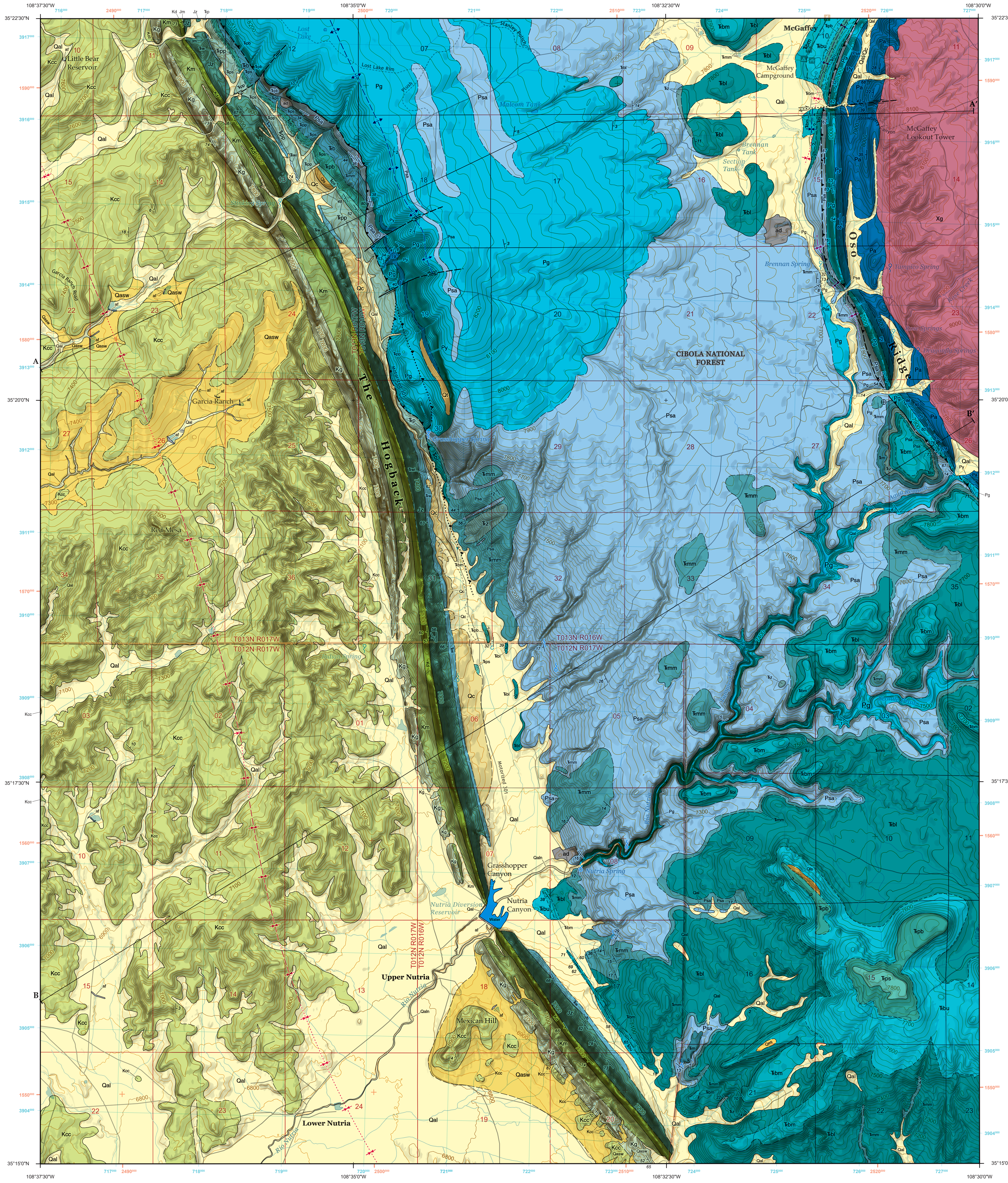
NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES A RESEARCH AND SERVICE DIVISION OF NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

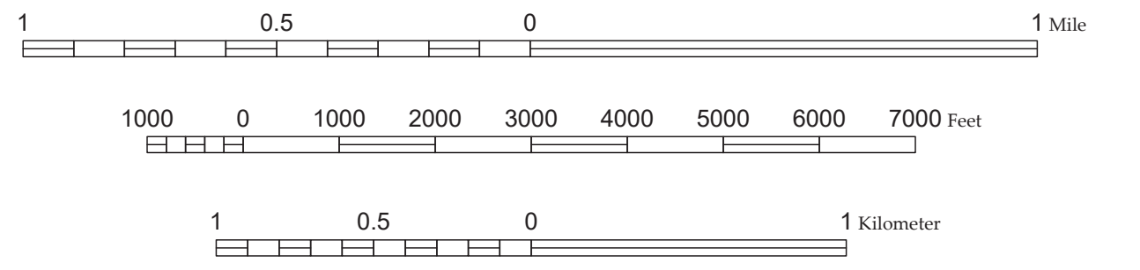
NMBGMR Open-File Geologic Map 313
Last Modified September 2024



Base map from U.S. Geological Survey 2020. North American Datum of 1983 (NAD83)
Projection and 1,000-meter grid: Universal Transverse Mercator, Zone 12S, shown in blue.
10,000-foot ticks: New Mexico Coordinate System of 1983 (West Zone), shown in red.

