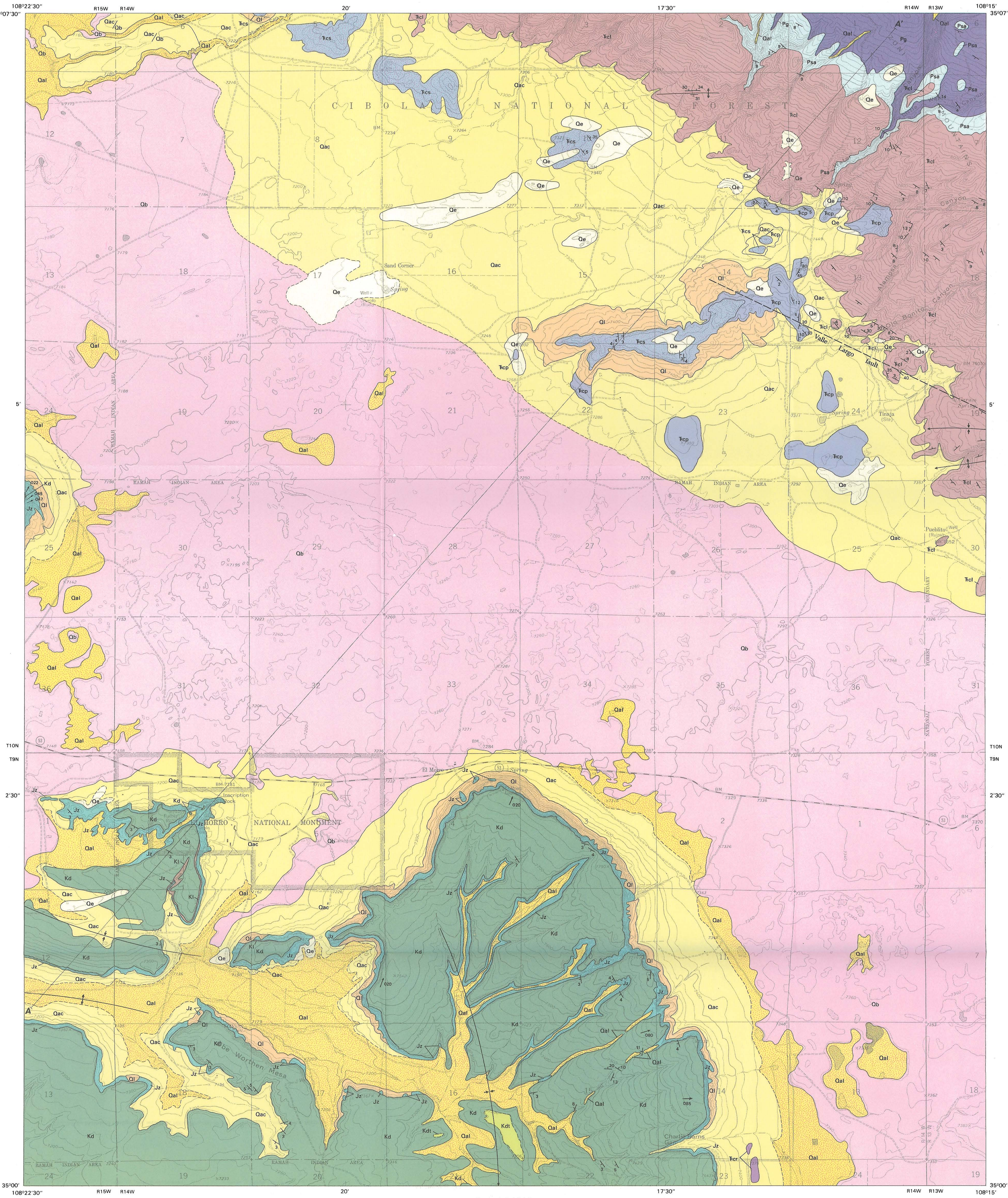
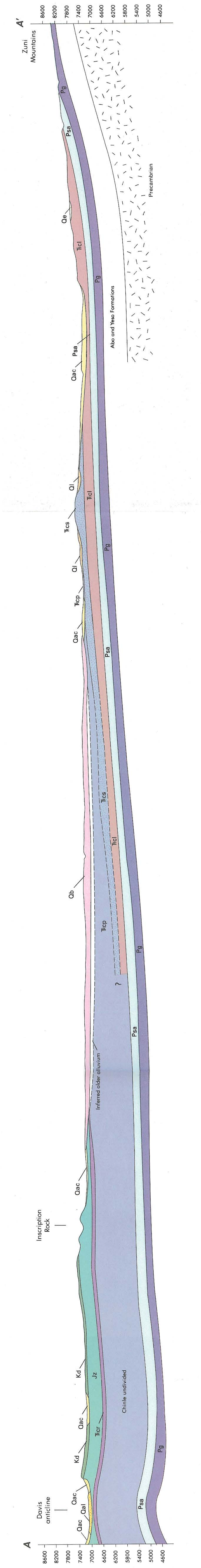
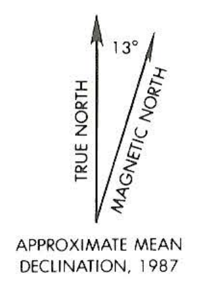
NEW MEXICO BUREAU OF MINES & MINERAL RESOURCES A DIVISION OF NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

