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Proposed Wilderness Legislation: BLM Wilderness Study Areas

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Since enactment of the Arizona Wilderness Act of 1984, emphasis has shifted to the Wilderness Study Areas (WSA's) administered by the U.S. Bureau of Land Management (BLM) in western and southern Arizona (Figure 1). The BLM has studied these 2,141,000 acres, in accordance with criteria established by Congress, and recommended that 982,000 of them be managed as wilderness. Their recommendations are included in environmental statements covering the Yuma, Lower Gila, Phoenix, Safford, Upper Sonoran, and Arizona Mohave districts (U.S. Bureau of Land Management, 1987a,b,c,d,e, 1989). The U.S. Geological Survey (USGS) and U.S. Bureau of Mines (BOM) are studying the geology and assessing the mineral potential of primarily those WSA's that the BLM recommended for partial or complete inclusion in the wilderness system. Many WSA's that the BLM concluded were unsuitable for wilderness status, however, are recommended for such status in pending legislation or are supported for wilderness designation by environmental groups. Federal agencies are not making mineral-potential assessments for most of those areas.

A bill (S 1080) has been introduced by Senators John McCain and Dennis DeConcini that designates as wilderness 895,150 acres administered by the BLM. Representative Morris K. Udall, chairman of the House Interior and Insular Affairs Committee, introduced two bills: HR 2570 designates as wilderness 1,430,480 acres of land administered by the BLM; HR 2571 designates as wilderness 1,387,910 acres of National Wildlife Refuge land (2,818,390 acres total). Representative Udall held hearings on these bills in Phoenix on June 9 and in Lake Havasu City on June 10. Senator John McCain and Representative Jim Kolbe held public meetings in Safford, Tucson, and Yuma.

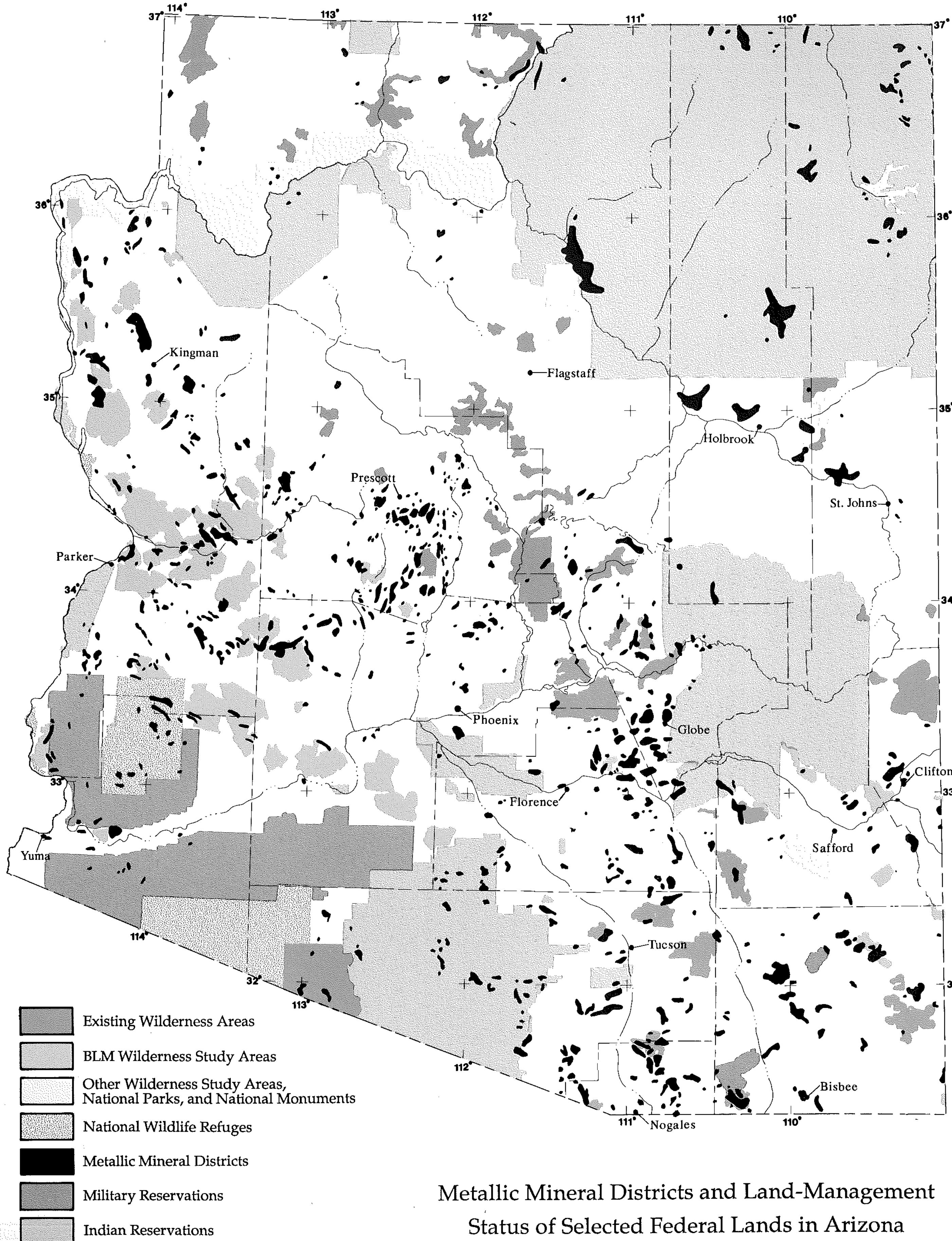
The Arizona Geological Survey (AZGS) reviewed the geology and mineral-resource potential of the WSA's and responded to the Interior and Insular Affairs Committee. The comments and conclusions, summarized below, are strictly those of the AZGS and are not intended to represent the State's position. The statutory mission of the AZGS is to assist the wise use of lands and mineral resources in Arizona by providing scientific and investigative research and information. Since 1981, AZGS geologists have been actively investigating the geologic framework and related mineral occurrences and preparing detailed geologic maps of western Arizona. To date, 18 maps have been published or placed on open file. This work is the basis of our comments.

The AZGS conducts *regional* geologic studies and does not attempt to locate specific ore deposits. Our mineral-potential estimates, therefore, may differ from those of mineral-exploration companies, which may have obtained detailed information such as geophysical or geochemical studies or drill-hole data. In addition, our mineral-potential estimates almost entirely emphasize the metallic minerals (copper, gold, silver, etc.); the nonmetals (clay, gypsum, limestone, etc.) are not included largely because of lack of data.

After reviewing the geology and mineral-resource potential of the WSA's, the AZGS has reached the following conclusions: (1) Knowledge of the geologic setting and mineral potential of many areas under review is inadequate to make final management decisions; (2) Based on review of available geologic literature, we conclude that there is high mineral potential in 16 of the 37 tracts recommended for wilderness under the BLM Proposed Action guideline; (3) Although mineral exploration has occurred for many years, additional deposits still remain to be discovered; and (4) Future mineral discoveries will not be restricted to copper, but will likely include gold, as well as other metallic and nonmetallic commodities.

