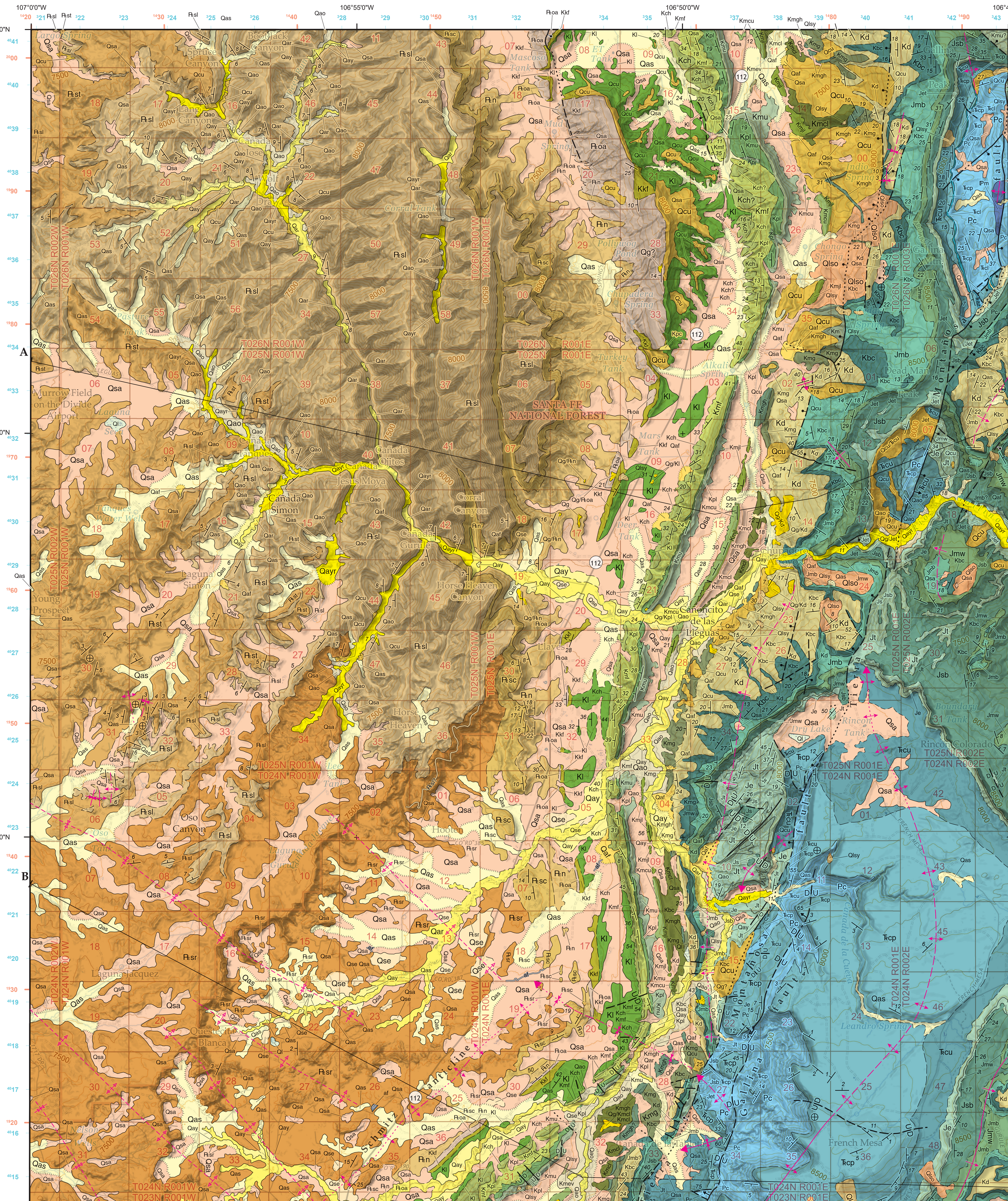
NMBGMR Open-File Geologic Map 316
Last Modified: June 2024



