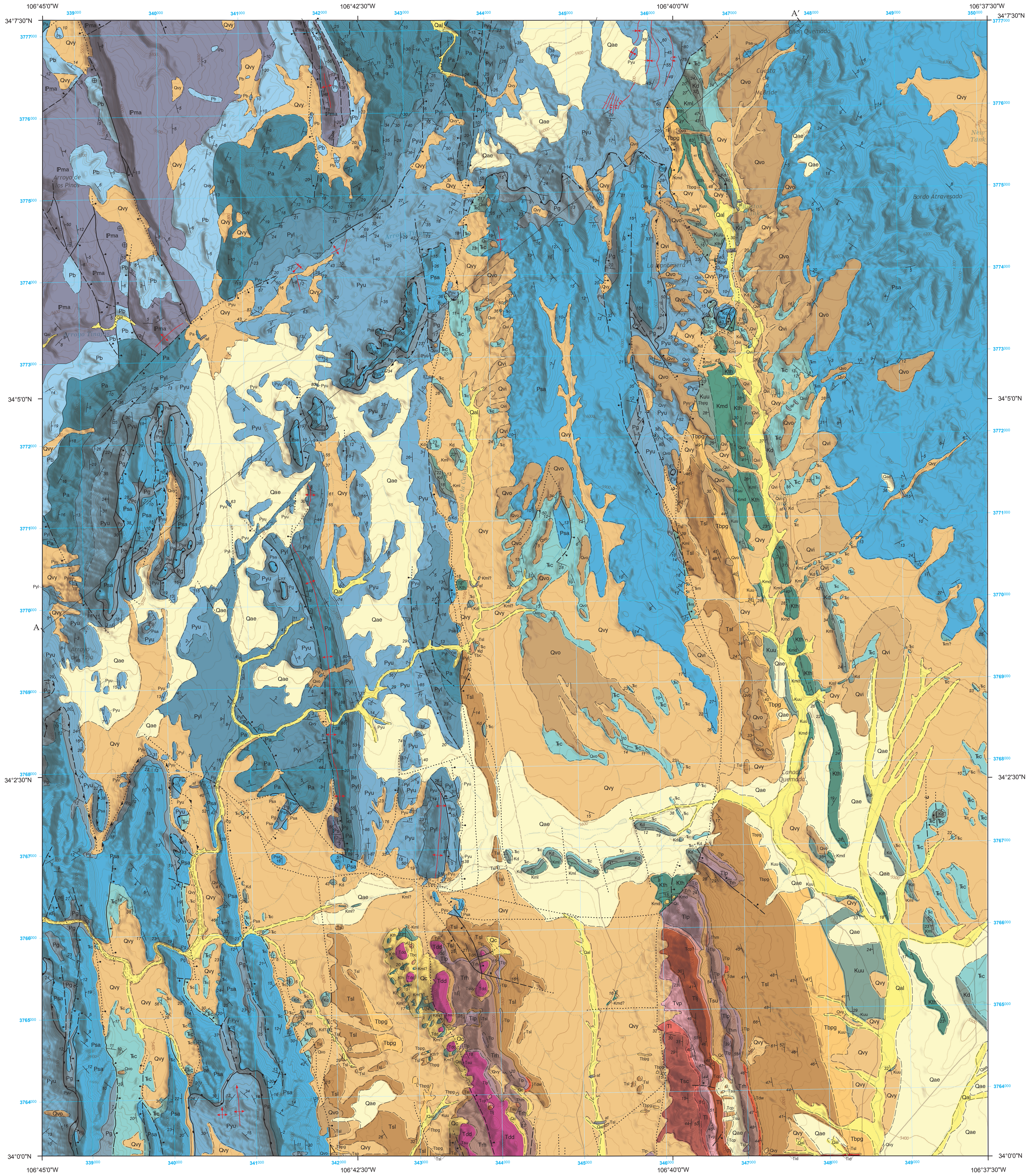
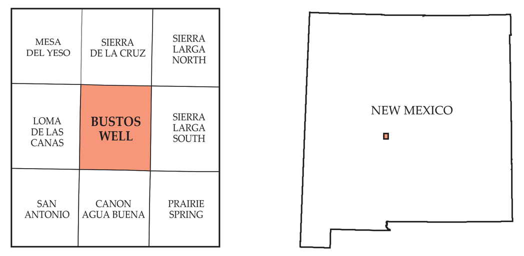


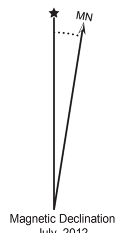
Base map from U.S. Geological Survey 1972, from photographs taken 1971, field checked in 1972.
1927 North American datum, UTM projection -- zone 13N
1000-meter Universal Transverse Mercator grid, zone 13, shown in blue.

