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ARIZONA GEOLOGICAL SURVEY

The State agency for geologic information

MISSION

To inform the public about geologic processes, materials, and resources in Arizona and assist citizens, businesses, governmental agencies, and elected officials in making informed decisions about managing Arizona's land, water, mineral, and energy resources.

GOALS

- Inform the public about geologic processes, materials, and resources in a timely, courteous manner.
- Map and describe the bedrock and surficial geology of Arizona.
- Investigate and document geologic processes and materials that might be hazardous to the public or have adverse impact on land use and resource management.
- Administer the rules, regulations, and policies established by the Arizona Oil and Gas Conservation Commission.

Ground-Water Pumping Causes Arizona to Sink

Larry D. Fellows
Director and State Geologist

The land has subsided in several parts of southern Arizona since 1950 and is still subsiding. Two dish-shaped areas in Maricopa and Pinal Counties, as much as 6 miles wide, have subsided more than 15 feet at their centers. Gigantic open cracks (*fissures*), commonly 5-10 feet wide and 10-20 feet deep, have developed along their margins (Figure 1). Subsidence and related features have already caused serious problems and have the potential to cause even more. Around Phoenix, urban development is moving into subsiding areas that were once predominantly rural. Subsidence is taking place within the City of Tucson.

What causes the land to subside? Subsidence is taking place in southern Arizona because ground water has been pumped over an extended period of time faster than recharge has occurred. Subsidence does not happen in northern Arizona because the geologic setting is different. Southern Arizona is susceptible to subsidence because it's in what geologists call the "Basin and Range" province, which consists of alternating linear mountain areas and structural basins.

The Basin and Range, which extends northwestward from western Texas and northern Mexico into southern Oregon and Idaho (Figure 2), developed from about 15 to 5 million years ago in response to crustal stretching. Rocks cracked and broke into large blocks,

(continued on page 2)

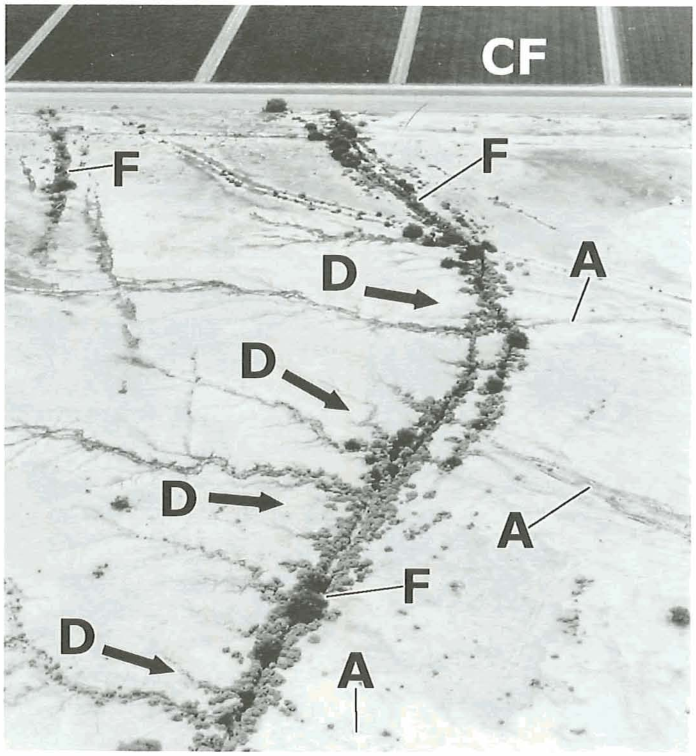

Figure 1. Fissures (F), which appear to stop at the edge of irrigated cotton fields (CF) southeast of Casa Grande in Pinal County, developed at right angles to existing stream channels. After heavy rainfall, runoff drains in the direction of the arrows (D) into the fissures. Channels on the right side of the fissures have been abandoned (A). Photograph by L. D. Fellows.

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some of which moved downward with respect to others and formed basins (Figure 3). Most of the blocks are bounded by fault zones, along which the fracturing and movement took place. Gravel, sand, silt, and clay particles, the weathering products of rocks in the adjacent mountain blocks, were transported by streams and deposited in the basins. The process took place so long that 5,000-10,000 feet or more of sediment filled some of the basins.

Basin-bounding fault zones may be more than a mile away from the present-day mountain fronts and buried beneath several hundred feet of sand and gravel. Basin-margin areas underlain by relatively thin sediment deposits are highly susceptible to overpumping.

