

Geologic Map of the Grapevine Draw 7.5-Minute Quadrangle, Eddy County, New Mexico

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Setting

The Grapevine Draw 7.5-minute Quadrangle lies on the northwestern side of the Pennsylvanian-Permian Delaware Basin, 40 km southwest of Carlsbad, NM and west of the upper reach of the Black River near U.S. Highway 62-180 (Fig. 1). Located in the Chihuahuan Desert, the climate is semiarid and vegetation is sparse. The southeast-facing escarpment of the Guadalupe Mountains, which exposes Permian marine carbonate rocks, rises abruptly from the plains to the east and crosses the northwestern corner of the map area. The Black River drains northward just west of the map area, turning northeastward and joining the Pecos River approximately 40 kilometers downstream near Malaga, NM. Grapevine Draw is an ephemeral drainage in the southern part of the map area.

A short reach of the upper Black River immediately east of the map area contains riparian areas where groundwater originating in the Guadalupe Mountains is discharged at the surface in springs and in wetlands along the valley floor. Portions of the wetlands are administered by the Bureau of Land Management and the National Park Service, along with the privately administered Washington Ranch facility. Water supply for the Carlsbad Caverns visitor center is obtained from Rattlesnake Springs, located a short distance west of the Black River and just south of Washington Ranch. The drainage from Rattlesnake Canyon in the Guadalupe Mountains reaches the Black River near Washington Ranch.

Much of the map area is surfaced by piedmont alluvium derived from the Guadalupe Mountains. The alluvial fill is up to 60 m thick, probably more in places, and overlies upper Permian evaporite rocks (calcium sulfate) of the Castile and overlying Salado formations. This bedrock gypsum is present at or near the surface to the east of Black River in an eroded bedrock "upland" that is part of a large area extending southward into Culberson County, Texas known as the Gypsum Plain. Dissolution of Permian evaporites has resulted in extensive karst development on the Gypsum Plain, and the region is pockmarked by features associated with solution subsidence. To the east of the map area, these features include large dissolution troughs and patches of younger Permian and Cretaceous strata that have foundered and subsided due to dissolution of the Permian evaporites. A number of smaller solution-subsidence features are present in the map area, many of which are depicted on the geologic map.

The Gypsum Plain ends where it adjoins the Black River, which is entrenched a few tens of meters below the level of the plain. West of the Black River the landscape rises toward the Guadalupe Mountains escarpment, which represents the boundary between the Delaware Basin to the east and the carbonate shelf to the northwest during middle Permian time.

