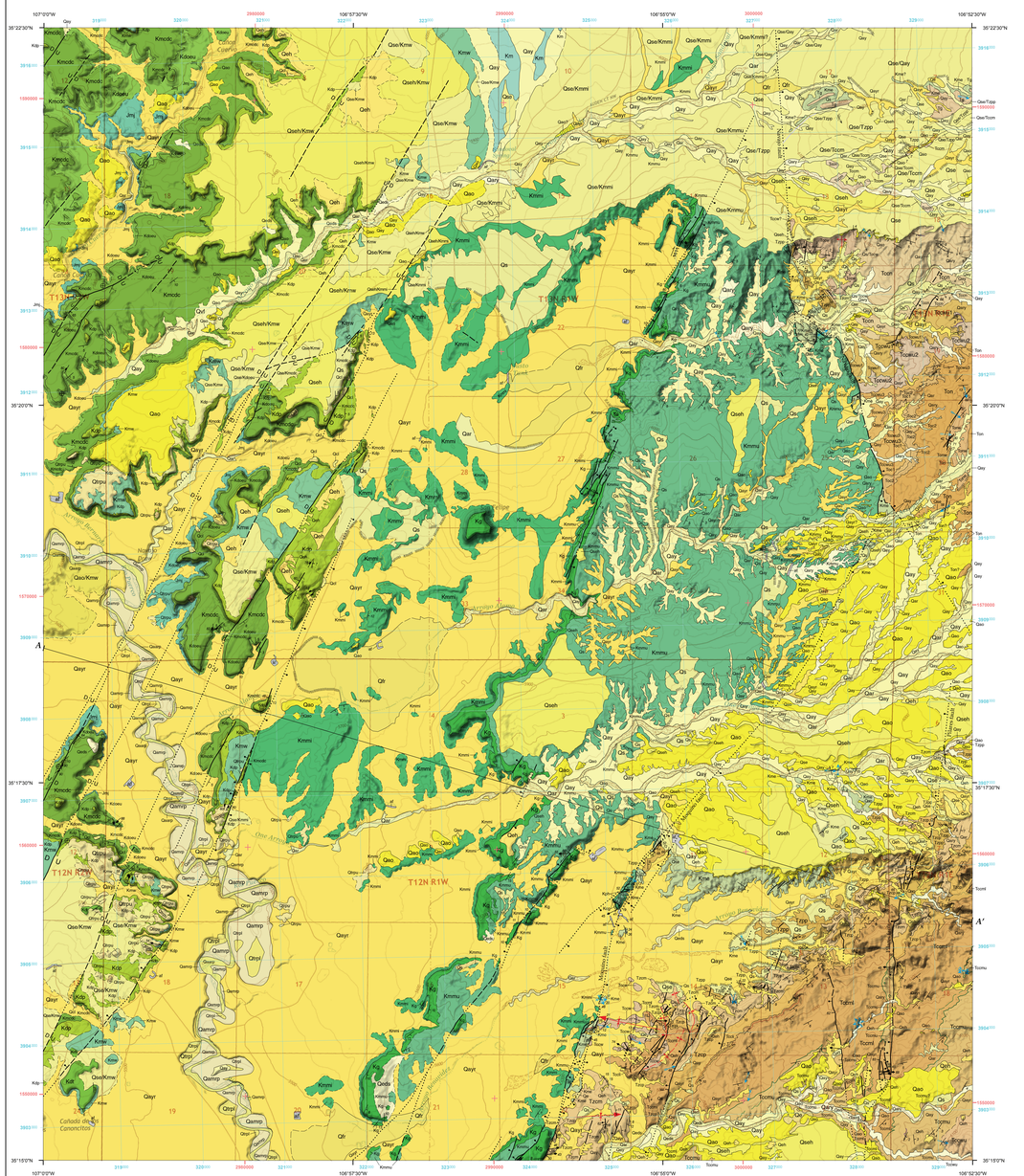

Base map from U.S. Geological Survey 2013.
North American Datum of 1983 (NAD83) World Geodetic System of 1984 (WGS84).
Projection and 1000-meter grid: Universal Transverse Mercator, Zone 13S
10 000-foot ticks: New Mexico Coordinate System of 1983(west zone), shown in red.

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

Quadrangle Location

Magnetic Declination
July, 2016
8º 51' East
At Map Center

Contour Interval 20 Feet

North American Vertical Datum of 1988

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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

New Mexico Bureau of Geology and Mineral Resources
Open-File Geologic Map 219

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Geologic Map of the San Felipe Mesa 7.5-Minute Quadrangle, Sandoval County, New Mexico

June, 2017

by
Daniel J. Koning and Geoffrey Rawling

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map may be based on any of the following: reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation.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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Explanation of Map Symbols

Geologic contact—Identity and existance certain, questionable where queried. location accurate where solid, approximate where dashed, and concealed where dotted.

Key bed—Identity and existence certain, location inferred.

Gradational contact—Identity and existence certain, location accurate where continuous and approximate where discontinous.

Fault—Identity and existence certain, questionable where queried. Solid where exposed, dashed where intermittent, and dotted where concealed.

Normal Fault—Identity and existence certain; solid where exposed, dashed where intermittent, dotted where concealed. Queried where identity is questionable. Bar-and-ball on downthrown block.

