Geologic Map of the El Paso Gap 7.5-Minute Quadrangle, Eddy and Otero Counties, New Mexico and Culberson County, Texas

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INTRODUCTION

The El Paso Gap 7.5′ quadrangle is located between approximately 36 and 46 miles southwest of Carlsbad New Mexico, immediately west of the Gunsight Canyon 7.5′ quadrangle, and immediately north of the Guadalupe Mountains National Park. Straddling the western escarpment of the Guadalupe Mountains in southeastern New Mexico, the fault that forms the escarpment also forms the easternmost fault of the Basin and Range/Rio Grande Rift Provence. Slicing diagonally across the southeastern third of the map, Guadalupe Ridge forms a major watershed divide that separates westward drainage into the Salt Flats from eastward drainage into the Pecos River. A hiking trail follows most of this ridge. Elevations in the quadrangle range from approximately 5,200 feet near the northwest corner to 7,313 feet on Guadalupe Ridge in the south-central portion of the map.

PREVIOUS WORK

Boyd (1958) mapped the El Paso Gap 15′ quadrangle which includes the following 7.5′ quadrangles: El Paso Gap, Pickett Hill, La Paloma Canyon, and Panther Canyon. Boyd also described the facies relationships, the paleontology, and the structural geology within the 15′ quadrangle. Immediately to the east, Hayes and Koogle (1958) mapped the Carlsbad Caverns West 15′ quadrangle (1:62,500 scale). Also to the east, Skotnicki and Allen (2023) mapped the Gunsight Canyon 7.5′ quadrangle and Allen and Skotnicki (2023) mapped the Grapevine Draw 7.5′ quadrangle. To the west, O’Neil (1998) mapped the Cienega School 7.5′ quadrangle. King (1948) and, subsequently, Skotnicki and Knight (2021), mapped the Guadalupe Mountains National Park immediately to the south.

METHODS

Geologic mapping was performed during the winter of 2022–2023. Map-unit contacts were augmented using recent-vintage, high-resolution, rectified-color aerial photography contained within the World Imagery (Clarity) obtained from the ArcGIS Map Service and updated to January, 2022. 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 (UTM) 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 (also shown in the cross section) are those historically employed by petroleum geologists operating in the northern Delaware Basin and Northwest Platform and conform to the Geolex standard classification scheme.

PALEOZOIC ROCKS

Yates Formation

The Yates Formation is exposed only within the southeastern quarter of the quadrangle. The unit is characterized by interbedded dolomite and siltstone/fine-grained sandstone. This unit characteristically contains many more interbeds of dark-yellow-weathering siltstone/fine-grained sandstone than does the overlying Tansill Formation (which does not outcrop within the map area) or the underlying Seven Rivers Formation. Dolomite is typically massive and fenestrated. The sandstone beds typically form darker slopes that are almost everywhere covered by debris shed from upslope dolomite beds and are rarely well exposed. In the lower elevations where not thickly forested, these slopes locally contain more vegetation than the dolomite beds and in aerial photos the sandstone layers are commonly distinguishable because of their slightly darker color. In aerial photos, the Yates Formation is commonly characterized by these alternating dark and light layers of varying thicknesses.

The Yates-Seven Rivers Contact

The contact between the overlying Yates Formation and the underlying Seven Rivers Formation is here defined as the contact between the lowermost thick sandstone layer of the Yates and the uppermost thick dolomite interval of the Seven Rivers Formation. Along some of the cliff edges in the southern portion of the map (particularly along the north side of North McKittrick Canyon) this relationship is relatively clear and easy to follow, but only locally. In most areas, however, and particularly in the more thickly forested areas, the relationship is obscure. 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 southeastern portion of the map the Yates Formation appears to 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 everywhere as a dashed contact.

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 (Figure 1). The unit characteristically forms cliffs and steep 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. Figure 2 shows a typical exposure of the Seven Rivers Formation.

A few roadcuts along the Guadalupe Ridge Road reveal good exposures of the unit, but most of the formation is within the higher elevations of the map, which are more densely vegetated.

Because of this, the best exposures are along the cliff faces and steep slopes of the major canyons in the southeastern portion of the map, which require quite a walk to access, and are best seen from the opposite sides of the canyons. Superficially, the Seven Rivers Formation appears very similar to the Grayburg Formation. Currently, the best way (and possibly the only way) to distinguish the two in the field is with reference to the Queen Formation.