Base map from U.S. Geological Survey 2023.
North American Datum of 1983 (NAD83)
Projection and 1,000-meter grid: Universal Transverse Mercator, Zone 13S, shown in blue.
10,000-foot ticks: New Mexico Coordinate System of 1983 (Central Zone), shown in red.
Roads....U.S. Census Bureau, 2015–2016
Names....GNIS, 2016
Hydrography....National Hydrography Dataset, 2014
Contours....IFSAR 4.5 m Digital Terrain Model, 2008
Wetlands....FWS National Wetlands Inventory 1977–2014
Public Land Survey System....BLM, 2019

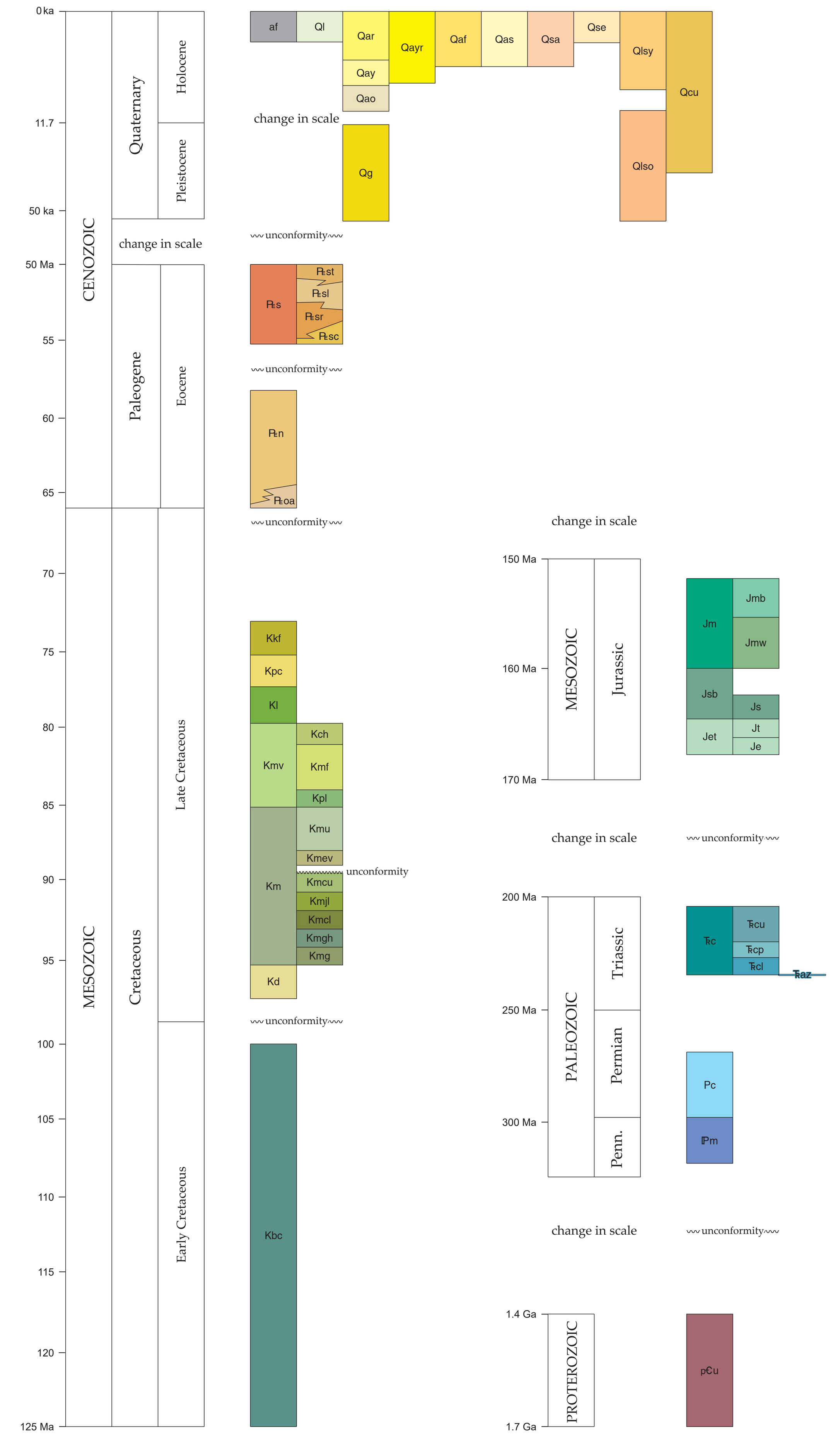
1:62,500

1 0.5 0 1 2 3 4 Miles
5,000 0 5,000 10,000 15,000 Feet
1 0.5 0 1 2 3 4 Kilometers

