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Arizona and the Superconducting Super Collider

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Arizona is among at least 17 States competing for what may be the largest scientific laboratory in history, the U.S. Department of Energy's Superconducting Super Collider (SSC), or Desertron, as it has been informally dubbed in the past. The SSC will be an oval-shaped particle accelerator 51.54 miles in circumference, 11 feet in tunnel diameter, and 40 times more powerful than any accelerators in existence. In addition to the main collider ring, the facility will include an injector complex, experimental areas, and a 500-acre laboratory area (Figure 1). Although most of the SSC will be built underground, as many as 11,000 acres will be required above ground to operate it.

The main collider ring will consist of a tunnel containing two adjacent tubes within which counter-rotating beams of protons accelerated to nearly the speed of light will collide head-on at specific interaction laboratories. These collisions will create a shower of subnuclear particles that will enable physicists to study the ultimate structure of matter and the nature of the forces and particles that together determine that structure. A better understanding of the initial moments of the universe may also result from SSC experimentation.

Construction of the SSC will cost the Federal government a minimum of $3 billion. During the past 3 years, millions of dollars have been allocated for SSC research and development; the technology and a 6-year construction plan for the project have been established. The decision to build the SSC in this country was recently approved by President Reagan and announced by Secretary John Herrington, head of the U.S. Department of Energy. Congressional approval of the project is considered likely by late spring of this year. All States will be requested to submit their site proposals for national consideration by August 31, 1987. The final site selection is expected to be made in July 1988.

The SSC will be a prestigious scientific center comparable in scale to NASA's Johnson Space Center in Houston, Texas and will be one of several colliding beam accelerators in the world (Figure 2). The State that is picked to host the SSC will emerge as a national leader in fundamental research. The SSC will bring substantial economic benefits to whichever State is chosen as its host, including an estimated 12,000 new jobs and an $8.4-billion increase in total State income during the first 13 years of the project. It is estimated that for every dollar spent on the SSC, $6 in economic activity will be generated in the surrounding communities. High-technology industries are expected to follow the SSC to its host State. With the stakes so high, it is understandable why there is intense competition among the States that are interested in hosting the SSC.

Arizona's efforts to host the SSC began in 1983 when former Governor Bruce Babbitt organized an SSC task force whose purpose was to assess the possibility of finding attractive SSC sites in Arizona. Much of the work was channeled through the University of Arizona. Members of the task force's working team included graduate students and faculty from many disciplines, headed by Dr. A. B. Weaver, coordinator of Interdisciplinary Program Administration. The original site-selection study located 31 potential sites for the SSC in Arizona.

