El Morro quadrangle is located 35 mi (56 km) by highway south of Grants, New Mexico, along the south slopes of the Zuni Mountains. It lies essentially in the transition zone between the Zuni Mountains and the southern Sandia Range. 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.

The quadrangle 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, 1865. The prominent cliffs lie along the south side of a natural east-west route through which was then unexplored, uncharted low mountain range, men, 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-Pecos-Creek-Ramah Valley tributary network. Parts of the quadrangle are poorly drained and have vaguely defined drainage patterns. The northwestern corner is drained by the San Juan Valley, which is tributary to the Ramah Valley via Toegye 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 coesites 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.

The deepness of scree and backfill in the major drainages influences the hydrology and water resources of the El Morro and Toegye 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 SE1/4 sec. 1 TNF E1SW. Drilling through basalt, however, is expensive. General hydrologic information in the area to the west of the El Morro quadrangle is provided by Couch (1931), 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 (1956), 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 Hopi Indian district, and Mapel (1980), who mapped and described the coal resources of the adjacent Toegye 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 deformation of the Zuni Mountains, was done with the encouragement of Richard M. Chamberlin and Frank E. Kottlowski. In addition, we are indebted to the state geologist of New Mexico, Dr. John K. Draper, and to the New Mexico Bureau of Mines and Mineral Resources for supplying the information we have used.

The writers have noted the occurrence of productoid brachiopods and mantellid cephalopods in the San Andres Limestone, and also investigated outcrops of the Zuni Sandstone that extend into the quadrangle. The sandstones of the Zuni Sandstone were exposed in the Ramah Valley prior to the construction of the Toegye Canyon road. The writers are indebted to the New Mexico Bureau of Mines and Mineral Resources for supplying the information we have used.

The manuscript is in preparation by Robert O'Sullivan of Arizona State University, and the authors wish to extend our thanks to him for his help in the preparation of this manuscript.

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2) lack of biostratigraphic control; no microfossil recovery or identification was attempted on samples from this interval. Kurtzke (1988) recovered and identified ostracods and algal remains from a lithologically similar unit in a stratigraphically similar position in the Luerro uplift 60 mi (97 km) to the east. The microfossil evidence he interpreted as suggesting an Early to Middle Triassic age for these Moenkopi strata. Hayden and Lucas (1989) have correlated provisionally Moenkopi strata in the Zuni Mountains area with the Holbrook Member, which is the uppermost member of the Moenkopi in eastern Arizona.

During Late Triassic time this thin blanket of Moenkopi sediments was buried by the thick fluviatile and lacustrine sequence that we now know as the Chinle Formation. The Moenkopi and the Chinle were deposited by fluviatile systems flowing generally westward across New Mexico and Arizona to deltaic areas in what is modern Nevada (Blakey and Guhlson, 1983).

During Early and Middle Jurassic time arid climates prevailed, and extensive eolian deposition took place in the Colorado Plateau region. However, in the Zuni Mountains-El Morro area, only the Middle Jurassic is preserved as the Zuni Sandstone (J2), the lateral and homotaxial equivalent of the Entrada and Cow Springs Sandstones (Anderson, 1983). The Zuni Sandstone thins at a moderate to high rate southward from El Morro. From regional relationships we can infer that it pinches out in the subsurface approximately 25 mi (40 km) south of the quadrangle. The Zuni pinchout is due to subniveal northward tilting accompanied by pre-Dakota beveling of the landscape.

The area remained stable and featureless for the remainder of the Jurassic Period and through Early Cretaceous time. Some minor reworking of the Zuni Sandstone took place in this time frame, and small, isolated patches of these deposits (K2) are preserved in the El Morro quadrangle. With the advent of Late Cretaceous time, beginning about 96 million yrs ago, the Western Interior seaway was encroaching upon New Mexico, leaving a sedimentary record that indicates lower coastal-plain, marginal-marine, and, finally, marine sedimentation. The Dakota Sandstone (K2) represents, for the most part, coastal-plain and marginal-marine deposition associated with the initial transgression of the seaway. Offshore, open-marine deposition is recorded in the Mancos Shale, which has been removed by erosion in the El Morro area. Regression of the sea, or coastal progradation, produces the depositional facies in reverse order; however, the regression was complicated by numerous major and minor readvances of the sea. The Zuni pinchout may reflect a shift in Laramide stresses across a basin fault zone. No significant local shear indicators have been found; however, the extra-local and regional faults, shear indicators, and fold structures support the hypothesis. The hypothesis is based on the concept of indentation-extrusion tectonics as described by Tapponnier and Molnar (1976) and Tapponnier et al. (1982).

Regardless of the exact model and pattern of local compressive deformation during the Laramide, numerous reverse faults, overturned folds, and local monoclinal and strike-slip faults were formed or reactivated. Some of these structures were rejuvenated again during the middle to late Tertiary when a different stress field was developing and playing a role in defining the Colorado Plateau and Basin and Range provinces.

During and following the Laramide orogeny several thousand feet of strata were removed from the Zuni uplift, along with some unknown but small Precambrian granitic rocks. Current elevations at present are near 9,000 ft (2,727 m). Nearest Precambrian basement exposures are 4 mi (6.4 km) to the north; it is 600-800 ft (183-244 m) to the Precambrian basement at the northeastern corner of the quadrangle.

