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Firstday road log, trip 2, from Washington Ranch to Lower Slaughter Canyon, Slaughter Canyon Cave, and Black River valley

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SLAUGHTER CANYON CAVE AND BLACK RIVER VALLEY

FIRST-DAY ROAD LOG, TRIP 2, FROM WASHINGTON RANCH TO LOWER SLAUGHTER CANYON, SLAUGHTER CANYON CAVE, AND BLACK RIVER VALLEY

DAVID LOVE, LEWIS LAND, AND VICTOR POLYAK

Assembly Point: Washington Ranch Road near tufa dam.

Departure Time: 8:00 AM

Distance: 21.5 miles

Three stops

SUMMARY

Trip 2 of the first day of the conference diverges from Trip 1 at the gate to Washington Ranch, turning right onto Rattlesnake Springs Road to proceed up the Black River valley toward the mouth of Slaughter Canyon, where spectacular vistas of the Capitan Reef and forereef talus facies can be observed. We then park vehicles and hike into lower Slaughter Canyon, where exposures of the Yates shelf facies and transition into the Capitan Reef can be seen in the north wall of the canyon. The hike continues up the south side of the canyon to the mouth of Slaughter Canyon Cave, which is formed primarily in the Capitan reef. Unlike Carlsbad Cavern, Slaughter Canyon Cave is not developed for the casual tourist. No special skills are required to tour the cave, but there are no paved trails, hand rails, or electric lights. We advise attendees to bring a light source with at least D cell batteries, since the galleries in Slaughter Canyon Cave are so large that normal caving lights are inadequate. After touring the cave and examining surface features in Slaughter Canyon, hike back to the vehicles and drive to the Bureau of Land Management Cottonwood Day Use Area on the Black River, where springs discharge from alluvium and karst conduits in the Castile gypsum. The final stop of the trip is 1 mile farther north at Rattlesnake Springs, a well-vegetated oasis that features large springs fed by a local Quaternary gravel aquifer. The spring pool and surrounding area provide habitant for fish and a plethora of birds and other animals.

Use road log for Trip 1 until arrival at gate to Washington Ranch.

0.4 **Yield sign** and gate to Washington Ranch. **Turn right** onto Rattlesnake Springs Road and proceed southwest. Brown sign points way to Rattlesnake Springs and Slaughter Canyon Cave. Note a higher terrace of Black River to the east. The terrace pinches out against the Gypsum Plain and Yeso Hills of the Castile Formation to south. The contact is blurred by an east-trending line of solution depressions. *0.1*

0.5 Road continues southwest on intermediate terrace of the Black River. Across valley toward Rattlesnake Canyon are remnants of piedmont gravel deposits sloping across Castile Formation. These gravels are at the same level or higher than this terrace. *0.1*

0.6 Well cemented limestone cobble conglomerate and stage IV soil exposed in roadcuts. 0.2

0.8 Road descends into depression east of deformed terrace. As road continues descent to the Black River, roadcuts expose steeply dipping fine-grained karst fill overlain by deformed terrace gravel with stage III soil (Figure 1.2.1). 0.1

0.9 Cross Black River. Note conglomerate bluffs and vertically deposited tufa along west bank of the Black River north

FIGURE 1.2.1. Tilted Quaternary gravels overlying fine-grained karst fill southwest of Washington Ranch.

of the bridge. These features may be examined by following the walking tour of Washington Ranch **(Land and Love, walking tour, p. 16)**. Three closely-spaced terraces and/or piedmont slopes west of the Black River may be delineated on aerial photographs of this area. These were lumped together as the Lakewood terrace by Horberg (1949). *0.1*

1.0 Ascend to slightly higher terrace west of the Black River. *0.1*

1.1 **Bear left** on CR 418 at junction of Washington Ranch Road and Rattlesnake Springs Road to Slaughter Canyon and Slaughter Canyon Cave. Whites City Fire Department-Washington Ranch Station at junction. Rattlesnake Springs Picnic area to right. *0.1*

1.2 Road continues on second calcareous-clastic terrace level close to Black River. *0.3*

1.5 Irrigated field to left on lower terrace of Black River. Use of pumped water for irrigation is limited by court rulings because nearby pumping affects discharge from Rattlesnake Springs and water budget for Pecos River. Irrigation ditches parallel both sides of the road. *0.4*

1.9 Road skirts remnant promontory of fine-grained gypsiferous deposits on left. Calcareous tufa deposits locally cap terrace to SSE, which is also affected by karst and modern sinkholes. Uphill farther east, traffic along US 62-180 crosses the top of the Gypsum Plain in the Yeso Hills, underlain by Permian Castile Formation. *0.1*

2.0 Bureau of Land Management Cottonwood Day Use Area to left. This area is Stop 2 on return route from Slaughter Canyon. *0.4*