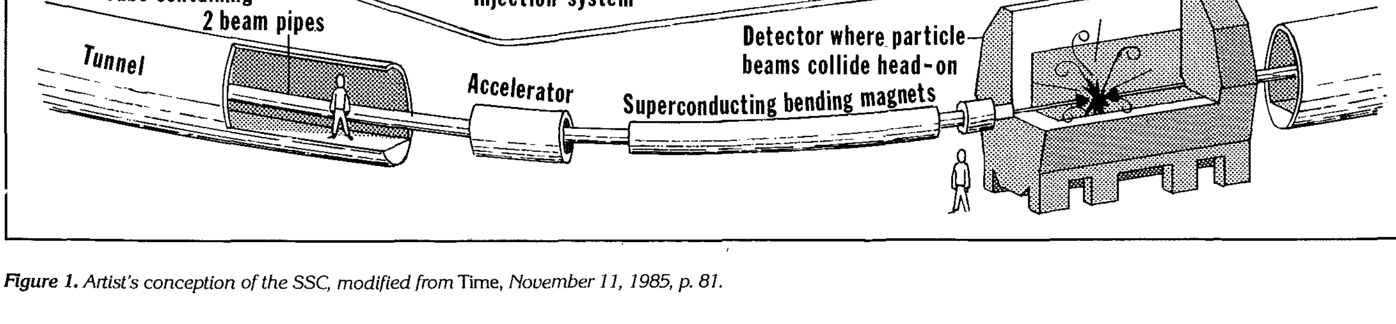


***Figure 1.** Artist's conception of the SSC, modified from* Time, *November 11, 1985, p. 81.*

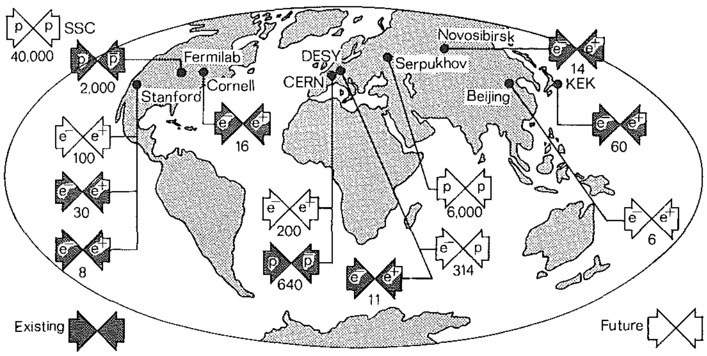


Figure 2. *The world's colliding beam accelerators. (CERN is in Geneva; DESY is in Hamburg.) Those designated as "future" are either under construction or are being planned. The colliders are labeled according to the particles used and the energies attained. Electrons are denoted e–, positrons e+; p stands for protons, p̄ for antiprotons. The numbers are the maximum total collision energy in billions of electron volts, or GeV. From Universities Research Association, 1987, To the heart of matter—the Superconducting Super Collider, p. 32.*

At that time the size, shape, and many other criteria were undetermined by the national SSC Central Design Group (CDG). Using its best estimates as to the important site criteria, the working team ranked the 31 sites and reduced the number to 7. In the spring of 1985, the CDG released its "site parameter document" (SSC Central Design Group, 1985), specifically outlining other important site criteria. At this time, the seven site areas were reduced to two: Sierrita and Maricopa (Figure 3). In February 1986 the CDG released the exact SSC dimensions and detailed site-specific investigations began.

The site criteria that the SSC requires are extensive and consist of a wide variety of geologic, topographic, demographic, economic, environmental, and political considerations. Accordingly, the University of Arizona SSC working team has been subdivided into groups focused on specific sets of criteria. Outside engineering consultants have been hired and the project has benefited from the advice and resources of numerous industrial groups, State agencies, and university personnel. The leadership of the project has recently been transferred to Dr. Peter Carruthers, head of the University of Arizona Physics Department.

