Geologic Map of the Serpentine Bends 7.5-Minute Quadrangle, Eddy County, New Mexico

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Scale 1:24,000

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INTRODUCTION

The Serpentine Bends 7.5-Minute quadrangle is located approximately 20 and 30 miles southwest of Carlsbad, New Mexico, immediately west of the Carlsbad Caverns quadrangle. Located along the southern escarpment of the Guadalupe Mountains in southeastern New Mexico, the quadrangle straddles two modern physiographic regions, the Guadalupe Mountains and lower Pecos River Valley, as well as three distinct geologic provenances: the Delaware Basin, Capitan Reef, and Northwest Shelf. Guadalupe Ridge forms a major watershed divide that extends more than 50 miles to the southwest into the Guadalupe Mountains National Park. A hiking trail follows most of this ridge. Elevations in the quadrangle range from approximately 3,800 feet in the southeast corner of the map, to 6,170 feet on Guadalupe Ridge in the southwest corner.

PREVIOUS WORK

Hayes (1957) mapped what was then known as the Carlsbad Caverns East quadrangle, which was the 1:62,500-scale geologic map that includes the more recent Carlsbad Caverns 7.5-Minute Quadrangle. Hayes and Koogle (1958) mapped the Carlsbad Caverns West quadrangle (1:62,500 scale) that includes the Serpentine Bends 7.5-Minute quadrangle.

METHODS

Geologic mapping was performed from fall 2020 to winter 2021-2022. Lithologic contacts were delineated using recent (2005, 2009, 2016) 10-meter-resolution aerial photographs. The workflow involved a combination of field observations and digitization of map and field data into an ArcGIS geodatabase based

on the GeMS data standard (USGS NCGMP, 2020). Coordinates reported herein are given as Universal Transverse Mercator easting and northing, in meters, using the North American Datum of 1983, zone 13. The classification of surficial deposits is briefly discussed below. Paleozoic bedrock unit names (cross section) are those historically employed by petroleum geologists operating in the northern Delaware Basin and Northwest Platform.

PALEOZOIC ROCKS

Tansill Formation

The Tansill Formation is exposed only in the southeastern third of the quadrangle where it forms high flat mesas and plateaus along the Capitan escarpment. The rock type is almost indistinguishable from the rocks within the underlying Yates Formation and is composed mostly of thick-bedded massive dolomite beds and minor, thin quartz siltstone and fine-grained sandstone beds. Locally faint layering within beds is defined by sub-horizontal fenestrae. By far the most accessible outcrops are along the northeast side of Rattlesnake Canyon, on the east-central side of the map, where they are best accessed via the Rattlesnake Canyon Trail. A detailed measured section from this area is included in the recent geologic map of the Carlsbad Caverns quadrangle (Skotnicki, 2020). The upper flat surfaces of the mesas and plateaus commonly exhibit patches of dark, silty soil filling in spaces between the rock outcrops. Some of this soil appears to be derived from the erosion of nearby siltstone/sandstone beds and some is here interpreted to be wind-blown dust and possible accumulation of insoluble residue derived from chemical dissolution of the dolomite beds. In aerial photos, this soil gives the mesa tops an overall darker color which could be confused with sandstone layers.

The Tansill-Yates Contact

Both the Tansill and Yates Formations are lithologically very similar and not easy to distinguish throughout the quadrangle. The best way to identify the contact (as defined) is to recognize the "triplet"—three thick ledges of dolomite, separated by two thick slope-forming siltstone/sandstone beds. The triplet is regionally widespread and forms a useful marker horizon, with the Tansill Formation being the uppermost dolomite ledge. Additionally, the Tansill is also slightly lighter gray than the Yates formation. Southeastward, closer to the reef front, both formations lose any unique distinctions and the two are indistinguishable.

Yates Formation

The Yates Formation is characterized by interbedded dolomite and siltstone/fine-grained sandstone. Characteristically it contains many more interbeds of dark-yellow weathering siltstone/fine-grained sandstone than does the overlying Tansill Formation or the underlying Seven Rivers Formation. Dolomite is typically massive and fenestrate. The sandstone beds typically form darker slopes that are, almost everywhere, covered by debris shed from upslope dolomite beds and are rarely well exposed. These slopes locally contain more vegetation than the dolomite beds, and in aerial photos the sandstone layers are commonly quite noticeable because of their slightly darker color. In the aerial images, the Yates Formation is characterized by alternating dark and light layers of varying thicknesses. Figures 1 and 2 show typical exposures of the Yates Formation.