2.4 Road continues on low, limestone-pebble terrace of Black River or distal piedmont of Slaughter Canyon fan. *0.2*

2.6 Cattle guard and gate. Watch for cows in road. *0.5*

3.1 Ballard Ranch road and irrigated field on right. *0.1*

3.2 Road descends into flat, irrigated field underlain by karst-fill alluvium. The karst consists of at least two conjoined sinkholes. A gas well spudded on piedmont gravel 400 m west of here encountered Castile Formation at 57 m and Lamar Limestone at 154 m, indicating thick piedmont alluvium and dissolution thinning of Castile gypsum. The partially dissolved Castile is more than 274 m thick beneath the Gypsum Plain to the east, and originally more than 520 m thick where unaffected by dissolution farther east in the Delaware Basin. The main dissolution front probably occurs beneath the course of the Black River. Numerous sinkholes pock-marking alluvium between the Guadalupe Mountain front and the Black River indicate that not all the Castile gypsum has been removed. *0.2*

3.4 Cattle guard and gate. Road ascends onto terrace (or distal piedmont) of Slaughter Canyon Draw. Washington Ranch Gas Plant at 10:30. *0.4*

3.8 Dip in road is crossing of Slaughter Canyon Draw. Between the Black River and the mouth of Slaughter Canyon to the west, remote sensing (aerial photography) suggests three closely spaced and at least two much higher levels of alluvium (younger ones are fan-shaped) related to Slaughter Canyon and canyons to the west-southwest above the modern channels (Figure 1.2.2). The route ahead crosses or parallels most of these levels. Roadcuts south of the dip expose the second level up of terrace/distal piedmont gravel from Slaughter Canyon. *0.2*

4.0 **Bear right** (west). Road to left leads to private ranch and El Paso Natural Gas' Washington Ranch Gas Plant (described in detail in Day 2 roadlog). Route is on third level of piedmont gravel (modern channel being 0; Holocene floodplain or terrace being 1; Late Pleistocene piedmont/alluvial fan being 2). *0.3*

4.3 Next higher piedmont gravel level (4) along Slaughter Canyon Draw at 2:00 to 3:00 and continuing upstream. Water wells drilled into the medial and proximal parts of Slaughter Canyon fan penetrated coarse- and fine-grained alluvium to depths of 84-94 m (Bowen, 1998, unpublished report) without encountering underlying Permian units. *0.3*

4.6 Cattle guard. Slaughter Canyon is deep notch in reef escarpment at 2:30-3:00. *0.4*

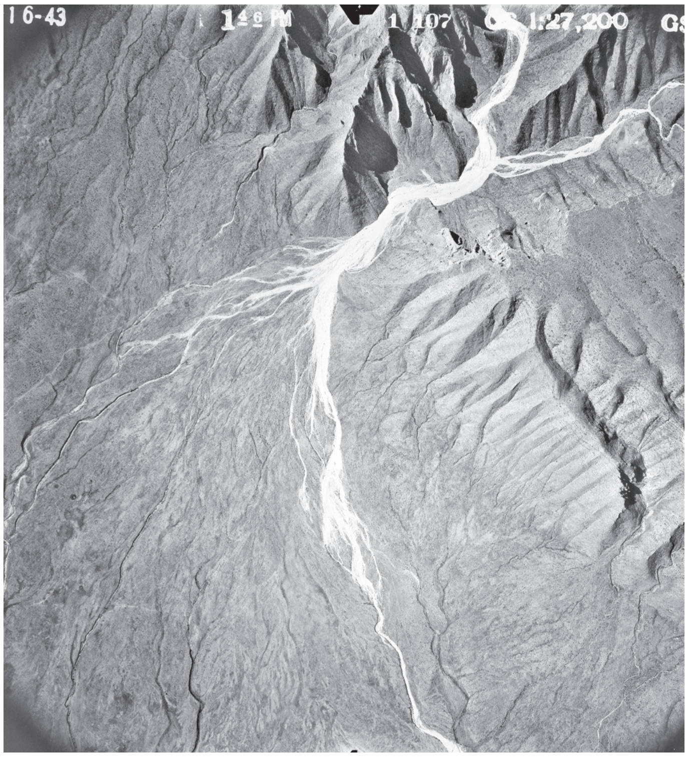

FIGURE 1.2.2. Slaughter Canyon alluvial fan.

