Recent Earthquakes in Northern Sonora

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On May 25, 1989, a 4.2-magnitude earthquake shook Agua Prieta, Sonora, and Douglas, Arizona. The epicenter of the earthquake, which occurred at 12:43 a.m. local time (07:43:18.6 Greenwich mean time), was in the San Bernardino Valley (Figure 1). Although no damage was reported, at least three ranches noted significant changes in water-well levels. The earthquake was followed by numerous smaller events, the largest of which had a magnitude of 3.4 and occurred the following day (Table 1). During the night-time hours of May 26-27 and June 8-9, the seismic station at Tucson recorded more than 50 microearthquakes (magnitude ≤ 2.0).

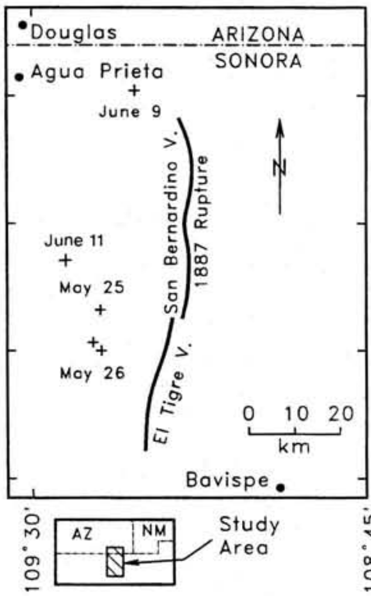

Figure 1. Location map of Pitaycachi fault region, showing epicenters of earthquakes that occurred on June 11, 1988, May 25, 1989, May 26, 1989, and June 9, 1989. Solid line indicates surface rupture due to 1887 earthquake. Note "bend" between northern and southern segments.

The recent earthquakes appear to be a continuation of seismic activity that began in 1987 near the Pitaycachi fault. The epicenters of the May 25th event and May 26th aftershocks are very near the epicenter of a 4.0-magnitude earthquake that occurred on June 11, 1988 (Wallace and others, 1988). The great Sonoran earthquake (magnitude > 7.2) ruptured the Pitaycachi fault in 1887 and is the largest historic earthquake in the southern Basin and Range Province. The Pitaycachi fault ruptures infrequently; the recurrence interval between large earthquakes is at least 100,000 years (Bull and Pearthree, 1988). Large earthquakes with long recurrence intervals typically have protracted aftershocks. It is possible that the recent earthquakes are aftershocks from the great Sonoran earthquake; however, the size (magnitudes > 4.0) and number of events since March 1987 are very unusual.

The May 25th earthquake was large enough to produce seismic waveforms that are usable in a focal mechanism study. Different types of earthquakes (strike-slip faulting versus thrust faulting, for example) produce very different seismic signatures. The May 25th event apparently was an oblique-slip normal-faulting episode. The focal mechanism is consistent with a fault plane that strikes N36°E, dips 65° to the west, and has a slip direction of -58° (a combination of vertical normal slip and left-lateral slip; the ratio is roughly 2:1 normal to strike-slip motion). This type of oblique slip is very common in the Basin and Range Province. Natali and Sbar (1982) found a similar faulting mechanism for microearthquakes along the northern part of the fault.

The May 25th event was located by using seismic recordings from the Caltech-USGS array in the Imperial Valley, the Tucson station (TUC), the Arizona-Sonora Desert Museum station (ASDM), and the New Mexico Institute of Mining and Technology array in central New Mexico. The accuracy of the location is ±4 kilometers in the east-west direction and ±5 kilometers in the north-south direction. The aftershocks of this event were located based on the assumption that the main event was perfectly located. Relative to the May 25th event, the May 26th and June 9th events are located with ±0.5-kilometer accuracy. The events of May 25 and 26 occurred near a major bend in the Pitaycachi fault. Natali and Sbar (1982), who operated an array of portable seismometers in the area, found a strong concentration of microearthquake activity near the bend. The June 9th earthquake was the only event not located within the southern part of the San Bernardino Valley. This earthquake occurred much closer to the Arizona-Sonora border, near the northern extent of the 1887 faulting.

