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

By
James Riesterer and Paul G. Drakos

Glorieta Geoscience, A Division of GZA Geoenvironmental, Inc.,
PO Box 5727, Santa Fe, New Mexico, 87502

September, 2024

New Mexico Bureau of Geology and Mineral Resources
Open-file Digital Geologic Map OF-GM 313

Scale 1:24,000

This work was supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program (STATEMAP) under USGS Cooperative Agreement 06HQPA0003 and the New Mexico Bureau of Geology and Mineral Resources.

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

Upper Nutria Quadrangle Executive Summary

The Upper Nutria 7.5 minute quadrangle is located in southwest McKinley County, approximately 21 km (13 miles) south-southeast of Gallup and 12 km (7.5 miles) north-northwest of Ramah. The northern and eastern portions of the map area are accessible via various unpaved county and Forest Service roads branching off of NM state highway 400. The southwest portion of the map are lies within the Zuni Reservation, and is accessible via the Nutria Road from the Village of Zuni. The portions of the map area that are not within the Zuni Reservation are a mix of US Forest Service and private land. Access was not granted to all of the private land holdings within the quadrangle and, for those portions, mapping is based on aerial photo interpretation in conjunction with mapping on adjacent parcels. It is the responsibility of the map user to research and request access permissions to Tribal and private lands as needed.

Geologic mapping of portions of the Upper Nutria quadrangle was originally conducted by Edmonds (1961). Portions of the quadrangle lying within the Zuni Reservation were mapped at various times by Drakos and Riesterer and compiled as both unpublished reports to the Zuni Tribe and as a New Mexico Geological Society field guide article (Drakos et al., 2013). Mapping and unit descriptions from the Fort Wingate quadrangle, located immediately north of the Upper Nutria quadrangle and mapped by Anderson et al. (2003), were utilized for defining Triassic units mapped on the Upper Nutria quadrangle.

The Zuni Mountains are a Cretaceous uplift associated with Laramide deformation (e.g. Thacker et al, 2021). Topography and structure on the quadrangle are dominated by the Nutria Monocline, commonly referred to as the Hogback, which follows a slightly sinuous, north-northwest to south-southeast trend in the middle of the quadrangle, and Oso Ridge in the far northeast quarter of the quadrangle. The southern extent of a low-angle reverse fault ('Stinking Spring thrust') mapped by Edmonds (1961) and Anderson et al. (2003) is mapped on the east side of the Hogback in the northern ½ of the quadrangle, where displacement of up to approximately 200 ft (60 m) places Permian units (San Andres Limestone or Glorieta Sandstone) over the Triassic Chinle Group sediments, resulting in less exposure of the Chinle in the northern portion of the Quadrangle than in the southern, where the reverse fault dies out. The Stinking Springs thrust is offset by several tear faults. A second reverse fault is mapped on the west-side of Oso Ridge in the northeast portion of the map. Offset on the Oso Ridge fault is approximately 200 ft (60 m).

Bedrock units in the Upper Nutria quadrangle range in age from Precambrian to Upper Cretaceous. Precambrian rock exposed in the core of the Zuni Mountains uplift in the northeast corner of the quadrangle consists of the Granite of Zuni Mountains. Granitic rocks are nonconformably overlain by the Permian Abo Formation that forms a west-dipping band along the western margin of the granite. Remnants of Pennsylvanian carbonate pebble conglomerate are locally preserved at the base of the Abo but are not mappable at 1:24,000 scale. The Paleozoic section overlying the Abo Formation includes the Yeso, Glorieta, and San Andres Formations, all of Permian age. These Formations are well-exposed along Oso Ridge, where they are steeply west-dipping to overturned strata, with the Glorieta Sandstone and Yeso Formation typically forming the crest of the ridge. Triassic Moenkopi and lower Chinle Group strata, including Zuni Mountains Formation, Lower Bluewater Formation, and the McGaffey Sandstone, are exposed along an asymmetric syncline west of Oso Ridge.

In the northern part of the quadrangle, the western flank of the Zuni Mountains (the area east of the Hogback and west of Oso Ridge) is a dip slope underlain primarily by Permian San Andres Limestone and Glorieta Formations, whereas in the southern and central portions of the quadrangle the dip slope is primarily McGaffey Sandstone, lower Chinle Group, and Moenkopi Formation strata with local windows into the underlying San Andres Limestone. The Glorieta Sandstone is also exposed in canyons eroded into the Zuni Mountains dip slope.

The Hogback (Nutria Monocline) comprises steeply west-dipping beds of Triassic through Cretaceous sediments. West of the Nutria Monocline the oldest rocks exposed at the surface are the gently dipping (generally <10° dip) Upper Cretaceous sandstone, shale, and coal beds of the Crevasse Canyon Formation. These beds are folded along a shallow syncline that runs parallel to the Nutria Monocline and is likely a continuation of the Allison syncline or, possibly, the Bááhááli syncline mapped on the adjacent Bread Springs Quadrangle (Thacker, *in press*). Within the Nutria Monocline, prominent hogback ridges are formed by resistant sandstone units in the Gallup Sandstone, Dakota Sandstone, and Zuni Sandstone Formations. The hogback ridges are separated by strike valleys of less resistant shale beds within the Gallup Sandstone and by tongues of the Mancos Shale underlying and interfingering with the Dakota Sandstone. East of the Zuni Sandstone are thin, but locally well preserved, exposures of the Iyanbito Member of the Triassic Wingate Formation which form fins of conglomeratic sandstone that overlie the generally less resistant Chinle Group sediments that form a strike valley east of the Hogback. The Chinle Group strike valley gradually broadens from north to south as the Stinking Springs thrust dies out.