Low-angle normal fault—Identity and existence certain, location accurate. Half-circles on downthrown block.

Oblique-slip fault, right-lateral offset—Identity and existence certain, location accurate. Arrows show relative motion; ball and bar on downthrown block.

Oblique-slip fault, left-lateral offset—Identity and existence certain, location accurate. Arrows show relative motion; ball and bar on downthrown block.

Plunging syncline—Large arrowhead shows direction of plunge

Plunging anticline—Large arrowhead shows direction of plunge

Monocline, anticlinal bend—Identity and existence certain, location accurate. Arrows show direction of dip; shorter arrow on steeper limb.

Monocline—Identity and existence certain, location accurate where solid and dashed where approximate. Arrow shows direction of dip.

Anticline—Identity and existence certain, location accurate.

A ⊢—⊣ *A′* Cross section line and label

Green lacustrine mudstone bed -not marker bed

Green lacustrine mudstone marker bed

White ashy stratum

U D Fault showing local normal or offset—U, upthrown block; D, downthrown block.

Inclined fault—Showing dip value and direction

Small, minor inclined fault—Showing strike and dip

Small, minor vertical or near-vertical fault— Showing strike

Small, minor inclined joint—Showing strike and dip

Small, minor vertical or near-vertical joint—Showing strike

⊕ Horizontal Bedding

Inclined bedding—Showing strike and dip

Inclined slicenline, groove, or striation on fault surface—Showing bearing and plunge

Fluvial transport direction

Sediment transport direction determined from imbrication

Sediment transport direction determined from crossbeds

Sediment transport direction determined from eolian crossbedding in vertical or near-vertical section

↑ Direction of ground-water flow—Approximately located

Exploratory Well

Correlation of Map Units

Description of Map Units

Holocene

af **Artificial fill and related ground disturbance—**Excavated sand, silt, and clay that was locally moved. Generally associated with berms, dams, and exploratory drilling projects. 1–5 m thick.

Qcl **Colluvium and landslide deposits—**Poorly-sorted boulder to cobble gravel with a matrix of sand and silt. Boulders may be up to several meters in diameter. Unit mantles the base of slopes or forms semi-coherent toreva blocks that have moved downslope. Mapped from air photos and designated only where underlying bedrock geology is completely obscured. 1–10 m thick.

Qe **Eolian sand, undifferentiated—**Eolian sand (as dunes or sand sheets) deposited in a variety of geomorphic settings: slopes, valley floors, and low ridges adjoining wide, active arroyos. Dunes commonly anchored by juniper trees and less than 2 m in height, but locally dunes are higher. Deposit is loose and massive to vaguely cross-laminated. Sand is pale brown to yellowish brown (10YR 6/3-5/4), medium-grained, subrounded to rounded, and well-sorted. <5 m thick.

Qeh **Eolian sand on topographic highs—**Light-yellowish-brown to brownish-yellow (10YR 6/4-6) sand deposited on topographic highs by eolian processes. Low-angle cross-stratified to massive. Sand is fine- to medium-grained, subrounded, well-sorted, and composed of quartz, minor feldspar, and 10–15% lithic + mafic grains; the lithic grains include volcanic grains and chert. Loose. 1–2 m thick.

Qeds **Eolian sand as dunes or sheet forms—**Light-brown to tan sand deposited as dunes or sheet-like deposits adjoining active drainages. Low-angle cross-stratified to massive. Sand is fine- to coarse-grained (mostly fine- to medium-grained), subrounded to rounded, and well-sorted. Loose and non-cemented. 1–5 m thick.

Qs **Slopewash or sheetflood deposits—**Unit underlies small piedmonts at the foot of hillslopes; these piedmonts commonly lack a distinctive fan morphology. Sediment is derived from nearby uphill lithologic units and lithologically similar to younger alluvium (Qay), except that channel-fills and bed forms are overall thinner. May grade laterally into adjoining Qay. 1–6 m thick.

Qse **Slopewash and sheetflood deposits along with minor eolian sand —**Unit underlies small piedmonts at the foot of hillslopes, similar to unit Qs, or extends well up onto side slopes (but below the mesa-capping Qseh deposits). Lithologically similar to Qs. Derived from nearby uphill lithologic units but also inferred to contain reworked eolian sediment. Includes minor eolian dunes and sheets. May laterally grade into adjoining Qay. 1–10 m thick.

Qseh **High-level slopewash and sheetflood deposits containing minor eolian sediment—**Sand and slightly clayey-silty sand (generally <10% fines) underlying topographically high-level, low-sloping, and geomorphically stable surfaces. Sand is commonly massive (locally containing scattered, very minor pebbles) and has experienced cumulic soil development manifested by ped development, clay illuviation, and calcium carbonate accumulation. Peds are moderate to strongly developed, coarse to very coarse, and subangular blocky to prismatic. Clay illuviation is faint to distinct and clay coverage of ped faces variable. Calcium carbonate accumulation exhibits stage I to II carbonate morphology (following Giles et al., 1966). Sand is yellowish-brown to light-yellowish-brown (10YR 5-6/4) or brown to light-brown (7.5YR 5-6/4), very fine- to coarse-grained (mostly fine- to medium-grained), subrounded (lesser subangular), and well-to moderately sorted. Locally overlain by eolian dune forms generally <1 m tall (but locally 2–3m tall). Lower contact is commonly gradational with underlying older alluvium. Deposit is generally 0.5–3.0 m thick.