1:24,000

CONTOUR INTERVAL 20 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929





Magnetic Declination
July, 2012
08.996° East
At Map Center

Quadrangle Location

New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map 237

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the National Cooperative Geologic Mapping Act (Award Number: G13AC00186), administered by the U. S. Geological Survey, and by the New Mexico Bureau of Geology and Mineral Resources, (L. Greer Price, *Director and State Geologist*, Dr. J. Michael Timmons, *Geologic Mapping Program Manager*).

This draft geologic map is preliminary and will undergo revision. It was produced from either scans of hand-drafted originals or from digitally drafted original maps and figures using a wide variety of software, and is currently in cartographic production. It is being distributed in this draft form as part of the bureau's Open-file map series (OFGM), due to high demand for current geologic map data in these areas where STATEMAP quadrangles are located, and it is the bureau's policy to disseminate geologic data to the public as soon as possible.

After this map has undergone scientific peer review, editing, and final cartographic production adhering to bureau map standards, it will be released in our Geologic Map (GM) series. This final version will receive a new GM number and will supercede this preliminary open-file geologic map.

DRAFT

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

http://geoinfo.nmt.edu

Geologic Map of the Bustos Well 7.5-Minute Quadrangle, Socorro County, New Mexico

June 2014

by
Cather, S. M.[1], Osburn, G. R.[2], Flores, S. C. [3], and Green, M.[3]

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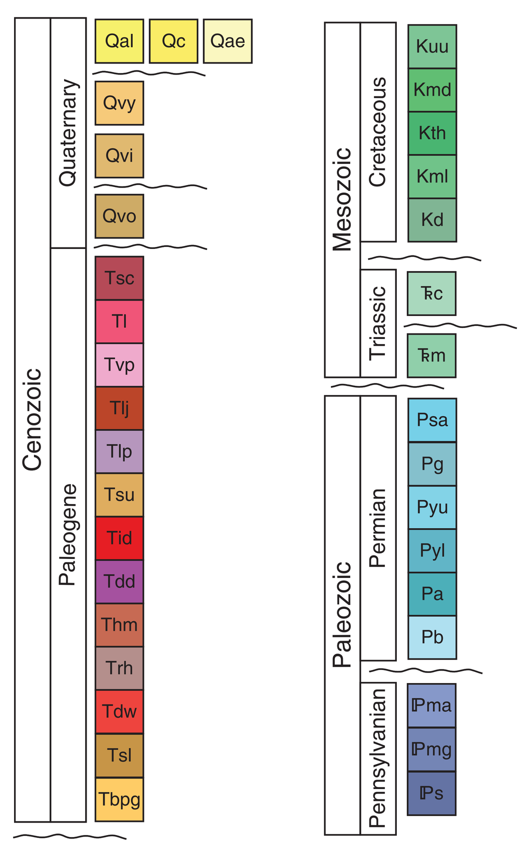
Comments To Map Users

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 associated with recent development may not be shown.

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.

The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Geology and Mineral Resources. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico, or the U.S. Government.