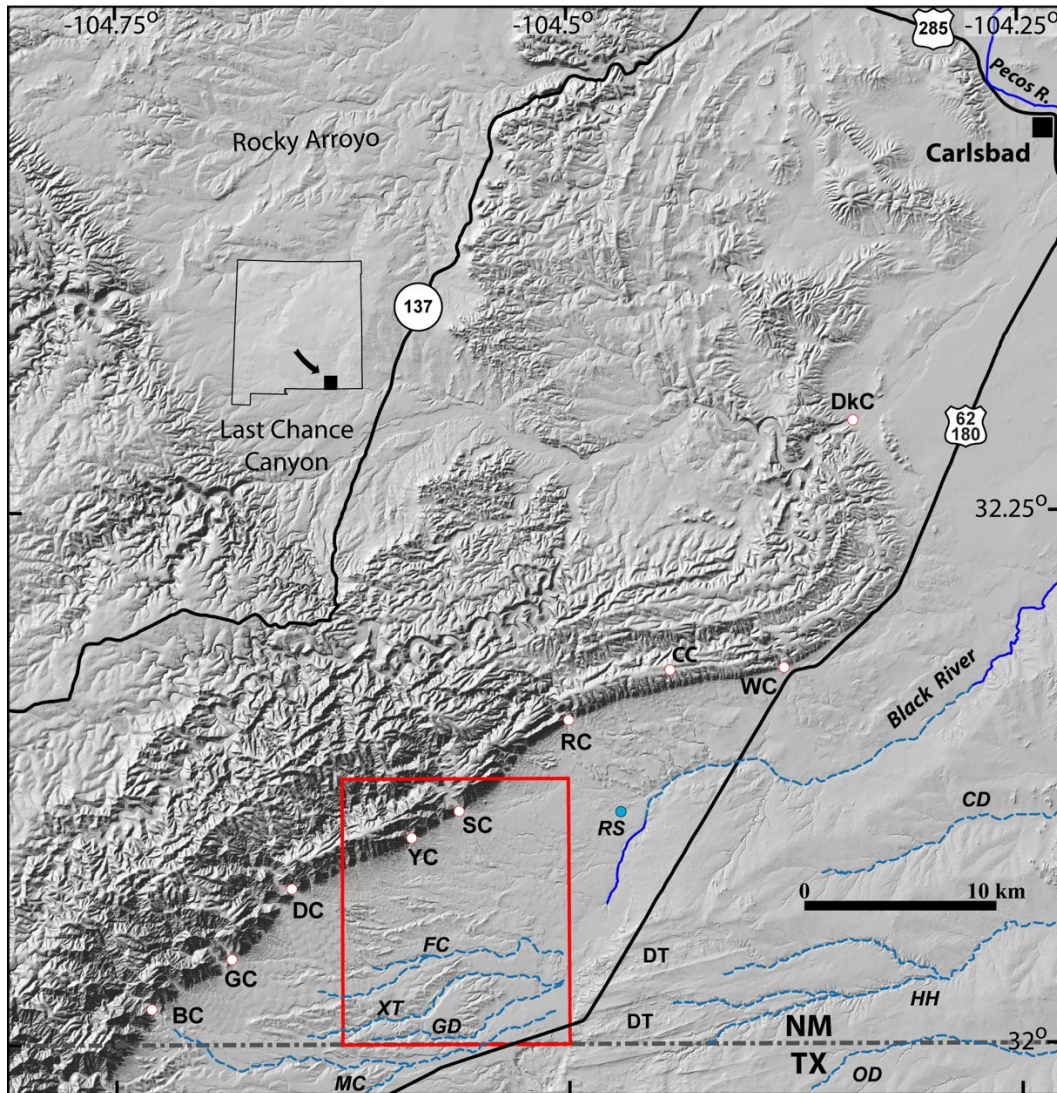


Figure 1. Location of the map area in southeastern New Mexico. Labeled features are: DkC-Dark Canyon, WC-Walnut Cyn., RC-Rattlesnake Cyn., SC-Slaughter Cyn., YC-Yucca Cyn., DC-Double Cyn., GC-Gunsight Cyn., BC-Big Cyn., MC-McKittrick Cyn., GD-Grapevine Draw, XT-XT Draw, FC-Franks Canyon, CD-Cottonwood Draw, HH-Hay Hollow, OD-Owl Draw, CC-Carlsbad Caverns, RS-Rattlesnake Springs, DT-dissolution trough on the Gypsum Plain.

Marine-shelf strata exposed in the map area include a shelf-margin/slope facies (Capitan Formation), and correlative shelf facies of the (ascending order) Seven Rivers, Yates and Tansill Formations (i.e. upper part of the Artesia Group). Correlative lithofacies that were deposited in the basin pertain to the upper part of the Delaware Mountain Group (Bell Canyon Formation), which consists largely of fine-grained siliciclastic sediment farther out in the basin. The Bell Canyon Formation directly underlies the evaporite deposits of the Castile Formation.

Piedmont alluvium is organized in the map area into older, intermediate and younger units that are all assigned relative Quaternary ages. Absolute age data are not available for these deposits. The surface disposition of piedmont alluvial units consists of younger deposits inset against and overlying older accumulations of sediment that together form a landscape of coalescent alluvial fans and eroded, relict fan remnants. In the northern part of the map area, surface deposits are relatively young with a few older intermediate fan remnants present, and gross surface topography is comparatively subdued. The southern part of the map area exhibits east-west ridges of older, eroded alluvium cut by incised drainages containing younger fills. This subtle change in geomorphic character from north to south may reflect the presence of Permian evaporites in the subsurface and differing degrees of solution subsidence.

Drainages in the southern part of the map area (e.g., McKittrick and Big Canyons, XT Draw, Franks Canyon; Fig. 1) end where they approach the valley floor of the Black River. Here, younger sediment transported in these drainages is spread out in alluvial aprons that form the southern divide of the upper Black River valley. These aprons are interspersed with and apparently fill a number of subsidence depressions. The courses of these southern drainages align with the large dissolution troughs on the gypsum plain just to the east, suggesting a relation between evaporite dissolution and shallow-groundwater flow paths.