GEOLOGIC MAP 72



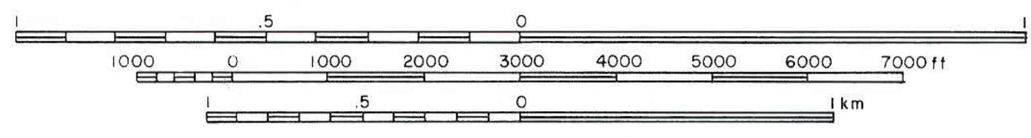


Base from U.S. Geological Survey, 1963; photorevised, 1981
Geology by O. J. Anderson and C. H. Maxwell, 1989



APPROXIMATE MEAN DECLINATION, 1987

Scale 1:24,000



INDEX MAP OF NEW MEXICO

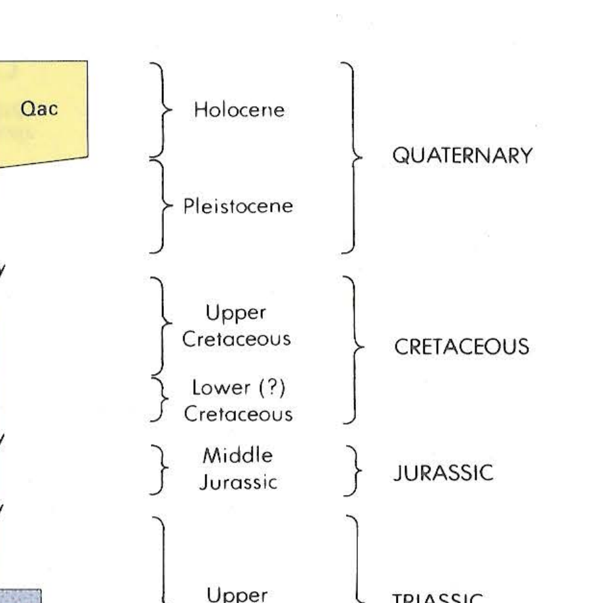
Geologic color separations and layout by C. A. Salisbury
Edited by J. C. Love

Geology of El Morro quadrangle, Cibola County, New Mexico

by Orin J. Anderson[1] and Charles H. Maxwell[2], 1991

[1] *New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801*
[2] *Formerly (now retired) U.S. Geological Survey, Denver, CO 80225*

CORRELATION OF UNITS



DESCRIPTION OF UNITS

Qe

Eolian deposits (Holocene)—Windblown silt and sand in small dunes and sheets; only the thickest accumulations shown. Entire area is characterized by small deposits oriented in an east–northeast direction; blowouts, with dunes on lee (east–northeast) side, are common in the northern part of the area

Qal

Alluvium (Holocene)—Mainly silt and fine-grained sand in active stream floodplains; includes some eolian and colluvial deposits

Qac

Alluvium, colluvium, and eolian deposits (Holocene and Pleistocene)—Variable mixtures of alluvium and colluvium, small landslide blocks, and small sand dunes, generally stabilized by vegetation, on windward (west–southwest) and leeward sides of cliffs and steep hills. A typical example is the slope west of the visitors center at El Morro National Monument

