Geologic Map of the Puerco Dam 7.5-Minute Quadrangle, Sandoval County, New Mexico

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Open-file Digital Geologic Map OF-GM 269

Scale 1:24,000

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HEADING 1: QUATERNARY units

Heading 2: Hillslope, upland, and mass movement units

Qse Slopewash, sheetflood, and eolian deposits, undivided (middle Holocene to present) –

Long—
Subequal proportions of loose slopewash, sheetflood, and eolian sediment deposited in drapes and aprons adjacent to side slopes and piedmonts. Eolian deposits consist of light yellowish brown to very pale brown (10YR 6-7/4), well sorted, subrounded to well-rounded, silty, vfL-fL sand (<5% fU-mU) composed of 75-80% quartz and 20-25% lithics+feldspar with no clay. This sand is strongly calcareous and occurs in massive to thick (40-50 cm), wedge- to dune- or lunette-shaped, internally massive to vaguely low-angle cross-stratified beds. Slopewash and sheetflood deposits are similar to one another and consist of yellowish brown (10YR 5/6), well sorted, rounded to well-rounded, silt to vfU sand composed of >95% quartz. This sediment contains sparse subangular to subrounded, fine to coarse pebbles of lithologies derived from adjoining slopes. Rills and swales feature flow structures such as ripples and microbars. Outside of rills, slopewash and sheetflood deposits are typically massive. Bar-and-swale topography features up to 40-50 cm of relief. Soils generally not observed in this unit. Commonly bioturbated by fine to very coarse roots and burrows. 2-3 m thick.

Short—
Loose sand and silt covering side slopes and piedmonts. Eolian sand is light yellowish brown to very pale brown (10YR 6-7/4), calcareous and occurs in wedge- to dune- or lunette-shaped, massive to low-angle cross-stratified deposits. Slopewash and sheetflood sediment is yellowish brown (10YR 5/6), contains sparse pebbles, and forms bar-and-swale topography with up to 50 cm of relief. 2-3 m thick.

Qse General Lithology HKEY 01.01.01.06.01

Qsc Slopewash, sheetflood, and colluvial deposits, undivided (upper Pleistocene to present) – Subequal proportions of sandy slopewash/sheetflood deposits and gravelly colluvium mantling side slopes and footslopes. See descriptions for **Qse** and **Qct**. 2-5 m thick.

Qsc General Lithology HKEY 01.01.01.01.00

Qesc Eolian, slopewash, sheetflood, and colluvial deposits, undivided (upper Pleistocene to present) –

Long—
Loose sand, silt, and gravel found on side slopes, piedmonts, and interfluves. See descriptions for **Qse** and **Qct**. In the central part of the quadrangle, unit consists of yellowish brown (10YR 5/6), well sorted, subrounded to rounded, silty, vfL-fU sand (3-5% mL-mU) composed of quartz with 5-10% lithics (chert) and up to 5% whitish grains that may be kaolinite. This sand is slightly to moderately calcareous in the upper 70 cm of the deposit and is mostly non-stratified and structureless or with vague low-angle cross-stratification (rare). Unit contains 7-20% scattered, subrounded to well-rounded granules or very fine pebbles to coarse cobbles of granite, quartzite, vesicular basalt, petrified wood, chert, sandstone, and other lithologies derived from Rio Puerco terrace deposits. <5-6 m thick in most places.

Short—
Loose sand, silt, and gravel found on side slopes, piedmonts, and interfluves. See descriptions for **Qse** and **Qct**. Sandy deposits may be slightly to moderately calcareous, massive or (rarely) low-angle cross-stratified, containing up to 20% granules to coarse cobbles. <5-6 m thick.

Qesc General Lithology HKEY 01.01.01.01.00

Qls Landslide deposits (middle(?) Pleistocene to Holocene) –

Long—
This unit primarily consists of multi-generational landslide complexes dominated by an older subunit (**Qls2**) and a younger, inset subunit immediately south of Mesa Prieta (**Qls1**). A smaller slide is found approximately 1.6 km northwest of Las Lagunitas Ranch. Unit consists of very poorly sorted, angular to subangular, cobble to boulder gravel with minor pebbles. Boulders are generally concentrated at back-tilted toes of reactivated slides and slumps. Clast lithologies below Mesa Prieta are dominantly basalt (**Qb**), although rounded pebbles and cobbles of lithologies common in Rio Puerco terrace gravels are abundant, suggesting that the landslides have buried or reworked older Rio Puerco terrace gravel deposits. Matrix/in-fill consists of a mix of **Qse**-like sand and silt, and clay from underlying Mancos Shale units. Prominent headscarps and back-tilted toes are observed. Forms hummocky and/or furrowed topography. Thickness unknown. Divided into 2 subunits flanking Mesa Prieta:

Short—
Very poorly sorted, angular to subangular, cobble to boulder gravel with minor pebbles. Large boulders are concentrated at back-tilted toes of reactivated slides and slumps. Clasts are mostly basalt (**Qb**) with subordinate Rio Puerco gravel below Mesa Prieta. Forms hummocky and/or furrowed topography. Thickness unknown. Divided into 2 subunits flanking Mesa Prieta:

> **Qls1 Younger landslide subunit (uppermost Pleistocene to Holocene)** – Unit is inset into **Qls1** (i.e. reactivated), is finer-grained (fewer large boulders), and supports less vegetation. Occasional to common back-tilted toes in middle to upper exposures.
>
> **Qls2 Older landslide subunit (uppermost Pleistocene to Holocene)** – Unit exhibits more diverse failure structures than **Qls1** such as radial cracking on the east side of Mesa Prieta and lateral cracking on back-tilted toes. Boulders up to sedan-size are observed.