Piedmont alluvium to the north of the map area is underlain at the land surface by exposures of Permian sulfate. Within the map area, two small exposures of Permian bedrock gypsum were encountered a short distance to the northeast of the mouth of Slaughter Canyon. These outcrops may represent the southernmost exposures of upper Permian evaporites in proximity to the mountain front. The exposures are small and quite weathered, and the rock does not exhibit the distinct laminations that characterize the Castile Formation. Large pieces and blocks of brown, cross-bedded sandstone and conglomerate are present in the colluvium that surfaces these hillslopes; this coarse-grained siliciclastic debris is especially abundant on the western side of the larger exposure of Permian gypsum. The overall texture, color, and composition of clasts in the sandstone and conglomerate are similar to other exposures of Cretaceous rocks that have been encountered on the Gypsum Plain to the east. The Cretaceous? rubble near Slaughter Canyon was likely displaced to its current position and intermingled with upper Permian gypsum by solution subsidence.

The disposition and thicknesses of Pennsylvanian-Permian sedimentary rock units underlying the Castile and Capitan formations are depicted on the geologic cross section. The upper Paleozoic sequence of rocks in the subsurface consist of marine and marginal-marine carbonate and siliciclastic sediment that accumulated in the Delaware Basin at equatorial latitudes along the western shore of Pangea. Lithostratigraphic unit names are those commonly used by petroleum geologists working in the Delaware Basin. Regional tectonism during Pennsylvanian time created a northwest-southeast trending compressional structure commonly referred to as the Huapache flexure or monocline, the axis of which crosses the Guadalupe Mountains from the vicinity of the Last Chance Canyon label in Figure 1 southeastward toward Rattlesnake Canyon and the NM-TX state line. The map area lies on the upper, southwestern limb of this structure, and uppermost Pennsylvanian and lowermost Permian units are relatively thin here compared with their thickness farther out in the basin to the east.

Late Cretaceous-Paleogene (Laramide) crustal contraction resulted in substantial regional uplift across western North America, including the greater Delaware Basin area, but evidence for Laramide deformation of sedimentary rocks underlying the western Delaware Basin is subdued. Regional Laramide uplift was followed by flexural uplift of the Delaware Mountains during Neogene basin and range crustal extension. Uplift involved relative down-dropping of the Salt Basin graben to the west, substantial down-to-the-west faulting along the western side of the Guadalupe Mountains, and tilting of the eastern side of the range and western Delaware Basin. Structure contours on top of the Bell Canyon Formation suggest overall eastward tilting of Guadalupian basinal strata in the vicinity of the map area of one or two degrees.

The distribution of surface features and deposits depicted on the geologic map are part of a larger landscape, the lower Pecos River valley, that developed in conjunction with Neogene uplift of the Guadalupe Mountains and a variety of regional factors and events spanning the last several million years. Many details of this relatively recent geologic history, which included significant fluctuations in climate and the widespread dissolution of thick sequences of Permian evaporites, continue to be worked out.

Description of Map Units

Cenozoic Era Quaternary System

Anthropogenic

d -- Disturbed areas (Highway 62-180 and the road to Slaughter Canyon).

Eolian, alluvial, and colluvial deposits

Qaed -- Alluvial and eolian silt, sand, clay and gravel in closed or nearly closed depressions (Holocene). Primarily silt and sand; may contain gravel and cobbles washed in from depression margins. Fines are generally pale-tan to brown. Most of the depressions are probably karstic structures resulting from subsurface dissolution of Permian evaporites. Fills in smaller depressions may be thin (< 1 m) to a few meters thick; thicker fills may be present in depressions in the southeastern part of map area.

Short Description: Accumulations of sediment in closed or nearly closed depressions.

Qay -- Alluvium along active drainages (Holocene). Alluvial sand, mud, and gravel along active drainages, including deposits underlying low terraces within and adjacent to modern channel systems. Deposits commonly contain abundant, poorly-sorted pebbles, cobbles, and boulders of Permian carbonate rocks,

although in some reaches surface deposits are comparatively fine-grained pale-tan to reddish-brown silty sand, sand, and pebbly sand. Unit is typically inset against younger piedmont alluvium (Qpy) on the distal piedmont slope, and merges with Qpy toward the mountain front. Thickness of the deposits including low fill terraces is probably less than a few meters in most areas.