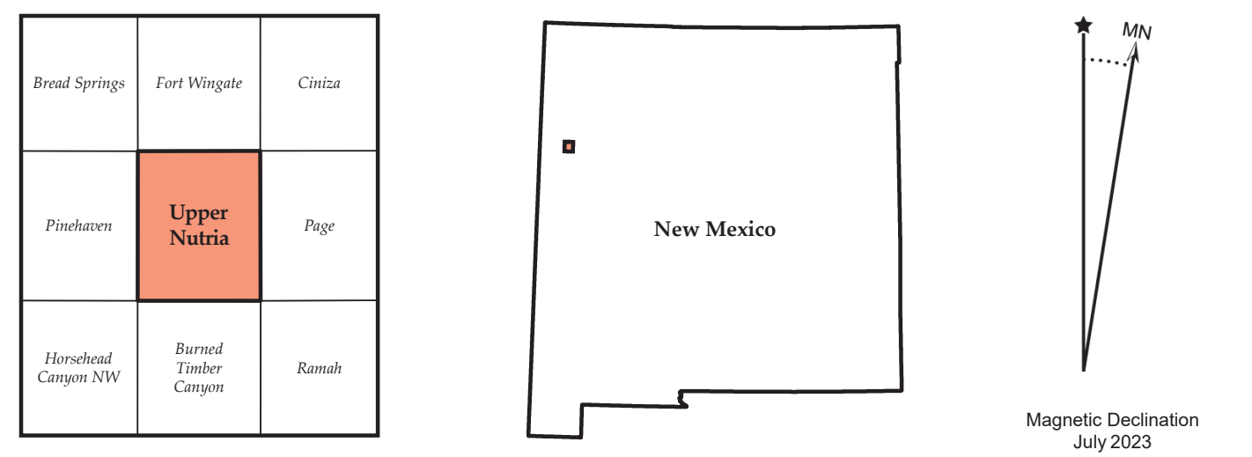
Roads................ U.S. Census Bureau, 2015–2016
Names................GNIS, 2016
Hydrography................National Hydrography Dataset, 2014
Contours................IFSAR 4.5 m Digital Terrain Model, 2008
Wetlands................FWS National Wetlands Inventory 1977–2014

1:24,000



Contour Interval 20 Feet

North American Vertical Datum of 1988



Magnetic Declination
July 2023
8° 48' East
At Map Center

Quadrangle Location

New Mexico Bureau of Geology and Mineral Resources
New Mexico Tech
801 Leroy Place
Socorro, New Mexico
87801-4796

[575] 835-5490

Digital layout and cartography by the NMBGMR Map Production Group:
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 313

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Geologic Map of the Upper Nutria 7.5-Minute Quadrangle, Navajo Nation and Zuni Reservation, and McKinley County, New Mexico

September 2024

by
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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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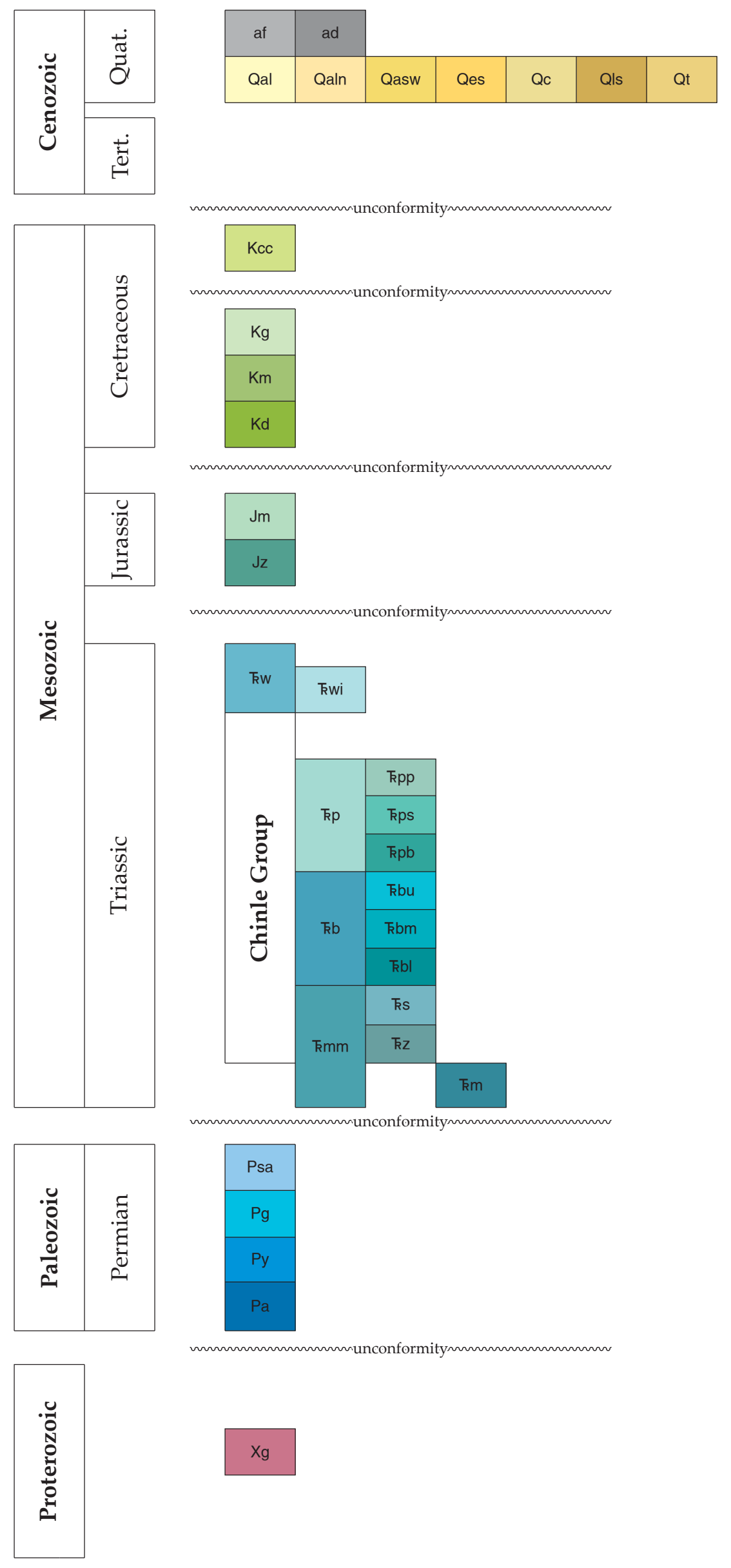
Correlation of Map Units



