APPENDIX I
DESCRIPTIONS OF GEOLOGIC UNITS DEPICTED IN PLATE I (CROSS SECTIONS OF THE EAST SAN AGUSTIN BASIN AND UPPER ALAMOSA CREEK)

Neogene-Quaternary Sediment

Valley bottom alluvium

Qva **Valley-fill alluvium (latest Pleistocene to uppermost Holocene)** — Sand with lesser gravel, silt, and clay. Underlies the floors of large arroyos or valleys. Basin fill under the Plains of San Agustin.

Basin fill under the Plains of San Agustin (away from well control)

QTsf **Santa Fe Group, undivided (Miocene to Holocene)** — Sand with subordinate gravel, silt, and clay. Proportion of gravel increases towards bedrock-cored uplands, whereas silt and clay is inferred to be most common near the center or west-center of the C-N graben. Variably consolidated and cemented.

QTsuppm **Santa Fe Group, proximal to medial piedmont-slope deposits (Miocene to Holocene)** — Sand, clayey-silty sand, gravelly sand, and gravel deposited in the proximal to medial parts of piedmonts. Weakly to moderately consolidated and poorly cemented.

QTsupp **Santa Fe Group, proximal piedmont-slope deposits (Miocene to Holocene)** — Sand, gravelly sand, and gravel deposited in the proximal parts of piedmonts. Weakly to moderately consolidated and poorly cemented.

North graben basin fill

Upper Santa Fe Group

Qsupwc **Western piedmont-slope deposits, upper coarse unit (Quaternary, mostly Pleistocene)** —
Long: Interbedded sandy pebbles, pebbly sand, and sand; abundant clay. Pebbles and sand are angular to subrounded. Pebbles are composed of intermediate volcanic detritus with 25-60% felsic tuffs; 2-10% basaltic andesite; minor (each <5%) of quartz, sandstone, limestone, and granite. Sand bodies are 1-12 ft thick. Sand is pinkish gray to pink to gray, mostly medium- to very coarse-grained, and composed of volcanic lithics (similar to pebbles in composition), minor feldspar, and 3-20% quartz. Proportion of gravels and intermediate volcanics increases up-section. Sharp lower base. Deposited on a piedmont flanking the eastern Datil Mtns that prograded eastward over older basin floor deposits. ~320-340 ft thick.

Short: Sandy pebbles, pebbly sand, sand, and clayey sands. Pebbles mostly composed of intermediate volcanic clasts and 25–60% tuffs (including Hells Mesa, Vicks Peak, and La Jencia Tuffs). Sand is mostly medium to very coarse and composed of volcanic lithics, minor feldspar, and 3–20% quartz. Proportion of gravels and intermediate volcanics increases up-section. Sharp lower base. 320–340 ft thick.

QTsupw **Western piedmont-slope deposits (Pliocene to lower? Pleistocene) —**
Long: Sand and clayey sand that is pink to light brown to pinkish white. Sand is very fine- to very coarse-grained and subangular to subrounded. Minor pebbles (proportion likely increases to west) that are very fine to medium, subangular to subrounded, and composed of intermediate volcanic rocks with 30–50% felsic tuffs (likely includes Datil Well and Rock House Canyon Tuffs). Deposited on an east-sloping piedmont flanking the eastern Datil Mountains.

Short: Sand and clayey sand that is pink to light brown to pinkish white. Sand is very fine- to very coarse-grained and subangular to subrounded. Minor pebbles (proportion likely increases to west) that are very fine to medium, subangular to subrounded, and composed of intermediate volcanic rocks with 30–50% tuffs (likely includes Datil Well and Rock House Canyon Tuffs).

QTsupw-bf **Western, distal piedmont-slope deposits interfingering with minor basin-floor strata (Pliocene to lower? Pleistocene) —**
Long: Sand and pebbly sand composed of felsic volcanic detritus (predominately Hells Mesa Tuff) with 1–20% intermediate volcanics; sand is mostly white to light gray, medium- to very coarse-grained, subangular, and contains 10–20% feldspar, and 10–15% quartz. Very minor clayey intervals. Interpreted distal western piedmont environment interbedded with minor tongues of finer-grained basin-floor facies.

Short: Sand and pebbly sand composed of felsic volcanic detritus (predominately Hells Mesa Tuff) with 1–20% intermediate volcanics; sand is mostly white to light gray, medium- to very coarse-grained, subangular, and contains 10–20% feldspar, and 10–15% quartz. Very minor clayey intervals. Interpreted distal western piedmont environment interbedded with minor tongues of finer-grained basin-floor facies.

QTsubf **Basin floor deposits (Pliocene to lower? Pleistocene) —** Sand and muddy sand, with up to 10% pebbles. Sand is light gray, fine- to coarse-grained, subangular, and composed of diverse felsic tuffs (≤5% intermediate volcanics); variable feldspar and 1–10% quartz grains. Local clay-sandy clay bodies up to 17 ft thick. Inferred basin floor depositional environment, with sediment sourced from the Datil and Gallinas Mountains.