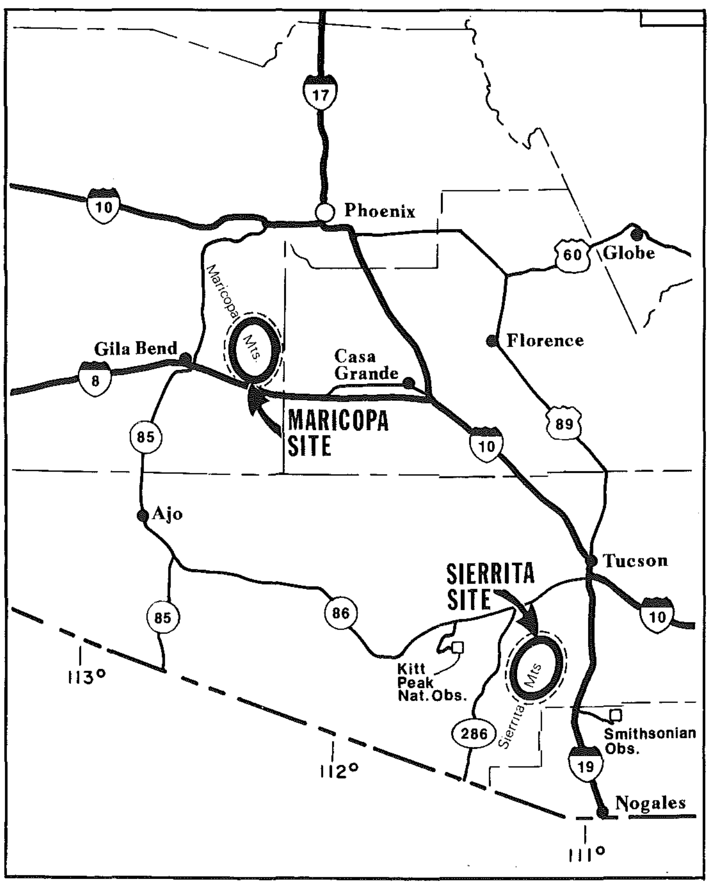


Figure 3. *Arizona SSC sites.*

Site research has proceeded on six principal fronts: geology, construction/engineering, hydrology, environmental studies, geographic studies, and political/economic issues. This report will discuss only the geologic studies and some of the geologic information for each site. Geologic site investigations have been concerned primarily with the following: (1) the fitting of the SSC oval to the site topography; (2) subsurface bedrock, alluvial geology, and depth to bedrock in alluvial ground; (3) engineering properties of the bedrock and alluvium; (4) important structures that might impact construction; (5) natural and manmade seismic hazards and the maximum credible seismic event (the most severe earthquake) that the site could experience; (6) other potential geologic hazards such as subsidence, collapsing soils, and volcanism; (7) site-specific soil conditions; (8) natural background terrestrial radiation; and (9) creation of maps and images using satellite imagery to present different perspectives of the sites.

Determination of Site Configurations

Because of the infinite number of ways a 51.54-mile oval-shaped ring can be located and tilted within a given area (the SSC requires that the ring must be planar and tilted no more than 0.25° from horizontal), a computer program was developed to allow quick manipulation of the ring in the site area to determine the optimal orientation. The best configuration of the ring was determined for each site to (1) avoid certain surface obstacles (openpit mines, residential areas, etc.); (2) maintain shallow ring levels in the areas where laboratories would be built, ideally near the surface; and (3) meet other site-specific technical considerations.

Once the ring location and tilt were determined for each site, the specific geology along the entire 51.54-mile circumference of the ring horizon was determined so that construction methods and costs could be estimated. The determination of the site geology has involved gathering published and unpublished data and conducting original field work, principally by University of Arizona investigators. These investigations remain an ongoing process at both sites.

Sierrita Site Geology

The geology of the Sierrita site (Figure 4) is now sufficiently well understood to permit reliable construction-plan assessment. The bedrock geology of the north and east sections of the ring was revealed by Anamax Corporation's geologic staff, who provided substantial drill-hole information for that area. The southeastern and western sections of the ring, which pass through Tertiary fanglomerates, were examined through geophysical surveys (gravity and seismic refraction), under the guidance of Dr. Ben K. Sternberg (University of Arizona) during the summer of 1986. The surface geology of the southern and northwestern sections of the ring has been mapped and extrapolated down to ring level. Some drill-hole information for the southern section has also been provided by J. David Lowell, Inc.

Beginning in the northern site area, the Sierrita ring will pass through several plutonic units ranging from Precambrian to early Tertiary in age. Continuing clockwise (to the east), the ring will pass into Cretaceous and Tertiary volcanic rocks and fanglomerates (Cooper, 1973). In the southern site area the ring passes through the Cerro Colorado Mountains, which consist of Tertiary volcanic rocks, Cretaceous sediments, and Precambrian granite (Smith, 1966). In the western site area the ring passes through Tertiary and Quaternary fanglomerates, Precambrian granite, and a 1- to 2-mile-wide strike belt of Paleozoic and Mesozoic metasediments and metavolcanics (Drewes and Cooper, 1973).