Qls1, Qls2 General Lithology HKEY 01.01.01.11.02

<u>Heading 2:</u> Valley-floor units

Qaarp Active alluvium of the Rio Puerco (modern) –

Long—
Loose, non-calcareous sand, silt, and clay filling modern channel of Rio Puerco that is 7-10 m across in most places. Sand is olive brown (2.5Y 4/3, moist), poorly to moderately sorted, rounded to well-rounded, and consists of vfL-mU grains of similar composition to **Qam** bordering the Rio Puerco. Occasional skims of granules to fine pebbles of mafic volcanics, sandstone, and granite observed in the modern channel and on bars. Common white, powdery salt casts observed at low water. Thickness unknown; in lower Rio Puerco (downstream of Interstate 40), post-1999 deposits are <0.5 m thick (Friedman et al., 2015).

Short—
Loose, non-calcareous sand, silt, and clay filling modern channel of Rio Puerco. Olive brown (2.5Y 4/3) when moist. Common white salt casts observed at low water. In lower Rio Puerco (downstream of Interstate 40), post-1999 deposits are <0.5 m thick (Friedman et al., 2015).

Qaarp General Lithology HKEY 01.01.01.03.02

daf Disturbed or artificial fill (<100 years old) – Sand and gravel that has been moved by humans to form berms and dams.

daf General Lithology HKEY 06.03.00.00.00

Qam Modern alluvium (<100 years old) –

Long—
Loose to very weakly consolidated sand, silt, and minor clay deposited in channels, bars, levees, and overbank settings along the Rio Puerco and its tributaries. In the historical arroyo cut of the Rio Puerco, unit consists of light yellowish brown (2.5Y 6/3, dry) to olive brown (2.5Y 4/4, moist), poorly to moderately sorted, rounded to well-rounded, vfL-mL sand composed of 65-75% quartz, 15-25% feldspar, and 10-20% lithics (volcanics>chert) with trace clay. This sand is non- to very weakly calcareous and horizontal-planar laminated or, less commonly, massive. Occasional lenses of rounded to well-rounded pebble and pebble-cobble gravel are comprised of approximately 60-70% sandstone+granite+quartzite and 30-40% mafic volcanics. Along Salado Creek, unit consists of pale brown to light yellowish brown (10YR-2.5Y 6/3), very poorly sorted, subrounded to well-rounded, vfU-vcL sand (2-3% vcU sand to granules) composed of 70-85% quartz, 10-20% lithics (volcanic>>sandstone), and 5-10% feldspar. Subordinate sediment consists of light olive or light yellowish brown (2.5Y 5/3-4 or 6/3), moderately well sorted to well sorted, rounded to well-rounded, silty, vfL-fL sand composed of 75-80% quartz and 20-25% lithics+feldspar. This sand is very weakly calcareous, thinly laminated or thin-bedded to non-stratified, and cross-laminated to planar cross-stratified (foresets 5-8 cm thick) or internally massive. Some transverse and point bars feature very poorly to poorly sorted, subrounded to well-rounded pebbles (75-90%), cobbles (15-20%), and boulders (up to 5%) of 65-70% basalt or basaltic andesite, 25-30% sandstone, and 0-10% other lithologies. Gravel is clast-supported and imbricated. Rare or occasional buried A horizons up to 5 cm thick are observed. Banks and bars are up to 1.5 m above the modern channel. Total thickness unknown; correlative deposits in lower Rio Puerco exceed 5-6 m (Friedman et al., 2015).

Short—
Loose to very weakly consolidated sand, silt, and minor clay deposited along the Rio Puerco and its tributaries. Occasional bars of subrounded to well-rounded pebble-cobble gravel. Pale brown to light yellowish brown or olive (10YR-2.5Y 6/3 or 2.5Y 5/3-4). Banks and bars are up to 1.5 m above the modern channel. Total thickness unknown.

Qam General Lithology HKEY 01.01.01.03.02

Qah Historical alluvium of the Rio Puerco (150-100 years old) –

Long—
Loose to weakly or moderately consolidated sand, silt-sand, and clay underlying low terraces in the historical arroyo cut of the Rio Puerco. Silt-sand and clayey intervals are approximately subequal whereas sand lenses are subordinate; proportions vary laterally. Silt-sand consists of

light olive brown (2.5Y 5/4), moderately well sorted, subangular to rounded, silt to vfU sand (trace fL) composed of 65-70% quartz, 15-20% lithics (volcanics), and 10-20% feldspar with no clay. This sediment is weakly to moderately calcareous, thick- to very thick-bedded (40-130 cm), tabular to broadly lenticular, and internally massive to horizontal planar-laminated. Grades laterally to up to 110 cm of thin- to medium-bedded (7-20 cm), tabular, internally massive to horizontal planar-laminated silt and clay interbeds. Gray to light brownish gray (2.5Y 5-6/1 to 6/2) clay is also common and occurs in weakly calcareous, thick (35-80 cm), tabular to lenticular, internally massive to horizontal planar-laminated beds. Subordinate sand lenses consist of brown (10YR 5/3) to grayish or light olive brown (2.5Y 5/3-4), poorly sorted, subrounded to well-rounded, fU-cL grains composed of 70-75% quartz, 15-20% feldspar, 10-15% lithics (volcanics) with no clay. These lenses are weakly calcareous, medium-bedded (15-30 cm), trough cross-stratified to ripple cross-laminated with occasional climbing ripples, and perhaps reverse graded with mostly coarse sand in upper 15-20 cm. Occasional thin (up to 2 cm) intercalations of clay and iron oxide staining occur in sand lenses. Rare to common bioturbation by very fine to very coarse roots. Deposit is capped by a ~15 cm A horizon and a buried 20-25 cm A horizon in the upper 40 cm. Tread height is 4-6 m above modern grade; deposit is >6 m thick.

