

Geologic Map of the Bond Draw and Cottonwood Hills 7.5-Minute Quadrangles, Eddy County, New Mexico

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Scale 1:36,000

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Geologic Setting

The Bond Draw and Cottonwood Hills 7.5-minute quadrangles (Fig. 1) lie within the northwestern part of the Permian Delaware Basin, extending from 16 kilometers south of Carlsbad, NM, to the New Mexico-Texas state line. Two north-south and two east-west paved roads provide primary access to the map area. However, many unpaved roads provide secondary access. The Black River, a small perennial stream that flows eastward through the northern part of the map area, joins the Pecos River about 7 kilometers downstream. The Bond Draw quadrangle is named for a tributary drainage that joins the Black River from the south; the Cottonwood Hills lie in the northwestern part of that quadrangle. In the central part of the map area, Cottonwood Draw joins Hackberry Draw to form Red Bluff Draw, which is joined by Hay Hollow farther downstream. Owl Draw runs through the southern part of the map area. Drainage is eastward across the map area toward the Pecos River. The Southern Canal of the Carlsbad Irrigation District supplies Pecos River water to farmland between the canal and the Pecos River. The Southern Canal reaches the Black River in the northeastern part of the map area. Located in the Chihuahuan Desert, the climate is semiarid and vegetation is sparse.

The map area is underlain by upper Permian (Lopingian) siliciclastic, evaporite (gypsum), and carbonate strata of the Rustler Formation. Rustler strata are present at shallow depth across much of the map area and extend at or near the land surface eastward to the Pecos River. Strata underlying the Rustler Formation in the map area are a thick sequence of upper Permian calcium-sulfate (gypsum/anhydrite) and halite-bearing evaporite deposits assigned to the Salado and underlying Castile formations. Dissolution of Permian evaporites has resulted in differential land subsidence at all scales as well as chaotic bedding orientations in outcrops of Rustler strata. Older Permian strata beneath the thick sequence of Salado and Castile evaporites are little deformed, however, other than being tilted slightly (~1 degree in the map area) to the east.

The regional eastward dip of bedrock strata combined with the relative flatness of the local landscape causes the Rustler Formation to give way to the Salado Formation near the land surface to the west of the map area. The position of the Rustler/Salado contact on the landscape is uncertain because Quaternary deposits largely cover it and the Permian strata are weathered and variably deformed/displaced by solution subsidence. Probable Salado gypsum is present in cutbanks along Hay Hollow and Cottonwood Draw a few kilometers to the west of the map area, and Salado gypsum may be present near the land surface in low, covered areas in the southwestern part of the map area. Conversely, carbonate rocks and redbed siliciclastics of the Rustler Formation are

present on higher interfluvial ridges several kilometers to the west of the map area. Overall, the area south of Black River consists of an extensive bedrock upland underlain at shallow depth in the map area by Rustler strata. Salado and Castile evaporites underlie the upland west of the map area. This evaporite terrane extends east and south into Culberson County, Texas, and is referred to as the Gypsum Plain. Dissolution of evaporites beneath the Gypsum Plain has resulted in pervasive karst development.

A little farther to the west of the map area, the escarpment of the Guadalupe Mountains rises abruptly above the Gypsum Plain. The Guadalupe Mountains, which mark the western edge of the Delaware basin, expose marine-shelf carbonate rocks of the Permian (Guadalupian) Capitan Formation and Artesia Group. Strata deposited within the Delaware basin that are equivalent to the shelf-margin carbonate rocks are assigned to the Bell Canyon and underlying Cherry Canyon formations, which consist largely of fine-grained siliciclastic sediment. The Bell Canyon Formation underlies the Castile Formation in the basin. The carbonate rocks forming the margin of the Guadalupian marine shelf enclose the Delaware basin on three sides (west, north, and east), forming an arched, curvilinear path through Eddy and Lea counties, with the basinal deposits lying to the south. As noted, the shelf-margin rocks are exposed in the Guadalupe escarpment, and are present in the shallow subsurface in the vicinity of Carlsbad to the north.