Qaarp **Active alluvium of the Rio Puerco—**Unlithified sediment dominated by clay and silt in the active channel of the Rio Puerco. Incised into units Qamrp and Qtrpl. Estimated to be 1–3 m thick.

Qamrp **Modern alluvium alongside the active channel of the Rio Puerco—**Sand, silt, and clay deposited alongside the active channel of the Rio Puerco; lies within the larger, historic arroyo cut into unit Qay. Unit tread stands a few meters above the valley floor and lies 7–9 m below Qay surface. Probably 1–3 m thick.

Qar **Recent alluvium in tributary arroyos to the Rio Puerco—**Sand and variable gravel (pebbles and local cobbles) deposited in arroyos during modern to recent historic time. 1–3 m thick.

Qfr **Recent alluvial fan deposits at the mouths of incised arroyos—**Sand and minor gravel, clay, and silt deposited as broad lobes at the mouths of incised arroyos. A given deposit may be a composite of slightly different-age fan lobes. Relatively well-vegetated by woody shrubs. 1–5? m thick.

Qay **Younger alluvium—**Unconsolidated deposits, underlying valley floors, whose associated treads typically rise >1 m above recent channels and are inferred to be >100 years old. Includes fan deposits inferred to be >100 years old based on subdued surface morphology. Near the Rio Puerco, the unit consists of sand, silt, and clay that are wavy to horizontal-planar laminated to thin-bedded; minor brown to purplish-brown organic-rich lenses locally present. Deposits in southwest-flowing canyons in the eastern quadrangle are composed of relatively massive sand or pebbly sand (light-brown to pink to tan) containing minor very thin to thin beds of sandy pebbles. Local buried soils generally consisting of grayish A horizons. Gravel composition consistent with erosion from the Ceja Formation or the Navajo Draw Member of the Arroyo Ojito Formation. Sand is fine- to very coarse-grained, subrounded, and variably sorted. Surface lacks notable soil development and is commonly eroded. Along the Rio Puerco, this unit is lithified enough to support vertical arroyo exposures up to 7 meters high but easily excavated by hand. 1–10 m thick.

Qary **Combined recent alluvium and subordinate younger alluvium—**See descriptions for units Qar and Qay.

Qayr **Combined younger alluvium and subordinate recent alluvium—**See descriptions for units Qay and Qar.

Qtrpl **Lower, historic terrace deposits of Rio Puerco—**Thin, sandy strath deposit(s) alongside the modern channel of the Rio Puerco. Generally, the tread is inset 5–6 m below the younger alluvium (Qay) surface and stands ~5 m above the modern channel. However, higher treads are locally present (still below the Qay surface) and included in this unit. Approximately 0.5–2.0 meters thick.

Pleistocene

Qtrpu **Upper terrace deposits of the Rio Puerco—**Sand and gravel terrace deposits whose treads lie above the Qay surface. Exposures reveal clast supported pebble to cobble gravel with sandy matrix. Clast compositions include granite, basalt, chert, quartzite, and sandstone. Tread surfaces range from 3–45 m above the surface of Qay. Loose. Thicknesses for correlative deposits on the Benavidez Ranch quadrangle to the south range from 1–14 m.

Qao **Older alluvium, undivided—**Sand and pebbly sand, containing minor sandy pebbles, deposited by tributaries to the Rio Puerco and preserved as eroded terrace deposits. Gravel commonly occupies thin to medium, lenticular bedsand comprised primarily of pebbles (<5% cobbles) that are subangular to rounded and moderately to poorly sorted; gravel composed of chert, cemented sandstone, minor quartzite+quartz, up to 30% granite, and 0–10% intermediate volcanic rocks. Sand and pebbly sand are in thick beds that are internally massive, yellowish brown to light yellowish brown to 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). Weakly to well consolidated, but not cemented. 1–15 m thick.

Miocene

Arroyo Ojito Formation

Ton **Navajo Draw Member—**Pale-brown to very-pale-brown sandstone (10YR 6-7/3) interbedded with mudstone and very fine- to fine-grained sandstone, the latter being in very thin to thick, tabular beds. 10–50% channel fills composed of sand and subordinate gravel; sand is horizontal-planar laminated to cross-laminated (foresets up to 20 cm thick) or massive; gravel generally in 1–30 cm-thick beds that are tabular to lenticular. Gravel are sand- to clast-supported, consist of pebbles with 0.5–2% cobbles, subrounded to rounded, moderately sorted, and composed of chert, FeO fragments, trace-5% hbl-plagioclase phyric dacite, 1–8% quartzite+quartz, and 1% petrified wood. Channel-fill sand is fine- to very coarse-grained, subrounded, poorly to moderately sorted, and composed of quartz, minor feldspar, and 10–20% lithic grains (volcanic+chert+FeO). Weakly consolidated, with 1% moderate to strong cementation. >100 m thick.

