National Park Service
U.S. Department of the Interior

Natural Resources Stewardship and Science
Geologic Resources Division
Cave and Karst Program

CAVE AND KARST RESOURCES SUMMARY

Big Bend National Park

Texas

Gerald Atkinson
Texas Speleological Survey
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Looking southwest from Terlingua Creek, the Terlingua fault zone forms steep limestone cliffs on the northeast side of Mesa de Anguila. These high walls are composed of thick sequences of Lower Cretaceous Del Carmen Limestone, Sue Peaks Formation, and Santa Elena Limestone. (Photo by Dale L. Pate, 1991)

LOCATION & AREA

Big Bend National Park was established in 1944 to preserve the Chihuahuan Desert and mountains within the Big Bend of the Rio Grande along more than 110 miles of the Texas-Mexico border southeast of El Paso in Brewster County, Texas. It encompasses more than 1250 square miles (801,163 acres) with elevations ranging from 527 meters (1730 feet) to 2,385 m (7,825 feet). Annual precipitation in the park ranges from as little as 13 cm (5 inches) in the lowermost desert to greater than 51 cm (20 inches) in the mountains.

The park was established as a Biosphere Reserve in 1976. In 1978, the United States Congress designated a 307 kilometers (191-mile) section of the Rio Grande a Wild and Scenic River, 111 km (69 miles) of which lie on the southern park boundary from Mariscal Canyon eastward. Big Bend National Park is the largest protected area of Chihuahuan Desert topography and environment in the United States (Handbook of Texas Online, 2010).

GEOLOGY

Big Bend National Park offers some of the most diverse and scenic landscapes of all national parks, and is renowned for its spectacular and complex geology. The Chisos Mountains are the centerpiece of the park with rugged volcanic peaks in an evergreen and oak woodland setting. Mesa de Anguila, Mariscal Mountain, and the Sierra del Carmen are uplifted limestone mesas and mountains bounding the west, southern, and east sides of the park, respectively, where they form steep, majestic cliffs and deep, intervening canyons (Turner, et al, 2011).

The geologic history of Big Bend National Park spans over a billion years from the Proterozoic ~ 1,500 Million Years Before Present (Ma) to the present. The oldest outcrops within the park are Paleozoic in age (~ 460 –310 Ma), but earlier tectonism in the Proterozoic most likely created basement zones of weakness that are reflected in the predominantly NW-SE pattern of structural trends observed today (figure 1). The oldest recorded tectonic episode in the park is mountain building associated with the Marathon Orogeny from Mississippian to Permian time (~ 330–285 Ma). During this event, deep ocean basin rocks originally deposited to the south were thrust northwestward onto the North American continent by convergence between the North and South American plates. Only remnants of the Marathon Orogeny rocks can be seen in the present-day landscape of the park; these remnants include small outcrop belts in the Persimmon Gap area (Turner, et al, 2011; Page, et al, 2008).

Subsequent to the Marathon Orogeny, the region's highlands slowly eroded during Triassic and Jurassic time (~ 250–145 Ma) as evidenced by a major unconformity separating rocks of the Lower Cretaceous Glen Rose Limestone above from rocks of the Mississippian-Pennsylvanian units below. (Page, et al, 2008; Turner, et al, 2011). Deposition during the Cretaceous (~ 115–65 Ma) consisted of a thick section of shallow marine carbonates (limestone and dolomite) and shales deposited on a stable platform. These units include, from base to top, the Glen Rose Limestone, Telephone Canyon Formation, Del Carmen Limestone, Sue Peaks Formation, Santa Elena Limestone, Del Rio Clay, Buda Limestone, Boquillas Formation, Pen Formation, Aguja Formation, and Javelina Formation (figure 2). Collectively they are more than 1400 m (4,600 ft) thick, and several of the units contain known and potential cave-forming rocks.

The Late Cretaceous–Early Tertiary Laramide Orogeny (70–50 Ma) was a period of contractional deformation that produced monoclinal uplifts, basins, major faults, and large amplitude folds from northeast-southwest directed compression. Structures formed during this event include the Mesa de Anguila monocline, an uplifted mesa on the west margin of the park; the Sierra del Carmen-Santiago Mountains monocline, an uplifted and thrust-faulted monocline bounding the eastern part of the park; the Tornillo Basin which developed between the uplifted monoclines; the Mariscal Mountain and Cow Heaven anticlines; and the Santiago thrust fault and smaller-scale thrusts at Mariscal Mountain (Page, et al, 2008; Turner, et al, 2011).