QTsupe-bf **Interfingering distal eastern piedmont slope and basin-floor deposits interfingered with eastern, distal piedmont-slope deposits (Pliocene to lower? Pleistocene) —** Sand interbedded with clayey-fine-grained sediment and pebbly sand. Sand is white to gray to pinkish gray, fine- to very coarse-grained, subangular, and composed of phenocryst-poor tuffs and (in lower 1/3 of unit) a feldspar-quartz-biotite phyric tuff; 1-5% quartz grains. Inferred to be deposited near the margin of the eastern basin floor and distal eastern piedmont (sourced from the same paleotopographic high as unit QTsupe).

QTsupe **Eastern piedmont-slope deposits (Pliocene to Pleistocene) —**
Long: Monolithic sand that is gray (7.5YR hue), angular, and mostly medium- to very coarse-grained; 1–10% pebbles. Sand bodies are <5 ft thick. Sand predominately composed of a phenocryst-poor tuff (trace phenocrysts of sanidine, quartz, biotite); <1% quartz grains. Inferred deposition by west-flowing drainages sourced from a paleotopographic high to the east-southeast. Does not include piedmont sediment derived from the Gallinas Mountains, which presumably lies to the north of the cross-section lines.

Short: Sand that is gray, angular-subangular, and mostly medium- to very coarse-grained; 1–10% pebbles; composed of a phenocryst-poor tuff (probably unit Tvpt). Inferred deposition by west-flowing drainages sourced from a paleotopographic high to the east-southeast. Does not include piedmont sediment derived from the Gallinas Mountains, which presumably lies to the north of the cross-section lines.

Middle Santa Fe Group

Tsmpw **Western piedmont-slope deposits (middle to upper? Miocene) —** Interbedded sand and clayey-silty sand (±pebbly sands to the west) that is pinkish white, very fine- to very coarse-grained, subangular to subrounded, and composed of tuffs with variable intermediate volcanic grains. Deposited on the east-sloping piedmont along the eastern Datil Mountains.

Tsmpw-bf **Western, distal piedmont-slope deposits interfingering with basin-floor strata (middle to upper? Miocene) —** A unit comprised of interfingering or mixing of units Tsmbf and Tsmpw.

Tsmbf **Basin-floor deposits (middle to upper? Miocene) —**

Long: Interbedded clayey-silty sand and minor sand; white to light gray (5YR) to pinkish gray and redder than overlying strata. Sand is mostly fine- to coarse-grained, subangular, and composed of diverse tuffs with 1–30% intermediate volcanic grains, 10–25% feldspar, and 1–15% (mostly 5–10%) quartz grains. Relatively high clay content inferred from resistivity curves in wireline logs.

Short: Interbedded clayey-silty sand and minor sand; white to light gray (5YR) to pinkish gray and redder than overlying strata. Sand is mostly fine- to coarse-grained, subangular, and composed of diverse tuffs with 1–30% intermediate volcanic grains, 10–25% feldspar, and 1–15% (mostly 5–10%) quartz grains. Relatively high clay content inferred from resistivity curves in wireline logs.

Middle-lower Santa Fe Group

Tsmlpw **Western piedmont-slope deposits (lower to upper Miocene) —** Interbedded sand and clayey-silty sand (±pebbly sands to the west) that is pinkish white to pinkish gray, very fine- to very coarse-grained, subangular to subrounded, and composed of a mixture of felsic tuffs and intermediate volcanic grains together with minor feldspar and quartz. Deposited on the western piedmont (sloping eastward) adjacent to the Datil Mountains.

Tsmlbf **Basin-floor deposits (lower to upper Miocene) —**

Long: Interbedded clayey-silty sand and minor sand; white to light gray (5YR) to pinkish gray and slightly redder than overlying strata. Sand is mostly fine- to coarse-grained, subangular, and composed of diverse tuffs with 1–30% intermediate volcanic grains, 10–25% feldspar, and 1–15% (mostly 5–10%) quartz grains. Relatively high clay content inferred from resistivity curves in wireline logs. Deposited on a basin floor.

Short: Interbedded clayey-silty sand and minor sand; white to light gray (5YR) to pinkish gray and redder than overlying strata. Sand is mostly fine- to coarse-grained, subangular, and composed of diverse tuffs with 1–30% intermediate volcanic grains, 10–25% feldspar, and 1–15% (mostly 5–10%) quartz grains. Relatively high clay content inferred from resistivity curves in wireline logs.

