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# THE SONORA EARTHQUAKE OF 1887

By John Randolph Sumner*

## Introduction

The 1887 Sonoran earthquake is historically the largest to have occurred in the southern portion of the Basin-Range province. The surface faulting associated with the earthquake had a normal sense of movement, typical of the Basin-Range province, with vertical offsets of as much as 4 meters and a fault trace 50 km long. The original report of the earthquake (Aguilera, 1888) contains several map errors which are sustained in a subsequent condensed translation (Aguilera, 1920) and in textbook accounts (Figure 31-2 of Richter, 1958) The errors include mislocation of the fault trace 7 km too far to the east and failure to locate the mountain range (elevations $>6000$ ft) that lies east of the fault. Figure 1 is a corrected version of Richter's Figure 31-2 and is designed to replace it. The historic fault scarp occurs along the east side of the San Bernardino Valley of northeastern Sonora, Mexico. This valley is part of a long, continuous rift valley that extends through 6° of latitude, from 27°N to 33°N, along the west side of the Sierra Madre Occidental province in Mexico and into the Basin-Range province of Arizona.

## The 1887 Earthquake Scarp

As reported by Aguilera (1888, 1920) and confirmed in recent visits, the 1887 fault scarp is 50 km long and reaches a maximum height of 4 meters toward the middle. The scarp faces west and extends along the base of the range on the east side of the San Bernardino Valley. Offset on the scarp is primarily dip-slip. There is some controversy about the amount of strike-slip offset across the scarp. Aguilera did not perceive significant strike-slip displacements although Gianella (1960) reported right-lateral offsets of up to 6 m, north of the Bavispe River where the scarp cuts andesite. It may be that Gianella observed the effect of repeated movements on the fault. It should be noted that the likely orientation of extension in this region is northwest-southeast, and, from the observations of Thompson and Burke (1973) in Nevada, there ought to be nearly equal components of strike-slip and dip-slip offset on the 1887 fault scarp.

The 1887 scarp cuts alluvium and presently appears (1974) fresh and little modified by 90 years of exposure in a semi-arid environment (average annual precipitation, 40 cm). A photograph of the scarp is shown in Figure 2. The scarp has been degraded, however, particularly in areas of small ($<1$ meter) initial vertical offset. One reason for the integrity of the scarp is that the alluvium is firmly cemented with caliche. In those stretches of the fault scarp with vertical offsets exceeding 2 meters, there is slight rounding at the top of the scarp and approximately one-half meter of rubble at the base of the scarp. The rubble thins away from the scarp over a distance of 2 to 3 meters. Some large blocks, up to 0.3 meters across have fallen from the scarp. In areas affected directly by running water, blocks up to 3 meters across are calving from the scarp.

At the northern limit of the scarp, where Aguilera (1920) observed a 0.2-meter vertical offset, the scarp now appears as a gentle slope, 2 to 4 meters across, that contains numerous rounded pebbles and cobbles. The rubbly slope separates relatively flat regions that have a difference in elevation of approximately 0.5 meters.

*Present address: Exxon Production Research Company, P.O. Box 2189, Houston, Texas 77001.

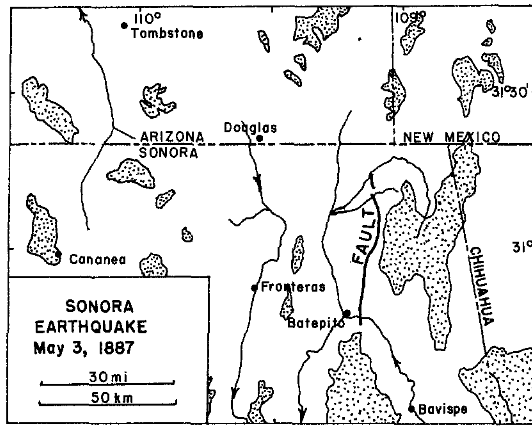


FIG. 1. Sonora earthquake, 1887. Faulting according to Aguilera (1888) and this study. Stippled areas are at elevations over 6,000 ft. This is a corrected version of Figure 31-2 from Richter (1958) in which fault was mislocated 7 km too far to the east and mountain range to the east of the fault was not shown. Scarp features shown near river in the Richter figure are interpreted as non-tectonic (lurch cracks) and are not shown in this figure.

FIG. 2. Photograph of 1887 fault scarp viewed from the west taken in June, 1974, approximately 200 m south of easternmost gravity station of Figure 3. Note rounding of caliche-cemented alluvium at top of scarp, debris at base, break in slope marked with shrubs about 2 meters behind scarp, dissection of scarp in left-hand side of photo caused by small wash.

## EARTHQUAKE INTERVAL

Older fault scarps or fault-line scarps, apparently not caused by the 1887 earthquake nor observed by Aguilera (1920), occur near the center of the San Bernardino Valley (see Figure 3). These scarps occur as broad, gentle breaks in slope with 1 to 2 meters of relief in the otherwise flat alluvial valley and as alignments of triangular facets