Tonw **Navajo Draw Member, inferred western provenance lithofacies—**Tongue of light-orange (7.5YR 6/4-6) sand with subordinate sandy pebble-conglomerate and 1–5% reddish-brown, clay-rich beds. Pebbles are in very thin to medium, tabular to lenticular beds and composed fine chert, 1–5% quartz, and 2–5% quartzite. Sand is commonly horizontal-planar laminated to very thinly bedded, fine- to very coarse-grained (mostly medium-grained), subrounded, well-sorted, and composed of quartz, minor feldspar, and 5–7% chert-dominated lithic grains. Weakly consolidated. 30 m thick.

Toc2 **Subunit 2 of gradational zone between the Arroyo Ojito and Cerro Conejo Formations—**Light-orange sand containing 5% brown or yellowish-brown mudstone and 5–10% gravelly channel fills. Conglomerates are locally cross-stratified. Interfingers northeastward with lowest Ton strata. 12–18 m thick.

Cerro Conejo Formation

Toc1 **Subunit 1 of gradational zone between the Arroyo Ojito and Cerro Conejo Formations—**Pinkish sand that lies between the reddish sand of Tccwu3 and the gravel-bearing strata of unit Toc2. ~5 m thick.

Tccwu **Western provenance lithofacies assemblage, upper part of unit—**Orangish sandstone with subordinate (~10–20%) mudstone and clayey sandstone near its base. Sand occurs in thin to thick, tabular beds that are internally horizontal-planar laminated to massive to low-angle cross-laminated. Sand is mostly fine- to coarse-grained and reddish-yellow to pink to light-brown (5-7.5YR 6/6-7/3; 7.5YR 6-7/4). Mudstone occurs in reddish intervals as thick as 10 m, where mudstone is interbedded with very thin to thin, tabular beds of very fine- to medium-grained sand and clayey sand; mudstone beds are mostly very thin to medium, tabular, dominated by clay, and reddish-brown to light-brown (2.5-5YR 4-5/4; 7.5YR 4-6/4). 1–15% strong cementation of the sandstone by calcium. Mostly non-cemented and weakly to well consolidated. Where exposed to the south of the quadrangle, the lower contact is relatively sharp and planar and the unit is ~120 m. Progrades over units Tccmu and Tccn. Description modified from Koning and Jochems (2014).

Tccwu3 **Western provenance lithofacies assemblage, upper part of unit, subunit 3—**Thick, tabular beds (commonly internally massive) of red to orange sandstone. Sand is fine- to medium-grained, subrounded, moderately sorted, and composed of quartz, minor feldspar, and 10–13% chert. Very minor reddish, silty-clayey sand in very thin beds. Similar to unit Tccwu1. 15–20 m thick.

Tccwu2 **Western provenance lithofacies assemblage, upper part of unit, subunit 2—**Light-brown (7.5YR 6/4), cleans and with indistinct bedding; locally interbedded with orange sand. Massive or vaguely horizontal-planar laminated. Sand is fine- to medium-grained (minor coarse-grained), subrounded, moderately to well-sorted, and composed of quartz, minor feldspar, and 10–20% chert + mafic grains (1–20% of lithic fraction are volcanic grains). Weakly to moderately consolidated. 15 m thick.

Tccwu1 **Western provenance lithofacies assemblage, upper part of unit, subunit 1—**Reddish sandstone in medium to thick, tabular beds that are internally massive (most common), horizontal-planar laminated, or low-angle cross-laminated. Sand is yellowish-red (5YR 5/6) to reddish-yellow (7.5YR 6/6), very fine- to medium-grained (mostly fine-grained), subrounded, moderately to well-sorted, and composed of quartz, minor feldspar, and 10–15% lithic grains (chert>>volcanic grains, the latter being <15% of sand faction). 1–15% clay-rich sand. Weakly to moderately consolidated with 1% strong cementation. 30 m thick.

Tccw **Western provenance lithofacies assemblage, undivided—**Light-orange sandstone in thin to thick (mostly 1–2 m thick), tabular to lenticular beds that are internally massive to laminated (horizontal-planar to low-angle cross-laminated); bedding breaks commonly defined by thin, tabular beds of reddish clayey, very fine-low to medium-low, poorly sorted sand. Minor burrows. Sand is light-reddish-brown to reddish-yellow (5-7.5YR 6/4-6), fine- to coarse-grained (mostly medium-grained), subrounded, moderately sorted, and contains 3% thin lenses of coarse-grained sand. Sand composed of quartz, minor feldspar, 10–15% chert, and trace–5% volcanic grains. Unit becomes conglomeratic up-section, where gravel consists of rounded pebbles of chert, 0.5–1% rhyolites-dacites, 2% vein quartz, 1–5% Proterozoic clasts, 1–2% quartzite, and trace petrified wood. Local white, fine ash in thin beds. Approximately 110–120 m thick.

Tccn **Northern provenance lithofacies assemblage at Navajo Draw—**Light-gray to pink to very-pale-brown (7.5YR7/2; 7/3-4; 10YR 7/4) sandstone in vague, thin to thick, lenticular to broadly lenticular beds (up to 20 m wide); sand within these beds is massive, horizontal-planar laminated, or cross-laminated (foresets up to 20 cm thick and commonly low-angle). Sand is fine- to coarse-grained (mostly medium-grained); subrounded, and moderately to well sorted; medium-upper to coarse-upper sand is mixed with finer sand or may be in separate lenticular lamina or thin beds. Sand composed of quartz, minor feldspar, and 10–15% lithic grains (containing 15–60% volcanic grains in the lithic fraction, rest is mainly chert). Trace reddish paleosols ~20 cm thick and characterized by 5% clay accumulation, massive texture, and weak ped development. Trace clayey sand beds ~10 cm thick and tabular. Unit thickness of 50–70? m.