Short—
Loose to moderately consolidated sand, silt-sand, and clay underlying low terraces in the historical arroyo cut of the Rio Puerco. Massive to horizontal-planar laminated; sand lenses are trough cross-stratified to ripple cross-laminated. Grayish, brownish, or olive colors predominate (10YR-2.5Y). Commonly capped by a ~15 cm A horizon. Tread height is 4-6 m above modern grade; >6 m thick.

Qah General Lithology HKEY 01.01.01.03.02

Qar Recent alluvium (<1000 years old) –

Long—
Very weakly consolidated sandy gravel and subordinate sand. Clast-supported gravel consists of very poorly sorted, subrounded to well-rounded pebbles (50-90%), cobbles (10-50%), and boulders (0-7%) in very weakly calcareous, medium to very thick (25-110+ cm), broadly lenticular, well imbricated, normally graded beds. Clast lithologies include 65-70% basalt or basaltic andesite and 30-35% sandstone (visual estimate). Gravel matrix consists of dark yellowish brown (10YR 4/4), poorly sorted, subangular to rounded, fU-cU sand composed of 60-65% quartz, 20-25% lithics (volcanic>sandstone), and 10-20% feldspar with 5-10% brownish clay films. Deposit contains rare to occasional lenses of light yellowish brown (2.5Y 6/3-4), poorly to moderately sorted, subrounded to rounded, vfU-mU sand with 5-10% more quartz than gravel matrix and no clay. Rare lenses of light brownish gray to pale brown (10YR 6/2-3), very poorly sorted, subangular to rounded, pebbly, fU-vcU sand of composition similar to gravel matrix. Sand lenses are trough to planar cross-stratified (foresets 10-15 cm thick). No soil

development observed. Bar-and-swale relief up to 60 cm at surface. Tread height up to 3.6 m above modern grade. <6-8 m thick.

Short—
Very weakly consolidated pebble-cobble gravel and subordinate sand. Gravel is well imbricated and normally graded. Sand lenses are trough to planar cross-stratified with foresets up to 15 cm thick. Colors include dark yellowish brown (10YR 4/4), light yellowish brown (2.5Y 6/3-4), and light brownish gray to pale brown (10YR 6/2-3). Tread height up to 3.6 m above modern grade. <6-8 m thick.

Qar General Lithology HKEY 01.01.01.03.01

Qay Younger alluvium (middle to upper Holocene) –

Long—
Weakly to moderately consolidated sand, mud, and subordinate silt in variable proportions underlying valley floors cut by the Rio Puerco and its tributaries. Along the Rio Puerco, unit includes light olive brown to light yellowish brown (2.5Y 5-6/3), weakly to moderately calcareous, slightly sandy (<5-7% subrounded to rounded, vfU-mU) mud in thick to very thick (70-120 cm), tabular, internally massive beds. Mud is interbedded with silt and sand; silt is light olive brown (2.5Y 5/3-4; less commonly light yellowish brown to pale brown, 2.5Y 6-7/4) and occurs in medium to thick (20-50 cm), tabular, internally massive to rare horizontal planar-laminated beds. Silty intervals constitute 10-15% of exposures along Rio Puerco in quad. Sand consists of light olive brown (2.5Y 5/3-4), moderately well sorted, subrounded to well-rounded, slightly silty, vfL-fL grains (10-10% fU) composed of 60-70% quartz, 20-30% feldspar, 10-20% lithics (volcanics +/- chert or granite). Sandy intervals are very weakly calcareous, medium- to thick-bedded (20-45 cm), mostly broadly lenticular, and horizontal planar-laminated to low-angle cross-laminated (foresets up to 10 cm thick) or, less commonly, internally massive. Sand contains rare to occasional lenses of matrix-supported, subrounded to well-rounded, fine to medium pebble gravel. Clast lithologies include 40-50% mafic volcanics, 40-50% sandstone, 10-15% granite, and <10% other lithologies including limestone (visual estimate). Along Salado Creek, unit consists of light olive brown (2.5Y 5/3-4), poorly to moderately sorted, subrounded to well-rounded, silty, vfL-mU sand (trace-2% cL-vcU) composed of 80-90% quartz, 10-15% lithics (volcanic, sandstone), and 5-10% feldspar with 5-15% brownish clay films. This sand occurs in very weakly to weakly calcareous, thinly laminated to very thick (2 mm to 150+ cm), mostly tabular, horizontal-planar to ripple cross-laminated or massive beds. Deposit contains trace to 3% subangular to rounded, fine to coarse pebbles of 60-70% basalt or basaltic andesite and 30-40% sandstone (visual estimate). Rare to occasional thin (1-5 cm), tabular, massive interbeds of light gray (2.5Y 7/2), weakly calcareous, silty clay. Occasionally overlies locally-derived colluvium consisting of angular, cobble-boulder gravel composed entirely of Mesozoic sedimentary clasts. Occasional fine to medium charcoal and occasional to common bioturbation by fine to coarse burrows. Unit may feature buried A, Bw, and/or Bt horizons up to 30-50 cm

thick. Along Rio Puerco, unit exhibits piping, cracking, and/or collapse within 60 m of modern arroyo wall, as well as occasional filled channels up to 20 m across. Basal relief is as much as 2-3 m in places due to onlapping of Mesozoic bedrock rather than scour. Tread height 8-12 m above modern grade. At least 8-10 m thick in quad; Bryan and McCann (1936) reported a thickness of 25 m in the upper Rio Puerco watershed.

Short—
Weakly to moderately consolidated sand, mud, and subordinate silt. Along Rio Puerco, unit contains lenses of matrix-supported pebble gravel with volcanics and subordinate sandstone; floating basalt pebbles are more common along tributaries. Commonly light olive brown (2.5Y 5/3-4). Tread height 8-12 m above modern grade. At least 8-10 m thick in quad.

Qay General Lithology HKEY 01.01.01.03.02

Qayr Combined younger alluvium and subordinate recent alluvium (middle Holocene to present) – See descriptions for units **Qay** and **Qar**.

