

Geologic Resource Evaluation Scoping Summary

Amistad National Recreation Area, Texas

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The Geologic Resource Evaluation (GRE) Program provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this document), a digital geologic map, and a geologic resource evaluation report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and monitoring and research needs. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues, and if possible include a site visit with local experts.

On April 23, 2008, the National Park Service held a GRE scoping meeting for Amistad National Recreation Area at the visitor information center on Highway 90. Chief of Education and Resource Management Greg Garetz welcomed the group and presented some background information about the national recreation area. Andrea Croskrey (Geologic Resources Division) facilitated the assessment of map coverage, and Bruce Heise (Geologic Resources Division) led the discussion regarding geologic processes and features. Ric Page (U.S. Geological Survey) highlighted the U.S.–Mexico Borderlands Project, which is mapping the Amistad area at a scale of 1:250,000; the open-file report of this dataset is nearing review and may be available by the end of 2008.

Participants at the meeting included NPS staff and volunteers from Amistad National Recreation Area and staff from the Geologic Resources Division, as well as cooperators from the Texas Speleological Survey, Texas Bureau of Economic Geology, and Colorado State University (table 3). On April 24, the group participated in a field trip on land and water with stops at many of the alcoves at the reservoir's edge, the Amistad dam, and local road cuts.

Park and Geologic Setting

Located between the arid plains of western Texas and northern Mexico, and close to the tropical influence of the Gulf of Mexico, the Amistad region frequently experiences cycles of drought and flood. In order to provide flood control, a stable water supply, and recreational opportunities, the International Boundary and Water Commission (ICBW) joined with its Mexican counterpart—the Comisión Internacional de Límites Y Aguas (CILA)—to harness the Rio Grande. Named in 1969 for the Spanish word for “friendship,” Amistad Dam created the reservoir at the confluence of the Rio Grande, Pecos River, and Devils River. The reservoir extends 117 km (73 mi) up the Rio Grande, 40 km (25 mi) up the Devils River, and 23 km (14 mi) up the Pecos River. Collecting and storing water from both U.S. and Mexican tributaries, the amount each country contributes to the reservoir determines its water rights. The elevation boundary of the national recreation area is 1144.3 feet regardless of normal pool level; most of the 23,675 ha (58,500 ac) managed by the National Park Service are submerged.

Enjoyed annually by 1.7 million visitors, including many “winter Texans,” Amistad National Recreation Area hosts excellent year-round, water-based recreation such as boating and fishing, as well as land-based camping and picnicking. The reservoir's clear waters—an outcome of the area's limestone foundation—also make it ideal for swimming and SCUBA diving. In addition to recreational opportunities, Amistad protects some of the world's best examples of prehistoric art, notably pictographs. According to a wayside display, “these remarkable assemblages of costumed figures, animals, geometric designs, and other difficult-to-identify objects that are found in rock shelters along the Pecos, Rio Grande, and Devils rivers are truly unique.” Carbon-14 dating revealed that the oldest pictographs at Amistad are 4,000 years old, from the

Lower Pecos River style, but archaeologists surmise that human habitation in the region extends as far back as 10,000 years ago.

Although most interpretive programs focus on the rock art and the history of archaeological excavations in the region, abundant paleontological resources surrounding the reservoir offer further opportunities for interpretation. Amistad National Recreation Area has a rich paleontological record that remains relatively unexplored (Visaggi et al. 2008). Steep canyons of Cretaceous limestone (Salmon Peak Limestone) surround the reservoir; Devils River Limestone, Del Rio Clay, Buda Limestone, and Boquillas Formation are also exposed within the national recreation area. Of the Cretaceous marine fauna fossilized at Amistad (see “Paleontological Resources” section), the most interesting are probably rudistid reef builders, which are quite distinct from the coral reefs of modern oceans. Archaeological excavations have also unearthed Quaternary flora and fauna. The caves that host these Quaternary remains (e.g., Panther and Parida) are another notable resource. Richly colored (red, yellow, orange, and black) rock-art panels up to 5 m (16 ft) in height (fig. 1) decorate these caves. Scoping participants toured Panther and Parida caves during the field trip.