Table 1. *Recent seismicity in Pitaycachi area.*

Date	Origin Time	Lat*	Long*	M*
5-25	07:43:18.6	30.823°N	109.389°W	4.2
5-26	09:08:16.8	30.753°N	109.401°W	3.4
5-26	11:52:11.2	30.742°N	109.392°W	2.4
6-9	17:03:20.7	31.252°N	109.271°W	2.8

* Lat=latitude; Long=longitude; M=magnitude

With the exception of the June 9th event, all the recent activity appears to be concentrated near a significant struc-

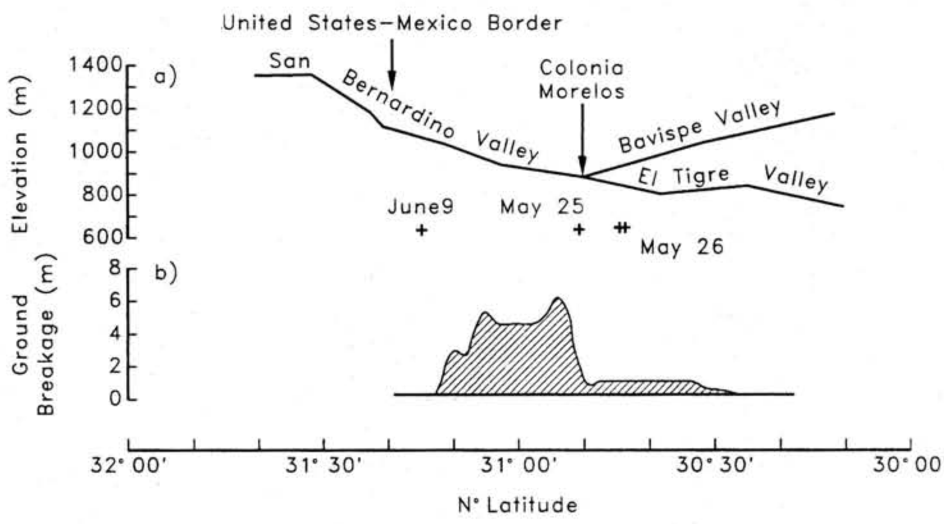

Figure 2. Elevations for the San Bernardino and El Tigre Valleys projected onto a north-south profile. The vertical displacement from the 1887 great Sonoran earthquake is also shown. Near Colonia Morelos, the 1887 fault trace takes an abrupt bend and crosses into the El Tigre Valley. It is also at this point that the fault displacement from the 1887 earthquake drops to less than 1 meter. Between this elevation and ground-breakage profiles, the location of recent seismic activity is projected onto the north-south profile. Note that the activity is concentrated near Colonia Morelos.

tural discontinuity in the Pitaycachi fault. The northern segment of the 1887 surface rupture is along the east side of the San Bernardino Valley and strikes approximately north-south. At 30°50'N latitude, the fault makes an abrupt bend to the southwest and runs along the eastern margin of the El Tigre Valley. This bend is near the confluence of the Rio San Bernardino, which flows from the north, and the Rio Bavispe, which flows from the southeast; beyond their confluence, these streams drain to the south through the El Tigre Valley (Figure 2). Bends or complexities in a fault zone can serve to terminate rupture during earthquakes. Stress appears to concentrate in the region of faulting complexity, often referred to as a *restraining point*.