The Sierrita SSC ring crosses seven known faults, none of which are active (Menges and Pearthree, 1983), and none of which contain shear zones that are expected to cause construction problems. In the eastern site area, the ring will cross two Tertiary normal faults in the

Demetrie Volcanics (Cooper, 1973). In the Cerro Colorado Mountains, the ring will also cross two Tertiary normal faults (Smith, 1966; Keith and Theodore, 1975). Brecciated zones along these Tertiary normal faults are well-cemented and quite competent, based on the field investigations of the working team. In the northwest ring area, the ring crosses three Mesozoic thrust faults (Drewes and Cooper, 1973) that are associated with ductile shear zones as wide as 100 feet (Thoms, 1966). Field examination by tunneling experts has determined that tunnel construction can be carried out through these zones without significant difficulty. The San Xavier fault, a well-documented fault with hundreds of feet of brecciation reported along its fault zone (Cooper, 1973), occurs in the northeastern Sierrita Mountains, but does not cut the SSC-ring alignment. The ring was located so that it would avoid (go beneath) this fault.

The natural seismic hazard for the Sierrita site is not considered a threat to SSC construction and operations. The Pitaycachi fault in Mexico, the rupture site of the 1887 Sonoran earthquake, has been judged to be capable of producing the maximum credible earthquake for the site. Because of the fault's distance from the Sierrita site and the estimated interval of 10^5 years for the recurrence of seismic events (Bull and others, 1984), the hazard is considered to be extremely small for the estimated 50- to 100-year lifetime of the SSC. The nearest neotectonically active (i.e., within the past 3 million years) fault occurs east and northeast of Tubac 10 miles away from the site (Menges and Pearthree, 1983). Because this fault's estimated interval for recurrence of seismic events is also 10^5 years and because the timing of its last event is uncertain, it too is estimated to pose a statistically remote threat to SSC operation. Reactivation of the faults that the SSC will cross is thought to be very unlikely because (1) much of the fault-zone material is cemented and consolidated; and (2) the faults show no sign of activation within the past few million years, an interval during which large-magnitude earthquakes, although uncommon, still occurred from time to time.

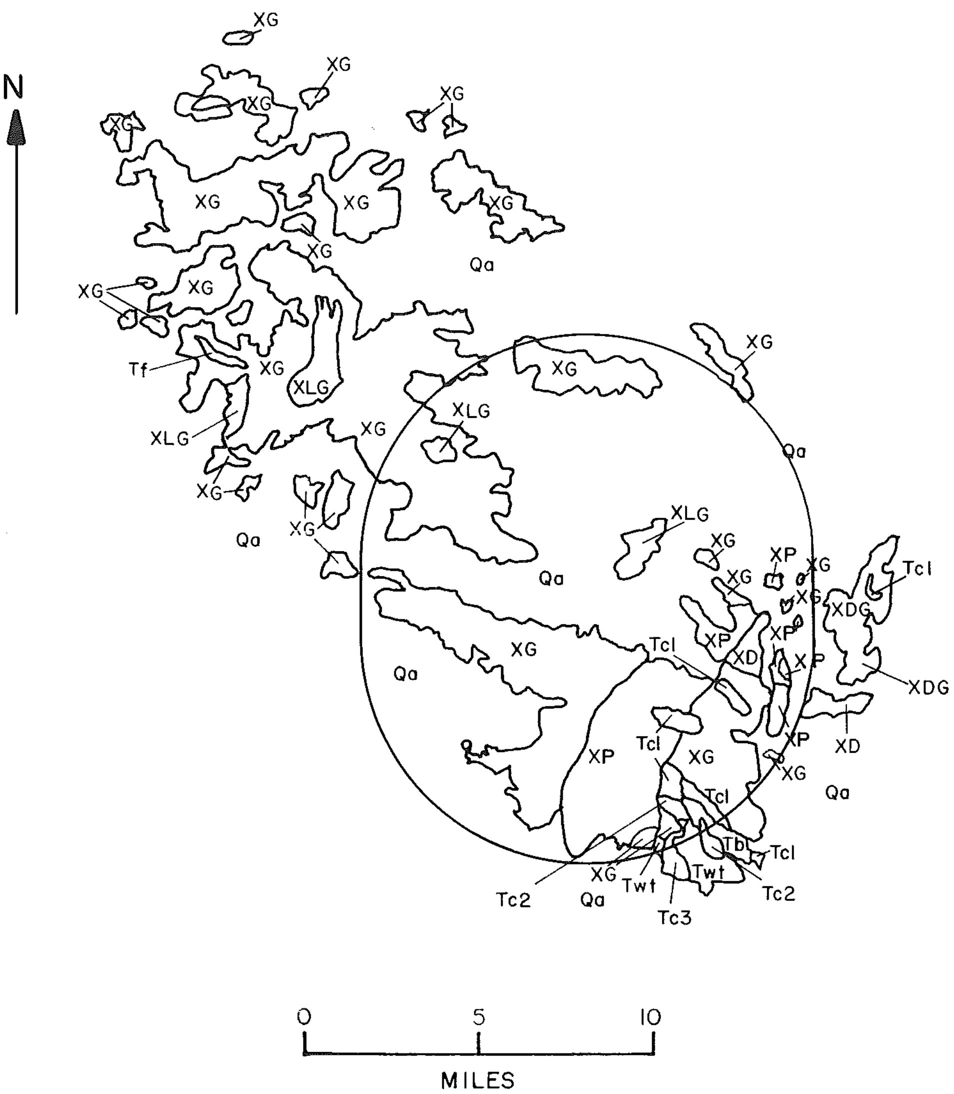
The Sierrita SSC site is carefully located to avoid alluvium that is subsiding due to ground-water overdraft or is likely to subside during the lifetime of the project. The SSC is predominantly located on the mountain pediments away from thick sequences of alluvium in the Santa Cruz and Avra Valleys. The alluvial stretches of Altar Valley that are crossed are areas of stable water-table levels where subsidence is not an expected threat (Reeter and Cady, 1982).