Thicknesses of Permian and Pennsylvanian sedimentary rock units underlying the Rustler, Salado, and Castile formations in the map area, based on well-log picks, are depicted on the cross section accompanying the map. These older rock units consist of marine and marginal marine carbonate and siliciclastic deposits that accumulated in a subsiding basin (Delaware basin) at equatorial latitudes along the western margin of Pangea. Underlying Ordovician through Devonian sedimentary rocks were deposited in the Tobosa basin, a precursor to the Permian Basin. The Tobosa basin gradually subsided during early Paleozoic time, accumulating a relatively complete sequence of sedimentary deposits. The collision of Gondwana with Laurussia beginning in the early Carboniferous led to segmentation of the Tobosa basin into the uplifts and basins commonly associated with the Permian basin (i.e., Diablo and Central Basin platforms, Delaware and Midland basins). This late Paleozoic episode of tectonic crustal deformation is apparently expressed along the cross-section line by a flexure in the Pennsylvanian rocks, and infilling of the resulting structural relief by eastward thickening of early Permian (Cisuralian) Wolfcamp and Bone Spring strata.

Regional uplift of western North America during the late Cretaceous-Paleogene Laramide orogeny apparently resulted in minor internal deformation of strata in the Delaware basin. Neogene crustal extension followed, which resulted in basin-and-range faulting to the west (e.g., Salt Basin graben) and flexural uplift of the Guadalupe

Mountains. In the vicinity of the map area, sedimentary rocks, including an indeterminate thickness of Mesozoic strata, have been eroded and removed by the Pecos River and precursor fluvial systems. Fan-piedmont deposits have spread eastward from the Guadalupe escarpment, and progressive entrenchment of the Pecos River valley below the level of the High Plains (Ogallala) constructional surface has ensued. An interesting facet of the late Neogene-Quaternary development of the lower Pecos Valley involves dissolution of Permian evaporites and associated land subsidence over a range of spatial scales. The lack of chronology of most of the Quaternary deposits in the lower Pecos region is a problem worthy of investigation. Until this happens, many details of the Quaternary geologic history of the lower Pecos River Valley will remain open to speculation.