5.0 **Turn right** at junction onto Colwell Ranch Road-CR 422 toward Slaughter Canyon. *0.6*

5.6 Coarse boulder-cobble gravel exposed at 9:00 in terrace. Ascend onto higher terrace (level 4) to west. *0.4*

6.0 Guadalupe Mountain escarpment spectacularly exposed at the mouth of Slaughter Canyon at 2:00. Slaughter Canyon can be identified by the large bare rock resembling the side of a north-facing elephant on the north side of the canyon mouth (Figure 1.2.3). The elephant is developed mainly in the massive reef facies of the Capitan, but its hind leg is upper slope conglomeratic talus deposits. Yucca Canyon is at 12:00 to 1:00. Yucca Canyon alluvial fan is developed below the mountain front. The classically shaped fan is pock-marked by more than a dozen recent deep sinkholes that still receive runoff from the head of the fan. *0.3*

6.3 Descend into small tributary of Slaughter Canyon Draw and cross cattleguard. *0.3*

6.6 Dips in road here and ahead cross tributaries to Slaughter Canyon drainage including past and current paths of Yucca Canyon Draw, which skirts Yucca Canyon alluvial fan on its south side and swings northeast to Slaughter Canyon Draw. Remnants of high (level 5) piedmont gravels cap Castile Formation on skyline to southwest. *0.2*

6.8 Bouldery medial piedmont gravel along route probably is derived from Yucca Canyon to the west. *0.2*

7.0 **Bear left** on Slaughter Canyon Road-CR 423. CR 422 continues straight to local ranch and ends. *0.5*

7.5 Crossing over unusual divided two-lane underpass for cattle. Ditch under road exposes well-cemented carbonate piedmont conglomerate and petrocalcic soil. *0.4*

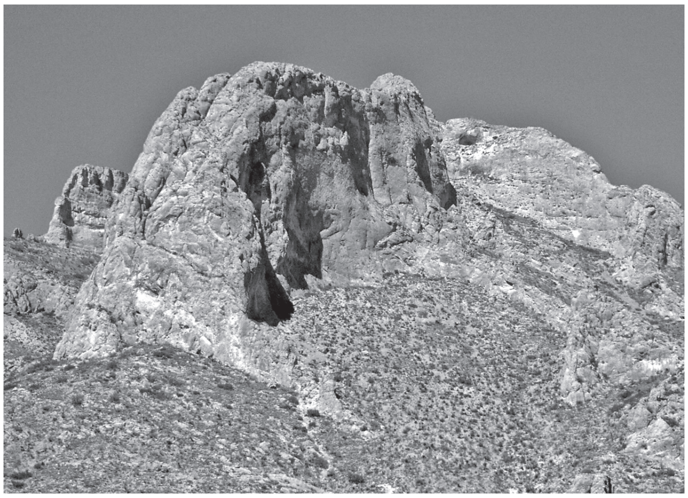

FIGURE 1.2.3. Capitan Reef and forereef talus exposed on north side of mouth of Slaughter Canyon. See Plate 5A for a color image.

7.9 **Sharp right.** Slaughter Canyon straight ahead. Nuevo Canyon at 2:00. Sinkholes and hummocky topography affect alluvial surfaces on both sides of route to northeast. *0.2*

8.1 Cross tributary drainage gathering runoff from Yucca Canyon fan. Capitan escarpment from 10:00 to 2:00 formed on erosion-resistant facets of fore-reef talus with approximately 35° dips (mostly original depositional dip, except for Miocene-Quaternary uplift and northeastward tilting of Guadalupe Mountains block). *0.9*

9.0 Cattle guard. Enter Carlsbad Caverns National Park, Slaughter Canyon area. Brown sign commands, "No hunting or collecting of any plants, animals or minerals. Overnight parking or camping prohibited." Proximal part of Slaughter Canyon fan at 12:00 to 1:00. Slaughter Canyon Draw evulsed from draining southwest to northeast during the 20th century (1941 flood events?). Recent bar and swale topography on the proximal part of the fan gives way downslope on the less recent medial and distal portions of the fan to increasingly larger sinkholes to the northeast. Note dense vegetation, including stands of sotol, algerita, yuccas, catclaw, and grasses at the mouth of the canyon. *1.2*

10.2 Stop 1: Slaughter Canyon and Slaughter Canyon Cave.

Park cars and prepare for hike into Slaughter Canyon.

The walls of Slaughter Canyon provide one of the best natural cross-sections of the Capitan Reef limestone and adjacent shelf facies. Forereef talus deposits dip basinward 25-35° at the mouth of the canyon. The hike into the canyon provides many opportunities for viewing these stratigraphic relationships, described in detail in Brown (2005a, 2006).

See minipaper by Brown on Slaughter Canyon geology. p. 22.

The hike continues up the south wall of the canyon to visit Slaughter Canyon Cave. This cave is formed in the massive Capitan Reef and forereef talus facies, a stratigraphic setting similar to that of Carlsbad Cavern.