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

Qvae -- Sand, mud, gravel, and gypsite underlying the upper Black River valley floor (Upper Pleistocene to Holocene). In general, sediment is relatively fine-grained and likely contains significant amounts of wind-blown dust trapped by grasses and shrubs, together with gypsite washed in from embankments eroded in Permian evaporites. The southeastern corner of the map area contains small areas of Qvae, which is more extensively represented to the east along the escarpment that forms the eastern margin of the upper Black River valley. Unit ranges from brown to pale gray in color and contains in the map area significant contributions of sand and gravel from alluvial aprons and piedmont drainages to the west. Available water-well logs from the upper Black River valley floor suggest that approximately 20 m of clayey sediment is present beneath the surface in some areas; other areas are underlain at shallow depth by "white gypsum." Shallow groundwater emerges at the surface to the east of the map area along the perennial upper reach of the Black River and in the Bottomless Lakes sinkhole pond.

Short Description: Valley-floor sand, mud, gravel and gypsite of the upper Black River valley.

Qac -- Undivided valley alluvium and colluvium in the Guadalupe Mountains (Middle Pleistocene to Holocene). This composite unit includes alluvium along active channels, terrace deposits, hillslope colluvium along canyon walls, and unmapped areas of bedrock along scoured channel reaches and cut banks. Deposits consist of pale-tan to brown siliciclastic silt and sand, gravel, cobbles and boulders. Larger clasts are dominantly pale-colored dolomite and gray limestone derived from surrounding Permian shelf and shelf-margin strata of the Artesia Group and Capitan Formation. Accumulations of sediment above active channels are commonly cemented. Deposits may locally be several meters thick beneath terraces and colluvial wedges. Map unit merges eastward with piedmont alluvium in the vicinity of the mountain front.

Short Description: Undivided alluvium and colluvium in larger canyons of the Guadalupe Mountains.

Qpy -- Younger piedmont alluvium (sand, gravel, cobbles, boulders, and mud) (Upper Pleistocene to Holocene). Coarser debris, including cobbles and boulders in the vicinity of the mountain front, are Permian carbonate rocks derived from the Guadalupe Mountains and from reworking of older piedmont alluvium. Pale-tan to reddish-brown silty sand, sand, and pebbly sand comprise much of the unit in some areas. Gravelly deposits are present in lenticular channels and in more continuous, decimeter- to meter-scale beds, and are commonly indurated with calcium carbonate cement. Includes accumulations of sediment in active channels, together with deposits graded to levels a few meters above active channels and colluvium or slope wash at the base of older fan remnants. Focusing of surface runoff toward areas

underlain by younger piedmont alluvium is commonly expressed by a relative abundance of vegetation and darker shades on aerial imagery. Surface roughness (microtopography) is locally pronounced close to the mountain front where cobble- and boulder-sized clasts are plentiful. Some drainages floored by Qpy deposits exhibit subvertical walls deeply cut into cemented gravel of older alluvium. Cutbank exposures of Qpy deposits up to a few meters thick are present in some areas.

Short description: Younger piedmont alluvium.

Qpi2 -- Intermediate piedmont alluvium, younger map unit (Upper Pleistocene to Holocene?). In the map area, these deposits are graded to a somewhat higher level than deposits of Qpy, and are inset against older piedmont alluvium along the larger valleys and draws that drain eastward from the Guadalupe Mountains. Bar and swale microtopography is evident on depositional surfaces. Comparatively young deposits of gravelly alluvium in the western Delaware Basin, including relatively young deposits underlying the piedmont slope in the map area, are commonly cemented with calcium carbonate. This probably reflects a predominance of carbonate dust and debris in the region and the arid climate. Preservation of microtopography and inset relations with other piedmont map units suggest a relatively young age for Qpi2 deposits. Erosion of older piedmont deposits, transport of sediment from the Guadalupe Mountains and Qpi2 deposition may have occurred primarily during the last glacial episode. Thickness of the deposits is variable, ranging from decimeters to perhaps several meters. Exposures in deeply incised drainages near the mountain front generally reveal up to a few meters of Qpi2 sediment overlying surfaces scoured into older alluvium.

Short Description: Intermediate piedmont alluvium, younger map unit.