Big Bend lies within a large volcanic field known as the Trans-Pecos volcanic belt (Bohannon, 2011), and major episodes of volcanism and plutonism occurred in the park from ~ 46 to 28 Ma (Maxwell, et al, 1967; Page, et al, 2008; Turner, et al, 2011). Principal features formed during this time period include numerous volcanic flows extruded from a complex system of volcanic vents and lava domes in the western part of the park and adjacent areas of Mexico, and the Pine Canyon caldera complex in the high Chisos Mountains. Laccolithic complexes developed and intruded Cretaceous and Tertiary sedimentary rocks to form the Rosillos Mountains, McKinney Hills, and Grapevine Hills (Page, et al, 2008; Turner, et al, 2011; Bohannon, 2011). Pseudokarst caves have been documented in these volcanic flows in the Chisos Mountains and western areas of the park, and in the volcaniclastic sediments of the Eocene-Oligocene-age Chisos Formation (~ 33-45 Ma).

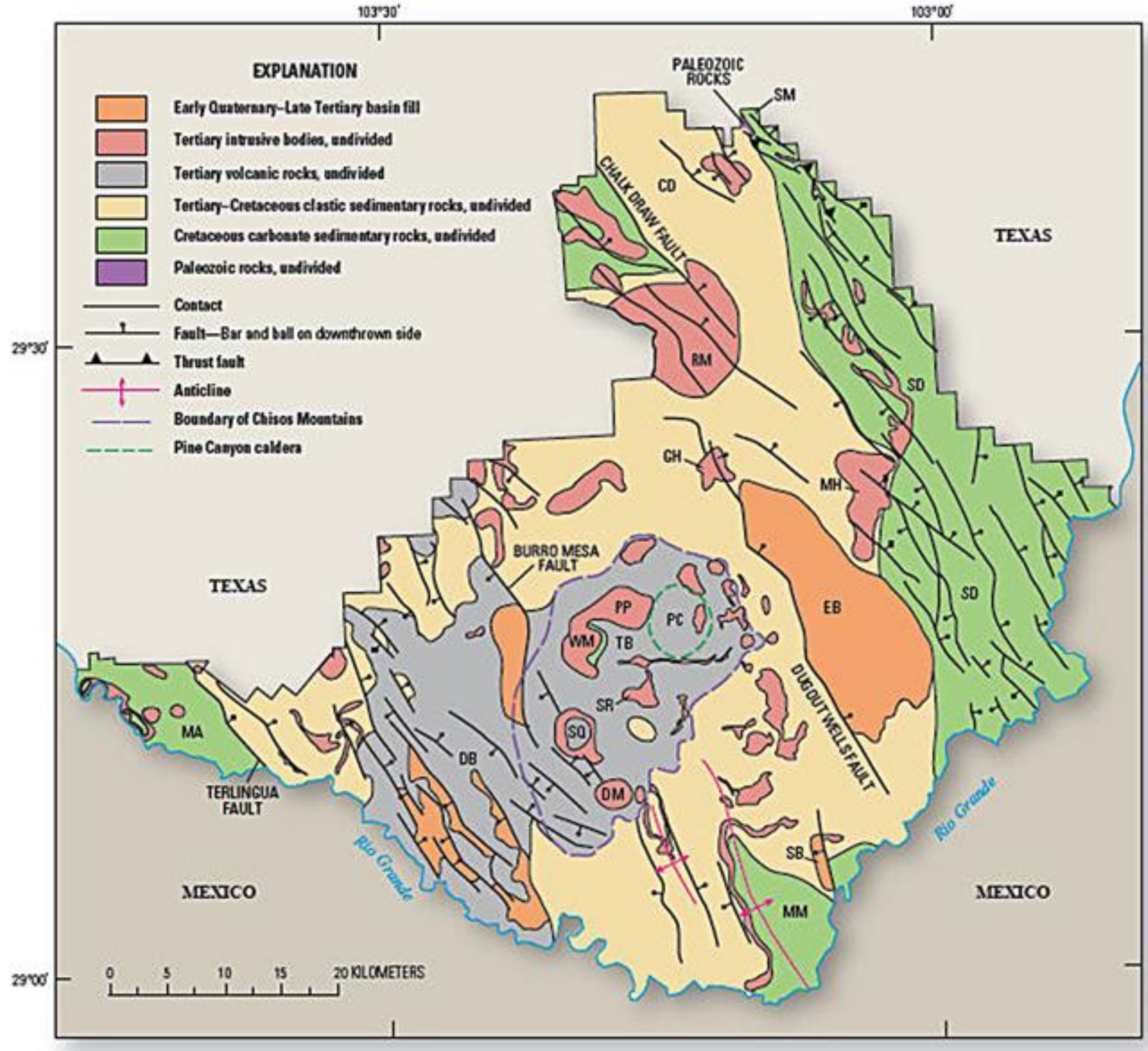

Figure 1. *Simplified geologic map of Big Bend National Park showing late Tertiary Basin and Range faults (last major tectonic episode in BBNP), middle Tertiary volcanic and plutonic features, and present-day distribution of generalized rock units (colors). Geologic features are designated by upper case letters and include: SM, Santiago Mountains; CD, Chalk Draw Graben; NP, Nine Point Mesa; RM, Rosillos Mountains; SD, Sierra del Carmen; GH, Grapevine Hills; MH, McKinney Hills; EB, Estufa Bolson; MM, Mariscal Mountain; PC, Pine Canyon caldera; B, The Basin; PP; Pulliam Peak; WM, Ward Mountain; SR, South Rim; SQ, Sierra Quemada; DB, Delaho Bolson; and MA, Mesa de Anguila. Thick black dashed line in central part of figure is outline of Chisos Mountains; green dashed line is Pine Canyon caldera. Solid black lines with bar and ball are late Tertiary Basin and Range faults; bar and ball is on downthrown side. From Page, et al (2008).*

System	Series	Stage	Group	Name of Formation	Thickness (Feet)	Lithology
QUATERNARY	PLEISTOCENE TO MIOCENE			Older alluvium deposits (includes Udden's Dugout Clays and Gravels)	100– 500	Clay, silt, sandstone, and conglomerate
TERTIARY	OLIGOCENE OR YOUNGER	POST-DUCHESNEAN	Big Bend Park	South Rim Formation	1,000–1,500	Lava flows, ash beds, tuff, flow breccia, irregularly bedded sandstone, and conglomerate
		DUCHESNEAN				
	EOCENE (Upper)	UINTAN?		Chisos Formation	1,500–2,600	Indurated tuff interbedded with clay, mudstone, tuffaceous sandstone, ash beds, lavas, sandstone, and conglomerate
	EOCENE (Middle)	BRIDGERIAN			1,170	Base is a massive yellow cross-bedded sandstone overlain by tuff, mudstone, tuffaceous sandstone, indurated tuff, and lavas