Tsmlp **Piedmont-slope deposits (lower to upper Miocene) —**

Long Sand interbedded with minor muddy sand and minor very fine-pebbly sand. Sand is light gray (5YR hue), medium- to very coarse-grained, angular to subangular, and composed of a crystal-poor tuff (with 0.5–5% phenocrysts composed of sanidine, quartz, and minor biotite—inferred to be Vicks Peak Tuff), 1–3% sanidine, 1–3% quartz, and 0.5% biotite. In upper half of deposit, the

monolithic tuff is mixed withr other tuff types. Source area uncertain: it may be to east-southeast or possibly eastern flank of Datil Mountains (when the Vicks Peak Tuff may have occupied a much-larger area).

Short: Sand interbedded with minor muddy sand and very fine-pebbly sand. Sand is light gray, medium- to very coarse-grained, angular to subangular, and composed mostly of a monolithic, phenocryst-poor tuff (0.5–5% phenocrysts of sanidine, quartz, and minor biotite) plus 1–3% sanidine, and 1–3% quartz. Source area uncertain: it may be to east-southeast or possibly eastern flank of Datil Mountains.

Lower Santa Fe Group

Tslpw **Basin-floor deposits interfingering with western, distal piedmont-slope strata (lower to middle Miocene) —** Interbedded sand and clayey-silty sand (±pebbly sands to the west); sand probably composed of felsic tuffs, minor biotite-phyric intermediate volcanic grains, minor feldspar, and trace-3% quartz (compositions are conjectural). Deposited on the western piedmont (sloping eastward) adjacent to the Datil Mountains.

Tslbf **Basin-floor deposits (lower to middle Miocene) —** Clayey-silty sand interbedded with silt-clay and 1-15% clay-poor sand. Sand is pinkish gray to light gray, very fine- to coarse-grained, subangular, and composed of felsic volcanic grains with 5–20% intermediate volcanics (aphyric to biotite±hornblende phyric), 5–25% feldspar, <10% biotite, and ≤5% quartz. Felsic grains consists mainly of an orangish gray, porphyritic rock (tuff?) containing 10–20% phenocrysts of quartz, feldspar, and lesser biotite+hornblende up to 1 mm long. Local clayey intervals up to 20 ft thick; non-clayey sand bodies are mostly <10 ft thick. Inferred deposition on the basin floor.

Tsls **Sandy fluvial unit (lower Miocene) —**

Long: Clayey-silty fine sand interbedded with minor sand intervals. Sand is light gray to pinkish gray, mostly medium- to coarse-grained (minor fine and very coarse), and angular to subangular. Sand is composed of felsic grains with subordinate intermediate volcanic detritus (increasing down-section), 10–20% feldspar, 1–10% biotite, and <5% quartz (quartz decreases down-section). Felsic grains are the same as in unit Tslbf. Sand bodies locally fine-upwards and are mostly 1–15 ft thick. Unit coarsens down-section to sand and silty sand. Inferred deposition by an ephemeral river.

Short: Clayey-silty fine sand interbedded with minor sand intervals. Sand is lt gray to pinkish gray, mostly medium- to coarse-grained, and angular to subangular. Sand is composed of felsic grains with subordinate intermediate volcanic detritus, 10–20% feldspar, 1–10% biotite, and <5% quartz. Sand mostly are 1–15 ft thick. Unit coarsens down-section to sand and silty sand. Inferred fluvial deposition.

Basin Fill of the Upper Alamosa basin

Upper Santa Fe Group

Tsuppm **Proximal and medial piedmont-slope deposits (upper Miocene to Pliocene) —**

Long: Gravelly intervals interbedded with subordinate to subequal fine sand and clayey-silty fine sand. Gravel composed mostly of rhyolitic rocks (flows and tuffs), includes pebbles-cobbles and minor boulders, and bedding typically is very thin to medium and tabular. Gravel matrix is reddish to brownish sand that is medium- to very coarse-grained and subrounded to subangular. Fine sediment is reddish to light brown to tan, and in medium to thick, tabular beds; clay-silt content is estimated at 3–25%. Up-section increase in proportion of fine sediment as well as paleosols (illuviated clay horizons / calcic horizons). Deposited on the medial to proximal piedmont.

Short: Gravelly intervals interbedded with subordinate to subequal fine sand and clayey-silty fine sand. Gravel composed mostly of rhyolitic rocks; bedding typically very thin to medium and tabular. Gravel matrix: reddish to brownish sand that is medium- to very coarse-grained. Fine sediment is reddish brown to light brown to tan; medium to thick, tabular beds; clay-silt content is estimated at 3–25%.

Tsupd **Distal piedmont-slope deposits (upper Miocene to Pliocene) —** Reddish to light brown to tan, fine sand and clayey-silty sand interbedded with subordinate gravelly intervals. Fine sediment is mostly in thick beds or is massive. Gravelly intervals are laminated to thinly bedded and include pebbles and cobbles.

Tsu_playa **Playa deposits (upper Miocene to Pliocene) —** Brown to reddish brown clay interbedded with minor, tabular beds of very fine- to fine-grained sand and clayey fine sand.