Contour Interval 100 Feet
North American Vertical Datum of 1988

Magnetic Declination
September 2023
8° 8' East
At Map Center

Correlation of Map Units



Description of Map Units

CENOZOIC
Quaternary
Anthropogenic

af — **Artificial fill (late Holocene)**—Unconsolidated clay, silt, and fine sands accumulated behind artificial dams or berms that raise local base level. Alluvial, eolian, and slope-wash input. Estimated thickness of the deposits are 2–3 m.

Drainage Deposits

Ql — **Lacustrine deposits (Quaternary)**—Unconsolidated clay, silt, and very fine lower sands in terminally drained ponds or shallow depressions. Abundant dark-brown organic content; minor eolian and slope-wash input. Approximate thicknesses of deposits are 0–4 m.

Qayr — **Recent and Younger Alluvium, undivided (Quaternary)**—See descriptions above for units Qar and Qay.

Qar — **Recent Alluvium (Quaternary)**—Unconsolidated clays, silts, sands, gravels, and cobbles including active channel and floodplain and the lowest terrace surface. Found 0 to 3 m above modern channel grade. Approximately 1–4 m thick.

Qay — **Younger Alluvium (Quaternary)**—Unconsolidated clays, silts, sands, gravels, and cobbles forming an inactive alluvial terrace surface 3–8 m above channel grade. Thickness is approximately 4–9 m.

Qao — **Older Alluvium (Quaternary)**—Unconsolidated clays, silts, sands, gravels, and cobbles forming an inactive alluvial terrace surface greater than 8 m above channel grade. Thickness is greater than 9.

Qaf — **Alluvial fan (Quaternary)**—Unconsolidated clays, silts, sands, gravels, cobbles, and boulders forming fans that are grading and interfingering with adjacent Quaternary deposits. Thickness is approximately 10 m.

Qg — **Terrace gravels (Quaternary)**—Unconsolidated deposits of boulders, cobbles, and gravels of locally derived and exotic rock types. Commonly found as lag gravels on raised topographic surfaces or as deposits 2–3 m thick.

Slope Wash, Alluvial, and Eolian Deposits

Qas — **Alluvium and slope wash (Quaternary)**—Unconsolidated clays, silts, sands, and gravels with minor, active alluvial channels and sloped floodplains with significant input from slope wash. Estimated thickness is 1–5 m.

Qsa — **Slope wash and alluvium (Quaternary)**—Unconsolidated clays, silts, sands, and gravels in small basins and slopes dominated by slope wash, shallowly incised alluvial channels, and low-relief fans. Estimated thickness is 1–5 m.

Qse — **Slope wash and eolian (Quaternary)**—Unconsolidated clays, silts, and sands deposited on raised topographic positions or in small shallow basins. Contain sheet-flow sediments sourced from hillslopes (i.e. slope wash) with input of windblown sediments. Thickness is 0–2 m.

Qcu — **Colluvium, undivided (Quaternary)**—Unconsolidated boulders, cobbles, gravels, sands, silts, and clays forming thick, incised, mantles on hillslopes. Clasts up to 5 m in diameter. Thickness is approximately 1–20 m.

Qlsy — **Younger landslides, undivided (Quaternary)**—Unconsolidated rock and sediment moved by mass-wasting processes with fresh morphological features. Consists of jumbled and deformed locally derived rock types. Thickness is approximately 0–4 m.

Qlso — **Older landslides, undivided (Quaternary)**—Unconsolidated rock and sediment moved by mass-wasting processes with obscured morphological features. Consists of jumbled and deformed locally derived rock types. Thickness is approximately 0–20 m.

