Subsidence Areas and Earth-Fissure Zones

Ground-water basins in southern Arizona have been filled with the weathering products of adjacent mountains. These materials include interlayered units composed of gravel, sand, silt, and clay-sized particles. Water occupies the spaces between the rock particles. When this water is removed, the particles become more compacted and consolidated. If the decline in ground-water level is sufficient, the overlying land surface will settle or subside. For many years land surveyors have had problems in closing traverses in several areas in the State because the bench marks in subsiding areas had settled, whereas those on bedrock had not.

Subsidence in the central portions of ground-water basins has occurred gradually over large areas with few noticeable effects. Locally, however, the effects have been dramatic: casings of deep water wells have appeared to rise out of the ground (Figure 1). In reality, the casings have remained stationary, but the land has subsided. Collapse of water-well casings reported in areas of water-level decline may be a subsidence-related phenomenon. Near Eloy subsidence of 15 feet has occurred since 1947 (Figure 2; Schumann, 1986). Ground-water levels have been lowered by more than 500 feet in two parts of southern Arizona: southwest of Casa Grande near Stanfield and south of Chandler near Chandler Heights (Schumann and others, 1986). Subsidence has been documented by the National Geodetic Survey (NGS), which in 1980-81 ran a Second Order, Class 1 level network across Arizona. Several Federal, State, and local agencies provided funding so the NGS could do additional leveling in areas with known or suspected subsidence (Winikka, 1981). The NGS determined that subsidence had occurred in a number of localities near Phoenix and in one section of Tucson.

In some areas of ground-water-level decline, earth fissures have subsequently developed. Fissures begin as tiny cracks that are barely visible (Figure 3). Seeds, most commonly those of the creosote bush, that are washed into the cracks germinate and grow. The vegetation causes the cracks to appear as dark lines on air photos (Figure 4). Small holes often develop along the cracks because of collapse (piping) into underlying open spaces. Surface runoff flowing into the cracks enlarges them and fissures begin to develop (Figure 5). Some individual fissures are as much as 50 feet wide and 16 feet deep (Figure 6). New fissures tend to form adjacent and parallel to older fissures. A zone of fissures 10 miles long is present east of the town of Picacho in Pinal County (Figure 7).

Earth fissures cause damage to highways, railroads, and canals; frequent maintenance is required. The canal route of the Central Arizona Project was planned to avoid potential problems with fissures. The canal is visible from I-10 between Tucson and Phoenix at the base of the Picacho Mountains just northeast of Picacho Peak. This alignment was used to avoid the extensive earth-fissure zone mentioned in the preceding paragraph.

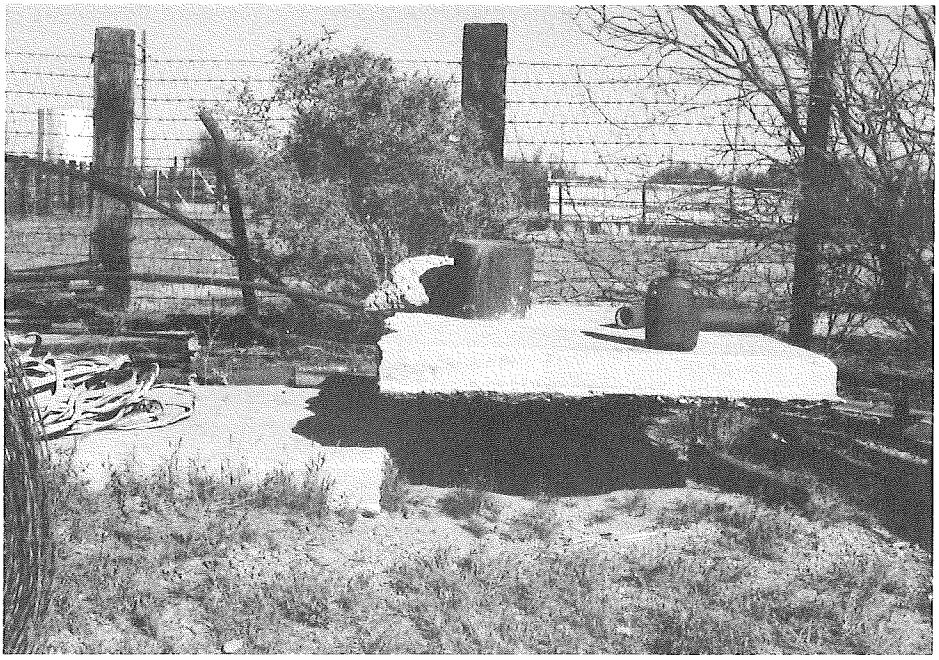

Figure 1. Protruding water well near Stanfield, Arizona. Subsidence around the well reportedly occurred during the 1970's. Sounding of the well revealed a collapsed casing. Photo by Robert B. Genualdi.