Qayr General Lithology HKEY 01.01.01.03.02

Heading 2: Alluvial fan units

Qfr Recent fan alluvium (<1000 years old) – Sand and minor gravel, clay, and silt deposited as broad lobes at the mouths of incised arroyos and on piedmonts. Graded to the level of **Qar** deposits in places. Poorly exposed. 1-5? m thick [description modified from Koning and Rawling, 2017].

Qfr General Lithology HKEY 01.01.01.03.01

Qfy Younger fan alluvium (middle to upper Holocene) – Sand, gravel, and subordinate clay-silt deposited on small fans graded to the treads of **Qay** deposits, particularly in the Rio Puerco valley and near the mouths of Cañada Nervio and Salado Creek. Poorly exposed. <5-7 m thick.

Qfy General Lithology HKEY 01.01.01.03.01

Heading 2: Terrace units

Qtrp Terrace deposits of the Rio Puerco (middle to upper Pleistocene) –

Long—
Loose to moderately consolidated, sandy gravel underlying terraces along the valley of the Rio Puerco. Clast-supported (rarely matrix-supported) gravel consists of very poorly to poorly sorted, subrounded to well-rounded pebbles (50-90%), cobbles (10-50%), and boulders (typically <5%, rarely up to 20%) up to 1.5 m long in moderately to strongly calcareous, poorly stratified or medium to very thick (25-90+ cm), tabular or lenticular, internally massive or moderately well imbricated to vaguely trough cross-stratified beds. Clast lithologies include 15-55% basalt and basaltic andesite (vesicular to dense), 25-50% sandstone, 15-30% granite, and minor amounts (up to 5-15% each) of chert, quartzite, petrified wood, and limestone. In **Qtrp6** deposits, the proportion of basalt and basaltic andesite increases from 25-30% to 45-50% below the confluence of the Rio Puerco and Salado Creek; the proportion of sandstone decreases from 35-40% to 25-30%. Gravel matrix consists of brown to yellowish brown (10YR 5/3-6) to dark yellowish brown (10YR 4/3-4) or light olive brown (2.5Y 5/4), very poorly to moderately sorted, subangular to well-rounded (mostly subrounded to rounded), silty, vfL-vcL sand (<10-20% vcU to granules) composed of 15-85% quartz, 5-85% lithics (volcanic>chert+granite), and 5-30% feldspar with 0-5% clay flakes. Less commonly, colors include strong brown (7.5YR 5/8) where deposit is cemented by FeOx minerals, light brown (7.5YR 6/4) where calcite-cemented, or grayish brown to gray (10YR 5/2 to 6/1) where loose. Rare to occasional (<15%) lenses of light olive brown (2.5Y 5/3) to pale brown (10YR 6/3), moderately well sorted, subrounded to rounded, silty to pebbly, vfL-cL sand composed of <80% quartz (larger grains may be volcanic lithics) with no clay. These lenses are massive to low-angle cross-laminated with occasional FeOx staining. Older terrace deposits (**Qtrp3-6**) are distinguished by occasional to common calcite or FeOx cementation, greater proportions of quartzite and granite clasts (5-15%), and stronger carbonate accumulation (stage II-IV) in soils below their surfaces. Seven terrace deposits are mapped by relative height above modern grade:

Short—
Loose to moderately consolidated, imbricated to trough cross-stratified pebble-cobble and pebble-cobble-boulder gravel with minor sand lenses. Common matrix colors are brown to yellowish brown (10YR 5/3-6), dark yellowish brown (10YR 4/3-4), or light olive brown (2.5Y 5/4). Seven terrace deposits are mapped by relative height above modern grade:

Qtrp1 Lowest terrace deposit of the Rio Puerco (upper Pleistocene) – Tread height 9-19 m above modern grade. >2.7-3.2 m thick (basal strath not exposed).

Qtrp2 Lower terrace deposit of the Rio Puerco (upper Pleistocene) – Tread height 19-28 m above modern grade. 3.5-4.0 m thick.

Qtrp3 Middle terrace deposit of the Rio Puerco (middle Pleistocene) – Tread height 28-38 m above modern grade. 3.0-6.0 m thick.

Qtrp4 Middle-upper terrace deposit of the Rio Puerco (middle Pleistocene) – Tread height 50-56 m above modern grade. 0.5-3.0 m thick.

Qtrp5 Upper-middle terrace deposit of the Rio Puerco (middle Pleistocene) – Tread height 67-81 m above modern grade. 2.0-6.0 m thick.

Qtrp6 Upper terrace deposit of the Rio Puerco (middle Pleistocene) – Tread height 85-100 m above modern grade. Up to 9.8 m thick.

Qtrp and subunits General Lithology HKEY 01.01.01.03.01

Qts Terrace deposits of Salado Creek (middle to upper Pleistocene) –

Long—
Loose to strongly consolidated, sandy gravel underlying terraces along the valley of Salado Creek. Mostly clast-supported gravel consists of very poorly to moderately sorted, subangular to well-rounded (mostly rounded to well-rounded) pebbles (60-100%), cobbles (0-35%), and boulders (0-20%) in weakly to moderately calcareous, medium to very thick (12-100+ cm), lenticular, well imbricated to vaguely trough or planar cross-stratified beds (foresets up to 10 cm thick). Clast lithologies include 70-85% basalt and basaltic andesite (vesicular to dense), 10-25% sandstone, and minor amounts (up to 5-10% each) of chert and limestone. Gravel matrix consists of grayish brown (10YR 5/2) to brown or yellowish brown (10YR 5/3-4) to pale or light yellowish brown (10YR 6/3-4), poorly to moderately well sorted, subangular to rounded, vfL-mU sand (10-15% cL sand to granules) composed of 60-85% quartz, 5-25% feldspar, and 10-20% lithics (volcanic>>sandstone) with no clay. Older deposits (Qts4-7) are distinguished by greater calcite cementation and stronger carbonate accumulation (stage II+) in soils below their surfaces. Basal gravels may scour underlying Mesozoic sedimentary bedrock up to 0.5 m. Seven terrace deposits are mapped by relative height above modern grade:

Short—
Loose to strongly consolidated pebble, pebble-cobble and pebble-cobble-boulder gravel. Common matrix colors are grayish brown (10YR 5/2) to brown or yellowish brown (10YR 5/3-4) to pale or light yellowish brown (10YR 6/3-4). Seven terrace deposits are mapped by relative height above modern grade:

Qts1 Lowest terrace deposit of Salado Creek (upper Pleistocene) – Tread height 10-19 m above modern grade. 2.5-3.1 m thick.

