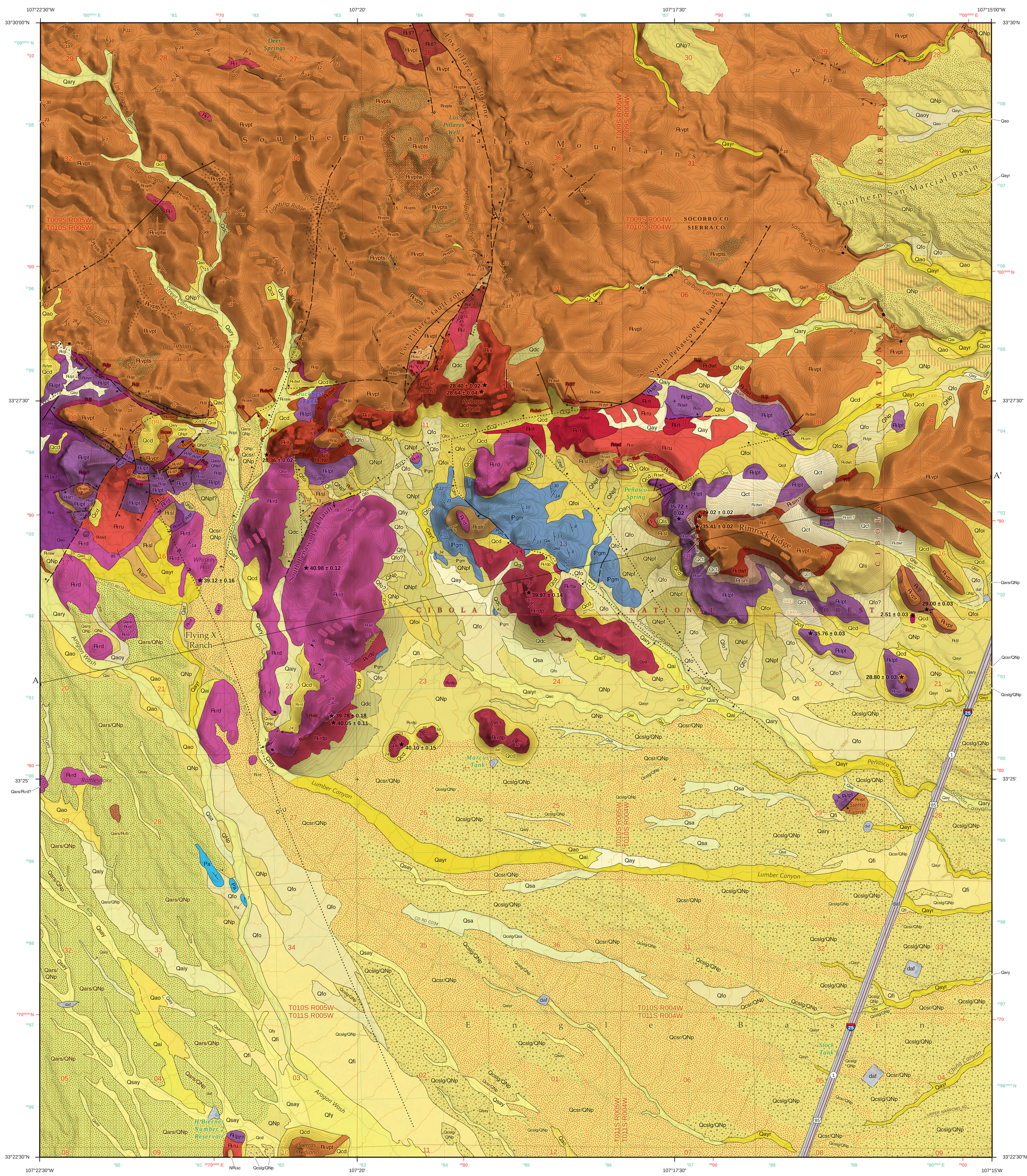
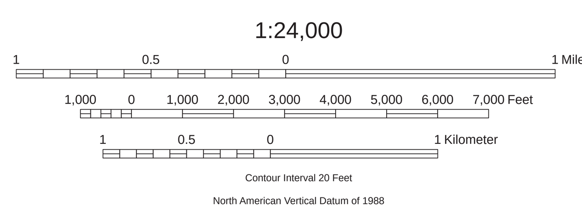
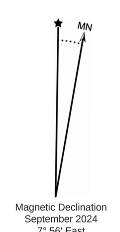


North American Datum of 1983 (NAD83)
Projection and 1,000-meter grid: Universal Transverse Mercator, Zone 13S, shown in blue.
10,000-foot ticks: New Mexico Coordinate System of 1983 [West (Sierra) and Central (Socorro) Zones], shown in red.

Digital base map data..............U.S. Geological Survey, 2019
Contours and hillshade..............IFSAR 4.5 m Digital Terrain Model, 2007





Quadrangle Location

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

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New Mexico Bureau of Geology and Mineral Resources
Geologic Map 87

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Geologic Map of the Sierra Fijardo 7.5-Minute Quadrangle, Sierra and Socorro Counties, New Mexico

April 2026

by

Rebecca L. Gougnour, Shari A. Kelley, Daniel J. Koning, and Andrew K. R. Hoxey

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 rocks and deposits, and the occurrence of structural features. Lithologic and fault contacts are irregular surfaces that form boundaries between different ages or types of units. Data depicted on this geologic map may be based on any of the following: field geologic mapping, a compilation of published and unpublished work, and/or photogeologic interpretation. Locations of contacts are not surveyed but are plotted by relative position on a topographic or orthophotographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the geologist's interpretation.

