December 2016 by:
Garrett Jorgensen, Dan Toyama, Jennifer Foote, James Hunter, Sean Lewis, Todd Roberts, Beth Cortright, Jim Cox, Evan Hubbard, Scott Christenson, Dan Cornew, John Lyles, Jennie McDonough, Carrin Rich, Phil Thommes, Minori Yoshida, Brian Kendrick, Kevin Lorms, James Reiner, Rick Reynolds, and Adam Zipkin

Fort Stanton Cave

By Pete Lindsley

Fort Stanton Cave is one of three well-known caves in New Mexico. Carlsbad Cavern is probably the best-known cave to the general public, and Lechuguilla is likely the best-known cave among experienced cavers.

Fort Stanton Cave was named for the nearby military fort which was established in 1855. It was initially surveyed in 1877 by members of the Wheeler Expedition. Fort Stanton Cave became known for its strong airflow in numerous breakdown-blocked passages.

A strong team of diggers worked in Fort Stanton Cave at the same time the historic sections of the cave were being surveyed using modern techniques, starting on Sept. 7, 1967. The outstanding feature of Fort Stanton Cave is the overall extent of the passages, which can be compared to Carlsbad Cavern, shown at the same scale in the map on a following page.

During the 1950s to 1990s, several new sections of Fort Stanton Cave were discovered while pursuing efforts at various dig sites. In 1958, the New Section was discovered beyond Three-Way Hill and, ultimately, a major dig at a blowing crevice in the wall, called Babb's Burrow, broke through to Lincoln Caverns.

Ron Lipinski, Kevin Strong and Jennifer Foote at Lincoln Caverns' Rainbow Wall. Photo by Pete Lindsley.

Main Corridor of Fort Stanton Cave. Photo by Kenneth Ingham.

Historically, the Main Corridor of Fort Stanton was sometimes flooded by water leaking into the cave from nearby Rio Bonito. The northeastern extension, called Conrad's Branch, often sumped at Fool's Crawl, where the passage dipped down into a muddy area. During times of drought the water slowly leaked out of the sump and the early explorers occasionally were able to brave the mud and water. They then visited the continuation of the main passage, called Snowflake due to large numbers of calcite rafts on the floor of what was often a dry passage. Snowflake was heading directly toward Government Spring, which had been an important water source for the historic military fort.

Following the airflow, the diggers turned east at Sewer Pipe Landing just before Fool's Crawl and dug into a virgin room larger than seen before in the cave. The room was eventually named Don Sawyer Memorial Hall (DSMH) after a cave specialist working for the Bureau of Land Management.

The cave was declared a National Natural Landmark by the National Park Service in 1974. Around the same time, another dig connected to Snowflake through an area known as Skyscraper Domes. But there was still plenty of air to follow, and the surface geophysical measurements being done by geologist John McLean indicated more passage lay to the east of the known parts of the cave.

Another caver, Lloyd Swartz, focused his dig efforts on an area named Priority 7 (meaning "high priority" in computer lingo) in the Snowflake Junction area. By August 2001, the cave had just reached seven miles in length. September 1, 2001, marked the date of the best discovery so far. Lloyd, John McLean, Dave Becker, and Andrew Grieco broke through the nasty and dangerous Priority 7 dig into pristine Snowy River, with a virgin, white calcite crystal floor that went under a low ledge to the north, and around a bend and out of sight to the south.

A caver peers into the darkness ahead along Snowy River passage. Photo by Kenneth Ingham.

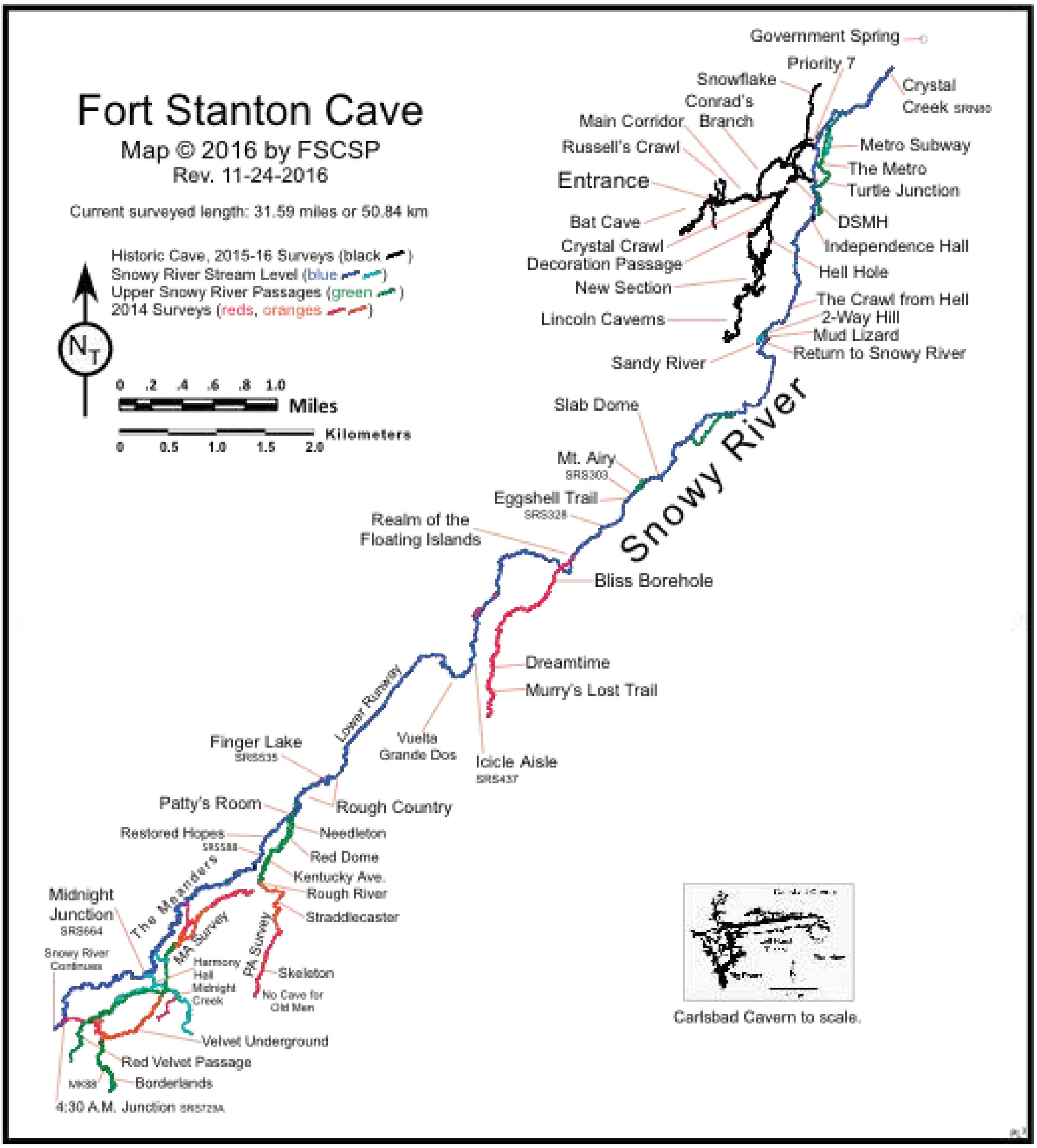
Covered in mud from the digging, the team stopped in their tracks on the bank of a dry, snow-white calcite river that looked like it could go over 1000 feet! How could they check out this virgin passage without doing significant damage to the crystal floor? They chose to stop and tell the BLM about the discovery.

It would be almost another two years before a BLM environmental assessment was finished, and protection of the delicate floor was resolved. The cave was also closed for half of each year during the winter months because the only entrance to Fort Stanton was also the site of a bat hibernaculum, and cavers were always protective of the bats.

Heading upstream, the first side passage to Snowy River was found on July 4, 2003, and was named Mud Turtle, after a rock formation next to the river of white calcite. Explorers quickly surveyed over a mile of the new Snowy River and associated passages. To the north Snowy River ended in a large room named Lincoln's Bathtub, with a small spring, which was named Crystal Creek. The lake in the lowest level of the room sumps, but the cavers realized this water was most likely the source of water in nearby Government Spring.

Then, the route to Snowy River was closed through the problematic Priority 7 dig. One final trip was taken to verify our surveys with a cave radio beacon at the end of the Mud Turtle passage, which fortunately was right under the edge of Don Sawyer Memorial Hall. So, a 44-foot access shaft was dug down the far wall of DSMH.

Four years later, on July 1, 2007, the cavers going to Snowy River via the new route through the access portal discovered that Snowy River was silently flowing clear, clean water. Now we knew how the white calcite was being deposited. Then again, where was the water coming from? How far would the passage go? How long would we have to wait before the flow stopped and the floor dried out enough to



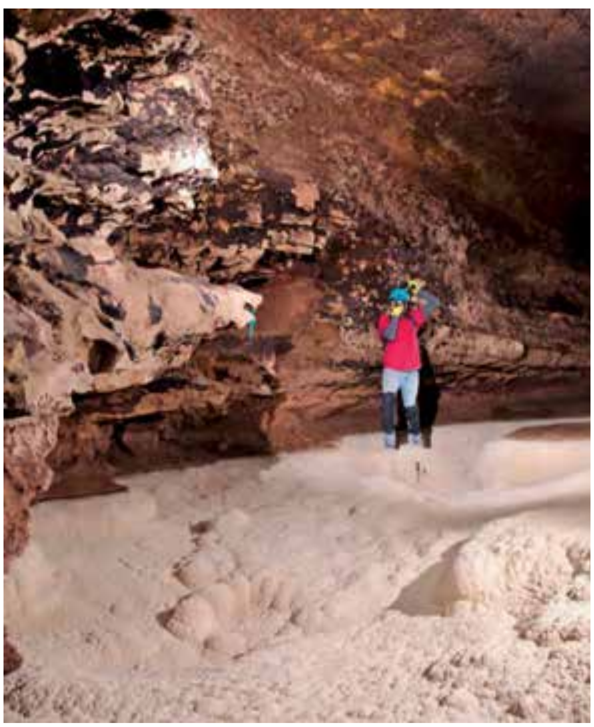
prevent any damage from exploration and survey teams? Cavers realized that Fort Stanton Cave, with the discovery of Snowy River, was unique when compared to the other major caves that many of us had visited, including Mammoth Cave, Jewel Cave, Wind Cave and others.

Our microbiologists viewed the new discoveries as a unique laboratory and began their studies of the ferromanganese deposits in Snowy River.

Following some skillful politics and a visit by a member of the U.S. Senate, the Fort Stanton – Snowy River Cave National Conservation Area was created by the U.S. Congress in 2009. Then, in January, 2011, the BLM officially closed to recreation Fort Stanton Cave and other bat caves in New Mexico as a precaution against contamination with White Nose Syndrome (WNS).

Snowy River was found to flow after winters when there was significant snow pack on Sierra Blanca, followed by a wet spring. Each time Snowy River flowed, exploration was blocked.

In Fort Stanton Cave Study Project expeditions—which remained allowable for science-based research and exploration with a severely limited 120 entry tickets per year—special "strong and light" survey teams were formed, with many members assisting from various other significant cave projects around the country. Teams experienced numerous, multi-faceted, push "day trips," lasting 25–35 hours at times, before permission was finally granted to establish a camp at Midnight Junction (MJ), some 11 miles into the cave. The cave was pushed into the National Forest, and Snowy River passage exploration was halted just short of private property.



Surveying in Snowy River. Photo by Kenneth Ingham.

In August 2014, a science team about halfway upstream toward MJ, encountered another flow heading toward Turtle Junction. Not wishing to take a chance on being on the wrong side of a potential sump, they retreated to Turtle Junction and left the cave. Snowy River was still flowing two years later in October 2016 at the end of the season. Our teams were hopeful that our hydrology predictions of the flow stopping by Christmas 2016 would come true. This would allow exploration to continue before another year passed. However, this was not to be. Snowy River still flows as of April 2016.

The recreational closure of the cave continues in 2017 as WNS continues slowly moving west toward New Mexico. Hydrological exploration and deep penetration survey trips, other science research trips, photographic documentation of historic passages, LIDAR surveys, and special safety and conservation trips all require special proposals,

LIDAR Survey Team in the Main Corridor, May 2014. Photo by Pete Lindsley.

which must be approved by the BLM Cave Management Team for each year.

Unfortunately, even with using on-site, state-of-the-art decontamination techniques for all cave visitors, we have been unable to secure permission for visitors attending the 2017 NSS Convention.

We are planning to have a new book—*12 Miles from Daylight*, describing the 160-plus years of exploration of Fort Stanton Cave—

available at the time of the 2017 Convention. Details will be available at the Fort Stanton Cave Study Project web site: http://FSCSP.org/, where you can also download the latest version of *CaverQuest* – Fort Stanton and enjoy some of the passages where our cameras and LIDAR units have already visited and expect to continue in the future.