The Yates-Seven Rivers Contact

The contact between the overlying Yates Formation and the underlying Seven Rivers Formation is defined as the contact between the lowermost thick sandstone layer of the Yates, and the uppermost thick dolomite interval of the Seven Rivers Formation. In the northeast portion of the map this relationship is relatively clear and easy to follow, both on the ground and in aerial photos. Towards the southwest, however, in the higher elevations and steeper terrain, the distinction is not so obvious. Material shed from upslope sandstone beds collects locally on lower dolomite ledges and also on mesa tops, making them appear to contain more sandstone then they actually contain. Also, on many steep slopes dolomite debris commonly mantles and obscures the thinner slope-forming layers. Even with these uncertainties, in the southern portion of the map the Yates Formation appears to mostly form many of the uppermost flat tops of mesas. However, even in aerial photos it is difficult to confidently identify this contact and, on the map, it is drawn as a dashed contact. Figure 3 shows a typical exposure of this contact.

Figure 1. Looking southeast towards the mouth of Slaughter Canyon near the south-central edge of the map. Layers of the Yates Formation overlie the massive slopes of the Capitan Formation. The very top of the plateau on the north side of the Canyon is capped by the Tansill Formation.

Figure 2. From same vantage point as in Figure 1, looking west. As mapped, the tentative contact between the Yates (above) and Seven Rivers (below) was placed at the top of the cliff in the lower third of the photo.