Paleogene

Rs — **San Jose Formation (Eocene)**—The San Jose Formation consists of two sandstone-dominated members and two mudrock-dominated members. We follow the stratigraphy defined by Smith (1992a). Total thickness ranges from 287–616 m in the Llaves quadrangle (Smith, 1988).

Rst — **Tapicitos Member (Eocene)**—The unit is composed of brick-red to red siltstone interbedded with green, brown and tan siltstone and lenticular, white, sandstone beds that are similar in texture and composition to the underlying Llaves Member. Up to 135 m thick regionally (Hobbs and Pearthree, 2021), maximum exposed thickness in the map area is 150 m, but in most places only 90 m is preserved (Baltz, 1967).

Rsl — **Llaves Member (Eocene)**—This member is composed of white to yellow, coarse- to fine-grained, poorly sorted arkosic sandstone to gravelly sandstone; the sand grains are subangular to subrounded. The gravel size generally ranges from granules to small pebbles (1–10 mm), but some intervals on the east side of the exposure contain pebbles to cobbles up to 15 cm in diameter. 95–135 m thick regionally (Hobbs and Pearthree, 2021), maximum thickness is 213 m at the type section (Baltz, 1967).

Rsr — **Regina Member (Eocene)**—Consists of variegated red, white, green, and olive brown, fine-grained, poorly cemented sandstone, mudstone, and siltstone intercalated with yellow, white, and gray, medium- to coarse-grained, well-cemented, lenticular, ledge-forming sandstones exhibiting fining-up sequences. 175–500 m thick (Baltz, 1967).

Rsc — **Cuba Mesa Member (Eocene)**—Thick, cliff-forming tan to yellow sandstone to gravelly sandstone. Sandstone is medium- to very coarse-grained; the sand grains are angular to subrounded, with subangular grains predominating. Approximately 100 m thick (Baltz, 1967).

Rn — **Nacimiento Formation (Paleocene)**—The lower part of the Nacimiento Formation is red and green mudstone interbedded with sandstone; fine-grained sandstone and siltstone; white, trough cross-bedded sandstone; and sandy mudstone. The middle section is poorly exposed, gray to green shale and lenticular sandstone. The upper section is primarily gray, fine- to coarse-grained, gravelly, trough cross-bedded sandstone and gray and brown mudstone. Unit is 180–380 m thick (Baltz, 1967; Fitter, 1958).

Rsoa — **Ojo Alamo Sandstone (Paleocene)**—White to tan, fine- to coarse-grained, stacked sandstones that are poorly sorted and angular to subrounded; interbedded with thin, sandy siltstone and silty mudstone. Commonly micaceous. Occasionally calcium-carbonate cemented. Unit is 14–30 m thick (Fitter, 1958; Baltz, 1967; Crouse et al., 1992); Unit is 30–75 thick in petroleum wells.

MESOZOIC
Cretaceous

Kkf — **Kirtland and Fruitland Formations (Late Cretaceous)**—Characterized by carbonaceous shale or low-quality coal that is interbedded with green siltstone; olive-gray, black, and gray, silty shale; and thin, white, angular to subangular sandstones. Siltstone contains abundant muscovite in places. Petrified wood replaced by silica or hematite is present. Unit is 12–120 m thick (Fitter, 1958; Baltz, 1967; Crouse et al., 1992); Unit is 12–45 m in petroleum wells.

Kpc — **Pictured Cliffs Sandstone (Late Cretaceous)**—Thin beds of tan to gray sandstone, tan siltstone and black shale. A landslide-scar exposure of Pictured Cliffs Sandstone near the northern boundary of the map reveals sandy to silty shale and thin-bedded, fine-grained sandstone with carbonaceous plant debris (Baltz, 1967). Unit is 10–18 m thick (Fitter, 1958; Baltz, 1967); Unit is 14–52 m in petroleum wells.

