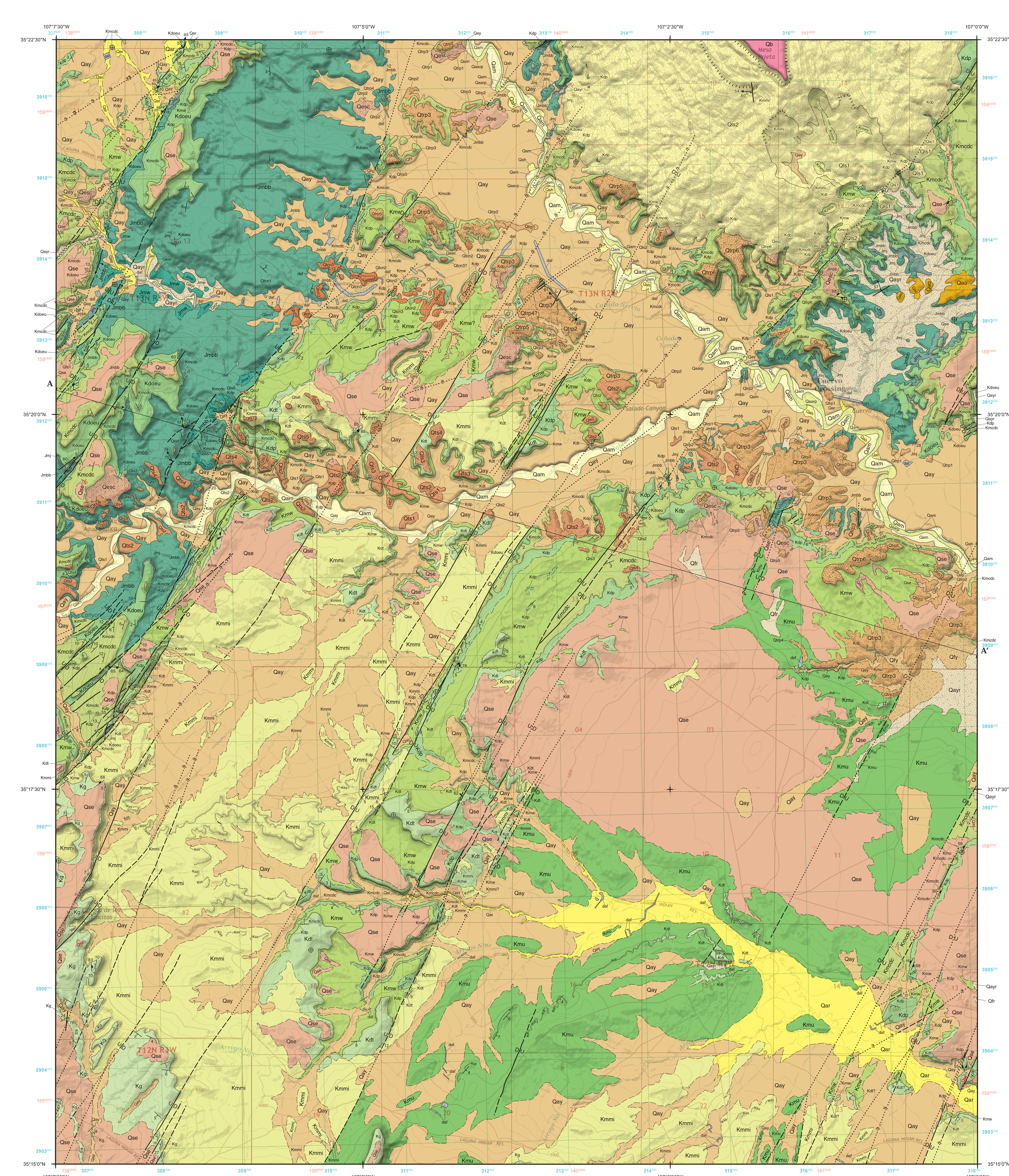

Base map from U.S. Geological Survey 2010.
North American Datum of 1983 (NAD83) World Geodetic System of 1984 (WGS84).
Projection and 1,000-meter grid: Universal Transverse Mercator, Zone 13S shown in blue.
10,000-foot ticks: New Mexico Coordinate System of 1983 (central zone), shown in red.