Qts2 Lower terrace deposit of Salado Creek (upper Pleistocene) – Tread height 24-36 m above modern grade. Up to ~7 m thick.

Qts3 Lower-middle terrace deposit of Salado Creek (middle Pleistocene) – Tread height 36-47 m above modern grade. Approximately 2-5 m thick.

Qts4 Middle terrace deposit of Salado Creek (middle Pleistocene) – Tread height 47-69 m above modern grade. 2.1-2.4 m thick.

Qts5 Upper-middle terrace deposit of Salado Creek (middle Pleistocene) – Tread height 77-80 m above modern grade. 2.0-3.2 m thick.

Qts6 Upper terrace deposit of Salado Creek (middle Pleistocene) – Tread height 88-95 m above modern grade. Approximately 1-3 m thick.

Qts7 Uppermost terrace deposit of Salado Creek (middle Pleistocene) – Tread height 108-116 m above modern grade. 3.5-3.8 m thick.

Qts and subunits General Lithology HKEY 01.01.01.03.01

Qtcn Terrace deposits of Cañada Nervio (middle to upper Pleistocene) – Loose to moderately consolidated pebble-cobble and pebble-cobble-boulder gravel. Gravel is imbricated to perhaps cross-stratified. Clast lithologies and color similar to those of Salado Creek terrace deposits. Three terrace deposits are mapped by relative height above modern grade:

Qtcn1 Lowest terrace deposit of Cañada Nervio (upper Pleistocene) – Tread height 2-5 m above modern grade. 1.7-2.0 m thick.

Qts2 Lower terrace deposit of Cañada Nervio (upper Pleistocene) – Tread height 5-8 m above modern grade. Approximately 1-3 m thick.

Qts3 Lower-middle terrace deposit of Cañada Nervio (middle Pleistocene) – Tread height 9-17 m above modern grade. Approximately 1-3 m thick.

Qtcn and subunits General Lithology HKEY 01.01.01.03.01

Qao Older alluvium (middle to upper Pleistocene) –

Long—
Weakly to well consolidated but not cemented sand and pebbly sand containing minor sandy pebbles. Preserved as eroded terrace deposits along Arroyo Cuervo. Gravel commonly occupies thin to medium, lenticular beds and is comprised primarily of pebbles (<5% cobbles) that are subangular to rounded and moderately to poorly sorted. Sand and pebbly sand are in thick beds that are internally massive, yellowish brown to light yellowish brown or very pale brown to

brownish yellow (10YR 5/4-6; 6/4-6; 7/3), very fine- to very coarse-grained (mostly fine- to medium-grained), subrounded to subangular, and moderately to well sorted. Locally slightly silty (<10% fines). 1-15 m thick [description modified from Koning and Rawling, 2017].

Short—
Weakly to well consolidated sand and pebbly sand preserved as eroded terrace deposits along Arroyo Cuervo. Fine to medium sand and pebbly sand are yellowish brown to light yellowish brown or very pale brown to brownish yellow (10YR 5/4-6; 6/4-6; 7/3) and in thick beds that are internally massive. 1-15 m thick [description modified from Koning and Rawling, 2017].

Qao General Lithology HKEY 01.01.01.03.01

Heading 2: Volcanic units

Qb Basalt of Mesa Prieta (lower Pleistocene) –

Long—
Dark gray to black basalt flow that is massive and dense in its lower 8-10 m of exposure. Grades upward to an interval of very vesicular, medium- to thick-bedded basalt. Phenocrysts in both intervals include 3-7% olivine (medium to very coarse, anhedral; not strongly weathered) and trace to 1% plagioclase (very fine to fine, euhedral laths). Plagioclase-rich groundmass. Weathers very dark brown or very dark reddish brown. Rare to occasional calcite amygdales. Occasional to common xenoliths of vesicular basalt or basaltic andesite are 7-25 cm long. Two flows capping Mesa Prieta were dated at 2.05 +/- 0.13 Ma and 2.36 +/- 0.30 Ma ($^{40}Ar/^{39}Ar$; Hallett et al., 1997). At least 12-15 m thick.

Short—
Dark gray to black basalt flow that is massive and dense grading upward to vesicular, medium to thick beds. Phenocrysts include 3-7% olivine and trace to 1% plagioclase. Plagioclase-rich groundmass. Weathers very dark brown or very dark reddish brown. Two flows capping Mesa Prieta were dated at 2.05 +/- 0.13 Ma and 2.36 +/- 0.30 Ma ($^{40}Ar/^{39}Ar$; Hallett et al., 1997). At least 12-15 m thick.

Qb General Lithology HKEY 03.01.02.01.00

---Unconformity---

HEADING 1: Cretaceous rocks

Kmu Mancos shale, undifferentiated (Upper Cretaceous) –

Long-

Dark-colored Mancos shale whose stratigraphic position could not be determined and/or in areas where unit **Kdt** pinches out laterally and thus subdivisions of the Mancos Shale based on stratigraphic position relative to **Kdt** are not valid.