Estimates of mineral potential are based on two types of information: (1) past metallic and nonmetallic mineral production and (2) consideration of the geologic setting and other geologic factors that have predictive value in locating undiscovered mineral deposits. The BOM has compiled production data for Arizona, but the quality and availability of geologic information are highly variable. Detailed geologic maps cover only a small fraction of the total land currently under consideration for wilderness status in Arizona. Until such maps are made and detailed information about the nature and distribution of rock types is available, one cannot accurately or objectively assess mineral-resource potential. Designation of an area as wilderness without adequate information about mineral-resource potential would, in our opinion, be premature. Restricted access to areas designated as wilderness will inhibit or prevent future acquisition of geologic data, not only by the AZGS and USGS, but also by land-management agencies, mineral explorationists, university faculty and students, and other scientists. This is especially true in desert areas because the lack of naturally occurring drinking water necessitates use of motor vehicles, which are prohibited in wilderness areas, or pack animals to conduct geologic research.

In the absence of detailed geologic studies, only very general estimates of mineral-resource potential can be made; these are based solely on past mineral production and regional geologic setting. Such estimates are crude and likely to be inaccurate. They fail to take into account that new geologic interpretations and models will be developed as knowledge increases. In addition, such estimates do not consider that, as exploration and production techniques improve, mining of lower-grade ore or even new commodities might become economic.



Metallic Mineral Districts and Land-Management Status of Selected Federal Lands in Arizona

Some individuals and groups have stated that because prospectors and mineral explorationists "have spent over a century thoroughly exploring and claiming significant mineral deposits," there is little left to discover. Statements such as this reveal an alarming lack of understanding of mining and mineral exploration. Even though most of the obvious mineral deposits exposed *at the land surface* have been discovered, knowledge of what lies *below the surface* is extremely limited. This subject was addressed in the Summer 1988 issue of *Fieldnotes* (now called *Arizona Geology*; Fellows, 1988).

Statements such as this also ignore that changes and improvements in exploration and production techniques and increases in metal prices commonly make a mineral deposit that was once uneconomic to mine into one that can be mined profitably. Most large, low-grade gold deposits in the western United States, such as the Copperstone mine in La Paz County, western Arizona (Spencer and others, 1988), were discovered during the past 20 years and were not economically viable until the price of gold increased dramatically in the 1970's. Development of heap-leaching techniques allows recovery of gold from very low-grade ores. Detachment faults and mineral deposits (such as Copperstone) that are associated with them were not understood until the early to mid-1980's. New geologic models and concepts will be developed in the future.

In 1983 the AZGS completed a map and report on known metallic mineral districts and production in Arizona (Keith and others, 1983). This bulletin was essentially a progress report. Future mineral discoveries will be made both within and outside the metallic mineral districts defined in this bulletin. The Copperstone mine does not appear on the map or in the report because its orebody was discovered *after* the report was published.

We are also aware of comments that "almost all the mineral potential in question is copper." This statement is incorrect. Dozens of mineral-exploration companies are currently exploring for gold, not copper, in western Arizona. One reason, perhaps, is that the recently discovered Mesquite mine northwest of Yuma (in California) is expected to yield approximately $1 billion worth of gold. The geologic setting of much of western Arizona is similar to that of the Mesquite mine. Other metals and nonmetals will be sought in the future as economic conditions dictate.

Figure 1 (left). Modified from U.S. Bureau of Land Management Wilderness Status Map, June 1986, scale 1:1,000,000.

Arizona has large areas of essentially undisturbed public land, significant portions of which are mineralized. Rational decisions about how to manage lands currently being reviewed for wilderness status must be based on accurate information and must be made carefully because large portions of those areas have mineral potential. Designation of public lands as wilderness will make additional geologic study difficult, and in some cases, virtually impossible. Mineral development will not be allowed. In light of past mineral production and regional geologic setting and in the absence of detailed geologic studies, we express deep concern at the large amount of public land proposed for wilderness status.

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_____ 1987b, Final environmental impact statement, proposed wilderness program for the Lower Gila South EIS Area, La Paz, Maricopa, Pima, Pinal, and Yuma Counties, Arizona: 322 p.

_____ 1987c, Final environmental impact statement, proposed wilderness program for the Phoenix Wilderness EIS Area, Maricopa, Mohave, Pima, Pinal, and Yavapai Counties, Arizona: 231 p.

_____ 1987d, Final environmental impact statement, proposed wilderness program for the Safford District Wilderness EIS Area, Cochise, Gila, Graham, and Greenlee Counties, Arizona and Hidalgo County, New Mexico: 506 p.

_____ 1987e, Final environmental impact statement, proposed wilderness program for the Upper Sonoran Wilderness EIS Area, La Paz, Maricopa, Mohave, and Yavapai Counties, Arizona: 394 p.

_____ 1989, Final environmental impact statement, proposed wilderness program for the Arizona Mohave Wilderness Areas, Greenlee, Maricopa, Mohave, Pima, Pinal, and Yavapai Counties, Arizona and Grant County, New Mexico: 284 p.

Publications Discuss 1983 Floods in Arizona

Tropical storm Octave off the coast of Baja California was the main cause of the outstanding floods of October 1983 in southeastern Arizona and western New Mexico. The long period of rainfall from September 27 to October 3 was the result of the interaction of a high-altitude low-pressure trough and a persistent supply of moist tropical air from Octave. As much as 11 inches of rain fell during the 7-day storm period. The persistent rains led to record floods on the San Francisco, Gila, San Pedro, and Santa Cruz Rivers and other smaller streams. Large channel changes took place on many of these waterways. Eight lives were lost as a result of the floods; damage was estimated to be $226.5 million.

A new report published by the U.S. Geological Survey describes the floods and documents their significance in the hydrologic record. The report specifies maximum discharges, flood frequencies, inundated areas, channel changes, and flood damage. *Floods of October 1983 in Southeastern Arizona*, by R.H. Roeske, J.M. Garrett, and J.H. Eychaner, was released in 1989 as Water-Resources Investigations Report 85-4225-C. It may be purchased for $12.50 from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225.

The Arizona Geological Survey also published a report on the 1983 floods. *Channel Change Along the Rillito Creek System of Southeastern Arizona, 1941 Through 1983: Implications for Flood-Plain Management*, by M.S. Pearthree and V.R. Baker, was released in 1987 as Special Paper 6. The authors discuss the historical behavior of this alluvial stream system, identify potential sites of bank erosion and lateral channel migration, and suggest flood-plain management alternatives to Federal regulations currently applied to semiarid regions. Special Paper 6 may be purchased for $20.25 ($16.00, plus $4.25 for shipping) from the Arizona Geological Survey, 845 N. Park Ave., #100, Tucson, AZ 85719.

