# Patterns of Earth-Fissure Development: Examples From Picacho Basin, Pinal County, Arizona

*by Steven Slaff*
**Arizona Geological Survey**

Earth fissures are open surficial tension cracks in sediments that may display vertical or horizontal displacement. They range up to 15.2 meters (50 feet) wide, 18.3 meters (60 feet) deep, and 15.8 kilometers (9.8 miles) long. Earth fissures are relatively common in central, southern, and western Arizona, where sedimentary basins have undergone substantial ground-water depletion. They have already damaged several man-made structures. More damage will occur within the next few decades as ground-water levels continue to decline and urbanization encroaches into areas where fissures exist or could form.

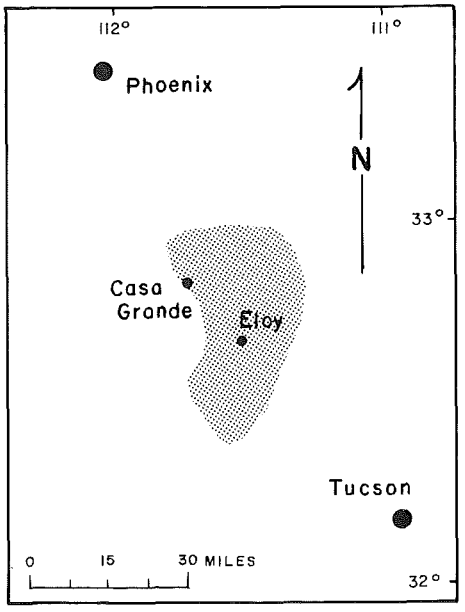


*Figure 1. Location map showing approximate extent of Picacho basin (shaded area).*

Most earth fissures form as a result of compaction of sediment caused by ground-water withdrawal. In Arizona, they primarily occur in basins where ground-water levels have substantially declined (Schumann and Genualdi, 1986). As ground water is withdrawn, buoyant forces are removed from unconsolidated or semiconsolidated sediment, which compacts at depth, causing subsidence of the land surface. Variations in the thickness or character of sediment cause some areas to subside more than adjacent areas. This differential subsidence produces horizontal stresses in sediment. Earth fissures develop where tensional stress levels are high, typically around the margins of basins where lateral variations in subsurface geology are most abrupt.

Earth fissures are a significant geologic hazard in Arizona. Differential land subsidence and the resultant earth fissures have damaged a variety of facilities in central and southern Arizona: roads, railroads, pipelines (water, petroleum, natural gas, and sewage), water wells, canals, buildings, and an earth-filled dam (Schumann and others, 1984). The Central Arizona Project (CAP) aqueduct and subsidiary aqueducts cross areas with known earth fissures. Hazards posed by existing and potential earth fissures were, therefore, considered in CAP planning and construction. The aqueduct was routed to avoid crossing a fissure that developed during the planning phase of the project, and portions of the aqueduct were specially engineered to withstand the development of earth fissures. Yet in 1988, a fissure opened and damaged the aqueduct in northern Avra Valley. Clearly, further study is needed to determine the extent