Correlation of Map Units



Explanation of Map Symbols

- Contact - Identity and existence certain, location accurate
- Contact - Identity or existence questionable, location approximate
- Fault (unspecified) - Identity and existence certain, location accurate
- Fault (unspecified) - Identity and existence certain, location approximate
- Fault (unspecified) - Identity or existence questionable, location approximate
- Fault (unspecified) - Identity and existence certain, location concealed
- Fault (unspecified) - Identity or existence questionable, location concealed
- Normal fault - Identity and existence certain, location accurate; ball and bar on downthrown block
- Normal fault - Identity and existence certain, location approximate; ball and bar on downthrown block
- Normal fault - Identity or existence questionable, location approximate; ball and bar on downthrown block
- Normal fault - Identity and existence certain, location concealed; balll and bar on downthrown block
- Low-angle normal fault - Identity and existence certain, location accurate
- Low-angle normal fault - Identity and existence certain, location approximate; half-circles on downthrown block
- Low-angle normal fault - Identity or existence questionable, location approximate; half-circles on downthrown block
- Low-angle normal fault - Identity and existence certain, location concealed; half-circles on downthrown block
- Thrust fault - Identity and existence certain, location accurate; sawteeth on upper (tectonically higher) plate
- Thrust fault - Identity and existence certain, location concealed; sawteeth on upper (tectonically higher) plate
- Anticline - Identity and existence certain, location accurate
- Overturned anticline - Identity and existence certain, location accurate; beds on one limb are overturned; arrows show dip direction of limbs
- Syncline - Identity and existence certain, location accurate
- Overturned syncline - Identity and existence certain, location accurate; beds on one limb are overturned; arrows show dip direction of the limbs
- Monocline, anticlinal bend - Identity and existence certain, location accurate; arrows show direction of dip; shorter arrow on steeper limb
- Plunging anticline - Large arrowhead shows direction of plunge
- Plunging syncline - Large arrowhead shows direction of plunge
- Horizontal bedding
- Inclinecd bedding - Showing strike and dip
- Vertical bedding - Showing strike
- Overturned bedding - Showing strike and dip
- Cross section line

Map Unit Descriptions

Cenozoic Erathem

Neogene

Middle(?) Pleistocene–Holocene

Qal — **Alluvium (Holocene)** — Sand, gravel, and mud in, and adjacent to, modern arroyo channels. Alluvium is typically at or near the grade of modern channels. 0–10 m thick.

Qc — **Colluvium and talus (upper Pleistocene–Holocene)** — Gravelly deposits of poorly sorted colluvium and talus blocks on, or adjacent to, steep slopes. 0–5 m thick.

Qae — **Eolian deposits (upper Pleistocene-Holocene)** — Eolian sand and loessic silt locally reworked by alluvial processes. Deposits are stabilized by vegetation in most areas. Includes intercalated alluvial deposits and thin, discontinuous eolian veneers on stable upland surfaces. 0–5 m thick.

Qvy — **Younger piedmont alluvium (upper Pleistocene)** — Gravel, sand, and minor mud deposited at low elevations (less than about 5 m) above modern stream grade. Alluvium is representative of deposition in a variety of piedmont environments, including alluvial fans, paleovalley and arroyo fills, strath terraces, fill terraces, and pediment surfaces. 0–15 m thick.

Qvi — **Intermediate-age piedmont alluvium (upper? Pleistocene)** — Gravel, sand, and mud deposited at intermediate elevations (about 5-10 m) above modern stream grade. Range of depositional environments is similar to Qvy. 0–10 m thick.

Qvo — **Older piedmont alluvium (middle? Pleistocene)** — Gravel, sand, and mud deposited at higher elevations (more than about 10 m) above modern stream grade. Range of depositional environments is similar to Qvy. 0–15 m thick.

Paleogene

Upper Eocene–Oligocene

Tsc — **South Canyon Tuff** — Light gray to light purple, densely welded, crystal-poor to moderately crystal-rich rhyolite ignimbrite. Crystals are mostly sanidine and quartz; lithic fragments are common. About 150–250 m thick. 40Ar/39Ar age is 27.4 Ma (all 40Ar/39Ar ages reported here are from McIntosh et al., 1991, except where noted).

Tl — **Lemitar Tuff** — Pink, densely welded, moderately crystal-rich rhyolite ignimbrite. Crystals are sanidine, plagioclase, quartz, and biotite; lithics are minor. Thickness is about 0–110 m. 40Ar/39Ar age is 28.0 Ma.

Tvp — **Vicks Peak Tuff** — Light gray, moderately welded, crystal-poor rhyolite ignimbrite. Thickness ~110 m. 40Ar/39Ar age is 28.6 Ma.

