Structural geology of the Malpais Valley, San Rafael, New Mexico

T. E. Kelly and Charles B. Reynolds

1989, pp. 119-121. https://doi.org/10.56577/FFC-40.119

in:

Southeastern Colorado Plateau, Anderson, O. J.; Lucas, S. G.; Love, D. W.; Cather, S. M.; [eds.], New Mexico Geological Society 40th Annual Fall Field Conference Guidebook, 345 p. https://doi.org/10.56577/FFC-40

This page is intentionally left blank to maintain order of facing pages.

STRUCTURAL GEOLOGY OF THE MALPAIS VALLEY, SAN RAFAEL, NEW MEXICO

T. E. KELLY[1] and CHARLES B. REYNOLDS[2]

[1]Geohydrology Associates, Inc., Albuquerque, New Mexico 87107; [2]Charles B. Reynolds & Associates, 4409 San Andres Avenue NE, Albuquerque, New Mexico 87110

Abstract—A shallow seismic reflection survey across the Malpais Valley near San Rafael identified a syncline and an anticline disrupted by a graben in the subsurface. Nearly 200 m of alluvium, present beneath a thin layer of basalt, fills a channel cut into the graben. More than 300 m of displacement occurred. The principal movement occurred between 2.3 my and 0.78 my ago.

INTRODUCTION

The Zuni Mountains and many of the other structures in west-central New Mexico are associated with Laramide deformation. These structures have been studied in detail, and there is an extensive bibliography which describes their structural history. The post-Laramide history of the region has been obscured by the vast North Plains volcanic field south of the Zuni Mountains. Owing to the inhospitable terrain on the volcanics, very little information is available, and the structure and stratigraphy beneath the volcanics is poorly understood. However, in 1976 a seismic survey was made by Plains Electric Generation and Transmission Cooperative as part of region-wide exploration for ground water in west-central New Mexico. This was a shallow seismic reflection survey made by Charles B. Reynolds and Associates as a subcontractor to Geohydrology Associates, Inc. The seismic work helps to define the history of the Malpais Valley which separates the Zuni uplift from the slightly-deformed strata on Las Ventanas Ridge east of the valley (Fig. 1).

STRATIGRAPHY AND SEISMIC PROFILE

Three distinct stratigraphic sequences are present along the Malpais Valley south of the Village of San Rafael. The Zuni Mountains form an asymmetric Laramide dome having a Precambrian core flanked by concentric bands of Permian and Triassic strata. The Leonardian Yeso Formation is the oldest unit exposed in the San Rafael area. On the west side of the Malpais Valley the section consists of, in ascending order, the Yeso, the Glorieta Sandstone, the San Andres Limestone and the basal Chinle Formation. According to Cooley (1959, p. 66), the unconformity separating the San Andres from the Chinle becomes progressively greater from west to east, and in the San Rafael area the basal Chinle may be Upper Triassic.

On the east side of the valley, rocks ranging from the Middle and Upper Jurassic San Rafael Group to the Cretaceous Mancos Shale are present. These exposures mark the southern limit of the Morrison Formation, which pinches out southeast of San Rafael. Locally, there is a thin alluvial cover on these Mesozoic strata.

The basalt flows which blanket the Malpais Valley have been conveniently grouped by Maxwell (1982, fig. 1) as "flows from the Zuni Mountains." These include flows from El Calderon and the Bandera cone, both of which originated on the southwest flank of the Zuni Mountains, and the McCartys flow which was extruded from a cone nearly 40 km south of San Rafael. According to Crumpler (1982, p. 292), these flows range in age from 500,000 to 1000 years. However, there is some historical evidence to suggest that the McCartys flow may be as young as 400 years (Maxwell, 1982, p. 300). Alluvium was deposited contemporaneously with the various flows.

According to Kelley and Clinton (1960, fig. 7), the Zuni uplift is the most faulted structure on the Colorado Plateau, having faults and joints with a diverse pattern. On the eastern fringe of the uplift, Kelley (1967, p. 29) described the pattern of faults and joints as semi-radial which is characteristic of an epianticlinal system although this pattern is not readily apparent near San Rafael (Fig. 1). Most of these are high-angle, normal faults with throws up to 75 m; however, the Sedgwick fault, which bounds the highest peak, may have a throw of 915 to 1219