Ql

Landslide deposits (Holocene and Pleistocene)—Large sandstone landslide blocks, talus, and mudslides; may be partly covered by colluvium and eolian deposits

Qb

Basalt flows (Pleistocene)—Weathered basalt generally covered with soil, alluvium, or sand dunes; forms open grasslands with small outcrops of basalt. Rock is slightly porphyritic olivine tholeiite; ages of 0.788 Ma near Cerro Bandera east of map area and 1.38 Ma several miles southwest of map area reported by Luedke and Smith (1978). Unit includes essentially the same flows as "Qbo" of Maxwell (1986)

Dakota Sandstone (Upper Cretaceous)

Kdt

Twowells Tongue—Light-gray and light yellowish-gray, fine- to medium-grained sandstone; generally crossbedded; unit is poorly exposed and may not exceed 25 ft in thickness

Kd

Main body—Sandstone, mudstone and carbonaceous mudstone/shale, and conglomeratic sandstone. Upper part is light-gray to light yellowish-gray, fine- to medium-grained, thinly bedded, locally crossbedded sandstone; low-angle crossbeds in thin tabular sets. Top of unit, and thus upper contact of Kd, not exposed, but may include as much as 20 ft of poorly developed Whitewater Arroyo Tongue of Mancos Shale. Middle part is olive-gray and light- to dark-gray mudstone and shale with fine- to coarse-grained lenticular sandstone beds, which are commonly crossbedded. Lower part consists of medium- to coarse-grained, crossbedded sandstone and conglomeratic sandstone; pebbles in conglomeratic facies are chiefly quartzite and chert and do not exceed 1.25 inches in diameter. Lower part generally a ledge or cliff former, especially the basal 3–25 ft, which are well indurated with silica cement. Lower part is from 0 to 50 ft thick. Absent in those areas where mudstone (middle part) rests on pre-Dakota rocks. Where lower part is absent the Dakota is not a cliff former. Locally gradational into underlying reworked Zuni Sandstone. Thickness of Dakota does not exceed 125 ft

Kl

Reworked deposits of Zuni Sandstone (Lower ? Cretaceous)—This light-colored sandstone represents fluvial reworking of up to 30 ft of the upper part of the Zuni Sandstone; present at several locations in the region, notably in the southern part of El Morro National Monument and southward. The reworking involves redistribution of the eolian sand, oxidation, addition of some clay and chert grains and pebbles, and introduction of lenses of pebble conglomerate. The top few inches down to 1–2 ft are commonly reworked throughout the region but are not mapped separately; typical examples are found along the trail on top of the mesa above Inscription Rock

Jz

Zuni Sandstone (Middle Jurassic)—Generally pale yellowish-gray or tan sandstone; however, locally chalk white or pale greenish gray; very well sorted, fine- to medium-size, well-rounded grains largely of quartz; large-scale eolian crossbeds in upper part, smaller crossbeds and flat bedding in lowest part. Conspicuous bleached zone at top; locally contains crosscutting zones of red or greenish-gray staining and large, spheroidal, gray-brown nodules with calcitic cement and introduced organic material. Lowermost part contains red sandstone and thin layers of red sandy mudstone; may be equivalent to the Entrada Sandstone (Anderson, 1983). Lower contact with the Chinle Formation is not exposed. Thickness varies from approximately 200 ft in southeastern part of the quadrangle to as much as 350 ft at El Morro Lookout in sec. 4 T9N R14W

Chinle Formation (Upper Triassic)

Ʀcr

Rock Point Member—One small area of outcrop in southeastern part of quadrangle; however, Rock Point is inferred elsewhere under a cover of colluvium, talus, or basalt. Outcrops approximately 1 mi west of northwest corner of map area are composed of alternating red-brown, even-bedded, fine-grained, silty sandstone and chocolate-brown to red, thin-bedded, fine-grained sandstone that grades upward into a friable, well-sorted reddish-brown sandstone and chert-pebble conglomerate (Smith, 1958)