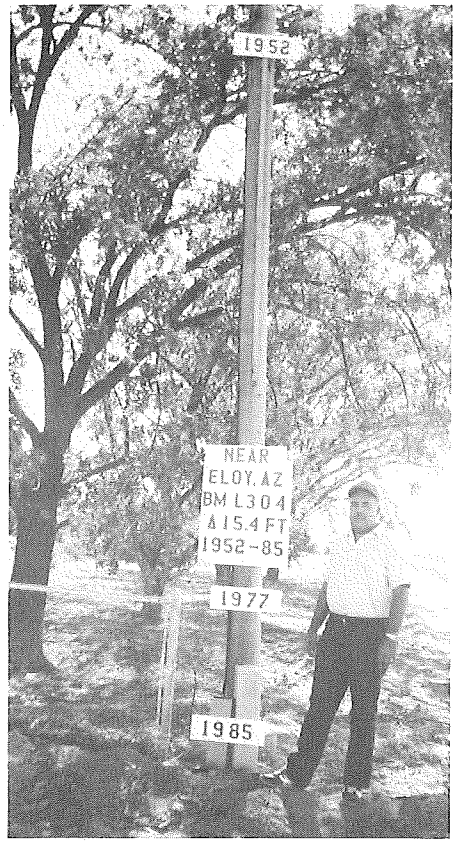

Figure 2. Bench mark L304, located about 3 miles south of Eloy, Arizona, subsided more than 15 feet between 1952 and 1985. Relative elevations of the bench mark are shown by the signs on the powerline pole. Herb Schumann of the U.S. Geological Survey, who is 6' 2" tall, is included for scale. Photo by the U.S. Geological Survey.

When fissures develop in irrigated agricultural areas, portions of entire fields are sometimes abandoned (Figure 8). Uneven subsidence could even change the slope of previously leveled fields, causing problems with the flow of irrigation water.

Subsidence and earth fissures in urban areas cause a variety of problems such as those in Paradise Valley, described by Harmon (1982) and by Larson and Péwé (1983) in previous issues of *Fieldnotes*. Any structure built across a fissure will likely become seriously damaged (Figure 9). Homeowners must be cautious about watering lawns and shrubs to avoid enlarging a fissure. Streets must be repaired. Water mains, sewer lines, and gas pipes could rupture. Differential subsidence could also change the gradient of sewer lines and disrupt the intended flow directions.

Residents in some areas near earth fissures have used them as dumps (Figure 10). Because these fissures are believed to be extremely deep, the potential for ground-water contamination may be great.

In 1982 an ad-hoc interagency land-subsidence committee was formed. Ed Nemacek, Arizona Department of Water Resources, served as chairman of the group, which, in cooperation with the NGS, prepared a subsidence-monitoring plan. The plan, which was printed by the National

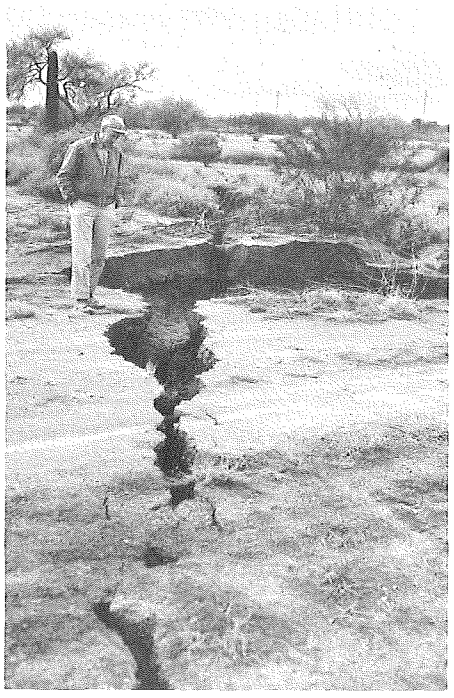

Figure 3. Earth fissure east of Mesa, Arizona prior to erosion and enlargement by captured water. Photo by Herbert H. Schumann.