Roads....................©2006-2010 Tele Atlas
Names....................GNIS, 2008
Hydrography....................National Hydrography Dataset, 2005
Contours....................National Elevation Dataset, 2000

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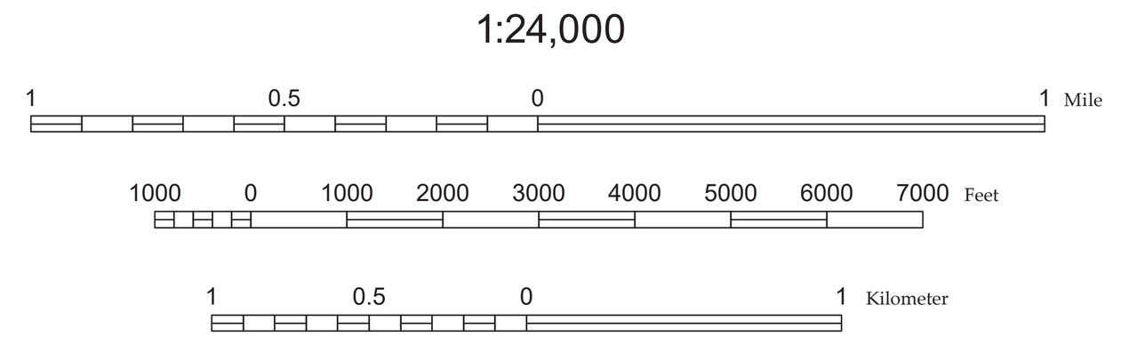
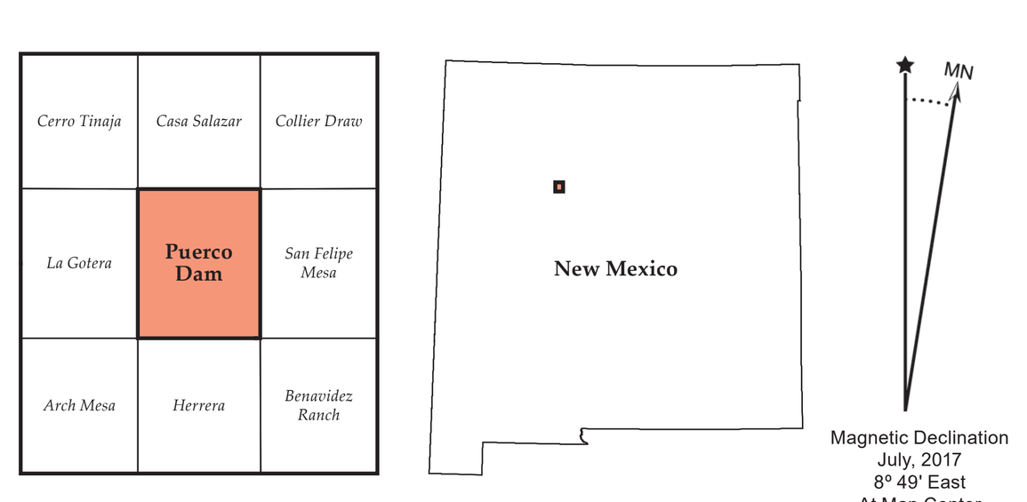


Contour Interval 20 Feet
North American Vertical Datum of 1988



Quadrangle Location

New Mexico Bureau of Geology and Mineral Resources
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801 Leroy Place
Socorro, New Mexico
87801-4796

[575] 835-5490

This and other STATEMAP quadrangles are available for free download in both PDF and ArcGIS formats at:

http://geoinfo.nmt.edu

New Mexico Bureau of Geology and Mineral Resources
Open-File Geologic Map 269

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

June, 2018

by
Geoffrey C. Rawling and Andrew P. Jochems

New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, NM 87801

Comments to Map Users

A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map may be based on any of the following: reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes may not be shown due to recent development.