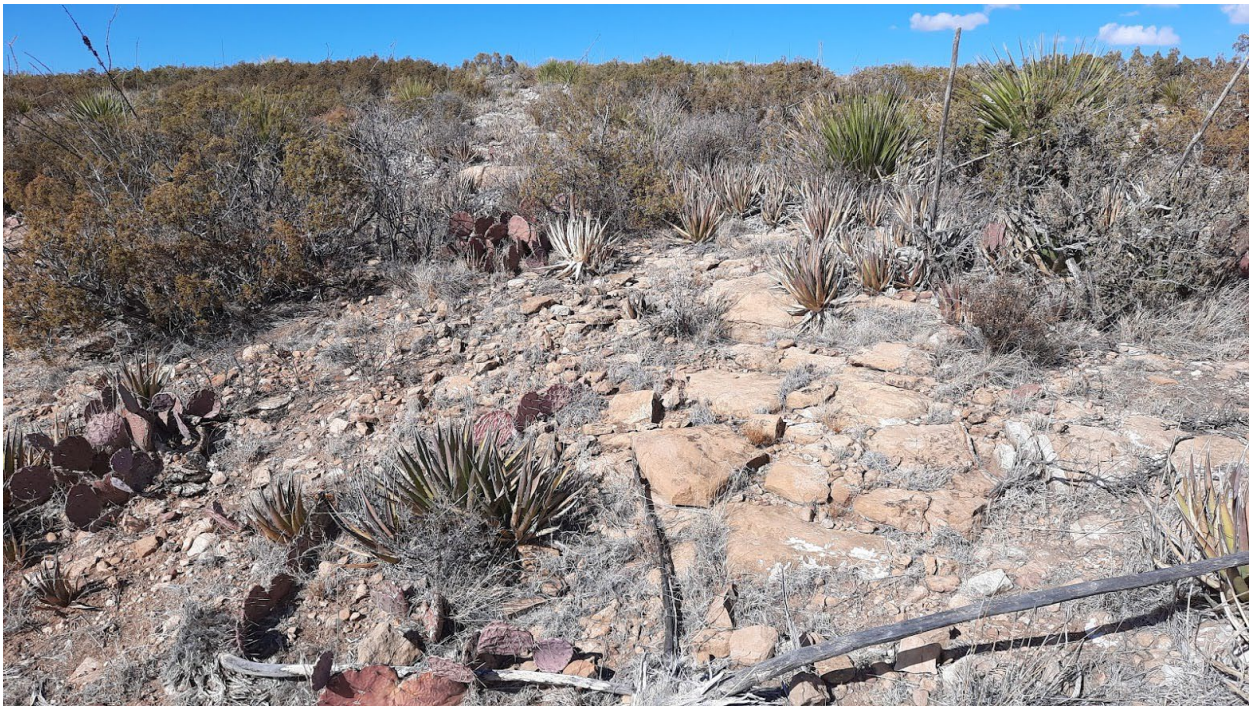

Figure 3. The contact between the overlying Yates Formation and the underlying Seven Rivers Formation trends diagonally through the cactus and agave in the lower left portion of the photo. The outcrop is fine-grained quartz sandstone at the very base of the Yates Formation.

Seven Rivers Formation

The Seven Rivers Formation is characterized by a rather thick interval of dolomite containing very few sandstone interbeds. The dolomite is commonly thick-bedded and massive, with beds between 1-3 meters thick separated by thin partings. From a distance, the formation appears regularly bedded and conspicuously contains very few siltstone/fine-grained sandstone beds up to a few tens of centimeters thick, mostly in the lower portion of the exposed outcrops. The unit characteristically forms cliffs and steep ledgy slopes that appear light gray both on the ground and in aerial photos and lack the darker-yellowish color imparted by sandstone beds abundant in the other formations. Figures 4 and 5 show typical exposures of the Seven Rivers Formation.

Figure 4. A typical exposure of the Seven Rivers Formation showing light gray dolomite and the absence of sandstone layers. This location is near the north-eastern edge of the map, looking east.

Figure 5. An outcrop view of the Seven Rivers Formation showing fenestrate texture possibly created by microbial mats.

Figure 6. The uppermost red sandstone layer in the Queen Formation at this location is sharply overlain by dolomite beds of the Seven Rivers Formation. Location is in the north-central part of the map looking southeast.

Figure 7. This exposure in the north-central portion of the map shows the uppermost red sandstone and siltstone unit of the Queen Formation, exhibiting a chaotic brecciated texture with angular clasts of dolomite floating within the red quartz-rich matrix.

The Seven Rivers-Queen Contact

The contact between the Seven Rivers Formation and the underlying Queen Formation is probably the most difficult to define and recognize. As defined here, the contact is placed between the lowermost thick interval of dolomite of the Seven Rivers Formation and the uppermost thick sandstone bed of the Queen Formation (Figure 6). In practice, however, this is not an easy contact to identify. The sandstone layers in the upper part of the Queen Formation form recessive slopes that are, almost everywhere, covered by debris shed from upslope dolomite beds. Some of the best exposures are within the drainages in the northwest portion of the quadrangle, where sandstone beds are locally exposed in stream cuts. Additionally, the upper portion of the Queen Formation contains several light gray, ledge-forming dolomite beds of different thicknesses that appear identical to the dolomite beds within the Seven Rivers Formation. Therefore, this contact was most easily mapped along the change in slope between the steep cliff-forming dolomite beds above, and the mostly slope-forming sandstone beds below. The reader should be aware that this contact is shown on the map with question marks to denote this uncertainty.

Queen Formation

The Queen Formation is not well exposed within the map area. The most accessible exposures are in the northwest portion of the map where sandstone beds are exposed within stream cuts and several well= maintained dirt roads follow the creek beds. The formation is dominated by layers of fine-grained

sandstone and siltstone that commonly form gentle slopes covered with debris. Here exposed, the beds are often planar bedded and locally show minor and faint planar and trough cross-beds. Within the map area, the unit contains less abundant and thinner dolomite layers that form ledges. Locally, portions of the uppermost dolomite beds are dismembered, brecciated, and appear to have foundered within the siltstone. The uppermost siltstone beds are commonly deep red in color and contain abundant angular dolomite clasts (Figures 7 and 8). These features suggest that the top of the Queen Formation may represent an erosional unconformity that was partly karsted before deposition of the overlying Seven Rivers Formation. The best exposures are within the southwestern portion of the map, where steeper slopes show the most exposure, but these areas are difficult to access. In aerial photos, the Queen Formation is commonly darker and exhibits shades of yellow and tan, compared to the overlying lighter gray dolomite beds of the Seven Rivers Formation. The large meander bend on the west-central side of the map probably formed there because of the presence of the softer, more erodible sandstone layers of the Queen Formation exposed there (Figures 9 and 10).