Resizing this map would cause the details of the map to be misrepresented and result in erroneous interpretations. Using this product at a scale different than originally intended requires verification of site-specific conditions with detailed surface mapping or subsurface exploration. Topographic and cultural changes may not be shown due to recent development.

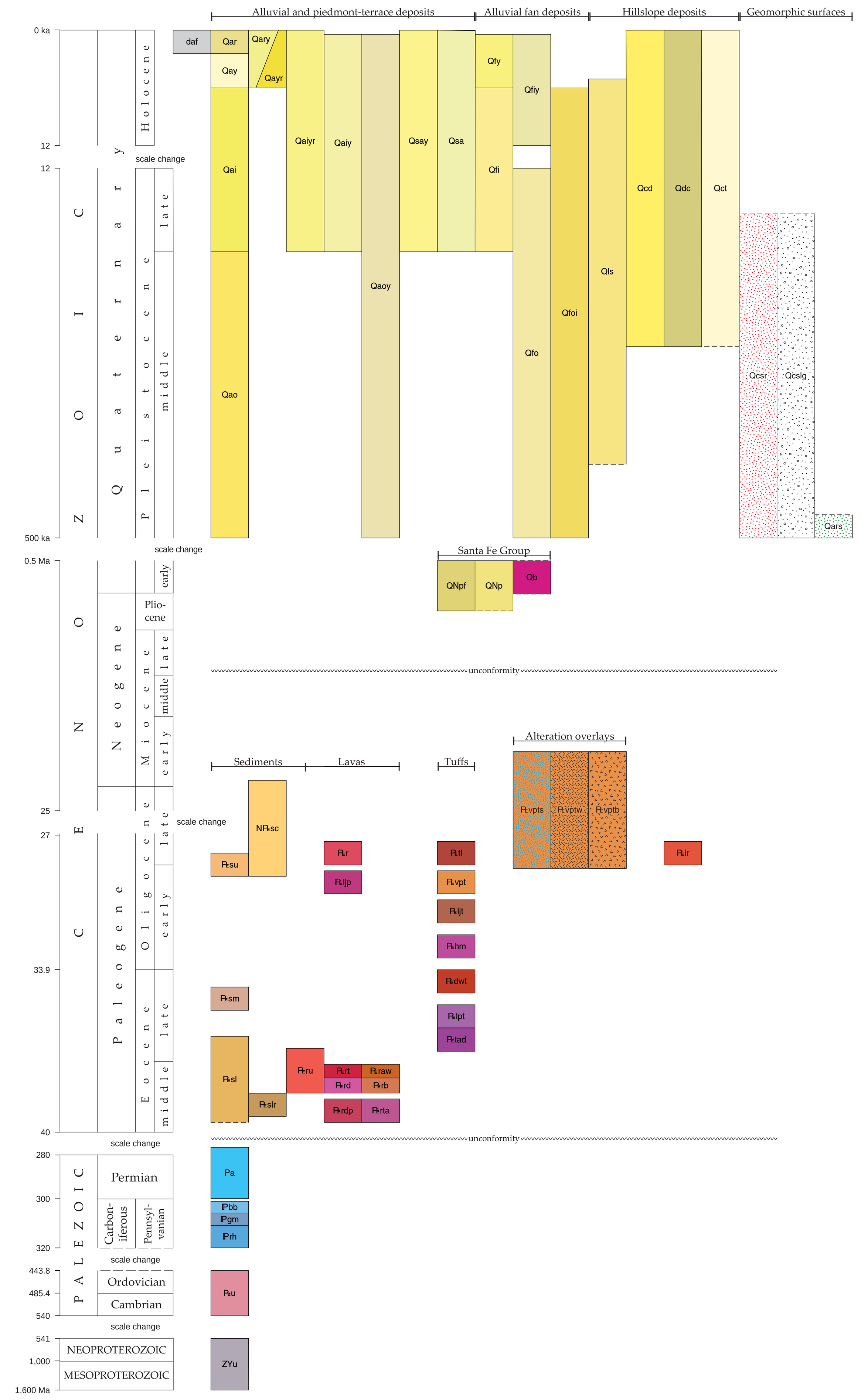
Cross sections are constructed based on the author's interpretations of geologic mapping and available geophysical and subsurface (drill hole) data. Cross sections should be used to understand the map area's general geologic framework and not be the sole source of information for locating or designing wells, buildings, roads, or other human-made structures.

Point symbols can be set to rotate around a point of observation using their azimuth values. The point of observation can be one of three possibilities: the trailing end—or tail—opposite the arrowhead or other ornamentation of the symbol; the midpoint—or center of the symbol; or the head of the symbol. See the symbol codes described in the GIS data (FGDC_Symbols nonspatial table) for attributes that describe the azimuth measurement convention and the location of the point of observation for each symbol.

Each publication carries the original date of publication and the latest revision date. Occasionally updates are required and in many cases these updates are only made to the GIS data in the Geodatabase, not the PDF. It is beneficial to compare the GIS data with the PDF to review any changes. While maps are created, updated, and produced as a GIS geodatabase, even if updates are carried out on the GIS data files, citations to these maps should reflect this original publication date with the revisions date and the original authors listed. If required, the updated data as digital products are available for download from the map's publication webpage.