Investigations of other geologic properties, such as soil variations and natural terrestrial radiation levels at the ring site, have revealed that approximately four types of general soil associations occur (Richardson and Miller, 1974). Nine uranium anomalies have been detected by airborne radiometric surveys

Correlation of Map Units

AGE	SEDIMENTARY ROCKS	EXTRUSIVE ROCKS	INTRUSIVE ROCKS
Quaternary	Qal—recent alluvium Q—Quaternary undiv.		
Tertiary	Tn—Nogales sediments	Tvs—silicic volcanics Tvi—intermed. volcanics Tt—Tinaja Peak Fm.	Trs—Ruby Star Granodiorite Ti—intrusive rocks
Cretaceous	Kan—Angelica Arkose	TKa—andesitic volcanics Kvs—volcanics undiv. and sediments Ka—andesitic volcanics Krb—Red Boy Rhyolite Kd—Demetrie Volcanics	
Jurassic			Js—Sierrita Granite JTrh—Harris Ranch Monzonite
Triassic	Trv—Rodolfo Fm.	TrO—Oxframe Volcanics	
			Mzgr—Mesozoic granite and granodiorite
Paleozoic	Pz—Paleozoic undiv.		
Precambrian			PCi—Precambrian intrusives undiff.

***Figure 4.** Bedrock geology for the Sierrita SSC site.*



Correlation of Map Units

Quaternary	Qa—alluvium	
Tertiary	Tc3—conglomerate Twt—welded tuff Tc2—conglomerate Tb—basalt Tcl—conglomerate	Tf—felsite dikes (correlation uncertain)
Precambrian	XLG—leucocratic granite XG—granite XDG—diorite/granite undiff. XP—Pinal Schist	XD—diorite (correlation uncertain)

Figure 5. Bedrock geology for the Maricopa SSC site.

(Texas Instruments, Inc., 1978); this information is required for the proposal but does not significantly affect the site's suitability. Landsat imagery has been used to provide aerial views of the site and to create low-level perspectives of it from radial locations.