Figure 8. A good exposure of the contact between the Seven Rivers Formation (above) and the Queen Formation (below).

Figure 9. The slopes of this wide valley in the west-central part of the map are underlain by the soft sandstone layers of the Queen Formation, while the ridges are capped by the Seven Rivers Formation. Looking south.

Figure 10. This photo was taken from the same location as Figure 9 but from a higher altitude using a drone.

Castile Formation

The Castile Formation is exposed only in the southeastern corner of the quadrangle, south of the Capitan Formation escarpment, where it originally formed a thick deposit within the Delaware Basin. Because it is relatively soft, most of the unit has been eroded and is covered by younger Quaternary deposits. The best outcrops of the unit are exposed in the walls of drainages where alternating light-colored and dark-colored laminae are visible. Scholle, Goldstein, and Ulmer-Scholle (2007) reported that 209,000 individual 'lamination cycles' have been observed in the 1,800 feet thickness of the Castile Formation, which are thought to represent seasonal (yearly) varves. The laminae are commonly folded and contorted at the centimeter scale which has been interpreted to be the result of the "structural effects of Tertiary block faulting, anhydrite-gypsum transformation during uplift, and flowage at the outcrop [scale] due to erosion of laterally adjacent deposits" (Scholle et al., 2007). Figure 11 shows a typical outcrop of the Castile Formation in the southeast corner of the map.

Figure 11. Typical exposure of the Castile Formation in the southeastern corner of the map.

Folds

Because of the very shallow dips of the lagoonal carbonate formations within the quadrangle, most of the bedding attitudes were determined using aerial photos in conjunction with the Stereo Analyst tool in ArcGIS. The attitudes obtained this way are shown on the map as a special symbol that is distinct from the strike-and-dip symbol used for bedding attitudes measured on the ground (see the map legend). The paucity of vegetation and lack of thick soil allowed many attitudes to be estimated, providing excellent resolution across the map. The fold axes are shown as thin magenta lines on the map. They represent shallow synclines and anticlines whose parallel axes trend mostly east-northeast west-southwest, parallel to the band of exposure of the Capitan Formation. Unlike most of the fold axes within the neighboring Carlsbad Caverns quadrangle immediately to the east, most of the fold axes are very subtle and not easy to identify. Because of this, all of the axes are shown with a dashed line pattern to denote this uncertainty. The fold axes are roughly parallel to the folds and thrusts within the Marathon fold belt to the south, in southwestern Texas, suggesting that the two fold belts may have been created at the same time.

QUATERNARY DEPOSITS

These deposits were subdivided based on relative age and their position in the landscape. Many of these are referred to as "terrace" deposits because they tend to form thin deposits that reside and different and distinct levels on the landscape. The reader should be aware that in this report the word terrace is used mostly in this context and each level may not be related to any specific drainage or stream.

Throughout most of the map area, in the winding stream valley incised into the Paleozoic carbonate formations, all of the Quaternary deposits were mapped as Qa. This unit encompasses a wide range of ages from early Pleistocene to recent. The deposits in most of the flat floors of these valleys are probably Holocene in age but, as mapped, there are slightly higher terrace remnants and slope deposits that are likely older than Holocene.

The Quaternary deposits in the lowlands in the southeastern corner of the map are mostly subdivided into piedmont alluvial fan deposits (Qpf) along the escarpment, and the intermediate-age terrace deposits (Qti) that form the gently sloping valley floor away from the mountain front. These two deposits are probably at least partly coeval. More detailed mapping may be able to distinguish these ages better.

The oldest Quaternary deposit (Qto) forms a thin terrace that rests on top of remnants of the Castile Formation (Pcs). This deposit is high in the landscape and is deeply dissected, and represents the level of the valley floor that used to exist at least 50 feet higher than it does today.

The different ages of Quaternary deposits in other areas of the Southwest are commonly distinguished on the basis of (1) position in the landscape, (2) degree of dissection, and (3) the degree of soil development, including calcium-carbonate cement. In the Serpentine Bends quadrangle, only the first two criteria are useful. The third is not very useful. Both young and old deposits are commonly strongly cemented with

carbonate because of the great abundance of soluble carbonate upstream within the Paleozoic rocks, so the relative abundance of carbonate cement is not useful. Figures 12 and 13 show typical examples of Quaternary deposits in the central portion of the map, while Figures 14 and 15 show examples of deposits in the southeast corner of the map.