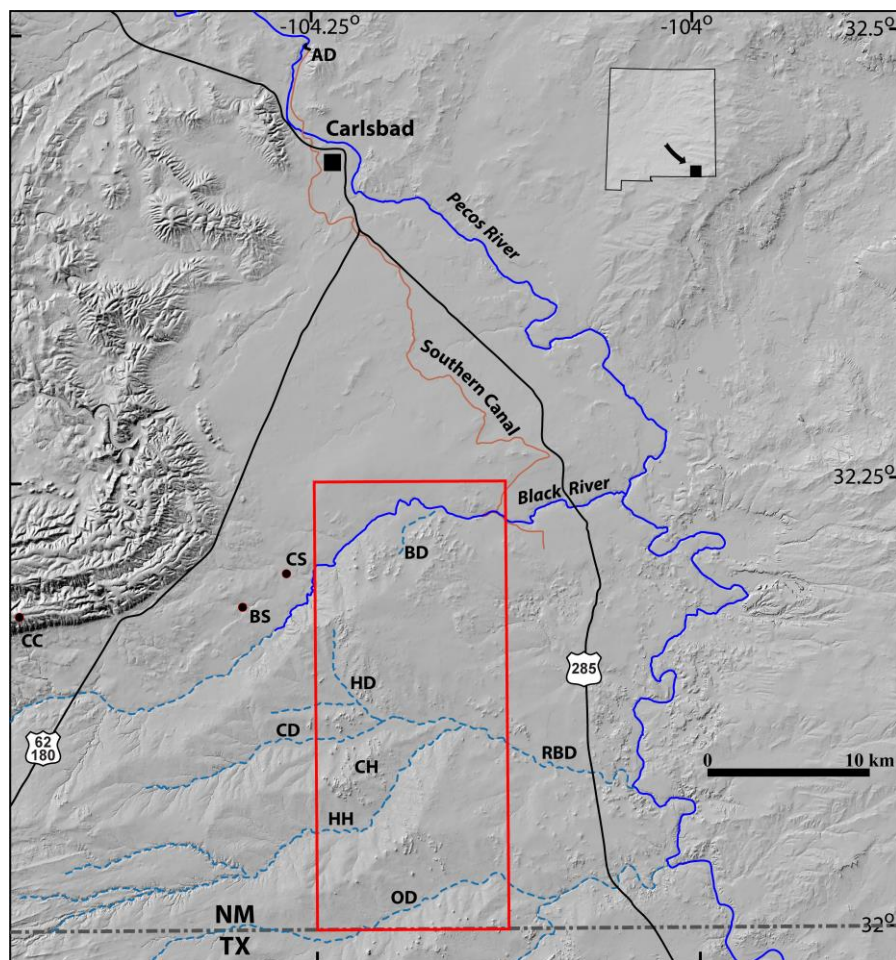


Figure 1: Location of the map area in southeastern New Mexico. Labeled features are: AD-Avalon Dam, BD-Bond Draw, CS-Castle Spring, BS-Blue Spring, HD-Hackberry Draw, CD-Cottonwood Draw, CH-Cottonwood Hills, HH-Hay Hollow, RBD-Red Bluff Draw, OD-Owl Dr.

Description of Map Units

Anthropogenic

d—Disturbed areas (paved roads and irrigation canals).

Hydrologic

w—Water in Black River channel.

Cenozoic Erathem

Quaternary System

Eolian, alluvial, and colluvial surface deposits

Qay—Alluvium in active drainages—Alluvium in active drainages (Holocene). Alluvial sand, mud, and gravel associated with active drainages, including deposits underlying low terraces adjacent to incised channels. Sediment is generally pale tan, brown, or reddish-brown silt and sand containing various amounts of gravel. Generally less than 2 meters thick.

Short Description: Alluvial sand, mud, and gravel along active drainages.

Qae—Eolian/alluvial surface deposits—Windblown silt and fine sand, fine- to coarse-grained slope-wash alluvium, rocky colluvium, and regolith, generally forming a thin mantle over weathered Rustler Formation bedrock (Upper Pleistocene to Holocene). Siliciclastic deposits range in texture from silty, sandy mud to gravelly sand, and are generally tan, brown, or pale red in color. This lithologically heterogeneous unit includes areas surfaced by pale-gray gypsite, which may represent accumulations of gypsum dust and/or weathering of near-surface Permian gypsum bedrock. Rocky colluvial deposits surrounding hills of Permian bedrock are locally cemented by calcium carbonate; some of these apparently older colluvial deposits may be Pleistocene in age. Although a significant proportion of the surficial cover is likely composed of eolian dust, extensive deposits of eolian sand (dunes) are not present in the map area. Deposits generally range from less than one meter to a few meters in thickness but might be 10 meters thick or more in some areas (e.g., along drainages low in the landscape or in thick colluvial wedges).

Short Description: Windblown silt and fine sand, slope-wash alluvium, and hill-slope colluvium/regolith, generally overlying weathered bedrock at shallow depth.

Qaed—Eolian/alluvial deposits in depressions—Accumulated eolian and alluvial silt, sand, clay, and gravel in closed or nearly closed depressions (Holocene). Map unit generally consists of pale-tan to brown silt and sand with minor amounts of locally derived coarser alluvium. The depressions likely represent areas that have undergone relatively recent subsidence caused by the dissolution of underlying Permian evaporites. Qaed deposits are probably on the order of several meters thick or less.

Short Description: Silt, sand, clay, and gravel in closed or nearly closed depressions.

Qvae—Valley-floor alluvium—Valley-floor sand, mud, gravel, and gypsite underlying floodplains and low terraces of larger drainages (Upper Pleistocene to Holocene). In general, deposits are relatively fine-grained and likely contain significant amounts of windblown dust trapped by grasses and shrubs, together with gypsiferous sediment and reddish mud derived from erosion of Permian bedrock. Fills on the order of a few meters in thickness in the larger west-to-east-flowing ephemeral drainages in the map area are brown, pale-red, and gray in color. Small unmapped exposures of weathered and commonly brecciated Rustler Formation strata are locally exposed along cutbanks and channel floors in gullied and scoured reaches. Ephemeral seeps and areas subject to flooding are apparent in local reaches of the larger drainages; cutbanks in some areas consist of reddish mud infused or surfaced by a dusting of efflorescent salts.

Discontinuous, relatively narrow incised channels are common in the major drainages.

Qvae deposits along the Black River are generally gray in color, consisting of comparatively fine-grained, locally gypsiferous mud underlying terrace levels a few meters or more above the present channel. Coarser-grained deposits carried in during floods are also present. Perennial stream flow is sustained in the Black River's lower reach by groundwater discharge at Blue Spring and Castle Spring, located a short distance west of the map area.

Short Description: Valley-floor sand, mud, gravel, and gypsiferous sediment underlying floodplains and low terraces of larger drainages.