Tccm **Mixed or indeterminate provenance, undivided—**Well-bedded sandstone in medium to thick, tabular beds with common internal horizontal-planar laminations. Somewhat similar to the Chamisa Mesa Member of the Zia Formation, but the lower Cerro Conejo Formation has more reddish intervals and less common rhizolith features. Sand color is pink to light-brown to very-pale-brown (7.5-10YR 6-7/4), with minor light-reddish-brown (5YR 6/4) and reddish-yellow (5-7.5YR 6/6) beds. Sand is mostly fine- to medium-grained and silty-clayey very fine- to fine-grained, subangular to rounded (mostly subrounded), well- to moderately sorted, and composed of quartz, minor feldspar, and 7–15% lithic grains. Within finer sand are trace lenses (up to 3 cm thick) of medium- to coarse-grained sand, where the coarse grains contain 20–35% grains of chert and felsic volcanics. Beds locally fine upward from basal medium- to coarse-grained sand. trace thin beds composed of fine, white ash commonly altered to clays. Trace to 1% reddish-brown clayey sand in laminae to very thin beds. ~150 m thick.

Tccmu **Mixed or indeterminate provenance, overlies green mudstone marker beds—**Strata overlies laterally continuous, green lacustrine mudstone. See description for unit Tccm. 60 m thick

Tccml **Mixed or indeterminate provenance, underlies green mudstone marker bed—**Strata underlies laterally continuous, green lacustrine mudstone. See description for unit Tccm. About 50–55 m stratigraphically above base of unit lies a 5 m-thick interval of pink sandstone (7.5YR 6/4) interbedded with relatively abundant calcium carbonate+sand — some beds could be classified as a sandy limestone with wavy to tabular, laminations to thin beds. ~10–15% of beds are strongly cemented by calcium carbonate in the lower 55 m of the unit, which are locally bioturbated (nodular or burrowed). ~90 m thick.

Tccli **Lowest strata occurring as a tongue within the Cañada Pilares Member of the Zia Formation—**Reddish-yellow to yellowish-red (5YR 5-6/6) sandstone in very thin to thin, tabular-beds; locally cross-laminated (foresets up to 10 cm tall) or horizontal-planar laminated. Sand is medium- to coarse-grained, rounded to subrounded, and contains 25% lithic grains (mix of volcanics and chert). Minor interbedded claystone or siltstone. 1–3 m thick.

Zia Formation

Tzcp **Cañada Pilares Member—**Slope-forming, reddish-brown mudstone interbedded with subordinate intervals offine sandstone and silty fine sandstone (0.5–5 m thick). Mudstone is clay-rich and reddish brown (5YR 4/4). There are sparse, thick beds of greenish mudstone near the top of the unit. Sandstone is in well-defined, laminated to very thin, horizontal-planar beds. Sand is mostly very fine- to fine-grained, but locally has very sparse, very thin lenses of medium- to very coarse-grained sand. Fining-upward trends locally seen in the sand intervals. Sand is light-reddish-brown to yellowish-red (5YR 6/4-5/6), less commonly very-pale-brown (10YR 7/3), and subrounded to rounded, well to moderately sorted, and composed of quartz, minor feldspar, and minor lithic grains (dominated by chert). Sandstone intertongues terminate within mudstone in southward direction. Lower contact is relatively sharp, but the upper contact intertongues with the overlying Cerro Conejo Formation (unit Tccml). Note that we only include in the Cañada Pilares Member Slope-forming, reddish-brown mudstone interbedded with subordinate intervals of fine sandstone and silty fine sandstone (0.5–5 m thick). Mudstone is clay-rich and reddish-brown (5YR 4/4). There are sparse, thick beds of greenish mudstone near the top of the unit. Sandstone is in well-defined, laminated to very thin, horizontal-planar beds. Sand is mostly very fine- to fine-grained, but locally has very sparse, very thin lenses of medium- to very coarse-grained sand. Fining-upward trends locally seen in the sand intervals. Sand is light-reddish-brown to yellowish red (5YR 6/4-5/6), less commonly very-pale-brown (10YR 7/3), and subrounded to rounded, well to moderately sorted, and composed of quartz, minor feldspar, and minor lithic grains (dominated by chert). Sandstone tongues become more abundant northwards. Lower contact is relatively sharp, but the upper contact intertongues with the overlying Cerro Conejo Formation (unit Tccml). Note that we only include in the Cañada Pilares Member the lower, mudstone-rich half of what Tedford and Barghoorn (1999, fig. 3) call the Cañada Pilares Member. Weakly to moderately consolidated and 38 m thick.

Tzcpi **Cañada Pilares Member tongue in lowest Cerro Conejo Formation strata—**Similar to that described for unit Tzcp, but occurring as a 6–8 m-thick tongue in basal strata of Tccml.