Qpi1 -- Intermediate piedmont alluvium, older map unit (Middle Pleistocene). Deposits are graded to a higher level than deposits of Qpi2, and remnant surfaces are generally smoother. Qpi1 fan remnants underlie interfluvial ridges and isolated knolls in the northern part of the map area, and extend eastward up to 20 m above the floors of larger drainages in the southern part of the map area. Gravelly strata are well-cemented and finer grained deposits are typically poorly exposed, even in subvertical drainage cuts. Episodes of landscape erosion, sediment mobilization and accumulation of Qpi1 alluvium may be associated with any of the glacial-interglacial climatic fluctuations that occurred during the mid-Pleistocene. Unit probably ranges from less than one to several meters in thickness.

Short Description: Intermediate piedmont alluvium, older map unit.

Qpo -- Older piedmont alluvium (Lower? to Middle Pleistocene). Surface exposures are generally well-cemented conglomerate, containing subangular to rounded pebbles, cobbles and boulders derived from Permian carbonate rocks in the Guadalupe Mountains. Finer grained strata are poorly exposed. Remnants of older piedmont alluvium are preserved as east-west oriented ridges that have been eroded and stripped down to resistant conglomeratic strata. Interfluvial summits underlain by Qpo remnants rise up to 40 m above adjacent drainages. Slumping and tilting of the deposits, likely due to solution

subsidence over extended periods of time, is evident in places. Hale (1955), based on borehole lithologic logs available at that time, reported an estimated maximum thickness of 60 m of accumulated fill sediment in the upper Black River valley, with gravel (conglomerate) comprising a comparatively small proportion of the total alluvial fill.

Short Description: Older piedmont alluvium.

QT -- Undivided clastic deposits (Pliocene? to Holocene). Cross section only. The maximum thickness of QT depicted on the cross section is somewhat larger than Hale's (1955) estimate of 60 m, based on interpretations of more recent borehole logs and the probability that thicker accumulations may be present locally due to dissolution of Permian evaporites and subsidence of overlying fills.

Short Description: Undivided fill sediment above Permian bedrock.

Paleozoic Erathem

Permian System

Lopingian Series

Pcs -- Castile and Salado Formations, undivided (Lopingian). Finely crystalline calcium sulfate (hydrated to gypsum near the land surface), interlaminated with calcite (typical Castile Formation lithology), or vaguely laminated to structureless anhydrite (Salado Formation). The Castile Formation overlies the Bell Canyon Formation in the subsurface, and the Salado Formation is overlain by the Rustler Formation to the east of the map area. The Castile Formation consists mainly of laminae of white to pale-gray gypsum (anhydrite) and thinner, dark-gray laminae of calcite, which alternate repetitively through hundreds of meters of section. Regionally, 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). Intervals of nodular anhydrite and breccia resulting from dissolution of halite and collapse are commonly encountered in drill cores in the basin. The Salado Formation overlies the Castile Formation in the subsurface east of the Pecos River, where it consists of a thick sequence of halite and other soluble chloride salts, some named anhydrite beds, and minor amounts of admixed and intercalated siliciclastic mud. It is unclear if or how much of the Salado Formation is present in the western Delaware Basin; soluble salts in the Salado Formation that may have been present have been removed by dissolution, and the thick accumulations of chloride salts present in deeper parts of the Salado Formation depositional basin to the east may be represented by sulfate facies in basin-margin areas to the west. The small area mapped as Pcs in the southeastern corner of the map area is close to the well-known state-line roadcut that exposed typical laminated Castile Formation strata, and outcrops on the Gypsum Plain just above and east of the highway also consist of the interlaminated anhydrite-calcite lithology, characteristic of the Castile Formation. In contrast, the small exposures of Permian gypsum near the mouth of Slaughter Canyon do not exhibit the sharply defined calcite laminae of the Castile Formation, and may represent accumulation of post-Castile Formation anhydrite. The combined thickness of Castile

and Salado Formations strata remaining along the cross section line ranges from about 65 to 200 m, with all of the original halite and much of the sulfate apparently removed by dissolution. The unit likely extends along the mountain front at least as far south as Double Canyon, as indicated by a group of sinkholes on intermediate fan remnants there. Several kilometers to the southwest along the escarpment, near the mouth of Big Canyon, Castile and Salado Formation strata have been completely removed, and the Bell Canyon Formation is exposed at the surface.

Short description: Finely crystalline calcium sulfate, with interlaminated calcite (typical Castile Formation lithology), or vaguely laminated to structureless calcium sulfate.