Cross sections are constructed based upon the interpretations of the author made from geologic mapping, and available geophysical, and subsurface (drillhole) data. Cross sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other man-made structures.

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Digital layout and cartography by the NMBGMR Map Production Group:
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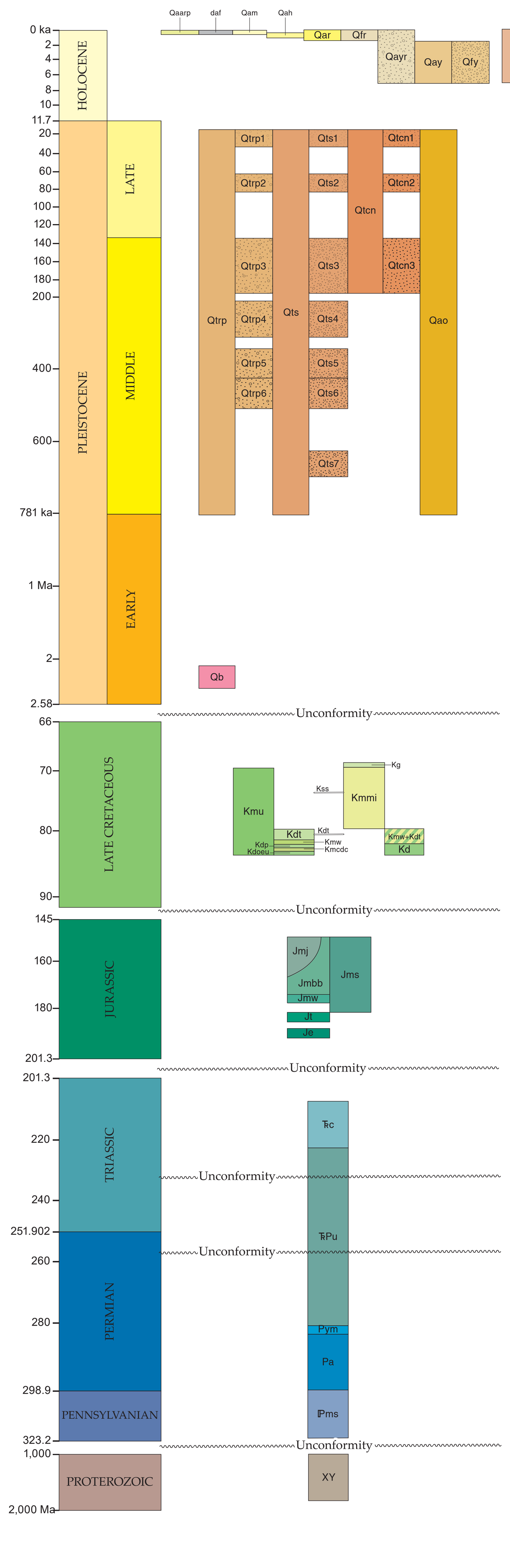
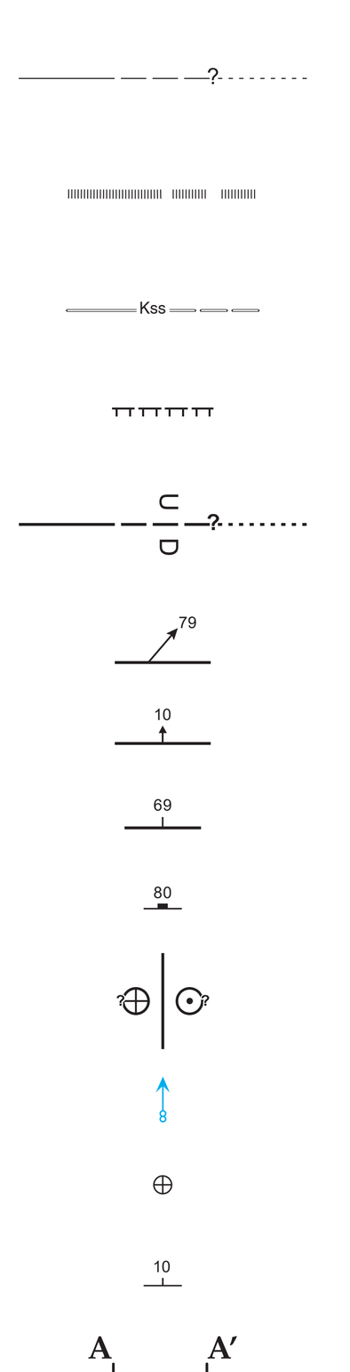
Correlation of Map Units