Qvg—Valley-floor gypsite—Valley-floor gypsite along major drainages (Upper Pleistocene to Holocene)A relatively porous aggregate of gypsum silt, sand, and gravel in a fine-grained gypsiferous matrix, derived from weathering and transport of Permian bedrock gypsum. Unit is white to light-gray, is generally thinly mantled by brown eolian dust, and may exhibit a durable decimeter-scale surficial crust. Cutbank

exposures commonly reveal a basal one or two meters containing abundant rounded pebbles of white gypsum. Commonly cross-stratified and intercalated with pale-brown siliciclastic sediment, overlain by a meter or more of massive, fine-grained gypsite that may represent eolian deposition. Qvg deposits are common along Hay Hollow but are present in other major drainages and tributaries in the map area. Surface accumulations of gypsite that occupy higher positions on the landscape are included in map unit Qae.

Short Description: Valley-floor gypsite along major drainages.

Qbr—Black River valley-border alluvium—Composite map unit consisting mainly of surficial valley-border alluvium and colluvium along Black River, locally inset against or overlying somewhat older alluvial-plain deposits. For the most part, surface deposits consist of tan and brown mud, sand, and gravel carried in by the Black River or locally derived from hill slopes and drainages on both sides of the river. Coarse deposits contain sub-angular to rounded pebbles and cobbles of Permian carbonate and sandstone likely derived from the Guadalupe Mountains to the west, and from nearby bedrock exposures to the south and north of the river. Beds of coarse-grained, well-sorted, thinly bedded to laminated sandstone, likely representing fluvial deposition, are exposed at a few localities. Exposures of cemented gravel, sparse in the map area but increasingly common along incised reaches of the Black River downstream, contain minor amounts of rounded siliceous pebbles (quartz, chert, quartzite), likely recycled from Cretaceous conglomeratic strata that once covered the region. Some geologists (e.g., Bachman, 1980; Cikoski, 2019) assign these deposits of cemented coarse sand and gravel to the Pleistocene Gatuña Formation, which was originally named for pale red sandy and gravelly alluvium lying beneath a pedogenic carbonate caprock (Mescalero caliche) to the east of the Pecos River. Qbr deposits underlie a gently sloping surface slightly entrenched below the extensive Orchard Park alluvial plain to the north, and locally merge with thin deposits (Qae, Qay) overlying bedrock on both sides of the river. Depth to bedrock in the vicinity of the river, based on available driller's logs, is variable and, locally, may be up to 50 meters, according to a few reports. The thickness of Quaternary deposits generally appears to be; about 18 m along the western reach of Black River in the map area, 30 m in the central reach where the river valley widens, and 15 m or less along the eastern reach downstream from the low Rustler hills that are present on both sides of the river. In the vicinity of the Black River crossing of the Southern Canal, Rustler Formation carbonate bedrock is locally exposed in the river bed.

Short Description: Valley-border alluvium and colluvium along Black River, locally inset against or overlying somewhat older alluvial-plain deposits.

Qop—Orchard Park alluvial-plain deposits—Clastic deposits underlying the Orchard Park alluvial plain north of Black River (Middle to Upper Pleistocene). Silt, sand, clay, and gravel (commonly conglomeratic) underlying the large, triangular-shaped area extending east-west between the Pecos River and the Guadalupe Mountains and south-north between the Black River and Carlsbad. The unit is largely covered by a thin mantle of Holocene eolian and alluvial deposits similar in age to unit **Qae**, which is mapped extensively over the bedrock upland that extends southward of Black River. In the map area, **Qop** deposits are expressed at the land surface as small gravelly knolls and locally along the incised Black River drainage in artificial exposures (trenches, gravel pits, excavations along the Southern Canal), where they are included in the map unit **Qbr**. Shallow-borehole logs indicate that the unit consists mainly of relatively fine-grained red and yellow sandy, silty, and pebbly alluvium. Discontinuous beds and lenses of gravel up to several meters thick, typically well cemented by calcium carbonate, make up a smaller proportion of the deposits. Carbonate-cemented gravelly intervals are variously reported as "gravel," "conglomerate," and "limestone" in driller's logs. Hills of Permian bedrock rise above **Qop** deposits in the map area and elsewhere on the alluvial plain. To the west and north of the map area, Quaternary gravelly deposits with a well-developed pedogenic carbonate horizon rise above the plain in small hills and ridges that likely represent older fan-piedmont deposits derived from the Guadalupe Mountains to the west. Accumulations of pedogenic carbonate (caliche) are commonly noted in well-driller's logs extending to a depth of a few meters below the Orchard Park surface. Fractures in **Qop** conglomerate locally provide groundwater to water wells in the area and to Blue Spring and Castle Spring, which sustain a perennial flow in the lower reach of Black River above its confluence with the Pecos. The alluvial plain underlain by **Qop** deposits has long been considered equivalent (e.g., Hale, 1945; Horberg, 1949) to the Orchard Park plain or terrace initially identified in the Roswell reach of the Pecos Valley to the north. As with most Quaternary (and perhaps older) deposits in the lower Pecos region of New Mexico, chronology is lacking, and age assignments are relative and speculative; the middle to late Pleistocene age reported here is provisional, and older alluvial deposits may be present at depth. As discussed by Hale (1945), the thickness of the "valley fill" underlying the Orchard Park plain is variable, likely due partly to the dissolution of Permian evaporites and associated land subsidence. Hale (1945) reported maximum thicknesses for the valley fill to the north of the map area ranging from 60 to 80 meters.