Tj — **La Jencia Tuff** — Pink to gray, densely to moderately welded, crystal-poor, rhyolitic ignimbrite that exhibits compound cooling. Upper part of unit is prominently flow-banded. Crystals are mostly sanidine and quartz; lithics are typically sparse. Thickness ~140 m. 40Ar/39Ar age is 28.9 Ma.

Tcp — **Tuff of South Crosby Peak(?)** — light gray, poorly welded, moderately crystal-rich ignimbrite. About 30–50 m thick. 40Ar/39Ar age is ~29.7 Ma.

Tlp — **La Jara Peak Basaltic Andesite** — Aphanitic to slightly porphyritic mafic flows and associated breccias of mostly basaltic andesite composition. Phenocrysts are mostly plagioclase and clinopyroxene. In the quadrangle, the unit occurs as several tongues 0–80 m thick intercalated within the stratigraphic interval between the lower Spears Formation and the base of the Tuff of South Crosby Peak(?).

Tsu — **Upper Spears Group** — Dark- to medium-gray volcaniclastic sandstone and conglomerate. Debris-flow breccias are locally present. Clast lithotypes are mostly dark gray basaltic andesite (plagioclase- and clinopyroxene-bearing) but also andesite-dacite (plagioclase- and amphibole-bearing) and ignimbrite clasts. 0–120 m thick. Spears Group terminology used as defined by Cather et al. (1994).

Tid — **Andesite to basaltic andesite dike** — Mafic to intermediate-composition dike ~5–10 m wide in southeastern part of quadrangle. Commonly exhibits greenish alteration. Probably represents an intrusive equivalent of the La Jara Peak Basaltic Andesite.

Tdd — **Dacite extrusive rocks** — Medium brownish gray, plagioclase and amphibole-bearing lava. Composed of a single flow 0–90 m thick with an autobrecciated base. The flow yielded a 40Ar/39Ar age of 34.7 Ma (M. Green, written commun., 2012), but this is anomalously old based on the age of underlying 32.1 Ma Hells Mesa Tuff.

Thm — **Hells Mesa Tuff** — Brownish pink, crystal-rich, densely welded rhyolitic ignimbrite. Crystals are sanidine, quartz, and biotite; lithics are sparse. Exposed as erosional remnants within paleovalleys. 0–15 m thick. 40Ar/39Ar age is 32.1 Ma.

Trh — **Rock House Canyon Tuff** — Light gray, crystal-poor rhyolitic ignimbrite. Phenocrysts are mostly sanidine with rare quartz, biotite, and hornblende(?). Poorly to moderately welded. Contains local zones of abundant flattened pumice. About 90–150 m thick. 40Ar/39Ar age is 34.4 Ma

Tdw — **Datil Well Tuff** — Medium brownish gray, crystal-rich rhyolitic ignimbrite. Crystals are mostly sanidine with subordinate plagioclase and minor quartz, biotite, and pyroxene(?). Lithic-rich and pumice-poor. 0–50 m thick. 40Ar/39Ar age is 35.5 Ma.

Tsl — **Lower Spears Group** — Medium- to light-gray volcaniclastic sandstone, conglomerate, debris-flow breccia, and minor mudstone. Clasts are dominated by plagioclase- and amphibole-bearing andesite and dacite. Non-volcanic clasts are locally present above transition with underlying Baca Formation. Thickness is ~760 m. Age range is ~39–36 Ma (Cather et al., 1987). Usage of the term Datil Group is after Cather et al. (1994).

Middle Eocene

Tbpg — **Baca Formation (middle Eocene)** — Fluvial red-bed sandstone, conglomerate, and minor mudstone deposited in piedmont environments. Sandstone is commonly cross-bedded; conglomerate contains pebbles, cobbles and boulders of Paleozoic and Proterozoic lithotypes. Clasts are dominantly (>90%) Proterozoic lithotypes (granite, gneissic granite, schist, and quartzite) near the base of the unit. Paleozoic clast types (limestone sandstone, siltstone) increase in abundance upsection in most areas. About 300 m thick. Granite boulders as much as 2.5 m in diameter are present in the southwestern part of the quadrangle. Nomenclature after Cather et al. (2013).