Explanation of Map Symbols



Contact—Identity and existence are certain; questionable where queried. Location is accurate where solid, approximate where dashed, and concealed where dotted.

Gradational contact—Identity and existence are certain. Location is accurate where solid, and approximate where dashed.

Key bed—Identity and existence are certain. Location is accurate where solid and approximate where dashed.

Head scarp of landslide—either inactive, subdued or indistinct. Location is approximate.

Generic Fault—Identity and existence are certain; questionable where queried. Location is accurate where solid, approximate where dashed, and concealed where dotted. Local offset represented by a U, on the upthrown block and D, on the downthrown block.

Lineation on a fault surface showing the orientation of the trend and plunge.

Inclined fault showing the dip of the fault plane.

Minor inclined fault showing the dip of the fault plane.

Minor inclined joint showing the strike and dip of the joint.

Strike-Slip Fault in cross section—Identity of slip-sense is questionable, existence is certain. Location is accurate. The circled dot is toward and circled plus is away from the observer.

Sediment transport direction determined from imbrication

Horizontal bedding

Inclined bedding

Cross section line

Description of Map Units

Quaternary

Hillslope, Upland, and Mass Movement Units

Qse **Slopewash, Sheetflood, and Eolian Deposits, undivided**—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. The 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.

Qsc **Slopewash, Sheetflood, and Colluvial Deposits, undivided**—Subequal proportions of sandy slopewash/sheetflood deposits and gravelly colluvium mantling side slopes and footslopes. See descriptions for **Qse**. 2–5 m thick.

Qesc **Eolian, Slopewash, Sheetflood, and Colluvial Deposits, undivided**—Loose sand, silt, and gravel found on side slopes, piedmonts, and interfluves. See descriptions for **Qse**. In the central part of the quadrangle, the 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). The 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.

Qls **Landslide Deposits**—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 (not mapped). The 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 two subunits flanking Mesa Prieta:

- **Qls1** **Younger Landslide**—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 the middle to upper exposures.
- **Qls2** **Older Landslide**—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.

Valley-Floor Units

Qaarp **Active Alluvium of the Rio Puerco**—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).

daf **Disturbed or Artificial Fill**—Sand and gravel that has been moved by humans to form berms and dams.

Qam **Modern Alluvium**—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, the 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, the 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).

Qah **Historical Alluvium of the Rio Puerco**—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 the 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 the modern grade; deposit is >6 m thick.

Qar **Recent Alluvium**—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. The 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 the surface. Tread height up to 3.6 m above the modern grade. <6–8 m thick.

Qay **Younger Alluvium**—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 the quad. Sand consists of light-olive-brown (2.5Y 5/3-4), moderately well-sorted, subrounded to well-rounded, slightly silty, vfL–fL grains (10–15% 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, the unit consists of light-olive-brown (2.5Y 5/3-4), poorly to moderately sorted, subrounded to well-rounded, silty, vfL–mU sand (trace to 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 (0.2–150+ cm), mostly tabular, horizontal-planar to ripple cross-laminated or massive beds. The deposit contains trace–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. The unit may feature buried A, Bw, and/or Bt horizons up to 30–50 cm thick. Along the Rio Puerco, the unit exhibits piping, cracking, and/or collapse within 60 m of the 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 the 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.