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

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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 manmade 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.

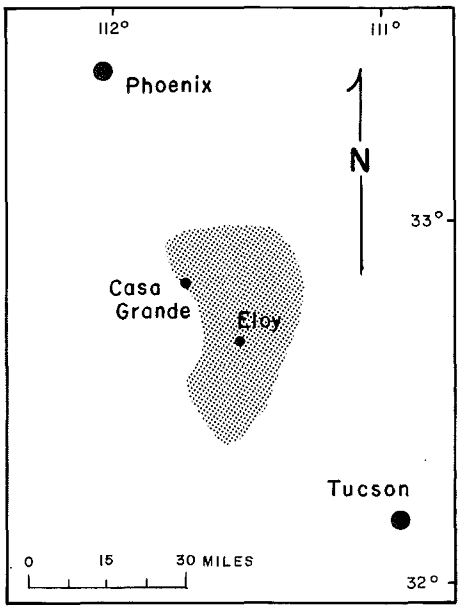

***Figure 1.** Location map showing approximate extent of Picacho basin (shaded area).*

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

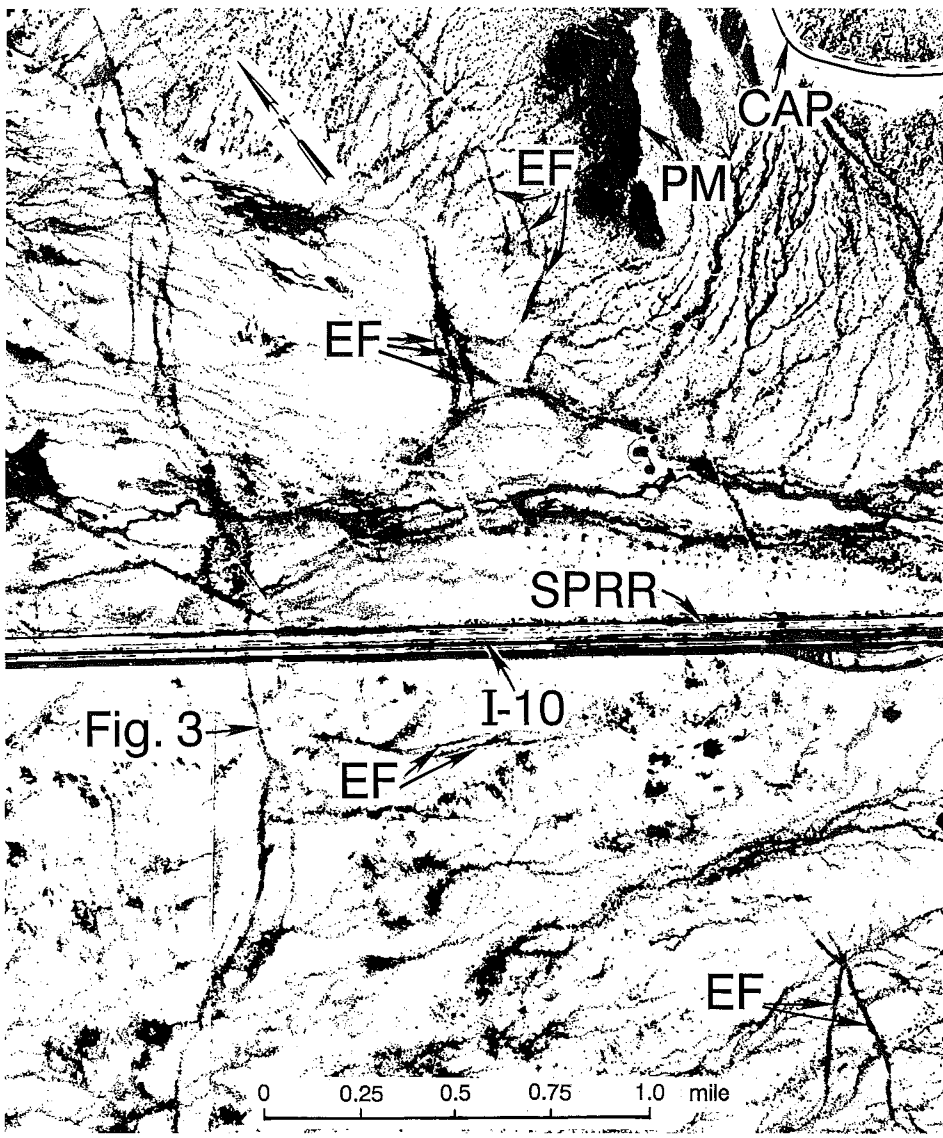

***Figure 2.** Aerial photograph of part of the eastern portion of Picacho basin. The old earth fissure discussed in the text is shown as a system of dark lines extending from top to bottom on the left side of the photo. Identified features are as follows: EF - other earth fissures; PM - southern end 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

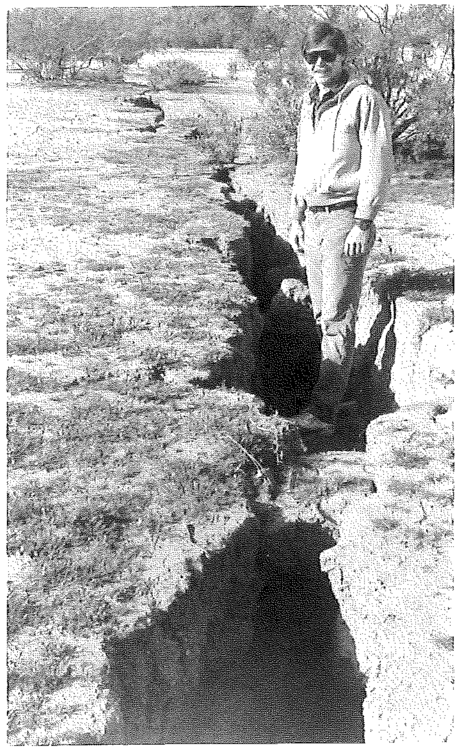

Figure 3. Ground view toward the southwest of a portion of the old earth fissure discussed in the text. Note steep to vertical walls, narrow width, and lack of large vegetation along the crack. These and other features suggest the relative youthfulness of this portion of the fissure. An older portion,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

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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.