Guadalupian Series

Marine-shelf deposits

Artesia Group

Pt -- Tansill Formation (Guadalupian). Pale-weathering, light-gray to tan, bedded dolomitic grainstone, packstone, wackestone and mudstone. In general, carbonate sediments deposited near the shelf margin are fossiliferous grainstones and packstones forming centimeter- to meter-scale beds that are variously planar-laminated, cross-laminated, nodular, wavy bedded, or structureless. Common fossils include macroscopic skeletons and fragments of crinoids, brachiopods, and gastropods; fusulinids, calcareous algae (e.g., *Mizzia*), and other microfossils are apparent under magnification in some samples. Shelfward (west) from the Guadalupe Mountains escarpment, beyond the map area, tabular to wavy beds containing abundant pisoliths are common. Farther shelfward, thinly bedded carbonate mudstone exhibiting fenestral fabric is commonly exposed at the surface. Lateral changes in carbonate lithofacies are also expressed as vertical changes through the Tansill Formation succession, with carbonate lithofacies alternating vertically in meter-scale, shoaling-upward bed sets or parasequences. This stratigraphic cyclicity in Tansill Formation and underlying Artesia Group carbonates has received detailed study in the Guadalupe Mountains, leading to reconstructions of relative fluctuations in sea level during Guadalupian time. Rarely exposed siliciclastic intercalations in the upper part of the Tansill Formation are pale, yellowish-brown laminae and thin beds, consisting dominantly of siltstone with scattered grains of very fine-grained sand. Approximately 90 m thick in the map area.

Short description: Thin, medium, and thick beds of dolomitic carbonate, with rare thin beds and laminae of siliciclastic silt and fine-grained sand.

Py -- Yates Formation (Guadalupian). Beds of light-gray to tan dolomitic carbonate, interbedded with yellowish-brown siltstone to fine-grained sandstone. The Yates Formation is distinguished from the overlying and underlying Tansill and Seven Rivers Formations by a relative abundance of siliciclastic beds, which generally facilitates identification of the formation on aerial photographs and borehole gamma-ray logs. Carbonate beds in the Yates Formation exhibit an array of bedding types, sedimentary

structures and fabrics, similar to the Tansill Formation and other formations of the Artesia Group. Exposures of siliciclastic intervals in cut banks reveal decimeter- to meter-scale beds of yellow, greenish-gray, and brown siltstone and fine-grained sandstone that are commonly planar- or cross-laminated. In most areas, siliciclastic intervals weather to colluviated slopes that support a relative abundance of vegetation. Approximately 100 m thick in the map area.

Short description: Bedded dolomitic carbonate containing a comparative abundance of interbedded siliciclastic silt to fine-grained sand.

Psr -- Seven Rivers Formation (Guadalupian). Bedded, cliff-forming dolomitic carbonate is the dominant lithology; siliciclastic intervals are minor compared to the overlying Yates Formation. Carbonate facies of the Seven Rivers Formation accumulated in the map area immediately shelfward of the western margin of the Delaware Basin, and are similar to carbonate facies in the overlying Yates and Tansill Formations. The Seven Rivers Formation overlies the Queen Formation of the Artesia Group to the west. As with the Yates and Tansill Formations, the Seven Rivers Formation grades eastward into shelf-margin facies of the Capitan Formation, and to the west of the map area merges rather abruptly with strata containing redbed and evaporite lithofacies. Approximately 80 m thick in the map area.

Short description: Cliff-forming beds of dolomitic carbonate similar to those of the overlying Yates and Tansill Formations, with relatively minor siliciclastic intervals.

Shelf-margin deposits

Pc -- Capitan Formation (Guadalupian). The Capitan Formation consists of gray fossiliferous limestone, and is distinguished from Artesia Group strata by an apparent paucity of bedding. This distinction between bedded carbonate of the Artesia Group and the comparatively structureless Capitan Formation carbonate is generally apparent on aerial photographs and was mapped on that basis. The Capitan Formation has traditionally been divided into shelf-margin and shelf-slope facies. Viewed from a distance, this distinction is generally apparent along the mountain front as pale-colored carbonate cliffs overlying darker-gray, vaguely bedded strata that appear to be inclined 10 to 20° toward the basin. Exposures in scoured reaches of drainages reveal a diverse assemblage of macrofossils in the Capitan Formation, including sponges, corals, brachiopods, bryozoans, gastropods, and crinoids. This rich biogenic framework was apparently engulfed quickly by marine carbonate cement as the Guadalupian carbonate shelf aggraded and prograded into the Delaware Basin. Slumpage of deposits as the carbonate shelf advanced into the basin may have resulted in local systems of subvertical fractures that today stand as conspicuous “blades” rising above surrounding cliffs in some of the canyons along the Guadalupe Mountains escarpment. Exposed surfaces of the Capitan are commonly pitted or vuggy, and in places exhibit centimeter- to decimeter-scale elongate voids, variously filled with calcite spar. The rocks locally appear brecciated, with dark-gray angular carbonate clasts floating in a lighter-gray matrix. Conspicuous fractures, several centimeters in width and meters in length, filled with *Archaeolithoporella* and other microbial remains, are common in the Capitan Formation. Sandstone dikes of two types, relatively thin