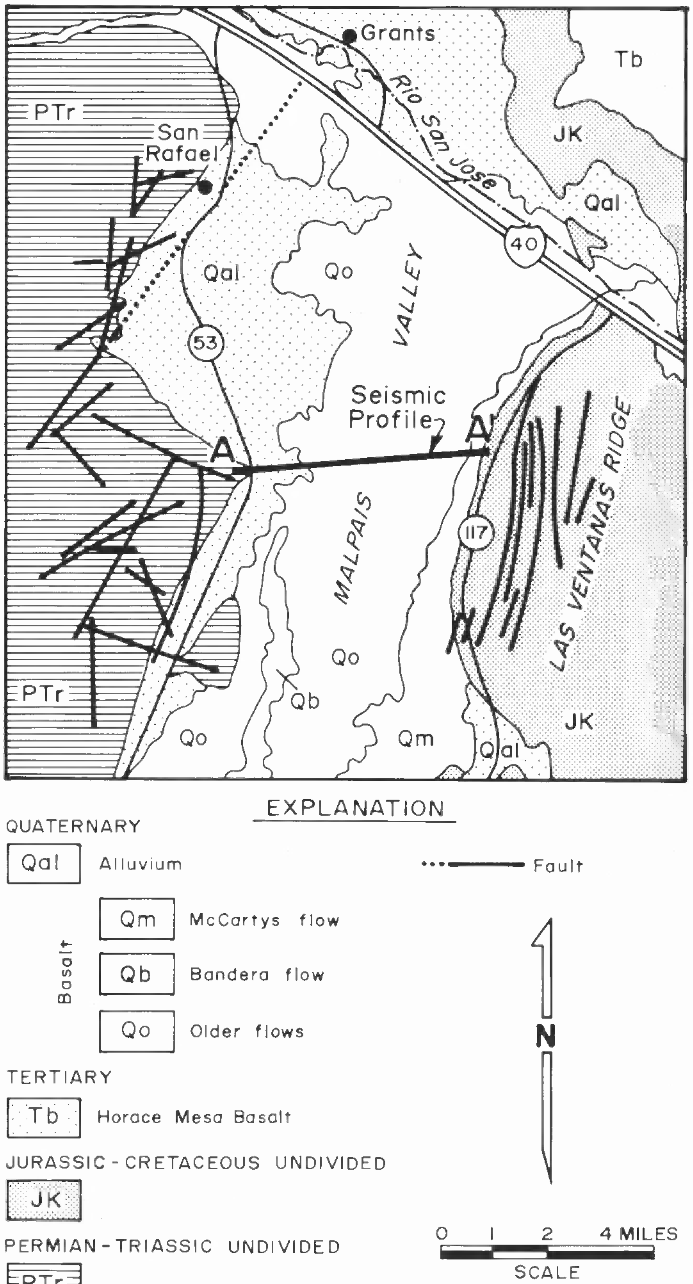

FIGURE 1. Generalized geologic map of San Rafael area showing location of seismic profile across Malpais Valley. Cross section A-A' shown in Figure 2. Modified after Gordon (1961, plate 1) and Maxwell (1982, fig. 1).

m (Kelley, 1967, p. 29). On the east side of the valley, there are a number of closely spaced, high-angle, normal faults which cut the Mesozoic section (Fig. 1). The total displacement on most of these faults is less than 61 m. The strike of these faults is generally parallel to the major trend on the west side of the valley, and the semi-radial pattern is generally lacking.

The stratigraphic relationships on opposite sides of the valley indicate that major faults are concealed beneath the alluvium and basalts of the valley. The narrowest point in the valley is approximately 5 mi south of San Rafael at a point where a telephone line was constructed across the malpais. The west end of this line crosses the Permian-Triassic contact at an elevation of 1982 m; basal Dakota is present at about the same elevation on the east end of the line, suggesting minimum structural relief of 610 m.

In order to determine the structure of the Malpais Valley and the amount of alluvium that might be present beneath the basalt, a shallow seismic reflection survey was made along the telephone line which traverses the valley at its narrowest point (Fig. 1). The survey consisted of an east-west single reflection line about 7.25 km long. The stations were 100 m apart along the line. Elevations were determined from topographic maps. A 300-kg steel weight, serving as the seismic energy source, produced about 3000 joules when allowed to free-fall a distance of about 1 m. An average of about three drops per station was used. The receiver array consisted of 12 digital-grade geophones of 10 Hz rating spaced 3.5 m apart in line. The completed reflection records were studied, and seismic events or "lineups" considered most likely to be bedding plane reflections were picked. The selected seismic events were then converted to a migrated depth section using the point-arc method and velocities normal for the rocks believed present.

The data obtained by the survey were regarded as "fair" quality, but this was surprisingly good considering the presence of surficial basalt over most of the line length. The main structural features identified by the profile were: (1) a faulted syncline near the western end of the line; (2) a faulted anticline in the central part of the profile; (3) a fault system imposed upon the folds and forming a graben; (4) nearly 200 m of alluvial fill in the graben; and (5) a total thickness of basalt of about 30 m (Fig. 2).