Lower Santa Fe Group

Tslppm **Proximal and medial piedmont-slope deposits (lower to middle Miocene) —**

Long: Pebbly sand and sandy conglomerate. Gravel consists of pebbles with 1–30% cobbles; clast-supported and composed of rhyolitic lavas, welded tuff, and minor non-welded tuff. Sand is tan, mostly coarse- to very coarse-grained, and subrounded to subangular. Well-bedded (horizontal planar to cross-stratified); near the mountain front are minor thin to very thick beds of sandstone and pebbly sandstone that are internally massive (interpreted as debris- or hyperconcentrated-flows). More cemented and steeply dipping than unit Tsuppm.

Short: Pebbly sand and sandy conglomerate. Gravel consists of pebbles with 1–30% cobbles. Sand is tan, and mostly coarse- to very coarse-grained. Well-bedded (horizontal planar to cross-stratified); near the mountain front are minor beds of sandstone and pebbly sandstone that are internally massive (interpreted as debris- or hyperconcentrated-flows). More cemented and steeply dipping than unit Tsuppm.

Tslpd **Distal piedmont-slope deposits (lower to middle Miocene) —** Not exposed. Presumably similar to unit Tsupd but more steeply dipping and cemented.

Tsl_playa **Playa deposits (lower to middle Miocene) —** Not exposed. Presumably similar to unit Tsu_playa but more steeply dipping and cemented.

Mogollon-Datil volcanic field rocks

Unless otherwise noted, descriptions are compiled from Osburn and Chapin (1983), Osburn et al. (1993), and geologic mapping by Charles Ferguson and G.R. Osburn in and near the C-N embayment and Upper Alamosa basin.

Lavas

Tbtr **Beartrap Canyon Rhyolite (upper Oligocene) —** Phenocryst-poor (<10%) to phenocryst-rich (>10%) rhyolite lava and lava domes. Phenocrysts include feldspar, biotite, and quartz. Description from Osburn and Ferguson (2007).

Trpw **Rhyolite of Pinon Well (lower to upper Oligocene) —** Light-brown to pink, phenocryst-poor, flow-banded rhyolitic lavas that commonly have abundant spherulites. Contains 1–4% sanidine phenocrysts. 90–500 ft (27–150 m) thick. From Osburn et al. (1993).

Tb **Basalt (Oligocene) —** Phenocryst-poor, vesicular, mafic lava containing <10% phenocrysts of olivine, pyroxene, and plagioclase. Matrix commonly has abundant plagioclase microlites <0.2 mm long. Up to 1,150 ft (350 m) thick. From Ferguson and Osburn (2011, 2012) and Osburn and Ferguson (2010).

Tba **Basaltic andesite (Oligocene) —** Gray to brown, vesicular, aphanitic to slightly porphyritic lavas containing less than 5% phenocrysts of plagioclase (<3 mm-long) and ferromagnesium minerals (pyroxene ± hornblende), the latter commonly altered. 0–200 m thick. From Ferguson and Osburn (2012) and Osburn et al. (1993).

Ta **Andesite (upper Eocene to Oligocene) —** Lava that contains 2–15%, 2–20 mm-long plagioclase phenocrysts with lesser pyroxene (<2.5 mm long). 0–500 ft (0–150 m) thick. From Ferguson and Osburn (2012).

Tlma **Andesite of Lion Mountain (upper Oligocene) —** Dark gray to purple, coarsely porphyritic, dense to vesicular andesitic lavas. 10–25% phenocrysts that include plagioclase, biotite, pyroxene, and magnetite. 0–700 ft (0–210 m) thick. From Osburn et al. (1993).

Tadlc **Andesite of Dry Leggett Canyon(?) (upper Eocene) —** Uncertain correlation from the Sun No. 1 well (Chamberlin et al., 1994a). Dark-colored, porphyritic andesite that contain abundant, stubby phenocrysts composed of plagioclase and black pyroxene. Described using Finnell and Ratté (2006) from outcrops near the New Mexico-Arizona border.

Tawhc **Andesite of White House Canyon (upper Eocene) —** Purple-gray, vesicular lava flows containing prominent phenocrysts of plagioclase and clinopyroxene that are 1–2 cm long. Also contains abundant small (1 mm) olivine crystals altered to iddingsite. Calcite-filled amygdules are common. Described using Lopez and Bornhorst (1979).

Intrusives

Tir **Rhyolitic rocks (Oligocene) —** Felsic intrusions that are crystal-poor or have up to 8% phenocrysts containing abundant sanidine. From Osburn and Ferguson (2007, 2011).

Tid **Dacitic rocks (Oligocene) —** Contain 5–25% large phenocrysts of plagioclase with variable biotite and hornblende. From Osburn and Ferguson (2007).

Ignimbrites

Ttu **Tuff, undivided (Oligocene) —** Nonwelded rhyolitic ignimbrite probably correlative to the South Canyon or Turkey Springs Tuff. Contains 2–10% phenocrysts (<2.5 mm) of plagioclase, sanidine, quartz, and sparse biotite. 0–60 ft (0–20 m) thick. From Ferguson and Osburn (2012).