Mesozoic Erathem

Upper Cretaceous

Kuu — **Undivided Upper Cretaceous strata consisting of the Gallup Sandstone (Lower Coniancian), Mulatto tongue of the Mancos Shale (Middle Coniacian), and Crevasse Canyon Formation (Coniacian–Santonian?)** — Gallup Sandstone is fine grained, gray to yellowish gray, regressive coastal barrier-island sandstone and mudstone. About 5–15 m thick. Mulatto tongue of the Mancos Shale is drab marine shale about 30 m thick that is intercalated within the lower Crevasse Canyon Formation about 50 m stratigraphically above the top of the Gallup sandstone. Crevasse Canyon Formation (mostly the Dilco Member) is drab to gray sandstone, mudstone, and coal deposited in coastal plain and fluvial settings. Thickness is as much as 300 m. Typically poorly exposed.

Kmd — **D-Cross Tongue of the Mancos Shale (Upper Middle Turonian–Lower Coniacian)** — Noncalcareous, medium gray, marine shale. About 90 m thick with a sharp basal contact and a gradational upper contact. Fossils Prioncyclus wyomingensis (Meek) and Scaphites warreni Meek and Hayden, Prioncyclus novimexicanus (Marcou), Forresteria sp., Lopha sannionis (White), and sparse Ostrea elegantula White.

Kth — **Tres Hermanos Formation (Middle Turonian)** — Sandstone and shale unit that forms a regressive-transgressive wedge of nearshore marine and non-marine deposits that is about 80 m thick with a gradational base and a sharp top. Consists of three unmapped members, in ascending order: Atarque Sandstone Member (lower Middle Turonian) — Regressive coastal barrier sandstones that weather light gray to dark brown or buff. Lower sandstones are transitional with underlying shale and constitute a 5–7 m thick, ridge-forming unit that has very fossiliferous lenses and concretionary sandstone bodies with Pleuriocardia (Dochmocardia) pauperculum (Meek) and Gyrodes spp. Uppermost bed is commonly a brackish water coquina of Crassostrea soleniscus (Meek). Carthage Member (middle Middle Turonian) — Marine, marginal marine, and non-marine sandstone and shale slope-forming unit ~60 m thick; lower two-thirds contains thin, fine grained sandstone beds of paludal-lacustrine or crevasse splay origin and discontinuous, cross-bedded channel sandstones. The upper third contains marine shale with fossiliferous concretions and Prionocyclus hyatti (Stanton). Fite Ranch Sandstone Member (upper Middle Turonian) — Highly bioturbated, coastal barrier sandstone that coarsens upward from very fine grained to fine grained. Sandstones are light gray, but weather light to dark brown and constitute a 10–12 m thick ridge-forming unit with sharp top and gradational base. Contains Lopha bellaplicata novamexicanum Kauffman.

Kml — **Lower part of the Mancos Shale (Middle Cenomanian–Lower Turonian)** — Calcareous to noncalcareous gray marine shale with minor, thin sandstone beds near base and top. Sharp basal contact and gradational upper contact. Calcareous shale in upper part of unit contains abundant Pycnodonte newberryi (Stanton). Thin sandstones in basal 15 m contain common Ostrea beloiti Logan. About 135 m thick.

Kd — **Dakota Sandstone (Middle Cenomanian)** — Gray to yellow, fluvial to marginal marine medium to coarse-grained sandstone and minor mudstone. No body fossils have been found in the Dakota. About 5–20 m thick.

Tc — **Chinle Formation (Upper Triassic)** — Red, gray and maroon fluvial mudstone with subordinate sandstone, limestone-pebble conglomerate, and limestone. Forms slopes and valleys. Locally includes Moenkopi Formation. About 200 m thick. Formation-rank nomenclature after Cather et al. (2013).

Tm — **Moenkopi Formation (Middle Triassic)** — Red-brown, brown, and buff continental mudstone, sandstone and minor conglomerate. Locally mapped as part of the Chinle Formation where thin or poorly exposed About 10–30 m thick.