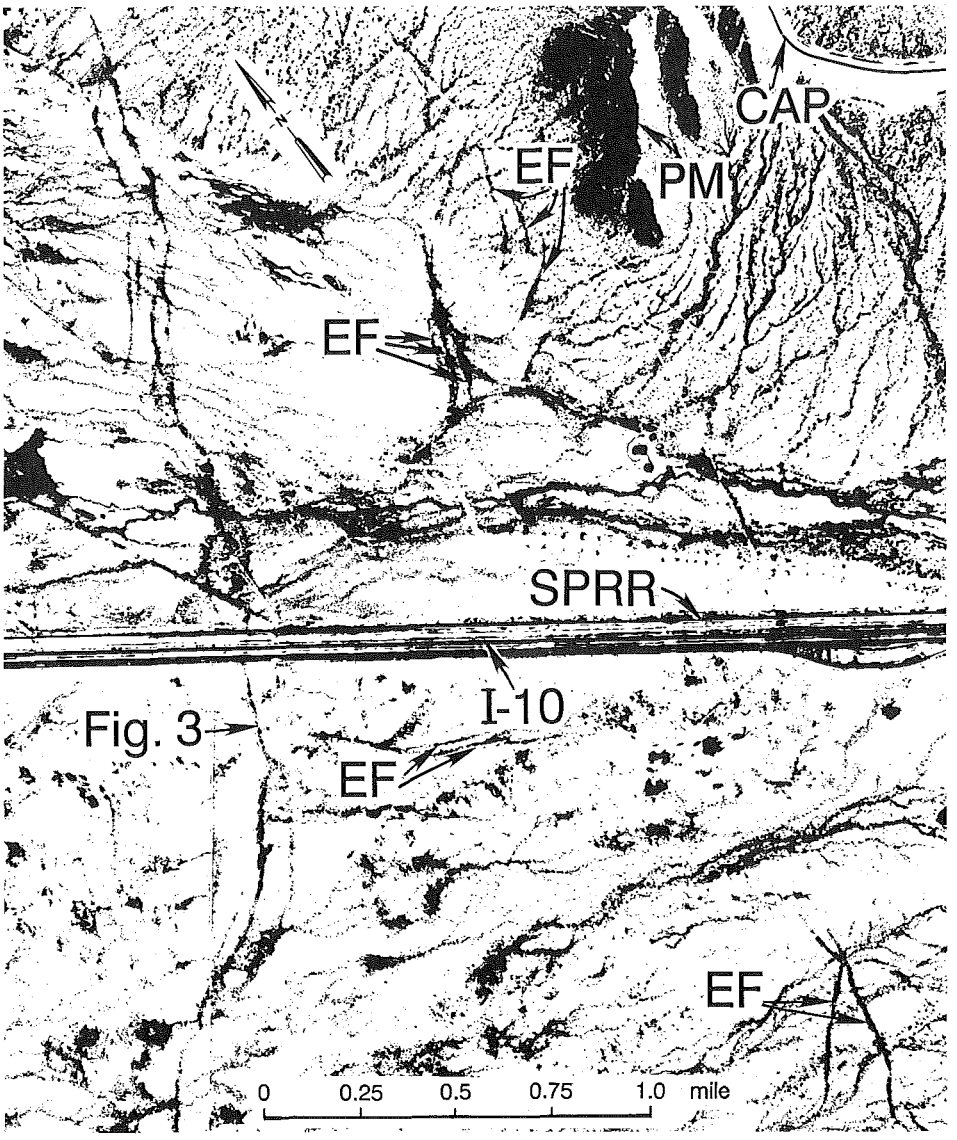


*Figure 2. Aerial photograph of part of the eastern portion of Picacho basin. The old earth fissure discussed in the text is shown as a system of dark lines extending from top to bottom on the left side of the photo. Identified features are as follows: EF - other earth fissures; PM - southern end of Picacho Mountains; CAP - Central Arizona Project aqueduct; SPRR-Southern Pacific Railroad tracks; I-10 - Interstate Highway 10; Fig. 3 - location of Figure 3. The photograph was taken by the Arizona Department of Transportation in August 1987.*

and severity of hazards posed by land subsidence and earth fissures in central and southern Arizona.

The first earth fissure in Arizona reported in the scientific literature formed in 1927 in Picacho basin between the Picacho Mountains and the town of Picacho (Leonard, 1929; see Figure 1 for the location of Picacho basin). When first recognized, the feature was approximately 305 meters (1,000 feet) long, up to 15 centimeters (6 inches) wide, and up to 4.6 meters (15 feet) deep. Its northeast trend was perpendicular to the local drainage direction, so it intercepted the discharge of several small streams and was eroded into a much wider fissure that resembled an arroyo. Such a feature is now termed a *fissure gully* (Kam, 1965). The fissure crossed the Southern Pacific Railroad tracks and the Tucson - Casa Grande highway (now U.S. Highways 93 and 84 and Interstate Highway 10), but caused little damage.

This earth fissure has extended considerably and is now at least 15.8 kilometers (9.8 miles) long. It is the longest fissure in Picacho basin. From the air, it appears as a thin anastomosing line (Figure 2). The line is dark and conspicuous because plants grow larger and closer together along the fissure than in the surrounding area. A ground view of it is shown in Figure 3. Numerous other fissures have opened in Picacho basin during the past 60 years, primarily along its eastern and western margins.