Ttst **Turkey Springs Tuff (upper Oligocene) —** Welded to non-welded, light gray to pink, rhyolitic ash-flow tuff containing 2–30% (increasing upwards) phenocrysts of quartz, sanidine, plagioclase, biotite, and hornblende. Contains up to 20% pumice lapilli and 5–10% lithic lapilli. Difficult to differentiate from Tsct without stratigraphic context. 0–1,650 ft (0–500 m) thick. From Osburn and Ferguson (2007, 2010).

Ttst_cauld **Turkey Springs Tuff, intra-caldera facies (upper Oligocene) —** Similar to unit Ttst, but >150 m thick and fills the Beartrap Canyon caldera.

Tsct **South Canyon Tuff —** Grayish tuff where phenocryst content increases up-section from 2–6% to 15–25%. Phenocrysts composed predominately of quartz and sanidine in most places. Near the Mount Withington caldera, 4–30% phenocrysts composed of plagioclase, sanidine, quartz, and biotite; <5% lithic-lapilli and 5–25% pumice lapilli. 0–1,650 ft (0–500 m) thick. From Osburn and Chapin (1983), Osburn et al. (1993), Osburn and Ferguson (2010); Ferguson and Osburn (2012).

Tsct_cauld **South Canyon Tuff, intra-caldera facies —** Rhyolitic ash-flow tuff containing 4–30% phenocrysts of plagioclase, sanidine, quartz, and biotite. Lithic lapilli are generally <5% and pumice lapilli 5–25%. Phenocryst content is ~5% at base but increases abruptly to 30% in upper parts. Five to six subunits can be differentiated based on phenocryst content and compositions. Probably >3,300 ft (>1,000 m) thick. From Osburn and Ferguson (2011).

Tbgt **Bloodgood Canyon Tuff —** Slightly pinkish, poorly to non-welded rhyolitic ignimbrite containing 2–10% phenocrysts of sanidine, plagioclase, quartz, and biotite. Quartz phenocrysts are up to 3 mm and commonly strongly embayed. Biotite is more abundant in this unit than in other quartz phenocryst-bearing ignimbrites of the region. Identification as Bloodgood Canyon Tuff is tentative. 0–50 ft (0-15 m) thick. From Ferguson and Osburn (2012).

Tvpt Vicks Peak Tuff (lower Oligocene) —

Long: Light gray and very crystal poor, moderately pumice-rich, moderately to densely welded tuff with well-developed eutaxitic structure (up to 25% strongly flattened pumice). 1–3% chatoyant sanidine phenocrysts, with trace phenocrysts of biotite, pyroxene, quartz, & plagioclase. 2–5% andesitic lithic clasts. Phenocryst content increases to 1–15% near the Upper Alamosa basin, but still dominated by sanidine. 0–300 ft (0–90 m) thick. From Harrison (1980) and Osburn et al. (1990); Ferguson and Osburn (2011).

Short: Light gray and very crystal poor, moderately pumice-rich, moderately to densely welded tuff with well-developed eutaxitic structure (up to 25% strongly flattened pumice). 1–3% chatoyant sanidine phenocrysts, with trace phenocrysts of biotite, pyroxene, quartz, & plagioclase. 2–5% andesitic lithic clasts. Phenocryst content increases to 1–15% near the Upper Alamosa basin. 0–300 ft (0–90 m) thick. From Harrison (1980) and Osburn et al. (1990); Ferguson and Osburn (2011).

Tljvpt **La Jencia and Vicks Peak Tuff, undivided (lower Oligocene) —** See units Tvpt and Tljt.

Tljt **La Jencia Tuff (lower Oligocene) —** Multiple-flow, compound cooling unit of light to dark gray to light brown to purple, crystal poor, moderately to densely welded tuff. Commonly exhibits lineated pumice. Contains 2–10% phenocrysts composed of 3–7% sanidine, <0.5% quartz, <0.5% plagioclase, <0.5% biotite. 2–5% lithic fragments. From Harrison (1980) and Osburn and Chapin (1983).

Thmt **Hells Mesa Tuff (lower Oligocene) —** Multiple-flow, simple cooling unit of white to pink to reddish-brown, moderately to densely welded tuff that is crystal-rich & quartz-rich. 20–40% phenocrysts that include: 25–30% feldspar (mostly sanidine and plagioclase), 5–8% quartz, 2–4% biotite. Base is 20 ft- (6 m-) thick, white, and poorly welded. Abrupt increase in quartz percentage 10–25 ft (3–7 m) above the base. 0–800 ft thick (0–245 m). From Harrison (1980), Osburn and Chapin (1983), and Osburn et al. (1993).