Explanation of Map Symbols

——— — — — –?– – –	Contact—Identity and existence are certain or questionable where queried. Location is accurate where solid, approximate where long dashed, and inferred where short dashed.
—··—··—	Internal contact—Identity and existence are certain. Location is approximate.
⇌	Strike-slip fault, right-lateral offset—Identity and existence are certain. Location is accurate where solid, approximate where dashed, and concealed where dotted. Arrows show relative motion.
⇋	Strike-slip fault, left-lateral offset—Identity and existence are certain. Location is accurate where solid, approximate where dashed, and concealed where dotted. Arrows show relative motion.
—▾— —▾— ···▾···	Thrust fault—Identity and existence are certain. Location is accurate where solid, approximate where dashed, and concealed where dotted. Sawteeth on upper (tectonically higher) plate.
⇕	Anticline—Identity and existence are certain. Location is approximate.
⇕	Antiform—Identity and existence are certain. Location is approximate.
⇅	Syncline—Identity and existence are certain. Location is approximate where dashed and concealed where dotted.
⊕	Horizontal bedding
29 ⁄	Inclined bedding—Showing strike and dip.
✕	Vertical bedding—Showing strike.
60 ⁄	Overturned bedding—Showing strike and dip.
♁	Spring
A ├──┤ A′	Cross section line and label

Description of Map Units

QUATERNARY

af **Disturbed deposits (Quaternary)**—Deposits disturbed by anthropogenic activities.

ad **Limestone quarry (Quaternary)**—Limestone quarry in San Andres Limestone.

Qaln **Rio Nutria alluvium (Quaternary)**—Alluvium deposited adjacent to the Rio Nutria and Tampico Draw. In the Rio Nutria drainage, alluvium includes fine-grained marshy deposits near the Nutria Spring and coarser deposits of sandy, pebble- to boulder-size, rounded to subrounded gravel in the lower portion of Nutria Canyon, upstream of the Nutria Spring and downstream of the bedrock channel in Nutria Canyon. Upper reaches of Nutria Canyon and Tampico Draw contain generally coarse-grained, less than 7 ft (2 m) thick, poorly sorted pebble- to cobble-gravel size deposits with minimal soil development and some low terraces 7–10 ft (2–3 m) above local base level; generally not mappable at 1:24,000 scale.

Qal **Alluvium (Quaternary)**—Alluvium deposited in Tampico Draw, and in dry washes/arroyos throughout the map area consisting of reworked silt, sand, clay and gravel from the older underlying units. In drainages within the The Hogback (Nutria Monocline) (both those that cross-cut the structure and those running along the strike valleys) and on the dip slope of the monocline east of The Hogback, alluvial deposits commonly comprise dark-reddish-brown (2.5YR 3/4 to 5YR 4/3, locally 7.5YR 3/3) to red, silt, clay, sandy clay, and sand with scattered chert and quartzite pebbles throughout and local gravel lenses. The subordinate coarser fraction (pebbles to cobbles and rare boulders) represents contribution of colluvium from adjacent colluvial slopes or, where alluvial valleys are cut into pebbly units of the Chinle Group, reworking of the underlying unit. Qal sediment deposits exhibit minimal soil development; A-Bw-C profiles typify these soils. Thickness ranges from 6 ft (2 m) or less to greater than 21 ft (7 m). Qal in narrow canyons is not mappable at 1:24,000 scale.

Qasw **Slope wash alluvium (Quaternary)**—Slope wash deposits on hillslopes and undifferentiated thin alluvial, colluvial, and eolian deposits mantling slopes below mesas, on Kcc hillslopes west of The Hogback, and in the strike valleys within The Hogback.

Qes **Eolian deposits (Quaternary)**—Thin <1.5 ft (0.5 m) eolian deposits of loose, silty, fine-grained quartz-lithic sand mantling underlying bedrock units; restricted to a single mappable deposit on this quadrangle. Included as part of Qal and Qasw units in other parts of the map area.

Qc **Colluvium (Quaternary)**—Poorly sorted slope wash and mass wasting deposits from local sources with common fine-grained eolian sand matrix at the surface; mapped only where extensive or where covering critical relations; thickness unknown but likely less than 7 ft (2 m).