Slaughter Canyon Cave has formed in the lower Capitan Reef and within the Forereef member of the Capitan Limestone (Jagnow, 1977). The cave is developed along fractures parallel to the Huapache Monocline and perpendicular to the reef escarpment. Slaughter Canyon cave, formerly known as New Cave, contains some of the most impressive stalagmites and columns in the Guadalupe Mountains (Figure 1.2.4), as well as some of the largest rooms in the Guadalupes.

Much of the cave floor is covered by a thick deposit of fossil guano. The age and paleontology of this guano deposit have been of interest to the Park. Unsuccessful attempts at dating the guano using ^{14}C analyses are recently explained by its antiquity, proven using uranium-series dating of a flowstone that caps the guano near one of the mining trenches. The uranium-series date for the flowstone is 210,000 years old (Polyak et al., 2006). Gary Morgan at the New Mexico Museum of Natural History is currently studying the bone assemblage within the guano deposit. A remnant piece of thick gypsum block in the center of the main passage not far from the guano mining trenches indicates that Slaughter Canyon Cave is a sulfuric acid cave. In addition to the speleogenetic gypsum, this cave is well-decorated with carbonate speleothems and contains an impressive fossil guano deposit, all of which will yield a rich geologic history.

Commercial guano mining operations began in Slaughter Canyon Cave in 1941 at the same time that mining was terminated by the Park in Carlsbad Cavern. These operations were reportedly intermittent. Sometime during 1956 or 1957 the price of guano jumped from $3.50 to $7.00 per 100 lbs, and a jeep with a bucket mounted in the front was brought into the cave as a quick way of transporting guano to the ore cars at the cave's entrance (Adams et al. 1957). Mining operations have since ceased, and the cave is now protected by a large gate. Guided tours of this cave are routinely available through arrangements with Carlsbad Caverns National Park. Much can be learned about the cave from the Park guides on these tours.

FIGURE 1.2.4. Speleothems in Slaughter Canyon Cave.

See minipaper by Polyak et al., for expanded discussion of guano stratigraphy in Slaughter Canyon Cave, p. 23.

After trip to cave, return to parking lot and re-trace route north to BLM Cottonwood Recreation Area along the Black River. *8.2*

18.4 Stop 2: Black River springs, BLM Cottonwood Recreation Area.

Although the Black River is an ephemeral stream along most of its course, short portions are permanently flooded where they are fed by spring discharge (Figure 1.2.5). The Black River originates in Black Canyon in the high Guadalupe Mountains to the southwest. After emerging from the mountains, the river flows across the flats for several km before disappearing into a shallow sinkhole ~8 km to the southwest. Streamflow re-emerges in headwater springs of the lower Black River in a 10 m deep gully 3 km south of here. Less than a km east of these springs, a cluster of sinkholes known as Bottomless Lakes is formed in a thin veneer of alluvium overlying Castile gypsum. The largest of these sinks is permanently water-filled and apparently spring-fed.

This reach of the Black River is fed by springs discharging along the bank to the right of the viewing platform. However, unlike Rattlesnake Springs just 1.6 km to the north, the Black River springs apparently discharge from an alluvial aquifer composed in part of clastic gypsum, or gypsite, derived from the Castile Formation. Water quality measurements indicate high sulfate content in the springs at this stop, whereas Rattlesnake Springs appears to discharge from a carbonate aquifer (Hill, 1996). TDS concentrations of 1338 mg/l have been measured along this reach of the Black River.

A 5 m high remnant promontory composed of fine-grained gypsiferous deposits occurs at this site. A former channel of the Black River apparently went around this promontory whereas the present Black River cuts through it. A small cave is located in bluffs of this promontory ~100m NW of the viewing platform (Figure 1.2.6). More extensive fine-grained gypsiferous terrace deposits 7-9 m above river level continue upstream and downstream on the east side of the river. These deposits contain a few lenses of limestone gravel from the west, but appear to be derived primarily from the Castile Formation to the east. Sares (1984) described some gypsiferous deposits in the area as gypsum-clast sand. Here they may be precipitated by evaporation of spring water. To the southeast, some of these gypsiferous deposits may be "piedmont" deposits derived from outcrops of Castile gypsum to the east. They are interbedded with aeolian siliciclastic loess, but some of them are overlain by thin tufa. After stop, return to vehicles and continue north to Rattlesnake Springs turnoff. *0.9*

19.3 Junction of CR 418 and 418-A. Washington Ranch Fire Station to left. **Continue straight** on CR 418-A. *0.2*

19.5 **Turn left** onto PR 68, unpaved road to Rattlesnake Springs. *0.1*

FIGURE 1.2.5. Black River, BLM Cottonwood Recreation Area. This portion of the Black River is fed by spring discharge from an alluvial aquifer composed in part of clastic gypsum (gypsite) derived from the Castile Formation.