The views and conclusions in these map documents are those of the authors and should not be interpreted as necessarily representing the official policies, expressed or implied, of the State of New Mexico or the U.S. Government.

Correlation of Map Units



Explanation of Map Symbols

Contact—The identity and existence are certain; where questionable or unspecified, features will be queried. The location is accurate where solid and approximate where dashed.

Gradational contact—Identity and existence are certain. The location is accurate where solid and approximate where dashed.

Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—The identity and existence are certain; where questionable or unspecified, features will be queried. The location is accurate where solid, approximate where dashed, or concealed where dotted.

Normal fault—The identity and existence are certain; where questionable or unspecified, features will be queried. The location is accurate where solid, approximate where dashed, or concealed where dotted. Ball and bar on downthrown block.

Oblique-slip fault, left-lateral offset—The identity and existence are certain; where questionable or unspecified, features will be queried. The location is accurate where solid or concealed where dotted. Arrows show relative motion; ball and bar on downthrown block.

Head or main scarp of landslide—Active, sharp, distinct, and location is accurate. Hachures point down scarp.

Map Unit Beds—The identity and existence are certain; where questionable or unspecified, features will be queried. The location is accurate where solid and approximate where dashed. The color and label denote the map unit.

Dike (Ᵽir)—The identity and existence are certain. The location is accurate.

Cross section line and label.

★ 29.02 ± 0.02 Radiometric sample locality—Showing age.

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

Inclined bedding—Showing strike and dip.

Inclined flow banding, lamination, layering, or foliation in igneous rock—Showing strike and dip.

Vertical flow banding, lamination, layering, or folidation in igneous rock—Showing strike.

Approximate plunge direction of inclined generic (origin or type not known or not specified) lineation or linear structure (1st generation, L1).

Inclined generic (origin or type not known or not specified) lineation or linear structure—Showing trend and plunge.

Inclined slickenline, groove, or striation on fault surface—Showing trend and plunge.

Paleocurrent direction determined from imbrication.

Outcrop point too small to map as an area at map scale The color and label denote the map unit.

Unnamed Geomorphic Surfaces in the Northeastern Corner of the Quadrangle

Gray, higher geomorphic surface on unit QNp in the northeastern part of the quadrangle.

Red, lower geomorphic surface on unit QNp in the northeastern part of the quadrangle.

Cross Section and Correlation of Map Units Only

Unconformable contact—Identity and existence are certain. Location is accurate.

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

Description of Map Units

QUATERNARY

Anthropogenic Deposits

daf **Disturbed ground and artificial fill (0 to 150 years)**—Human-related excavations and fill of sand and gravel for the purpose of constructing dams and road beds. The fill is up to 10 m thick.

Hillslope and Mass Wasting Deposits

Qct **Colluvium and talus deposits (Holocene and late to middle Pleistocene)**—Subangular pebble- to cobble-sized gravel blanketing steep hillslopes. There is a subordinate matrix of poorly sorted, angular to subangular, clayey-silty sand. This deposit is usually mapped below steep cliffs where thick deposits of broken rock accumulate. The unit is commonly in 5-m-wide topographic chutes. The deposit is typically unconsolidated and <8 m thick.

Qcd **Colluvium and lesser debris flow deposits (Holocene and late to middle Pleistocene)**—Poorly sorted, angular to subangular, clayey-silty sand and pebble- to cobble-sized gravel. Colluvium drapes the foot of relatively smooth slopes, and debris flows are inferred under small, steep fans (convex-up, bulbous landforms at the mouths of steep, low-order drainages). The matrix is commonly reddish where mapped on Ᵽvpt. The proportion of colluvium is greater than the proportion of debris flows. The deposit is typically <8 m thick.

Qdc **Debris flow deposits and lesser colluvium (Holocene and late to middle Pleistocene)**—Poorly sorted, angular to subangular, clayey-silty sand and pebble- to cobble-sized gravel. Colluvium drapes the foot of relatively smooth slopes, and debris flows are inferred under small, steep fans (convex-up, bulbous landforms at the mouths of steep, low-order drainages). The proportion of debris flows is greater than the proportion of colluvium. The deposit is typically <8 m thick.

Qls **Landslide deposit (middle Holocene to middle Pleistocene)**—Landslide deposit on the east side of Rimrock Ridge that underlies a 200-m-wide, bulbous landform below a concave-up, shallow hollow on the hillslope. Boulders and cobbles of Vicks Peak Tuff (Ᵽvpt) are common on the surface. The deposit likely consists of a massive to chaotic, poorly sorted mixture of gravel (pebble- to boulder-sized) with a clayey to sand matrix. The thickness of the deposit is ≈10–15 m.

Post-Santa Fe Group Alluvial Deposits

Alluvial Deposits

Qar **Recent alluvium (0-150 years)**—Sandy gravel, pebbly sand, and sand on the lowest part of valley floors, inferred to be <150 years old and lacking topsoil development. Two geomorphic components are (1) modern channels with notable bar-and-swale topography and pebbles through boulders, and (2) low terraces ≈1 m above grade with dm-scale bar-and-swale topography and sediment dominated by sand and pebbles. The deposit is less than 3 m thick.

Qay **Younger alluvium (late to middle Holocene)**—Sandy gravel and gravelly sand under low terraces (<2 m high) exhibiting thin to thick, tabular to lenticular beds. Sand is mostly brown and fine- to very coarse-grained. Topsoil generally has a Stage I+ carbonate morphology. Buried soils are characterized by Bk and Bw horizons. The surface is smooth and has a weakly developed pavement. The deposit is weakly consolidated and 2–10(?) m thick.