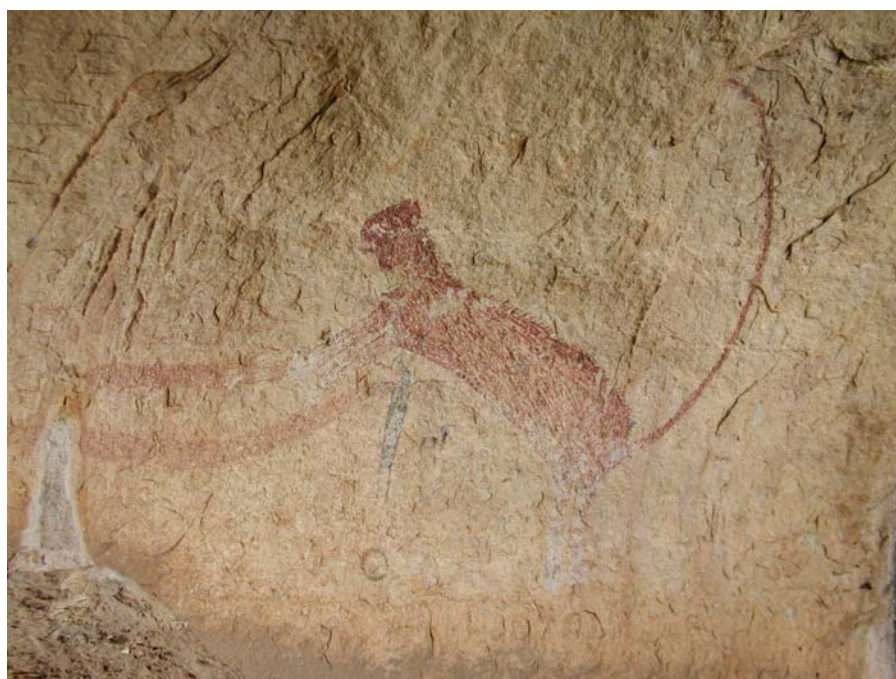


Figure 1. Pictograph of panther in Panther Cave, Amistad National Recreation Area, Texas. NPS photo/Katie KellerLynn.

Geologic Mapping Plan for Amistad National Recreation Area

During the scoping meeting, Andrea Croskrey (Geologic Resources Division) showed some of the main features of the GRE Program’s digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of being GIS compatible. The NPS GRE Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation for the GRE Program and allows for rigorous quality control. Staff members digitize maps or convert digital data to the GRE digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase and shapefile format, layer files complete with feature symbology, FGDC-compliant metadata, a Windows HelpFile that captures ancillary map data, and a map document that displays the map and provides a tool to directly access the HelpFile. Final products are posted at <http://science.nature.nps.gov/nrdata/>. The data model is available at <http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm>.

When possible, the GRE Program provides large-scale (1:24,000) digital geologic map coverage for each park’s area of interest, which is often composed of the 7.5-minute quadrangles that contain parklands (fig. 2).

Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). The process of selecting maps for management begins with the identification of existing geologic maps in the vicinity of the park (table 1). Scoping session participants then discuss mapping needs and select appropriate source maps for the digital geologic data or, if necessary, develop a plan to obtain new mapping.

Table 1 lists source maps for Amistad National Recreation Area. The group agreed that GMAPs 72509 and 74114 were not good candidates because of their small scale (1:250,000) and the existence of larger scale maps. Eddie Collins (Texas Bureau of Economic Geology) offered the original 1:24,000-scale data used to produce GMAP 74916 (scale 1:100,000) in GIS format. Participants decided to use these data to cover the following 7.5-minute quadrangles: Rough Canyon, Rough Canyon SE, Flat Rock Creek SW, Del Rio NW, Del Rio NE, Mud Creek North, Del Rio SW, Del Rio SE, and Mud Creek South (fig. 2). Five of these quadrangles are not “quadrangles of interest” for the national recreation area: Flat Rock Creek SW, Mud Creek North, Del Rio SW, Del Rio SE, and Mud Creek South. Depending on the difficulty of the conversion process, these five quadrangles may not be included in the final map product.

GRE staff will digitize *Geology of the Carta Valley Fault Zone Area: Edwards, Kinney, and Val Verde Counties, Texas* (scale 1:96,000) to cover the Satan Canyon and Miers Ranch quadrangles. Depending on the difficulty of digitizing, the final map product may also include the following quadrangles: Dolan Springs, Open Hollow, Holcomb Draw, Carta Valley NE, Clark Waterhole, Carruthers Draw, Carta Valley, Carta Valley SE, Flat Rock Creek NW, Flat Rock Creek North, and Flat Rock Creek South (see fig. 2).

GRE staff will digitize the USGS 1:62,500-scale published maps (i.e., GMAPs 1111, 1113, 1114, 1115, and 1116) to cover the following quadrangles: Cook Creek North, Lozier Canyon North, Pumpville, Harkell Canyon, Still Canyon, Mayfield Canyon, Bakers Crossing, Telephone Canyon, Cook Creek South, Lozier Canyon South, Ramsey Canyon, Langtry, Shumla, Pecos High Bridge, Dead Mans Pass, Lechuguilla Creek, Zuberbueler Bend NW, Seminole Canyon, Comstock, Gillis Ranch, Zuberbueler Bend, Box Canyon, and California Creek (see fig. 2). The Bakers Crossing 15-minute quadrangle (GMAP 1111) is a possible source map but does not cover any quadrangles of interest, so GRE staff may not digitize it. This may also be the case for half of the Maldvado 15-minute quadrangle (GMAP 1114).