Ttgm **Tuff of Granite Mountain (possibly associated with early Hells Mesa Tuff eruptions; lower Oligocene) —** Purplish-gray, crystal-rich, ash-flow tuff overlain by the Hells Mesa Tuff. Contains phenocrysts of sanidine and plagioclase in about subequal proportions and lesser biotite; quartz is generally absent. From Osburn and Chapin (1983) and Chamberlin (1974).

Tbct **Blue Canyon Tuff (upper Eocene) —** Tan to light gray, moderately to poorly welded, moderately crystal rich tuff. 15–21% phenocrysts that include: 6–8% plagioclase, 8–10% sanidine, 1.5–3% biotite, <1% clinopyroxene, and <1% hornblende. 0–100 ft (0–30 m) thick. From Harrison (1980) and Osburn and Chapin (1983).

Trhct **Rockhouse Canyon Tuff (upper Eocene) —** White to light gray. Poorly to non-welded at top and bottom. Partially welded middle part that is mostly densely welded and has columnar joints on either side of a platy layer. Pumice (up to 5 mm) content is variable (10–30%). Phenocrysts: 3–9% sanidine, ≤1% biotite, ≤1% plagioclase. 0–350 ft (0–107 m) thick. From Harrison (1980) and Osburn and Chapin (1983).

Trhct-Tknt **Rockhouse Canyon and Kneeling Nun Tuffs, undivided (upper Eocene) —** See descriptions for units Trhct and Tknt.

Ttlw **Tuff of Lebya Well(?) (upper Eocene) —** Uncertain identification in the Sun No. 1 well by Chamberlin et al. (1994a). Reddish brown to purplish-gray, densely welded ash-flow tuff containing 10–20% phenocrysts of sanidine and plagioclase (6:1 sanidine vs plagioclase abundance). Matrix is aphinitic and contains eutaxitic pumice lapilli. Described from Ratté et al. (1990).

Tknt **Kneeling Nun Tuff (upper Eocene) —** Uncertain identification in the Sun No. 1 well by Chamberlin et al. (1994a). Light-gray, pinkish-brown, or nearly white, ash-flow tuff that is partially to densely welded. Unit contains 15–20% phenocrysts of mainly sanidine and quartz, with minor plagioclase and biotite. Described from Ratté et al. (1990).

Tdwt **Datil Well Tuff (upper Eocene) —** Light gray & moderately welded. Grades up from crystal poor to crystal-rich. The upper part has 20–25% phenocrysts that include: 18–22% chatoyant sanidine, 1–2% apple-green pyroxene, & 1% euhedral biotite. 10% pumice. Basaltic and lithic fragments common. 0–80 ft (0–25 m) thick. Described from Harrison (1980) and Osburn and Chapin (1983).

Sedimentary rocks and interbedded volcanic rocks

Upper Spears Group

Tspu **Upper Spears Group (lower to upper Oligocene) —** White to gray to brown to reddish brown, volcaniclastic conglomerate and sandstone and clayey sandstone, locally tuffaceous; clasts and grains are commonly subangular. Contains variable proportions of debris-flows. Lies above the Hells Mesa Tuff. Variable thickness.

Tsps **Upper Spears Group, sandstone (Oligocene) —** Volcaniclastic sandstone and minor conglomerate. 0–250 ft (0–75 m) thick. From Osburn and Ferguson (2010).

Tbts **Beartrap Canyon Formation sedimentary rocks (upper Oligocene) —** Volcaniclastic sandstone, conglomerate, and lesser non-welded felsic tuff. Clasts and lithics are chiefly rhyolite. Sandstone and conglomerate are commonly complexly interbedded. Local moderate- to high-angle, cross-stratified, medium- to thick-bedded sandstone suggestive of eolian deposition. From Osburn and Ferguson (2010).

Tspcp **South Crosby Peak Formation (lower Oligocene) —** Tan to reddish brown to pinkish gray, volcaniclastic conglomerate, sandstone, and clayey sandstones. Unit includes pinkish-white ash-fall tuffs (well-bedded) and minor ash-flow tuffs (poorly welded); tephra may be fluvially reworked and contain ≤4% plagioclase, sanidine, quartz, and biotite. From Lopez and Bornhorst (1979) and Osburn and Chapin (1983).

Middle Spears Group

Tspm **Middle Spears Group (upper Eocene to lower Oligocene) —** Volcaniclastic sandstones, conglomerates, and debris-flow breccias that lie below the Hells Mesa Tuff and above the Dog Springs Formation or lower Spears Group.

Tsprw **Rincon Windmill Formation (upper Eocene to lower Oligocene) —** Conglomerate and sandstone (including eolian sandstones). Locally, the presence of the Blue Canyon Tuff allows differentiation into and upper and lower unit. 275–500 ft (85–150 m) thick. From Harrison (1980) and Osburn and Chapin (1983).