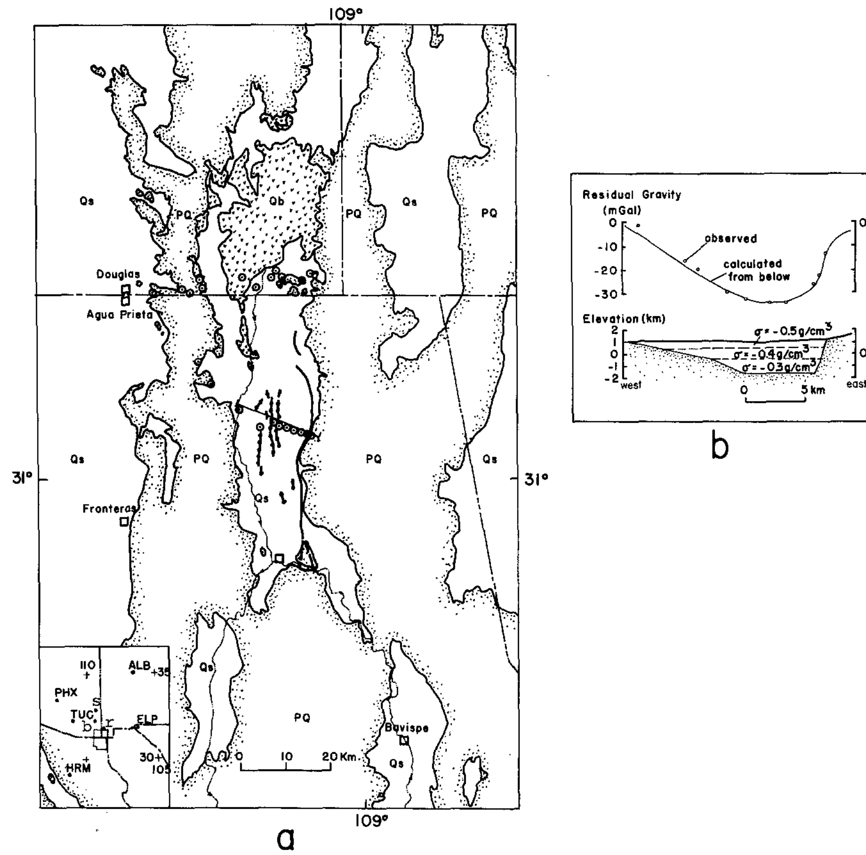


FIG. 3. Sonora earthquake, 1887. (a) Stippled areas labeled PQ mark pre-Quaternary bedrock of limestone and andesite. Unshaded areas labeled Qs locate alluvial basins of Tertiary and Quaternary age. Small v's labeled Qb locate Quaternary basalts of the San Bernardino volcanic field. Heavy lines locate fault scarps; historically active trace lies on east side of valley. Older scarps in center of valley are marked additionally with dots. Small circles locate gravity stations. Letters *b*, *s*, and *r* in the *inset map* locate Bowie and Safford, Arizona, and Rodeo, New Mexico. (b) Model geologic section for the gravity traverse across the central portion of the valley. Stippled area represents bedrock of andesite and limestone; unshaded region represents alluvial fill.

cut in older alluvium. There are also subdued west-facing scarps on either side of the 1887 fault scarp. All these features are offset down to the west. More vigorous vegetation typically accompanies these features. Several distinct drainage regimes occur in the alluvial sediments of the valley, as observed from the degree and style of erosion. It should be possible to date the various tectonic features in the valley since there are lake sediments exposed in bluffs along the river and in the walls of several large washes that cross the valley. Additional field studies are necessary to identify which tectonic features cut the lake sediments and also to date the sediments. The contrast in appearance between the virtually unaltered scarp of the 1887 earthquake and the vegetated and subdued scarps in the central portion of the valley and adjacent to the 1887 scarp suggests that thousands of years separate major earthquakes in the valley.

## Structural Framework of the Valley

A gravity profile across the central portion of the valley shows a steep gravity gradient (10 mGal/km) over the 1887 scarp. The axis of a 35-mGal gravity low parallels the valley axis and lies two-thirds of the way between the San Bernardino River and the eastern side of the valley. A two-dimensional geologic model based on the gravity profile across the middle of the valley (stations and model located in Figure 3) indicates that there are approximately 3 km of alluvial fill in the eastern half of the valley. This area of greatest depth to basement is bounded on the east by the 1887 scarp and on the west by the older, vegetated scarps and truncated alluvial surfaces in the middle of the valley.

The large negative gravity anomaly does not continue north of the northern limit of 1887 ground breakage, rather a gravity saddle consisting of a 15-mGal low that is 25 km wide crosses the valley to the north at the San Bernardino volcanic field (Aiken and Sumner, 1974). North of the volcanic field, again on the continuation of the valley, two closed gravity lows of 30- to 35-mGal relief occur that are 15 to 20 km across, the width of the valley, and 40 to 50 km long (Aiken and Sumner, 1974; Eaton, 1972). The lows are elongate parallel to the valley axis and are separated by a gravity saddle that is 15 km long and has a gravity low of 15 mGal. The two lows are centered over Rodeo, New Mexico and Safford, Arizona and the saddle is centered over Bowie, Arizona. The gravity lows are interpreted to locate areas with over 3 km of alluvial fill; the gravity saddles locate areas with about 1 km of fill. Although there is not extensive gravity coverage on the southern continuation of the valley, the valley of the Rio Bavispe, it is likely that the same habit of closed, elongate basins separated by bedrock saddles continues. Apparently faulting occurs only adjacent to those regions containing gravity lows, with faulting of lesser magnitude in the area of gravity saddles.

## Conclusion

The 1887 Sonora earthquake occurred in the San Bernardino Valley of northeastern Sonora, Mexico. Older scarps, truncated alluvial features, and badlands terrain juxtaposed upon older erosional features all indicate a long and continuing deformational history for the valley. The 1887 scarp retains a fresh appearance because the caliche-cemented alluvium holds up well in the semi-arid climate of the region. Steep gravity gradients and large gravity lows over the valley indicate that the fault has a total normal offset of about 3 km. Map errors of original and subsequent reports on the 1887 earthquake have been corrected with a redrafting of Figure 31-2 of Richter (1958).

## Acknowledgments

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Department of Geological Sciences
Lehigh University
Bethlehem, Pennsylvania 18015

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