The scale of *Generalized Geologic Map of the Comstock-Indian Wells Area, Val Verde, Terrell and Brewster Counties, Texas* (GMAP 1117) is 1:250,000 and therefore will not be used for the final map product. However, this publication includes rose diagrams of the orientation of joints, lineaments, and stream segments that cover the area of interest and may be included in the HelpFile.

In July 2008 the GRE Program received scanned versions of the needed International Boundary and Water Commission (IBWC) maps from the Texas Bureau of Economic Geology. These maps, part of an investigation for the Big Bend District that includes nine plates (scale 1:50,000), cover a four-mile buffer on both sides of the Rio Grande. GRE staff will use three of these plates (see table 1) to at least cover the U.S. side of the Box Canyon OE S and Amistad Dam quadrangles (see fig. 2). GRE staff may digitize a larger portion of these maps if the data quality is good and the units match well with adjacent maps.

As for the Mexican side of Amistad, GRE staff has two options. First, Ric Page (U.S. Geological Survey) mentioned a geodatabase created from 1:250,000-scale paper geologic maps from the Mexican Geological Survey for the United States–Mexico Border Health Project. Second, for the Mexico side of the reservoir, Eddie Collins (Texas Bureau of Economic Geology) mentioned a dissertation by C. I. Smith completed in 1970. Though the map produced for this dissertation appears to have finer detail than the USGS geodatabase, GRE staff would have to digitize it. Both products are at scale 1:250,000. Therefore, GRE staff will use the USGS geodatabase and “clip” and “edge match” these data to the other datasets covering the U.S. side of Amistad National Recreation Area.

Because the source maps for the NPS GRE geologic geodatabase for Amistad were published at a variety of scales (i.e., 1:12,000, 1:24,000, 1:50,000, 1:62,500, 1:96,000, and 1:250,000), prepared by a number of authors, and cover two countries, well-written metadata or divisions of data by source are necessary to minimize confusion and misuse of the final compiled data. Eddie Collins (Texas Bureau of Economic Geology) would consider assemble a stratigraphic column to assist in the correlation of all these different sources and help to reconciling nomenclature. Bruce Heise (Geologic Resources Division) and Eddie Collins will discuss the scope and funding.

In addition to the maps listed, scoping participants suggested a couple other data sources that could be included in the final digital product. Though these sources do not provide geologic units, they show other important geologic information. First, the International Boundary and Water Commission did extensive work on identifying karst features in the area where the dam was built. The accompanying map for this study (GMAP 74945) is published at scale 1:12,000 and shows sinkhole areas and karst features. Andrea Croskrey (Geologic Resources Division) has contacted Gilbert Anaya (International Boundary and Water Commission) for a newer copy of the map. The commission will also provide the most recent version of the international boundary to edge match the Mexico and U.S. geologic maps together. Second, at least six localities are paleontologically significant at Amistad National Recreation Area: (1) Rock Quarry, (2) Spur 454 (Sunrise Trail), (3) Old Route 277 South (Boat Launch), (4) Coontail Spin, (5) Panther Cave, and (6) Parida Cave (Christy Visaggi, University of North Carolina Wilmington, e-mail to Andrea Croskrey, Geologic Resources Division, June 12, 2008). Andrea Croskrey has requested these data points from Joe Labadie (Amistad National Recreation Area; joe_labadie@nps.gov) and Jack Johnson (The Shumla School; coauthor of Visaggi et al. [2008]; archaeojack@aol.com). Some of these localities are also archaeologically significant and considered “sensitive” by the National Park Service. If these data points are available, GRE staff will not make this GIS layer publically available.

Summary of Mapping Plan

- Convert 1:24,000-scale Del Rio area from existing GIS data (Quadrangles: Rough Canyon, Rough Canyon SE, Flat Rock Creek SW, Del Rio NW, Del Rio NE, Mud Creek North, Del Rio SW, Del Rio SE, and Mud Creek South).
- Convert 1:250,000-scale Mexico area from existing GIS data.
- Digitize 1:50,000-scale IBWC strip maps (Quadrangles: Box Canyon OE S and Amistad Dam).
- Digitize parts of 1:62,500-scale maps (Quadrangles: Pumpville, Harkell Canyon, Still Canyon, Mayfield Canyon, Ramsey Canyon, Langtry, Shumla, Pecos High Bridge, Zuberbueler Bend NW, Seminole Canyon, Comstock, Gillis Ranch, Zuberbueler Bend, Box Canyon, and California Creek).
- Digitize 1:96,000-scale TBEG (Quadrangles: Satan Canyon and Miers Ranch).
- Obtain and digitize 1:12,000-scale IBWC map of sink and karst features (Quadrangle: Amistad Dam).
- Include rose diagrams from GMAP 1117.
- Include paleo GPS points (if available).
- Obtain current international boundary file from the International Boundary and Water Commission and include in geodatabase.