Qary **Recent and younger alluvium (0 years to middle Holocene)**—Recent alluvium (Qar) and subordinate younger alluvium (Qay); see detailed unit descriptions above. The deposit is 1–10(?) m thick.

Qayr **Younger and recent alluvium (0 years to middle Holocene)**—Younger alluvium (Qay) and subordinate recent alluvium (Qar); see detailed unit descriptions above. The deposit is 1–10(?) m thick.

Piedmont-terrace Deposits

Qai **Intermediate alluvium (middle Holocene to late Pleistocene)**—An allostratigraphic deposit above Qay and below Qao. A coarse and fine lithofacies are recognized and lack calcic soil horizons with greater than Stage II morphology. The coarse lithofacies is sandy gravel and gravelly sand, and the fine lithofacies is clayey-silty very fine to fine sand. The 1- to 4-m-thick deposit has a smooth, weakly to moderately varnished surface.

Qao **Older alluvium (middle Pleistocene)**—Poorly exposed sandy gravel and gravelly sand underlying terraces inset below the Cuchillo (Qcsr and Qcslg) and Aragon (Qars) geomorphic surfaces, and whose treads are above adjoining Qai and Qay surfaces. The tread of Qao is reddish-brown in aerial photography due clast varnishing, overturned clasts with orange varnish on their undersides, and/or Bt or Bw soil horizons in the topsoil. The deposit is 1–3 m thick.

Composite Units of Piedmont-terrace Deposits and Alluvium

Qaiyr **Intermediate, younger, and recent alluvium (Holocene to late Pleistocene)**—Intermediate alluvium (Qai) and subordinate to subequal younger and recent alluvium (Qay and Qar, respectively); see detailed unit descriptions above. The deposit is generally several meters thick.

Qaiy **Intermediate and younger alluvium (late Holocene to late Pleistocene)**—Intermediate alluvium (Qai) and subordinate to subequal younger alluvium (Qay); see detailed unit descriptions above. The deposit is generally several meters thick.

Qaoy **Older and younger alluvium (late Holocene to middle Pleistocene)**—Older alluvium (Qao) and subordinate to subequal younger alluvium (Qay); see detailed unit descriptions above. The deposit is 1–4 m thick.

Qsa **Sandy sheetflood and alluvial deposits filling swales on Cuchillo surface (Holocene to late Pleistocene)**—Reddish-brown to brown, massive, clayey to silty, very fine- to fine-grained sand filling topographic swales on the Cuchillo geomorphic surface (Qcsr and Qcslg). The deposit is interbedded with coarser alluvium (sand and gravel) and overprinted by a cumulic soil lacking strong calcic horizons. This fine sediment gradationally overlies sandy gravel and gravelly sand. The deposit is moderately consolidated and 1–4 m thick.

Qsay **Younger, sandy sheetflood and alluvial deposits (Holocene to late Pleistocene)**—Similar to unit Qsa but also mapped underlying smooth drainage floors inset below the Aragon geomorphic surface (Qars) in the southwestern part of the map area. The browner and darker, lower fine-grained sediment is capped by 10–40 cm of lighter-colored sand (grayish-brown to light-brownish-gray to pale-brown) typical of that seen in unit Qay. The deposit is moderately consolidated and 1–4 m thick.

Alluvial Fan Deposits

Qfy **Younger alluvial fan deposits (late to middle Holocene)**—Gravel and sand, correlative to younger alluvium (unit Qay), underlying subtle, fan-shaped lobes on the low-sloping piedmont in the southwestern part of the map area. The surface is smooth but weakly varnished. The deposit is 1–5 m thick.

Qfiy **Intermediate to younger alluvial fan deposits (late Holocene to late Pleistocene)**—Gravel and sand, correlative to intermediate and younger alluvium (Qai and Qay, respectively), underlying alluvial fans. There is weak to moderate varnish on the gravels. The surface is smooth and moderately vegetated. Its tread is a few meters lower than adjoining surfaces on Qfo or QNpf. The deposit is 1–5 m thick.

Qfi **Intermediate alluvial fan deposits (middle Holocene to late Pleistocene)**—Gravel and sand, correlative to intermediate alluvium (unit Qai), underlying alluvial fans at the foot of steep slopes and fan-shaped lobes on relatively low-sloping piedmonts. The surface is weakly to moderately varnished. The deposit is 1–5 m thick.

Qfoi **Older and intermediate alluvial fan deposits (middle Holocene to middle Pleistocene)**—Gravel and sand, correlative to older and intermediate alluvium (units Qao and Qai, respectively), underlying alluvial fans at the mouths of low-order drainages that drain steep terrain. The surface is weakly to well varnished and 4–11 m above adjoining Qay surfaces. The estimated thickness is 1–12 m.

Qfo **Older alluvial fan deposits (late to middle Pleistocene)**—Gravel and sand, correlative to the older alluvial unit (Qao), underlying alluvial fans at the foot of steep slopes. It also forms fan-shaped lobes on low-sloping piedmonts. The surface is moderately to strongly varnished and has a reddish-brown color. Its tread height relative to nearby Qay is 4–11 m. The deposit is locally inset below QNpf or onlaps proximal QNpf. Its thickness is about 2–12 m.