Short Description: Clastic deposits underlying the Orchard Park alluvial plain north of Black River.

Qacs-Qafn—Alluvial aprons—The unit represents alluvial aprons extending eastward from the bedrock uplands in the northeastern part of the map area (Middle to Upper Pleistocene). These accumulations of clay, silt, sand, and gravel extend eastward toward the Pecos River and merge indistinctly westward with map unit **Qae**. Still, overall the unit is thicker than **Qae** deposits and contains gravel clasts likely carried in by a prehistoric (Pleistocene) Pecos River. Eroded remnants of rounded gravel containing exotic clasts are present in proximity to the **Qacs-Qafn** deposits, and are mapped separately (unit **Qrg**). **Qacs-Qafn** deposits are tan to brown in color, with reddish hues present in some areas; gravel clasts are dominantly rounded, pale-tan-gray carbonate, and reddish-gray to dark-gray chert, presumably derived from local (Rustler Formation) sources or reworked from prehistoric Pecos River deposits. Gravel is commonly cemented by calcium carbonate, and gully cuts and excavations expose accumulations of pedogenic carbonate that fill entirely, or nearly completely fill, void spaces (Stage II-III pedogenic carbonate morphology). A generalized distinction between coarser-grained, gravelly deposits (**Qacs**) and finer-grained, silt-sand-clay deposits (**Qafn**) is depicted on the map, with finer-grained deposits occupying a lower position on the local landscape. Few well-driller's logs were obtained for areas mapped as **Qacs-Qafn**; the available logs suggest that the alluvial aprons may be up to 30 meters thick in places, thinning in proximity to surface exposures of Permian bedrock.

Short Description: Alluvial aprons extending eastward from bedrock uplands in the northeastern part of the map area.

Qrg—Old Pecos River gravel deposits—Deposits of rounded gravel on interfluvial summits and low ridges underlain by Permian bedrock, containing cobble-sized clasts of quartzite and porphyritic igneous rock (Middle to Upper Pleistocene). These deposits are present in the northeastern part of the map area. They are generally obscured by Holocene eolian deposits and colluvium; however, well-rounded clasts over 10 cm in diameter, suggesting fluvial transport, are scattered across the surface where the unit is mapped. The deposits are probably cemented by calcium carbonate below the surface in most areas. Clasts consist largely of carbonate, presumably Permian in age, but minor amounts of purple and gray quartzite and igneous porphyry are present. Rounding, inferred provenance, and large clast size suggests fluvial transport by an ancestral Pecos River that transported cobble-sized clasts from source areas to the north in central New Mexico. Siliceous clasts scattered across the land surface and incorporated in Quaternary deposits are commonly observed throughout the northwestern Delaware basin. However, the size of those clasts is typically smaller (up to a few centimeters). The interpretation favored here is that they are reworked from beds of Cretaceous conglomerate that once blanketed the region. As mapped, **Qrg** deposits appear to define

an arcuate swath truncated on the north by the incised Black River valley; additional field transects are needed to delineate their full lateral extent. In the vicinity of the northern mapped exposures, the rounded gravel deposits form a thin veneer of scattered clasts over Rustler Formation carbonate strata. Continuing southward, the deposits form ridges with rounded summits that rise nearly 10 meters above the surrounding terrain. Where the deposits cross the map area to the east, they are surrounded by and contribute gravel to relatively thick accumulations of coarse alluvium mapped as Qacs. The deposits appear to be 5-to-10-meters thick or less based on topography, but may be thicker in some areas and nearly stripped from the landscape in others.