Figure 4. Vegetation, visible as dark lines, along earth fissures southeast of Casa Grande, Arizona. Photo by Herbert H. Schumann.

Oceanic and Atmospheric Administration, included a small-scale map that showed areas of subsidence caused by declines in ground-water levels. In 1986 Phil Briggs (Arizona Department of Water Resources) and Larry Fellows (Arizona Geological Survey) agreed that their agencies would collaborate on publishing this map at a larger scale. While planning the project, Fellows and Greg Wallace (Arizona Department of Water Resources) concluded that the original map should be updated before it was printed. They sought the assistance of Dick Raymond (retired, U.S. Bureau of Reclamation), Herb Schumann (U.S. Geological Survey), and Carl Winikka (Arizona Department of Transportation), all of whom had contributed to the present understanding of subsidence and earth fissures in Arizona. Jerry Bartell was instrumental in obtaining from the U.S. Bureau of Reclamation the donation of helicopter time required to update the inventory of earth fissures that had been done in 1977. During May 1986, Schumann, Raymond, and Bill Wellendorf completed the inventory. Raymond and Wellendorf volunteered their time on the project without salary.

"Land Subsidence, Earth Fissures, and Water-Level Change in Southern Arizona," a result of this project, was recently published as Map 23 by the Arizona Bureau of Geology and Mineral Technology, Geological Survey Branch. The map shows ground-water basins within which water levels in wells have been lowered as much as 500 feet by ground-water depletion. It also shows areas where earth fissures related to differential land subsidence have developed. Authors of the map are Herb Schumann and Robert Genualdi (Arizona Department of Water Resources).

The map scale is 1:1,000,000; 1 inch on the map equals approximately 16 miles on the ground. The map covers the southern portion of Arizona, south of 34° north latitude, where man-induced lowering of

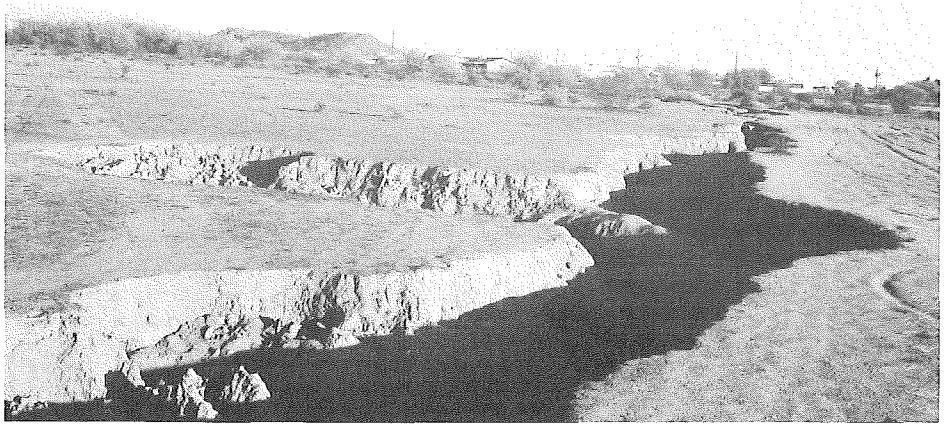

Figure 5. Earth fissure east of Mesa, Arizona showing enlargement by water erosion. Photo by Herbert H. Schumann.