The Arizona Geological Survey (AZGS) is involved in a cooperative research project, supported by the U.S. Bureau of Reclamation (BUREC) and Arizona Department of Transportation (ADOT), to document the locations of earth fissures and study their development in Picacho basin. The basin contains numerous manmade structures that could be damaged by earth fissures: the CAP aqueduct, several highways, and a gas pipeline. It also provides an unusual opportunity to study the progressive development of earth fissures because the ADOT Location Section has taken high-quality aerial photographs of the basin 12 times between 1959 and 1989. Through the use of these photographs, the AZGS, BUREC, and ADOT hope to learn more about the patterns and rates of fissure propagation, test the ability to identify earth fissures on 1:24,000- and larger-scale photographs, and develop techniques for accurately locating earth fissures on topographic base maps. The methods developed in this study should also be useful in assessing the extent of earth-fissure hazards in other areas of the State.

The AZGS is using interpretation of aerial photographs and field studies to verify the location and extent of earth

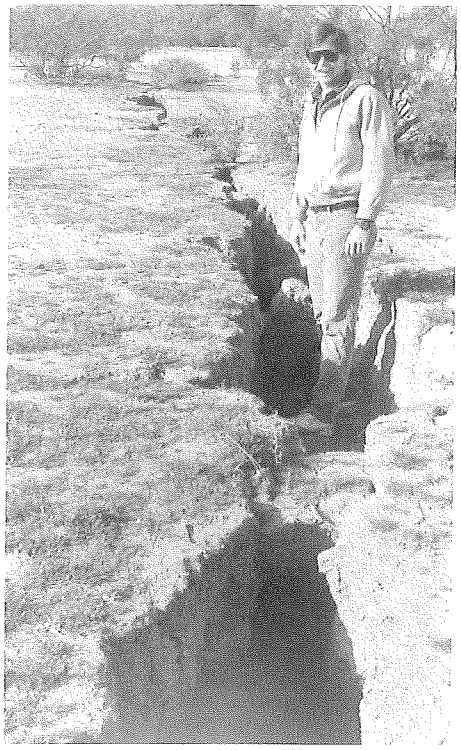

*Figure 3. Ground view toward the southwest of a portion of the old earth fissure discussed in the text. Note steep to vertical walls, narrow width, and lack of large vegetation along the crack. These and other features suggest the relative youthfulness of this portion of the fissure. An older portion, lined with mature vegetation, parallels this crack to the left of the field of view.*

fissures in Picacho basin and to collect data concerning their morphologies and physical parameters. A sequence of changes in fissure shape with time has been established so that the relative age of a fissure may be estimated by examining and measuring several parameters. Development trends in map-view fissure patterns have also been noted: the patterns are relatively simple when the fissures first appear, but become increasingly complex as the fissures develop. It was hoped that by observing a young fissure on a recent aerial photograph and then examining the same site on an older aerial photo, researchers could identify telltale signs of incipient fissure development on the older photo. Unfortunately, no such signs have been detected on 1:24,000-scale aerial photos. The narrowness, discontinuity, and lack of vegetation concentrations render very young fissures invisible or indistinguishable from other linear and arcuate patterns. Aerial photographs at considerably larger scales are useful in some cases, but the time required to interpret them restricts their use to site-specific studies.

Several factors may influence the timing and nature of fissure development. Earth fissures are correlated with ground-water withdrawal. More pumping may result in more fissures. The AZGS will compare records of ground-water levels with rates of earth-fissure development for various intervals within the past 30 years. Some fissures reportedly formed during or immediately after intense precipitation (Leonard, 1929; Pashley, 1961; Larson and Pewe, 1983). To determine how common this relationship is, the AZGS will use weather records to compare the occurrence of major storms with the development of fissures in Picacho basin. The AZGS is also mapping the distribution of surficial deposits to compare fissure morphologies and rates of fissure propagation with types of sediment and soil. The results of these investigations, including 1:24,000-scale maps, will be released later this year.

### References


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## Hiring Trends in the Geosciences

Hiring in the geosciences this year will be down 19.3 percent from 1988, according to the 1989 edition of the annual Geoscientific Employment and Hiring Survey. Hiring of hydrologists/hydrogeologists and engineering geologists, however, is expected to rise by 26.7 and 16.5 percent, respectively. The survey also reveals that 83.4 percent of new hires will have a master's degree or higher and that three out of five new hires will come directly from college campuses.

The survey is available for $10.00 from the American Geological Institute, 4220 King St., Alexandria, VA 22302; tel: (800) 336-4764.