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

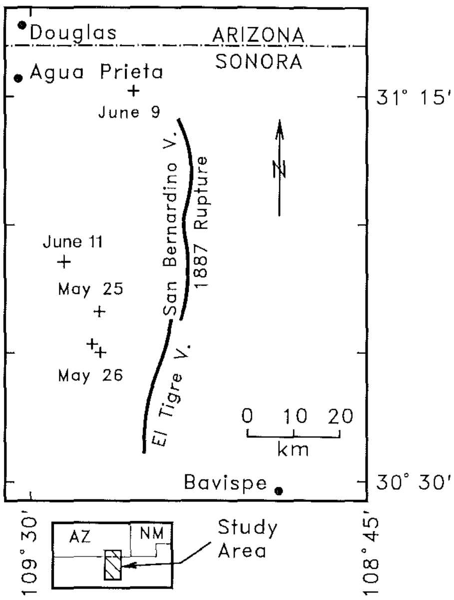

Figure 1. Location map of Pitaycachi fault region, showing epicenters of earthquakes that occurred on June 11, 1988, May 25, 1989, May 26, 1989, and June 9, 1989. Solid line indicates surface rupture due to 1887 earthquake. Note "bend" between northern and southern segments.

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).

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

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

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.

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

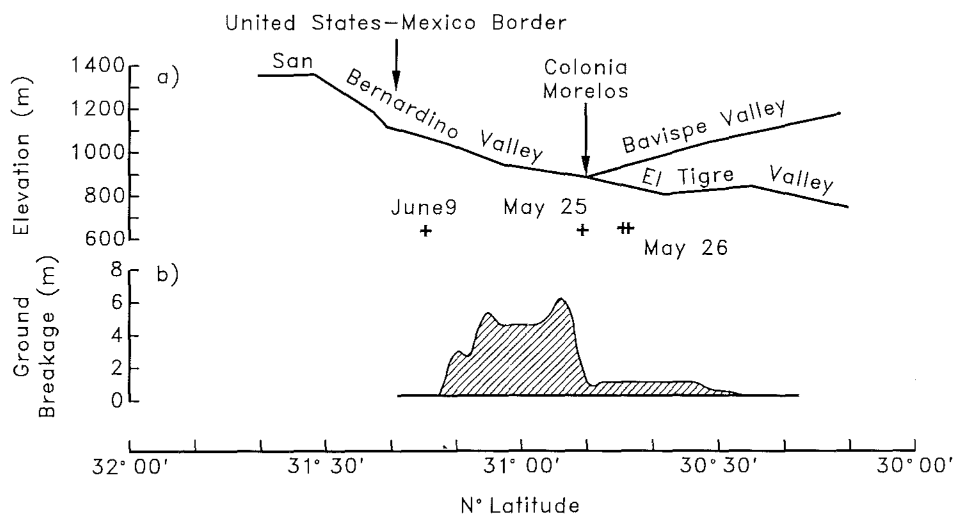

Figure 2. Elevations for the San Bernardino and El Tigre Valleys projected onto a north-south profile. The vertical displacement from the 1887 great Sonoran earthquake is also shown. Near Colonia Morelos, the 1887 fault trace takes an abrupt bend and crosses into the El Tigre Valley. It is also at this 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.

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New AZGS Publications

The following publications may be purchased from the Arizona Geological Survey (AZGS), 845 N. Park Ave., #100, Tucson, AZ 85719. For price information on these and other publications, contact the AZGS office at (602) 882-4795.

The Contributed Map Series replaced the Miscellaneous Map Series in January 1989 because the latter title did not adequately describe the source and status of these publications. This series provides an outlet for geologic maps, produced by geologists who are not associated with the AZGS, that are considered to represent significant contributions to the scientific literature on the geology of Arizona. Many of these maps are from theses and dissertations and would not be readily available to the public if they were not placed in the Contributed Map Series. The maps are reproduced as blueline copies made from mylars provided by the authors.

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.

New Publications List Available

The Arizona Geological Survey (AZGS) has issued a new publications list, which includes 13 new maps and reports and a detailed subject index. For a free copy, contact the AZGS at 845 N. Park Ave., #100, Tucson, AZ 85719; tel: (602) 882-4795.

AZGS Hosts Workshop on Landslides in Arizona

by Philip A. Pearthree
Arizona Geological Survey

From May 16 to 19, 1989, the Arizona Geological Survey (AZGS) hosted an informal workshop on methods for evaluating landslide hazards in Arizona. Dr. Earl E. Brabb from the U.S. Geological Survey (USGS) Office of Earthquakes, Volcanoes, and Engineering in Menlo Park volunteered to visit the AZGS to share his expertise in landslide recognition and mapping. Brabb has extensive experience worldwide in evaluation of potential landslide hazards and has encouraged State geological surveys to conduct landslide inventories. Other agencies concerned about landslides in Arizona and adjacent States were invited to attend the workshop; representatives of the U.S. Forest Service, New Mexico Bureau of Mines and Mineral Resources, and Nevada Bureau of Mines and Geology attended.

Landslides (also termed *mass movements* or *mass wasting*) are downslope movements of masses of earth material driven by gravity. Landslide masses may fall, flow, slide, or roll downslope. Water is typically an important component of the landslide, but landslides are distinguished from water floods by the relative importance of debris (rock and soil) in the movement. Landslides are typically triggered by unusually large amounts of precipitation or seismic shaking, although rockfalls and rockslides may occur without any obvious external control. Landslides include rockfalls, rockslides, debris avalanches, slumps, earthflows, and debris flows. Most of these landslide types are known to have occurred in Arizona (Reiche, 1937; Pewe, 1978; Dubois and Smith, 1980; *Arizona Geology*, 1988). Landslides have damaged highways (Realmuto, 1985) and homes (Pewe, 1978) in the State. Debris flows in tributary canyons are probably responsible for many of the famous rapids of the Colorado River in the Grand Canyon (Webb and others, 1987).

The principal objective of the AZGS workshop was to learn how to evaluate the landslide potential within a State or region by defining the types and extent of landslide hazards in different areas. This information may then be used to determine the types of detailed larger-scale studies required in areas where landslides have occurred.

Most of the workshop was devoted to learning strategies for developing map inventories of landslides. These include criteria for recognizing landslides on aerial photographs, classification of landslides, appropriate scales for landslide inventories, and assessment of current knowledge of landslide hazards within the State or region. Physical evidence of a landslide may be divided into erosional features where the landslide originates and depositional features where the landslide terminates. Workshop participants reviewed aerial photographs of different areas of Arizona to establish criteria for recognizing characteristic features of landslides. They plotted these features on USGS 30′ x 60′, 1:100,000-scale quadrangle maps. This scale was chosen because it is small enough for a reconnaissance survey, yet large enough to allow some detail on the map. Landslides were differentiated as slumps and earthflows, rotational block slides, debris flows, and rockfalls; steeply sloping areas where recent erosion was evident were also noted.

The primary intent of making 1:100,000- and smaller-scale map inventories is not to locate every landslide or mass movement, but to provide a basis for assessing the extent and kinds of landslide hazards that affect a given area. Field studies would be used only to spot-check interpretations based on aerial photographs; it would not be feasible to field check a large number of landslide features in a reconnaissance survey. Ambiguities concerning the origin of some features would not be resolvable at this scale, nor would small landslide features be recognizable. Nonetheless, landslide inventories of this type should provide useful information to responsible agencies or private consultants concerned with landslide hazards in Arizona.