Short Description: Deposits of gravel on interfluvial summits and low ridges underlain by Permian bedrock, containing cobble-sized clasts of quartzite and porphyritic igneous rock.

Paleozoic Erathem

Permian System

Lopingian Series

Pr—Rustler Formation (Lopingian)—Lithologically heterogeneous strata consisting of siltstone, fine-grained sandstone, mudstone/shale, gypsum, and carbonate. Carbonate strata of the Culebra Dolomite Member, the next-to-lowest member of the Rustler Formation, are pale-gray carbonate mudstone forming thin tabular beds, commonly exhibiting abundant, mm-scale voids or vesicles. Macro-invertebrate fossils are not apparent. Beds of gray, yellowish-weathering, vaguely bedded to structureless carbonate mudstone are commonly present several meters below the Culebra Member. Carbonate strata in the Rustler Formation are relatively resistant to erosion and form most of the low hills and ridges in the map area. The Virginia Draw Member at the base of the Rustler Formation is largely comprised of intervals of fine-grained siliciclastic sediment and beds of gypsum. Virginia Draw strata are underlain by the Salado Formation and are generally poorly exposed in the map area. In some gully-cut outcrops, Virginia Draw redbeds and gypsum are steeply tilted or brecciated, likely the result of solution subsidence, and masses of secondary selenite are abundant. Disturbed Virginia Draw strata in the map area and elsewhere east and west of the Pecos River are considered by some geologists (e.g., Hayes, 1964; Gard, 1968) to represent Salado Formation "residues" left behind following dissolution and removal of salt in the formation. Hence, previous geologic maps (e.g., Kelley, 1971; Bachman, 1980) have variably assigned such deposits in the map area to the Salado Formation. Nonetheless, it seems clear that the deposits in question are present a few tens of meters or less below

Culebra carbonate strata, and are assigned here to the Rustler Formation. Rustler deposits above the Culebra Member have been removed over much of the map area, although younger Rustler strata are apparently present beneath some of the covered areas. Exposed remnants of Culebra carbonate in the map area are a few meters thick. Based on cuttings logs obtained from boreholes drilled using cable tools, the underlying Virginia Draw Member (including intervals logged as "redbeds" and "shale") is on the order of 50 to 70 meters thick in the map area. Borehole logs from some areas suggest that nearly 100 meters of Rustler strata in total may be present in parts of the map area.

Short description: Siltstone, fine-grained sandstone, redbed mudstone, gypsum, and carbonate.

Ps—Salado Formation (Lopingian)—Cross-section only. Based on cable-tool cuttings logs, the Salado Formation underlying the map area consists primarily of gypsum (or anhydrite), with lesser amounts of shale and sandstone. Salt and potash are reported in minor amounts in some boreholes, especially in the eastern part of the map area. To the east of the Pecos River, in contrast, the Salado formation consists dominantly of salt (halite) with economically important potash zones, a number of named anhydrite beds, and minor amounts of siliciclastic mudstone and fine sandstone. This lateral change from chloride (east) to sulfate (west) evaporite mineralogy may reflect post-depositional dissolution and removal of salt toward the west, and/or a westward facies change from halite to anhydrite precipitation in the basin as the Salado was being deposited.

Redbeds overlie the Salado Formation in the lower part of the Rustler Formation, and this lithologic change is generally indicated on gamma-ray logs. The Salado is underlain by the Castile Formation, which also consists largely of anhydrite in its upper part. Siliciclastic sediment near the base of the Salado in the map area generally produces a response on gamma-ray logs, providing a reasonably consistent basis for identifying the contact between the two formations. To the west of the map area, it is more difficult to differentiate the Salado and Castile based on typically available geophysical logs. The thickness of the Salado Formation in the vicinity of the cross-section, based on gamma-ray log picks and borehole cuttings logs, ranges from approximately 120 to 220 meters.

Short description: Gypsum or anhydrite, with lesser amounts of shale, sandstone, and, in some areas, salt.