Short –

Dark-colored Mancos shale whose stratigraphic position could not be determined

Kmu General Lithology HKEY 01.01.01.10.02

Kg Gallup Sandstone (Upper Cretaceous) –

Long -

Cliff-forming quartz sandstone. Lower portion forms a ledge or cliff and is calcareous, fine- to medium-grained, but locally coarse to very coarse, pale tan to medium reddish-brown quartz sandstone with a few percent of dark mafic minerals and/or chert. Grains are subangular to subrounded. Parallel, medium- to very thick-bedded, to crossbedded with multi-directional troughs. In coarse, trough crossbedded areas, white chert and dark mafic minerals and lithic fragments (?) may be 15-20% of the rock. Upper portion weathers back from cliff edge and is white to pale grey. It is composed of friable fine- to medium-grained poorly-sorted, non-calcareous quartz sandstone with a few percent of pink, white, and black chert grains. Medium- to thick-bedded with broad, multi-directional trough crossbeds. Unit weathers into distinctive "beehive" domes. 35-40 m thick.

Short-
(1) Lower ledge-former comprised of calcareous, quartzose sandstone that is fine- to medium-grained (locally coarse to very coarse) and pale tan to reddish-brown; medium to very thick, tabular bedded and trough cross-bedded. (2) Upper non-cliff-former, white to pale gray, composed of friable, fine- to coarse-grained, non-calcareous quartzose sandstone that is trough cross-bedded. 35-40 m thick.

Kg General Lithology HKEY 01.01.01.09.01

Kmmi Middle part of Mancos Shale between the Gallup Sandstone and Two Wells Sandstone Tongue of the Dakota Sandstone (Upper Cretaceous) —

Long –

Poorly exposed shale. Dark gray to light-yellowish brown to pale brown fissile shale and silty shale. Laminated to thin-bedded. Upper 1 m consists of interbedded shale and very fine- to fine-grained sandstone, representing a gradational zone with the overlying Gallup Sandstone; below this transitional zone lies very fine-sandy shale. Sparse boulder-size concretions cemented by calcium carbonate and lesser silica. The Semilla sandstone bed (**Kss**) is light-brownish gray silty to very fine-sandy shale with abundant decomposed concretions and a crumbly, non-fissile weathering aspect. The sandstone bed forms a prominent east-west ridge across the broad valley in the southwest portion of the quadrangle. The ammonite *Spathites puercoensis* was identified in this bed and is characteristic of this unit (Cobban et al., 1988). 160–180 m thick.

Short-
Gray to light yellowish brown to pale brown, fissile mudstone (clay>silt) and shale in laminated to very thin, tabular to slightly wavy beds (<1 cm of relief). Local gray and greenish colors. Upper 1 m grades into overlying Gallup Sandstone, below this transition lies very fine-sandy shale. Trace boulder-size concretions cemented by CaCO3. Poorly exposed. 160-180 m thick.

Kmmi General Lithology HKEY 01.01.01.10.02

Kdt Twowells Sandstone Tongue of the Dakota Sandstone (Upper Cretaceous) –

Long -
Shaley sandstone coarsening-upward to clean sandstone. Lowermost beds are medium gray fine- to medium-grained, non-calcareous, quartz sandstone with clay matrix and are gradational into the underlying Whitewater Arroyo Shale Tongue. The thin- to medium-thickness beds are parallel. Uppermost beds are light gray to pale brown, fine- to coarse-grained, moderately well-sorted noncalcareous quartz sandstone with several percent of lithic fragments, mafic mineral grains, chert, and dark green to black glauconite, which is distinctive of the unit. Upper beds are thin to very thick with planar crossbeds prominent locally. In the southeast portion of the quadrangle the unit is discontinuous and grades laterally into a zone of light gray to pale brown silty and very fine sandy calcareous shale with gradational upper and lower contacts and abundant septarian concretions. 5-15 m thick.

Short-
Coarsening-upward shaley sandstone and sandstone. Lowermost beds: gray, fine-to medium-grained, non-calcareous, quartz sandstone with a clay matrix; lenses of dark shale a few cm-thick; thin to medium, tabular beds. Uppermost beds: light gray to pale brown, fine- to medium-grained, quartzose sandstone; thin- to medium-bedded with local prominent cross-bedding (planar foresets). 5-15 m thick.

Kdt General Lithology HKEY 01.01.01.09.01

Kmw Whitewater Arroyo Shale Tongue of the Mancos Shale (Upper Cretaceous) –

Long-
Poorly exposed dark grayish-brown to light grey fissile shale and yellowish-brown to very pale brown massive silty shale. Low piles of rubble from weathered septarian concretions are common. Often forms a grass-covered expanse above cliffs of the Paguate Sandstone. 18-25 m thick.

Short-
Poorly exposed dark grayish-brown to light grey fissile shale and yellowish-brown to very pale brown massive silty shale. 18-25 m thick.

Kmw General Lithology HKEY 01.01.01.10.02

Kmw + Kdt Whitewater Arroyo Shale Tongue of the Mancos Shale and Twowells Sandstone Tongue of the Dakota Sandstone, undivided (Upper Cretaceous) –

Cross-section only

Kdp Paguate Sandstone Tongue of the Dakota Sandstone (Upper Cretaceous) –

Long-
Massive, cliff-forming clean quartz sandstone. White to pale tan, fine- to locally very fine-grained clean quartz sandstone. Grains are rounded to well-rounded. Unit often has little discernible bedding and is thus massive in appearance. Medium-brown, filled burrows and round to oval concretions are abundant. Generally makes a bold cliff and abundant blocky rubble with boulders up to 10 m in diameter. In most areas a distinctive clean quartz sandstone upper layer is present, 0.5 – to 1 meter thick, that is lighter in color to white, not calcareous, well-bedded, and has well-developed, regular joints. The main body of the unit has irregular, less abundant joints. Base of the unit is usually somewhat gradational with the underlying shale; upper contact is sharp. 6-15 m thick.