Knowledge of landslide occurrence in Arizona is limited because no systematic statewide survey of landslides has been conducted. The AZGS has conducted two assessments of landslide occurrence in Arizona, which were partially funded by the USGS. These assessments involved compiling published literature on landslides in the State (Welty and others, 1988) and studying highway-maintenance records of the Arizona Department of Transportation (Realmuto, 1985). The distributions of landslides compiled by these authors were compared with independent assessments that workshop participants made using aerial photographs. In every area surveyed, the above compilations were found to substantially underestimate the number of landslides that have occurred. In addition, a recently completed inventory of landslides in northern New Mexico revealed many landslides that were previously unreported (Guzzetti and Brabb, 1987). A systematic survey is clearly needed to outline the extent of potential landslide hazards in Arizona.

The AZGS is beginning a program to compile an inventory of landslides in the State, building on the insights gained during the recent workshop. Researchers will map landslides using aerial photographs that will probably range in scale from 1:24,000 to 1:129,000 and plot them on 1:100,000-scale topographic base maps. During the next several years, the AZGS plans to complete a uniform statewide reconnaissance survey of landslides that local governments and other agencies can use to estimate landslide potential in their specific areas.

References

Arizona Geology, 1988, Debris flow threatens Arizona homes: Arizona Geological Survey, v. 18, no. 3, p. 4.

Dubois, S.M., and Smith, A.W., 1980, The 1887 earthquake in the San Bernardino Valley, Sonora: Historical accounts and intensity patterns in Arizona: Arizona Bureau of Geology and Mineral Technology Special Paper 3, 112 p.

Guzzetti, Fausto, and Brabb, E.E., 1987, Map showing landslide deposits in northwestern New Mexico: U.S. Geological Survey Open-File Report 87-70, scale 1:500,000, 2 sheets.

Pewe, T.L., 1978, Geologic hazards in the Phoenix area: Arizona Bureau of Geology and Mineral Technology Fieldnotes, v. 8, no. 1-2, p. 18-20.

Realmuto, V.J., 1985, Preliminary map of selected mass-movement events in Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report 85-16, 9 p., scale 1:500,000, 2 sheets.

Reiche, Parry, 1937, The toreva-block; a distinctive landslide type: Journal of Geology, v. 45, p. 538-548.

Webb, R.H., Pringle, P.T., and Rink, G.R., 1987, Debris flows from tributaries of the Colorado River, Grand Canyon National Park, Arizona: U.S. Geological Survey Open-File Report 87-118, 64 p.

Welty, J.W., Roddy, M.S., Alger, C.S., and Brabb, E.E., 1988, Bibliography of Arizona landslide maps and reports: Arizona Geological Survey Open-File Report 88-14, 13 p.

Publication Addresses Water Issues

Arroyo is a quarterly newsletter that addresses water concerns in Arizona and the Southwest. Each issue features a different concern, such as reclaimed water use, instream flows, and climate change. The newsletter serves a broad audience, including policy makers, researchers, and the public. Subscriptions are free.

For more information, contact Joe Gelt, Editor, *Arroyo*, Water Resources Research Center, Geology Bldg., Rm. 314, University of Arizona, Tucson, AZ 85721; (602) 621-7607.

Engineering and Environmental Geology Publications

These publications were compiled by and may be purchased from the Arizona Geological Survey (AZGS). For price information, contact the AZGS office at 845 N. Park Ave., #100, Tucson, AZ 85719; tel: (602) 882-4795. The publication series are abbreviated as follows: B=Bulletin; FS=Folio Series; M=Map; OFR =Open-File Report; SP=Special Paper.

REPORTS

B 193--Arizona Earthquakes, 1776-1980, by S.M. DuBois, A.W. Smith, N.K. Nye, and T.A. Nowak, Jr., 1982, 456 p., scale 1:1,000,000 (includes M 16).

SP 3--The 1887 Earthquake in San Bernardino Valley, Sonora: Historical Accounts and Intensity Patterns in Arizona, by S.M. DuBois and A.W. Smith, 1980, 112 p.

SP 6--Channel Change Along the Rillito Creek System of Southeastern Arizona, 1941 Through 1983; Implications for Flood-Plain Management, by M.S. Pearthree and V.R. Baker, 1987, 58 p.

OFR 83-19--Neotectonic Framework of Arizona; Implications for the Regional Character of Basin and Range Tectonism, by C.M. Menges, 1983, 109 p.

OFR 83-20--Distribution, Recurrence, and Possible Tectonic Implications of Late Quaternary Faulting in Arizona, by P. A. Pearthree, C.M. Menges, and Larry Mayer, 1983, 51 p.

OFR 85-4--Reconnaissance Analysis of Possible Quaternary Faulting in Central Arizona, by P.A. Pearthree and R.B. Scarborough, 1984, 75 p., scale 1:250,000.

OFR 86-8--Late Quaternary Faulting and Seismic Hazard in Southeastern Arizona and Adjacent Portions of New Mexico and Sonora, Mexico, by P.A. Pearthree, 1986, 22 p.

OFR 86-15--Sedimentary Successions of the Prehistoric Santa Cruz River, Tucson, Arizona, by C.V. Haynes, Jr., and B.B. Huckell, 1986, 44 p.

OFR 87-3--Geology, Radioactivity, and Radon at the Cardinal Avenue Uranium Occurrence, Southwestern Tucson, by J.E. Spencer, D.F. Emer, and J.D. Shenk, 1987, 16 p.

OFR 87-6--Summary Report of Geotechnical Investigations, 9/86 Through 2/88, Maricopa Superconducting Super Collider (SSC) Site, Maricopa County, Arizona, by Engineers International, Inc., 1988, 144 p., scale 1:24,000 and 1:62,500, 2 sheets.

OFR 87-7--Geotechnical Engineering Investigations for Arizona's SSC Sites, by J.S. DeNatale, E.A. Nowatzki, and J.W. Welty, 1987, 338 p.

OFR 87-12--A Report on Earthquake Activity Recorded at Station Flagstaff in 1984, by D.S. Brumbaugh, J. Davis, and L. Roberts, 1987, 40 p.

OFR 88-5--Additional Geotechnical Engineering Investigations for Arizona's Maricopa SSC Site, by E.A. Nowatzki, Eugene Muller, J.S. DeNatale, G.A. Ibarra-Encinas, A.M.F. Al-Ghanem, and J.W. Welty, 1988, 221 p.

OFR 88-7--Volume 3, Geology and Tunneling of the Maricopa SSC Site Proposal, by J.W. Welty, 1988, 260 p.