Kl — **Lewis Shale (Late Cretaceous)**—Light-gray to dark-gray shale with minor intercalated siltstone, fine-grained sandstone, and limestone concretions. Unit is often distinctive at surface due to abundant, angular fragments of concretions that disintegrate on weathering. Thickness is 580 m (Fitter, 1958; Baltz, 1967); Unit is 446–660 m in petroleum wells.

Kmv — **Mesaverde Group (Late Cretaceous)**—The Mesaverde Group includes the Cliff House Sandstone, the Menefee Formation, and the Point Lookout Sandstone.

Kch — **La Ventana Tongue of the Cliff House Sandstone (Late Cretaceous)**—Gray, tan, to orange- brown sandstone interbedded with sandy siltstones, and thin layers of gray shale. The lower part of the unit is medium-grained and thickly bedded. The upper part is fine- to medium-grained, tan to orange-brown sandstone that is thinner bedded and contains gray shale. Unit is 33 m thick (Fitter, 1958); Unit is 26–64 m in petroleum wells.

Kmf — **Menefee Formation (Late Cretaceous)**—Light-gray to dark-gray, carbonaceous shale intercalated with coal, ironstone, and mottled-white, gray, and brown, sandstone beds. Sandstones are lenticular, very fine- to coarse-grained with planar-laminated bedding and occasional mud rip-ups. Coal lenses 0.2 to 8m thick. Unit is 115 m thick (Fitter, 1958); Unit is 48–115 m in petroleum wells.

Kpl — **Point Lookout Sandstone (Late Cretaceous)**—Gray to tan, medium- to fine-grained, well-sorted sandstone with shale beds and trace muscovite. The sand grains are angular to subangular. Unit is 29 m thick (Fitter, 1958); Unit is 31–81 m in petroleum wells.

Km — **Mancos Shale (Late Cretaceous)**—We divide the Mancos Shale into a basal Graneros Shale overlain by the Greenhorn Limestone Member, which is in turn overlain by the Carlile Member that contains (on this quadrangle) the Juana Lopez Member.

Kmu — **Upper Mancos Shale (Late Cretaceous)**—Poorly exposed, gray, shale-forming slopes below the Point Lookout Sandstone. Unit is 291–375 m thick in petroleum wells.

Kmev — **El Vado Sandstone (Late Cretaceous)**—This relatively thin sandstone is composed of sub-centimeter to <5cm beds of limey, quartz-rich, sparsely to abundantly fossiliferous, very fine- to medium-grained, moderately well-sorted, sometimes ripple-laminated, sandstone beds separated by 1–15 mm shale intervals. Unit is about 6 m thick where exposed; Unit is 87–125 m thick in petroleum wells.

Kmcu — **Upper Carlile Shale (Late Cretaceous)**—This poorly exposed, black-shale interval lies below a significant unconformity and above the Juana Lopez Member (Ridgely et al., 2013; Cheney, 2018). Unit is 104–178 m thick in petroleum wells.

Kmjl — **Juana Lopez Member (Late Cretaceous)**—The Juana Lopez is a regionally distinctive interval of yellow to reddish-brown, weathering gray, thinly bedded, sometimes ripple-laminated, shelly, recrystallized limestone to sandy limestone with thin shale and sandy siltstone interbeds. Unit is 30–34 m thick in petroleum wells.

Kmcl — **Lower Carlile Member (Late Cretaceous)**—The lower Carlile Member is composed of monotonous, dark-gray to black shale, weathering light-gray with brown-red and tan-yellow weathering patina. Thickness is 100 m.

Kmgh — **Greenhorn Limestone (Late Cretaceous)**—Light-gray to white, weathering limestone interbedded with shale, silty shale, and silty sandstone. Shales are gray-weathering, and pale-brown to light-gray, with occasional shell fossils (Inoceramidae sp.) and thin, shell-hash horizons. Unit is about 10 m thick at the surface; Unit is 23–43 m thick in petroleum wells.

Kmg — **Graneros Member (Late Cretaceous)**—Generally poorly exposed, gray to black, sometimes calcareous, platy to laminated, fossiliferous, sometimes contains concretions, slope-forming shale. Unit is 53 m thick (Fitter, 1958); Unit is 14–39 m thick in petroleum wells.