Geomorphic Surfaces on Pleistocene Deposits

Qcsr **Cuchillo geomorphic surface, reddish unit (late? to middle Pleistocene)**—Areas of the Cuchillo geomorphic surface that appear reddish-brown in aerial photography, likely due to surface clast varnishing or overturning of rubified undersides of these clasts, Bt or Bw soil horizon development, and (or) slopewash/sheetfloods reworking these soils. The Cuchillo geomorphic surface (usage per McCraw and Williams [2012]) is developed on QNp and Qao and lies ≈5–6 m below the Aragon geomorphic surface.

Qcslg **Cuchillo geomorphic surface, grayish unit (late? to middle Pleistocene)**—Areas of the Cuchillo geomorphic surface that appear light-gray in aerial photography and lie 1–5 m above Qcsr. Based on limited observations, the soils of this unit lack Bt and Bw horizons, clast varnishing is minimal, and it has calcic horizons that are less developed than Stage IV. The Cuchillo geomorphic surface (usage per McCraw and Williams [2012]) is developed on QNp and Qao and lies ≈5–6 m below the Aragon geomorphic surface.

Qars **Aragon geomorphic surface (early Pleistocene)**—Surface mapped over moderately dissected terrain on the west-central section of the map, west of Aragon Wash. It projects eastward about 5–6 m over the adjoining Cuchillo geomorphic surface to the east. The surface is also present on the northeastern portion of the map. The surface consists of relatively broad (50–200 m wide), concordant ridges and exhibits a local relief of 5–10 m.

Santa Fe Group

The Santa Fe Group is a name applied to synextension, clastic basin fill of the Rio Grande rift and includes interbedded or intercalated volcanic flows (Baldwin, 1956; Spiegel and Baldwin, 1963). Only the uppermost strata of the Santa Fe Group crop out in the map area.

Qb **Basanite (early Pleistocene)**—Massive, black to very dark-gray, aphanitic basanite containing plagioclase laths ≤ 0.2 mm long. The basanite is locally a scoria. There are also 0.5% olivine phenocrysts ≈2 mm across. A ≈1-m-wide, north-trending dike is present. The unit is poorly exposed. Groundmass $^{40}Ar/^{39}Ar$ age is 2.51 ± 0.03 (this report: $^{2}90^{000m}$ E, $^{37}01^{800m}$ N).

QNpf **Palomas Formation under alluvial fan landforms (early Pleistocene to middle Pliocene)**—Gravelly Palomas Formation strata underlying distinctive alluvial fan landforms adjacent to steep-sloped bedrock. Strata are commonly light-gray in aerial imagery due to inferred erosion. See description of unit QNp below.

QNp **Palomas Formation (early Pleistocene to middle Pliocene)**—Sandy gravel and minor pebbly sand in thin to thick, tabular to lenticular beds. Gravel consists of pebbles with ≈20–30% cobbles and 1–10% boulders. Gravel matrix mostly consists of medium- to very coarse-grained sand that has 1–15% clay in the matrix, imparting a reddish color. Local paleosols with orangish Bt or Bw horizons overlie calcic horizons. The thickness likely ranges from 10 to 200 m.

PALEOGENE

Intrusive Igneous Units

Ᵽir **Rhyolitic intrusions (late Oligocene)**—Rhyolite domes containing 20–35% quartz (1–4 mm) and sanidine (1–3 mm) and trace biotite (≤1 mm) in a fine-grained white matrix. The unit displays large-scale flow banding, possibly from extrusive dome building. The margin of the intrusion is commonly xenolith-rich and is commonly associated with brecciated host rock, typically Vicks Peak Tuff (Ᵽvpt). Sanidine $^{40}Ar/^{39}Ar$ ages range from 28.36 ± 0.02 to 28.46 ± 0.04 Ma (this report).

Extrusive Volcanic and Volcaniclastic Units

Ᵽr **Rhyolite flow (late Oligocene)**—Pink to gray, flow-banded rhyolite lava that is generally aphanitic. Unit contains sparse quartz and sanidine phenocrysts typically 0.5–1 mm (≤5 mm), which are aligned with flow banding. Flow brecciation and botryoidal hematite mineralization are present. Unit has a rheomorphic green-blue, glassy base. Unit has a minimum thickness of ≈12–18 m, but top of unit may have been eroded in the map area.

Ᵽtl **Local quartz-bearing tuff (late Oligocene)**—Light- to dark-brown, crystal-rich, lithic-rich, glassy tuff with 10–25% sanidine and quartz, <1% biotite, and trace hornblende. Unit contains 2–15% lithics (≤11 cm long) in an ashy matrix. Locally, the unit has a black, glassy basal vitrophyre and caps a white volcaniclastic sandstone. The unit has limited exposure in the map area and is likely a local unit. The maximum exposed thickness is ≈18 m.

Ᵽvpt **Vicks Peak Tuff (early Oligocene)**—Light-gray, crystal-poor tuff with 0.5% euhedral sanidine (0.5–2.0 mm). Spherulites 2–4 cm in diameter are common. Moderately to very strongly welded with 2–5% fiamme (≤1 mm thick and 1–10 cm long). Commonly strongly foliated. Commonly has black, glassy basal vitrophyre. At least ≈180 m thick in the northern half of the map area. Sanidine $^{40}Ar/^{39}Ar$ age is 28.80 ± 0.03 Ma (this report).