FIGURE 1—Exposures of the Seven Rivers Formation on the north side of the Middle Fork of Big Canyon (east-northeast of Devil's Den Canyon), showing thick-bedded, light-gray dolomite. The photo was taken from the northeast side of Canyon Ridge near 13S 520988m E, 3544407m N.

FIGURE 2—Good exposures of the Seven Rivers Formation showing thick-bedded, light-gray dolomite with both planar and wavy bedding contacts. This location is a roadcut along the Guadalupe Ridge Road a little more than one mile north of Devil's Den Canyon, looking north.

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 (which may be equivalent to the "Shattuck member" as described by Boyd, 1958)(see Figure 3). 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 northeast portion of the quadrangle, where sandstone beds are locally exposed in streamcuts. 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 dashed everywhere on the map to denote this uncertainty. Because much of the Queen Formation and overlying Seven Rivers Formation is at least partially vegetated with oak trees and pinon pine trees, it is almost impossible to view the contact on the ground from a nearby hill. Because of this, most of the contact was drawn using aerial imagery.

FIGURE 3—Roadcut exposures of the contact between the Queen Formation (below) and the Seven Rivers Formation (above) showing less-resistant tan sandstone and more-resistant thick-bedded light-gray dolomite. The contact between the two formations was drawn at the base of the uppermost, thick dolomite beds. This location is a roadcut along the Guadalupe Ridge Road a little more than one mile south of Deer Hill, looking east.

Queen Formation

The Queen Formation is dominated by relatively planar layers of fine-grained quartz sandstone, locally interbedded with thinner and less abundant dolomite layers. Most of the unit exists in the northeastern quarter of the map where it forms a relatively flat and high mesa ('Queen Mesa') that forms a homocline dipping gently to the northeast. This unit is characteristically rusty yellow in color and, where extensively weathered, commonly forms rusty-orange, sandy soils (Figure 4). The formation contains less abundant dolomite beds, commonly interbedded between thicker sandstone beds. On some weathered bedrock slopes, the sandstone and dolomite exhibit a similar color and weathering style and distinguishing between the two rock types from a distance is very difficult (Figure 5).

The Queen Formation, as mapped, is thicker in the north and thins to the south. In Devil's Den Canyon (the small canyon immediately north of the headwater divide of North McKittrick Canyon) the mostly-sandstone formation forms a conspicuous slope on the north side of that canyon which appears to disappear as it wraps around the east side of the canyon. In aerial imagery, this slope is traceable southward across the headwater divide of North McKittrick Canyon and is interpreted to be a much thinner continuation of the Queen Formation. If so, this slope also allows for a distinction between the underlying Grayburg Formation and the overlying Seven Rivers Formation, at least locally, south of North McKittrick Canyon.

FIGURE 4—A typical exposure of the sandstone of the Queen Formation showing light-rusty-orange sandstone debris and dark soil. This location is a roadcut along the Guadalupe Ridge Road north of Klondike Gap.

Figure 5. A roadcut exposure of the Queen Formation showing thin- to thick-bedded light-orange sandstone. The thicker, lighter-colored layer near the top is dolomite. This location is along the Guadalupe Ridge Road at Klondike Gap.

The Grayburg-Queen contact

Within the quadrangle, the Grayburg-Queen contact is much easier to define than the Queen-Seven Rivers contact. The upper part of the Grayburg Formation is dominated by beds of light-gray dolomite with very few interbedded sandstone layers. The bottom part of the Queen Formation is dominated by dark-rusty-yellow, fine-grained sandstone beds that are mostly recessive-weathering. Thus, the contact is here defined as a rather sharp lithologic contrast, a color contrast, and a slope-steepness contrast. The best location to see this contact is at the top of the west-facing fault scarp that forms the east wall of Upper Dog Canyon and Shattuck Valley (see Figure 6). This is in contrast, however, to Boyd's (1958, p. 28) description that the "boundary between the Grayburg and the Queen is difficult to recognize on the surface and in the subsurface." His description may, in part, be the result of extensive soil development on the relatively flat uplands of the 'Queen Mesa' where most of the Queen Formation resides, which obscures much of the contact. Also, the lower part of the Queen Formation does contain light-gray dolomite layers that may resemble more of a gradational contact than a sharp contact. Boyd's observation that the contact is also difficult to recognize in the subsurface is puzzling, though, because the distinction between sandstone and dolomite, and their thicknesses, should be easy to recognize in drill cuttings. Boyd (1958) did mention that, north of the map near Last Chance

Canyon, he followed individual sandstone layers that pinched out between dolomite or into neighboring sandstone layers, contributing to the difficulty in defining the base of the Queen.