Kd — **Dakota Formation (Late Cretaceous)**—Tan, fine- to medium-grained, moderately to well-sorted, commonly bioturbated, quartz sandstone with thin- to medium-tabular bedding that is locally cross-bedded. Variably interbedded with shale. The grains are subrounded to angular. Asymmetric ripple marks are common. Unit is 30–35 m thick.

Kbc — **Burro Canyon Formation (Early Cretaceous)**—White, light-yellow, orange, and buff, conglomeratic sandstone with thin lenses of green or, more rarely, red mudstone (Saucier, 1974). The sandstone is fine- to medium-grained, quartzose, and kaolinitic. Small-scale trough cross-bedding is associated with conglomeratic channels. Conglomerate clasts are mostly chalky white chert with varicolored quartzite and chert pebbles up to 2.5 cm in diameter. Unit is 25 to 30 m thick, thinning toward the south.

Jurassic

Jm — **Morrison Formation (Late Jurassic)**—Two members of Morrison Formation, the Brushy Basin and the Westwater Canyon Sandstone members, are exposed in the Llaves area.

Jmb — **Brushy Basin Member (Late Jurassic)**—Variegated light-greenish-gray, light-gray, grayish-yellow-green, light-olive-gray, yellowish-brown, and drab-reddish-brown bentonitic mudstones with discontinuous beds of cross-bedded to massive white, yellow, tan or grayish-tan sandstone. Unit is up to 50 m thick.

Jmw — **Westwater Canyon Member (Late Jurassic)**—A thick, white to buff, ledge- and cliff-forming, laminated to trough cross-bedded sandstone with occasional conglomeratic sandstone, and abundant horizons of mudstone rip-up clasts. Ranges in thickness are from 0 m, between channels, to 75–100 m in channels.

Jsb — **Summerville Formation and Bluff Sandstone, undivided (Late to Middle Jurassic)**—Slope-forming, pinkish-tan, very fine- to medium-grained, well-sorted, friable, eolian sandstone with cross-beds in thick sets. **Js** is the Summerville Formation and it was mapped separately where only the base of the formation was exposed. Unit thickness is 100–125 m.

Jet — **Todilto Formation and Entrada Sandstone, undivided (Middle Jurassic)**—The Todilto Formation (Labelled **Jt** when mapped seperately) consists of a lower, limestone-dominated interval (Luciano Mesa Member) overlain locally by a gypsum interval (Tonque Arroyo Member) (Lucas et al., 1985, 1995; Kirkland et al., 1995). The Entrada Sandstone (Labelled **Je** when mapped seperately) is a yellow, grayish-orange and red, crossbedded and ripple-laminated, cliff-forming eolian sandstone. Unit thickness is 55–75 m (Fitter, 1958; Crouse et al., 1992).

Triassic

Tc — **Chinle Group (Late Triassic)**—The Chinle Group is divided into two informal subdivisions (upper and lower) and the medial formal formation, the Poleo Sandstone.

Tcu — **Upper Chinle Group (Late Triassic)**—An informal upper unit that includes reddish-brown, bentonitic mudstone that forms extensive slopes and dissected badlands. Petrified wood is common. Lower part is primarily sandstone, with lesser amounts of mudstone and siltstone that range in color from reddish-brown to green; the sandstone beds are very fine-grained to fine-grained, lightly calcium-carbonate cemented, micaceous and typically ripple-laminated to thinly-laminated. 176 m thick north of the Rio Gallina (Lookingbill, 1953).

Tcp — **Poleo Sandstone (Late Triassic)**—Yellow-brown, yellow-gray, white, and red sandstone, conglomerate, siltstone, silty sandstone, and mudstones. Sandstones contain occasional rip-up clasts, potassium feldspar, mica, and plant imprints. Commonly exhibits honeycomb weathering and is found in well-indurated beds less than 1 m thick with tabular to trough cross-bedding. 23–54 m thick on French Mesa (Crouse et al., 1992).