Sediment in the basins became saturated with water, which occupies the spaces between the individual particles of rock. Ground water can be pumped readily from layers known as aquifers. Subsidence occurs when an aquifer is dewatered and the sand and gravel particles within it get squeezed together more closely. Compaction reduces the porosity of the aquifer and, if enough water is removed, the overlying land surface slowly sinks.

What kinds of problems are caused by land subsidence? Subsidence and earth fissures cause varied problems (Figures 1, 4-7). Fissures have cut highways, roads, airports, canals, building foundations, swimming pools, and ponds. Fissures have caused buildings to be condemned. (Not all foundation cracking is due to land subsidence induced by ground-water pumping.) In some areas people use open fissures as dumps and create potential for liquid waste to percolate downward into an aquifer. Open fissures are potential hazards to people who are unaware of their presence. Subsidence can cause the land slope to change. This disrupts irrigation and sewage systems, which depend on gravity flow. Farmers who irrigate crops have had to abandon fields or have them releveled so that the irrigation water flows in the right direction. One of the first indicators of subsidence is the collapse of water well casings. Streams or washes that once drained in a certain direction may now channel water into other areas, causing water to stand or flooding to occur where it never did before. Land surveyors have difficulty closing traverses if any of the benchmarks in the traverse have subsided.

What parts of Arizona are subsiding? Many basins in southern Arizona contain more than 1,600 feet of sedimentary deposits (Figure 8). Excessive pumping in a number of them has already induced subsidence and fissures. Additional impacts will occur if pumping continues. Subsidence can be expected even in basins that have not yet been affected if ground-water pumping exceeds recharge.

Subsidence has been known in Pinal County since 1927 and in the Phoenix and Tucson areas since the 1950s. The lead article in the Spring 1998 issue of *Arizona Geology* is a description of a 4,400-foot-long

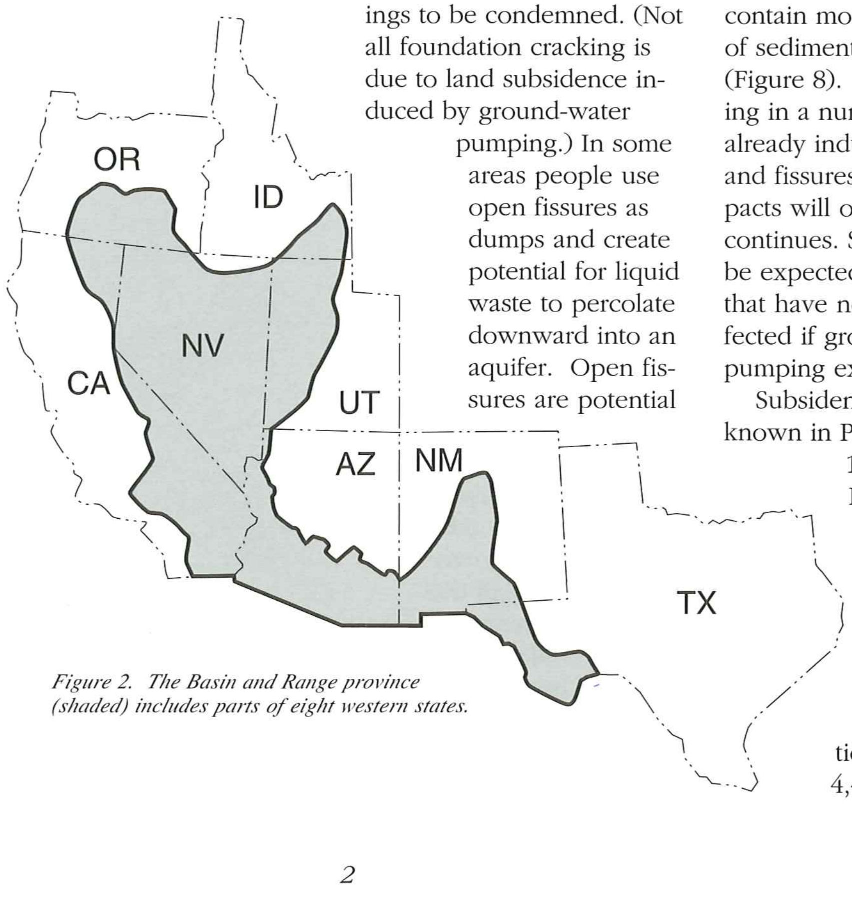

Figure 2. The Basin and Range province (shaded) includes parts of eight western states.