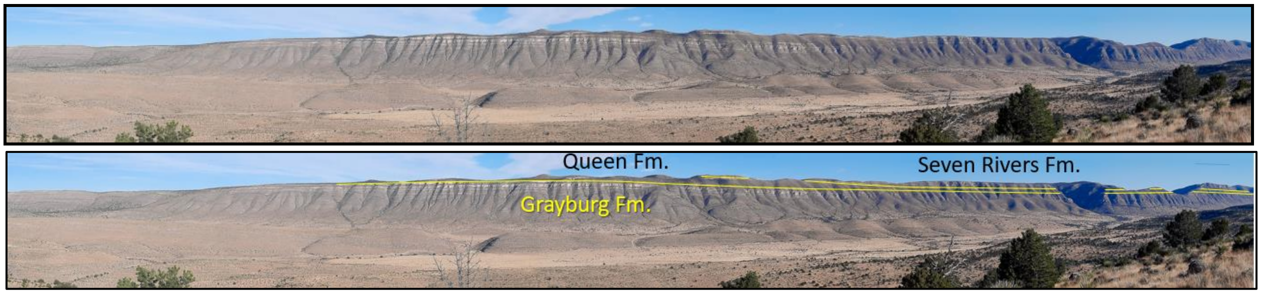

FIGURE 6—The Shattuck Valley fault scarp provides a panoramic view of three of the Permian formations. The Grayburg Formation (Pg) forms the light-gray layers of much of the lower portion of the slope. It is overlain by a darker layer of the Queen Formation (Pq) at the top of the cliff in the center of the image, and is overlain on the right side of the image by the light-gray dolomite layers of the Seven Rivers Formation (Psr). This image was taken from very close to 13S 512688.57m E, 3549543.24m N.

Grayburg Formation

As Boyd (1958, p. 9) pointed out, the Grayburg Formation was defined by Dickey (1940) who defined the Type section within an oil well in northeastern Eddy County, New Mexico, though, more recently, (as Boyd also mentioned) Moran (1954) proposed a new Type section for the unit. Skotnicki and Knight (2021) measured a detailed stratigraphic section on the Shattuck Valley fault scarp, immediately south of the state line. Some of the best and most accessible exposures of the Grayburg Formation are found in the northwestern portion of the map within Stone Canyon and along the El Paso/Carlsbad Road. In this area, the Grayburg Formation is comprised mostly of dolomite layers, with a few thin sandstone layers that typically weather a light shade of orange. The central portion of the canyon also contains the thickest continuous exposure of the Formation in the quadrangle—approximately 400 feet. Figure 7 shows an outcrop of this unit east of the El Paso/Carlsbad Road.

FIGURE 7—A typical exposure of the Grayburg Formation showing thick-bedded, light-gray dolomite. This location is near the north-central edge of the map, within the bedrock north of Shattuck Valley, looking north.

Capitan and Goat Seep Formations

The Capitan and Goat Seep Formations represent the ancient reef (the uppermost portion) and the debris shed off the reef into deeper water (most of the lower portion of the unit) (Figure 8). The two formations are identical. Previous researchers subdivided the two based on their lateral association with the Grayburg and Queen Formations (Goat Seep) and the overlying Carlsbad Group (Capitan Formation). This association is exposed in only one location, in a natural cross section, in the cliff face immediately north of El Capitan in the Capitan Peak 7.5′ quadrangle to the south. Even there, the Goat Seep and Capitan Formations form one continuous unit with no visible contact. From the perspective of defining units on a geologic map, the two units are indistinguishable and there is nothing to be gained by trying to force-fit this arbitrary distinction onto a map. Therefore, both units are shown as the Capitan Formation. Boyd (1958) stated that the upper sandstone unit of the Queen Formation (the Shattuck Member) is approximately equivalent to the highest part of the Goat Seep Formation as he mapped it in North McKittrick Canyon.