Table 1. Published Geologic Maps in the Vicinity of Amistad National Recreation Area

GMAP ¹	Citation	Format	Notes
74916	Collins, E. W. 2007. <i>Geologic map of the Del Rio, Texas, area</i> . Scale 1:100,000. Miscellaneous Map 45. Austin, TX: University of Texas, Bureau of Economic Geology.	GIS of some format	Original GIS files created from 1:24,000 quads to make the 1:100,000 quad; provided by Eddie Collins
1113	Freeman, V. L., 1964. <i>Geologic map of the Langtry quadrangle, Val Verde County, Texas</i> . Scale 1:62,500. Miscellaneous Geologic Investigations Map I-422. Reston, VA: U.S. Geological Survey.	Paper	Digitize entire map
1116	Freeman, V. L. 1964. <i>Geologic map of the Shumla quadrangle, Val Verde County, Texas</i> . Scale 1:62,500. Miscellaneous Geologic Investigations Map I-424. Reston, VA: U.S. Geological Survey.	Paper	Digitize entire map

GMAP ¹	Citation	Format	Notes
1111	Freeman, V. L. 1965. <i>Geologic map of the Bakers Crossing quadrangle, Val Verde County, Texas</i> . Scale 1:62,500. Miscellaneous Geologic Investigations Map I-434. Reston, VA: U.S. Geological Survey.	Paper	Might not digitize
1117	Freeman, V. L. 1968. Generalized geologic map of the Comstock-Indian Wells area, Val Verde, Terrell, and Brewster counties, Texas. Scale 1:250,000. In <i>Geology of the Comstock-Indian Wells Area, Val Verde, Terrell, and Brewster Counties, Texas</i> . Plate 1. Professional Paper 594-K. Reston, VA: U.S. Geological Survey.	Paper	Joint rose diagrams for HelpFile
74975	International Boundary and Water Commission. 1955. <i>Rio Grande upper dams investigations, Big Bend District, areal geologic map, Reagan Canyon to San Francisco Creek (area 5)</i> . Scale 1:50,000. El Paso, TX: International Boundary and Water Commission.	Scanned paper	Outside quadrangles of interest
74976	International Boundary and Water Commission. 1955. <i>Rio Grande upper dams investigations, Big Bend District, areal geologic map, San Francisco Creek to Indian Creek Reach (area 6)</i> . Scale 1:50,000. El Paso, TX: International Boundary and Water Commission.	Scanned paper	Outside quadrangles of interest
74977	International Boundary and Water Commission. 1955. <i>Rio Grande upper dams investigations, Big Bend District, areal geologic map, Indian Creek to Del Rio Ranch (area 7)</i> . Scale 1:50,000. El Paso, TX: International Boundary and Water Commission.	Scanned paper	Digitize
74978	International Boundary and Water Commission. 1955. <i>Rio Grande upper dams investigations, Big Bend District, areal geologic map, Indian Creek to Del Rio Ranch (area 8)</i> . Scale 1:50,000. El Paso, TX: International Boundary and Water Commission.	Scanned paper	Digitize
74979	International Boundary and Water Commission. 1955. <i>Rio Grande upper dams investigations, Big Bend District, areal geologic map, Indian Creek to Del Rio Ranch (area 9)</i> . Scale 1:50,000. El Paso, TX: International Boundary and Water Commission.	Scanned paper	Digitize for Box Canyon and Amistad Dam quads
74945	International Boundary and Water Commission. 1963. <i>Major sink areas and karst features near Amistad Dam, United States and Mexico, United States section. Rio Grande International Dams Project, Amistad Dam and Reservoir</i> . El Paso, TX: International Boundary and Water Commission.	1" = 1000' 1:12,000	Texas Speleological Survey might digitize; Gilbert Anaya is getting back to GRE staff
?	International Boundary and Water Commission. 2008.	Official international boundary	Gilbert Anaya is getting back to GRE staff
1114	Sharps, J. A. 1963. <i>Geologic map of the Malvado quadrangle, Terrell and Val Verde counties, Texas</i> . Scale 1:62,500. Miscellaneous Geologic Investigations Map I-382. Reston, VA: U.S. Geological Survey.	Paper	Might just digitize half
1115	Sharps, J. A., and V. L. Freeman. 1965. <i>Geologic map of the mouth of Pecos and Feely quadrangles, Val Verde County, Texas</i> . Scale 1:62,500. Miscellaneous Geologic Investigations Map I-440. Reston, VA: U.S. Geological Survey.	Paper	Digitize entire map
?	Smith, C. I. 1970. <i>Lower Cretaceous stratigraphy, northern Coahuila, Mexico</i> . Scale 1:250,000. Report of Investigations 65. Austin, TX: University of Texas, Bureau of Economic Geology.	Paper	Use digital USGS data instead
74114	Stoeser, D. B., G. N. Green, L. C. Morath, W. D. Heran, A. B. Wilson, D. W. Moore, and B. S. Van Gosen. 2005. <i>Preliminary integrated geologic map databases for the United States: Central states—Montana, Wyoming, Colorado, New Mexico, Kansas, Oklahoma, Texas, Missouri, Arkansas, and Louisiana</i> . Scale 1:100,000. Open-File Report OF-2005-1351. Reston, VA: U.S. Geological Survey.	Shapefiles	Don't use
72509	Texas Commission on Environmental Quality. 2004. <i>Geologic atlas of Texas</i> . Scale 1:250,000. Austin, TX: Texas Commission on Environmental Quality.	Clipped, scanned, georeferenced TIFs	Don't use
?	USGS Border Health project	Geodatabase	Convert Mexico portion from Ric Page; not published yet but will be a USGS open-file report
?	Visaggi, C. C., J. G. Johnson, A. S. Johnson, J. P. Kenworthy, and V. L. Santucci. 2008. Amistad National Recreation Area paleontological survey. Geologic Resources Division Technical Report. Draft (March 2008). Denver, CO: National Park Service, Geologic Resources Division.	GPS points	Paleo locations
1112	Webster, R. E. 1982. <i>Geology of the Carta Valley fault zone area: Edwards, Kinney, and Val Verde counties, Texas</i> . Scale 1:96,000. Geologic Quadrangle Map GQ-0053. Austin, TX: University of Texas, Bureau of Economic Geology.	Paper	Only digitize the Satan Canyon quad