19.6 Cattleguard and gate: Entrance to Carlsbad Caverns National Park-Rattlesnake Springs Picnic Area. *0.3*

19.9 Picnic area to left. Watch for wild turkeys. **Continue straight.** *0.2*

20.1 Irrigation ditch to right carries water from Rattlesnake Springs to Washington Ranch. *0.2*

20.3 Cross irrigation ditch flowing from Rattlesnake Springs to left. **Bear right,** drive around loop, and park on shoulder. *0.1*

20.4 Stop 3: Rattlesnake Springs Picnic Area.

Rattlesnake Springs Picnic Area is part of Carlsbad Caverns National Park (Figure 1.2.7). According to Bowen (1998, unpublished report), the Rattlesnake Springs water right was first claimed in 1880 by a local rancher and is the oldest water right in the Black River valley. The National Park Service bought nearly 80 acres of land for the 105 acre-ft water right in 1934. Facilities were constructed here during the Civilian Conservation Corps era between 1942 and 1944. A 12 km pipeline was built from Rattlesnake Springs to Carlsbad Caverns National Park headquarters to the north at the top of the Guadalupe escarpment. This pipeline continues to provide all the water for the park. The springs also provide water supply for Washington Ranch.

Rattlesnake Springs is a prolific local water resource, discharging at rates up to 7,200 liters/min from Quaternary limestone cobble conglomerates of the Slaughter Canyon alluvial fan. Groundwater appears to discharge in part from karstic solution conduits formed in the conglomerate aquifer (Land and Love, 2006). Water from the springs is of good quality, with TDS of ~450 mg/l. Monitoring wells installed around Rattlesnake Springs penetrated gravel, conglomerate, and fine-grained alluvium in the upper 10-36 m and mostly fine-grained sandstone, siltstone and clay to total depth at 61 m. This two-part stratigraphy is similar to that seen in Pleistocene terraces along the Black River where conglomerate overlies deformed fine-grained karst fill.

FIGURE 1.2.6. Gypsum cave in bluff above Black River, Cottonwood Recreation Area.

The springs are popular with bird watchers, and provide an oasis for many local plants and animals, including a flock of wild turkeys, frequently observed near the picnic area down the road from the springs.

After touring springs, return down PR 68 to junction with CR 418-A. *0.8*

21.2 Junction with CR 418-A. Turn left onto CR 418-A. *0.1*

FIGURE 1.2.7. Rattlesnake Springs, the principal source of water for Washington Ranch, discharges from a karstic limestone cobble conglomerate aquifer.

21.3 South gate to Washington Ranch. Quaternary gravels in bluffs along east side of Black River at 2.00. *0.2*

21.5 Stop sign. Washington Ranch headquarters straight ahead. Park vehicles.

End of Day 1 - Trip 2 Road Log

THE MOUTH OF SLAUGHTER CANYON

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Slaughter Canyon has the best exposures of the Yates shelf facies and transition from shelf to equivalent Capitan massive and upper slope facies. Lower slope and basinal facies are not exposed in the canyon. We will view stratigraphic relations at the mouth of the canyon and discuss stratigraphic features farther up the canyon.

Canyon Mouth. Stratigraphic relations near the mouth of the canyon are best seen on the north wall from a position near the entrance to Slaughter Canyon Cave. For orientation, locate the elephant's back (Figure 1.2.8). Immediately west of the elephant, the uppermost vertical cliff on the skyline is bedded lower Tansill formation with an outer shelf grainstone facies. Tansill grainstone facies extends above the elephant to the east until it is truncated by erosion just as beds are expanding and interfingering with sponge-algal material.

The thin siltstone at the base of the cliff (recessive vegetated zone) marks the top of the Yates Formation. This is the uppermost Yates siltstone, equivalent to the upper Triplet siltstone in Walnut Canyon. The bedded zone under the siltstone is upper Yates shelf deposits. At this position close to the reef, Yates is predominantly a skeletal grainstone belt with few siltstones. The Yates shelf section expands to the northwest at the expense of the reef facies.

Most of the Yates-equivalent exposed at the mouth of the canyon is reef facies. Reef sponge-algal facies forms the sparsely vegetated massive unit immediately west of the upper part of the elephant and most of the elephant. The upper part of the Elephant is oldest Tansill equivalent reef, and the middle part is Yates Triplet-equivalent reef. Reef facies just west of Elephant is equivalent to the upper Hairpin member. In McKittrick Canyon, the upper Hairpin-equivalent reef forms an almost vertical reef wall; a similar morphology is likely here but undocumented.