Figure 12. Looking south across a meander bend near the very center of the map. The active channel deposits are light gray while the slightly older flat terrace is covered with darker silty soil.

Figure 13. The active channel deposits are commonly unconsolidated and dominated by clasts of dolomite.

Figure 14. Stream cut exposure of Qpf. Notice large boulders and light gray carbonate cement.

Figure 15. Stream-cut exposure of Qti.

REFERENCES

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UNIT DESCRIPTIONS, SERPENTINE BENDS 7.5-MINUTE QUADRANGLE

Cenozoic

Anthropogenic units

daf - Disturbed ground and artificial fill (Historic to Modern) - Areas where intensive human activities obscure the nature of the underlying geology. Compacted gravels, sands, and muds underlying artificial constructions. Only mapped where extensive. Deposits are about 0-3 m thick.

Alluvial deposits

Qa – Alluvial deposits, undivided (Quaternary to Modern) - Unconsolidated to strongly indurated sand and gravel dominated by clasts of carbonate surrounded by a silty to sandy carbonaceous matrix, including terraces with silty, variably developed soil cover. As mapped, most of these deposits are probably Holocene in age. Estimated thickness up to 5 meters.

Qty – Youngest terrace deposits (Quaternary) – Exposed only in the southeast corner of the map. Terraces cut into alluvial piedmont deposits derived from the Guadalupe Mountains. This younger unit consists of several terrace levels which sit lower than Qti, Qto, and Qpf. Top surfaces and slopes are mantled by fine-grained eolian deposits and regolith. Stream cut exposures and rare scoured top surfaces show carbonate gravel strongly cemented by carbonate.

Qti – Intermediate terrace deposits (Quaternary) – Exposed only in the southeast corner of the map. Terraces cut into alluvial piedmont deposits derived from the Guadalupe Mountains. This intermediate unit consists of several terrace levels which sit higher than Qty and lower than Qto. At least partly coeval with reactivation of Qpf alluvial fans. Top surfaces and slopes are mantled by fine-grained eolian deposits and regolith. Stream cut exposures and rare scoured top surfaces show carbonate gravel strongly cemented by carbonate.

Qto – Oldest terrace deposits (Quaternary) – Exposed only in the southeast corner of the map. Terraces cut into alluvial piedmont deposits derived from the Guadalupe Mountains. This older unit consists of several terrace levels which sit higher than Qti. At least partly coeval with some deposition of Qpf alluvial fans. Top surfaces and slopes are mantled by fine-grained eolian deposits and regolith. Stream cut exposures and rare scoured top surfaces show carbonate gravel strongly cemented by carbonate.

Qpf – Piedmont fan deposits (Quaternary) – Exposed only in the southeast corner of the map. Sloping alluvial piedmont deposits derived from the Guadalupe Mountains, which have not been cut into terraces since deposition. At least partly coeval with some interval of Qto and Qti terrace surface formation. Slopes

are mantled by fine-grained eolian deposits and regolith. Stream cut exposures and rare scoured surfaces show carbonate gravel strongly cemented by carbonate.

Paleozoic

Permian

Ochoan Series (Upper Permian)

Pcs – Castile Formation (Ochoan) - Laminated to thin beds of alternating dark-colored and light-colored bands interpreted as anhydrite and/or gypsum (uncertain) deposited within the Delaware Basin. Layering is mostly contorted and is rarely consistent for more than a few meters. Both stream cut exposures and upper surface exposures show abundant brittle deformation cracks. Many mapped areas are mantled by a thin layer of alluvial and eolian deposits a few cm thick.

Guadalupian Series (Middle Permian)

Artesia Group

Pt – Tansill Formation (Guadalupian) – Mostly light-gray dolomite with minor, thin siltstone beds that are dark-tan in color. Dolomite beds are mostly thick-bedded and massive though locally faint layering within beds is defined by sub-horizontal fenestrae. No fossils are obvious. The lower portion of this unit forms a prominent cliff that overlies the uppermost slope-forming, thick siltstone layer of the underlying Yates Formation. Close to the reef front (unit Pc) the unit contains some teepee structures, but fewer than in the immediately underlying Yates Formation. Some beds contain abundant pisoids (or pisoliths), but overall pisoids are less abundant in the Tansill Formation within the quadrangle than within the Yates Formation.