FIGURE 8—Looking southeast towards the mouth of Big Canyon in the southeast corner of the map, from near the very southeast point of Big Canyon Ridge. The layered strata belong to the Seven Rivers Formation, overlain by the darker Yates Formation that forms the tops of the mesas. All of the steep slopes below exhibiting the vertical fluted ridges are composed of the Capitan Formation.

DIFFICULTIES MATCHING FORMATIONS ACROSS THE STATE LINE

A quick examination of the geologic maps south of the state line (King, 1948) and north of the state line (Hayes and Koogle, 1958; and Boyd, 1958) reveals that the formations and contacts do not match across that boundary. Others have lamented this long-lasting disparity in such a geologically important mountain range. In fact, this was the motivation for creating the more recent geologic map of the Guadalupe Mountains National Park (GMNP) (Skotnicki and Knight, 2021), promoted and partially supported by the National Park Service (NPS) and spearheaded by Jonena Hearst of the NPS. Even the new map of the GMNP, however, failed to resolve this issue.

At least four circumstances conspired to make this an even longer-lasting dilemma:

1. Vegetation in the higher elevations south of the state line obscures the geologic contacts.
2. All sandstone beds thin dramatically towards the reef front, coinciding with the state line.
3. North McKittrick Canyon forms a big gap exactly in the same area (see Figure 9).
4. The arbitrary coincidence of the state line with this same area created convenient, and sometimes firm, boundaries to state-sponsored geologic surveys.

The author's conclusion, having mapped both north and south of the state line, is that some other means must be used to correlate formations between the southern and central portions of the Guadalupe Mountains. Even with modern technology that includes georectified seamless aerial imagery (a portion of which allows for viewing the landscape in 3D, as does Google Earth), visual examination and interpretation is inadequate. Add to this the presence of 'sequence boundaries' within and between formations, particularly where they transition into the reef front, and the task becomes even more complicated. Perhaps isotope trends, rare-earth-element trends, microfossil assemblages, or some other method focused on comparing stratigraphic sections, might be key to creating correlations not just across the state line but throughout the region.

FIGURE 9—In this nearly 180° panorama, the center of the image faces south, from the north side of North McKittrick Canyon, looking toward the higher elevations within the Guadalupe Mountains National Park.

STRUCTURE

Faults

Only two faults are mapped within the quadrangle. Both are normal faults. The largest, here named the Shattuck Valley fault, forms the steep, west-facing cliff slicing north–south through the center of the map. As Boyd (1958) observed, the northern and southern portions of the fault form relatively obvious lineaments across the land surface and the trace of the fault is easy to recognize. Much of the central portion of the fault, however, is cryptic and not easy to see at all.

Near the northern edge of the map, east of Stone Canyon and the El Paso Gap/Carlsbad Road, a prominent lineament of the Shattuck Valley fault separates layered carbonate bedrock on the steep, east side from darker and grass-covered alluvial deposits forming the lower slope. This prominent lineament is visible both in aerial imagery and from the road (Figure 10). The alluvial deposits are interpreted to be Holocene in age because they show almost no incision and exhibit immature, silty and sandy soils. The contact between the Holocene alluvium and the bedrock shows no visible scarp, but it is evident from the lineament itself that the edge of the bedrock probably represents the location of the fault. Because of this relationship, the fault is shown here as a dotted (concealed) line buried by a very thin and recent mantle of Holocene alluvium. Immediately south of this lineament, the fault, as drawn, climbs up over a small ridge ~1 mile east–southeast of Rattlesnake Tank. The rock layers immediately west of the fault dip rather steeply to the west, in one location as much as 51° and, as Boyd (1958) observed, probably represents fault-drag folding along this large structure. Since the rocks on both side of the fault here are interpreted to be the Grayburg Formation (**Pg**), displacement across the northern portion of the fault is not very great compared to exposures further south.

FIGURE 10—The prominent lineament on the slope represents the trace of the northern portion of the Shattuck Valley fault.