	EOCENE (Lower)	WASATCHIAN	Tornillo		356– 770	Soft, gray, and yellowish-gray conglomeratic sandstone and varicolored and mottled clay
	PALEOCENE	TIFFANIAN OR TORREJONIAN		Black Peaks Formation	850 plus	Varicolored clay interbedded with ledge-forming, cross-bedded, yellow, buff, and gray sandstone and lenses of conglomerate
		PUERCAN				
CRETACEOUS	GULFIAN	MAESTRICHTIAN		Javelina Formation	350– 850	Gray, dull green, blue, red, yellow, purple, brown, black, and white clay, with thin layers of sandstone; clay commonly bentonitic; contains fossil wood and dinosaur bones
		CAMPANIAN		Aguja Formation	800–1,300	Nonmarine dark carbonaceous clay, some silt, and layers of coal interbedded with brown and yellowish-brown sandstone—300–700 feet thick; contains fossil wood and dinosaur bones Marine sandstone and silty clay, with a shelly sandstone generally present at the base—500–700 feet thick
		SANTONIAN				
		CONIACIAN	Terlingua	Pen Formation	200– 600	Dark grayish-blue gypsiferous marl and clay that weathers yellow, with concretionary limestone and layers of calcareous sandstone
				BOQUILLAS FORMATION: San Vicente Member	330– 400	Gray and bluish-gray chalk and gray to buff argillaceous flaggy limestone
		TURONIAN		BOQUILLAS FORMATION: Ernst Member	475	Gray, buff, and yellowish-brown flaggy limestone interbedded with gray and buff marl
	COMANCHEAN	CENOMANIAN		Buda Limestone	100	Whitish, dense, brittle limestone and nodular limestone interbedded with marl
				Del Rio Clay	1– 125	Light gray and yellow clay, clay-shale, and thin-bedded limestone
		ALBIAN (Upper)		Santa Elena Limestone	750– 850	Mostly massive, heavy-bedded, dense, cherty limestone, with thin marly limestone beds near base
				Sue Peaks Formation	75	Shale, marl, and thin marly, nodular limestone ledges
		ALBIAN (Middle)		Del Carmen Limestone	350– 450	Massive, heavy-bedded, dense, cherty limestone
				Telephone Canyon Formation	40– 130	Thin, nodular, marly limestone and marl
				Maxon Sandstone	10	Medium-grained, calcareous sandstone
		ALBIAN (Lower)		Glen Rose Limestone	600	Dense limestone interbedded with calcareous shale; conglomerate and coarse sandstone at base; exposed on flanks of Persimmon Gap and the Solitario
ORDOVICIAN TO PENNSYLVANIAN				Paleozoic rocks undifferentiated; considered equivalent to the Tesnus, Caballos, and Maravillas Formations, and probably older limestone and shale	Unknown	Strongly folded rocks, including slightly metamorphosed shale, chert, novaculite, and limestone; exposed at Persimmon Gap and in the Solitario
				Metasedimentary rocks	Unknown	Fine-grained schist, metaquartzite, phyllite, and marble exposed in the Sierra del Carmen near Boquillas, Coahuila, Mexico