The Zuni Mountain highlands and dip slope are recharge areas for the Yeso, San Andres-Glorieta, and Sonsela Sandstone, which are locally and regionally important aquifers. The Rio Nutria is the prominent surface water feature on the Upper Nutria quadrangle, and base flow in this stream is maintained by discharge from the San Andres-Glorieta (Psg) aquifer. Perennial segments of the Rio Nutria provide habitat for the endangered Zuni Bluehead Sucker. The Psg aquifer also discharges at several springs in the Upper Nutria Quadrangle, the most prominent of which is Nutria Main spring (Drakos et al., 2013). The Rio Nutria emerges from Nutria Canyon and flows across the Chinle Group strike valley, but fluvial terraces have not been observed in the quadrangle. Quaternary deposits on the Upper Nutria quadrangle are limited primarily to reworked sediments filling ephemeral valleys, discontinuous coarse gravelly alluvial deposits mantling bedrock in canyon bottoms along the Rio Nutria, Tampico Draw and Six-Mile Draw, and thin colluvial deposits mantling hillslopes. Soils in these deposits are generally weakly developed, with A-Bw-C profiles.

Acknowledgements

The authors wish to thank Zuni Pueblo for granting access to the portions of the Upper Nutria Quadrangle that lie within the Zuni Reservation boundary. Of exceptional help in gaining access and providing guidance on the Reservation were Loren Panteah, Kirk Bemis, Sheldon Lalio, and Andres Cheama. Dr. Steven Reneau joined the authors during mapping of the Oso Ridge area, and his insights, assistance with mapping, and conversation around the campfire were invaluable. We also wish to thank Jacob Thacker for his geologic insights, helpful reviews of the map, and assistance with the digital compilation.

References

Anderson, O.J., Maxwell, C.H., Lucas, S.G., 1998, Geology of the Fort Wingate quadrangle, McKinley County, New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Report 473, scale 1:24,000.

Drakos, P.G., Riesterer, J.W., and Bemis, K., 2013, Recharge sources and characteristics of springs on the Zuni Reservation, New Mexico: New Mexico Geological Society 64th Annual Field Trip Guidebook, p. 205-213.

Thacker, J.O., *in press*, Geologic Map of the Bread Springs 7.5 Minute Quadrangle, New Mexico Bureau of Geology and Mineral Resources.

Thacker, J.O., Kelley, S.A., and Karlstrom, K.E., 2021, Late Cretaceous-Recent Low-Temperature Cooling History and Tectonic Analysis of the Zuni Mountains, West-Central New Mexico; Tectonics, 40, e2020TC006643

Appendix A

Upper Nutria Quadrangle Unit Descriptions

James Riesterer and Paul G. Drakos

af — Disturbed deposits — Deposits disturbed by anthropogenic activities.
ad — Limestone quarry — Limestone quarry in San Andres Limestone.

Qaln — Rio Nutria alluvium — 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 — 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 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 the 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. The unit 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 — 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 — 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 — 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 — 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 — Angular and poorly sorted bouldery deposits derived from mass wasting of cliffs. Mapped only where underlying stratigraphy is significantly obscured.

Kcc — Crevasse Canyon Formation — 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 the 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 — 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 northern quadrangle 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 (noneffervescent 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 — 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 — 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, with gray to brownish-gray silty shale interbeds throughout. Unit is tan on weathered surfaces and white to buff on fresh surfaces. Bivalve casts, bioturbation, and woody fragments occur at the sandstone base. 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; the 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.

Jm — Morrison Formation — 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 Morrison 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 — 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 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).

TRw — Wingate Sandstone — 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 — (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 — 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 — 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 — 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 — 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. 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 the 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 — 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. Blue Mesa Member strata on the Upper Nutria quadrangle are up to 140 ft (43 m) thick.

TRb — Bluewater Creek Formation — 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 — Red (10R 4/4) to dusky red (10R 3/3) mudstone up to 110 ft (33 m) thick.

TRbm — McGaffey Member — 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 — 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 — 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 unit 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 Formations 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 — 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 San Andres Limestone or 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 San Andres Limestone.

TRz — Zuni Mountains Formation ("Mottled Strata") — 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 — 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 as much as 20 ft (6 m).

Psa — San Andres Limestone — 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 are 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. 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 — 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 (7.5YR 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 — 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 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 — 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 base of the Abo Formation. Thickness of the unit is up to 400 ft (120 m).

Xg — Granite of Zuni Mountains — 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%).

References

Anderson, O.J., Maxwell, C.H., Lucas, S.G., 1998, Geology of the Fort Wingate quadrangle, McKinley County, New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Report 473, scale 1:24,000.

Drakos, P.G., Riesterer, J.W., and Bemis, K., 2013, Recharge sources and characteristics of springs on the Zuni Reservation, New Mexico: New Mexico Geological Society 64th Annual Field Trip Guidebook, p. 205–213.

Heckert and Lucas, 2003, Triassic stratigraphy in the Zuni Mountains, west-central New Mexico: N. M. Geological Society, 54th Field Conference, p.241-244.

Hayden and Lucas, 1989, Stratigraphy of the Triassic Moenkopi Formation, west-central New Mexico: N. M. Geological Society, 40th Field Conference Guidebook, p. 59.

Lucas and Hayden, 1989, Triassic stratigraphy of west-central New Mexico: N. M. Geological Society, 40th Field Conference Guidebook, p. 191-212.

Thacker, In Press, Geologic Map of the Bread Springs 7.5-Minute Quadrangle, McKinley County, New Mexico: New Mexico Bureau of Geology and Mineral Resources Open-File Geologic Map.