The slightly folded strata have been cut by six distinct faults or fault zones. All appear to be normal faults; the greatest throw is present on the faults which bound the graben. Owing to the stratigraphic relationships seen in outcrop, the sum of the displacements of the faults downthrown to the east must be greater than the sum of those downthrown to the west. The strata in the syncline west of the graben appear likely to be of Permian age and are blanketed by a thin layer of alluvium. At the east end of the profile, the velocities indicate that the Cretaceous strata have been downthrown to the west and are covered by alluvium and basalt.

The thickness of the basalt is inferred to be about 30 m. The geometry of the reflections from within the alluvium suggests interbedded sand, gravel and siltstone.

STRUCTURAL EVOLUTION OF THE MALPAIS VALLEY

The history of the Zuni uplift has been described by Kelley and Clinton (1960), Kelley (1963, 1967) and Woodward (1982). The Zuni uplift emerged during Late Cretaceous through Eocene time, contemporaneous with other Laramide structures of the Colorado Plateau. Development of the semi-radial fault system occurred at this time. Also, the bounding faults of the Zuni uplift represented zones of weakness along which later volcanism and structures would form. Kelley (1967, p. 30) estimated that the region was blanketed by 1800 to 3000 m of sediment which were later stripped away from the Zuni uplift. However, much of this stratigraphic sequence remained in place adjacent to the uplift, and the Mt. Taylor volcanics were extruded on rocks of Late Cretaceous age. Crumpler (1982, p. 291) reported that the Mt. Taylor volcanics range in age from 4.5 my to 2.3 my, whereas the McCartys flow may be 1000 years old or younger.

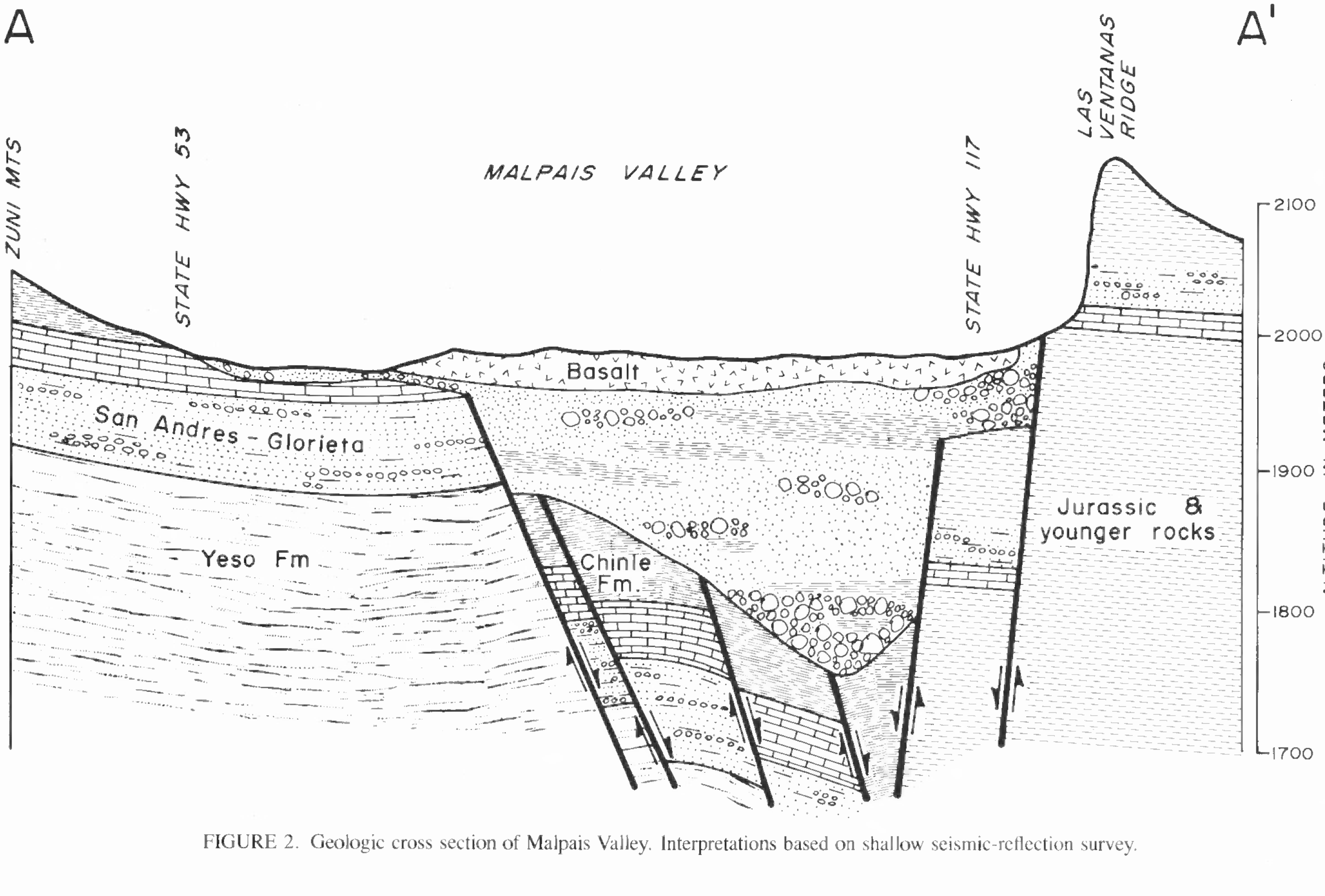

FIGURE 2. Geologic cross section of Malpais Valley. Interpretations based on shallow seismic-reflection survey.