Maricopa Site Geology

Research on the geology of the Maricopa site has proceeded more slowly than that of the Sierrita site because of the lack of published and private geologic data for this region. Consequently, the Arizona SSC team has had to initiate a variety of geologic investigations in the area. This included 3 days of helicopter-based reconnaissance geologic mapping in the northern and southern Maricopa Mountains during October 1986. Geologists with the Arizona Geological Survey and U.S. Geological Survey aided in this work. Last December the team devoted 3 weeks to geophysical investigations of the basins surrounding the Maricopa Mountains. Additional mapping, geophysical surveys, and drilling are scheduled to take place this spring to define further the geologic conditions along the Maricopa SSC alignment.

The geology of the Maricopa site (Figure 5) shows less lithologic variation than that of the Sierrita site. The ring passes through well-indurated alluvial deposits in the northern and eastern ring area and through Precambrian Maricopa granite and Pinal Schist in the southeastern and southern ring area. The ring may also cut through several different Tertiary conglomerate units, a welded tuff, and a basalt unit, although the subsurface extent of these units must still be determined. The ring passes out of the Precambrian lithologies and into well-indurated alluvial deposits for most of its western length, except for a few short (less than 1 mile) stretches where it crosses back into the Maricopa granite. In the northwest area, the ring is in Maricopa granite.

The Maricopa SSC ring crosses several ductile shear zones in the northern and southern Maricopa Mountains. None of these shear zones show evidence of neotectonic activity, nor are they considered to be a seismic risk to SSC operation. The nearest neotectonically active fault is the Sand Tank fault located 10 miles southwest of the ring area. It is estimated that the Sand Tank fault last ruptured approximately 5,000-20,000 years ago (Menges and Pearthree, 1983). The statistical chances that it might rupture during the lifetime of SSC operation appear remote. The feasibility study conducted for the Palo Verde Nuclear Generating Station regarded the Pitaycachi fault in Mexico as the fault that is capable of producing the maximum credible earthquake for the station's site. Because the Maricopa SSC ring is near the Palo Verde site, the SSC team has adopted the study's conclusion that the seismic hazard to the SSC from the Pitaycachi fault is also remote (Fugro, Inc., 1975).

Subsidence due to ground-water overdraft and the presence of expansive clays are potential concerns in the Maricopa site region. Through extensive field investigations and consultation with outside experts, however, those alluvial regions that are unfit for SSC construction have been identified and the SSC ring has been oriented to avoid unstable ground conditions totally. Surface soil conditions and background terrestrial radioactivity levels at the Maricopa site are currently being studied.

Conclusion

Construction methods at both sites will involve hard-rock and soft-rock tunneling and some cut-and-cover excavation. All construction is expected to be above the water table at both sites. Cost and scheduling estimates are currently being derived for the entire construction effort. Preliminary results indicate that construction costs at either site will be low relative to costs in most other States and that total costs at both sites will be roughly the same.

Both sites appear to be very attractive. The Maricopa site's chief merits are (1) its proximity to Phoenix and Sky Harbor International Airport; (2) its stable geologic ground conditions, which are conducive to low-cost construction; and (3) its location on federally owned land, on which 90 percent of the ring will be built. If the SSC were located on private land, potentially expensive and time-consuming negotiations might be required to gain permission for SSC construction. The advantages of the Sierrita site are similar to those of the Maricopa site: (1) its proximity to Tucson and Tucson International Airport; (2) its stable geologic ground conditions; and (3) its location on State-owned land, on which 85 percent of the ring will be built. Another major attraction of the Sierrita site is its close proximity to both the Kitt Peak National Observatory and the Smithsonian [Mt. Hopkins] Astrophysical Observatory. Because so much of the SSC research will have implications for cosmological theory, the nearness of the particle-physics community to the astrophysics community could encourage an exciting and dynamic interchange of people and ideas.

The Arizona SSC team may propose one or both sites for national consideration, depending on how well each site meets the final criteria. The team will continue its efforts to attract this exciting and unique research facility.

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The AGS Contribution to the SSC Project

AGS geologist Stephen J. Reynolds boarding an Arizona Public Service helicopter during initial inspection of the Maricopa site.