wispy fractures with fine-grained siliciclastic fill, and thick (meter-scale), shelf-parallel dikes with coarse-grained (karstic?) fill have been documented. As reported in the extensive literature concerning the Capitan Formation, the unit transitions down slope into crudely bedded carbonate containing talus blocks and assorted debris, with comparatively steep, basinward dips. These slope deposits comprise the bulk of the formation's thickness. The carbonate deposits of the Capitan Formation interfinger with siliciclastic basin-fill sediment of the Bell Canyon Formation; the gradational contact between the two is symbolized with a saw-toothed line on the cross section. A short distance west of the map area, the Capitan Formation overlies the Goat Seep Formation, which is the shelf-margin equivalent of Artesia Group shelf strata immediately underlying the Seven Rivers Formation. As depicted on the cross section, the Capitan Formation is on the order of 450 m thick in the map area.

Short description: Massive fossiliferous limestone. Transitions shelfward into bedded carbonate of the upper Artesia Group, and basinward into siliciclastic deposits of the Bell Canyon Formation.

Basin deposits

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 the Hegler, Pinery, Rader, McCombs and Lamar Members), which thin to the east of the Guadalupe Mountains. Siliciclastics are similar to those in the underlying Cherry Canyon Formation, consisting mainly of fine-grained quartz and lesser feldspar (arkose to subarkose), coarse siltstone (many intervals enriched in organic matter), and minor, thin shaly beds. Siltstone and fine-grained sands are commonly finely laminated. Siliciclastic sediment is commonly present as channel fills, reflecting submarine density-flow processes. Carbonate intervals are dark- to light-gray, fossiliferous, thin- to medium-bedded limestone, which thicken and grade into the Capitan Formation along the margin of the Delaware Basin. The uppermost named limestone, the Lamar Member, 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 in the basin is picked at the top of a mixed siliciclastic-carbonate interval (Reef Trail Member) that overlies the Lamar Member limestone beds. The Bell Canyon Formation is approximately 260 m thick in the map area.

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

Pcc -- Cherry Canyon Formation (Guadalupian). Cross section only. Predominantly buff to brown, fine-grained sandstone to siltstone, with three named carbonate intervals (the Getaway and overlying South Wells and Manzanita Members) that thin eastward of the Guadalupe Mountains. Siliciclastic beds are

thinly to thickly bedded, frequently occupying discontinuous, submarine channels, are predominantly composed of quartz and lesser feldspar grains (generally altered), and are typically finely laminated. Carbonates are tan to dark gray, fossiliferous, and dolomitic. The contact between the Cherry Canyon and Brushy Canyon Formations was historically chosen in outcrop, to the southwest of the map area, at a lithologic change from comparatively coarse-grained channel sands of the Brushy Canyon Formation to finer-grained sand in the Cherry Canyon Formation beneath the Getaway Member limestone interval. Neutron density-porosity logs commonly show a distinct, laterally traceable log response that is compatible with such a change, although this response is poorly expressed in the logs examined for the map area. The top of the Cherry Canyon Formation is placed at the base of the lowest carbonate interval (Hegler Member) in the Bell Canyon Formation. Based on log picks, the Cherry Canyon Formation is approximately 355 m thick in the map area.

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

Pbrc -- Brushy Canyon Formation (Guadalupian). Cross section only. Very fine- to coarse-grained, tan and brown siliciclastic sandstone and siltstone, with shaly intervals in the lower part; unit may contain rare, thin beds of gray-brown carbonate and conglomerate near the base of the unit. The unit is thinly to thickly bedded; coarser grained sandstones are commonly present in lenticular channels. Sandstone and siltstone is commonly finely laminated. The contact between siliciclastic deposits at the base of the Brushy Canyon Formation and uppermost Bone Spring Formation carbonates is readily identified on borehole geophysical logs. Unlike the overlying formations of the Delaware Mountain Group, the Brushy Canyon Formation does not grade shelfward into transitional carbonate shelf-margin deposits; instead, it thins westward and overlaps the Bone Spring and Victorio Peak Formations, with a relatively thin, intervening interval of deposits (Cutoff Formation) that are discontinuously present in outcrops to the southwest of the map area (e.g., Harris, 1987). The combined Brushy Canyon Formation, including possible Cutoff Formation strata, is approximately 375 m thick in the map area.