Qls **Landslides (Quaternary)**—Poorly sorted debris that has moved chaotically down steep slopes; slumps or block slides (Toreva blocks) partially to completely intact, that have moved down slope; slumps and block slides usually display some rotation relative to their failure plane; thickness varies considerably depending on the size and nature of the landslide.

Qt **Talus (Quaternary)**—Angular and poorly sorted, bouldery deposits derived from mass wasting of cliffs. Mapped only where underlying stratigraphy is significantly obscured.

CRETACEOUS

Kcc **Crevasse Canyon Formation (Cretaceous)**— Interbedded sandstone, silty sandstone, shale, and coal. Sandstone is typically yellow (10YR 7/6-6/6) to pale-yellow (2.5Y 7/4) to light-yellowish-brown (2.5Y 6/4), moderately sorted, subangular to subrounded, fine (upper)- to medium (lower)-grained, carbonate cemented, lithic arkose with approximately 50-80% quartz grains and lesser weathered feldspar, and 5-25% dark mafic/lithic grains. Sandstones form low, massive, cliffy outcrops with local small-scale and large-scale trough cross-bedding, iron-oxide staining, and pebble-size rip-up clasts. Sandstone beds are separated by slope forming intervals comprising light-yellowish-brown (2.5Y 6/3), friable, organic-rich (plant fragments), locally micaceous, silty, very fine-grained sandstone, shale, and silty shale; at least three coal beds ranging in thickness from 3-4 ft (1.0-1.3 m) in an incomplete (upper and lower contacts not exposed) section measured in the SW ¼ section 14, T12N, R17W (base of section at 717863m E, 3905367m N). The basal contact of the Crevasse Canyon Formation unconformably overlies the uppermost layer of the Gallup Sandstone. Crevasse Canyon Formation outcrops in the map area are limited primarily to the Dilco Coal Member, with the upper members of the unit removed by erosion. Upper members of Crevasse Canyon Formation and Cleary Coal Member of overlying Menefee Formation are mapped on the Bread Springs quadrangle northwest of the Upper Nutria quadrangle (Thacker, in press). Total thickness of the Crevasse Canyon Formation on the Upper Nutria quadrangle is not known due to the incomplete section exposure, but is interpreted to be at least 500 ft (153 m) thick based on cross section construction.

Kg **Gallup Sandstone (Cretaceous)**—The Gallup Sandstone is well exposed on the west side of The Hogback where it comprises three distinct sandstone 'fins' separated by strike valleys with limited exposures of finer-grained sediment, with a fourth fin locally exposed near the quadrangle's northern boundary. Sandstones are lithologically very similar, comprising of generally well-sorted to moderately well-sorted, subangular to subrounded, fine (upper)- to medium (lower)- grained, arkosic arenites with minor (generally <5%) lithics. Sandstones are moderately friable, with weak silica cement (nonefferevescent in HCl) and form massive and locally bioturbated cliffs with few preserved sedimentary structures. The upper sandstone ranges from light-red (10R 6/6) to yellowish-red (5YR 5/6), the middle sandstone is typically white (10YR 8/1), and the lower sandstone is pale-red (10R 6/4). Lower sandstone includes intervals of moderately to poorly sorted, coarse-grained quartz sandstone with ≈10% weathered feldspar and <2% lithics. Limited exposures of fine-grained interbeds that form the strike valleys between the sandstone fins include thinly laminated carbonaceous shale and locally thin 6 in (15 cm) coal seams. The lowermost sandstone of the Gallup Sandstone is the basal contact that overlies the Mancos Shale. The thickness of the Gallup Sandstone is 300-400 ft (91-122 m).

Km **Mancos Shale (Cretaceous)**—The Mancos Shale is poorly exposed in strike valleys within The Hogback, above (west of) the Dakota Sandstone and below (east of) the Gallup Sandstone. The Mancos Shale is a medium- to dark-gray, fissile, marine shale and silty shale. Based on exposures in nearby areas, limestone concretions are present in the lower part of the Mancos (Anderson et al., 1998). The total unit thickness is up to 700 ft (213 m).

Kd **Dakota Sandstone (Cretaceous)**—The main body of Dakota Sandstone crops out as a prominent "fin" in The Hogback in the eastern portion of the map area. Well-sorted, subrounded to rounded, fine- to medium-grained, well- indurated (silica-cemented) quartz sandstone with 5-15% weathered feldspar and rare lithics in lower sandstone beds, and gray to brownish-gray silty shale interbeds throughout. The unit is tan on weathered surfaces and white to buff on fresh surfaces. Bivalve casts, bioturbation, and woody fragments occur at the sandstone base. The unit forms prominent cliffs with medium to thick beds. Outcrops have large- and small-scale planar bedding and trough cross-beds. Locally, basal 9-12 ft (3-4 m) is dark-gray to black, carbonaceous shale, and subrounded to rounded, medium-grained sandstone interbeds. The unit is approximately 100 ft (30 m) thick in the northern part of the map area; unit thickens southward to approximately 200-250 ft (61-76 m) at the southern map boundary, where it may include the Whitewater Arroyo Tongue of the Mancos Shale and the thin, Twowells Tongue of the Dakota Sandstone.