Alteration Zones of Ᵽvpt

Ᵽvpts **Silicified Vicks Peak Tuff (Oligocene?)**—Brown Ᵽvpt altered to silica. Commonly weathers to tall, rounded pillars.

Ᵽvptw **White, kaolinized Vicks Peak Tuff (Oligocene?)**—White, punky Ᵽvpt altered to kaolinite. The unit is rough and friable. Distinctive small-scale tension fractures observed in Ᵽvpt are well preserved in this unit.

Ᵽvptb **Brecciated Vicks Peak Tuff (Oligocene?)**—Ᵽvpt brecciated to tight, angular, clast-sized chunks. Stilbite mineralization is common throughout the breccia. No visible matrix between angular Vicks Peak Tuff clasts. Commonly occurs adjacent to Ᵽir but can be found throughout the northern portion of the map area where there is no visible Ᵽir.

Ᵽljp **La Jara Peak basaltic andesite (early Oligocene)**—Aphanitic, reddish-brown to black basaltic andesite with variable vesicularity. Vesicles commonly coated in light-green mineralization or filled with light-tan clay alteration. Unit is commonly highly altered to a dull, light-tan to yellow color or a glassy, brecciated, orangish-brown color. Thickness variable over short distances, likely a result of paleotopography. Unit is 5–33 m thick.

Ᵽljt **La Jencia Tuff (early Oligocene)**—Orange to brown to gray, crystal-poor tuff with 5–10% fiamme and 3–10% phenocrysts of sanidine. Occasionally has a dark, glassy vitrophyre. More poorly welded and grayish, with 5–10% phenocrysts and ≈3–8% lithics upsection. Sharply overlies Ᵽdwt or Ᵽlpt and is 10–25 m thick. Sanidine $^{40}Ar/^{39}Ar$ ages are between 29.00 ± 0.03 and 29.02 ± 0.02 Ma (this report).

Ᵽhm **Hells Mesa Tuff (early Oligocene)**—White to pink to peach-colored, lithic-poor (<5%), moderately welded tuff with 5–7% phenocrysts of quartz, biotite, sanidine, titanite, and sparse hornblende. It has an $^{40}Ar/^{39}Ar$ age of 32.35 ± 0.01 Ma from a sample north of the quadrangle (Cather et al., 2024). The thickness is variable, ranging from 1 to 3 m.

Ᵽdwt **Datil Well Tuff (late Eocene)**—Strongly welded, crystal-rich tuff with 3% lithics, 3–5% fiamme, and 25–30% phenocrysts of sanidine (≤4 mm) and lesser biotite (≤2 mm). Reddish-brown to maroon color. Upsection, the unit becomes gray and less welded, with 5–15% phenocrysts and 3–7% lithics. Thickness varies from ≈15 to ≈80 m but appears to pinch out to west. Sanidine $^{40}Ar/^{39}Ar$ age is 35.41 ± 0.02 Ma (this report).

Ᵽlpt **Luna Park Tuff (late Eocene)**—Light-brown to pink, crystal-rich tuff with 15–30% sanidine, 2–3% pyroxene, <3% biotite, 10% fiamme (≤4 cm), and 5–30% lithics (≤30 cm). Upsection, the unit is lighter in color and less welded and contains up to 5% biotite up-section. Up to ≈150 m thick in the eastern part of the map area. Sanidine $^{40}Ar/^{39}Ar$ ages are between 35.76 ± 0.03 and 35.72 ± 0.02 Ma (this report).

Ᵽtad **Tuff of Aragon Draw (late Eocene)**—Light-red to purple to brown, crystal-poor tuff with 1–15% sanidine phenocrysts (≤6 mm). Strongly welded. Highly rheomorphic. Brown variety has 10–15% chalky sanidine, trace biotite, and ≤35% lithics (commonly white and dacitic). Red to purple variety contains <10% sanidine, trace biotite, 20–25% fiamme, and ≤25% lithics. Unit is 6–46 m thick. Previously published age of 36.11 ± 0.03 Ma (Koning et al., 2014).

Spears Group

NⱣsc **Seferino Hill conglomerate (early Miocene? to late Oligocene)**—Matrix-supported, massive, very poorly sorted conglomerate. Clasts are angular to subangular and composed of Ᵽvpt. The unit consists of 50% pebbles, 30% cobbles, and 20–25% boulders in a red matrix of fine-grained sand, clay, and lesser coarser sand composed of angular to subangular Ᵽvpt and trace andesite. The unit is 5–8 m thick.

Ᵽsu **Upper Spears Group sediments (late to early Oligocene)**—Weakly to moderately cemented volcaniclastic sandstones and conglomerates. The unit is coarser-grained at the base, with subangular, cobble-sized clasts typically of Ᵽvpt composition. Unit fines upsection, with alternating beds of poorly sorted fine- to coarse-grained sandstone and moderately sorted fine- to medium-grained sandstone. The top of the unit is not exposed and minimum thickness is ≈18 m.

Ᵽsm **Middle Spears Group sediments (late Eocene)**—Poorly to moderately sorted, medium- to coarse-grained sandstone and minor conglomerate. Color is light-brown to white. Commonly contains subhedral feldspar and hornblende grains in an ashy, sandy matrix. Beds are typically 0.5–1.0 m thick. Locally contains intervals of homogeneous white ash. The unit is discontinuous and 25–45 m thick where present.