Top: Snowy River Island. Snowy River Passage is one of the most unique and largest formations in the world at over 8.5 miles in continuous length. In this image, the rocks that fell from overhead into the passage are high enough to stay above the water level when the passage floods during heavy rain season. Above: The U Turn. As if Snowy River Passage isn't unique and interesting enough on its own, it decided to make a grand sweep in a U turn from its normal straight-ahead course of flow. Photos and captions by Peter Jones.

Pre- and Post-Convention Guided Trips

Northern New Mexico

Exploration History of Gallina Cave

By John Lyles

Gallina Cave is well-known locally and is situated at approximately 9,600 feet elevation. It has just under half a mile of mapped passage with an active stream throughout. The water temperature is about 42° F, and the air is 48° F. The cave is reached after an arduous hike up a canyon, and many first-time trips have become temporarily lost. The first published map was made by Boy Scout Explorer Post 20 from Los Alamos, NM in 1963. It presented a fairly good representation of the cave.

In 1990, the young Pajarito Grotto began a resurvey of the cave. Under the direction of Bill Heath, a large group backpacked to the cave entrance and set up camp in steep, lush terrain with a gushing resurgence a few meters away. Heath led the survey of the first half of the cave, to the point where the active stream is re-encountered. Eastern U.S. cavers who had moved to New Mexico then joined the project, introducing synthetic underwear and nylon over-suits to the cold cave. John Ganter and Hillary Minich surveyed the main passage from the midpoint of the cave toward a sump that reputedly ended the cave. In 1993, Bill Heath, Bill McIntyre, Jim Sturrock, and John Lyles added a small amount of new survey to the map. Heath and Lyles returned in 1995 to push the upstream and downstream sumps. Using a wetsuit, Lyles found the upstream lead would require a dry suit and tank. Downstream was a low cobble crawl in water, and was not extensively pushed. It didn't appear to sump completely.

In late 1995, cave diver James Brown appeared at Lyles' home. James, Ron Simmons, and John Schweyan had revolutionized sump diving in the northeastern U.S. during the late 1980s. A team of Brown, Ganter, Lyles, and Sturrock, along with surface Sherpas, hiked to the cave carrying scuba gear, including a single tank, lead weights, dry suit, and a dive computer adjusted for an altitude far above sea level. The gear was taken to the back of the cave where James suited up. Bubbles rose from the murk as Brown's dive lights flickered through clouds of silt. After a few minutes, he surfaced to report that the pool turned sharply to the right and then descended into an impassable hole, the source of the water. The cavers exited the cave, enjoyed a small fire outside, and hauled the gear back down the mountain in chilling fall temperatures.

One team surveyed additional tight fissures in 1996. Then activity waned in the cave for

Gallina Cave entrance. Photo by Gerald Atkinson.

about a decade. In 2008, undergraduate student Justin Bobb of Fort Lewis College took on a cave hydrology project. He began a systematic study of Gallina's water flow, including on the surface, and of CO_2 levels in the cave.

Starting in 2014, members of Pajarito Grotto began a complete resurvey of the cave using modern techniques and software for mapping. This work is ongoing, and additional scooped and unchecked leads have been found that need to be documented. A line-plot map of Gallina Cave is included here.

The perennial stream in Gallina arises at a sump, flows through much of the cave, and then resurges near the entrance. The cave is not significantly decorated with speleothems. Near the first significant room, there is a climb-up that appears to be close to a small entrance. Packrats have taken most of the survey stations into their nests in this area. The cave has several small waterfalls and has moderate potential for further passage discoveries downstream in the low cobble crawl, and in some of the stream pass-throughs close to the entrance. There are leads in side alcoves along the main stream in the second half, but the walls are structurally weak, with unconsolidated breccia.

Because of public knowledge of the cave, including reports in Santa Fe newspapers, Gallina Cave has seen occasional misuse by visitors, including being tagged with spray paint, littered with beer cans, and gunshot through the register container.

It still remains an adventure to hike to this cave, as the forest is absolutely beautiful in summer. One passes wild berries while trekking through Ponderosa pines, followed by groves of aspen, then fir and other coniferous trees.

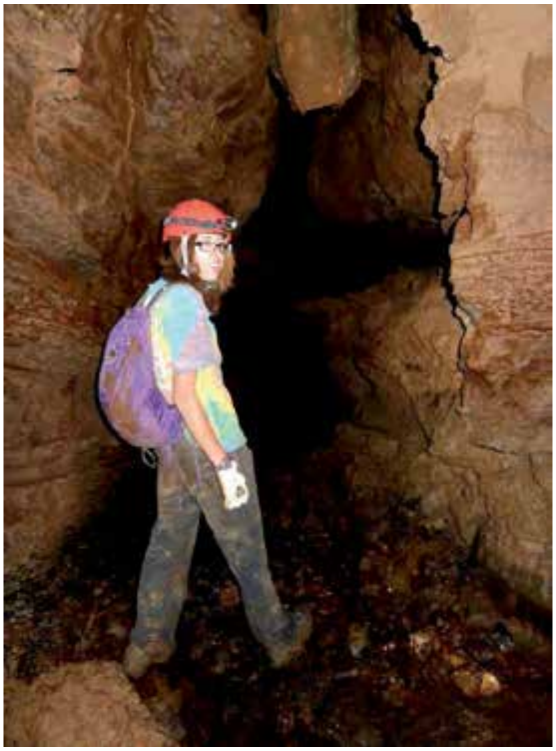
Caution: Beware of bears!

Gallina Cave Description from a 2015 Southwestern Regional Flyer

Gallina Cave is wet, cold, and a long hike from the vehicles, even longer if you are unable to drive up the 4WD access road. Go in the morning to avoid afternoon storms. Bring rain gear for the hike, in case. Preparation should include changing into your caving outfit at the cave in order to have dry clothes, socks and shoes for the return trip. Take a trash bag to store clothes inside the entrance. I prefer wetsuit socks or Seal Skins under caving boots, and expedition polypro long-johns with non-cotton coveralls in the cave—nice when surveying. It can be a full day to hike and get to the back of the cave, so bring a lunch and plenty of water.

The cave has about 3,250 feet of surveyed passage, following a stream at the beginning and end. There are some soda straws, cave pearls and flowstone, but the scenic features are more the clean-washed stream passages than the dripstone.

The cave appears to transport water from under a nearby ridge, possibly crossing under Cave Creek from Gallina Creek. A sump dive by Jim Brown, with John Lyles, Jim Sturrock and



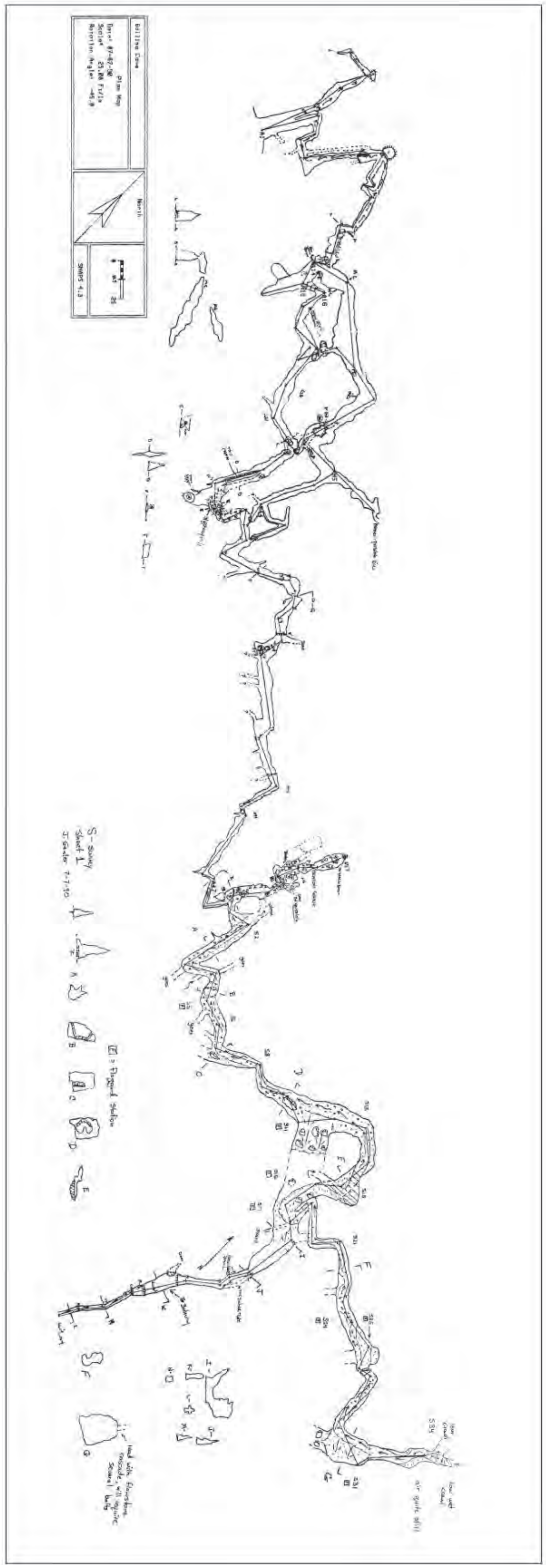
Jenna Burgess in a stream passage, Gallina Cave. Photo by G. Atkinson.

John Ganter as sherpas, was performed in October 1995 to determine if the cave continued beyond the upstream sump. Unfortunately, it constricted to a small hole with a good flow coming out. The water temperature averages 42º F with the air 48º F.

Entering the cave, crawl through the right fork (left goes downstream which, is short and wet), and try to cross the creek using the logjam materials as rafts to keep your arms, feet, and legs dry. Once you are on the opposite bank, move quickly along the left mud bank on hands and knees around the bend. It is possible to stay dry if you are agile and use hand holds in the ceiling and bank. Past this low point, the cave opens to walking passage. Continue past a small waterfall coming in from the side, and climb up near a painted Zia symbol. Don't be fooled that you are done with the water, as there is a short, dry stretch, then another bit of water.

Once out of the water, you must squeeze up a tight chimney called the Lemon Squeeze, passing packs. At the top, continue to follow the cave southeast, duck-walking, then standing up. There is a lower wet level that is exposed in a series of slick muddy pits. Be careful when negotiating around these in the center of the passage. Pass through a small room with the best display of small soda straws. After making the correct duck-unders and belly crawls in several places, the passage continues for several hundred feet before becoming a slot, where you must go under, then over to continue.

You will make a final climb-down into the Lunch Room. Beyond it, you will reach the stream again. A particularly beautiful area is found by going left after the Lunch Room, when reaching the stream again, heading downstream until it disappears under a wall. It's quite sporting and loud when the water level is up. Upstream, the passage continues to enlarge. Follow the water upstream, staying on the silt banks to the high route on the right where convenient, until reaching the terminal room. Be careful of the cave pearls on the floor in the center of the room, below the white flowstone. The stream disappears just beyond.



Hummingbird Cave, Jemez Mountains

Distance from NSS Campground: About 58 miles (93.3 km) to parking area for cave, 80-minute drive one-way. Hike to cave is about 300 feet (91.4 m).

County: Sandoval
Ownership: U.S. Government – Santa Fe National Forest

Length: 33.5 m (109.8 feet)
Depth: 6.1 m (20.1 feet)
Elevation: 8,100 feet

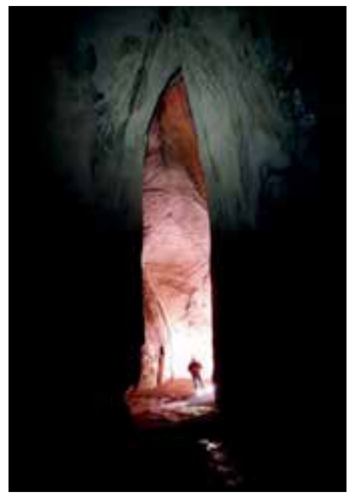
Synopsis: A tectonic cave in tuff.

Description: Hummingbird Cave is formed in the Upper Bandelier Tuff along the north wall of a canyon. This is a tectonic cave created by the widening of a fracture (by running water and freezing action) that was originally created by gravitational block slip away from the cliff face. There are numerous small caves and waterfall alcoves along this cliff face, but Hummingbird is the largest known. There is a small altar in the back of the cave where trinkets are occasionally left by locals.