Ʀcp

Petrified Forest Member—Grayish-red to reddish-brown and variegated purple-red shale, silty shale, and mudstone; locally mottled greenish gray; interbedded reddish-brown siltstone and friable sandstone; limestone-pebble conglomerate at top and a few thin lenses of coarse-grained sandstone near top. Petrified Forest Member mostly covered by basalt or colluvium in map area. Estimated thickness approximately 1,100 ft

Ʀcs

Sonsela Sandstone Member—Yellowish-gray to grayish-red, fine- to coarse-grained sandstone with granule to pebble conglomerate; medium to thick crossbed sets; thin partings of purple-gray and red siltstone and mudstone. Appears to thin westward; maximum thickness 140 ft

Ʀcl

Lower member—Grayish-red and reddish-brown sandstone interbedded with reddish-brown siltstone. Contains medium- to coarse-grained, arkosic, micaceous sandstone beds and lenses of pebble conglomerate. Both calcitic- and silicic-cemented facies present. Forms conspicuous dip slope in northeastern part of quadrangle. May be all or in part correlative with the Lower and Middle Triassic Moenkopi Formation. Thickness 100–150 ft

Psa

San Andres Limestone (Lower Permian)—Upper part is massive, pinkish-gray, fossiliferous limestone, locally containing productid brachiopods; middle part is yellowish-gray sandstone with calcitic cement, locally grading into sandy dolomitic limestone; lower part is mostly yellowish-gray to gray, thick-bedded, fossiliferous, dolomitic limestone with thin calcareous shale partings and thin sandy limestone lenses. Lower part is generally the thickest of the three. Forms cliffs and dip slopes. Total thickness 115–145 ft

Pg

Glorieta Sandstone (Lower Permian)—Very pure, well-sorted, white to buff, medium- to coarse-grained quartz sandstone; massively crossbedded; weathers yellow to light brown; well cemented with silica or calcite; forms cliffs, ridges, or dip slopes; approximately 150 ft thick; base not exposed in quadrangle

MAP SYMBOLS

020 ↗	**Bearing of slickensides**—In basal Dakota Sandstone
├─┤	**Measured-section locality**

(additional symbols on envelope)

INTRODUCTION

El Morro quadrangle is located 35 mi (56 km) by highway southwest of Grants, New Mexico, along the south flank of the Zuni Mountains. It lies essentially in the transition zone between the Zuni Mountains and the southern Zuni Basin. Ready access is provided by NM–53, which extends east–west across the quadrangle (Fig. 1). Several secondary roads lead north and south of the main highway, allowing easy access to the Zuni Mountains, North Plains basalt flow, and the Ramah–Navajo Agency. No towns or villages presently exist within the quadrangle; however, a store and campground are maintained at El Morro, approximately 1 mi (1.6 km) east of the entrance to El Morro National Monument.