OFR 88-8--Volume 3, Geology and Tunneling of the Sierrita SSC Site Proposal, by J.W. Welty, 1988, 270 p.

OFR 88-11--Background Radioactivity in Selected Areas of Arizona and Implications for Indoor-Radon Levels, by J.E. Spencer, D.F. Emer, and J.D. Shenk, 1988, 14 p.

OFR 88-12--Reconnaissance of Gamma-Ray Spectrometer Survey of Radon-Decay Products in Selected Populated Areas of Arizona, by D.F. Emer, J.D. Shenk, and J.E. Spencer, 1988, 88 p.

OFR 88-14--Bibliography of Arizona Landslide Maps and Reports, by J.W. Welty, M.S. Roddy, C.S. Alger, and E. E. Brabb, 1988, 13 p.

OFR 88-15--Reconnaissance Assessment of Quaternary Faulting in the Gila River Region from San Carlos Reservoir to Coolidge, Arizona, by R.B. Scarborough and P.A. Pearthree, 1986, 12 p., scale 1:250,000.

OFR 88-20--Potential Land Surface Subsidence at the Arizona SSC Site; Considering Past, Current and Possible Future Ground-Water Withdrawal, by S.J. Brooks, 1988, 28 p.

MAPS

M 16--Historical Epicenters in Arizona, 1830-1980, by S.M. DuBois, T.A. Nowak, A.W. Smith, and N.K. Nye, 1982, scale 1:1,000,000 (included in B 193).

M 22--Map of Late Pliocene-Quaternary (Post-4-m.y.) Faults, Folds, and Volcanic Outcrops in Arizona, by R.B. Scarborough, C.M. Menges, and P.A. Pearthree, 1986, scale 1:1,000,000.

M 23--Land Subsidence, Earth Fissures, and Water-Level Change in Southern Arizona, by H.H. Schumann and R.B. Genualdi, 1986, scale 1:1,000,000 (also printed at 1:500,000 as OFR 86-14).

FS 1--Environmental Geology of the McDowell Mountains Area, Maricopa County, Arizona, by G.E. Christenson, D.G. Welsch, and T.L. Pewe, 1978, scale 1:24,000, 10 sheets.

FS 2--Environmental Geology of the Tempe Quadrangle, Maricopa County, Arizona, by T.L. Pewe, C.S. Wellendorf, and J.T. Bales, 1986, scale 1:24,000, 8 sheets.

OFR 83-4--Tucson Metropolitan Area; (a) Ease of Excavation and Potential Erodibility, (b) Flood Hazards, (c) Slope Relief, by R.B. Morrison, 1977, 4 p., scale 1:120,000, 3 sheets.

OFR 83-21--Map of Basin and Range (Post-15-m.y.a.) Exposed Faults, Grabens, and Basalt-Dominated Volcanism in Arizona, by R.B. Scarborough, C.M. Menges, and P.A. Pearthree, 1983, 25 p., scale 1:500,000, 2 sheets.

OFR 83-22--Map of Neotectonic (Latest Pliocene-Quaternary) Deformation in Arizona, by C.M. Menges and P.A. Pearthree, 1983, 48 p., scale 1:500,000, 4 sheets.

OFR 84-1--Late Pliocene and Quaternary Geology, Ajo Quadrangle, by R.B. Morrison, 1983, scale 1:250,000.

OFR 84-2--Late Pliocene and Quaternary Geology, El Centro Quadrangle, by R.B. Morrison, 1983, 6 p., scale 1:250,000.

OFR 84-3--Late Pliocene and Quaternary Geology, Lukeville and Sonoyta Quadrangles, by R.B. Morrison, 1983, 6 p., scale 1:250,000.

OFR 85-161--Preliminary Map of Selected Mass-Movement Events in Arizona, by V.J. Realmuto, 1985, 9 p., scale 1:500,000, 2 sheets.

OFR 86-11--Map Showing Areas in Arizona with Elevated Concentrations of Uranium, by J.E. Spencer and J.D. Shenk, 1986, scale 1:1,000,000.

OFR 88-4--Quaternary Geologic Map of the Salome 30′ x 60′ Quadrangle, by K.A. Demsey, 1988, scale 1:100,000.

OFR 88-17--Geologic Map of Quaternary and Upper Tertiary Alluvium in the Phoenix North 30′ x 60′ Quadrangle, Arizona, by K.A. Demsey, 1988, scale 1:100,000.

OFR 88-18--Surficial Geologic Maps of the Tucson Metropolitan Area, by M.A. McKittrick, 1988, 7 p., scale 1:24,000, 12 sheets.

OFR 88-20--Potential Land Surface Subsidence at the Arizona SSC Site; Considering Past, Current, and Possible Future Ground-Water Withdrawal, by S.J. Brooks, 1988, 28 p.

OFR 88-21--Geologic Map of Quaternary and Upper Tertiary Deposits, Tucson 1^{o} x 2^{o} Quadrangle, Arizona, by P.A. Pearthree, M.A. McKittrick, G.W. Jackson, and K.A. Demsey, 1988, scale 1:250,000.

OFR 89-2--Surficial Geologic Maps of the Northeastern, Southeastern, and Southwestern Portions of the Tucson Metropolitan Area, by G.W. Jackson, 1989, 6 p., scale 1:24,000, 7 sheets.

Environmental Geology Problems in the United States

The 1988-89 Environmental Geology Committee of the Association of American State Geologists (AASG) surveyed the magnitude and type of environmental geology problems that occur across the Nation. For the purpose of the survey, *environmental geology* was defined as "the interaction of geologic factors, materials, and processes with, and their impacts on, current or projected human activities." The committee was composed of John W. Rold (Colorado), chairman, Genevieve Atwood (Utah), Robert B. Forbes (Alaska), Haig F. Kasabach (New Jersey), Raymond Lasmanis (Washington), Walter Schmidt (Florida), and James H. Williams (Missouri). The committee prepared and distributed a questionnaire to each State Geologist. Forty-two completed the survey. Excerpts from the committee report, which was presented at the annual meeting of the AASG in Norman, Oklahoma, May 13-17, 1989, are given below.

When asked to identify the five major current and future environmental geology problems, State Geologists expressed most concern about ground water and ground-water pollution (Table 1). When asked about "typical" environmental geology problems and how they affect the State, State Geologists consistently listed solid waste, toxic waste, ground-water pollution, non-point-source pollution, underground storage tanks, and flood-plain flooding. None of these items were judged to be "no problem" (Table 2). Other frequently mentioned major problems were shoreline erosion or inundation, low-level radioactive waste, flash flooding, radon in homes, and landslides. Snow avalanches and volcanoes were listed least frequently as being either a major or a minor environmental problem.

Most State geological surveys serve in an advisory role for the environmental geology items listed in these tables. Very few have regulatory responsibility. Many surveys are committing considerable amounts of time and money to investigate and mitigate ground-water pollution, map aquifers, provide information used in land reclamation, and study seismicity. Radon is being addressed by many surveys, but with fewer funds.