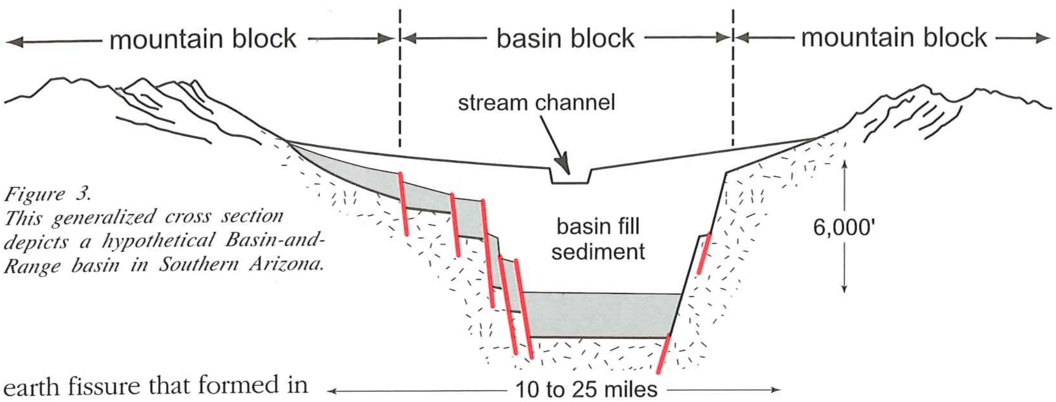

Figure 3. This generalized cross section depicts a hypothetical Basin-and-Range basin in Southern Arizona.

earth fissure that formed in the Harquahala Plain west of Phoenix after a heavy rain associated with Hurricane Nora in September 1997. Subsidence is suspected in other basins, but has not yet been measured.

The Basin and Range part of Arizona is not the only place where subsidence due to ground-water pumping is a known or potential problem. Las Vegas has been experiencing serious subsidence and related problems for several years. Subsidence has been recorded also near Deming, New Mexico. Potential exists for subsidence and related problems to occur in other basins within the Basin and Range province outside of Arizona.

How does one know that the land is subsiding? Subsidence takes place so gradually that it's hardly noticeable. It makes no noise and doesn't cause the ground to shake. Until a few years ago, subsidence could be confirmed only by conducting a land survey across the suspected area. A new method involves making repeat satellite-radar images. By this method, called *radar interferometry,* minute changes in the altitude of the land surface can be detected. Using this technique, the NPA Group, Edenbridge, United Kingdom, measured subsidence in western Maricopa County and the central Tucson basin. According to Ren Capes, Manager of Applications Development, the NPA Group determined that the central Tucson area subsided a maximum of 9 cm (3.5 in) between June 1993 and March 1997. This study, in combination with a previously generated result using a one-year temporal separation, indicated that the rate of subsidence was between 1.5 and 2.0 cm (0.6-0.8 in) per year for that period. A smaller area 5 mi southwest of the central area subsided about 6 cm (2.4 in) from June 1993 to March 1997.

Can subsidence be stopped? Subsidence can be stopped by slowing the rate of ground-water pumping so that recharge takes place as fast as or faster than pumping. If water is pumped back into the ground, however, subsidence will not be reversed. Once done, it's permanent.

Where can I get more information? The Arizona Geological Survey (AZGS), in cooperation with the Arizona Department of Water Resources (ADWR) and a dozen other governmental agencies, established the Center for Land-Subsidence and Earth-Fissure Information (CLASEFI). The purpose of CLASEFI is to serve as a central source of information about subsidence and related problems. Raymond C. Harris (AZGS) is the coordinator of CLASEFI activities.

Much information has been published about the cause and impacts of land subsidence. The AZGS published "Land Subsidence and Earth Fissures in Arizona," (Down-to-Earth 3) and bibliographies of published and unpublished maps and reports on subsidence (Open-File Reports 95-8 and 95-11). In addition, the AZGS maintains a web site that includes subsidence information. The ADWR, which periodically measures water levels in wells to determine changes, is now measuring land subsidence with Global Positioning System equipment. The U.S. Geological Survey, Water Resources Division, has released reports that describe land subsidence. The Water Resources Research Center and the Department of Geosciences at the University of Arizona also have information about subsidence on their web pages.

Visit the AZGS web page (**www.azgs.state.az.us**) for more information and links to other web sites.

Figure 4. An earth fissure cut this road in Pinal County several miles east of Chandler Heights. Photograph by R. C. Harris.

Figure 5. The land subsided more than 15 feet in Pinal County south of Eloy from 1950 to 1985. The marker on the pole shows where the land surface was in 1952. More subsidence has undoubtedly taken place since 1985. Photograph provided by H.H. Schumann.