Tsprwu **Upper Rincon Windmill Formation (upper Eocene to lower Oligocene) —** Light-brown, well-sorted, argillaceous, feldspathic, eolian sandstones that are well-bedded or massive. Bedding is typically steeply dipping to low-angle cross stratification. 100–200 ft (30–60 m) thick. From Harrison (1980).

Tsprwl **Lower Rincon Windmill Formation (upper Eocene) —** Brownish sandy conglomerate with minor sandstones. Gravel includes pebbles through cobbles with local boulders. 175–300 ft (53–91 m) thick. From Harrison (1980).

Tspcc **Chaves Canyon Formation (upper Eocene) —**

Long**:** Sandstone, conglomerate, and debris-flow deposits. Lower 175–200 ft (50–60 m) consists mainly of medium- to coarse-grained sandstones composed of feldspar with ~30% mafic grains; minor lenses of pebble conglomerates; planar-bedded with local trough cross bedding. Above lies brownish volcaniclastic conglomerates, gravelly sandstones, and minor tuffaceous sandstones that are planar-bedded or locally cross-stratified. Quartz grains scarce. 250–500 ft (75–150 m) thick. From Harrison (1980), Coffin (1981), and Osburn and Chapin (1983).

Short: Sandstone, conglomerate, and debris-flow deposits. Lower 175–200 ft consists mainly of medium- to coarse-grained sandstones composed of feldspar with ~30% mafic grains; minor lenses of pebble conglomerates. Above lies brownish volcaniclastic conglomerates, gravelly sandstones, and minor tuffaceous sandstones. Planar-bedded or locally cross-stratified. Scarce quartz grains. 250–500 ft thick. From Harrison (1980), Coffin (1981), and Osburn and Chapin (1983).

Lower Spears Group

Tspl **Lower Spears Group (middle to upper Eocene) —** Sandstone, clayey sandstone, and conglomeratic sandstone deposited as mudflows and lahars. Greenish to purplish-gray to dark gray, massive, poorly sorted, and matrix-supported; contains numerous rounded to subangular boulders, cobbles, pebbles, and sand in a fine-grained matrix of plagioclase, K-feldspar, biotite, magnetite, and clay minerals. From McLemore (2010). 0–3,000 ft (0–900 m) thick.

Tspds **Dog Springs Formation (middle to upper Eocene) —**

Long: Light-tan to brown sandstone, clayey sandstone, and conglomeratic sandstone dominated by tuffaceous debris flows (tuff breccias) that are crystal-rich and nonpumiceous; minor ash-flow tuffs. Phenocrysts of feldspar, hornblende, and biotite present in matrix and in lava clasts. Includes large blocks of Paleozoic limestone and autobrecciated volcanic rocks transported by debris flows.

Massive; bedding, if present, is commonly chaotic or folded-contorted. Well-cemented. 0–3,000 ft (0–900 m) thick. From Harrison (1980); Osburn and Chapin (1983).

Short: Light-tan to brown sandstone, clayey sandstone, and conglomeratic sandstone dominated by tuffaceous debris flows (tuff breccias) that are crystal-rich and nonpumiceous; minor ash-flow tuffs. Includes large blocks of Paleozoic limestone and autobrecciated volcanic rocks. Massive; bedding, if present, is commonly chaotic or folded-contorted. Well-cemented. 0–3,000 ft (0–900 m) thick.

Undivided volcaniclastic sedimentary and volcanic rocks

Tbts-Tbr **Beartrap Canyon Formaton sedimentary rocks + rhyolite flows (upper Oligocene) —** Rhyolite flows typically contain less than ~10% phenocrysts of feldspar, biotite, and ± quartz. See unit Tbts for description of sedimentary rocks.

Tbas **Interbedded basaltic andesite and sedimentary rocks (Oligocene) —** See descriptions of units Tba, Tpsu, and Tpsm.

Tspm-Ta **Interbedded middle Spears Group and andesite flows (upper Eocene to lower Oligocene) —** See descriptions for units Tspm and Ta.

Tlrp-Tsm **Datil Group rhyolitic pyroclastic rocks and ignimbrites, interbedded with middle Spears Group, undivided (upper Eocene) —** See descriptions for units Tsm, Tdwt, Tknt, Ttlw, Trhct, and Tbct.

Tspcc-Tdwt **Chaves Canyon Formation and Datil Well Tuff, undivided —** See descriptions of units Tspcc and Tdwt.

Undifferentiated bedrock underlying thick intra-caldera tuffs

Ttst_brcf **Undifferentiated bedrock underlying the Turkey Springs Tuff in the Beartrap Canyon caldera —** Bedrock includes the Mogollon-Datil volcanic sequence; especially thick units are Tsct and Tsct_cauld, Tvpt, Thmt, Trhct, and Tspl. Underlying strata are Paleozoic strata (Pz) followed by crystalline rocks. Not differentiated due to likely structural complications and lack of subsurface data.