The vegetated zone below and southeast of the reef is Yates and Tansill equivalent upper slope facies. The slope facies is exposed along the south side of the creek bed just inside the canyon and along the trails to Slaughter Canyon Cave and Ogle cave. The narrow, southwest-facing side of the lower leg of the elephant shows basinward bedding dips exceeding 45 degrees, indicative of upper slope skeletal grainstones just below the vertical reef wall. Dips shallow to about 30 degrees farther east in the lower part of the exposed slope. Most of the upper slope facies comprise boulder conglomerate and skeletal grainstone. West of the elephant, slope facies correlates to the lower part of the Yates Hairpin dolomite. The slope equivalent to the top of the Yates is probably about a third to half way up the slope just east of the elephant. The recessive, slightly orange bed two-thirds of the way up the slope may be equivalent to the Ocotillo siltstone and the base of the "post Lamar" or Reef Trail Member of the Bell Canyon Formation. If so, the overlying unit is upper Tansill, the shelf equivalent of which is not exposed here.

Canyon Interior. The best dip exposures of shelf strata are on the north wall of North Slaughter Canyon, about two kilometers up-canyon from the parking area. Examples of shelf lithology have been delivered to the canyon mouth for your viewing pleasure, courtesy of Slaughter Draw flooding. Facies transitions on the north wall can be viewed obliquely from the Slaughter Canyon Cave trail.

The upper cliff-forming formation is the Lower Tansill Formation. The underlying slope-forming unit with resistant carbonate beds alternating with vegetated siltstone is the Yates Formation. The Seven Rivers Formation is exposed at the updip end of the canyon. Carbonate beds in the shelf formations show similar lateral facies distribution. Updip peritidal facies are replaced successively by pisolitic facies, restricted oolitic and skeletal packstones, open marine skeletal grainstones, and finally sponge-algal boundstones.

As shelf beds are traced to the east, they are abruptly replaced by a massive carbonate. These are thick-bedded, open marine skeletal grainstone and sponge-algal reef facies that form the shelf margin. This shelf-to-reef transition climbs up section toward the east and reflects the overall progradation of the shelf system over the basin throughout Capitan deposition. Slope facies are mostly boulder conglomerates, cemented mudstones, and skeletal grainstones; the Yates slope equivalents also contain pockets of siltstone. Bedding is poorly expressed in the upper slope facies.

Beds in the Yates and Seven Rivers formations dip and expand towards the shelf margin. After removal of late tilting by flattening on the Tansill, shelf facies still have significant dip. This dip was originally interpreted as a primary depositional feature reflecting change in water depth of depositional facies towards the shelf edge (Dunham 1972, Pray 1977, Osleger 1998). With this interpretation, the reef facies formed at water depths from 20 to 60 meters (Osleger 1998). Others interpret the dip to be an early secondary feature related to differential compaction (Saller 1996; Hunt et al., 2002). This interpretation is based mainly on facies distribution on the shelf, stacking patterns within high frequency cycles, and presence of basinward-tilted geopetal structures. With this interpretation, the facies changes along shelf beds is related to progressive environmental restriction rather