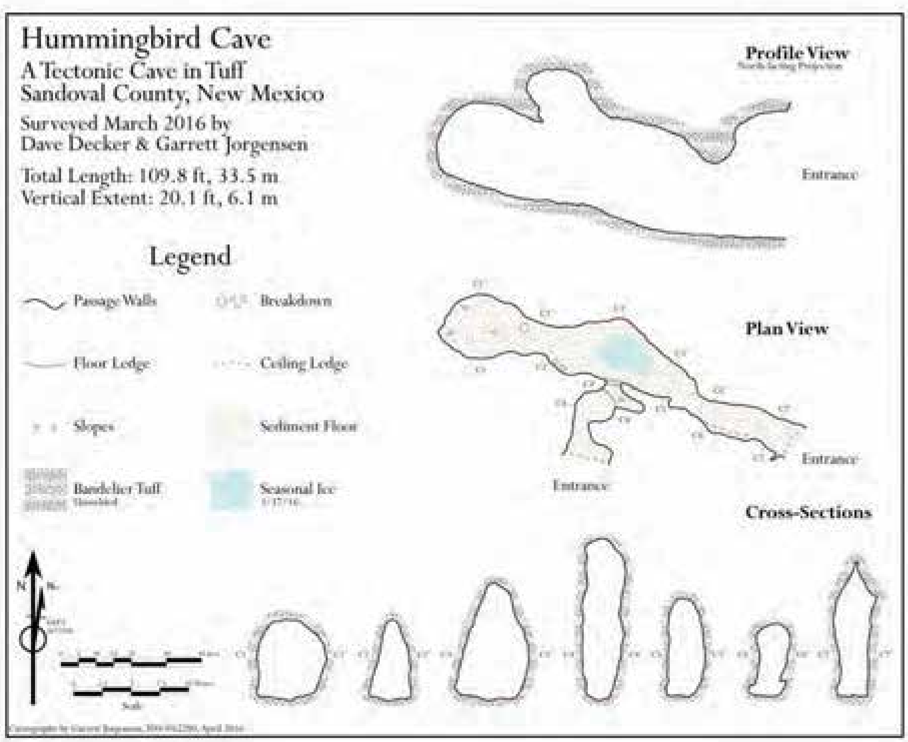
Recommended: This trip should be combined with a trip through Gilman Tunnels and Ponderosa Winery as a half-day drive.

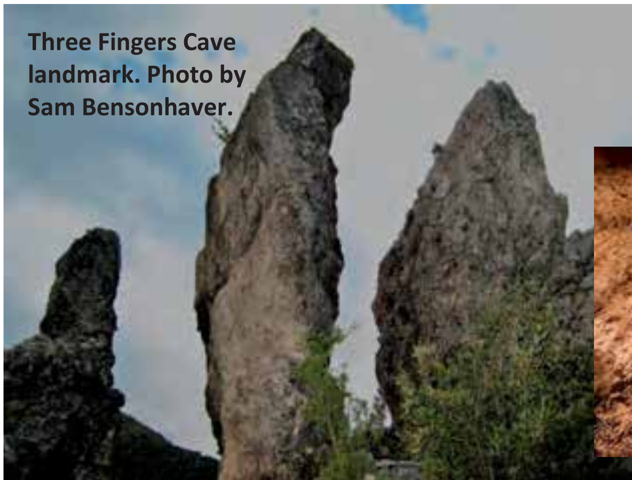
Special equipment or precautions: None.

Parking:
N 35° 52.750'
W 106° 42.040'



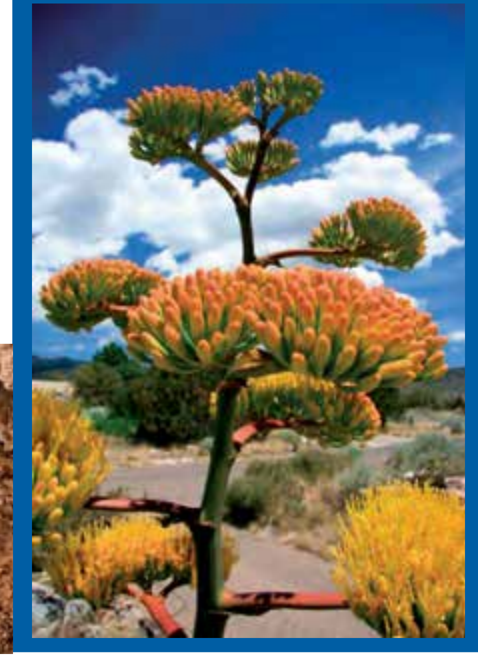
Hummingbird Cave Shelter. Photo by Dave Decker.



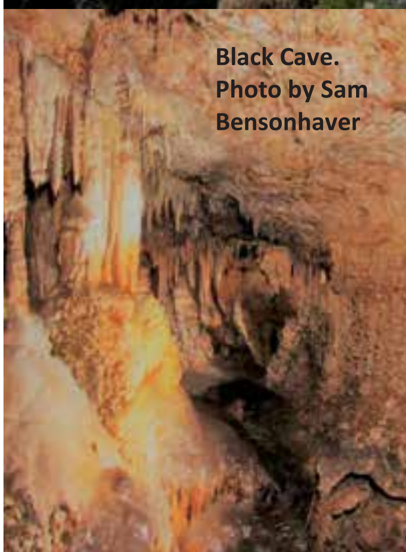


Three Fingers Cave landmark. Photo by Sam Bensonhaver.

A century plant agave. Photo by Sam Bensonhaver.



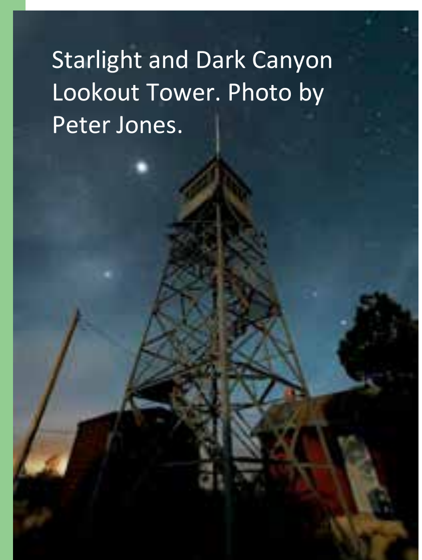
Bear Skeleton, Pink Panther Cave. Photo by Peter Jones.



Black Cave. Photo by Sam Bensonhaver

Southern New Mexico

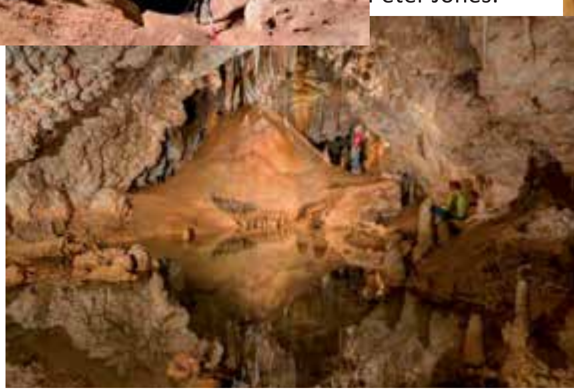
Guadalupe Mountains and Chosa Draw



Starlight and Dark Canyon Lookout Tower. Photo by Peter Jones.

Scott Christenson rappels into Deep Cave. Photo by Peter Jones.

New Year's Eve Gallery, Hell Below Cave. Photo by Sam Bensonhaver.



Lake Room, Virgin Cave. Photo by Peter Jones.

Amy Pierce stands in the delicate rimstone pool area of Andy's Cave. Photo by Peter Jones.

Andy's Cave

Alternate Names: C-51
County: Eddy
Ownership: U.S. Government – Lincoln National Forest

Length: 213 m (698 feet)
Depth: 33 m (109 feet)
Elevation: 6015 feet

Synopsis: A relatively small, well-decorated cave.

Description: The entrance is a 1-m-square hole, dropping 20 m as a free rappel into a narrow slot and then onto the top of a breakdown pile. From there, one can go two ways. The passage to the NW goes to a dry pool of silt and mud that ends fairly quickly after about 45 m. The other passage to the SE leads to the major part of the cave and is well-decorated but relatively dry. A second, 10-m drop into a second parallel passage can be down-climbed with a hand line, but vertical gear is recommended. The cave is developed along two parallel joints and passages average 2 to 6 m wide and 5 to 12m high.

Special equipment or precautions: Rope and vertical gear for two drops. The entrance drop becomes a waterfall during heavy rains.

Permissions: Permit required.

References:

Jones, Peter. 2012. Discovery of Nudnick and Andy's Caves. Pp. 56-60 in: *Southwestern Region, NSS: 50 years 1962 - 2012*, Linda Starr (ed.), Southwestern Region of the NSS, 112 pp.

Black Cave

Alternate Names: C-03
County: Eddy
Ownership: U.S. Government – Lincoln National Forest

Length: ~470 m (~1550 feet)
Depth: 30 m (97 feet)
Elevation: 6520 feet

Synopsis: A horizontal cave known for its black speleothems.

Description: Black Cave gets its name from the coloring of the formations in the main part of the cave. Once thought of as a rather small but pretty cave of no particular merit, upon further exploration, a lower section was discovered which is highly decorated and has at least one lake. (The main portion of Black Cave is an easy trip along a series of parallel, joint-controlled passages that average 2- to 11-m wide and from 1.5- to 11-m high. A vertical crack 15 cm wide by 2 m high at the back of the third parallel passage blows air but becomes too tight. The lower portion of the cave requires a traverse over a pool. Black Cave contains black-coated stalactites, stalagmites, and flowstone, with grapestone, popcorn, lily pads, some massive gypsum, and a fairly deep lake at the back.

Special equipment or precautions: none

Permissions: Permit required.

References:

Belski, Dave, Carol Belski, and Fritzie Hardy (eds.). 1986. Black Cave. Pp. 34, 35 in: *1986 NSS Convention Guidebook, Tularosa, New Mexico, NSS Convention Guidebook* No. 25, vi + 65 pp.

Hose, Louise, Steve Peerman, and Larry Pardue (eds.). 2009. Black Cave. Pp. 13, 14 in: "Scientific Rambles through southeast New Mexico and Caves of the Guadalupe Mountains and Surrounding Area, New Mexico." *Field Trip Guidebook for the 15th International Congress of Speleology of the International Union of Speleology, National Speleological Society*, 35 pp.

A white stalagmite stands out proudly against the dark background in Black Cave. Photo by Peter Jones.

Cave Tree Cave

Alternate Names: C-46
County: Eddy
Ownership: U.S. Government – Lincoln National Forest

Length: 175 m (575 feet)
Depth: -18 m (-60 feet)
Elevation: 6565 feet

Synopsis: A well-decorated, horizontal fissure cave.

Description: The small, gated entrance is obscure and often difficult to locate. A 1.3-m

Speleothems in Cave Tree Cave. Photo by Sam Bensonhaver.

cross the pristine flowstone. The cave consists of three fissure passages developed on parallel joints. A very tight squeeze about 1 m off the floor on the left wall near the back of the cave connects to the Soda Straw Splendor passage. The cave is very well-decorated, with clear helictites, soda straws up to 1.5 to 2 m long, columns, stalactites and stalagmites, flowstone, cave pearls, and snake dancers. One needs to proceed with caution in the narrow passages to avoid damaging the speleothems.

Special equipment or precautions: Aqua socks. Move with caution in the narrow passages to avoid damaging the speleothems.

Permissions: Permit required.

Deep Chamber: Deep Cave has a long drop into the main chamber. The giant room has many large stalagmites and columns as well as an abundance of broomstick stalagmites. Photo by Peter Jones.

Deep Cave

Deep Entrance looking out. Deep Cave is not only deep, but also large in volume. The entrance is about 50' high and wide and only gets larger on the inside. Photo by Peter Jones.

Alternate Names: Deep Hole
County: Eddy County
Ownership: U.S. Government – Carlsbad Caverns National Park

Length: 292 m (958 feet)
Depth: 140 m (459 feet)
Elevation: 6135 feet

Synopsis: A large, well-decorated cave with a deep entrance drop.

Description: The large entrance passage measures 8 m wide by 15 m high and slopes down from the 15-m diameter entrance at a 45° angle. It lands on a ledge containing a large boulder and a small stalagmite overlooking a large and deep pit that contains Jim White's 1935 ladder. The vertical, offset drop requires the use of a 110-m rope and is rigged from this ledge. The drop brings you to the top of a breakdown hill in a large, dome-shaped room that is about 100 m below the entrance datum. The room is 150 m long, 50 to 75 m wide and approximately 45 m high. Except for one pool, the cave is dry and is well-decorated with totems, columns, shields, large stalagmites, dogtooth spar, bell canopies and helictites. Jim White reportedly first entered the cave in 1911 and dropped a lantern while unsuccessfully attempting to descend the entrance drop by rope. He returned in May 1935 with Ben Jerome, Pete Jerome, Dave Mitchell, and Lonnie Wilson, and successfully reached the bottom of the drop using a wire and wooden ladder that remains in the cave today. The group spent five days exploring the cave, and Jim found his old lantern from 1911 at the base of the entrance drop.