Tsct_brcf **Undifferentiated bedrock underlying the South Canyon Tuff in the Mount Withington caldera —** Bedrock includes the Mogollon-Datil volcanic sequence; especially thick units are Tvpt, Thmt, Trhct, and Tspl. Underlying strata are Paleozoic strata (Pz) followed by crystalline rocks. Not differentiated due to likely structural complications and lack of subsurface data.

Trhct_brcf **Undifferentiated bedrock underlying the Rockhouse Canyon Tuff in the Sullivan's Hole caldera —** Bedrock includes middle Spears Group interbedded with probable Kneeling Nun and other older ignimbrites, a thick lower Spears Group (Tspl), Paleozoic strata (Pz), followed by crystalline rocks. Not differentiated due to likely structural complications and lack of subsurface data.

Sedimentary rocks predating the Mogollon-Datil volcanic field

Tbaca **Baca Formation (lower to middle Eocene) —**

Long: Reddish mudstones and red to light gray sandstone deposited in a closed basin in the late-early to middle Eocene. Divided into three subjacent parts: (1) Lower 700 ft (215 m) is largely mudstone

with a few thin beds of arkosic, fine to coarse sandstone; (2) middle 480 ft (146 m) has more abundant sandstone (mostly very fine- to fine-grained), but sandstone is still subordinate to mudstone and siltstone; (3) upper 310 ft (94 m) has subequal sandstone vs mudstone-siltstone. These subunit descriptions are from the Sun No. 1 well, (NMBGMR petroleum archives). In outcrop, sandstones are moderately to well-cemented by calcite and lesser silica. General description is from Chamberlin (1981); Cather (1980); Cather and Johnson (1984); Chamberlin et al (1994b).

Short: Reddish mudstones and red to light gray sandstone deposited in a closed basin in the late-early to middle Eocene. Sandstones are moderately to well-cemented by calcite and lesser silica. From Chamberlin (1981); Cather (1980); Cather and Johnson (1984); Chamberlin et al (1994b).

Mz **Mesozoic strata, undivided (Triassic through upper Cretaceous) —**

Long: This unit includes the following subunits, listed from oldest to youngest with thickness values. Triassic strata: reddish and composed mainly of siltstone and silty mudstone, with subordinate very fine- to fine-grained, light gray sandstones; 105–500 ft (32–150 m). Dakota Sandstone: quartz-rich sandstone interbedded with subordinate shale and siltstone; 29–37 m (95–121 ft). Mancos Shale: medium-gray shale to silty shale; 161–166 m (530–545 ft). Tres Hermanos Formation (tongue in Mancos Shale): very fine- to medium-grained, quartzose sandstone that generally coarsens-upwards; 115–185 ft (35–56 m). Gallup Sandstone: interbedded shale-siltstone and very fine- to medium-grained sandstone; 245 ft (75 m). Crevasse Canyon Formation: interbedded 1) yellowish brown to yellowish gray, fine- to medium-grained feldspathic sandstones, and 2) yellowish brown shales, dark gray carbonaceous shales, gray siltstones, and local thin coal seams. From Chamberlin et al. (1994b) and the Sun No. 1 well (NMBGMR petroleum archives).

Short: Sandstone, siltstone, and mudstone strata belonging to undivided Triassic strata, Dakota Sandstone, Mancos Shale, Tres Hermanos Formation, Gallup Sandstone, and the Crevasse Canyon Formation.

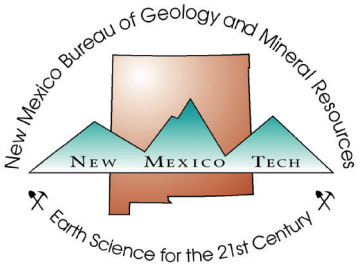
Pz **Paleozoic strata, undivided (Pennsylvanian to Permian) —**

Long: Includes the following units, listed from oldest to youngest with thickness values. Madera Group: limestone, sandstone, siltstone, shale, and mudstone; 130–3,300 ft (40–1,000 m). Abo Formation: red, maroon, or reddish brown siltstone, shale, and fine sandstone; 380–935 ft (115–285 m). Yeso Formation: gray to light red siltstone-sandstone (mostly very fine- to medium-grained); minor amounts of dolomite, limestone, and shale; 1480 ft (450 m). Glorietta Sandstone: fine- to medium-grained quartz arenites; 100–200 ft (30–60 m). San Andres Limestone: light brownish gray to pinkish gray, micritic limestone and dolomites; 380–430 ft (115–130 m). Descriptions are from the Sun No. 1 well (NMBGMR petroleum archives); Jahns et al. (1978); Lucas and Kues (1994).

Short: Sandstone, siltstone, limestone, shale, dolomite, and mudstone associated with the Madera Group, Abo Formation, Yeso Formation, Glorieta Sandstone, and the San Andres Limestone.

Proterozoic rocks

XYu **Crystalline rocks (Paleo- to Meso-Proterozoic) —** Granitic gneiss as well as possible granite, gneiss, schist, and amphibolite.



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