Pc—Castile Formation (Lopingian)—Cross-section only. Finely crystalline calcium sulfate interlaminated with calcite, with two relatively thick salt intervals in the lower part. The Castile Formation consists mainly of laminae of white to pale-gray gypsum

(anhydrite) and thinner, dark-brownish-gray laminae of calcite, which alternate repetitively through hundreds of meters of section. The formation also contains a thin, basal laminated limestone and discrete halite intervals that provide a basis for dividing the formation into members (Anderson et al., 1972). Halite intervals in the Castile have been variably removed by dissolution across the Delaware basin; in the map area, the lower two intervals (Halite I and II) are largely intact and are each on the order of 60 meters or more in thickness. The Castile is overlain by the Salado Formation and rests on the Guadalupian Bell Canyon Formation. The total thickness is approximately 460 meters.

Short description: Finely crystalline calcium sulfate interlaminated with calcite, with two thick intervals of salt in the lower part.

Guadalupian Series

Delaware Mountain Group

Pbc—Bell Canyon Formation (Guadalupian)—Cross-section only. Predominately buff to brown, fine-grained sandstone to siltstone, with five named carbonate intervals (from oldest to youngest; Hegler, Pinery, Rader, McCombs, and Lamar members), which thin eastward from the escarpment forming the east side of the Guadalupe Mountains. Siliciclastic sediment consists mainly of fine-grained quartz and lesser feldspar (arkose to subarkose), coarse siltstone (many intervals enriched in organic matter), and shaley intervals. Siltstone and fine sand are commonly finely laminated. Carbonate intervals are dark- to light-gray, fossiliferous, thin- to medium-bedded limestone, which thickens and grades into the Capitan Formation along the margin of the Delaware Basin. The uppermost named limestone, the Lamar, extends farther basinward than the underlying carbonate intervals and is readily apparent on gamma-ray logs. The top of the Bell Canyon Formation, beneath the Castile Formation, is picked at the top of a siliciclastic interval (Reef Trail Member) that overlies the Lamar limestone beds. The Bell Canyon is approximately 275 meters thick in the map area.

Short description: Fine-grained sandstone and siltstone, with five named carbonate intervals that thin eastward from the Guadalupe escarpment.

Pcc—Cherry Canyon Formation (Guadalupian)—Cross-section only. Predominantly buff to brown, fine-grained sandstone to siltstone, with three named carbonate intervals (from oldest to youngest; Getaway, overlying South Wells, Manzanita members), that

thin eastward of the Guadalupe escarpment. Siliciclastic deposits are predominantly composed of quartz and lesser feldspar grains (generally altered) and are typically finely laminated. Some siliciclastic beds reportedly occupy discontinuous submarine channels. Carbonates are tan to dark gray, fossiliferous, and dolomitic. The contact between the Cherry Canyon and underlying Brushy Canyon formations was historically chosen in outcrop, to the southwest of the map area, at a lithologic change from comparatively coarse-grained sand of the Brushy Canyon to finer-grained sand in the Cherry Canyon Formation. Neutron density-porosity logs show a distinct, laterally traceable log response that is compatible with such a change. The top of the Cherry Canyon Formation is placed at the base of the lowest carbonate interval (Hegler) in the Bell Canyon Formation. The Cherry Canyon is approximately 330 m thick in the map area.

Short description: Fine-grained sandstone and siltstone, with three named carbonate intervals that thin eastward from the Guadalupe escarpment.

Pbrc—Brushy Canyon Formation (Guadalupian)—Cross-section only. Fine- to coarse-grained, tan and brown siliciclastic sandstone and siltstone, with shaley intervals in the lower part. Near the unit's base, it may contain thin beds of gray-brown carbonate and conglomerate. The unit is thinly to thickly bedded; coarser-grained sandstones are reportedly present in lenticular channels. Sandstone and siltstone is commonly finely laminated. The contact between siliciclastic sediment at the base of the Brushy Canyon Formation and uppermost Bone Spring carbonate is readily apparent on gamma-ray and resistivity logs. Unlike the overlying formations of the Delaware Mountain group, the Brushy Canyon does not grade shelfward (westward) into transitional carbonate shelf-margin or bank deposits. Instead, it thins westward and overlaps the Bone Spring/Victorio Peak formations, with a relatively thin, intervening interval of deposits (Cutoff Formation) that are discontinuously present in outcrops in the Guadalupe Mountains to the southwest of the map area. The Brushy Canyon is approximately 480 m thick in the map area.