Short-
Massive, cliff-forming sandstone composed of white to pale tan, fine- grained (locally very fine-grained), clean, quartzose sandstone. Abundant paleo-burrows and concretions. Base of unit is usually somewhat gradational, but upper contact is sharp. 6-15 m thick.

Kdp General Lithology HKEY 01.01.01.09.01

Kmcdc Clay Mesa Shale Tongue of Mancos Shale and underlying Cubero Sandstone Member of the Dakota Sandstone, undivided (Upper Cretaceous) –

Long-

Clay Mesa Shale Tongue consists of light to dark gray to very pale brown, parallel and very thin- to thin-bedded fissile shale and silty shale with thin limestone layers and concretions. The unit becomes more silty and sandy upwards as it grades into the overlying Paguate Sandstone Tongue. It is usually poorly exposed and covered by colluvium and rubble of the Paguate Sandstone Tongue, except in vertical cliffs. **Cubero Sandstone Member** is a ledge-former composed of well-sorted and subangular to subrounded quartz grains with less than 5 % black and white grains of probable chert. It is not calcareous. It is parallel and thin-bedded to locally medium-bedded. Bedding surfaces commonly display abundant filled burrows as well as a consistent joint pattern comprised of lozenges or diamonds. East of Arroyo Cuervo and south of Salado Creek the Cubero Sandstone is locally composed of two distinct sandstone beds that are similar in appearance, with the lower bed being very fine- to fine-grained. North of the Rio Puerco the sandstones locally show variations in thickness of several meters and lateral gradations into sandy shale over distances of several hundreds of meters. Lower contact is gradational with underlying shales of the Oak Canyon Member, upper contact is sharp. Variable in thickness, generally about ~25 m thick.

Short-
Clay Mesa Shale (upper unit): medium to dark gray, parallel- and very thin- to thin-bedded shale and silty shale; thin limestone layers and concretions; becomes more silty and sandy up-section. Cubero Sandstone (lower unit): ledge-former composed of quartzose sandstone; not calcareous; parallel- and thin-bedded (locally medium-bedded). Lower contact gradational, upper contact sharp. ~25 m thick.

Kmcdc General Lithology HKEY 01.01.01.10.02 (Clay Mesa Shale Tongue) and 01.01.01.09.01(Cubero Sandstone Member)

Kdoeu Oak Canyon and Encinal Canyon Members of the Dakota Sandstone, undivided (Upper Cretaceous) –

Long-
Conglomerate, sandstone, and shale. These two members of the Dakota Sandstone are clearly distinguishable in the field but the thinness of the Encinal Canyon Member and its position underlying the Oak Canyon Member on vertical or near-vertical slopes precludes its being shown separately on the map. **Encinal Canyon Member** consists of pebble to boulder conglomerate, shale, and sandstone. Basal conglomerate is usually present and overlies and was deposited on an irregular surface with relief of up to one meter scoured into the underlying Jackpile Sandstone Member of the Morrison Formation. Fine-grained intermediate to felsic volcanic rocks are abundant as clasts. Brilliant white chalky pebbles and clasts of chert are distinctive and characteristic of the unit. The basal conglomerate is absent in a few places, or only a few clasts of white chert may occur in basal sandstone. The conglomerate is overlain by black shale and white to grey sandstone. Sandstone is varied, with poorly sorted medium- to coarse-gained sandstone with local lenses of pebble conglomerate, and very fine- to fine-grained shaley, carbonaceous sandstone with abundant wavy stringers of black shaley and/or carbonaceous

material. Sandstone bedding is also varied, ranging from very thin to thin and parallel, to mottled and bioturbated. Thickness is 2 to 3 meters. Member is only present in the northeast corner of the quadrangle along the Arroyo Cuervo drainage. **Oak Canyon Member** consists of sandstone interbedded with and grading upwards into shale. Basal sandstone is usually 1 – 2 meters thick, pale brown, brownish-yellow, and dark yellowish-brown., quartzose, and not calcareous. Bedding is flat and even with local zones of cross-bedding between parallel beds. Quartz grains are medium- to coarse-grained and subrounded to well-rounded. A few percent of varicolored chert grains are present. The contact on the underlying Encinal Canyon Member is generally distinct and flat. Symmetric ripples are present on some bedding surfaces and pits and tubules are abundant, indicative of bioturbation. The sandstone forms a distinct brown ledge above the underlying cliff of lighter- colored Encinal Canyon Member and Jackpile sandstone. North of the Rio Puerco the basal sandstone may be 30 cm or less in thickness and locally is completely absent, along with the underlying Encinal Canyon Member. In these areas, black shale of the upper Oak Canyon Member rests directly on Jackpile sandstone. The upper Oak Canyon Member comprises most of the unit and is a poorly exposed shale with probable siltstone and bentonite beds. The shale is usually weathered back from the basal sandstone ledge and forms a rubble covered, vegetated slope below the overlying Cubero Sandstone Member. 18-23 m thick.

Short-
Oak Canyon Member (upper unit): ledge-forming sandstone interbedded with and grading upwards into thicker shale. Encinal Canyon Member (lower unit): Basal conglomerate (clast assemblage of white chert and intermediate to felsic volcanic rocks). Above lies black shale and white to grey sandstone (very thin to thin, tabular-bedded or mottled-bioturbated). Scoured basal unconformity. 18-23 m thick.