JURASSIC

Jm **Morrison Formation (Jurassic)**—The Morrison Formation crops out as an isolated "fin" within The Hogback in the northwest corner of the map area. The unit is white (7.5YR 8/1), moderately sorted, subangular, medium- to coarse-grained, arkosic litharenite; It is thinly bedded, with planar to low-angle cross-beds and scattered pebbles increase in frequency up-section. This unit is assigned to the Salt Wash Member on the adjacent Fort Wingate quadrangle by Anderson et al. (1998), who describe the Morrison Formation in this area as "bleached" and containing authigenic kaolinite. The north to south thinning of the Morisson Formation noted on the Fort Wingate quadrangle continues on the Upper Nutria quadrangle, and the unit pinches out altogether within 1 km of the northern quadrangle boundary. The maximum thickness of the unit is 20-32 ft (7-10 m).

Jz **Zuni Sandstone (Jurassic)**—The Zuni Sandstone forms prominent cliffs on the northeast side of The Hogback, where it comprises light-red (10R 6/6) to light-reddish-brown (2.5YR 6/4), well-sorted, well-rounded, fine-grained, quartz sandstone with minor feldspar and lithics. Generally noneffervescent in HCl (silica cement), but carbonate-cemented nodules/concretions are locally present. Typically well-lithified with abundant large-scale eolian cross-bedding and local planar bedding/laminae, although may locally be friable with weak carbonate cement. Anderson et al. (1998) mapped the eolian Entrada Sandstone underlying, and in conformable contact with, the Zuni Sandstone on the adjacent Fort Wingate Quadrangle. Unit thickness is as much as 700 ft (213 m).

TRIASSIC

TRw **Wingate Sandstone (Triassic)**—The Wingate Sandstone is present as a mappable unit underlying slopes below the prominent Zuni Sandstone cliffs on the east side of The Hogback. The unit consists of red (2.5YR 5/6) to reddish- yellow (5YR 6/6-6/8) to orange-brown, well-sorted, subangular siltstone, to very fine-grained lithic arkose. Unit is parallel bedded to low-angle cross-bedded with scattered chert pebble lenses. It effervesces weakly to moderately in HCl. Outcrops weather to rounded, bulbous ledges that are massive to thickly bedded (>0.5 m), with local laminae ≈1 cm thick. Total thickness of the Wingate Sandstone is 100-200 ft (30-61 m).

TRwi **Iyanbito Member (Triassic)**—(see Lucas and Hayden, 1989, p. 210, measured section UN-2) The unit consists of red (2.5YR 4/6) to reddish-brown (5YR 5/4), friable, locally trough cross-bedded, moderately sorted (within individual beds), rounded to subangular, very fine (upper)- to very coarse-grained feldspathic litharenite, with 10-20% lithics and scattered pebbles and granules in sandstone beds, and lenses of carbonate-cemented pebble conglomerate comprising predominantly of rounded chert, quartz, and quartzite. Sandstone beds are noneffervescent in HCl. Individual beds may range over 1-2 grain size classes. Fine parallel bedding is present within outcrops. Scattered exposures form distinctive low fins on the east side of The Hogback. Where this unit is too thin to be shown at 1:24,000 scale it is included in the Wingate Sandstone map unit. Member thickness is approximately 20 ft (6 m).

Chinle Group (Triassic)

Mudstones, siltstones, sandstones, and occasional conglomerates of the Chinle Group are ubiquitous, although generally poorly exposed, in the eastern portion of the quadrangle. Chinle Group beds dip steeply to the west (dips are locally >65°) within the strike valley east of The Hogback, becoming gentler to the northeast where they form a dip slope between the southwest strike valley and Oso Ridge. Fine-grained units within the Chinle Group are generally very poorly exposed, often obscured by a thin veneer of alluvium or slope-wash deposits.

Chinle Group nomenclature used on the Upper Nutria quadrangle follows the unit designations of Anderson et al. (1998) from the adjacent (to the north) Fort Wingate quadrangle. On the Fort Wingate quadrangle, the Chinle Group is subdivided, in descending order, into the Owl Rock, Petrified Forest, Bluewater Creek, Shinarump, and Zuni Mountains Formations (Anderson et al., 1998; Heckert and Lucas, 2003).

TRp **Petrified Forest Formation (Triassic)**—The Petrified Forest Formation underlies much of the strike valley east of The Hogback and forms the eastern reaches of the dip slope in the southeast corner of the quadrangle. On the Fort Wingate quadrangle, the Petrified Forest Formation has been subdivided into, from youngest to oldest, the Painted Desert, Sonsela, and Blue Mesa Members (Anderson et al., 1998). Logs of petrified wood are locally present.

TRpp **Painted Desert Member (Triassic)**—Poorly exposed within the Upper Nutria quadrangle. Maroon and gray shale (weakly effervescent with HCl) with minor beds of gray, fine-grained, subangular, well-sorted feldspathic, lithic-rich finely bedded sandstone described near Grasshopper Spring. Contains poorly exposed purplish-gray to reddish-gray (10R 5/1 to 2.5YR 5/1) silty crystalline limestone beds with minor chert nodules. Estimated thickness is up to 600 ft (183 m).