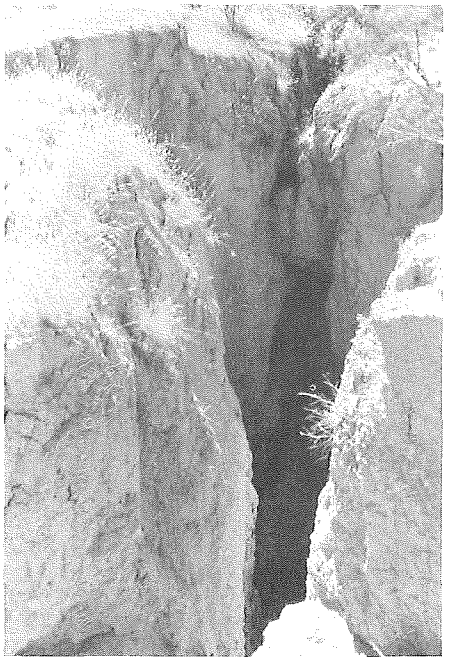

Figure 6. Earth fissure near Chandler Heights, Arizona. Fissure is 10 to 15 feet deep and 3 to 5 feet wide. Photo by Larry D. Fellows.

Figure 7. Earth-fissure zone that crosses Interstate Highway 10 (I-10) on west side of Picacho Mountains and east of Picacho, Arizona. Photo by Herbert H. Schumann.

Figure 8. Irrigated field south of Eloy, Arizona, near Friendly Corner. Note diagonally aligned earth fissure, darkened by vegetation. Photo by Herbert H. Schumann.

Figure 9. House damaged by earth fissure south of Stanfield, Arizona. (a, top) Aerial view. Note path of fissure darkened by vegetation. (b, bottom) Ground view. Note cracks in cement slab (foreground), yard, and house. Photos by the U.S. Geological Survey.

ground-water levels has occurred. A brief text summarizes the relationships among declines in ground-water level, land subsidence, and development of earth fissures. In addition, references to key articles on these topics are listed.

Map 23 is the first in a series of subsidence maps to be cooperatively prepared by the Arizona Department of Water Resources, Arizona Department of Transportation, Arizona Geological Survey, U.S. Geological Survey, and U.S. Bureau of Reclamation. Several 1:250,000-scale maps (1 inch on the map equals approximately 4 miles on the ground) will provide more detail than Map 23 could show; e.g., the larger scale maps will show individual earth fissures rather than fissure zones. Finally, earth fissures plotted on individual topographic maps at a scale of 1:24,000 (1 inch on the map equals 2,000 feet on the ground) will be released as open-file reports. *Fieldnotes* readers will be informed when these products are completed and available for purchase.

Map 23 may be purchased from the Arizona Geological Survey, 845 N. Park Avenue, Tucson, AZ 85719. Send a check or money order for $6.75 ($5.00 plus $1.75 for handling and shipping). Prepayment is required.

References

Harmon, D. B., 1982, Subsidence in northeast Phoenix; a new problem for engineers: Arizona Bureau of Geology and Mineral Technology Fieldnotes, v. 12, no. 3, p. 10-11.

Larson, M. K., and Péwé, T. L., 1983, Earth fissures and land subsidence hazards in northeast Phoenix: Arizona Bureau of Geology and Mineral Technology Fieldnotes, v. 13, no. 2, p. 8-11.

Schumann, H. H., 1986, Ground-water depletion and land subsidence in western Pinal County, Arizona: National Water Well Association, Conference on Southwestern Ground Water Issues, Tempe, 1986, Proceedings, p. 533-552.

Schumann, H. H., Laney, R. L., and Cripe, L. S., 1986, Land subsidence and earth fissures caused by ground-water depletion in southern Arizona, *in* Anderson, T. W., and Johnson, A. I., eds., Regional aquifer systems of the United States, southwest alluvial basins of Arizona: American Water Resources Association Monograph Series 7, p. 81-91.

Winikka, C. C., 1981, New leveling across Arizona: Arizona Bureau of Geology and Mineral Technology Fieldnotes, v. 11, no. 2, p. 10.

Figure 10. *Trash dumped in earth fissure near Chandler Heights, Arizona. Photo by Larry D. Fellows.*

Earth Science in High Schools Shows Major Decline

The Federal Census Bureau reports that the number of American high schools offering courses in earth science decreased by more than 90 percent from 1973 to 1982. In 1973 almost one-third (4,755) of all high schools offered a course in earth science, whereas by 1982 less than 3 percent (430) did. In terms of enrollment, the decrease was 95 percent (from 427,000 to 21,000). In 1982 only 0.2 percent of all high school students took a course in earth science. This figure contrasts with 23.5 percent who took a course in industrial arts, 23.9 percent in home economics, 46.4 percent in business, 24.2 percent in art, and 93.7 percent in health/physical education.