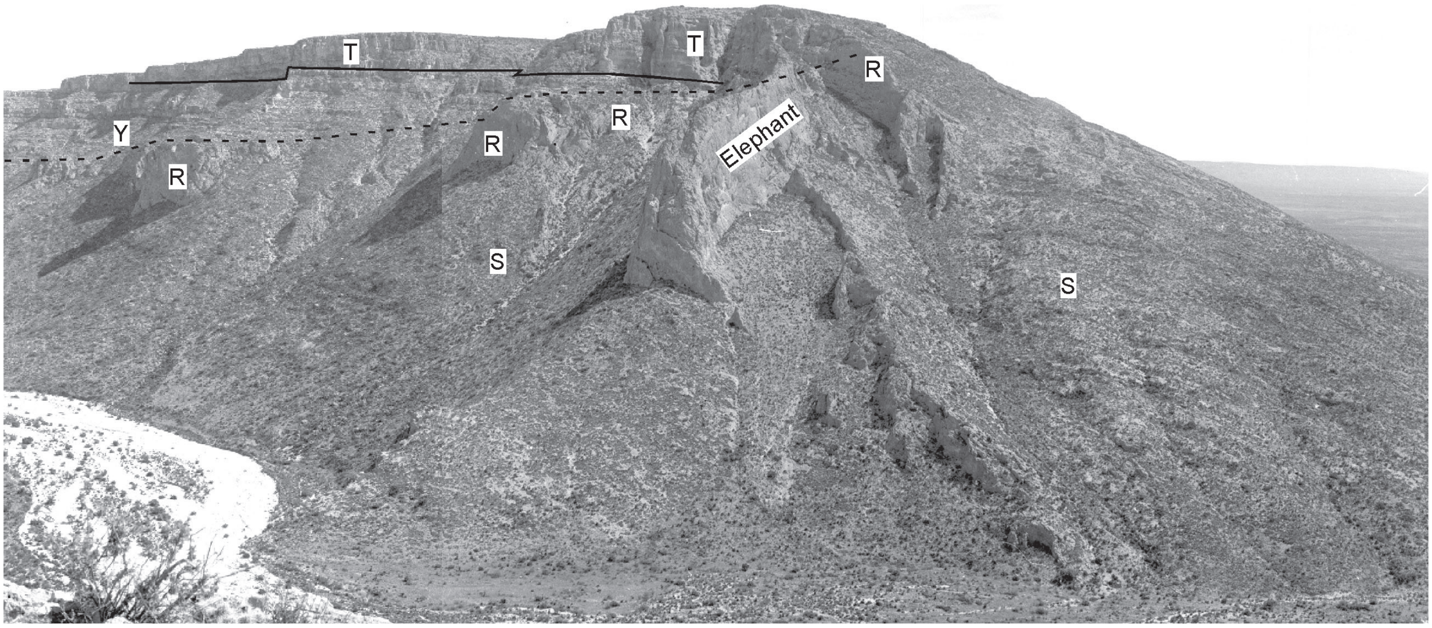

FIGURE 1.2.8. North wall of the mouth of Slaughter Canyon as seen from near the mouth of Slaughter Canyon Cave. T: Lower Tansill shelf facies; Y: upper Yates shelf facies; R: reef facies; S: slope facies.

than paleobathymetry. The secondary tilting interpretation currently has the most supporting data.

Finally, look at the top of the Tansill formation along the north wall. In general, the Top of Guadalupe Ridge does not follow Tansill bedding; it forms a flat surface truncating basinward-dipping Tansill beds. This is King's (1948) summit peneplain. Tansill members from the Ocotillo Siltstone and higher are eroded from this location. In Trans-Pecos Texas, this surface systematically cuts down section to the southwest. Relict basal Cretaceous strata overlie this surface farther north in the Guadalupe Mountains and at many other locations farther west, so this surface is pre-Albian. Erosion appears to be related to Early Cretaceous rift shoulder uplift during formation of the Chihuahua Trough (Brown 2003).

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OLD BAT GUANO IN SLAUGHTER CANYON CAVE

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Guano deposits can contain climatically restrictive faunal remains and for this reason some guano deposits can be considered low-resolution paleoclimate indicators, providing that the age of the guano can be established. Slaughter Canyon Cave in Carlsbad Caverns National Park houses a voluminous fossil bat guano deposit that has yielded climate-revealing paleontology (Morgan and Lucas, 2005). In an effort to determine the age of the guano for paleoclimate reasons, to shed light on the history of the cave, and to contribute interpretive history to Carlsbad Caverns National Park, we performed uranium-series (U-series) analyses on (1) a flowstone directly overlying the guano, (2) drapery on the wall near the flowstone, and (3) a stalagmite in a side passage between the entrance and the flowstone site (Fig. 1.2.9). We measured the age of the flowstone to be 211.6 ± 3.0 ka based on analyses of two subsamples of the flowstone that were weight-averaged (Table 1). The other two speleothems were too old for U-series dating, but important indirect isotopic information from the results is supportive of their age in general. This crudely stratified guano deposit consists almost entirely of poorly to well-crystallized hydroxyapatite with trace amounts of quartz and no obvious nitrogen-bearing minerals (based on XRD of 6 samples), supporting that it is mature. The samples of drapery near the guano and the stalagmite have radiometric dates that are beyond the U-series limits (>~400 ka) but also have isotopic disequilibrium of ^{234}U versus ^{238}U activities expressed as δ^{234}U (drapery and stalagmite δ^{234}Umeasured = 174±4 ‰ and 109±7 ‰ respectively). The U-series data show that these older speleothems exceed ~400 ka, but their ^{234}U/ ^{238}U activities are not in secular equilibrium (i.e., δ^{234}U=0‰), meaning they are younger 1-2 Ma. Based on the size of this guano deposit, it is highly likely that speleothems predating the guano would have been severely sculpted by the corrosive atmosphere produced by the large bat population. Yet drapery and stalagmites in the area show no significant corrosive carving, indicating that these speleothems postdate the guano deposit. The guano-dripstone-flowstone association indirectly reveals that the bat guano deposit is older than the oldest of our dated speleothems. Also, the commercially mine guano was mined commercially from Slaughter Canyon Cave had low nitrogen concentration (<3 %; Adams et al., 1957), supporting a fossil deposit. The age of the guano deposit absolutely exceeds 212 ka, and we suggest that it likely exceeds 400 ka as well. Assuming canyon incision rates of ~50 m/Ma (DuChene and Martinez, 2000), the entrance to Slaughter Canyon Cave, which is approximately 150 meters above the canyon floor, was created by incision of Slaughter Canyon ≤3 Ma; ample time for deposition of a guano deposit later covered by dripstone and flowstone speleothems as old as or older than 0.5 Ma.