During the National Geographic Expedition of 1924, Willis T. Lee, Carl Livingston, and others visited the entrance during the first week of August 1924, and made soundings of the entrance drop by dropping a can. The first complete survey of the cave was made in 1970.

Water Drop in the Deep: This water drop has a life span of roughly 5 minutes. As it grows in size, it finally touches the sharp point beneath it and disappears from the tip of the stalactite from which it grows, only to be replaced by yet another drop of water. Photo by Peter Jones.

Massive, "dead" stalactites, stalagmites, bell canopies and columns occur in Deep Cave. Many of the columns have fallen to the floor and are cracked perpendicular to their length. Other carbonate speleothems in Deep Cave include flowstone, draperies, popcorn, rimstone, dogtooth spar, helictites and shields. Two of the shields are noteworthy in that they have grown on a massive, 17-m-high stalagmite rather than along the wall. The shields, 2 m and 0.3 m in diameter, are oriented perpendicular to each other and have formed along cracks in the desiccated stalagmite. Antler helictites, similar to those in Left Hand Tunnel of Carlsbad Caverns, are also found in the cave. Deep Cave helictites have many horizontally bifurcating branches which resemble deer antlers.

Special equipment or precautions: Rope and vertical gear for entrance drop and hand line down to rigging ledge.

Permissions: Permit required.

References:

Belski, Dave, Carol Belski, and Fritzie Hardy (eds.). 1986. "Deep Cave." Pp. 29, 30 in: *1986 NSS Convention Guidebook*, *Tularosa, New Mexico*, NSS Convention Guidebook No. 25, vi + 65 pp.

Hell Below Cave

Alternate Names: C-09, Hell's Below Cave, Old Granddad Cave
County: Eddy
Ownership: U.S. Government – Lincoln National Forest

Length: ~760 m (~2500 feet)
Depth: 168 m (550 feet)
Elevation: 6710 feet

Synopsis: A large, well-decorated vertical cave.

A beautiful, active helictite in Hell Below Cave.
Photo by Peter Jones.

Description: The entrance of Hell Below (HB) Cave is a small, gated crawlway that opens to a descending talus slope for about 45 m to a 6-m-deep chimney. At the bottom of the chimney is a crawl that shortly opens out into the ceiling of a deep fissure cutting back under the entrance passage. The drop is about 20 m into the main corridor of the cave, which averages 3 to 13 m wide and 11 to 45 m high. The cave trends in a north-south direction with passages developed along several parallel joint trends. A deep rift in the floor of the main passage can be descended in several places, and leads to a difficult, multi-level fissure that has not been completely surveyed. The deepest section of the cave lies at the bottom of the rift, approximately 250 m from the entrance. Due to the extreme danger of falling gypsum and limestone blocks, this area is seldom visited.

Farther into the cave, the passage splits and the rate of decoration increases. Massive flowstone slopes, beautiful stalagmites, exquisite stalactites, astonishing helictites, and pristine cave pearls decorate the cave. Several lakes are present and speleothems seem to flow into the water. One lake is the size of a large, rectangular swimming pool and is over 2.5 m deep. Unique speleothems influenced by presently unknown biologic entities are found in some of the five large pools within the cave.

Lois Manno stands in The Gyp Joint, a side passage lined with gypsum formations, off the New Year's Eve Gallery of HB Cave. Photo by Peter Jones.

About 400 m from the entrance are two holes that lead to a second parallel passage called the New Year's Eve Gallery—a heavily decorated area with cave pearls and orange flowstone. The Gyp Joint, a side passage off the main corridor, is a narrow tunnel solidly encrusted with pure white gypsum for over 30 m. Depending upon the humidity in the cave, gypsum flowers, angel hair, and large gypsum extrusions can be found here. Calcite rafts are growing on some of the small pools in the Gyp Joint. Visitors need to take extreme care in this area, as it is easy to damage the delicate gypsum in the narrow passage.

Special equipment or precautions: Rope and vertical gear for the entrance area fissure.

Permissions: Permit required.

References:

Belski, Dave, Carol Belski, and Fritzie Hardy (eds.). 1986. "Hell Below Cave." Pp. 39-41 in: *1986 NSS Convention Guidebook, Tularosa, New Mexico*, NSS Convention Guidebook No. 25, vi + 65 pp.

Hose, Louise, Steve Peerman, and Larry Pardue (eds.). 2009. "Hell Below Cave." Pp. 19-21 in: *Scientific Rambles through Southeast New Mexico and Caves of the Guadalupe Mountains and Surrounding Area, New Mexico. Field Trip Guidebook for the 15th International Congress of Speleology of the International Union of Speleology*, National Speleological Society, 35 pp.

Speleothems in Speleogasm, Pink Panther Cave. Photo by Sam Bensonhaver.

Pink Panther Cave

Alternate Names: C-25
County: Eddy
Ownership: U.S. Government – Lincoln National Forest

Length: 351 m (1150 feet)
Depth: 42 m (137 feet)
Elevation: 6170 feet

Synopsis: A well-decorated, vertical cave with an articulated bear skeleton (the "Panther").

Panther Cave are well-hidden near the base of a 10-m cliff. The Entrance Room slopes downward and narrows into a high fissure that drops

Phyllis Boneau stands by the Pagoda formation in Pink Panther Cave. Photo by Peter Jones.

A close-up of the skull of a full short-faced bear skeleton in the bottom of Pink Panther Cave. This species went extinct about 11,000 years ago, yet the remains are in excellent shape. Photo and caption by Peter Jones.

vertically 15 m into the Main Hallway of the cave. From the bottom of the drop, the cave continues down the main corridor for about 110 m, averaging 5- to 10-m wide and 8- to 20-m high. The Main Hallway's entrance fissure extends into the ceiling along most of its length. At about the two-thirds point, another similar passageway intersects at a 45° angle. This passage is 45 to 60 m long, and named the Pit Hall after three or four small rimstone-lined pits.

The cave's namesake panther was found in the last of these pits, in a small room at the bottom under a huge deposit of flowstone and rimstone. The bones were covered with a coating of calcite about 5 mm thick. The articulated skeleton was initially misidentified as a mountain lion *(Felis concolor)*. It is actually a short-faced bear *(Arctodus simus)*.

The cave has an abundance of speleothems, including stalactites, stalagmites, totem poles, soda straws, helictites, cave coral, popcorn, draperies, flowstone, rimstone, gypsum crusts, and moonmilk. A number of multi-tiered bell canopies also occur in the cave.

Special equipment or precautions: Rope and vertical gear for the entrance drop.

Permissions: Permit required.

References:

Harris, Arthur H. 2009. *Pink Panther Cave. Pleistocene Vertebrates of Southwestern USA and Northwestern Mexico*, https://www.utep.edu/leb/pleistnm/sites/pinkpanthercave.htm [accessed 24 April 2016].

Hill, Carol A. 1978. "Mineralogy of the Pink Caves, Guadalupe Mountains, New Mexico," *Cave Research Foundation 1977 Annual Report*, p.15.

Red Lake Cave

Alternate Names: C-04
County: Eddy
Ownership: U.S. Government – Lincoln National Forest

Length: 31 m (100 feet)
Depth: 14 m (45 feet)
Elevation: 5590 feet

Synopsis: A small, vertical cave.

Description: The gated entrance measures 0.8 m wide by 2 m long, and drops 14 m to a single room approximately 12 m long, 4 to 6 m wide, and from 5 to 9 m high. The flat floor consists of dirt and minor breakdown. The remains of an old barbed wire and wooden rung ladder can be seen on the floor of the cave.

Special equipment or precautions: Rope and vertical gear for entrance drop.

Permissions: Permit required.

Three Fingers Cave

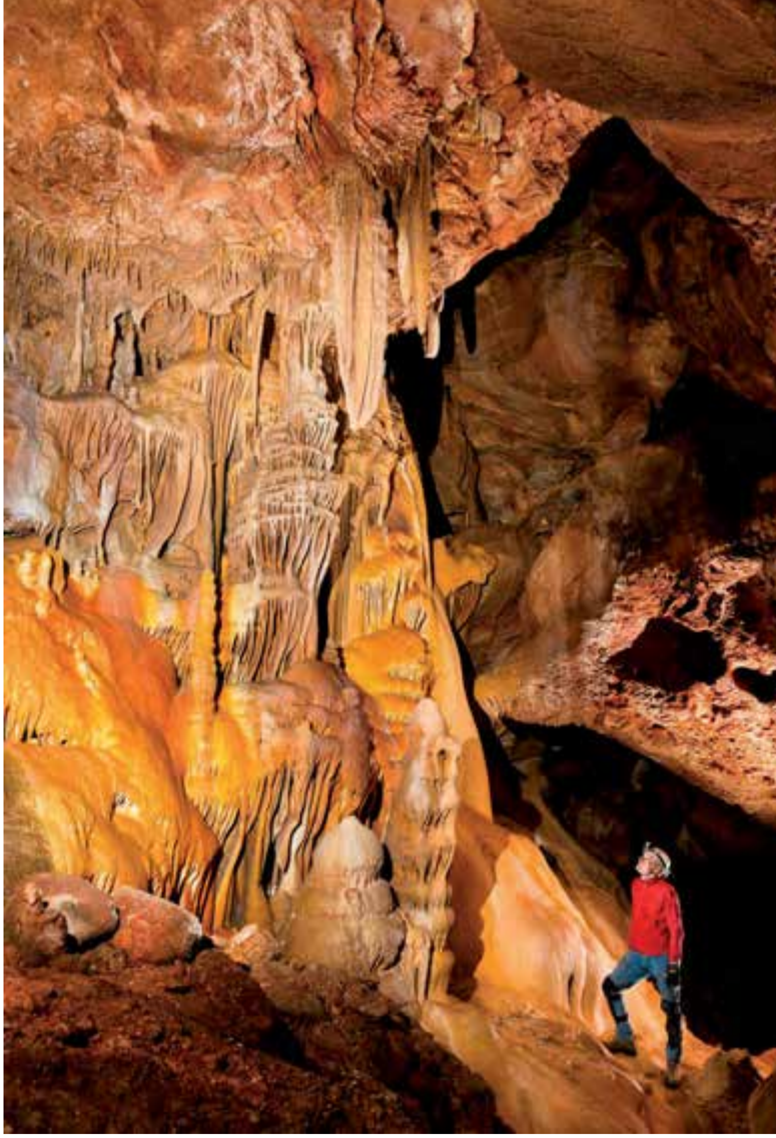
Alternate Names: C-30
County: Eddy
Ownership: U.S. Government – Lincoln National Forest

Length: 5955 m (19,538 feet)
Depth: 177 m (581 feet)
Elevation: 6190 feet

Synopsis: A large, well-decorated, multi-level maze cave.

Description: The narrow entrance to Three Fingers leads to the top of a 27-meter-deep, offset fissure that drops into a decorated, massive breakdown chamber (Bell Room). From there, an extensive, complex, multi-level maze extends in different directions. Numerous pits and breakdown leads abound. The lower cave is accessed by slithering down the Meador Pincher—a 30-cm by 1-m-wide and 4-m-deep vertical crack. The Temple of the Fiery Cave God is one of the sights along the "tourist route." Beyond the temple, a 23-m chimney leads down to the second largest room yet found, Three Fingers Hall. A 60-m rope is required to enter the hall. Bypassing the hall, one can continue down through house-sized boulders into areas that promise further leads. Despite repeated efforts over the years, no complete map of the cave has been drafted.

Three Fingers Cave has an abundance of spectacular formations throughout its many passages, but the centerpiece is the Bell Canopy in the main room at the bottom of the entrance drop. Photo and caption by Peter Jones.



Deep inside Three Fingers Cave is the bloody red wall of the Temple of the Fiery Cave God. Despite its name, it is a beautiful room inside a gorgeous cave. Photo and caption by Peter Jones.

Speleothem development is found throughout the cave. The Bell Room contains columns 3 to 5 m tall and is named for a prominent bell canopy stalagmite. The walls, floors, and ceilings throughout the cave are decorated with stalactites and stalagmites, shields, helictites, soda straws, popcorn, draperies, and cave pearls. The Temple of the Fiery Cave God is a beautiful display of large, multi-colored, actively growing flowstone cascade. Unusual mineralogies include celestite patches and goethite stalagmites. Many of the unusual speleothems and mineralogies from the famous Lechuguilla Cave also occur in Three Fingers Cave, but on a smaller scale in regard to size and distribution.

Special equipment or precautions: Rope and vertical gear for entrance drop.

Permissions: Permit required.

References:

Belski, Dave, Carol Belski, and Fritzie Hardy (eds.). 1986. "Three Fingers Cave." Pp. 46, 48 in: *1986 NSS Convention Guidebook, Tularosa, New Mexico, NSS Convention Guidebook* No. 25, vi + 65 pp.