Figure 6. Subsidence broke and offset this irrigation canal in western Maricopa County. Photograph by L.D. Fellows.

Figure 7. Earth fissures such as this one just east of the intersection of Baseline and Sossaman Road near Chandler Heights in Maricopa County are used commonly as dumps. Photograph by L. D. Fellows.

This map was modified from Depth-to-Bedrock Map, Basin and Range Province, Arizona, 1980, J.M. Oppenheimer and J.S. Sumner, scale 1:1,000,000.

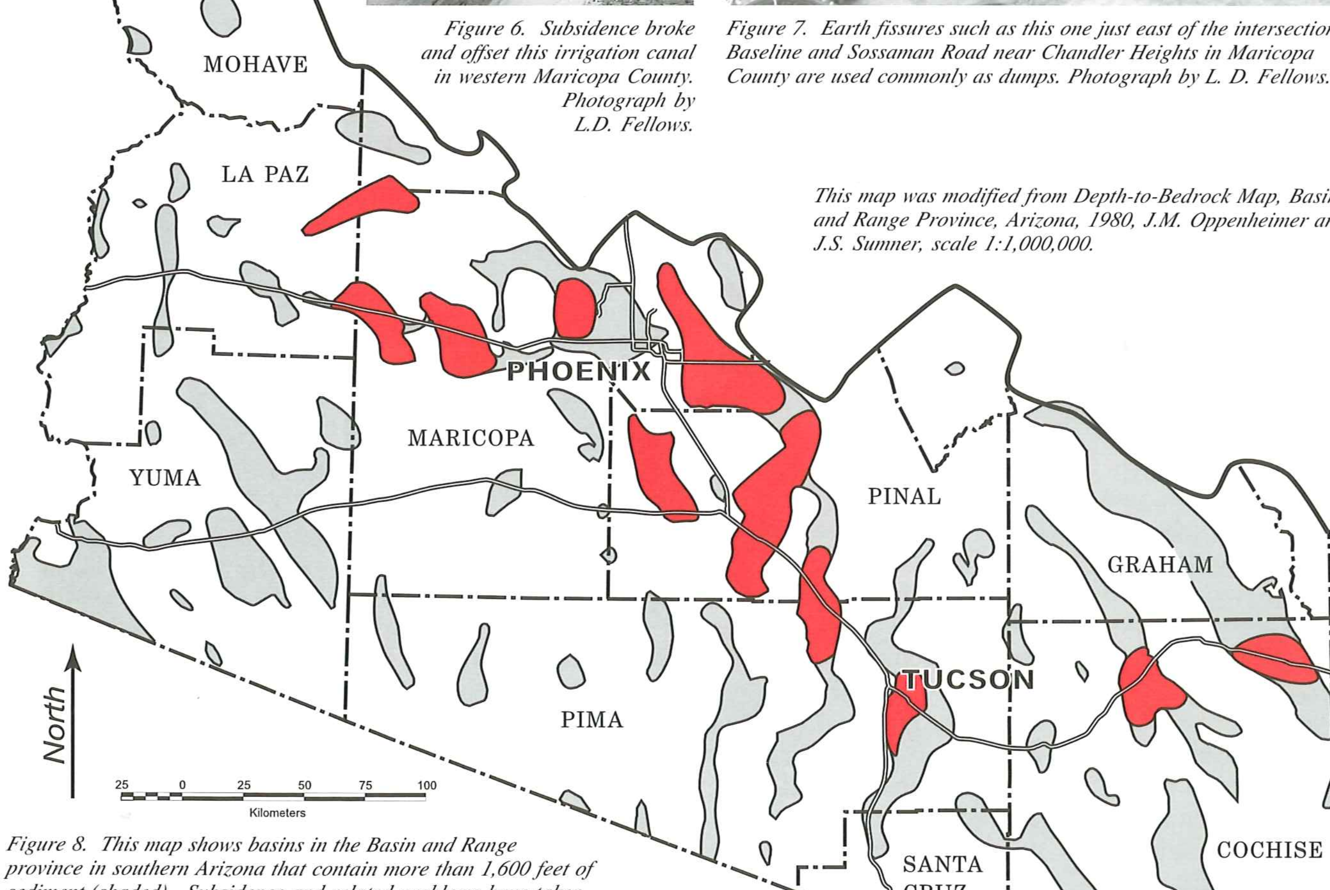

Figure 8. This map shows basins in the Basin and Range province in southern Arizona that contain more than 1,600 feet of sediment (shaded). Subsidence and related problems have taken place within those areas shown in red.