The flowstone itself was deposited during marine isotope stage 7, which is considered a warmer interglacial period globally (Pisias et al., 1997). In the southwestern United States, glacial periods are considered cooler and represent times of greater effective moisture, while interglacial periods result in much drier conditions based on the study of the last 134 ka (Menking et al., 2004; Polyak and Asmerom, 2005). Flowstone deposition would therefore be expected during glacial periods, not interglacial periods. In this sense, the 212 ka old Slaughter Canyon Cave flowstone might be a significant piece of evidence for a less effective isotope stage 7 interglacial to the southwestern United States.

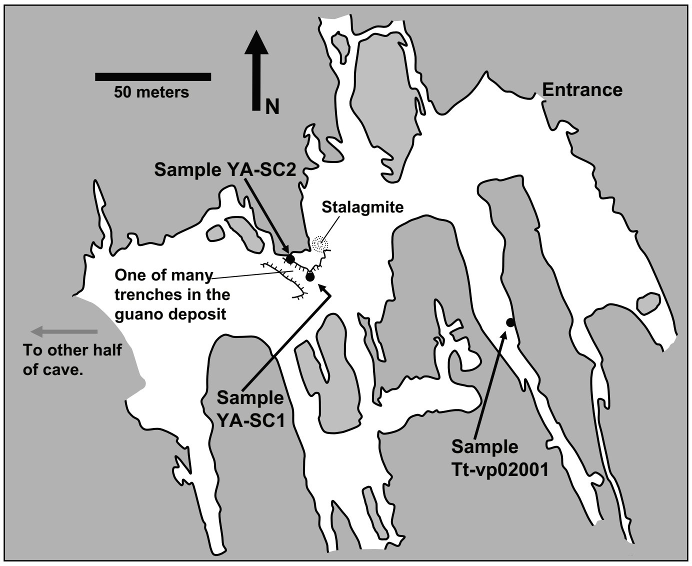

FIGURE 1.2.9. Map of front half of Slaughter Canyon Cave showing location of samples. Map was traced after Cave Research Foundation cave map included in Hill (1987).

TABLE 1. U-series data for three Slaughter Canyon Cave speleothems.

Sample	^{238}U (ppb)	^{232}Th (ppt)	^{230}Th/^{238}U (activity)	^{230}Th/^{232}Th (activity)
YA-SC-1 run1	229.0 ± 0.8	1386 ± 28	1.4399 ± 0.0111	727 ± 15
YA-SC-1 run2	229.1 ± 1.5	1373 ± 23	1.4392 ± 0.0225	734 ± 16
YA-SC-1-2 run1	168.3 ± 0.5	9596 ± 73	1.4012 ± 0.0109	75 ± 1
YA-SC-1-2 run2	168.4 ± 0.5	9621 ± 47	1.4195 ± 0.0133	76 ± 1
YA-SC-2 run1	446.0 ± 2.4	1589 ± 22	1.2341 ± 0.0134	1058 ± 18
YA-SC-2 run2	447.3 ± 2.4	1565 ± 16	1.2464 ± 0.0087	1088 ± 12
Tt-vp02001	356.1 ± 1.5	1153 ± 24	1.1530 ± 0.0098	1088 ± 24

Sample	$\delta^{234}U_m$ (‰)	$\delta^{234}U_i$ (‰)	uncorrected age (yr B.P.)	corrected age (yr B.P.)
YA-SC-1 run1	549 ± 7	994 ± 19	210827 ± 5063	210021 ± 5044
YA-SC-1 run2	549 ± 12	993 ± 37	210613 ± 10168	209815 ± 10106
YA-SC-1-2 run1	510 ± 5	923 ± 16	212015 ± 4837	210039 ± 4861
YA-SC-1-2 run2	508 ± 8	941 ± 24	220436 ± 6948	218474 ± 6903
			weight-averaged date =	**211588 ± 3000**
YA-SC-2 run1	175 ± 6			>400 ka
YA-SC-2 run2	173 ± 6			>400 ka
Tt-vp02001	109 ± 7			>400 ka

Sample sizes were 200 to 300 mg. YA-SC-1 is the flowstone capping the guano deposit. YA-SC-2 is drapery, and Tt-vp02001 is a pristine, unaltered stalagmite. (ppb = parts per billion, ppt = parts per trillion, m = measured, i = initial, B.P. = before present). Four analyses of two separate subsamples of YA-SC-1 were weight-averaged to obtain its final date.

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