One of the characteristics of the Colorado Plateau with its thicker crust (in relation to the Basin and Range province) is a relative paucity of volcanic rocks. Located as it is in the southeastern part of the Colorado Plateau province, the El Morro area escaped the extensive silicic and intermediate Oligocene volcanism that dominates the landscape beginning 60 mi (97 km) to the south. From 7 to 5 million yrs ago basaltic volcanism occurred in the general area, to the east-northeast near Grants, and 25 mi (40 km) to the east-

**FIGURE 2—Measured stratigraphic section in NE6/4, NE4/4, NW1/4, NW1/4, Cibola County, New Mexico.**

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper:</td>
<td>fine-grained, light-gray, medium-grained sandstone, thinning</td>
</tr>
<tr>
<td>Middle:</td>
<td>carbonaceous, multistoried clay, no fossil, dark gray, gray-brown, water-worn pebbles, grading upward to light gray, fine- to medium-grained sandstone, laminated beds at top</td>
</tr>
<tr>
<td>Lower:</td>
<td>conglomeratic, sandstone at base with quartzite and chert pebbles, grading upward to light gray, fine- to medium-grained sandstone, laminated beds at top</td>
</tr>
</tbody>
</table>

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**Table:**

<table>
<thead>
<tr>
<th>Stratigraphic units</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>K2</td>
<td>upper: fine-grained sandstone, light gray; middle: fine-grained sandstone, laminated; lower: conglomeratic sandstone, base with quartzite and chert pebbles, grading upward to light gray, fine- to medium-grained sandstone, laminated beds at top</td>
</tr>
</tbody>
</table>

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**Explanation:**

- **Carboneous**
- **Crossbedded sandstone**
- **Trace fossil, burrows**
- **Ripple-bedded zone**
Microbrutts preserved in Dakota Sandstone are found in many places in the south-central part of the quadrangle (secs. 3, 4, 9, 10, and 21 T9N R15W, and as well as in the small Dakota outcrops along the west-central margin of sec. 25). The microbrutts are commonly present as conjugate sets with nickpoints and minor displacement components that form a N22°-47°E direction, although more easily trends can be found at the sec. 14 locality.

HISTORICAL NOTES

The region in and around the El Morro quadrangle had a large Amerind population in prehistoric times. At least eight large pueblo complexes, including the two at El Morro National Monument, and innumerable small rooms (1-10 rooms) are found in the quadrangle. The area had many localities of permanent water and had sufficient moisture and soil suitable for the indigenous style of agriculture. Game animals were probably plentiful, as they are today. The pueblos in the area were built and occupied at least during the 12th and 13th centuries and possibly before and after that period.

The broad flat valley that crosses the center of the quadrangle became a natural passageway for the movement of people and goods during prehistoric time, during the Spanish conquest and settlement, and during the American exploration and settlement. The route was called the "ancient way" by the Spanish, who traveled through the area for 300 yrs, beginning with Coronado in 1540. American explorers began using it in 1849. The U.S. Army surveyed the area as a possible route for a transcontinental railroad in 1853. The route still is traveled because segments of it are paralleled by NM-53.

The abandoned settlement of Tijaya, 3 mi (5 km) north of NM-53, may have been established shortly after 1700, during the period of Spanish settlement following the Pueblo Revolt of 1680. The name appears on early 18th century maps but whether it refers to the settlements of the Descalzos or to an Indian pueblo approximately 3 + mi (5 km) west of the townsite is not clear. The Indian pueblo is circular, built around a depression cut by a large permanent spring; "tijaya" is Spanish for a large earthen jar used for storing water.

Following American settlement in the 1860s and 1870s, the major income-producing activities in the area were cattle ranching and logging. In 1893 a logging railroad of the George E. Breece Lumber Company was driven up Canyon Largo, east of Tijaya, and into the quadrangle near Caruso Spring, thence northward to the mouth of Water Canyon, and north-northwestward to the center of the quadrangle near its northern boundary south of Hereford. The railroad was dismantled sometime before 1943, and little evidence of its existence remains today.

El Morro (spanish, "the headland") was a major stopping place along the ancient way because of its permanent water hole and probably because of the protection it offered from the elements. The first known historical mention of El Morro is in the journal of the Espejo expedition in 1583, and the oldest proven message carved into the walls of Inscription Rock (El Morro) is by Don Juan de Oñate on the 16th of April, 1605. The last authenticated date is by U.S. Army Lieutenant Simpson in 1849 (Lohr, 1959). The El Morro National Monument was established in 1906 to preserve the old inscriptions and to prevent additional name carving. The National Park Service has administered it since 1953.

The pool of water at the base of the cliffs in El Morro National Monument is the only reliable source of water for the popularity with early explorers. It is not known if the containment is entirely natural or whether early Indians as- 
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The initial plunge pool may have become a more effective water trap by a fortuitous rockfall from the cliffs above that built up and strengthened the outside edge of the natural containment. The resulting talus pile stabilized, and blow sand and vegetation covered it. This natural trap became even more effective as the standing water allowed fine-grained suspended sediment to settle out and seal the bottom. The thickness of the fine-grained material at the bottom of the water hole is unknown. The natural water hole thus created was eventually breached, perhaps numerous times, on the north side near the cliff wall. Indians and early travelers probably made minor repairs, modifications, and "improvements" to the basic containment structure.

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