On the map, the middle portion of the Shattuck Valley fault is purposely left blank and, for now, uncertain. Boyd (1958) shows the fault here as a relatively low-angle planar feature where subsequent exhumation and erosion have created an apparently winding path of the fault across the slope. It is quite possible that Boyd's (1958) interpretation is correct. The area is, unfortunately, situated between private property on the west within the Shattuck Valley and a steep cliff on the east, so this area was not visited during the current study. It is also possible that the trace of the fault extends westward of the bedrock exposures where it is buried by Holocene alluvial deposits (**Qy**). Google Earth 3D view does not show a prominent lineament across bedrock in this area. Hence, rather than guess the location of the fault here, its real location is left for a more detailed future study.

The southern portion of the Shattuck Valley fault forms a weak lineament visible in aerial imagery, on the north side of Devil's Den Canyon. West of the lineament, the layers in the hills dip westward between 20–40° (Figures 11 and 12). These westward dips are interpreted as fault-drag folding within the hanging wall of the fault.

The second mapped fault forms the steep, linear, west side of the El Paso Ridge, in the west-central part of the map, and is here named the El Paso Ridge fault. The fault itself is barely exposed in a poor outcrop on top of the low divide in Section 30, T. 25 S., R. 20 E. Here, there is a linear separation between gray, rather coherent dolomite and pinkish-gray dolomite that is partly fragmental. In the small north–south drainage immediately north of this divide, very localized moderate to steep dips in the dolomite strata suggest a continuation of this structure. However, to the north, within the strata of Stone Canyon and on the small plateau immediately to the south, the layers do not show any obvious offset.

FIGURE 11—View of the Shattuck Valley fault scarp, looking north from the south side of Devil's Den Canyon. Note the west-dipping layers within the hill on the west side of the fault, in the center of the image.

FIGURE 12—View of the Shattuck Valley fault scarp, looking south. Note the west-dipping layers within the large hill downslope of the scarp, and within the hanging wall of the fault.

Boyd (1958) tentatively mapped a concealed fault along the west side of Upper Dog Canyon, mostly southwest of El Paso Ridge. This seems reasonable considering the steep, linear edge of the bedrock here. However, the bedrock strata dip very gently to the northeast, towards the El Paso Ridge fault, and newly mapped bedrock hills further out in the middle of the valley suggest a minimal amount of offset, if any. Without any exposure of the fault itself, a definitive answer may need to wait for a future study.

Folds

On the map there are two groups of folds—a group in the southeast quarter of the map and a group in the northwest quarter of the map. Both groups of folds deform Permian strata of Guadalupian age, and the northwest group is locally buried by Holocene sediments. Other than that, however, there are no additional constraints on the age of folding.

The group of folds in the southeast quarter of the map trends northeast–southwest and deforms both the Seven Rivers Formation and the overlying Yates Formation. These folds are barely visible. Strata in the limbs of the folds dip between only 2° and 4°, and the structures are noticeable only when standing on the edge of a plateau and looking across the canyon to the edge of the next plateau. Because the higher elevations here are in many areas covered with trees, it is not always possible to get a good view across the canyons, so it is quite likely that there are more folds then are shown on the map. It is also possible that some of these folds connect with folds of similar orientation to the east within the Gunsight Canyon 7.5′ quadrangle.

The group of folds in the northwest corner of the map trend approximately north–south. Even though this area mostly lacks trees or large shrub and is almost entirely exposed, the folds are not easy to see from a distance. Within the northern portion of Upper Dog Canyon, the bedrock on the west side of the valley dips up to 26° eastward (Figure 13), while the strata on the east side of the valley dip typically less than 5° westward. The valley itself closely parallels the axis of a broad north–south trending syncline (Figure 14). The axis projects southward through Martine Tank until it disappears into strata that dip entirely to the northeast, approximately one mile southwest of El Paso Gap. In this same area Boyd (1958) drew a north–south trending fault, and another parallel fault to the southwest. No evidence for these faults was observed during the current study.

Perhaps the most dramatic and easily observed fold occurs near the north edge of the map at the northern end of Shattuck Valley. Along the El Paso Gap/Carlsbad Road as it descends southward into the valley toward Effendale Tank, beautiful exposures of layered dolomite of the Grayburg Formation form gently tilted beds whose dips rotate around the northern end of the valley. The dips change direction rather abruptly along an axis that closely parallels the deep, narrow northwest-striking drainage that projects towards the road. Based on inward-dipping strata on both side of the Shattuck Valley, this axis probably projects southward along the entire length of Shattuck Valley.