Short description: Fine- to coarse-grained sandstone and siltstone, with shaly intervals and possible Cutoff Formation strata 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 intercalated dark-gray calcareous shale. Contains three regionally recognized sandy intervals, (in descending order) the first, second and third Bone Spring sands, consisting of light-gray to tan, fine-grained sand with micaceous, shaly or calcareous intervals (the stratigraphic position of the first and third Bone Spring sands are indicated on the cross section). The Bone Spring Formation merges westward (off the map area) with carbonate-bank deposits of the Victorio Peak Formation. The Bone Spring Formation is approximately 725 m thick in the map area.

Short description: Carbonate mudstone and subordinate 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 some carbonate and siliciclastic sand. The top of the Wolfcamp Formation, as depicted on the cross section, lies beneath the third Bone Spring sand; the base of the unit was chosen on wireline-logs at the top of a sequence of alternating shale and carbonate beds assigned to the Upper Pennsylvanian Cisco and Canyon Formation interval. The Wolfcamp Formation interval is relatively thin in the map area, ranging from about 60 to 195 m thick.

Short description: Calcareous and carbonaceous shale with carbonate and sandstone intercalations and interbeds.

Pennsylvanian Subsystem

Upper

IPcc -- Cisco and Canyon Formation, undivided (Upper Pennsylvanian). Cross section only. Interbedded carbonate and shale, with lesser amounts of coarser siliciclastic sediment likely present. Gamma-ray logs suggest carbonate and shale beds alternate on a scale of meters to several meters. The base is picked at the top of a prominent carbonate interval assigned here to the top of the Strawn Formation. The Cisco and Canyon Formation interval is relatively thin in the map area, ranging from about 15 to 80 m in thickness.

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

Middle

IPsa -- Strawn and Atoka Formation, undivided (Middle Pennsylvanian; may include Lower and Upper Pennsylvanian strata). Cross section only. Interbedded carbonate, sandstone and shale. Strawn Formation carbonates are gray to brown and fossiliferous; phylloid algal mounds are reportedly present in the Strawn Formation interval on the Northwest Shelf southeast of Carlsbad, New Mexico. Sandstones are tan to brown and generally medium-grained, with some pink feldspar grains reported from cuttings. Black shale is also reported. The underlying Atoka Formation in the Delaware Basin contains gray to brown carbonate and shaly limestone, some of which is cherty. The base of the Strawn and Atoka Formation interval is chosen at the top of the upper Morrow Formation carbonate interval, as indicated by gamma-ray and resistivity logs. Approximately 200 m thick in the map area.

Short description: Interbedded carbonate, sandstone and shale.

Lower

IPm -- Morrow Formation (Lower Pennsylvanian). Cross section only. The upper part of the Morrow Formation consists of brown to gray fossiliferous limestone and shaly limestone, some of which is oolitic or cherty, together with brown to gray, fine- to medium-grained sandstone, and shale. The lower part of the Morrow Formation contains intervals with an abundance of fine- to coarse-grained quartz sandstone, and lesser shale. None of the boreholes projected onto the line of the cross section completely penetrate the Morrow Formation, which is estimated from other logs to be approximately 220 m thick in the map area. The Morrow Formation overlies Mississippian strata consisting of shaly and underlying carbonate lithofacies in the map area.

Short description: Carbonate and intercalated shale in the upper part of the formation, overlying fine- to coarse-grained sandstone and lesser shale in the lower part of the formation.

Suggested Reading

Hill, C.A., 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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Hale, W.E., 1955, Ground-water conditions in the vicinity of Rattlesnake Springs, Eddy County, New Mexico: State of New Mexico State Engineer Office, Technical Report No. 3, 54 p.

Harris, M.T., 1987, Sedimentology of the Cutoff Formation (Permian), western Guadalupe Mountains, west Texas: New Mexico Geology, v. 9, p. 74-79.