The amount of slip that occurred during the great Sonoran earthquake changed dramatically near this bend in the fault zone (Figure 2). The slip was much greater north of the fault bend than south of it (Aguilera, 1920). This discrepancy raises several interesting questions: (1) Is the present seismicity a readjustment to the stress released during the 1887 earthquake and, thus, normal aftershock activity? (2) Did the 1887 rupture actually terminate at the bend so that the southern El Tigre Valley segment of the fault behaves independently of the northern San Bernardino Valley segment? (3) Is there a "slip deficit" along the southern segment of the fault? Is it possible that moderate to large earthquakes will occur along this segment to "catch up" with the slip on the northern segment? Although these questions are not likely to be answered soon, this recent concentration of earthquakes near the bend does suggest that seismicity in the San Bernardino Valley is worth monitoring.

Since 1987, the San Bernardino Valley has been the most seismically active area in northern Sonora and Arizona. It is difficult to assess whether this activity poses a significant hazard or whether seismicity in the area will soon decrease to a much lower level typical of southern Arizona. The locations of the recent earthquakes relative to the surface rupture of the 1887 event, however, raise several intriguing questions about potential seismic hazard in northern Sonora and southern Arizona.

References

Aguilera, J., 1920, The Sonoran earthquake of 1887: Seismological Society of America Bulletin, v. 10, p. 31-44.

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Natali, S.G., and Sbar, M.L., 1982, Seismicity in the epicentral region of the 1887 northeastern Sonoran earthquake, Mexico: Seismological Society of America Bulletin, v. 72, p. 181-196.

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Schmidt, E.A., 1989, Geologic map and cross sections of the northern Tortilla Mountains, Pinal County, Arizona: Contributed Map CM-89-A, scale 1:12,000, 6 sheets.

This map and these cross sections, originally included as part of the author's 1971 Ph.D. dissertation, depict geologic relationships among various rock units, including Precambrian crystalline rocks, Precambrian Apache Group, Laramide plutons, and middle and upper Cenozoic sedimentary and volcanic rocks. The area contains classic examples of tilted fault blocks bounded by low-angle normal faults formed during mid-Tertiary crustal extension.

Faulds, J.E., 1989, Geologic map of the Salt River region, Rockinstraw Mountain quadrangle, Gila County, Arizona: Contributed Map CM-89-B, scale 1:24,000, 3 sheets.

This map encompasses an area of approximately 50 square miles along the Salt River near its confluence with Cherry Creek. Detailed geologic mapping was directed at understanding the Tertiary structural and stratigraphic history of a structurally complex area. The Cherry Creek fault system extends north-south across the map area and displaces Oligocene and Miocene sedimentary and volcanic rocks, as well as underlying crystalline rocks.

Smith, C.H., 1989, Geologic map of the Little Rincon Mountains: Contributed Map CM-89-C, scale 1:10,000.

This map depicts the complex structures associated with Laramide ductile thrust faulting and emplacement of two-mica granite east of the Rincon Mountains near Tucson.

Jackson, G.W., 1989, Surficial geologic maps of the northeastern, southeastern, and southwestern portions of the Tucson metropolitan area: Open-File Report 89-2, 6 p., scale 1:24,000, 7 sheets.

Maps of surficial deposits provide a detailed geologic database for geologists, engineers, and others involved in land-use planning or assessment of geologic hazards and limitations. The detailed surficial geologic maps of this report delineate alluvial deposits and basin landforms, including alluvial fans and stream terraces of different ages and exposed and buried pediment areas. The following 7 1/2-minute quadrangle maps, which may also be purchased separately, are included in this report: 1-Agua Caliente Hill; 2-Tanque Verde Peak; 3-Vail; 4-Tucson SE; 5-Tucson SW; 6-San Xavier; 7-San Xavier Mission SW.

McGarvin, T.G., 1989, Index to published geologic maps of Arizona - 1988: Open-File Report 89-3, scale 1:1,000,000.

This index lists 27 sources of geologic maps of the State published during 1988. References include publications of the Arizona Geological Survey and U.S. Geological Survey, as well as articles published in *Geology*, the Geological Society of America *Bulletin*, and *Economic Geology*. The accompanying map identifies the areas within Arizona covered by each reference.

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