Tzcm **Chamisa Mesa Member—**Sandstone in medium to very thick, tabular beds that are internally horizontal-planar bedded (laminated to thin), tangentially cross-laminated, or massive. Compared to the lower Cerro Conejo Formation, the sand is somewhat cleaner in this unit and cemented beds commonly exhibit rhizoliths and paleo-burrows. Compared to Piedra Parada Member of Zia Formation, this unit is tabular-bedded and the sand is slightly redder. Typical texture of very fine- to medium-grained sand and silty very fine- to fine-grained sand. 5–20% of beds are well-cemented by calcium carbonate. Non-cemented sand is pink to light-brown (7.5YR 6-7/3-4) to very-pale-brown (10YR 7/3-4), Evidence of bioturbation is relatively common and includes massive textures, rhizoliths, and paleo-burrows. Near the southern quadrangle boundary is sparse (up to 10%), reddish, medium to thick and tabular beds of mixed clay, silt, and very fine- to medium-grained sandstone -- these disappear to the north. Grains are rounded to subangular (mostly subrounded), well to moderately sorted, and composed of quartz, minor feldspar, and 10–13% lithic grains. Moderately consolidated. 30–35 m thick.

Tzcmi **Chamisa Mesa Member tongue in uppermost Piedra Para Member—**Light-orangish sandstone. Sand is mainly reddish-yellow to pink (7.5YR 7/4-6) and very fine- to medium-grained. Local clayey fine- to coarse-grained sand (7.5YR 5/6). 2–3 m thick.

Tzzp **Piedra Parada Member—**White to light-gray to very pale-brown (10YR 8/1-7/2-7/3) sandstone that is in horizontal-planar beds or cross-stratified (with tangential foresets up to a few meters thick). Beds are mostly laminated to very thin. These thicker beds are less distinct and not as laterally extensive as those in the Chamisa Member Member of the Zia Formation. Sand is mostly medium- to coarse-grained and contains more volcanic (felsic-intermediate) lithic grains (15–30% of total) than overlying Santa Fe Group units. Weakly to moderately consolidated, with ~5–25% strong cementation by calcium carbonate. Base unconformably overlies the Menefee Formation, where there is meter-scale paleo-topographic relief. At the contact lies ventifacted pebbles and cobbles of volcanic rock. ~80 m thick.

Tz **Zia Formation, undivided—**Undivided Chamisa Mesa and Piedra Parada Members. See descriptions for units Tzcm and Tzpp.

Middle Eocene

Tg **Gallisteo Formation—**Light-orange conglomeratic sandstone. Very thin to medium beds. Gravel lacks volcanic clasts and consists of pebbles with 1–15% cobbles that are subrounded to rounded and composed of quartzite, chert, and Mesozoic sandstone; 1% reddish granite. Sand is white to pinkish-white to pink (7.5YR 8/1-3; 7/3), fine- to very coarse-grained, subangular to subrounded, mainly moderately sorted, and composed of quartz, 15–20% feldspar (common potassic feldspars), and 10–15% lithic grains composed of chert and minor granite. Discontinuous outcrops suggest paleovalley fill. ~20 m thick.

Late Cretaceous

Kme **Menefee Formation—**Fine-grained floodplain deposits interbedded with 15–30% sandstone channel-fills. Floodplain sediment consists of mudstone, siltstone, and very fine- to fine-grained sandstone. Mudstone is mostly light-gray to dark-grayish-brown; in contrast to unit Kcg, the mudstones of this unit are locally greenish-gray (~5% of unit). The mudstone is laminated to very thin, tabular to wavy bedded within medium to very thick, tabular beds. Interbedded in the mudstone are minor, thinly bedded, very fine- to fine-grained sandstones that likely represent crevasse splay deposition; these are lenticular to broadly lenticular (1:10 height : width ratio) and commonly white. Also interbedded in the floodplain deposits are coal beds, commonly 10–50 cm thick; these decrease in abundance up-section (1–5% in lower ~60 m, trace–0.5% higher in the section). The sandstone in the floodplain deposits are commonly horizontal-planar laminated. Local petrified wood, iron oxide concretions, and white ashes up to 15 cm thick. Sandstone channel fills range in size from ribbon forms (0.2–1.5 m-thick and ≤ 5 m wide) to broadly lenticular, amalgamated bodies (1–6 m thick and up to ~60 m wide). Channel-fills display trough cross-lamination (up to 30 cm thick) to tangential cross-lamination to horizontal-planar laminations. The sandstone is white to light-gray to very pale-brown, weathering to yellow- to light-yellowish-brown. Sand grains are very fine- to medium-grained. Variably cemented by calcium carbonate and possibly clay. Interpreted as a fluvial deposit. Base is not exposed on this quadrangle, but to the south it is gradational and conformable. ~550 m thick on Benevidez Ranch quadrangle to the south.

Kpu **Point Lookout Sandstone, upper part—**White sandstone weathering to yellow and brown. Sandstone is tangentially to trough-cross-laminated to horizontal-planar laminated. Sand is mostly fine- to medium-grained. Unit base is gradational over about 1–2 m. ~65 m thick.