—Excerpted from the *Journal of Geological Education*, 1986, v. 34, p. 282.

New Bureau Publications

The following publications may be purchased over the counter or by mail from the Bureau offices at 845 N. Park Ave., Tucson, AZ 85719. Orders are shipped via UPS; street address is required for fastest delivery. All orders must be prepaid by check or money order made out to the Arizona Bureau of Geology and Mineral Technology. Shipping and handling charges are listed below. If your total order is

$1.01 to $5.00, add $1.75	40.01 to 50.00, add 7.75
5.01 to 10.00, add 2.25	50.01 to 100.00, add 10.00
10.01 to 20.00, add 4.25	More than 100.00, add 10%
20.01 to 30.00, add 5.50	Foreign mail, add 40%
30.01 to 40.00, add 6.25	

Dickinson, W. R., 1987, General geologic map of Catalina core complex and San Pedro trough: Miscellaneous Map MM-87-A, 18 p., scale 1:62,500, 15 sheets; text: $3.00; maps: 50¢ each.

These maps were compiled from previously published and unpublished thesis maps, field reconnaissance, and local remapping by the author. The contacts on these maps are simplified because they were compiled as a basis for a smaller-scale compilation map. An index to data sources is included.

Schumann, H. H., and Genualdi, R. B., 1986, Land subsidence, earth fissures, and water-level change in southern Arizona: Map 23, scale 1:1,000,000; $5.00.

See "Subsidence Areas and Earth-Fissure Zones," p. 6-9.

Schumann, H. H., and Genualdi, R. B., 1986, Land subsidence, earth fissures, and water-level change in southern Arizona: Open-File Report 86-14, scale 1:500,000; $5.00.

This map shows the same information as Map 23, but at a larger scale.

Spencer, J. E., and Shenk, J. D., 1986, Map showing areas in Arizona with elevated concentrations of uranium: Open-File Report 86-11, scale 1:500,000; $3.00.

Radon gas is produced by the natural radioactive decay of uranium that is present in virtually all geologic materials. Radon produced in soil and rock can seep into overlying homes and buildings and can be present in indoor air in hazardous concentrations. Indoor-radon concentrations have been found to be greatest in areas where underlying rock and soil contain elevated concentrations of uranium. This map identifies the areas that are known to contain elevated uranium concentrations and thus are more likely to be associated with hazardous indoor-radon levels.

Spencer, J. E., and Welty, J. W., 1986, Mid-Tertiary ore deposits in Arizona: Open-File Report 86-12, 40 p.; $6.00.

Areas of economic mineralization in Arizona with recorded production have been divided into 455 mineral districts, approximately 180 of which are known or suspected of being mid-Tertiary in age. Gold and silver have been the most important metals produced from Arizona's mid-Tertiary districts. At average 1986 prices, all gold produced from these districts would be worth more than $1.6 billion; total silver production would be worth nearly $250 million. Copper, lead, zinc, uranium, molybdenum, tungsten, and manganese have also been produced from mid-Tertiary districts. Stratabound manganese and uranium deposits of mid-Tertiary age in west-central Arizona are moderate to large in size but are low grade and have not been major producers.

Most of Arizona's mid-Tertiary mineral deposits are within the geologically complex Basin and Range Province of southern and western Arizona, an area that is still incompletely mapped and understood. In addition, most mid-Tertiary and older rocks are buried under late Cenozoic sediments and basalts. Because the geologic knowledge about Arizona's Basin and Range Province is incomplete, major ore deposits could have been overlooked. Past production of precious metals from this region has been significant; exploration activity, therefore, is presently high, especially in western Arizona. New concepts and the recognition of new types of mineralization have resulted in new exploration models and increased interest in precious-metal deposits. The recent recognition of major low-angle normal (detachment) faults and associated rocks and structures as sites of base- and precious-metal mineralization is especially important.

This open-file report outlines the geology of several mid-Tertiary mineral districts that represent the range of deposit types. The deposits discussed in this report include three types associated with silicic to intermediate igneous rocks, one type associated with fine-grained dioritic dikes, those associated with detachment faults, and syngenetic to diagenetic stratabound manganese and uranium deposits.