Qayr **Combined Younger Alluvium and Subordinate Recent Alluvium**—See descriptions for units **Qay** and **Qar**.

Qfr **Recent Fan Alluvium**—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].

Qfy **Younger Fan Alluvium**—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.

Qtrp **Terrace Deposits of the Rio Puerco**—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 the deposit is cemented by FeOx minerals, light-brown (7.5YR 6/4) where calcite-cemented, and 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. Six terrace deposits are mapped by a relative height above the modern grade:

- **Qtrp1** **Lowest Terrace Deposit of the Rio Puerco**—Tread height 9–19 m above the modern grade. >2.7–3.2 m thick (basal strath not exposed).
- **Qtrp2** **Lower Terrace Deposit of the Rio Puerco**—Tread height 19–28 m above the modern grade. 3.5–4.0 m thick.
- **Qtrp3** **Middle Terrace Deposit of the Rio Puerco**—Tread height 28–38 m above the modern grade. 3.0–6.0 m thick.
- **Qtrp4** **Middle-Upper Terrace Deposit of the Rio Puerco**—Tread height 50–56 m above the modern grade. 0.5–3.0 m thick.
- **Qtrp5** **Upper-Middle Terrace Deposit of the Rio Puerco**—Tread height 67–81 m above the modern grade. 2.0–6.0 m thick.
- **Qtrp6** **Upper Terrace Deposit of the Rio Puerco**—Tread height 85–100 m above the modern grade. Up to 9.8 m thick.

Qts **Terrace Deposits of Salado Creek**—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 a relative height above the modern grade:

- **Qts1** **Lowest Terrace Deposit of Salado Creek**—Tread height is 10–19 m above the modern grade. 2.5–3.1 m thick.
- **Qts2** **Lower Terrace Deposit of Salado Creek**—Tread height is 24–36 m above the modern grade. Up to ≈7 m thick.
- **Qts3** **Lower-Middle Terrace Deposit of Salado Creek**—Tread height is 36–47 m above the modern grade. Approximately 2–5 m thick.
- **Qts4** **Middle Terrace Deposit of Salado Creek**—Tread height is 47–69 m above the modern grade. 2.1–2.4 m thick.
- **Qts5** **Upper-Middle Terrace Deposit of Salado Creek**—Tread height is 77–80 m above the modern grade. 2.0–3.2 m thick.
- **Qts6** **Upper Terrace Deposit of Salado Creek**—Tread height is 88–95 m above the modern grade. Approximately 1–3 m thick.
- **Qts7** **Uppermost Terrace Deposit of Salado Creek**—Tread height is 108–116 m above the modern grade. 3.5–3.8 m thick.

Qtcn **Terrace Deposits of Cañada Nervio**—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 a relative height above the modern grade:

- **Qtcn1** **Lowest Terrace Deposit of Cañada Nervio**—Tread height is 2–5 m above the modern grade. 1.7–2.0 m thick.
- **Qtcn2** **Lower Terrace Deposit of Cañada Nervio**—Tread height is 5–8 m above the modern grade. Approximately 1–3 m thick.
- **Qtcn3** **Lower-Middle Terrace Deposit of Cañada Nervio**—Tread height is 9–17 m above the modern grade. Approximately 1–3 m thick.

Qao **Older Alluvium**—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].

Qb **Basalt of Mesa Prieta**—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.

Cretaceous Rocks

Kg **Gallup Sandstone**—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 percents of dark mafic minerals and/or chert. Grains are subangular to subrounded. Parallel, medium- to very thick-bedded, to cross-bedded with multi-directional troughs. In coarse, trough cross-bedded areas, white chert and dark mafic minerals and lithic fragments(?) may be 15–20% of the rock. Upper portion weathers back from the 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 percents of pink, white, and black chert grains. Medium- to thick-bedded with broad, multi-directional trough cross-beds. Unit weathers into distinctive "beehive" domes. 35–40 m thick.