Most of the folds in the map area were probably created by east–west-directed compression, possibly during the Mesozoic or Paleogene. Faulting probably occurred much later, long after folding, and possibly during formation of the Basin and Range province/Rio Grande Rift during the Neogene. Interestingly, the Shattuck Valley fault is probably the easternmost fault of the Basin and Range/Rio Grande Rift. This fault extends southward into the Guadalupe Mountains National Park where it curves southeastward across The Bowl and down Bear Canyon on the southeast side of the Guadalupe Mountains.

FIGURE 13—View of tilted layers of the Grayburg Formation, looking north, within the eastern limb of an anticline, exposed in the northwestern corner of the map in the small canyon parallel to the trend of Stone Canyon.

FIGURE 14—Looking southwest towards Martine Tank from the southeast corner of Section 25, T. 25 S., R. 20. E.; the distant ridge forms an anticline. The axis of the adjacent syncline parallels the ridge in the hills closer to the viewer (east) than the dark patch of vegetation at the base of the ridge.

QUATERNARY DEPOSITS

The different ages of Quaternary deposits in other areas of the Southwest are commonly distinguished on the basis of (1) their position in the landscape, (2) the degree of dissection, and (3) the degree of soil development, including pedogenic calcium-carbonate cement. The oldest Quaternary deposits are interpreted to be Pleistocene in age (**Ql**) and were distinguished only in the northwest corner of the quadrangle. Deposits are formed slightly elevated with respect to the surrounding younger Quaternary deposits. They are everywhere strongly cemented with carbonate cement and typically form hard resistant exposures. Because of the carbonate cement, these deposits are also lighter gray in color compared to younger deposits. In good exposures, they are typically conglomeratic and contain subrounded small boulders, cobbles, and pebbles, surrounded by a cemented sand composed of carbonate grains.

The vast majority of the Quaternary deposits are interpreted to be Holocene in age (**Qy**). They show very minor dissection and minimal soil development (Figure 15). Most of these deposits exposed at the surface are composed dominantly of tan silt and form flat valley floors. Closer to the mountain fronts these deposits show slightly deeper dissection by streams, particularly along the eastern side of Shattuck Valley. Here, some of these deposits might be subdivided into a slightly older unit with more detailed work. Adjacent to the major drainages, such as the one flowing northward through Upper Dog Canyon, the active channel has incised the **Qy** deposits locally as much as 2 meters. Because of this relationship, the active channel was given its own label (**Qyc**). Locally, several distinct levels of stream terraces are visible adjacent to the active channel, but they were not visible everywhere and are commonly difficult to trace very far, so they were not mapped separately but, instead, are mostly included in **Qy**.

FIGURE 15—View of dissected Holocene alluvial deposits in the Upper Dog Canyon. Note the weak soil development.

DRAINAGE INTEGRATION

As Boyd (1958) recognized, three drainages cut directly across ridges; hence, are evidence of antecedence of the streams—the streams must have existed prior to formation of the ridges and valleys (for a great reference about how rivers cross mountains see Larson and others, 2017). Two of the canyons (and streams) that cut through Stone Canyon (Figures 16 and 17) and El Paso Gap (both cutting across El Paso Ridge in the northwest portion of the map), and the third cutting through the low bedrock ridge to the west, are oriented approximately northwest–southeast. This orientation is roughly parallel to most of the large canyons incised into the southeastern side of the Guadalupe Mountains. It is possible that these two canyons are incised remnants of streams that formerly flowed southeast when this area was once higher in elevation than it is now, before fault-related downward displacement. This makes sense considering that the folds were formed during a time of compression, which shortened and thickened the crust, likely forming a higher mountain range to the west.

FIGURE 16—Looking northwest downstream through Stone canyon. This drainage cuts across a bedrock ridge.

FIGURE 17—Looking southeast upstream through Stone Canyon.