Kms **Mancos Shale, Satan Tongue—**Interbedded sandstone, siltstone, and fissile shale. About 2/3:1/3 sandstone vs. shale. Shale and siltstone are grayish-brown to light-olive-brown. Sandstone is generally in very thin to thick, tabular beds that are internally low-angle cross-laminated to hummocky-laminated to horizontal-planar laminated. Sand is mostly very fine- to fine-grained and white to yellow, weathering to pale-brown. ~15 m thick.

Kph **Point Lookout Sandstone, Hosta Tongue —**White to pale-brown to yellow, cemented, cross-stratified to horizontal-planar laminated sandstone that lies below the Satan Tongue of the Mancos Shale. Foresets are up to 100 cm thick and tangential (mostly) to trough-cross-laminated. Sand is fine- to medium-grained. 0.5–1.0%, relatively thin, gray shale-mudstone laminae that commonly contain organic detritus. 22–30 m thick.

Kcg **Crevasse Canyon Formation, Gibson Coal-bearing Member—**Dark-colored, fine-grained deposits, interpreted as swamp and floodplain facies, interbedded with subordinate sandstone channel fills weakly to strongly cemented by calcium carbonate. 15–25% sandstone channel-fills that are up to 5 m-thick and lenticular over distances of 100s of meters, but also occur as thick, tabular beds. Internally, channel-fills are cross-stratified, with tangential foresets or trough cross-laminations being especially common, or horizontal-planar laminated. Sandstone is mostly fine- to medium-grained and light gray to white to very pale brown. Swamp + floodplain deposits contain 1–5% coal or organic-rich mudstone beds but generally consist of mudstone and siltstone displaying very dark gray to light-gray, brown, and grayish-brown to dark-grayish-brown colors. This fine-grained sediment exhibits horizontal-planar to wavy laminations. 1% of strata are light-gray (7.5YR 7/1) siltstone to very fine-grained sandstone in thin beds that are internally horizontal-planar to wavy laminated. Interbedded within the swamp + floodplain deposits are crevasse splay, fine- to medium-grained sandstones that are <20 cm thick and locally low-angle cross-stratified. Coal beds are thin to thick (up to 50 cm) and tabular. Local layers with abundant, concretionary iron-oxide chips, as well as local klinker zones. Base of unit intertongues northward with uppermost Mullato Tongue sands. Top contact is not exposed. 120–130 m thick on Benevidez Ranch quadrangle to the south.

Kcd **Crevasse Canyon Formation, Dalton Sandstone—**Pale-brown to light-yellowish-brown to light-gray (2.5Y 6-7/3; 10YR 6-7/2)) sandstone. Thick, tabular beds that are horizontal-planar laminated as well as low-angle trough-cross laminated. Sand is fine-grained and well-sorted. 5% strong cementation by calcium carbonate. Basal contact is sharp but conformable. >12 m thick (30–37 m thick where fully exposed to south).

Km **Mancos Shale, undifferentiated—**Dark-colored Mancos shale that could not be accessed or whose stratigraphic position could not be determined.

Kmmu **Mancos Shale, Mullato Shale Tongue—**Poorly exposed, fine-grained marine sediment that erodes readily and displays a distinctive yellow color. Gray, fissile shale with subordinate yellowish very fine-grained sandstone- and silty sandstone dominated intervals 5–10 m thick. Sandstone is very fine-grained and horizontal-planaar laminated or hummocky- to wavy- laminated; these sandy intervals contain variable amounts of gray clay lamina interbeds. trace to 1% laminae to very thin beds of crystalline gypsum, probably a product of diagenesis. Moderately to well consolidated. ~100 m thick.

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 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-cross-bedded 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 distinctly white to pale-grey in color. It is composed of friable fine- to coarse-grained, poorly-sorted, non-calcareous quartz sandstone. A few percent of pink and white chert grains are present. Broad, multi-directional trough crossbeds are dominant. Unit weathers into distinctive "beehive" domes. 15–40 m thick.

Kmmi **Middle part of Mancos Shale between the Gallup Sandstone and Two Wells Sandstone Tongue of the Dakota Sandstone—**Poorly exposed shale. Gray to light-yellowish-brown to pale-brown (2.5Y 6/1; 6-7/4), fissile mudstone (clay>silt) and shale in laminated to very thin, tabular to slightly wavy beds (<1 cm of relief). Local gray (N6/) and greenish colors (5Y 4/1; 2.5Y 6/3). Upper 1 m consists of interbedded mudstone 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. Trace boulder-size concretions cemented by calcium carbonate and lesser silica. Where visible, appears similar to underlying shale tongues of the Mancos. Obscured by alluvium and valley fill in the Rio Puerco valley. 160–180 m thick. Marker bed in Kmmi: Calcareous, brown, quartz sandstone with fossil shark teeth. Very thin-bedded to laminated. Makes a ledge.

Kdt **Two wells Sandstone Tongue of the Dakota Sandstone—**Coarsening-upward shaley sandstone and sandstone forming disconnected outcrops. Lowermost beds are medium-gray fine- to medium-grained, non-calcareous, quartz sandstone with clay matrix with lenses of dark shale a few cm-thick. Irregular orange iron stains are common. Thin to medium beds are parallel. In contrast, uppermost beds are light gray to pale-brown, fine- to medium-grained, moderately well-sorted quartz sandstone with several percent of lithic fragments, mafic mineral grains, chert, and notably, dark-green glauconite. Beds are thin to medium thickness with planar crossbeds prominent locally. 5–10 m thick.