A considerable amount of erosion followed the formation of Mt. Taylor and related flows. The base of Mt. Taylor, as well as flows which cap La Jara and San Fidel Mesas, and Mesas Chivato and Prieta, are all located at elevations of approximately 2300 m. The Rio San Jose cuts through these and the underlying strata; locally the base of this channel may be as much as 350 m below the base of the older volcanics. Presently the Rio San Jose drains Mt. Taylor, the north flanks of the Zuni uplift and the south rim of the San Juan Basin.

Inasmuch as the seismic survey failed to identify any buried basalt in the Malpais Valley, it seems likely that creation of the graben began after Mt.Taylor was in place and during the erosional cycle of the Rio San Jose. Approximately 50 m of alluvium accumulated in the valley of the Rio San Jose near Bluewater and Grants (Gordon, 1961, p. 37), and lesser amounts have been reported near Laguna by Forest Lyford (personal commun., 1978). Clearly, the Malpais Valley was tectonically active at this time. The seismic survey indicates that nearly 200 m of alluvium accumulated in the valley. Much of this probably was derived from relatively short drainage channels flowing off the east end of the Zuni Mountains such as Bonita Canyon and some of the shorter tributaries near San Rafael. There probably was also a major tributary which drained the North Plains volcanic area south of San Rafael; however, this tributary was buried beneath the younger flows.

According to Hunt (1938), the Mt. Taylor volcanics were introduced through the process of progressive stoping associated with collapse of the magma chamber. With the extrusion of the volume of magma which comprises Mt. Taylor, collapse of the overlying strata would be expected. However, the post-Mt. Taylor date and orientation of the graben are not readily compatible with the mechanism suggested by Hunt.

Woodward (1982, p. 141) noted that Late Cenozoic crustal extension resulted in development of the Rio Grande rift, a series of en echelon grabens filled with clastic sediments. There was contemporaneous volcanism associated with the development of these structures. The north-south San Rafael graben has the same orientation of the rift, and the age of the structure also is compatible. The seismic profile indicates that the formation occurred following extrusion of the flows of La Jara and San Fidel Mesas at 2.3 my and prior to discharge of the flows from El Calderon which have been dated as 0.78 my by Maxwell (1982, p. 301).

ACKNOWLEDGMENTS

The authors appreciate the comments and valuable review of this manuscript by Dr. Lee A. Woodward, University of New Mexico Geology Department, and Dr. Frank Kottlowski of the New Mexico Bureau of Mines and Mineral Resources. We are grateful to Plains Electric Generation and Transmission Cooperative for approval to publish the data in this article.

REFERENCES

Cooley, M. E., 1959, Triassic stratigraphy in the state line region of west-central New Mexico and east-central Arizona: New Mexico Geological Society, Guidebook 10, p. 66–73.

Crumpler, L. S., 1982, Volcanism in the Mount Taylor region: New Mexico Geological Society, Guidebook 33, p. 291–298.

Gordon, E. D., 1961, Geology and ground-water resources of the Grants-Bluewater area, Valencia County, New Mexico: New Mexico State Engineer, Technical Report 20, 109 p.

Hunt, C. B., 1938, Igneous geology and structure of the Mount Taylor volcanic field, New Mexico: U.S. Geological Survey, Professional Paper 189-B, p. 51–80.

Kelley, V. C., 1963, Geology and technology of the Grants uranium region: New Mexico Bureau of Mines and Mineral Resources, Memoir 15, 277 p.

Kelley, V. C., 1967, Tectonics of the Zuni-Defiance region, New Mexico and Arizona: New Mexico Geological Society, Guidebook 18, p. 28–31.

Kelley, V. C. and Clinton, N. J., 1960, Fracture systems and tectonic elements of the Colorado Plateau: University of New Mexico, Publications in Geology, no. 6, 97 p.

Maxwell, C. H., 1982, El Malpais: New Mexico Geological Society, Guidebook 33, p. 299–301.

Woodward, L. A., 1982, Tectonic framework of Albuquerque country: New Mexico Geological Society, Guidebook 33, p. 141–145.

Pahoehoe in Quaternary basalt near La Ventana arch at El Malpais National Monument. Photograph taken 22 January 1989 by Paul L. Sealey.