TRps **Sonsela Member (Triassic)**—White (10YR 8/1) to light-gray to pinkish-gray (5YR 7/1–7/2), well-sorted, rounded to subrounded, medium- to coarse-grained, arkosic arenite with approximately 5–10% weathered feldspar and typically less than 5% lithic grains. Contains chert-pebble and quartzite-pebble conglomerate beds (both clast supported and matrix supported) and intervals with scattered chert pebbles. Moderately friable, to well-cemented and noneffervescent in HCl. The unit is thin- to medium-bedded (<2 cm to >10 cm) with horizontal bedding, planar cross-bedding, and trough cross-bedding all present; trough cross-bed sets are 50–100 cm thick. The unit has minor shale interbeds and sandstone outcrops commonly occur as couplets separated by shaley intervals. Individual sandstone intervals may be as much as 60 ft (18 m) thick, and thickness of the entire unit is interpreted as up to 160 ft (49 m) thick in some locations based on cross section construction.

TRpb **Blue Mesa Member (Triassic)**—The base of the Blue Mesa Member is a distinctive reddish-brown (5YR 5/3–4/3) to reddish-gray (2.5YR 5/2), silty, fine- to very fine-grained, moderately effervescent, well-sorted, micaceous lithic feldspathic sandstone (≈50% quartz, 30% feldspar, 20% lithics and mica) or micaceous quartz-lithic sandstone. Unit is thinly bedded with planar bedding and low-angle cross-beds with ripple-marked surfaces commonly present. The Blue Mesa Member shale beds are red (10R 4/4, purple (5RP 3/2), and greenish-gray (5GY 8/1–10GY 6/1) shale (or red-purple shale with greenish-gray mottles), and is noneffervescent to strongly effervescent in HCl. The Blue Mesa Member strata on the Upper Nutria quadrangle are up to 140 ft (43 m) thick.

TRb **Bluewater Creek Formation (Triassic)**—On the Upper Nutria quadrangle, the Bluewater Creek Formation is subdivided into the Upper, McGaffey, and Lower Members. Upper and Lower Members of the Bluewater Creek Formation may be differentiated where the McGaffey Member sandstone is present. The Bluewater Creek Formation is present but poorly exposed throughout the eastern two-thirds of the quadrangle, east of The Hogback. The McGaffey Member sandstone forms small mesas and cuestas; Upper and Lower Members of the Bluewater Creek Formation shale beds are slope-forming units that are often mantled by a veneer of colluvium and/or slope-wash alluvium. Total thickness of the Bluewater Creek Formation is as much as 290 ft (88 m).

TRbu **Upper Member (Triassic)**—Red (10R 4/4) to dusky red (10R 3/3) mudstone up to 110 ft (33 m) thick.

TRbm **McGaffey Member (Triassic)**—Very pale-brown (10YR 7/3–8/3) to pinkish-gray (5YR 6/2) to olive-brown (2.5Y 4/3), well-sorted, rounded to subangular, fine-grained, moderately indurated, micaceous quartz-lithic sandstone or quartz-lithic arkose. The unit is noneffervescent to weakly effervescent in HCl. Outcrops form small rounded to vertical cliffs with abundant planar bedding (mm to cm scale horizontal laminations) and/or low angle cross-beds. Well-indurated, clast-supported to matrix-supported, limestone-pebble conglomerate ≈2–5 ft thick often found at the base of the McGaffey Member. Interbeds of limestone-pebble conglomerate sometimes occur within and at the top of the unit. Maximum thickness of the McGaffey Member sandstone is approximately 60 ft (20 m).

TRbl **Lower Member (Triassic)**—Red (10R 4/4–4/3), red-purple (5RP 2/2), and dark-bluish-gray (10B 4/1) mudstone and shale with pinkish-gray (7.5YR 7/2) shale interbeds; moderately to strongly effervescent in HCl. Thin (2–3 mm thick) calcite veins locally present. Includes petrified wood fragments and logs, and sandstone interbeds. The unit is up to 120 ft (36 m) thick.

TRmm **Zuni Mountains Formation, Shinarump Formation, and/or Moenkopi Formation (Triassic)**—Within the Upper Nutria quadrangle (and the Fort Wingate quadrangle), the base of the Chinle Group includes a coarse silica-pebble or pebble- to cobble-sized limestone conglomerate and sandstone unit (the Shinarump Formation) and a variegated siltstone and mudstone that appears to be pedogenically modified (the Zuni Mountains Formation). The Shinarump Formation is up to 40 ft (12 m) thick on the Upper Nutria quadrangle, and appears to represent discontinuous lenticular deposits. The Zuni Mountains Formation may reach a thickness of as much as 80 ft (24 m). The Zuni Mountains and Shinarump Formation are typically mapped together as TRmm, where too thin to map individually, and may also include thin Moenkoepi Formation beds. Stratigraphic relationships indicate the Shinarump Formation overlies the Zuni Mountains Formation.

TRs **Shinarump Formation (Triassic)**—Not mapped at 1:24,000 scale but is included within TRmm. Discontinuous and poorly exposed conglomerate containing abundant pebble- to cobble-sized quartzite and chert clasts with minor petrified wood; often occurs as lag gravel on slopes above the San Andres Limestone or the Moenkopi Formation sandstone and siltstone. Exposure in SE ¼, NW ¼ section 22, T12N, R16W, is trough cross-bedded, moderate- to well-sorted, fine- to medium-grained, quartz-lithic sandstone with abundant feldspar and chert- or quartzite-pebble conglomerate beds. A large outcrop south of Grasshopper Spring (NE ¼, NE ¼ section 31, T13N, R16W) is clast-supported, poorly sorted, well-cemented, limestone-chert-quartzite pebble to cobble conglomerate that forms flatirons at the base of a dip slope. This and other isolated occurrences (e.g. NW ¼, NW ¼ section 8, T12N, R16W) of very well-cemented, pebble to cobble conglomerate, composed entirely of well-rounded limestone clasts in crystalline limestone matrix, are interpreted as intrabasin deposits derived from reworking of the San Andres Limestone.