Hill, Carol A. 1979. "Mineralogy of Three Fingers Cave, Lincoln National Forest, New Mexico." *Cave Research Foundation 1978 Annual Report*, p. 18.

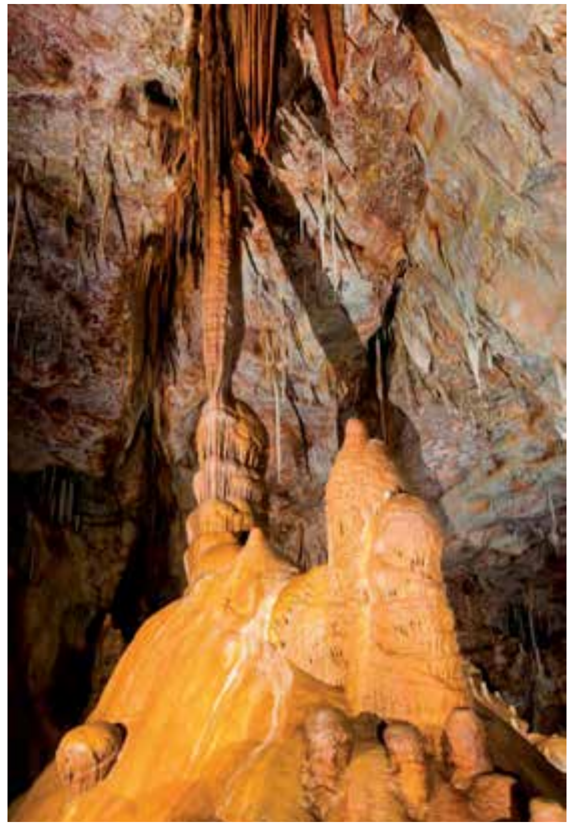
Hose, Louise, Steve Peerman, and Larry Pardue (eds.). 2009. "Three Fingers Cave." Pp. 27, 29 in: Scientific Rambles through Southeast New Mexico and Caves of the Guadalupe Mountains and Surrounding Area, New Mexico. *Field Trip Guidebook for the 15th International Congress of Speleology of the International Union of Speleology, National Speleological Society*, 35 pp.

Virgin Cave

Alternate Names: C-90, Blowing Cave
County: Eddy
Ownership: U.S. Government – Lincoln National Forest

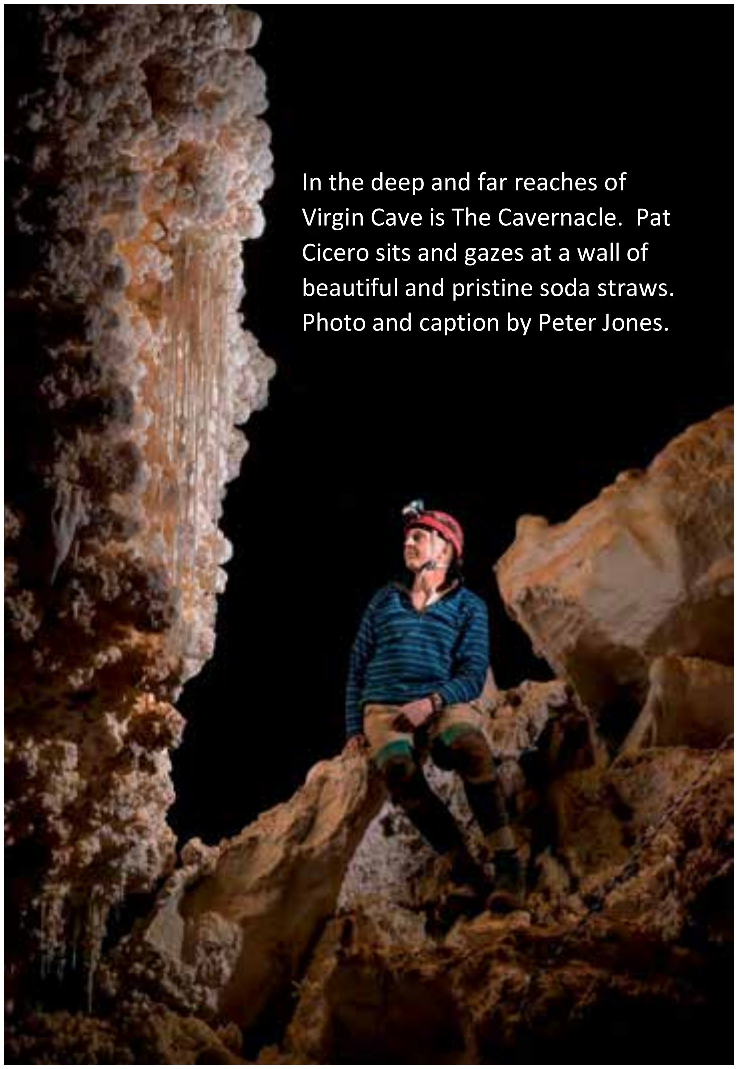
Length: 4892 m (16,050 feet)
Depth: 220 m (723 feet)
Elevation: 6710 feet

Synopsis: A large, well-decorated, vertical maze cave.



Grunge Hall Drapes: Virgin Cave is perhaps the most beautiful cave in Lincoln National Forest and also one of the most difficult. Grunge Hall is a beautiful chamber filled with many large and varied formations. Photo and caption by Peter Jones.

Description: From the canyon rim, one must drop about 120 m to reach the 1.3- by 3-m-high entrance crack that leads to what some consider one of the most beautiful caves in the Guadalupes. Entering the main part of the cave requires a 25-m rappel and the negotiation of a confusing maze. Above the drop, the cave continues into the ridge, along a maze route that requires exposed climbing and is considered difficult. This leads to the same area one would reach by going down through the Root Room to the Pseudo-Tolkien Room and on to the rear of

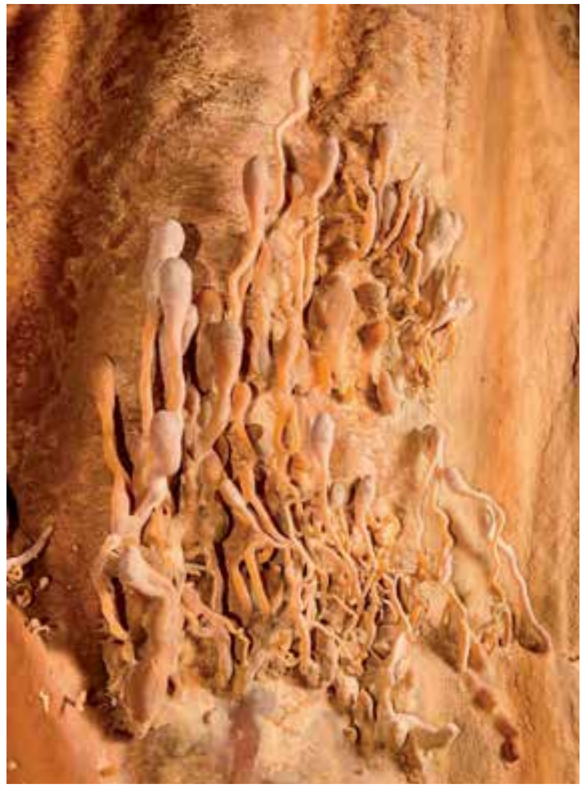


In the deep and far reaches of Virgin Cave is The Cavernacle. Pat Cicero sits and gazes at a wall of beautiful and pristine soda straws. Photo and caption by Peter Jones.

the cave. Most cavers take the scenic "tourist route," which leads to the Lake Room. Traveling to the Cavernacle area requires a special permit. A series of deep drops and a long tyrolean have been permanently rigged, thus saving cavers the experience of rigging and derigging 300 m of rope down the Four O'Clock Staircase and back up again to the Cavernacle.

Virgin is a heavily decorated cave, and many of the iconic features that are associated with the Guadalupe caves are found within it. The cave's exceptional speleothem displays include massive stalagmites and stalactites, totems, large sinuous snake dancers, the Peppermint Tree drapery, crystal-lined pools, dense helictite patches amongst soda straws, and other delights. Virgin Cave has suffered from heavy caver traffic, and despite the enormous efforts of both the High Guads Restoration and Virgin Cave Restoration projects to restore the cave, human impact can still be seen in all areas of the cave.

Special equipment or precautions: Vertical gear for the various drops in the cave. One should be proficient in advanced vertical techniques to visit the Cavernacle.



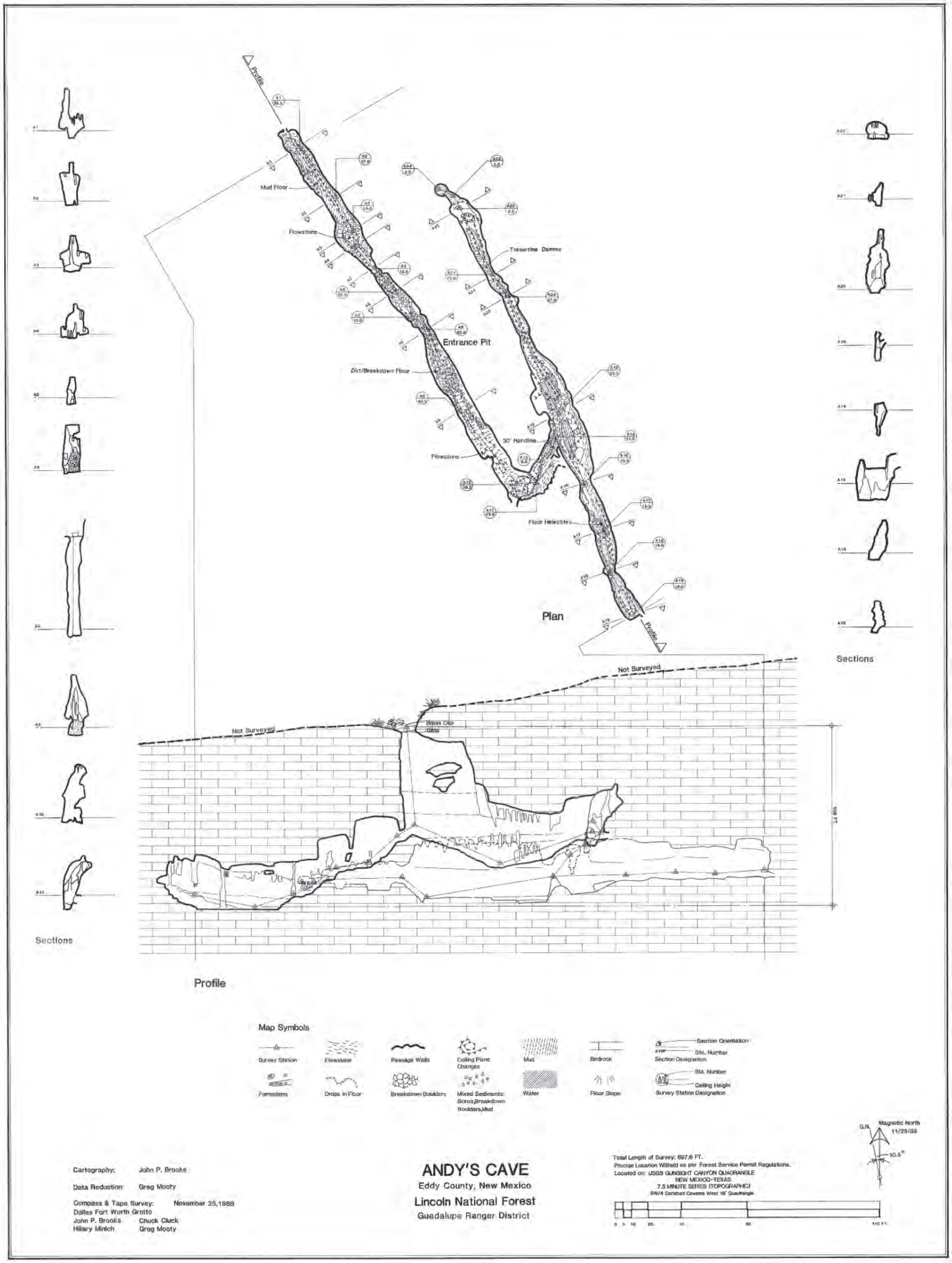
Virgin Cave in the Guadalupes is known for many spectacular sights and the Snake Dancers are but one of the many to be seen. Photo and caption by Peter Jones.