Ᵽsl **Lower Spears Group sediments (late to middle Eocene)**—Volcaniclastic sandstones and debris flows. Debris flow intervals are massive and very poorly sorted and contain pebble- to boulder-sized volcanic clasts in a well-cemented, ashy matrix. Sandstone intervals are fine- to coarse-grained and vary from ashy-white to green to light-brown. Unit interfingers with unit Ᵽrt and fills paleotopography within Ᵽrd. Unit has a minimum thickness of ≈45 m.

Ᵽslr **Lower Spears Group sediments, red (middle Eocene)**—Fine- to coarse-grained sandstone, locally pebbly. Unit is poorly to moderately sorted and moderately to strongly cemented. Color is typically light-brown but locally has a reddish hue. In coarse-grained layers, there are ≈2 mm subhedral crystals of hornblende, biotite, and feldspar. Strata are thin- to medium-bedded. Unit is thinner to the south (≈2 m) and becomes thicker to the north (≈75 m).

Red Rock Ranch Formation

Ᵽru **Red Rock Ranch Formation, undivided (late to middle Eocene)**—Gray, intermediate lavas and volcaniclastic sediments. Lavas contain up to 20% phenocrysts of hornblende, feldspar, and pyroxene and are commonly flow-brecciated. Also contains coarse-grained debris flow deposits of Ᵽsl. Forms a lag deposit north of Peñasco Spring. Includes smaller outcrops of unit Ᵽrt where it was too small to map separately. Maximum observed thickness of ≈145 m.

Ᵽraw **Plagioclase-pyroxene andesite flow, west (middle Eocene)**—Reddish- to purplish-brown, aphanitic to equigranular andesite. Phenocrysts are 65–70% anhedral to subhedral plagioclase (0.1–1.0 mm), with 1–3% green pyroxene (0.1–1.5 mm) and 1–3% hornblende up to 8 mm long. Minimum thickness of 35 m.

Ᵽrt **Pyroxene-plagioclase trachyandesite flow (middle Eocene)**—Reddish-brown to gray, variably vesicular trachyandesite with 10–15% phenocrysts of pyroxene, plagioclase, and hornblende (typically <2 mm). The vesicular variety typically has green mineralization coating the vesicles. The unit's thickness varies over short distances north of Peñasco Spring; it is 8–20 m thick where interbedded with unit Ᵽsl and at least 65 m thick northwest of Peñasco Spring.

Ᵽrb **Basaltic trachyandesite flow (middle Eocene)**—Light-gray, aphanitic, basaltic trachyandesite with 3% pyroxene and possible amphibole (1–2 mm). The unit is primarily observed as clasts, which exhibit strong varnish.

Ᵽrd **Hornblende-plagioclase dacite flow (middle Eocene)**—Dacite, trachydacite, and trachyandesite with 5–15% phenocrysts of subhedral hornblende (≤3 mm), subhedral to anhedral plagioclase (0.1–1.0 mm), trace biotite and pyroxene (≤1 mm). Porphyritic to equigranular, typically massive, locally brecciated and flow banded. Unit has a maximum thickness of 173 m. Plagioclase and hornblende $^{40}Ar/^{39}Ar$ ages range from 39.12 ± 0.16 to 40.99 ± 0.12 Ma (this report).

Ᵽrta **Trachyandesite flow, aphyric (middle Eocene)**—Aphyric, medium-gray trachyandesite. The unit contains 2% typically chalky plagioclase (2–3 mm, anhedral to subhedral), ≈2% hornblende, and 1% biotite. Mafic crystals are typically 0.5–1.0 mm. The unit forms relatively small, "nubby" exposures with hackly fracturing.

Ᵽrdp **Plagioclase-phyric dacite flow (middle Eocene)**—Dacite to trachydacite to andesite with 10–15% anhedral to subhedral plagioclase phenocrysts (≤7 mm long), commonly altered; 5–13% mafics (≤3 mm); trace to 1% quartz. Lavas commonly have a lower flow-breccia unit, locally are flow banded (e.g., 4 km southwest of Peñasco Spring), and have a maximum thickness of ≈160 m. Plagioclase $^{40}Ar/^{39}Ar$ ages range from 39.98 ± 0.14 to 40.1 ± 0.15 Ma (this report).

PALEOZOIC ROCKS

Permian

Pa **Abo Formation (late to middle Wolfcampian)**—Brick-red to reddish-brown mudstone with 25–30% ledge-forming, strongly cemented siltstone and very fine-grained sandstone (minor fine-grained sand). The unit is thin to medium, tabular beds that are distinctly horizontally or ripple mark-laminated. Mudstone is poorly exposed and inferred from descriptions of nearby outcrops (e.g., Seager and Mack, 2003; Lucas et al., 2012c).

Pennsylvanian

IPgm **Gray Mesa Formation (Desmoinesian)**—Micritic and massive limestone interbedded with laminated sandy limestone and brick-red, fine-grained sandstone. Both the micritic and sandy limestones contain fossils that include bivalves, brachiopods, and gastropods. Within the micritic limestone, there are local boulder-sized, yellow chert nodules, which often appear brecciated with the limestone. Strata have a minimum thickness of ≈92 m.