Paleozoic Erathem

Permian

Psa — **San Andres Formation (Permian, Leonardian)** — Interbedded limestone, dolostone, and gypsum. Limestone is brownish-black , pale yellowish-brown and medium gray, and ranges from wackestone to grainstone. Dolostone is brownish-gray to olive-gray, and locally gypsiferous. Bedded gypsum is abundant in the middle and upper part of the San Andres in the northeastern part of the quadrangle. Gypsum is white to light gray, laminated to massively bedded. Thickness is ~200 m. Locally includes 5–15 m of orange gypsiferous siltstone at the top of the unit that may be correlative with the Permian Artesia Group.

Pg — **Glorieta Sandstone (Permian, Leonardian)** — White to very pale orange, fine- to medium-grained, friable to well-indurated, crossbedded quartzarenite. Has scattered coarse, well-rounded, frosted quartz grains, especially in the lower half of the unit. Thickness is ~70 meters.

Pyu — **Upper Yeso Formation (Permian, Leonardian)** — Interbedded siltstone, gypsum, dolomitic limestone, sandstone, and shale. About 200 m thick. Consists of three unmapped members (in ascending order): the Torres, Cañas Gypsum, and Joyita Members. The upper two members are locally cut out by low-angle normal faults. Torres Member—Interbedded pale to moderate reddish-brown, grayish-pink or grayish-red, fine- to medium-grained quartzose sandstone, white to light gray gypsum thin layers and lenses of dolomitized oolitic limestone, and pale yellowish-brown to olive black limestone that ranges from carbonate mudstone to peloidal or oolitic packstone and grainstone and are locally sparsely fossiliferous, dolomitic, and argillaceous. Thickness is ~160 meters. Cañas Gypsum Member—Interbedded very light gray to white laminated to nodular-mosaic gypsum and minor, thin very fine-grained silty sandstone and a thin, fetid, gypsiferous calcareous mudstone and limestone. Thickness is 0–24 meters. Joyita Member—Pale reddish-brown to moderate reddish-orange, friable and calcareous, fine- to very fine-grained quartzose sandstone with scattered displacive halite casts and clay flakes on bedding surfaces. The upper beds display low-angle cross beds and ripple cross-laminations. Thickness is 0–30 meters. Nomenclature after Cather et al. (2013).

Pyl — **Lower Yeso Formation (Permian, Leonardian)** — The Meseta Blanca Member constitutes the lower Yeso Formation. The Meseta Blanca Member is interbedded very pale orange, pinkish-gray and moderate reddish-brown, very fine- to medium-grained quartzose sandstone, are very light gray to dark reddish-brown siltstone and are dark reddish-brown to grayish-red, slope forming mudstones and shales. Thickness is ~90 m. Top of the unit is placed at the base of the lowermost marine limestone in the Torres Member of the upper Yeso Formation. Base of unit is gradational in many places with the underlying Abo Formation. Nomenclature after Cather et al. (2013).

Pa — **Abo Formation (Permian, Leonardian)** — Interbedded dark reddish brown mudstone and shale, and grayish red to dark reddish brown siltstone, sandstone and, locally, thin conglomerate and rare limestone. Thickness is ~200 meters.

Pb — **Bursum Formation (Permian, Wolfcampian)** — Interbedded medium dark gray to grayish red mudstone; medium gray to brownish black, peloidal, fossiliferous, and locally dolomitic limestone, and grayish orange pink to grayish orange, fine to very coarse-grained, lenticular and trough cross-bedded sandstone. About 60 m thick.

Pennsylvanian

Pma — **Atrasado Formation of Madera Group (Desmoinesian, Missourian, and Virgilian)** — marine and paralic interbedded brownish-gray arkosic sandstone, greenish-gray to gray mudstone, and light gray limestone. Approximately 250 m thick. Nomenclature after Cather et al. (2013).

Pmg — **Gray Mesa Formation of Madera Group (Desmoinesian)** — Medium-gray, fossiliferous, commonly cherty, marine limestone, greenish-gray mudstone, and minor sandstone. Subsurface only. About 50 m thick regionally. Nomenclature after Cather et al. (2013).

Ps — **Sandia Formation (Atokan)** — Continental and marine, Arkosic to quartzite light brown sandstone, greenish-gray mudstone, and medium gray limestone. 90–175 m thick.

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Geologic Cross Section A—A'