Kmw **Mancos Shale, Whitewater Arroyo Shale Tongue—**Poorly exposed grey to yellowish-brown shale and silty shale. Rubbly, decomposed concretions are common. Generally forms a broad grass-covered expanse above the cliffs of the Paguate Sandstone. 18–25 m thick.

Kdp **Dakota Sandstone, Paguate Sandstone Tongue—**Poorly Massive, cliff-forming 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 massive and structureless. Medium-brown, filled burrows and round to oval concretionsare abundant. North of Navajo Draw 1.5 miles from the Rio Puerco the cliff-forming sandstone grades laterally into sandy shale with abundant dark-brown concretions up to 2 meters in diameter. Generally makes a bold cliff and abundant blocky rubble with boulders up to 10 m in diameter. West of the Rio Puerco 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. Base of the unit is usually somewhat gradational with the underlying shale, upper contact is sharp. 6–12 m thick.

Kmcdc **Undivided Clay Mesa Shale Tongue of Mancos Shale and underlying Cubero Sandstone Tongue of the Dakota Sandstone—**Clay Mesa Shale consists of medium to dark-gray, parallel, very thin- to thin-bedded shale and silty shale with thin limestone layers and concretions—subunit becomes more silty and sandy upwards as it grades into the overlying Paguate Sandstone Tongue; generally poorly exposed and covered by colluvium and rubble of overlying unit, except in vertical cliffs. Cubero Sandstone 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; not calcareous; parallel, thin-bedded to locally medium-bedded. Exposed bedding surfaces commonly display abundant paleo-burrows as well as a consistent joint pattern comprised of lozenges or diamonds. In the northern part of the mapped area, Cubero Sandstone is composed of two distinct sandstone beds that are similar in appearance, with the lower bed being very fine- to fine-grained. Lower contact is gradational with underlying shales of the Oak Canyon Member, upper contact is sharp. ~25 m thick.

Kdoeu **Dakota Sandstone, Oak Canyon and Encinal Canyon Members—**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 2–3 meters. Locally may be absent. The Oak Canyon Member consists of sandstone interbedded with and grading upwards into shale. Basal sandstone is brown, quartzose, medium-grained. Bedding is flat and even with local zones of cross-bedding between parallel beds. Quartz grains are medium- to coarse-grained, 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. Sandstone forms a distinct brown ledge above the underlying cliff of lighter- colored Encinal Canyon Member and Jack Pile 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.

Jurassic

Jmj **Morrison Formation, Jackpile Sandstone Member—**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 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 but it is usually a near-vertical cliff. >35 m thick.

Jms **Morrison and Summerville Formations, undivided—**Gray, green, and maroon mudstones interbedded with gray to brown, fine- to medium-grained sandstones. Sandstones interbedded with variagated mudstones (including green mudstones); lower part (Summerville Formation) consists of interbedded reddish sandstones and reddish- to greenish-gray mudstone. 220 m thick.

Jt **Todilto Formation—**Upper part is white to gray gypsum. Lower part is a gray, fetid, micritic limestone. 30 m thick.

Je **Entrada Sandstone—**Upper part is a fine- to medium-grained, crossbedded and tabular-bedded sandstone exhibiting various colors. Lower part is reddish-brown siltstone and sandstone. 61 m thick.

Triassic

Ꞧc **Chinle Formation—**Composed largely of reddish-brown mudstone and siltstone with minor sandstone channel fills. 460 m thick.

Ꞧa **Chinle Formation, Aqua Zarca Sandstone—**White, fine- to coarse-grained, moderately sorted, clean quartzose sandstone with minor feldspar and mica. Unit is moderately hard, well consolidated, and fractured. 47 m thick.

Ꞧm **Moenkopi Formation—**Reddish-brown siltstone, silty sandstone, or very fine- to fine-grained sandstone interbedded with mudstone and local gypsum. 18 m thick.

Permian

Psa **San Andres Limestone—**Limestone and subordinate dolomite, shale, siltstone, and gypsum. 24 m thick.

Pg **Glorietta Sandstone—**Quartzose sandstone that is typically cross-bedded. Colors range from white, yellow, to tan. 11 m thick.

Pyu **Yeso Formation, upper part—**Red sandstone and shale in addition to gray sandstone. Gypsum locally present, either as thin beds or dispersed in shale and sandstone, Unit includes the San Ysidro Member, which is predominately a sandstone. 110 m thick.

Pym **Yeso Formation, Meseta Blanca Sandstone Member—**Tabular, thinly bedded siltstone and fine sandstones. 174 m thick.

Pa **Abo Formation—**Reddish-brown mudstone interbedded with grayish-white to light-orange conglomeratic arkose. 162 m thick.

Pennsylvanian

ꟼm **Madera Group, undivided—**Gray-colored limestone interbedded with arkosic limestone, subarkosic sandstone, and mudstone. 365 m thick.

ꟼs **Sandia Formation—**Interbedded gray, subarkosic sandstone, grayish limestone, and brown claystone. 11 m thick.

Proterozoic

XY **XYu—**Biotite-bearing granite.

Geologic Cross Section A–A′