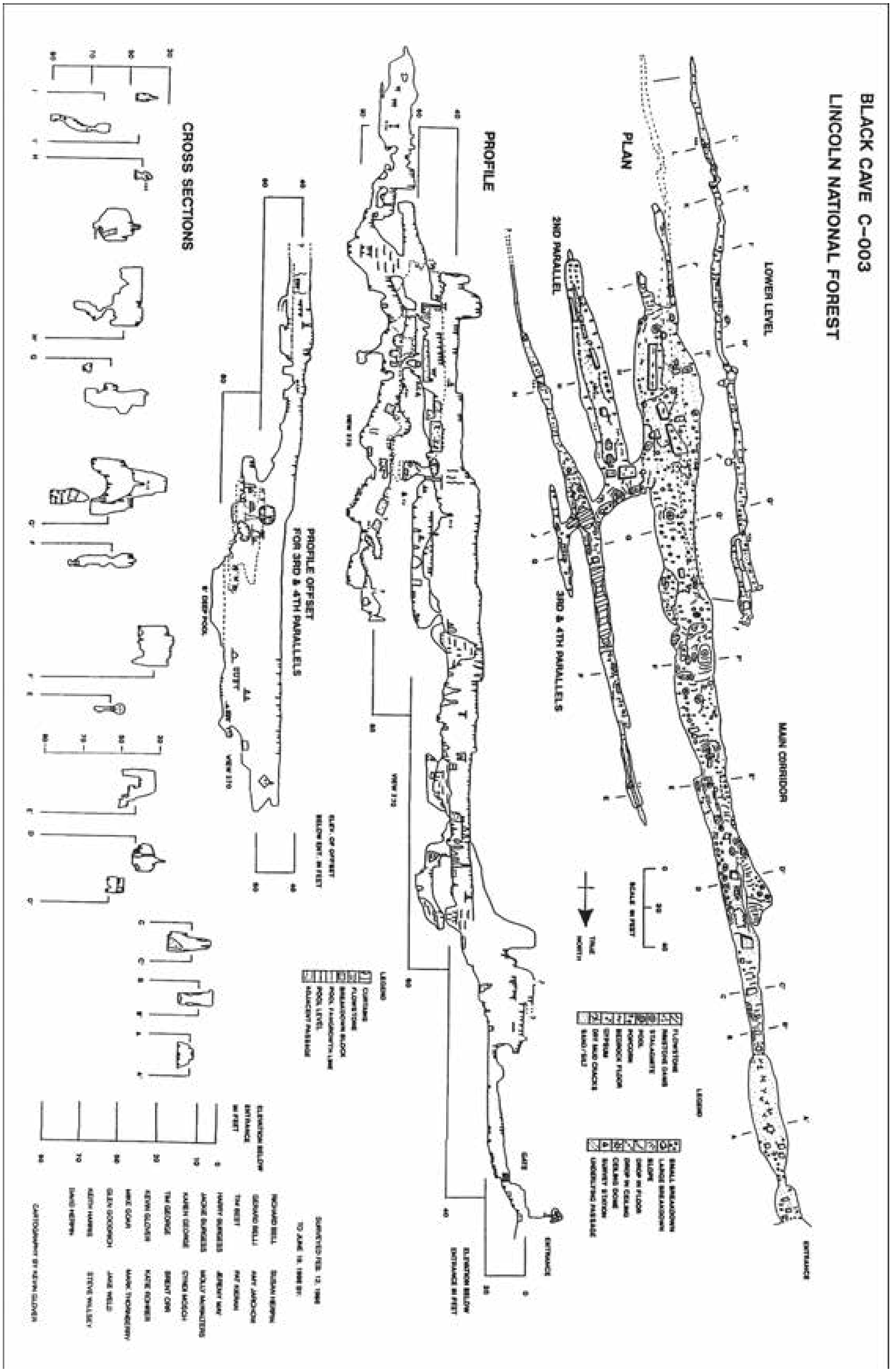
Permissions: Permit required.

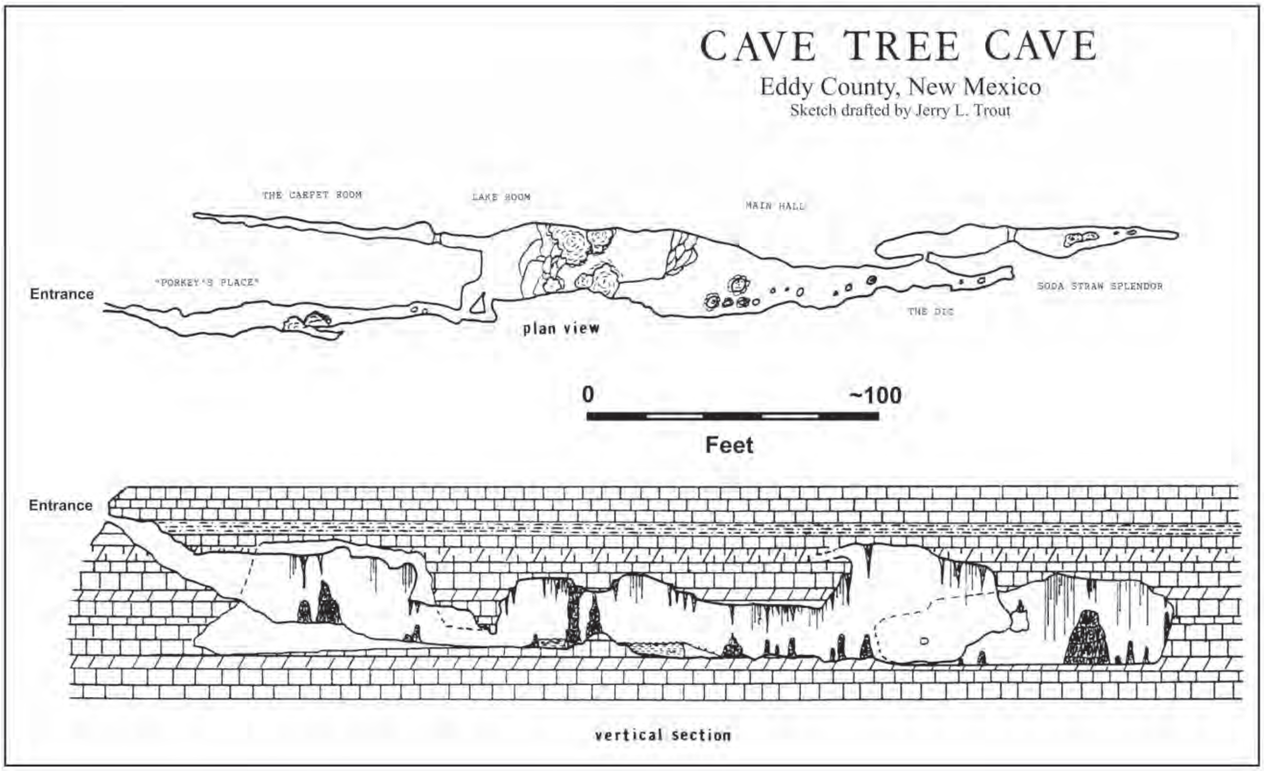
References:

Belski, Dave, Carol Belski, and Fritzie Hardy (eds.). 1986. Virgin Cave. Pp. 49-50 in: *1986 NSS Convention Guidebook, Tularosa, New Mexico*, NSS Convention Guidebook No. 25, vi + 65 pp.

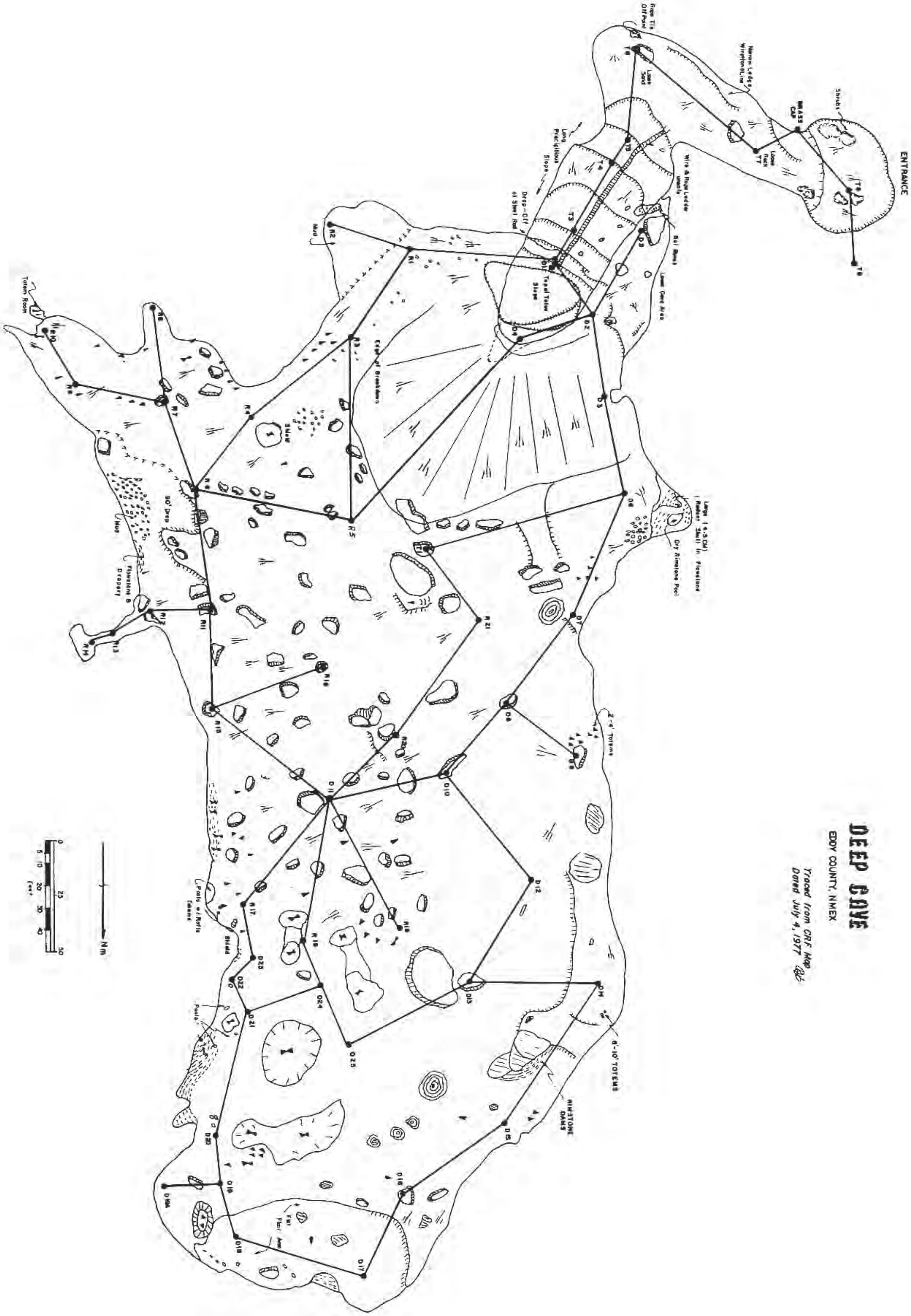
Hose, Louise, Steve Peerman, and Larry Pardue (eds.). 2009. Virgin Cave. Pp. 29, 30 in: Scientific rambles through southeast New Mexico and caves of the Guadalupe Mountains and surrounding area, *New Mexico. Field Trip Guidebook for the 15th International Congress of Speleology*.