The Arizona Geological Survey (AGS) contributed to the SSC project, during both site selection and subsequent examination of specific sites. AGS geologists attended planning sessions and provided expertise about the geology of the Sierrita and Maricopa sites. The Maricopa site was first suggested to the SSC working team by AGS geologist Stephen J. Reynolds. Reynolds, along with Dickson Cunningham and U.S. Geological Survey geologists Ed DeWitt and Gordon Haxel, completed a reconnaissance geologic map of the entire Maricopa Mountains, which were previously unmapped. AGS geologist Jon Spencer recently mapped a section of the southern Maricopa Mountains for the SSC project. In addition to this direct involvement, the AGS provided the SSC working team with geologic information such as gravity maps, regional cross sections, and geologic compilation maps.

Arizona Profile

Arizona has the thickest, youngest, bedded salt deposits known in North America, if not the world. One Miocene deposit in the Red Lake basin north of Kingman in Mohave County is estimated to contain more than 100 cubic miles of halite (NaCl), with thicknesses approaching 10,000 feet. The Luke salt bed west of Phoenix is also thought to be about 10,000 feet thick and of Miocene age.

The Picacho basin of south-central Arizona near Eloy is believed to contain the thickest anhydrite ($CaSO_4$) sequence in the world. This Miocene sequence, which consists of about 90 percent anhydrite and 10 percent interbedded shale, is nearly 6,000 feet thick.

Mineral and Oil-and-Gas Leasing

Leases and permits covering such diverse commodities as copper, sand and gravel, marble, oil and gas, and volcanic cinders generated a total of $4,483,988 in royalties and rentals during fiscal year 1985-86. This was an increase of almost 9 percent over last year's total of $4,124,949.

Of the 615 mineral leases in effect, copper continued to be the dominant royalty-producing mineral, accounting for 96 percent of the total royalty income of $1,321,150. This total is 6 percent higher than that of fiscal year 1984-85. Income from minerals other than copper rose 39 percent over last year to $58,760.

Royalties from mineral-materials sales agreements topped the million-dollar mark for the third consecutive year, at $1,587,699. This 37-percent increase from the previous fiscal year resulted in the emergence of mineral-materials sales as the primary revenue source, surpassing both mineral-lease royalties and oil-and-gas lease rentals.

As of June 30, 1986, some 774 prospecting permits covering about 350,000 acres were in effect. Although lease acreage was up by 13 percent over the previous fiscal year, income from rentals was down by 20 percent to $363,873. Uranium and precious metals continued to be the principal minerals sought by permit holders.

Total area covered by oil-and-gas leases at the end of fiscal year 1985-86 amounted to 1,120,331 acres, down by 31 percent from last year. Rental income, however, dropped by only 5 percent to $1,172,877. Thirty-one new leases covering 65,000 acres in Coconino and Apache Counties were issued during the year.

—Excerpted from Arizona State Land Department, 1986, Annual report, 1985-1986, p. 24.

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.