Kmu **Mancos shale, undifferentiated**—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.

Kmmi **Middle Part of Mancos Shale Between the Gallup Sandstone and Two Wells Sandstone Tongue of the Dakota Sandstone**—A poorly exposed, 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.

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**—Cross section only.

Kmw+Kdt **Whitewater Arroyo Shale Tongue of the Mancos Shale and Twowells Sandstone Tongue of the Dakota Sandstone, undivided**—Cross-section only.

Kdt **Twowells Sandstone Tongue of the Dakota Sandstone**—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 percents 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 cross-beds 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.

Kmw **Whitewater Arroyo Shale Tongue of the Mancos Shale**—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.

Kdp **Paguate Sandstone Tongue of the Dakota Sandstone**—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. The 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, 0.5–1 m 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. The base of the unit is usually somewhat gradational with the underlying shale; upper contact is sharp. 6–15 m thick.

Kmcdc **Clay Mesa Shale Tongue of Mancos Shale and Underlying Cubero Sandstone Member of the Dakota Sandstone, undivided**—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 thickness variations of several m and lateral gradations into sandy shale over distances of several hundreds of m. The lower contact is gradational with underlying shales of the Oak Canyon Member; upper contact is sharp. Variable in thickness, generally about ≈25 m thick.

Kdoeu **Oak Canyon and Encinal Canyon Members of the Dakota Sandstone, undivided**—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 it's being shown separately on the map. Encinal Canyon Member consists of pebble to boulder conglomerate, shale, and sandstone. The 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-grained 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 2–3 m. 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 m 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 percents 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 rubble-covered, vegetated slopes below the overlying Cubero Sandstone Member. 18–23 m thick.

Jurassic Rocks

Jmj **Jackpile Sandstone Member of the Morrison Formation**—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 cross-bed sets up to several m 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 percents of fine- to coarse-grained angular, chalky white kaolinite grains are present. The upper few m of sandstone are usually pure white due to abundant kaolinite grains and pore fill. Green and less common red mudstone are 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. 0–35 m thick.

Jmbb **Brushy Basin Member of the Morrison Formation**—Slope-forming mudstone and lensoidal fluvial sandstone. Mudstone is bentonitic and light-greenish-gray, reddish-gray and weak-red with abundant calcareous nodules 5–10 cm in diameter. Surface characterized by crumbly "popcorn" weathering texture due to the 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.

Jmw **Westwater Canyon Member of the Morrison Formation**—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 a chalky, appearing white clay and unit weathers into rounded forms. Where resistant, the matrix is quartz and unit weathers into angular blocks. Locally dark-colored outcrops are due to the variable development of iron-staining on the surface. Base not exposed in this area, however, the unit is up to 30 m thick on La Gotera quadrangle to the west (Moench et al., 1965).

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

Jt **Todilto Formation**—Cross section only. Gypsum overlying limestone. 30 m thick.

Je **Entrada Sandstone**—Cross section only. Sandstone and siltstone. 61 m thick.

Triassic and Permian Rocks

Ꞧc **Chinle Formation**—Cross section only. Mudstone, siltstone, and channel sandstone. 460 m thick.

ꞦPu **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. The unit contains multiple unconformities and is 210 m thick.

Permian Rocks

Pym **Meseta Blanca Sandstone Member of the Yeso Formation**—Cross section only. Siltstone and sandstone. 174 m thick.

Pa **Abo Formation**—Cross section only. Mudstone and arkosic sandstone 162 m thick.

Pennsylvanian Rocks

ℙms **Madera Group and Sandia Formation, undivided**—Cross section only. Limestone, shale, arkosic limestone, and sandstone.

Proterozoic Rocks

XY **Igneous and metamorphic rocks**—Cross section only.

Geologic Cross Section A–A'