¹GMAP numbers are unique identification codes used in the GRE database.

Proposed Geologic Map Sources for AMIS GRE Geologic Geodatabase

Amistad National Recreation Area, Texas

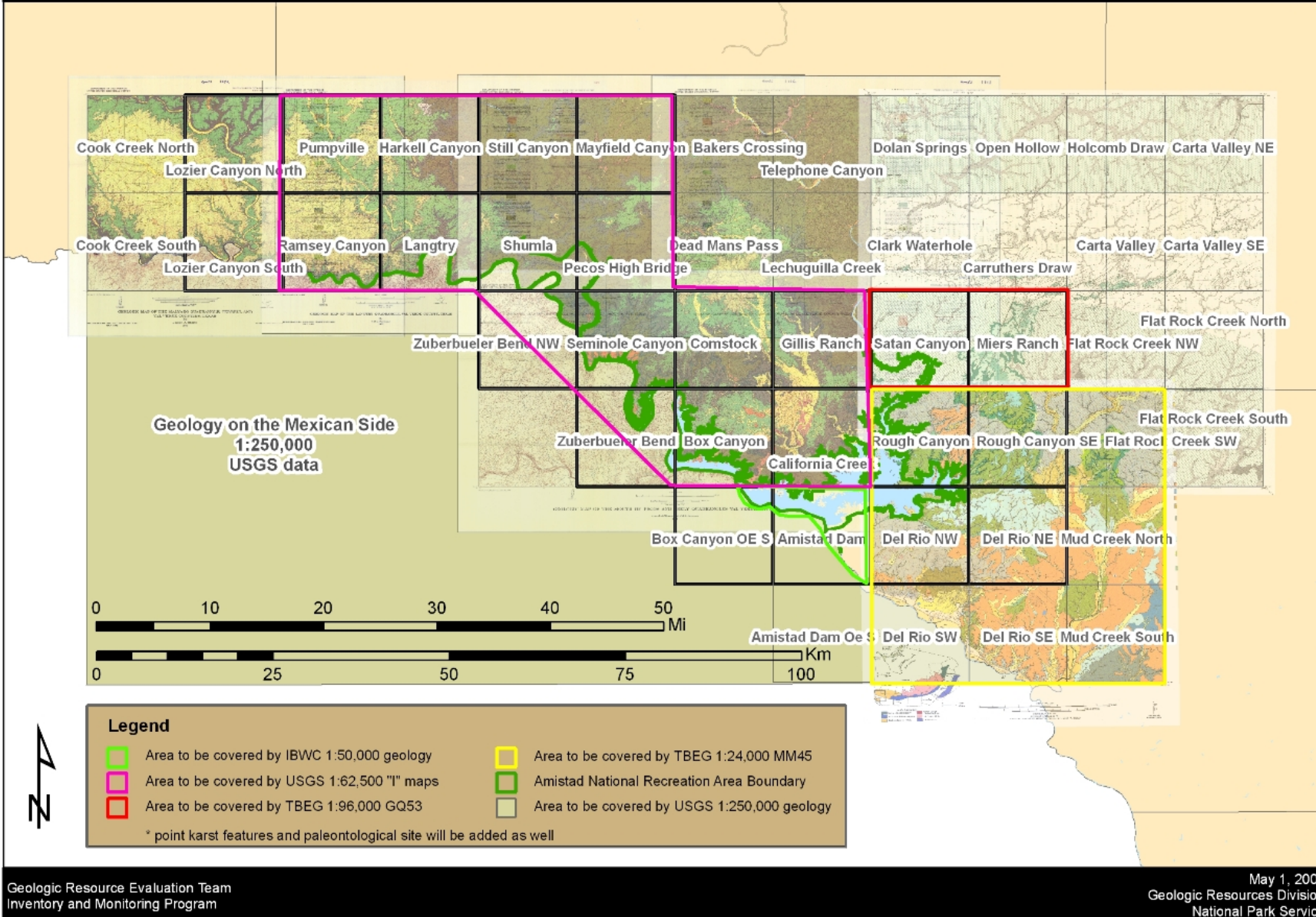


Figure 2. Area of Interest for Amistad National Recreation Area, Texas.