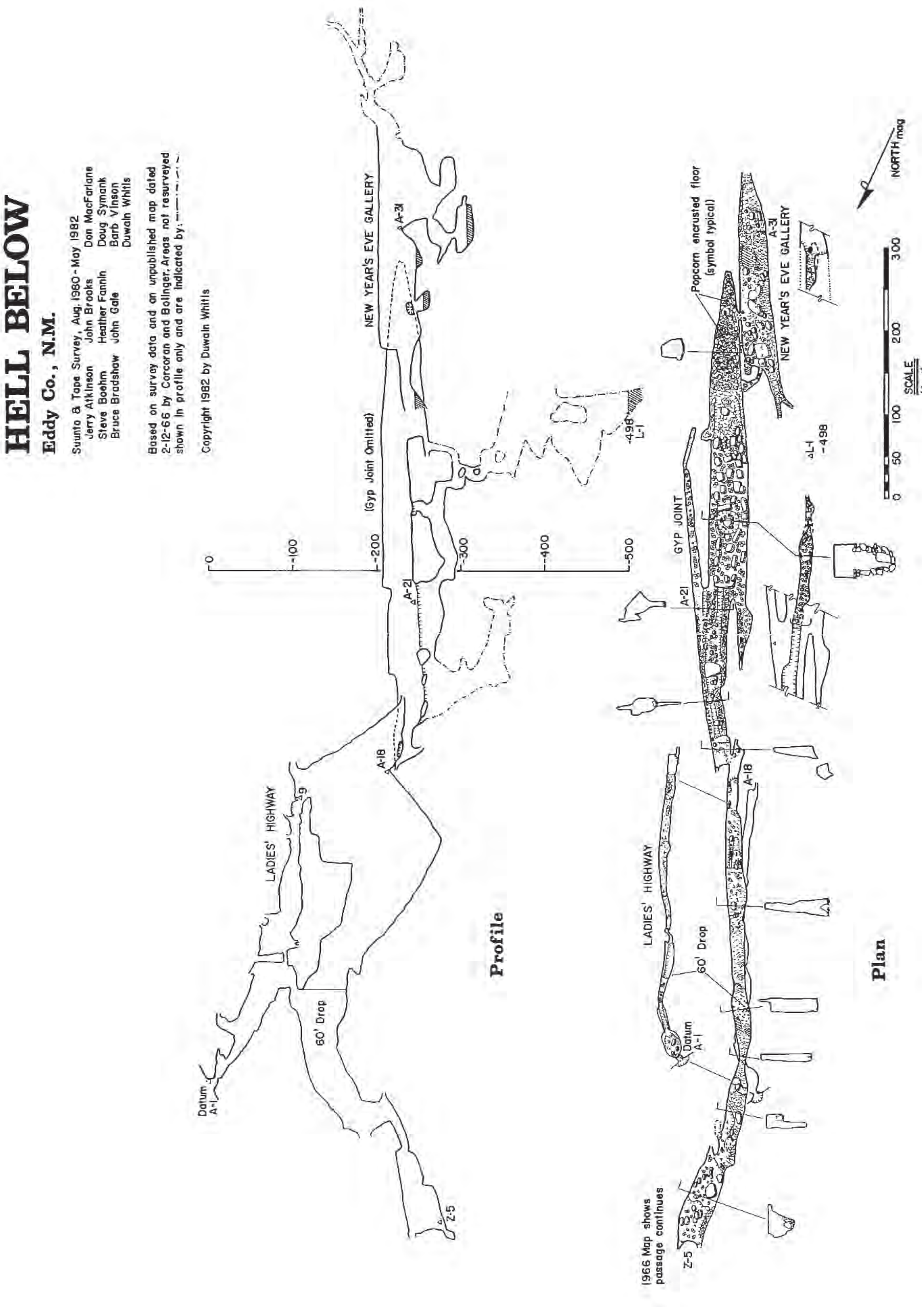

Profile
Mud Floor
Flowstone
Travertine Damns
Entrance Pit
Dirt/Breakdown Floor
30' Handline
Flowstone
Floor Helectites
Plan
Sections
Not Surveyed
Not Surveyed
Brass Cap
Gate
Sections
Profile
Map Symbols
Survey Station
Flowstone
Passage Walls
Ceiling Plane Changes
Mud
Bedrock
Section Orientation
Sta. Number
Section Designation
Formations
Drops in Floor
Breakdown Boulders
Mixed Sediments: Scree,Breakdown Boulders,Mud
Water
Floor Slope
Sta. Number
Ceiling Height
Survey Station Designation
G.N.
Magnetic North 11/25/89
10.5°
Cartography: John P. Brooks
Data Reduction: Greg Mooty
Compass & Tape Survey: November 25,1989
Dallas Fort Worth Grotto
John P. Brooks Chuck Cluck
Hilary Minich Greg Mooty
ANDY'S CAVE
Eddy County, New Mexico
Lincoln National Forest
Guadalupe Ranger District
Total Length of Survey: 697.6 FT.
Precise Location Witheld as per Forest Service Permit Regulations.
Located on: USGS GUNSIGHT CANYON QUADRANGLE
NEW MEXICO-TEXAS
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 Carlsbad Caverns West 15' Quadrangle

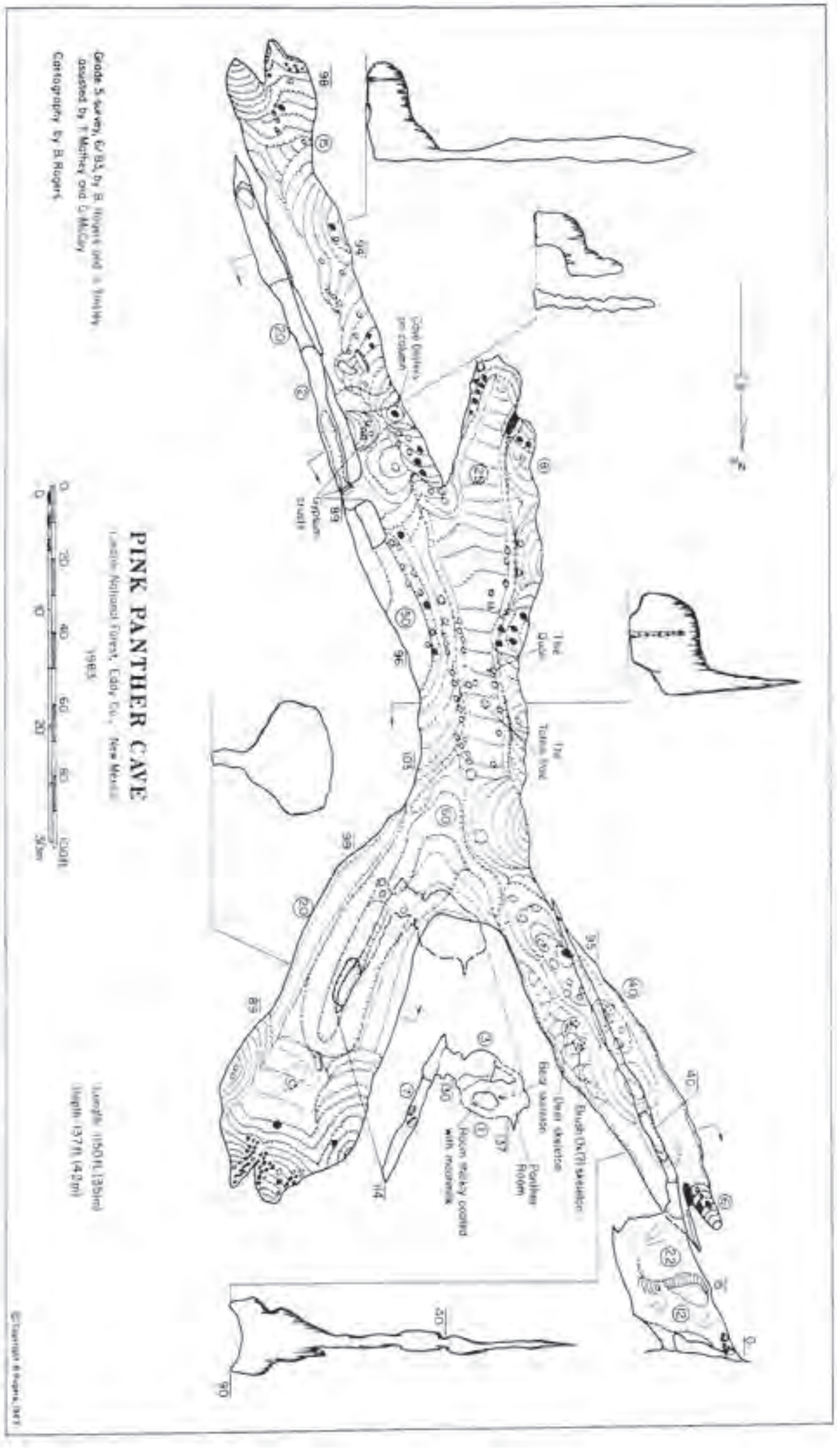

BLACK CAVE C-003
LINCOLN NATIONAL FOREST
PLAN
LOWER LEVEL
2ND PARALLEL
3RD & 4TH PARALLELS
MAIN CORRIDOR
PROFILE
PROFILE OFFSET FOR 3RD & 4TH PARALLELS
CROSS SECTIONS
ENTRANCE



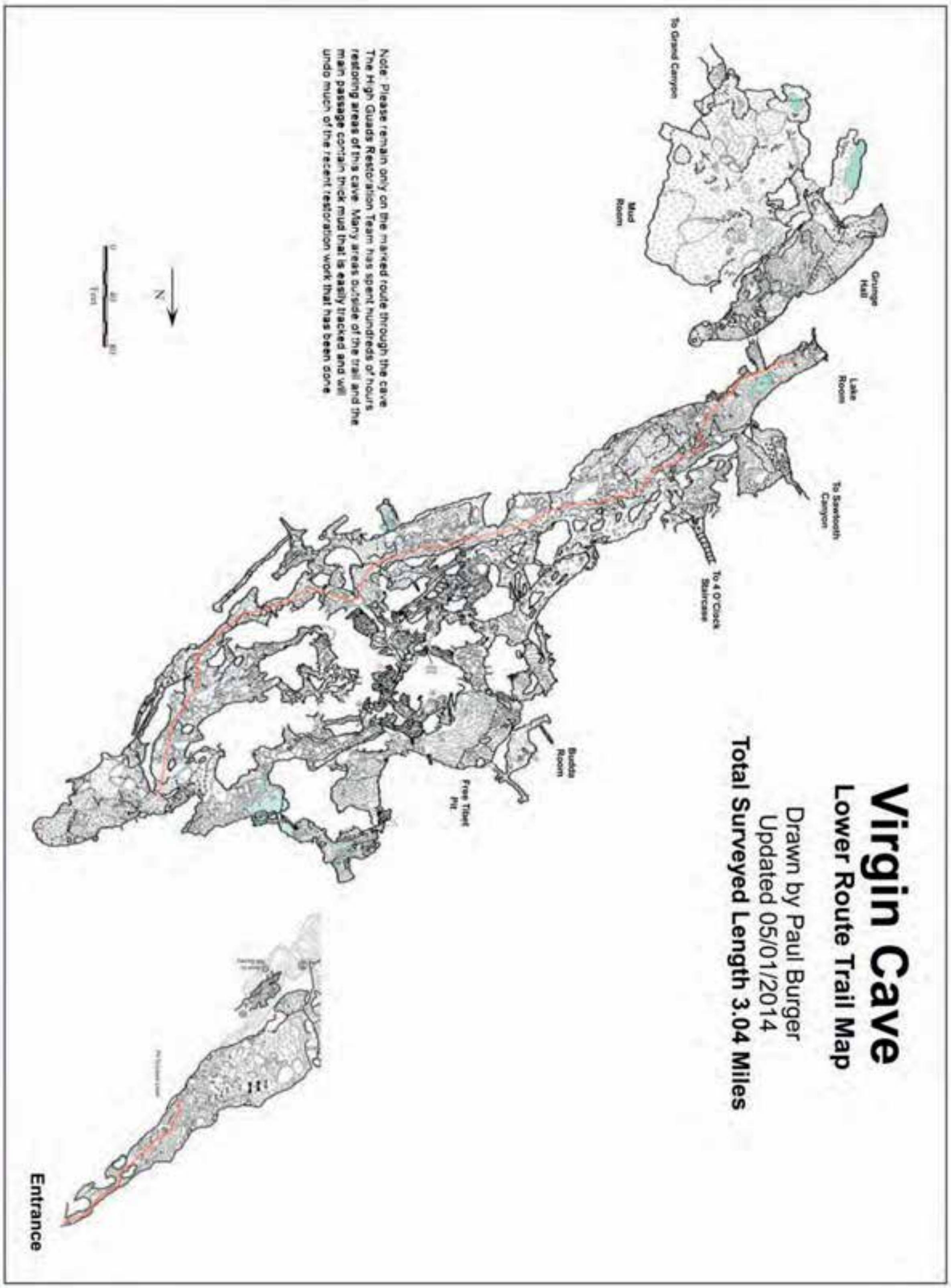
Ridge Above Deep. If there is one thing to be said about The Guads, it is rough and beautiful country. Access to many caves requires a long drive over 4WD roads, then a long hike and drop down into side canyons to the caves. Difficult, yes, but well worth the effort to see some of the finest caves in the entire world. Photo and caption by Peter Jones.