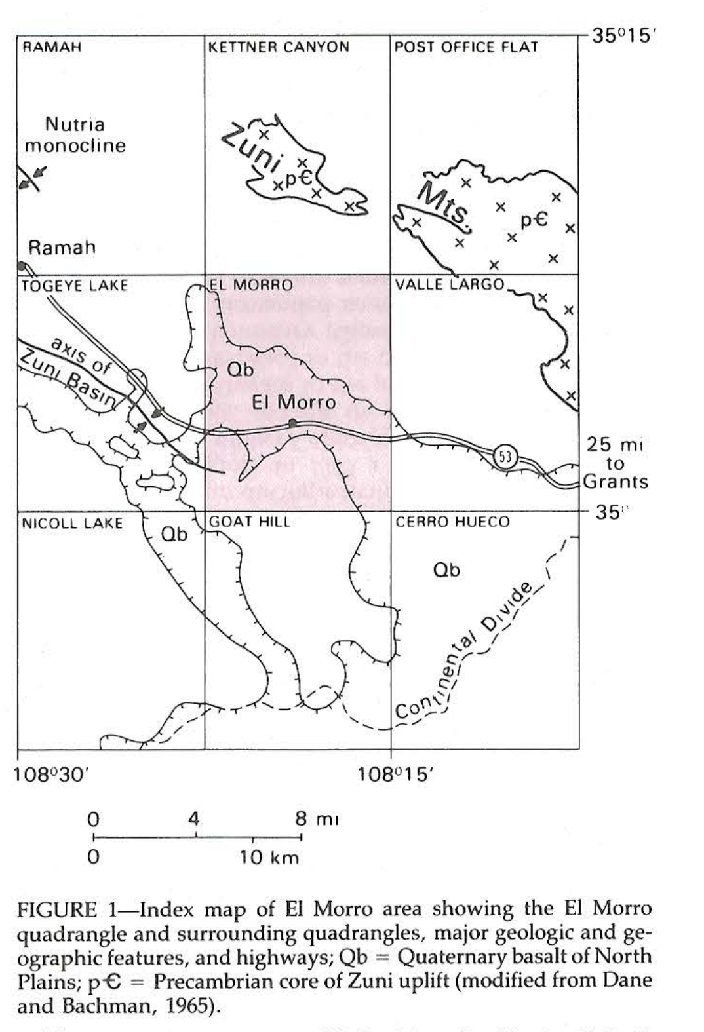


FIGURE 1—Index map of El Morro area showing the El Morro quadrangle and surrounding quadrangles, major geologic and geographic features, and highways; Qb = Quaternary basalt of North Plains; p€ = Precambrian core of Zuni uplift (modified from Dane and Bachman, 1965).

The monument was established by the National Park Service in 1906 for the purpose of preserving the inscriptions of names and dates carved into the bold white sandstone cliffs by early Spanish explorers and other visitors. The oldest of these inscriptions is dated April 16, 1605. The prominent cliffs lie along the south side of a natural east–west route through what was then unexplored, uncharted low mountain, mesa, and canyon country.

The Continental Divide crosses NM–53 10 mi (16 km) east of the quadrangle boundary, and thus the area is drained by the extensive Little Colorado River system, through the Zuni River–Pescado Creek–Ramah Valley tributary network. Parts of the quadrangle are poorly drained and/or have vaguely defined drainage patterns. The northwestern corner is drained by Muerto Canyon, which is tributary to the Ramah Valley via Togeye Canyon. The remainder of the quadrangle is drained by ephemeral tributaries to the Ramah Valley, but in places evidence of overland flow does not exist. Two structural blocks, identified by their associated cuestas and mesas, are the main influence on the local drainage network. The Dakota Sandstone-capped cuesta that extends from Ramah to a point on the west-central boundary of the El Morro quadrangle is herein referred to informally as the Ramah structural block. This block with gentle southwestward structural dip is on strike with and represents a lateral ramp associated with the Nutria monocline. Directly to the southeast of this lateral ramp is the El Morro block, which has contrasting dips and fold patterns.

The depth of scour and backfill in the major drainages influences the hydrology and water resources of the El Morro and Togeye Lake area. The relatively coarse alluvium that occupies old channels now buried under the North Plains basalt flow is likely to be a good local aquifer. Based on water well drilling information reported by a local rancher, the basalt is 180 ft (55 m) thick in the SE$^1/_4$ sec. 1 T9N R15W. Drilling through basalt, however, is expensive. General hydrologic information in the area to the west of the El Morro quadrangle is provided by Crouch (1991), Orr (1987), and Roybal et al. (1984).

Annual precipitation from 12 to 14 inches and a lack of arable land allow for very little dry-land farming. Small corn fields are limited to the wider tracts of alluvial valley floors. Annual precipitation increases to 16 inches at the higher elevations in the northern part of the quadrangle (Roybal et al., 1984).

Previous geologic studies in the vicinity include those of Smith (1958), who mapped this area (without benefit of topographic sheets) as part of the Inscription Rock 15-min quadrangle, Maxwell (1986), who mapped and described the El Malpais National Monument area to the east, Goddard (1966), who mapped the central core of the Zuni Mountains and discussed the fluorspar district, and Mapel (1985), who mapped and described the coal resources of the adjacent Togeye Lake quadrangle.