Tcl — **Lower Chinle Group (Late Triassic)**—Contains the Salitral Formation and the Agua Zarca Sandstone. The Salitral pinches out northward on French Mesa, is absent in the Rio Gallina dome. The Salitral Formation is red shale on French Mesa and is maroon to red siltstone in the Gallina Mountain dome. This unit is poorly exposed. The Agua Zarca (**Taz**) is a mappable 1–2-m-thick, white coarse-grained sandstone in the Gallina Mountain dome. Salitral is 6–30 m thick on French Mesa (Fitter, 1958); maximum unit thickness up to 15 m.

PALEOZOIC
Permian

Pc — **Cutler Formation (Early Permian)**—Mottled-white, orange-red to maroon, weathering gray to red-brown, medium- to very coarse-grained, angular to subangular sandstones with abundant feldspar, metallic minerals, and lithics and thick, slope-forming shales with abundant calcrete nodules. Occasional soft sediment deformation. Unit thickness is 100–440 m (Fitter, 1958; Lookingbill, 1953).

Pennsylvanian

IPm — **Madera Formation (Pennsylvanian)**—Green, medium-grained, arkosic sandstone with biotite; red, biotite-bearing, medium-grained, well-sorted arkose; thinly bedded, green, very fine- to fine-grained, well-sorted sandstone with little feldspar; and a 3–4-m-thick sandstone that is massive at the base and cross-bedded at the top. The exposed thickness is approximately 30 m.

PROTEROZOIC

pCu — **Proterozoic rocks (Proterozoic)**—Igneous and metamorphic rocks ranging from 1.7 to 1.4 Ga (only on the cross sections).

FIGURE 1—A photograph of the Rio Gallina anticline with major offset observable from the Tierra Montañosa fault.

Explanation of Map Symbols

Contact—The identity and existence are certain, and questionable where queried. The location is accurate where solid, approximate where long-dashed, inferred where short-dashed, and concealed where dotted.

Gradational contact—The identity and existence are certain. The location is accurate where solid.

Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—The location is accurate where solid, approximate where dashed, and concealed where dotted.

Normal fault—The identity and existence are certain. The location is accurate where solid, approximate where dashed, and concealed where dotted. Bar and ball are on the downthrown block.

Fault in cross section showing local up/down offset—The arrows show the relative motion along the fault plane.

Key bed—**af**—The identity and existence are certain. The location is accurate.

Key bed—**Rsl**—The identity and existence are certain. The location is accurate.

Key bed—**Tcl**—The identity and existence are certain. The location is accurate.

Key bed—**Kpl**—The identity and existence are certain. The location is accurate.

Key bed—**Kmjl**—The identity and existence are certain. The location is accurate.

Key bed—**Taz**—The identity and existence are certain. The location is accurate.

Anticline—The identity and existence are certain. The location is accurate where solid, approximate where dashed, and concealed where dotted. The large arrowhead shows the direction of the plunge.

Subsurface anticline (determined from well logs)—Identity and existence are certain. Location is inferred. Based on structural contours at the base of the Ojo Alamo Sandstone (Baltz et al. 1967).

Antiform—The identity and existence are certain. The location is accurate where solid and approximate where dashed.

Syncline—The identity and existence are certain. The location is accurate where solid, approximate where dashed, and concealed where dotted. The large arrowhead shows the direction of the plunge.

Subsurface syncline (determined from well logs)—Identity and existence are certain. Location is inferred. Based on structural contours at the base of the Ojo Alamo Sandstone (Baltz et al. 1967)

Monocline—The identity and existence are certain. The location is accurate where solid, approximate where dashed, and concealed where dotted. The arrow shows the direction of dip.

Area of **Kpc** outcrop. See Description of Map Units for unit description.

12 Inclined bedding—Showing strike and dip.

Horizontal bedding

Vertical bedding—Showing strike.

Fault showing local up/down offset—U is on the upthrown block, and D is on the downthrown block.

Fault showing local right-lateral strike-slip offset—Arrows show relative motion.