DEEP CAVE
EDDY COUNTY, NMEX
Traced from CRF Map
Dated July 4, 1977
ENTRANCE


HELL BELOW
Eddy Co., N.M.
Suunto & Tape Survey, Aug. 1980-May 1982
Jerry Atkinson John Brooks Don MacFarlane
Steve Boehm Heather Fannin Doug Symank
Bruce Bradshaw John Gale Barb Vinson
Duwain Whitis
Based on survey data and an unpublished map dated 2-12-66 by Corcoran and Bollinger. Areas not resurveyed shown in profile only and are indicated by:
Copyright 1982 by Duwain Whitis
Profile
Datum A-1
60' Drop
LADIES' HIGHWAY
A-18
A-21
(Gyp Joint Omitted)
NEW YEAR'S EVE GALLERY
A-31
-498 L-1
0
100
200
300
400
500
Z-5
Plan
1966 Map shows passage continues
GYP JOINT
Popcorn encrusted floor (symbol typical)
SCALE (feet)
0 50 100 200 300
NORTH mag


PINK PANTHER CAVE
1983
Panther Room


ENTRANCE
BOOMERS LANDING
BREAKDOWN
PILE
ENTRANCE
BOOMERS LANDING
BELL ROOM
THREE FINGERS HALL
SQUEEZE
ZEN ROOM
THREE FINGERS CAVE
EDDY COUNTY, NM
SCALE-FEET


Virgin Cave
Lower Route Trail Map
Drawn by Paul Burger
Updated 05/01/2014
Total Surveyed Length 3.04 Miles
Entrance
Free Tibet Pit
Budda Room
To 4 O'Clock Staircase
To Sawtooth Canyon
Lake Room
Grunge Hall
Mud Room
To Grand Canyon
Note: Please remain only on the marked route through the cave. The High Guads Restoration Team has spent hundreds of hours restoring areas of this cave. Many areas outside of the trail and the main passage contain thick mud that is easily tracked and will undo much of the recent restoration work that has been done.
N

Parks' Ranch Cave

Eddy County, New Mexico

By Sam Bono

Parks' Ranch Cave, at a little over four miles, is the longest gypsum cave in New Mexico and the second longest gypsum cave in the United States, after the 6.5-mile-long Jester Cave System of Greer County, Oklahoma. Both are quite small compared to the world's longest gypsum cave—Ukraine's Optymistychna Cave (try saying that fast three times,) which is 146.6 miles.

With 21 known entrances, this easy and fun horizontal cave is located only a few miles south of the turn-off to Carlsbad National Park, just off NM 62/180. Unlike the majority of caves in New Mexico, you usually have the opportunity to get as wet as you want while exploring Parks' Ranch. Some of the more stagnant pools emit a strong odor of hydrogen sulfide when the water is disturbed, so back in the olden days of carbide head lamps, this was a potentially explosive experience.

Parks' Ranch is formed in the white gypsum bedrock of the Castile Formation of Upper Permian Age (254 to 260 million years ago) by vadose water entering through as many as 14 sinkholes. Scalloping and other speleogens can be found throughout the cave, but there are no formations to speak of. The elliptical-shaped passages are joint controlled and wander every which way, but trend to the southeast.

Very dry, highly flammable tumbleweeds (Russian Thistles) can accumulate in the sinkhole entrances—another reason why some New Mexico cavers do not miss carbide lamps.

Yemane Asmerom and daughter Stella Asmerom in Parks' Ranch Cave. Photo by Dave Decker.

Parks' Ranch Cave System

Distance from NSS Campground: About 332 miles (535 km) to parking area at main cave entrance, 5½-hour drive one-way.

County: Eddy
Ownership: U.S. Government – BLM

Length: 6595 m (21,637 feet)
Depth: 30.5 m (100 feet)
Elevation: 3550 feet

Synopsis: Second longest gypsum cave in North America.

Description: The Parks' Ranch Cave System is 4.1 miles in length, has multiple levels, and contains 21 known entrances. It is the most visited cave in the Carlsbad District BLM Planning Area. Also, it is the longest gypsum cave on federal lands in the United States and the second longest gypsum cave in North America.

Zack LaPointe indicates gypsum bedding. Photo by Dave Decker.

The main entrances are located at the bottom of a large sink and lead to four walking passages. It is a horizontal cave with passages tending to be elliptical conduits with minor amounts of breakdown. Standing water occurs in many passages, so explorers may get wet up to their knees. Passages are joint-controlled and consist of a branchwork maze of interconnecting tributaries, trending generally southeast. A short video of the cave by the BLM can be viewed at: [https://www.facebook.com/BLMNewMexico/videos/1031878856842450/.](https://www.facebook.com/BLMNewMexico/videos/1031878856842450/)

Special equipment or precautions: This cave floods during heavy rains. Rattlesnakes are common near entrances.

Brandi Cron in Parks Ranch. Photo by K. Ingham.

References:

Belski, Dave, Carol Belski, and Fritzie Hardy (eds.). 1986. "Parks' Ranch Cave System." Pp. 23-24 in: *1986 NSS Convention Guidebook*, Tularosa, New Mexico, NSS Convention Guidebook No. 25, vi + 65 pp.

Breisch, Richard L. 1967. "Parks Ranch Cave System." *Southwestern Cavers*, 6(5):79-82 (December).

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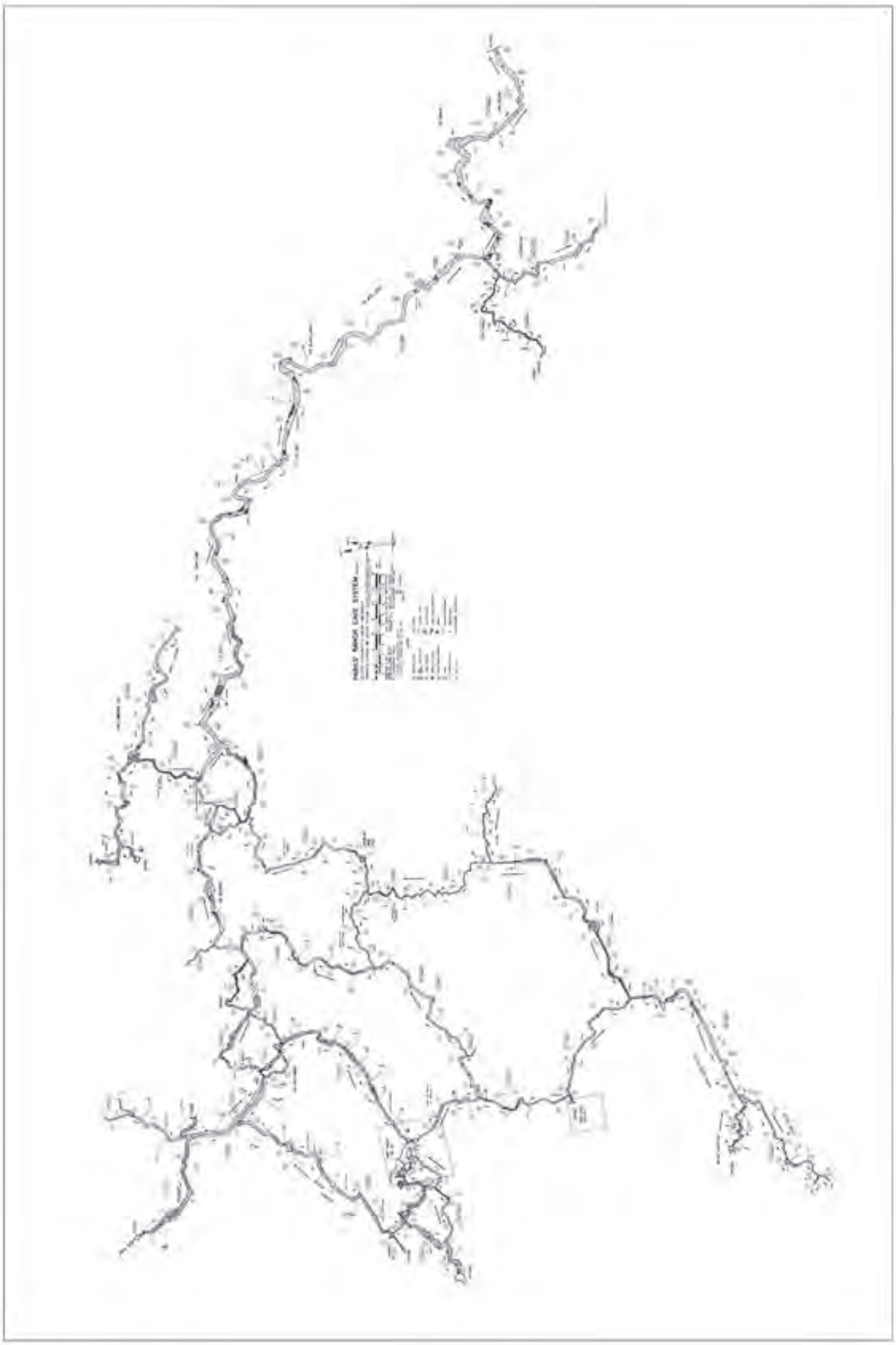

Carlsbad Cavern

Carlsbad Caverns National Park, Eddy County

By Sam Bono

For many years, this spectacular show cave was the longest in New Mexico, at around 32 miles. Now, it trails far behind the world-famous Lechuguilla Cave, which is 140 miles and still going. Carlsbad was briefly surpassed in length by Fort Stanton Cave, with currently 31.37 miles of passage. However, entry into Fort Stanton was prohibited for exploration in the astonishing Snowy River passage by rising water that has not permitted trips back into the far reaches of this passage.

Carlsbad Cavern entrance. Photo courtesy of World Beautiful Places

Who the first non-native American was to look down into the massive entrance of Carlsbad Caverns, we will probably never know. We do know the adventurous young cowboy, James Larkin White (1882–1946) entered the cave sometime in 1898. Jim worked for the nearby XXX Ranch, and one day while looking for stray cattle, he spotted "a plume of bats rising from the desert hills." Moving closer, Jim described the scene in his book *Jim White's Own Story* (1932): "I found myself gazing into the biggest and blackest hole I had ever seen, out of which the bats seemed literally to boil."

While not Carlsbad's discoverer, Jim was the first to extensively explore and promote the cave. He also mined its guano, and later served as the Chief Ranger of Carlsbad Cave National Monument, which he was instrumental in helping to establish. Seriously bitten by the caving bug, Jim explored many of the other caves in the Guadalupe Mountains. His wire-and-branch ladders can still be found in a number of vertical caves in the Guadalupe Mountains.

Both Carlsbad and Lechuguilla are located on the 46,776 acre Carlsbad Caverns National Park created in 1930; they are only two of 117 known caves in the Park. The Park is 20 miles southwest of Carlsbad, New Mexico, off US 62/180. In 1995, the Caverns were designated a United Nations World Heritage Site, one of only 23 in the United States, and one of only two caves, the other being Kentucky's Mammoth Cave, by far the world's longest.

Carlsbad, like most caves in the Guadalupe Mountains, is known for its immense rooms, massive formations, and extensive decorations. The Cavern's eight-acre Big Room, with its

View inside Carlsbad Cavern. Photo courtesy of Carlsbad Caverns National Park.

Hall of the Giants, Carlsbad Cavern. Photo by Tabitha Rossman.

225-foot-plus ceilings and deep pits, is probably the most impressive of the Cavern's known chambers.

After parking in front of the Caverns Visitor Center, walk to the southern edge of the parking lot and look south over New Mexico toward Texas. Imagine the ancient Permian Age seas that once covered this area and lapped against the cave-rich limestone barrier reef that you are standing on.

Besides the self-guided Natural Entrance and Big Room tours, four ranger-guided tours are currently offered inside the Cavern for an additional fee. They are: The Hall of the White Giant; King's Palace; Left Hand Tunnel; and Lower Cave. Outside the Cavern tours, Slaughter Canyon and Spider Caves are also available. Reservations are required and highly recommended for all these popular tours. Tour details and costs can be found online or by calling (877) 444-6777.

Not to be missed is the evening bat flight that led cowboy caver Jim White to the Cavern's entrance 119 years ago. Most non-rainy evenings from mid-May through mid-October, hundreds of thousands of Mexican (aka Brazilian) Free-Tail Bats exit the Cavern and head east to the Pecos River for their evening meal. This event is free and no reservations are required.

Please note that the Park Service will **not tolerate** any photography of the bats departing the cave.

Just as interesting if you are up and around before dawn, head back to the natural entrance and hear the bats return home. While it's hard to see them, you can hear the bats diving head first, bellies full, into the cave from hundreds of feet up—zip, zip, zip!

Roswell, NM
1958-1967, 1977-Present

Albuquerque, NM
1958 – Present

Grotto and Regional Patches

1968 - 1979

1986 NSS Convention
Tularosa, NM

Albuquerque, NM
1980s - ca. 2000

1978 Joint Organization
Restoration

1963 - Present

Las Cruces, NM
1972 - Present

Carlsbad Cavern Nat. Park
White City, NM

Recent Sandia Grotto
Ca. 2000 – Present

Agency & Area Patches

A privately-owned show cave. Grants, NM

Courtesy of the Antiquities Collection of Gary Soule, Wisconsin

NM Artifact Postcards and Brochure

from Antiquities Collection of Gary Soule, Wisconsin

Bandera Volcano Ice Cave, Grants, NM -- brochure


Huge Stalagmites, Big Room, Carlsbad Caverns – postcard


Jim White. Discoverer of Carlsbad Caverns -- postcard


Old Carlsbad Cavern Elevator Building -- postcard

Carlsbad Cavern Lunchroom – postcard


Ice Cave, Wooden Staircase – postcard


Carlsbad Cavern, Old Visitor Trail – postcard


Bandera Volcano Ice Cave, Grants. NM - postcard


Crystal Spring Dome, Carlsbad Cavern

Perpetual Ice Cave, Bandera Volcano postcard


Carlsbad Cavern visitors among formations – postcard