The Guadalupe Ridge Road closely follows the edge of the cliff on the east side of Shattuck Valley which itself forms a prominent drainage divide between east-flowing and west-flowing drainages. A notable exception is Devil's Den Canyon. Unlike all of the other drainages on the west side of the cliff that originate at the top of the cliff, Devil's Den Canyon (and its drainage basin) slices eastward of the cliff into the high country more than a mile. The reason for this is unclear. Boyd (1958) interpreted the low divide at the head of North McKittrick Canyon immediately to the south as resembling a beheaded canyon—a canyon that originally continued westward and was subsequently truncated by displacement along the Shattuck Valley fault. If so, it is possible that the original drainage of North McKittrick Canyon might have curved northward and then eastward, connecting with what is now Devil's Den Canyon. Without any more information, however, this is just speculation.

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APPENDIX: UNIT DESCRIPTIONS, EL PASO GAP 7.5′ QUADRANGLE

CENOZOIC ERATHEM

Quaternary System

Holocene Series

Holocene Sedimentary Deposits

Qyc Active channel deposits (Holocene)—Predominantly unconsolidated sand and gravel dominated by carbonate clasts surrounded by a silty to sandy carbonaceous matrix. Mostly devoid of vegetation though some low terraces, typically less than 1 m above the active channel, contain weak soil horizons and thicker vegetation. Thickness is unknown but probably less than several meters.

Qy Older Holocene sedimentary deposits (Holocene)—Deposits are composed of weakly to strongly indurated sand and gravel in a silty to sandy carbonaceous matrix. They form terraces typically between 1–3 meters above the active channel deposits. Most terraces have well-developed silty soil that supports abundant vegetation, particularly grasses. Estimated thickness of deposits are up to 5 meters.

Pleistocene Series

Pleistocene Sedimentary Deposits

Ql Pleistocene sedimentary deposits (Pleistocene)—Contains poorly sorted, angular- to subrounded-material from boulders to sand and silt composed dominantly of dolomite locally derived from the nearby bedrock and strongly cemented by carbonate. This unit forms small remnants slightly higher in the landscape than **Qy**, and exposed is mostly in the northwestern portion of the map.

PALEOZOIC ERATHEM

Permian System

Guadalupian Series

Artesia Group

Py Yates Formation (Permian, Guadalupian)—Interbedded dolomite and siltstone/fine-grained sandstone. Characteristically contains many interbeds of dark-yellow-weathering siltstone and fine-grained sandstone that tend to form vegetated slopes. Dolomite is typically light-gray, massive and fenestrated, and commonly weathers a darker-tan. In the southeast portion of the map, particularly closer to the Capitan Formation, the dolomite beds locally contain abundant beds of pisoids (or pisoliths) interbedded with wavy-laminated dolomite. No teepee structures were obvious within the map area. The Yates Formation was recognized only in the southeast portion of the map.

Psr Seven Rivers Formation (Permian, Guadalupian)—Thick-bedded, gray dolomite occurs in rather massive beds between 1–3 meters thick separated by thin partings. From a distance, the formation contains very few siltstone and fine-grained sandstone beds up to tens of centimeters thick, mostly in the lower portion of the exposed outcrops. Forms cliffs and steep ledgy slopes. The best exposures are along the steep cliffs in the southeastern potion of the map. The more accessible outcrops in the east-central portion of the map are mostly covered with vegetation and form slopes covered with soil and debris. The contact with the underlying Queen Formation is drawn above a thick interval of sandstone within the Queen Formation.

Pq Queen Formation (Permian, 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. The unit commonly forms deep rusty orange soils.

Pg Grayburg Formation (Permian, Guadalupian)—Light-gray to very pale yellowish gray laminated, fine-grained dolomite, interbedded with pale-orange siltstone and very fine-grained sandstone. Most beds are massive to weakly laminated and locally fenestrate. As mapped, this unit forms a thick sequence of layers that comprises most of the outcrops in the western half of the map. Some of the best exposures are seen along Route 137 in the north-central portion of the map and, in particular along the steep gorge where the stream cuts through the hills in the same area.

Capitan Formation

Pcp Capitan Formation (Permian, Guadalupian)—Massive dolomite and dolomite breccia. From a distance, the top of this unit exhibits a weakly developed inclined layering that dips southeastward between ≈15–30°. This layering is more pronounced up-section where it merges with the bedding in the lower part of the Seven Rivers Formation. Because of this, the contact as drawn, is dashed and is somewhat arbitrary. 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 sparite commonly fill 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 into the Delaware Basin. Typically forms very steep slopes and cliffs.