A State Health Department, Department of Environmental Quality, Department of Natural Resources, or similar entity is commonly designated as the "lead agency" for environmental problems. Most State Geologists reported that the State geological survey interacted favorably and effectively with those agencies.

The purpose of this survey was to assist State geological surveys and other government agencies and others in evaluating the magnitude of environmental geology problems and in setting program priorities. In a future issue of *Arizona Geology*, an article will focus on environmental geology problems in the *western* States, which are expected to have a number of common concerns.

Table 1. *Current and future environmental geology problems.*

CURRENT*

Ground water	22	Mined-land reclamation	3
Non-point-source pollution	17	Swelling soil	3
Point-source pollution	15	Underground storage tanks	3
Solid waste	15	Aquifer protection	2
Radon	14	Debris flows	2
Landslides	13	Sink holes	2
Low-level radioactive waste	13	Solution subsidence	2
Toxic waste	13	Underground injection	2
Shoreline erosion	10	Wetlands	2
Waste disposal	10	Aggregate availability	1
Earthquakes	8	Naturally occurring toxic elements	1
Subsidence	8	Permafrost	1
Flooding	7	Siltation	1
Flash flooding	5	Soil erosion	1
Mine subsidence	4	Tsunamis	1
Surface-water pollution	4	Volcanoes	1
High-level radioactive waste	3		

FUTURE**

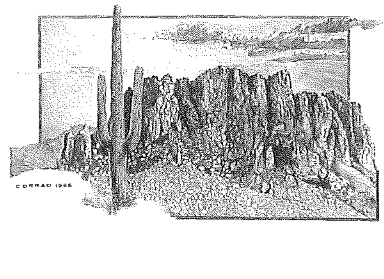
Ground water	23	Swelling soil	4
Non-point-source pollution	13	Aquifer protection	3
Waste disposal	13	Debris flows	3
Low-level radioactive waste	12	Waste and spills - oil and gas	3
Solid waste	11	Sinkholes	2
Sea-level rise and coastal erosion	10	Underground storage tanks	2
Toxic waste	10	Acid rain	1
Landslides	9	Environmental education	1
Point-source pollution	9	Great Lakes	1
Radon	7	Ground-water cleanup	1
Subsidence	7	Naturally occurring toxic elements	1
Earthquakes	6	Offshore leasing - oil and gas	1
Flooding	6	Permafrost	1
Flash flooding	4	Pollution by agricultural chemicals	1
High-level radioactive waste	4	Salt solution	1
Shoreline erosion	4	Tsunamis	1
Surface-water pollution	4	Volcanoes	1
		Wetlands	1

* Compiled responses of 42 State Geologists to this request: "List the five most important current environmental geology problems in your State." Figures indicate the number of State Geologists who cited the problem as a major concern.

** Compiled responses of 42 State Geologists to this question: "What do you foresee as the five major environmental geology problems in your State in the next 5 to 10 years?" Figures indicate the number of State Geologists who perceived that the problem will be a major concern.

Table 2. *"Typical" environmental geology problems. Figures indicate the number of State Geologists who judged the items to be major problems, minor problems, or no problem in their respective States. Forty-two States responded to the questionnaire.*

	Problem in State? Major	Minor	No
Solid waste	28	12	0
Toxic waste	27	11	0
Ground water			
Pollution	26	13	0
Non-point-source	23	13	0
Underground storage tanks	22	14	0
Flood-plain flooding	21	18	0
Shoreline erosion or inundation	19	9	8
Low-level radioactive waste	18	15	7
Flash flooding	15	16	8
Radon gas in homes	15	21	2
Landslides	13	25	6
High-level radioactive waste	11	15	18
Expansive soils	10	23	9
Subsidence			
Mine	10	18	11
Solution	6	16	19
Sink holes	8	16	15
Fluid withdrawal	5	12	19
Dam safety	9	20	6
Earthquakes	9	24	5
Debris flows	8	14	17
Rock falls	5	26	9
Snow avalanches	5	3	31
Volcanoes	3	5	33



Status of Registration of Geologists

In a report to the Association of American State Geologists (AASG), the Professional Affairs Committee summarized existing and recent legislation involving registration or certification of geologists. The following information was excerpted from that report, which was presented at the 1989 annual meeting of the AASG, held in Norman, Oklahoma, May 13-17, 1989. The committee, chaired by James H. Williams (Missouri), included Donald A. Hull (Oregon), Robert R. Jordan (Delaware), William H. McLemore (Georgia), and Norman K. Olson (South Carolina).

Recent Legislation

In 12 States, geologists are required by law to be registered to practice their profession: Arizona, Arkansas, California, Delaware, Florida, Georgia, Idaho, Maine, North Carolina, Oregon, South Carolina, and Tennessee (Figure 1). The three most recent States to enact registration laws and the years those laws became effective are Tennessee (1989), Arkansas (1988), and Florida (1987).

A registration and licensing bill was introduced in the Washington legislature early in 1989, but died in committee. A bill will be introduced in Ohio during the 1990 legislative session. In Vermont, a comprehensive professional registration bill may be introduced in 1990; a 1989 bill specifically addressing geologists went nowhere. A bill in New Hampshire was killed by referral to a study committee to review administrative procedures and set registration requirements. A new bill will probably be introduced during the next legislative session. In New Jersey, registration attempts were recently made, but no legislation was passed. Public hearings were held in Massachusetts in February 1989 on an act establishing a Board of Registration of Professional Geologists.

Registration initiatives are being taken in Texas. If enacted, the law may differ from that of most States because petroleum geologists may be exempted. The Association of Engineering Geologists (AEG) is seeking registration of engineering geologists, and the American Institute of Professional Geologists (AIPG) is working with others to broaden the list of specialties that would be registered.

Minimum Standards

States that require certification, but not registration, of geologists use as standards the minimum qualifications accepted by the AEG and AIPG. A written exam is generally not required for certification. States that mandate formal registration require a written and possibly an oral exam, as well as academic and work experience.

National Colloquium on Registration for Geologists

The Association of Engineering Geologists (AEG) will sponsor a National Colloquium on Professional Registration for Geologists at its 33rd annual meeting in Pittsburgh, Pennsylvania in October 1990. This one-day conference will bring together representatives from academia, the consulting arena, State boards of registration, State and local agencies, and professional and scientific geological societies. Volunteered and invited papers and panel discussions will focus on the advantages, disadvantages, and issues concerning professional registration of geologists. The AEG will publish the proceedings. For more information, contact Robert E. Tepel, Chairperson, AEG Committee on Professional Registration, 767 Lemonwood Ct., San Jose, CA 95120.