53 Inclined fault—Showing dip value and direction.

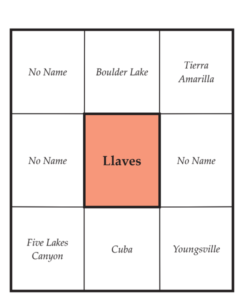
Small, minor antiform, vertical or near-vertical axial surface—Showing strike.

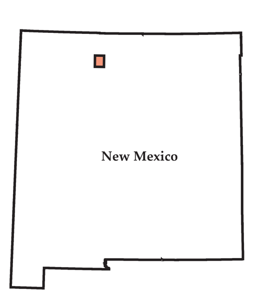
Small, minor anticline, vertical or near-vertical axial surface—Showing strike.

Small, minor syncline, vertical or near-vertical axial surface—Showing strike.

A A' Cross section line and label.

30-039-05350 (T.D. 911) Well location (in cross section)—The location and total depth (T.D. in meters) of a well used to establish stratigraphy and geologic unit depth.





Quadrangle Location

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801 Leroy Place
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87801-4796

[575] 835-5490

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

https://geoinfo.nmt.edu

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Phil L. Miller, Amy L. Dunn, Ann D. Knight, Tyler Askin, and Hannah N. Hunt

New Mexico Bureau of Geology and Mineral Resources
Open-File Geologic Map 316

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Geologic Map of the Llaves 15-Minute Quadrangle, Rio Arriba County, New Mexico

September 2024

by

Shari A. Kelley[1], Jon M. Krupnick[1], and Scott B. Aby[2]

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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, a 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 (drill hole) 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 human-made structures.

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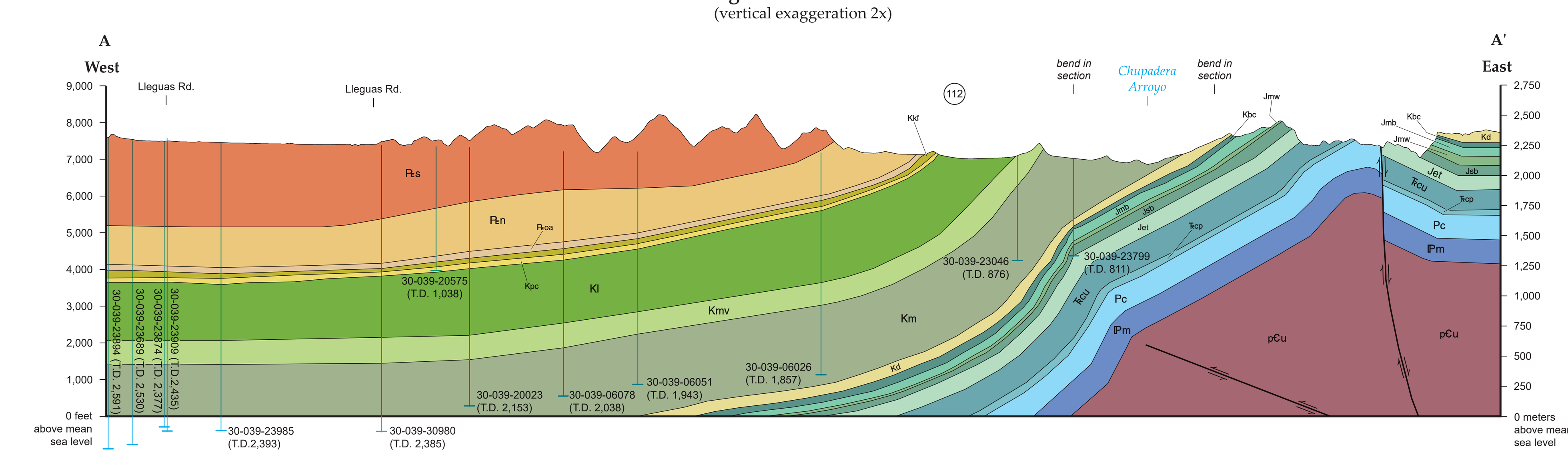
Geologic Cross Section A–A'

(vertical exaggeration 2x)



Geologic Cross Section B–B'

(vertical exaggeration 2x)