Figure 2. *Generalized stratigraphic chart for Big Bend National Park. Modified from Maxwell, et al (1967).*

The last major tectonic episode to affect Big Bend National Park was Basin and Range normal faulting from ~ 25 to 2 Ma (Page, et al, 2008; Turner, et al, 2011; Bohannon, 2011). Extensional movement on some of the major faults formed local depositional basins, such as the Estufa and Dehlaho bolsons, on the flanks of the high Chisos Mountains. Both of these basins filled with sediment during Miocene-Pliocene time (~ 23–2.5 Ma) (Turner, et al, 2011; Page, et al, 2008). Other notable Basin and Range faults in the park include the Terlingua and Sierra del Carmen fault zones. The Terlingua fault zone forms the steep limestone cliffs on the northeast side of Mesa de Anguila near the mouth of Santa Elena Canyon. The Sierra del Carmen fault zone consists of numerous northwest-striking normal faults that flank the Sierra del Carmen. The Terlingua and Sierra del Carmen fault zones are interpreted to have formed by reactivation of the older Laramide-age, Mesa de Anguila and Sierra del Carmen–Santiago Mountains monoclinal uplifts (Page, et al, 2008). Basin and Range faulting was the last structural event to modify the landscape into its present-day configuration.

For additional details of the geology of the region, see Turner, et al (2011), Bohannon (2011), Maxwell, et al (1967), and Poole, et al (2005).

CAVES & KARST

Big Bend National Park hosts a significant number of cave and karst features that represent a variety of karst (solutional) and pseudokarst (non-solutional) processes. The park contains 75 known and documented caves, 6 rumored or undocumented, 34 documented cave-like rockshelters, and 6 sinkholes and karst cavities (Texas Speleological Survey, 2016). Many more caves and karst features undoubtedly exist but have not been documented and/or discovered. The remote location of the cave-forming regions within the park, combined with difficult terrain and an extreme climate has limited the study and documentation of the park's cave and karst resources.

The caves within the park are generally small in size and somewhat inaccessible. Of the 75 known and documented caves, approximately 68 (91%) are solutional in origin and formed in limestone and dolomite. The longest known cave has a surveyed length of 287 m (941ft) and is a tectonic cave developed in Tertiary volcanics (figure 3). The deepest known cave has a surveyed depth of 65 m (213 ft) and is a solutional cave developed in the Santa Elena Limestone (figure 4). The average length and depth of the known caves in the park is 26 m (84 ft) and 8 m (26 ft), respectively.

Most of the known caves and karst features in the park are found in the limestones of the Lower Cretaceous units, specifically the Santa Elena Limestone and the Buda Limestone, with lesser occurrences in the various Tertiary volcanics, and sediments of the Tertiary Chisos Formation and Upper Cretaceous Aguja Formation (figure 2). Land, et al (2013) stated that 23% (~184,000 acres) of the park has surface outcrops that can support karst (solutional) processes. The Santa Elena Limestone consists of ~ 225 m (740 ft) of light-gray, thin- to thick-bedded, finely crystalline limestone and lesser yellowish-gray marly limestone, with brown chert nodules. It contains abundant silicified rudistids and some gastropods. The Buda Limestone is ~ 25 m (80 ft) thick and consists of an upper cliff-forming limestone, a middle slope-forming marly limestone, and a lower cliff-forming basal limestone. (Turner, et al, 2011