Geologic Features and Processes and Related Management Issues

The scoping session for Amistad National Recreation Area provided the opportunity to discuss management-related geologic issues and develop a list of geologic features and processes, which will be further explained in the final GRE report. During scoping, participants did not prioritize the issues, but discussion made it clear that caves have high management significance and paleontological resources are a significant yet unexplored feature. These are discussed first, followed alphabetically by other features and processes at the national recreation area.

Caves and Karst

In 1995, Dale Pate and Ron Kerbo (acting and former NPS cave management specialists) conducted an inventory of cave and karst resources at Amistad National Recreation Area. They noted 23 significant karst features and recommended that park staff and cooperators complete a cave management plan. In 1997 park staff did some preliminary work but did not finish the plan. Since then investigators and visitors have discovered additional caves, which park staff needs to add to the “dataset” of known information. As of April 2008, the count was up to 36. At about 1,290 m (4,000 ft) long, the longest known cave at Amistad National Recreation Area is Diablo Cave. Cavers mapped this cave in the 1950s and 1960s. The deepest cave—Goodenough Springs—is submerged; its “end” is 76 m (250 ft) below the entrance. Generally speaking the caves range from small sinkholes to conduits of up to 100 m (330 ft) in length. Typical drops for sinkholes are 11–18 m (35–60 ft). Such sinkholes may be a threat to unwary hunters or other backcountry users because they are not fenced or gated. Additionally, some of the caves contain “bad air” as a result of rotting vegetation (i.e., buildup of organic matter from the lake) that produces carbon dioxide that displaces oxygen. Park managers know of no threats to infrastructure from karst. All caves are presently closed to the public pending completion of a management plan. Park managers would like to establish some of the caves as “recreational caves” for visitor use but need guidance from experts before doing this.

The GRE Program may be able to provide some funding for a cave inventory. The Texas Speleological Survey is a candidate for completing such an inventory. At least three of the caves have large boulders at their entrances that would require heavy equipment to remove (and enter). The inventory would document locations to cave entrances, speleothem types, and cave biota such as “pink bacteria,” which participants observed during the field trip. Some of the caves are already known to have speleothems such as soda straws, stalagmites, and stalactites. Spectators have seen bat flights but have not documented any statistics. The caves also show some evidence of hypogene speleogenesis, similar to Carlsbad Caverns, which would produce some interesting mineralogy. The final GRE report will discuss cave formation, which likely includes spalling, some eolian erosion, and flood waters that dissolve the cement in the limestone.

During construction of the dam, many caves were destroyed, generally by workers filling them with concrete. Sinkholes periodically reopen and new ones develop in front of the dam. The outcome is water circumventing the dam; however, the dam does not appear to be at risk. Since 1992 springs south of the dam have documented increases in discharge (Stanton et al. 2007). This may be a result of increased head from the reservoir forcing surface water into the groundwater system. The U.S. Geological Survey, in cooperation with the International Boundary and Water Commission, has been monitoring springs in the vicinity of the dam on both the U.S. and Mexico sides (Stanton et al. 2007).

Paleontological Resources

The fossils at Amistad National Recreation Area may be “the best kept secret in Texas.” Fossil resources here are extensive (table 2), and exposures in caves make them quite accessible (by boat) for interpretation. However, fossil theft is a problem. Efforts are made by the law enforcement staff to stop the theft of rocks as well as cactus, another popular theft item in the park. Nevertheless, correspondence from Greg Garteiz relates two disturbing examples of resource theft:

I have personally stopped park visitors on two separate occasions, in my capacity as a Law Enforcement Park Ranger prior to moving into my current non-law enforcement position. The most disturbing was the husband and wife from Del Rio who had backed up to a fossil-bearing outcropping of flagstones just off of our Spur 454, one mile in from Hwy 90 west. This was at a location that is now an interpretive site along our Sunrise hiking trail, and is located well within the park. The people had already loaded their pick-up truck with these fossil-bearing rocks, and I made them unload the rocks back onto the ground. I am not aware of a recurrence of this type of incident at this particular location. The incident took place around 1997. They had told me that they felt that the lake level, which was low at the time, would eventually be coming back up, and they were simply preserving the fossilized rocks that would eventually be submerged and lost forever. They intended to use the rocks as decorative landscaping at their house.