TRz **Zuni Mountain Formation ("Mottled Strata") (Triassic)**—Mottled-red (10R 4/3), very pale-brown (10YR 4/3), brownish-yellow (10YR 6/6), and grayish-purple or reddish-gray (2.5YR 3/1), fine-grained, quartz-lithic sandstone, siltstone, and mudstone; noneffervescent with HCl. Outcrops exhibit extensive mottling locally, with ubiquitous vertical fracturing on 1–2 cm spacing, likely paleosol prismatic soil structure. Unit forms resistant knobs with sparse vegetation and trees exhibiting gnarled, stunted growth.

TRm **Moenkopi Formation (Triassic)**—The Moenkopi Formation is thin and discontinuous on the Upper Nutria quadrangle, where it was deposited disconformably on the San Andres Formation (Hayden and Lucas, 1989), referred to as the San Andres Limestone in this quadrangle. In many locations the Moenkopi Formation is only preserved where low spots on the undulatory (karstic) upper surface of the San Andres Limestone were infilled by the Moenkopi Formation, with the overlying materials subsequently stripped during uplift and erosion. The Moenkopi Formation is often entirely absent, with the Shinarump Formation or Zuni Mountains Formation sitting directly on the San Andres Limestone. The Moenkopi Formation is red (5YR 5/4) to reddish-brown (2.5YR 4/4) to dark-yellowish-brown (10YR 4/4) on weathered surfaces, and red and white on fresh surfaces. The unit is moderately to well-sorted, subangular, very fine- to medium-grained, planar bedded to trough cross-bedded, micaceous quartz-lithic sandstone or lithic arkose. Unit is weakly to moderately effervescent in HCl. Unit thickness is as much as 20 ft (6 m).

PERMIAN

Psa **San Andres Limestone (Permian)**—The San Andres Limestone is exposed in the Rio Nutria drainage, on the dip slope of the monocline, and along Oso Ridge in the northeast portion of the quadrangle. The San Andres Limestone interfingers with the underlying Glorieta Sandstone. Where interfingering was observed, the contact was mapped as the top of the uppermost Glorieta Sandstone/base of massive San Andres Limestone. Locally, paleokarst topography is developed at the top of the San Andres Limestone; Triassic (Moenkoepi Formation) strata locally fill karstic depressions in the San Andres Limestone. These Triassic deposits are only mapped where sufficiently large for 1:24,000-scale mapping. The largest spring on the quadrangle (Nutria Spring) discharges from near the base of the San Andres Limestone (Drakos et al. 2013). The unit is light- to medium-gray, coarsely crystalline, fossiliferous limestone; unit appears very light-gray on fresh surfaces with some silty/sandy limestone intervals. Characteristic 'eggshell' weathering. Unit contains interbeds of grayish-yellow dolomite with abundant calcite crystals and gray silty dolomite. Minor light-red (2.5YR 6/6), fossiliferous, crystalline-limestone beds found in the lower part of the San Andres Limestone. Fossils include brachiopod and pelecypod shells/ casts, crinoid fragments, and rare nautiloids. Brachiopods are the predominant fossil observed. Banded chert locally occurs at base of the San Andres Limestone. The unit thickness ranges from absent at a location in the east half of section 3 T12 N, R16W, where the Moenkopi Formation sits disconformably on the Glorieta Sandstone, to approximately 150 ft (0–48 m).

Pg **Glorieta Sandstone (Permian)**—The unit is exposed in the walls and at the bottom of the Nutria Canyon and its tributary drainages, on the gently east-sloping surface in the northeast portion of the quadrangle, and in Oso Ridge. Very well-sorted, white (2.5YR 8/1–8/2) to pink (7.5 YR 7/4), well-rounded, very well-indurated, fine-grained quartz arenite with <2% lithics. Noneffervescent in HCl. The unit forms massive or cross-bedded, blocky, highly fractured outcrops, cliffs, and steep-sided canyons up to 200 ft deep. Outcrops on top of Oso Ridge, just south of McGaffey Campground, have abundant fine (1–3 cm) planar beds and low-angle planar cross-beds. The Glorieta Sandstone on the west side of Oso Ridge is generally massive with minor cross- beds and forms blocky outcrops. Thickness of the unit is 200–250 ft (61–76 m).