Pseudokarst caves and features have been documented in both the Tertiary volcanics and various sediments of the Chisos and Aguja formations, rock units that cover a large area of the park. The Eocene-Oligocene-age Chisos Formation has an upper, cave-forming unit that consists of ~ 400-600m (1300-1950 ft) of gray, white, red, pink, and brown tuffaceous clay, mudstone, sandstone, siltstone, tuff, conglomerate, and some lacustrine limestone. The Upper Cretaceous Aguja Formation consists of ~ 100-280 m (325-920 ft) of light- to dark-gray and reddish shale and mudstone and light gray to reddish brown sandstone and siltstone. Interbeds of coal and carbonaceous shale occur throughout the unit as well as vertebrate fossils and petrified tree stumps.

Solutional caves and shelters are predominantly developed in the Lower Cretaceous limestones of the Santa Elena and Buda formations in the Mesa de Anguila, Mariscal Mountain, and Sierra del Carmen regions of the park. The solutional caves appear to be hydrothermal in origin as evidenced by abundant calcite spar covering walls, floors, and ceilings, and the presence of cupolas and multi-level, fissure-like passages in some cases. In one cave, the walls were once covered in a banded, multi-colored crust that was apparently mined at one time; perhaps ore mineralization that was deposited from hydrothermal fluids. The speleogenesis of the solutional caves in the park has had little study, and remains a topic of significant interest.

Pseudokarst caves and cavities (formed by non-solutional processes) represent approximately 7 (9%) of the known and documented caves within the park, and are generally developed in the volcanics of the Tertiary igneous extrusives, and sediments of the Tertiary Chisos Formation and Upper Cretaceous Aguja Formation. They consist of two types of pseudokarst processes: tectonic caves formed by fracturing and movement of the earth, and suffosion (piping) caves formed by the flow of water mechanically eroding sediments such as sandstone and mudstones. The latter are poorly studied in the park and represent a potentially significant karst type. No lava tubes are known to be present in the park.

Most caves have no significant speleothems but a few contain unusual secondary minerals. One cave has deposits of darapskite-halite ($Na_3(SO_4)(NO_3)\ H_2O$) + ($NaCl$), that are quite uncommon (Hill and Lindsley, 1978; Hill and Forti, 1997). Two caves are known to have bassanite ($2CaSO_4{\cdot}H_2O$) with anhydrite ($CaSO_4$) crusts that are also uncommon. Several caves have calcite spar crusts coating the walls, floor, or ceiling; often observed to be corroded.

ARCHEOLOGICAL/CULTURAL

The archeological resources in Big Bend National Park are not well known and a thorough survey of the entire park has never been done. Three archeological surveys conducted in the 1930s, 1960s, and from 1995-2010 investigated only a small portion (<8%) of the park (Keller, 2015; National Park Service, n.d.). The archeological and cultural resources of the caves and rockshelters of the park are even less known.

Of the known caves and rockshelters in the park, 23 are recorded as having cultural material present. Most material consists of either projectile points, lithic scatter, mortar holes, tool marks on breakdown, smoke-stained ceilings, and/or stone tools (Townsend and Boudinot, 2008a; 2008b; 2009; 2010; 2011; Peerman, et al, 1999; Peerman and Fleming, 2000; Prewitt, 1970; Setzler, 1933; Texas Speleological Survey, 2016). A few contain pictographs. Only three caves and shelters are known to have been professionally excavated by Frank M. Setzler from the U.S. National Museum in the early 1930s (Setzler, 1933; Prewitt, 1970; Santucci, et al, 2001).

Three caves are considered historical as they were mined in the past for either bat guano or minerals. Guano mining in the caves dates back to at least the early part of the 20th century (Mansfield and Boardman, 1932).

BIOLOGICAL

In Big Bend, bats make up the majority of mammal species. There are 21 species of bats that have been observed at the park (Nadeau, et al, 2014), including the endangered Mexican long-nosed bat (*Leptonycteris nivalis longala Stains*) (figure 5). A small colony of the rare Mexican long-nosed bat is present in one of the caves in the Chisos Mountains. It is known from only a few localities in the US and is rare throughout its known range (Arroyo-Cabrales, et al, 2008; Campbell, 2003). Due to serious population decline, the U.S. Fish and Wildlife Service added the bat to the list of endangered species in 1988. The number of bats in the cave fluctuates during the summer months, and though the fluctuation is not well understood, it may be in response to the presence or absence of agave and other cacti.