There was another incident in the same area of Spur 454, but on the other side of the road. A lone man had loaded the bed of his pick-up truck completely full of limestone rock that was lying on the ground in this location. It was not fossil-bearing limestone, but was pretty limestone none-the-less. I made him unload the rocks and wrote him a ticket for the offense. I have photos. There have been at least two other incidents that I can recall where people were loading the common non-fossil bearing limestone rock into their trucks for use as landscaping at their homes. They all responded the same way: They are only rocks, and you have plenty. What is the harm in taking a few rocks (Greg Garetz, Amistad National Recreation Area, e-mail, September 16, 2008).

With tremendous amounts of water coming down the Rio Grande at the present time, the lake will be back to conservation level, and possibly higher, within the next few weeks, and the opportunity to steal rocks will be temporarily reduced (Greg Garetz, Amistad National Recreation Area, e-mail, September 16, 2008).

In March 2006, Christy Visaggi (University of North Carolina Wilmington) completed field work to investigate the Cretaceous paleontological resources at Amistad. Other publications detail Pleistocene and Holocene fauna and flora unearthed during archaeological investigations. Visaggi inventoried 24 sites within the recreation area, eight Val Verde road cuts, and two neighboring sites managed by the Shumla School (Visaggi 2006). One of the neighboring sites is a fossiliferous locality where theft could be an issue inside the park (Sunrise Trail) and the other locality was at Seminole Canyon State Park and Historic Site (Christy Visaggi, University of North Carolina Wilmington, e-mail, September 7, 2008). The Geologic Resources Division will publish the paleontological survey as a technical report. Visaggi expects the report to be finalized by November 2008 (Christy Visaggi, University of North Carolina Wilmington, e-mail, September 7, 2008).

Table 2. Paleontological Resources at Amistad National Recreation Area

Age	Formation Name	Fossils
Pleistocene or Holocene	Alluvium	Mammals, birds, reptiles, amphibians, fish, mollusks, plants, pollen, and middens
Upper Cretaceous	Boquillas Formation	Unknown
	Buda Limestone	Bivalves, gastropods, cephalopods, echinoids, and ichnofossils
	Del Rio Clay	Bivalves, gastropods, forams, and ichnofossils
Lower Cretaceous	Salmon Peak Limestone	Bivalves, gastropods, echinoids, and ichnofossils
	Devils River Limestone	Bivalves, gastropods, and ichnofossils

Source: Visaggi et al. (2008).

Climate Change

Losing Ground: Western National Parks Endangered by Climate Disruption states, “A climate disrupted by human activities poses such sweeping threats to the scenery, natural and cultural resources, and wildlife of the West’s national parks that it dwarfs all previous risks to these American treasures” (Saunders et al. 2006). The authors contend that “a disrupted climate is the single greatest threat to ever face western national parks.” Because of the potential disruption that climate change could cause to park resources, including geologic features and processes, the GRE Program has begun to include a discussion of the effects of climate change

to park resources during scoping meetings. One notable change that may affect the resources at Amistad is increased humidity from the reservoir, which would impact pictographs.

Coastal and Lacustrine Features and Processes

Amistad reservoir boasts more than 1,370 km (850 mi) of shoreline, 870 km (540 mi) of which are in Texas. The reservoir experiences “wild fluctuations” of water level, from -59 to +7 around the “conservation level” of 1,117 feet above sea level. The State of Texas water master controls the water level; decisions are based primarily on irrigation/agricultural needs. Generally the reservoir has good water quality, though algal blooms have been known to form, for example in 1985. To enhance fish habitat, fishers have introduced exotic water plants (e.g., grass-like hydrilla). An exotic plant management team (EPMT) is assisting park staff in eliminating exotic species.

Known for its submerged resources such as Goodenough Springs, archaeological sites, and historic sites (e.g., submerged remnants of a ranch house, pump house, and two dams), Amistad reservoir is popular with SCUBA divers. Before the dam was constructed (1958–1968), investigators excavated and documented many of the archaeological sites that would become submerged.

Disturbed Lands

Disturbed lands are those park lands where the natural conditions and processes have been directly impacted by mining, development (e.g., facilities, roads, dams, abandoned campgrounds, and user trails), agricultural practices (e.g., farming, grazing, timber harvest, and abandoned irrigation ditches), overuse, or inappropriate use. The NPS Disturbed Lands Restoration Program, administered by the Geologic Resources Division, usually does not consider lands disturbed by natural phenomena (e.g., landslides, earthquakes, floods, hurricanes, tornadoes, and fires) for restoration unless influenced by human activities.