Py – Yates Formation (Guadalupian) – Interbedded dolomite and siltstone/fine-grained sandstone. Characteristically contains many more interbeds of dark-yellow weathering siltstone and fine-grained sandstone than does the overlying Tansill Formation. Dolomite is typically massive and fenestrate, and commonly weathers a dark-tan color compared to the lighter gray weathering of the Tansill Formation. In Rattlesnake Canyon, the unit contains abundant beds of pisoids (or pisoliths) interbedded with dolomite. Teepee structures are locally visible, particularly within a few hundred meters of the Capitan Formation, but are much less abundant within this quadrangle than they are to the northeast.

Psr – Seven Rivers Formation – Thick-bedded gray dolomite occurs in rather massive beds between 1–3 meters thick, separated by thin partings. From a distance, the formation appears regularly bedded and conspicuously contains very few siltstone/fine-grained sandstone beds, up to a few tens of centimeters thick, mostly in the lower portion of the exposed outcrops. Forms cliffs and steep, ledgy slopes.

Pq – Queen Formation (Guadalupian) – Quartz siltstone and fine-grained quartz sandstone. Grains are subangular to subrounded. Typically contains very planar thin to thick beds that commonly erode recessively and form slopes. Locally contains very minor thin beds of light-gray dolomite approximately 10–30 cm thick that typically form small resistant ledges. The uppermost 20 meters or so contain several thin- to thick-interbedded light-gray dolomite layers up to several meters thick. Locally, portions of the uppermost dolomite beds are dismembered, brecciated, and appear to have foundered within the siltstone. The uppermost siltstone beds are commonly deep red in color and contain abundant angular dolomite clasts. These features suggest that the top of the Queen Formation may represent an erosional unconformity that was partly karsted before deposition of the overlying Seven Rivers Formation, which has a sharp base. Good exposures are present in the northwest portion of the map, in the canyon immediately south of West Hess Hills.

Pg – Grayburg Formation (Guadalupian) – Cross section only. Yellowish-gray to very pale-orange laminated, fine-grained, generally oolitic dolomite and limestone, interbedded with pale-orange siltstone and very fine-grained sandstone. Contact with the Queen Formation is arbitrary. Description from Hayes and Koogle (1958).

Capitan Reef Complex

Pc – Capitan Formation, undivided (Guadalupian) – From a distance, this unit exhibits a weekly developed inclined layering that dips southeastward between ≈15 and 30 degrees. This layering is more pronounced closer to the Delaware Basin. In outcrop, most exposures appear massive and structureless. A faint brecciated texture is visible locally, where angular clasts of dolomite of all sizes are strongly cemented by different generations of carbonate. Coarse-grained light-yellow palisade calcite spar commonly fills dissolution fissures and cracks. Fossils of sponge and brachiopod fragments are locally visible. Forms steep slopes and imposing cliffs. This unit represents the Capitan Reef itself, and the fragmented debris shed from the ancient reef down into the Delaware Basin.

Pgs – Goat Seep Dolomite, undivided (Guadalupian) – Identical to the Capitan Formation. Arbitrarily subdivided on the basis of age. Shown only in cross section.

Delaware Mountain Group

Pbc – Bell Canyon Formation (Guadalupian) – Cross section only. Predominately buff to brown, fine-grained, subarkosic sandstone and siltstone, with some shaley intervals. Siltstone and fine sandstone are commonly finely laminated and carbonaceous. Unit contains named carbonate intervals, which thicken and grade into the Capitan Formation along the margin of the Delaware Basin.

Pcc – Cherry Canyon Formation (Guadalupian) – Cross section only. Predominately buff to brown, fine-grained, subarkosic sandstone and siltstone, with some shaley intervals. Siltstone and fine sandstone are

commonly finely laminated and carbonaceous. Unit contains named carbonate intervals, which thicken and grade into the Capitan Formation along the margin of the Delaware Basin.