Figure 3. Mexican long-nosed bat in flight.
Photo by Jack Milchanowski

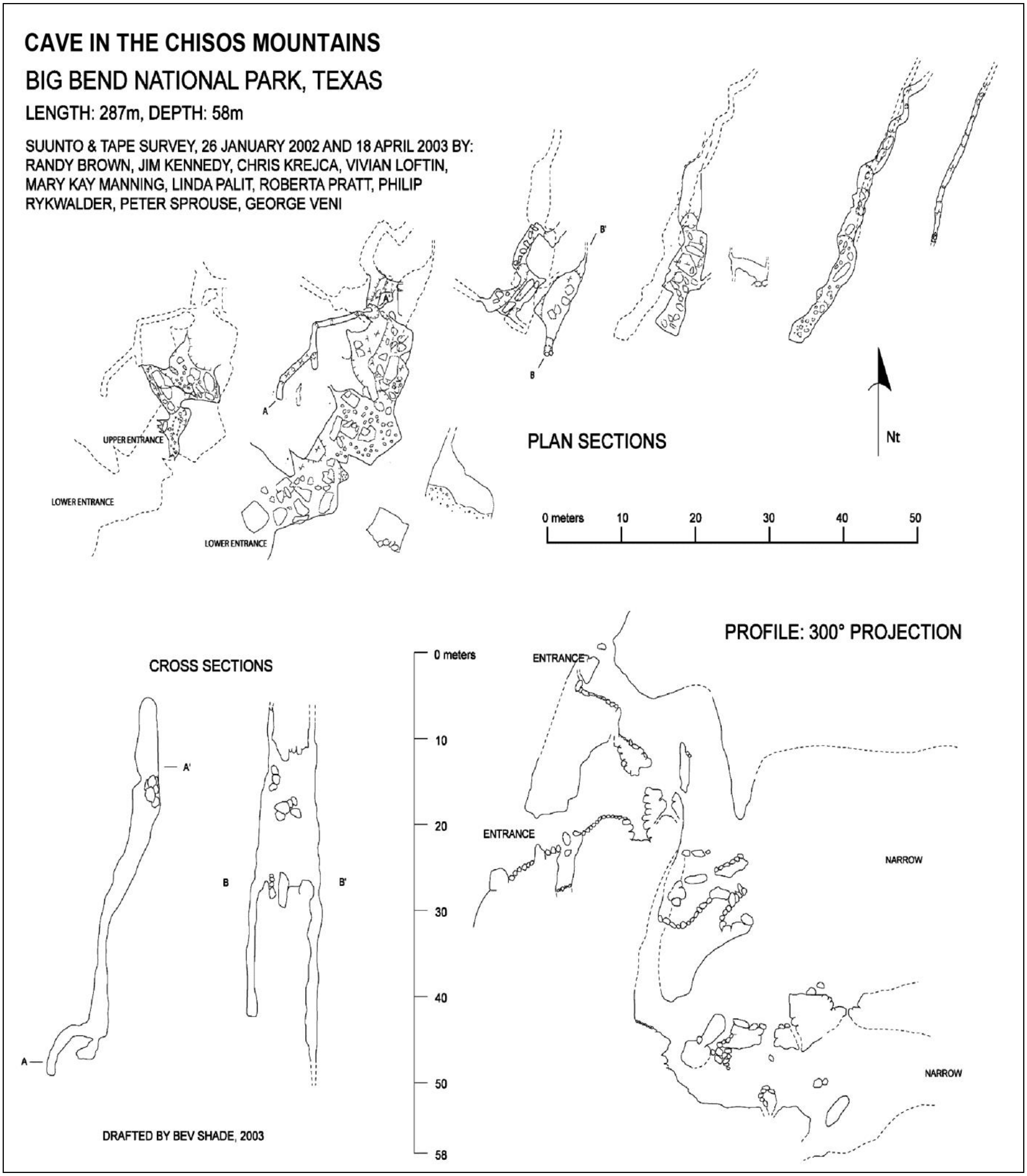

Figure 4. *Map of the longest known cave in Big Bend National Park.*

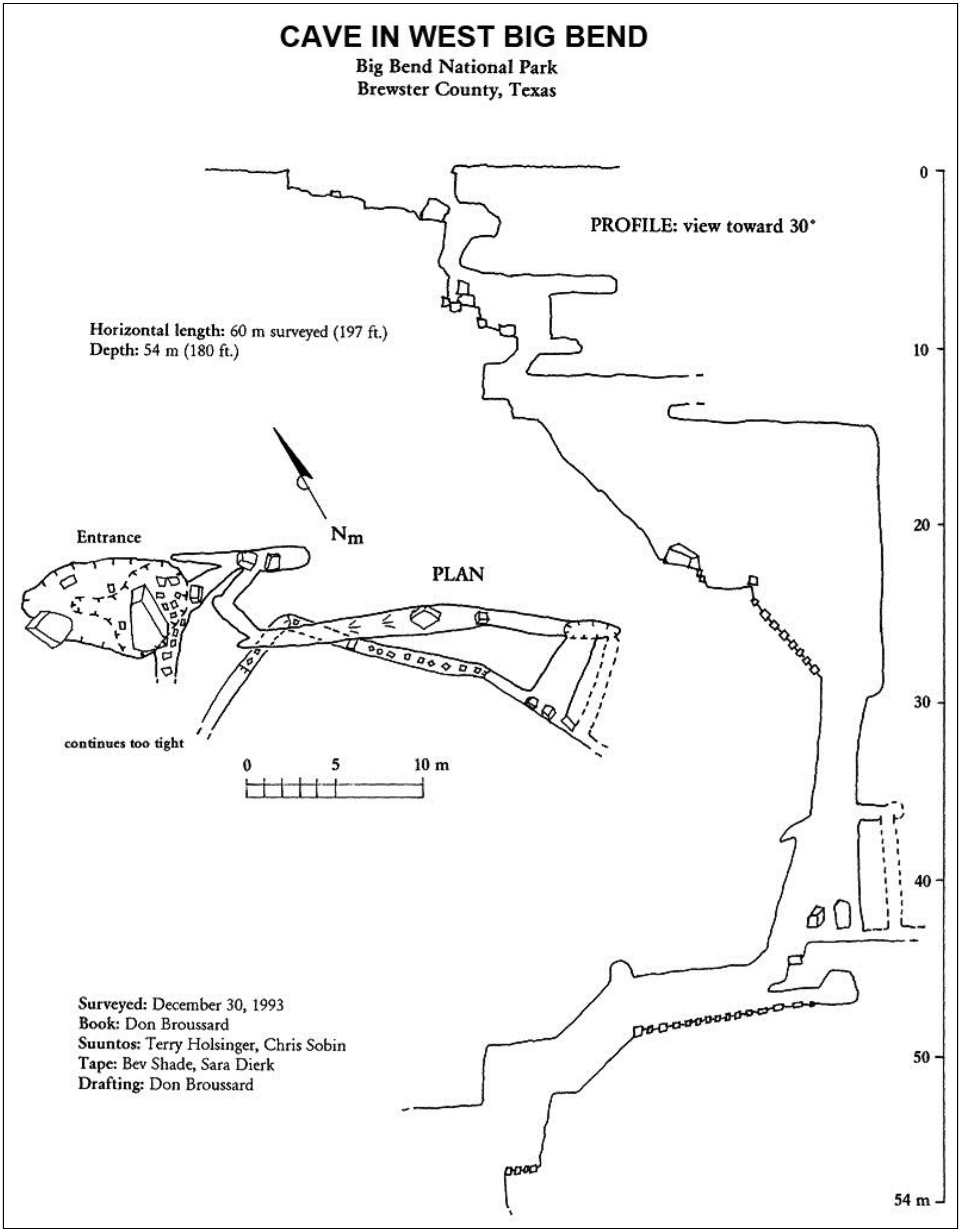

Figure 5. *Map of the deepest known cave in Big Bend National Park.*

The study of invertebrate fauna within the caves of the area is essentially non-existent. Only 4 caves within the park have recorded faunal listings in the Texas Speleological Survey files.

Although extremely limited, the records from the 4 caves indicate several faunal occurrences that are significant (Reddell, 2016). A juvenile scorpion of the genus *Pseudouroctonus* was collected in one cave and may be an undescribed species. Two caves had large spiders of the genus *Ctenus* that may be undescribed; the only species known from Texas is *C. valverdiensis* from caves near Del Rio. The Darkling beetle, *Eleodes (Caverneleodes) easterlai*, was described from one cave in the park and is otherwise known only from Cueva de San Vicente, Coahuila, Mexico. The Ground beetle, *Rhadine* sp., was collected from one cave in the park and may be an undescribed species but will require further study.

The relatively isolated setting of the caves in the region may promote endemism of select invertebrate species. It is quite probable that continued study of the park's cave fauna will result in the discovery of several undescribed species.