Kmcdc General Lithology HKEY 01.01.01.09.01 and 01.01.01.10.02 (Oak Canyon Member) and 01.02.01.03.00 (Encinal Canyon Member)

Kd Paguate Sandstone Tongue of the Dakota Sandstone, **Clay Mesa Shale Tongue of Mancos Shale, Cubero Sandstone Member of the Dakota Sandstone, and Oak Canyon and Encinal Canyon Members of the Dakota Sandstone, undivided (Upper Cretaceous**) -

Cross section only

---Unconformity---

<u>HEADING 1:</u> Jurassic rocks

Jmj Jackpile Sandstone Member of the Morrison Formation (Jurassic) –

Long-

Massive, cliff-forming, white sandstone and minor mudstone. Sandstones are massive and structureless to parallel and trough cross-bedded. Color ranges from dominantly white to pale pinkish-white to pale tan. Bedding ranges from thick to very thick, with some crossbed sets up to several meters in thickness. Sandstone is dominantly composed of rounded to angular, medium to coarse quartz grains. Chert grains and lithic fragments and/or mafic mineral grains are sparse. A few percent of fine- to coarse-grained angular, chalky white kaolinite grains are present. The upper few meters of sandstone are usually pure white due to abundant kaolinite grains and pore fill. Green and less common red mudstone is locally present as stringers and lenticular pods. Locally the unit makes a rubbly slope or irregular outcrop, but it is often a near-vertical cliff. 0 to 35 m thick.

Short-
Cliff-forming, white, quartzose sandstone and minor mudstone. Sandstones are massive or parallel- and trough cross-bedded. Color ranges from dominantly white to pale pinkish-white to pale tan. Bedding ranges from thick to very thick, with some crossbed sets up to several meters in thickness. Green and less common red mudstone is locally present as stringers and lenticular pods. 0 to 35 m thick.

Jmj General Lithology HKEY 01.02.01.04.00

Jmbb Brushy Basin Member of the Morrison Formation (Jurassic) –

Long-
Slope-forming mudstone and lensoidal fluvial sandstone. Mudstone is bentonitic and light greenish-gray, reddish-gray and weak red with abundant calcareous nodules 5 to 10 cm in diameter. Surface characterized by crumbly “popcorn” weathering texture due to high content of swelling clay minerals. Mudstone intervals often obscured by blocky sandstone colluvium derived from overlying units and/or sandstone interbeds. Sandstone beds and lenses identical in appearance and characteristics to underlying Westwater Canyon Member and represent intermittent deposition of sand in channels in a dominantly floodplain or lacustrine environment. ~ 75 m thick.

Short-
Slope-forming green red and gray bentonitic mudstone and medium- to coarse-grained pebbly cross-bedded fluvial sandstone. ~ 75 m thick.

Jmbb General Lithology HKEY 01.02.01.06.00

Jmw Westwater Canyon Member of the Morrison Formation (Jurrassic) –

Long-
Medium- to coarse- and very coarse-grained, locally pebbly, white, yellow, pale brown and darker –colored fluvial sandstone. Sandstone is internally massive and structureless to trough-

cross bedded with abundant scour features and coalesced lensoidal channel structures. Sandstone is composed of poorly-sorted subrounded to angular grains of quartz with ~ 15% dark colored lithic fragments and/or chert and sparse but distinct pink quartz and chert grains. Locally sandstones are arkosic. Consistently non-calcareous, but cementation is highly variable. Where friable, the matrix is chalky-appearing white clay and unit weathers into rounded forms. Where resistant, the matrix is quartz and unit weathers into angular blocks. Locally dark outcrop colors are due to variable development of iron-staining on surface. Base not exposed, up to 30 m thick on La Gotera quadrangle to the west (Moench et al., 1965).

Short-
Medium- to coarse- and very coarse-grained, locally pebbly, white, yellow, pale brown and darker –colored, noncalcareous, variably-cemented, fluvial sandstone. Base not exposed, up to 30 m thick on La Gotera quadrangle to the west (Moench et al., 1965).

Jmw General Lithology HKEY 01.02.01.02.00

Jms Jackpile Sandstone Member of the Morrison Formation, Brushy Basin Member of the Morrison Formation, Westwater Canyon Member of the Morrison Formation, and Summerville Formation, undivided (Jurassic) –

Cross section only. Interbedded sandstone and mudstone. 220 m thick.

Jt Todilto Formation (Jurassic) –

Cross section only. Gypsum overlying limestone. 30 m thick.

Jt General Lithology HKEY 01.02.02.00.00

Je Entrada Sandstone (Jurassic) –

Cross section only. Sandstone and siltstone. 61 m thick.

Je General Lithology HKEY 01.02.01.02.00

HEADING 1: Triassic and Permian rocks

Trc Chinle Formation (Triassic) -

Cross section only. Mudstone, siltstone, and channel sandstone. 460 m thick.

Trc General Lithology HKEY 01.02.01.06.00

TrPu Agua Zarca sandstone member of the Chinle Formation and Moenkopi Formation (Triassic), San Andres Limestone, Glorieta Sandstone, and upper part of the Yeso formation, undivided (Permian) –

Cross section only. Sandstone, siltstone, mudstone, limestone, shale, and gypsum. Contains multiple unconformities. 210 m thick.

TrPu General Lithology HKEY 01.02.00.00.00

HEADING 1: Permian rocks

Pym Meseta Blanca Sandstone Member of the Yeso Formation (Permian) –

Cross section only. Siltstone and sandstone. 174 m thick.

Pym General Lithology HKEY 01.02.01.04.00

Pa Abo Formation (Permian) –

Cross section only. Mudstone and arkosic sandstone 162 m thick.

Pa General Lithology HKEY 01.02.01.04.00

HEADING 1: Pennsylvanian rocks

Pms Madera Group and Sandia Formation, undivided (Pennsylvanian)

Cross section only. Limestone, shale, arkosic limestone, and sandstone

Pms General Lithology HKEY 01.02.00.00.00

---Unconformity---

HEADING 1: Proterozoic rocks

XY Igneous and metamorphic rocks

Cross section only

Pms General Lithology HKEY 04.00.00.00.00

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