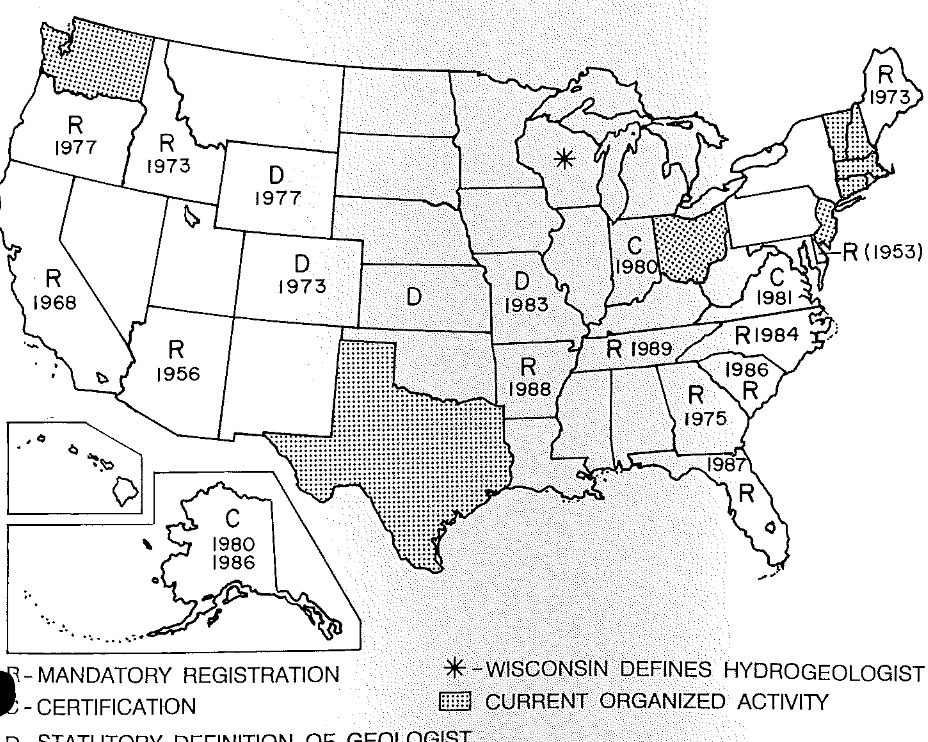


Figure 1. Status of legislation affecting geologists, May 1989.

Applicants can expect little uniformity in registration exams among the States. Written exams, for example, range from 2 or 3 hours to 8 hours in length; some States also require an oral exam. Some written exams are in two parts; one State administers a four-part exam. Some States assign geologist-in-training status to individuals who pass the first part of the exam until they gain enough professional experience to take the second part. States generally require 30 semester credit hours in geology, 24 of which must be at the junior-senior level. Five to seven years of full-time geologic work experience are also mandated, with a credit of 1 to 4 years given for advanced degrees.

Eight States allow reciprocity without a written exam; three require an exam. All require "at least as strict" qualifications. Exams are held once or twice a year in most States. This can pose difficulties for geologists moving into a State if temporary work status cannot be extended beyond the minimum reciprocity or temporary limit. Temporary registration generally ranges from 30 to 90 days. Some States will extend temporary status to a new resident until he or she is licensed by exam or qualification. The title awarded to a registered geologist varies from State to State and is as inconsistent as the exam. Titles include "qualified," "professional," "geologist," "licensed," and "certified."

Reciprocity problems are considered crucial. Seven southeastern States recently met to work on examination and reciprocity problems. They resolved to develop an association of geology boards to assist in standardizing exams, reciprocity, and similar issues.

All States require registration fees even if the geologist is licensed elsewhere. The costs are usually $20 to $50 for the exam and $50 to $70 for the license, although the total cost may reach $300, as in one State.

Federal employees are usually exempted from registration requirements; most States also exempt university faculty members. Most States require that only one member of a geologic firm be licensed. One State requires a licensed geologist in each State agency that has geologic responsibilities.

A State Board of Registration normally consists of five to seven members, including one lay member. California is unusual because its board comprises five public or lay members, two geologists, and one geophysicist, with the quorum set at five. In Arizona, geologists are registered by the State Board of Technical Registration, which also registers architects, assayers, engineers, landscape architects, and land surveyors. The nine-member board includes one member who is a geologist or an assayer.

Registration in Arizona

For information about registration requirements for geologists in Arizona, contact Ronald W. Dalrymple, Executive Director, State Board of Technical Registration, 1951 W. Camelback Rd., #250, Phoenix, AZ 85015; tel: 602-255-3503.

PROFESSIONAL MEETINGS

Water Quality and Quantity Issues into the 1990's, Arizona Hydrological Society. Annual symposium, Sept. 14-16, 1989, Casa Grande, Ariz. Contact David L. Kirchner, 3437 N. Valencia Ln., Phoenix, AZ 85018; tel: (602) 945-4580.

42nd Annual Symposium on Southwestern Geology and Paleontology. Sept. 23, 1989, Flagstaff, Ariz. Contact Mike Morales, Museum of Northern Arizona, Rt. 4, Box 720, Flagstaff, AZ 86001; tel: (602) 774-5211.

Rocky Mountain Section, American Association of Petroleum Geologists, Society of Economic Paleontologists and Mineralogists, and AAPG's Energy Minerals Division. Annual meeting, Oct. 1-4, 1989, Albuquerque, N. Mex. Contact James R. Connolly, Dept. of Geology, University of New Mexico, Albuquerque, NM 87131; tel: (505) 277-3817.

Arizona Geology: A Professional Perspective, American Institute of Professional Geologists and Arizona Geological Society. Symposium, Nov. 17, 1989, Phoenix, Ariz. Contact Erick F. Weiland, Terra Technology, 5531 E. Kelso St., Tucson, AZ 85712; tel: (602) 296-5940.

National Science Teachers Association. Regional convention, Nov. 30 - Dec. 3, 1989, Phoenix, Ariz. Contact JoAnne Wolf, Resource Center, Mesa Public Schools, 143 S. Alma School Rd., Mesa, AZ 85202.

American Institute of Mining, Metallurgical, and Petroleum Engineers. Annual Arizona conference, Dec. 3-4, 1989, Tucson, Ariz. Contact Dan Eyde, GSA Resources, Inc., P.O. Box 509, Cortaro, AZ 85652; tel: (602) 297-4330.

New Technologies for the Mineral Industry, U.S. Bureau of Mines. Open industry briefing, Dec. 5, 1989, Tucson, Ariz. Contact Michael N. Greeley, U.S. Bureau of Mines, 210 E. 7th St., Tucson, AZ 85705; tel: (602) 629-5110.

NAU Offers Ph.D. in Geology

The Arizona Board of Regents has authorized Northern Arizona University to offer a Ph.D. program in geology. The program will prepare geoscientists for industrial, academic, and government careers by providing advanced study on the geology of the Colorado Plateau and adjacent areas.

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