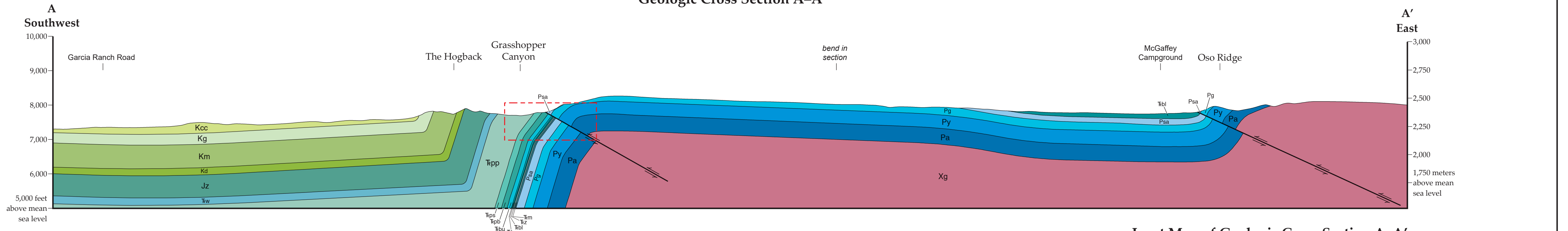
Py **Yeso Formation (Permian)**— Unit is composed of interbedded silty or sandy dolomite, limestone, and sandstone exposed on the east side of Oso Ridge in the northeast portion of the quadrangle and within the Hogback. Interbedded orange/red and white sandstone, light-brownish-gray (10YR 6/2) silty and sandy dolomite, and limestone. Three carbonate beds are generally present, each 3–6 ft (1–2 m) thick, comprising gray, crystalline, nonfossiliferous dolomite or limestone beds. Interbedded and overlying sandstone beds are predominantly orange, well-indurated, moderately to well-sorted, subangular to rounded, fine- to very fine-grained quartz sandstone, with minor to common lithics and weathered feldspar in orange intervals and minor (<2%) lithics and feldspar in white intervals. The lowest carbonate bed is the basal contact of the Yeso Formation and overlies the red Abo Formation sandstone. Thickness of the unit ranges from 300–400 ft (91–122 m).

Pa **Abo Formation (Permian)**—The Abo Formation is exposed in the area east of Oso Ridge in the northeast portion of the map. The Abo Formation includes red (10R–2.5YR 4/6), fine- to very fine-grained, silty, locally micaceous arkosic sandstone and interbedded shale. Massive to cross-bedded; thin (1–2 cm)- to medium-bedded (≈10 cm), moderately to well-indurated, minor white sandstone interbeds. Noneffervescent to strongly effervescent with HCl. Shale beds are covered, but shale and mudstone make up the majority of the Abo Formation on the adjacent Fort Wingate quadrangle (Anderson et al., 1998). Lower Abo Formation is more prominently cross-bedded and includes trough cross-bedded fine- to coarse-grained arkosic litharenite with calcite cement with minor granule- to pebble-conglomerate beds comprised of limestone and dolomite rip-ups. Includes some thin, discontinuous Pennsylvanian carbonate (limestone and dolomite) beds and trough cross-bedded sandstone deposited on irregular Precambrian granite surface at the base of the Abo Formation. Thickness of the unit is up to 400 ft (120 m).

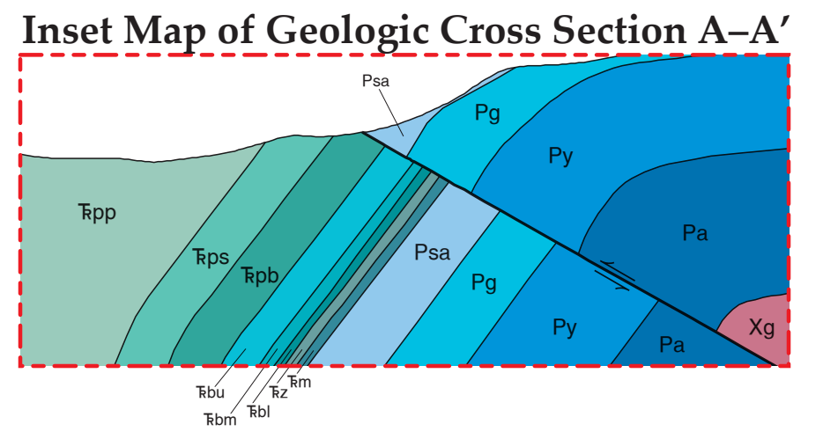
PROTEROZOIC

Xg **Granite of Zuni Mountains (Proterozoic)**—The granite of Zuni Mountains is exposed east of Oso Ridge, in the northeast portion of the map, where it forms rounded hills and underlies the high point (8,137 ft) on the quadrangle (McGaffey Lookout tower). Pink, somewhat friable, and abundantly weathered, "grussified" phaneritic granite (individual crystals 0.5–1 mm diameter), consisting of quartz (≈50%) – plagioclase (≈30-40%) – amphibole (≈10-20%) – muscovite (<1%).

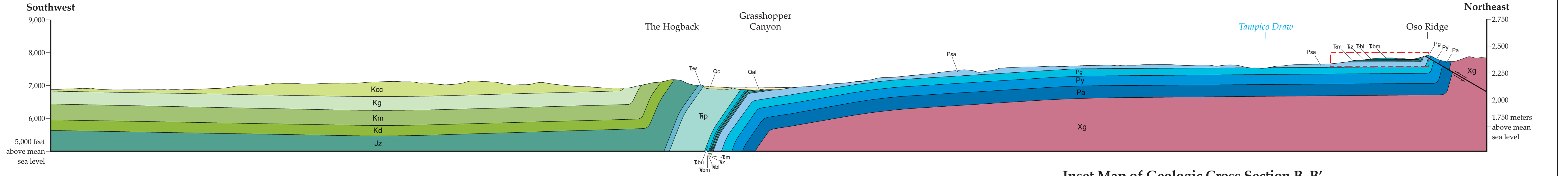
Geologic Cross Section A–A′



Inset Map of Geologic Cross Section A–A′



Geologic Cross Section of B–B′



Inset Map of Geologic Cross Section B–B′