Short description: Fine- to coarse-grained sandstone and siltstone, with shaley intervals in the lower part.

Cisuralian Series

Pbs—Bone Spring Formation (Cisuralian)—Cross-section only. Dark-gray to brown, thinly bedded carbonate mudstone, with varying amounts of dark-gray calcareous shale. Contains three regionally recognized sandy intervals (first, second and third Bone Spring sands) consisting of light-gray to tan, fine-grained sand with micaceous, shaley

or calcareous intervals (the stratigraphic position of the lower and upper sandy intervals are indicated on the cross section). The Bone Spring Formation is approximately 945 meters thick in the map area.

Short description: Carbonate mudstone and dark-gray shale, with three regionally recognized sandstone intervals.

Pw—Wolfcamp Formation (Cisuralian; unit may contain Upper Pennsylvanian strata in its lower part)—Cross-section only. Greenish gray, brown, and black calcareous and carbonaceous shale, with carbonate and siliciclastic sand beds. The top of the Wolfcamp Formation lies directly beneath the third Bone Spring sand; the unit's base is identified on wireline logs at the top of a sequence of alternating shale and carbonate beds assigned to the Upper Pennsylvanian Canyon-Cisco interval. The Wolfcamp interval ranges in thickness from approximately 430 meters along the western part of the cross section to 595 meters on the eastern end. The unit may contain Upper Pennsylvanian strata in its lower part.

Short description: Calcareous and carbonaceous shale with beds of carbonate and siliciclastic sand.

Pennsylvanian Subsystem

Upper

Pcc—Cisco-Canyon formations (Upper Pennsylvanian)—Cross-section only. Interbedded carbonate and shale, with lesser amounts of coarser siliciclastic sediment likely present. Gamma-ray logs suggest that carbonate and siliciclastic beds alternate on a scale of meters to several meters in the upper part of the unit and that thicker carbonate intervals are present in the lower part. The unit's base is placed at the top of a prominent carbonate interval assigned here to the top of the Strawn Formation. The Cisco-Canyon interval is approximately 130 meters thick in the map area.

Short description: Interbedded carbonate and shale, with beds of coarser siliciclastic sediment likely present.

Middle

Psa—Strawn-Atoka formations (Middle Pennsylvanian; may include Lower and Upper Pennsylvanian strata)—Cross-section only. Interbedded carbonate, sandstone, and

shale. Strawn carbonates are reportedly tan to brown and fossiliferous; sandstones are generally medium-grained, with pink feldspar grains reported from cuttings. Black shale is also reported. The underlying Atoka Formation contains gray to brown carbonate and shaley carbonate in its upper part, some of which is cherty, and the unit becomes sandy in its lower part. The base of the Strawn-Atoka interval is chosen at the top of the upper-Morrow carbonate interval, as indicated by gamma-ray and resistivity logs. Approximately 190 m thick, and may include Lower and Upper Pennsylvanian strata in part.

Short description: Interbedded carbonate, sandstone, and shale.

Lower

Pm—Morrow Formation (Lower Pennsylvanian)—Cross-section only. The upper part of the Morrow Formation consists of brown and gray fossiliferous carbonate, some of which is oolitic or cherty, together with beds of brown and gray, fine- to medium-grained sandstone and shale. Strata underlying this upper "Morrow lime" interval contain an abundance of fine- to coarse-grained quartz sandstone, with shale and carbonate interbeds. Dark-brown/black shale underlying the "Morrow clastics" interval is assigned by petroleum geologists to either the (Mississippian) Barnett Shale or the "lower Morrow shale." The thickness of Morrow strata, from the top of the Morrow lime to the base of the Morrow clastic interval, appears to increase eastward in the map area from approximately 260 to 315 meters along the cross-section line.

Short description: Carbonate with shale and sandstone interbeds in the upper part of the formation and underlying fine- to coarse-grained sandstone and shale of the Morrow clastic interval.

Suggested Reading

Hill, CA, 1996, *Geology of the Delaware Basin, Guadalupe, Apache, and Glass Mountains, New Mexico and West Texas: Permian Basin Section SEPM*, Publication No. 96-39, 480 p.

[This book provides a comprehensive summary of the geology of the region, and an extensive listing of pertinent scientific literature through 1996]

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