HYDROLOGICAL

Over 300 natural water sources occur within the boundaries of the park including over 200 springs, as well as numerous seeps, tinajas, man-made water holes, and stock tanks (National Park Service, 1996). Aquifers that exist in Big Bend National Park region include the Tertiary Volcanics (Igneous) aquifer and the "Upper Cretaceous Series," or what is known locally as the "Cretaceous Limestone" or "Santa Elena" aquifer (Porter, et al, 2009). The latter is the western extension of the Central Texas Edwards-Trinity aquifer and apparently underlies much of the Big Bend region. Most of the park's well water is derived from the Santa Elena Aquifer. The Lower Cretaceous limestones of the Santa Elena Aquifer are major contributors of groundwater discharge to the Rio Grande and adjacent springs, including that which supports the endangered Big Bend *Gambusia* at Rio Grande Village (Porter, et al, 2009). These spring complexes along the Rio Grande are threatened by increased unregulated groundwater pumping in Terrell County. If aquifer water levels are lowered as a consequence of drought or excessive well pumpage, then the regional water gradients will decrease and down-gradient reductions in spring flow and stream flow can be expected to occur. While no known caves intersect the water table within the park, surface water and groundwater contamination of the Santa Elena Aquifer remains a concern.

PALEONTOLOGICAL

Significant Cretaceous and Early Tertiary fossil plant and vertebrate localities are preserved in the Park, and paleontological research has been conducted in the park since the 1930s. Most caves in the park have no known, significant paleontological resources, but there is an important paleontological locality in two of the caves in the Chisos Mountain area. These caves were formed within a cluster of Tertiary intrusive dikes associated with the Chisos Formation. In 1932, the caves were excavated by Frank M. Setzler from the U.S. National Museum (Setzler, 1933; Santucci, et al, 2001; Wetmore, 1933). The remains of twenty-seven *Gymnogyps californianus* (California condor) were collected during the excavation. Radiocarbon analysis of condor material from the caves yielded a date of 12,580 ± 135 years B.P. (Emslie, 1987).

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ADDITIONAL RESOURCES

Big Bend National Park
Big Bend National Park

Cave Research Foundation
Cave Research Foundation Website

National Cave & Karst Research Institute
National Cave & Karst Research Institute

NPS Cave & Karst Program
NPS Cave & Karst Program

National Speleological Society
National Speleological Society

Texas Speleological Survey
Texas Speleological Survey

GLOSSARY OF TERMS

Most of these terms have been borrowed from several US Geological Survey online glossaries. For more definitions, the web links can be found at the end of this section.

anticline - a downward-curving (convex) fold in rock that resembles an arch. The central part, being the most exposed to erosion, display the oldest section of rock.
aquifer - a geologic formation(s) that is water bearing. A geological formation or structure that stores and/or transmits water, such as to wells and springs.
caldera - a volcanic crater that has a diameter many times that of the vent and is formed by collapse of the central part of a volcano or by explosions of extraordinary violence
cave - a natural opening into the earth that is large enough to admit humans
fault - a fracture in the Earth along which one side has moved in relative to the other. Sudden movements on faults cause earthquakes.
karst - a distinctive landscape (topography) that can develop where the underlying bedrock, often limestone or marble, is partially dissolved by surface or ground water.
laccolith - igneous rock that intrudes between sedimentary beds that causes the overlying bedrock layers to bulge upward as a dome.
orogeny - an episode of mountain building and/or intense rock deformation.
pluton - a large body of intrusive igneous rock that solidified within the crust.
psuedokarst - a landscape that is similar to or acts like karst but is not a solutional process.
speleogenesis - how caves are formed.
speleology - the exploration and study of caves.
spring - a water body formed when the side of a hill, a valley bottom or other excavation intersects a flowing body of groundwater at or below the local water table, below which the subsurface material is saturated with water.
syncline - a upward-curving (concave) fold in rock that resembles a trough. The central part contains the youngest section of rock.

tectonic - a process that causes movement and deformation across large areas of the Earth's crust.
unconformity - the contact between older rocks and younger sedimentary rocks in which at least some erosion has removed some of the older rocks before deposition of the younger.
water table - the top of the water surface in the saturated part of an aquifer.

USGS Geologic Glossary

USGS Water Science Glossary of Terms

ABBREVIATIONS

in (inches)
ft (feet)
mi (miles)
cm (centimeters)
m (meters)
km (kilometer)

Ma (million years before present)