ACKNOWLEDGMENTS—This study, primarily to describe the general geology of the area and to look for structural features that may be associated with the Laramide deformation of the Zuni Mountains, was done with the encouragement of Richard M. Chamberlin and Frank E. Kottlowski. In addition one of us (CHM) was also interested in the westward projection of the Valle Largo fault, as well as the local character and extent of the Moenkopi Formation and the Sonsela Sandstone Bed of the Chinle Formation. The New Mexico Bureau of Mines and Mineral Resources provided the support for the field work, which was completed in 1989. We want to especially thank Margery Detring for her help in the field, and for the courtesy and cooperation extended to us by Mr. Paul Davis, Mr. Reed Detring, Mr. S. R. Ferguson, and Mr. Sylvester Mirabal we express our gratitude. The text and map were reviewed and improved by Robert O'Sullivan of the U.S. Geological Survey and by R. M. Chamberlin of the New Mexico Bureau of Mines and Mineral Resources; a note of thanks goes to them and to Lynne McNeil, who prepared the manuscript.

GEOLOGIC HISTORY

The Precambrian core of the Zuni uplift has a long history as a mildly positive area, probably spanning most of Paleozoic time. The evidence based on Precambrian and early Paleozoic structural trends suggests that little or no deposition occurred during pre-Pennsylvanian time. The Pennsylvanian limestones that were deposited were subsequently removed by erosion during the Ouachita (ancestral Rockies) orogeny, leaving only isolated outcrops. There is thus no sedimentary record on the Zuni uplift of geologic activity during the preceding 270 million yrs of the Paleozoic. Away from the uplift the Pennsylvanian section thickens at a high rate.

As the Pennsylvanian sea retreated continental–fluviatile deposition ensued and imparted a distinctly different aspect to the Permian rocks. The basal Permian unit in the Zuni Mountains area and throughout much of New Mexico is the Abo Sandstone. Commonly, there are several feet of arkosic sandstone at the base of the Abo that grade upward into more mature, finer-grained sandstone and mudstone. The Abo is overlain by the Yeso Formation, which consists of fine-grained, marginal-marine sediments interspersed with evaporite and carbonate beds. Following deposition of the Yeso, a transgression of the Permian seaway resulted in deposition of the Glorieta Sandstone (*Pg*), a very mature, well-sorted, crossbedded, high-quartz sand deposited in beach, shoreface, and backshore-eolian settings. It is perhaps the most distinctive stratigraphic unit in the Permian, along with its lateral equivalent the Coconino Sandstone in Arizona. The Glorieta is the oldest Paleozoic unit exposed in the El Morro quadrangle. A shallow shelf environment was established relatively soon after deposition of the Glorieta Sandstone, and clastic sediment supply to the seaway was greatly reduced. On this shallow, warm, sediment-starved shelf, limestone began accumulating, ultimately to form the youngest Permian rocks of the Colorado Plateau, the San Andres Limestone (*Psa*)— the Kaibab Limestone in Arizona. The shallow sea teemed with life, as the San Andres locally is very fossiliferous, especially in the upper part. Productoid brachiopods dominate the faunal assemblage. The writers have noted the occurrence of productoid brachiopods and nautiloid cephalopods in the San Andres Limestone along the southwest flank of the Zuni Mountains from Upper Nutria to El Morro quadrangles. No collection was made, however, from the El Morro quadrangle. The age of the San Andres has been established as late Leonardian (McKee, 1938; Baars, 1962). Baars (1962) has also provided an excellent summary of Permian depositional systems of the Colorado Plateau.

At the close of Permian time, seas retreated, a long period of crustal quiescence ensued, and the karst surface, which had been initiated during Ochoan (latest Permian) time, continued to develop on the San Andres Limestone. Throughout much of Early Triassic time the area was one of low relief and nondeposition. By Middle Triassic time the continental–fluviatile sediments of the Moenkopi Formation had accumulated, although in very moderate thicknesses, across the Zuni Mountains and central New Mexico in general (Stewart et al., 1972). In the El Morro quadrangle we included these strata in the lower member of the Chinle Formation (*Ʀcl*), even though the lithologies—sandstone, siltstone, and conglomerate—indicate a Moenkopi presence. These two units were mapped together for the following reasons:

1) mappability; the unit has limited exposure, and the contact between a Moenkopi and a Chinle could not be picked on this quadrangle. The widespread unconformity between the two units elsewhere (Stewart et al., 1972) is not apparent at El Morro.

text continued on back