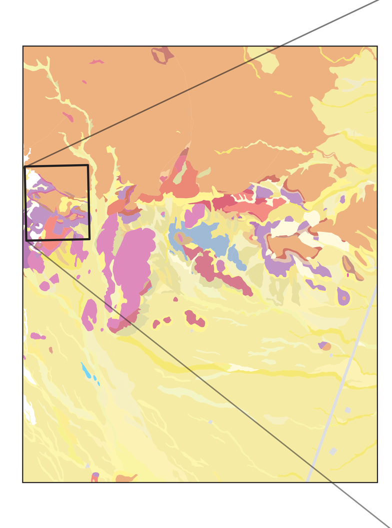
SUBSURFACE UNITS

IPbb **Bar-B Formation (upper Desmoinesian to Missourian)**—Dark-gray to dark-brownish-gray, thin- to medium-bedded limestone overlain by shale and conglomerate (containing pebbles and granules of limestone, dolostone, and chert). This unit is approximately 75 m thick. From Koning et al. (2012).

IPrh **Red House Formation (upper Morrowan to Atokan)**—Interbedded, maroon to pinkish-white, quartzose sandstone and conglomerate, dark-gray shale, and light-gray- to yellowish-tan-weathering limestone. The unit is approximately 555 m thick. From Koning et al. (2012).

Pzu **Lower Paleozoic strata, undivided (Ordovician to Cambrian)**—Includes the Bliss Sandstone, El Paso Group, and Montoya Formation. Cikoski and Koning (2013) inferred a thickness of ≈230 m from the West Elephant Butte Federal No. 1 well, but we use a thickness of ≈150 m given that these units pinch out to the north.

ZYu **Proterozoic rocks, undivided (Neoproterozoic to Mesoproterozoic)**—Meta-sandstone, quartzite, quartz or quartz-biotite schist, amphibolite schist and gneiss, and intercalated granite and granite-gneiss (Koning et al., 2018).



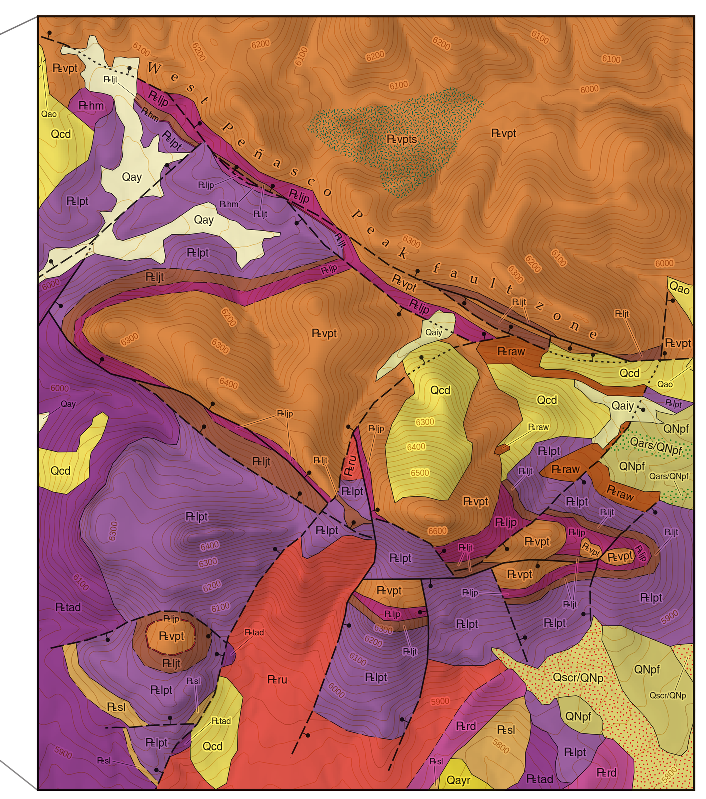
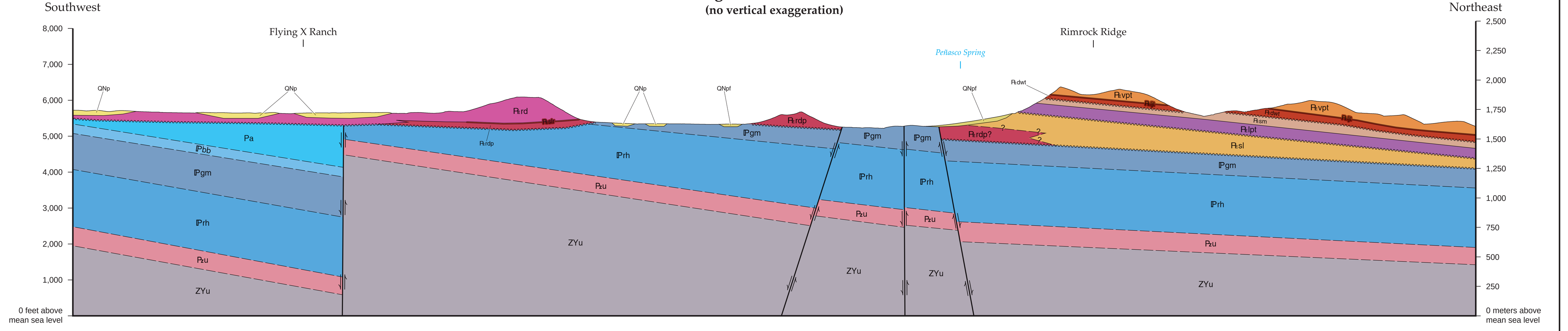


Figure 1—The West Peñasco Peak fault zone area is exceedingly complex and details were simplified for the 1:24,000 map scale. This figure captures some of the more detailed faulting and complex geology that could not be shown at that map scale. The image above shows the location within the 1:24,000 scale map, and the image to the right shows the complexities within this area.

Geologic Cross Section A–A'
(no vertical exaggeration)