Participants of GRE scoping identified some disturbances at Amistad National Recreation Area: 200 head of exotic mountain sheep have over-grazed certain areas, which may result in erosion and sedimentation. Furthermore, livestock from surrounding ranches trespass onto parklands. Now that subdivisions are popping up around the national recreation area, park staff anticipates that development will bring other disturbances. Park staff knows of an abandoned mine adit near Governor’s Landing access road. Prospectors may have been looking for mercury, though the commodity is uncertain.

Greg Garetz is not aware of any present administrative uses of any borrow pits in the national recreation area (Greg Garetz, Amistad National Recreation Area, e-mail, September 16, 2008). Gravel used by park staff for road base is either purchased from a local gravel company adjacent to the park, or taken from a location outside the park where a landowner donated a big pile of gravel. In the past, park managers used river gravel from a borrow pit about a mile or a mile and a half downstream from Amistad Dam. However, investigators discovered that this gravel had significant archeological debris intermixed with it, so park managers stopped using gravel from this location about 15 years ago. According to Greg Garetz, “This borrow pit was within the park, but we had to ask permission from the International Boundary and Water Commission before taking any gravel, if my memory serves me.”

Fluvial

Floods occurred on the Rio Grande and Devils River in 1932, the mid-1940s, and 1954. The 1954 flood was the flood that “broke the camel’s back” and prompted the formation of the International Boundary and Water Commission in 1958 and the damming of the Rio Grande for flood control in 1969. Today flooding occurs as a result of rainfall events, for instance Tropical Storm Charlie in 1998. Such events cause minor damage to bridges and boat docks, as well as erosion, which is a management concern for protecting archaeological sites.

Portions of the Devils and Pecos rivers still have natural flow conditions. Devils River is very clear. Pecos River does not have much of a sediment load, so is also very clear. In some reaches, however, the Pecos River is highly saline because it flows through a gypsum-rich basin. Springs near Pandale, Texas, freshen the water before it enters the reservoir, however. By contrast, Rio Grande has major sedimentation. Silt builds up at the mouth of the Pecos with as much as 26 m (85 ft) of fill. So much silt has accumulated that in areas “creeping silt” moves like a lava flow below the surface.

Geothermal Features and Processes

Common in karstic areas, dozens of springs occur in the vicinity of Amistad. Some of these springs are above the ambient temperature 29°C (85°F). Sulfur geothermal springs occur on the Mexican side and near Brackettville, Texas.

Hillslope Features and Processes

Creation of the reservoir and fluctuating water levels induce slope processes. For example a “slump site” has formed on the San Pedro arm of the reservoir, near the San Pedro bridge. As lake level dropped, the area slumped. This slump is near an archaeological site, which is a management concern. In addition, the steep cliffs in the national recreation area are a source of rockfall; “boulder fields” have formed in places along the base. Rockslides also originate from the railroad grade; the areas surrounding the two railroad tunnels generate rockfall.

Oil and Gas Exploration and Development

During scoping, participants mentioned that the Pennsylvanian-Permian sands in the vicinity of Amistad National Recreation Area are attractive for oil and gas exploration and development. Since scoping and at the request of Eddie Collins, Scott Hamlin (Texas Bureau of Economic Geology) checked production information in the area around Amistad, particularly for the Devils River Uplift and Ellenburger Formation, which participants thought might be a source in the vicinity of the national recreation area. Eddie Collins suspects that the Ellenburger Formation and younger strata probably have been exploration targets. The Ellenburger Formation is a local target east of Amistad. Farther southeast in south-central Kinney County production occurs from Cretaceous units that are either off or at the southeastern margins of the Devils River Uplift (Eddie Collins, Texas Bureau of Economic Geology, e-mail, September 19, 2008).

Seismic Features and Processes

Faults slice across Amistad National Recreation Area; however, active zones are farther west. Seismicity is not a management concern; even overhangs in the alcoves are not particularly susceptible to seismic activity.

Unique Geologic Resources

Unique geologic resources include natural features mentioned in a unit’s enabling legislation, features of widespread geologic importance, geologic resources of interest to visitors, and geologic features worthy of interpretation. The GRE Program also considers type localities and age dates as unique geologic resources. At Amistad National Recreation Area, unique features include several possible type sections along the Devils River and possibly along the Rio Grande near the dam. Workers also described the Del Rio clay downstream of the reservoir. During the field trip, participants stopped at a road cut along Highway 90 where the Boquillas Formation is exposed. This exposure hosts excellent teepee structures similar to those in the Yates Formation at Guadalupe Mountains National Park. These V-shaped non-tectonic folds are named because of their resemblance to this type of tent.

Volcanic Features and Processes

Volcanism in the area is Tertiary (Mexico) and Cretaceous (Texas) in age. The Cretaceous volcanics near Brackettville, Texas, are known to generate geothermal springs (see “Geothermal Features and Processes”).

Recommendations

Two recommendations emerged from the scoping process:

1. Inventory cave resources at Amistad National Recreation Area and complete the cave management plan.
2. Prioritize the protection of fossil resources and incorporate paleontology into interpretive themes.

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