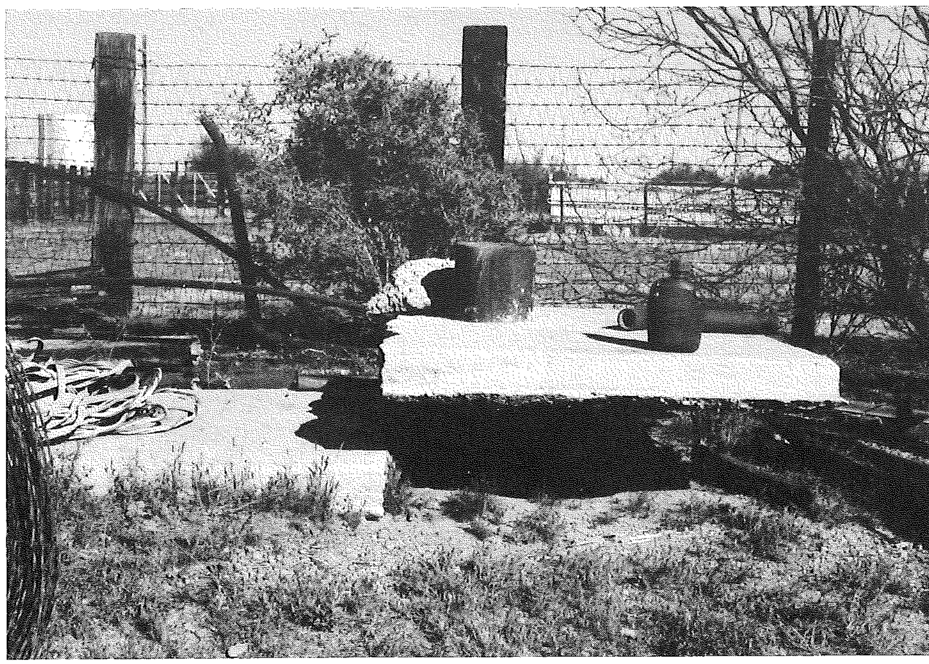


Figure 1. Protruding water well near Stanfield, Arizona. Subsidence around the well reportedly occurred during the 1970's. Sounding of the well revealed a collapsed casing. Photo by Robert B. Genualdi.

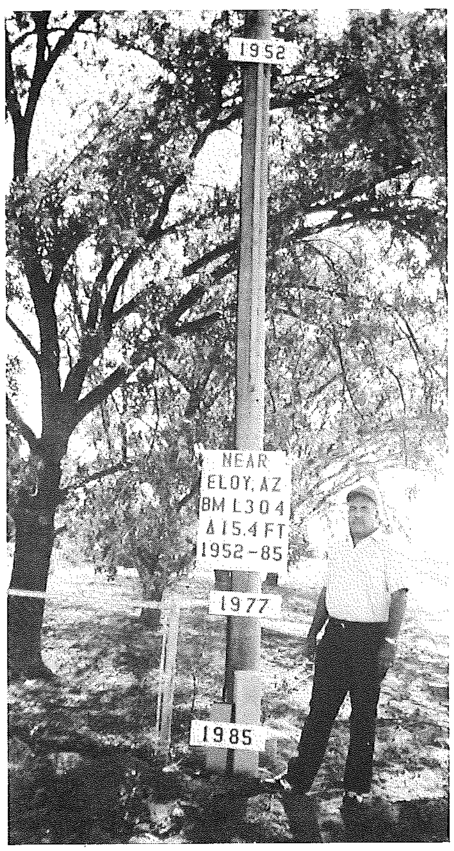


Figure 2. Bench mark L304, located about 3 miles south of Eloy, Arizona, subsided more than 15 feet between 1952 and 1985. Relative elevations of the bench mark are shown by the signs on the powerline pole. Herb Schumann of the U.S. Geological Survey, who is 6' 2" tall, is included for scale. Photo by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

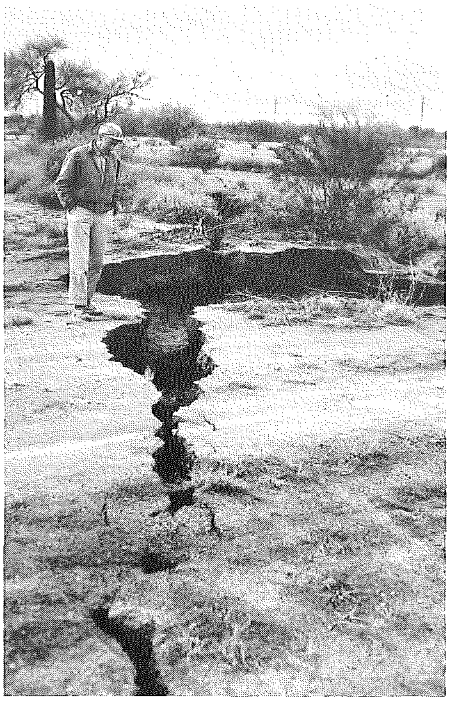


Figure 3. Earth fissure east of Mesa, Arizona prior to erosion and enlargement by captured water. Photo by Herbert H. Schumann.

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

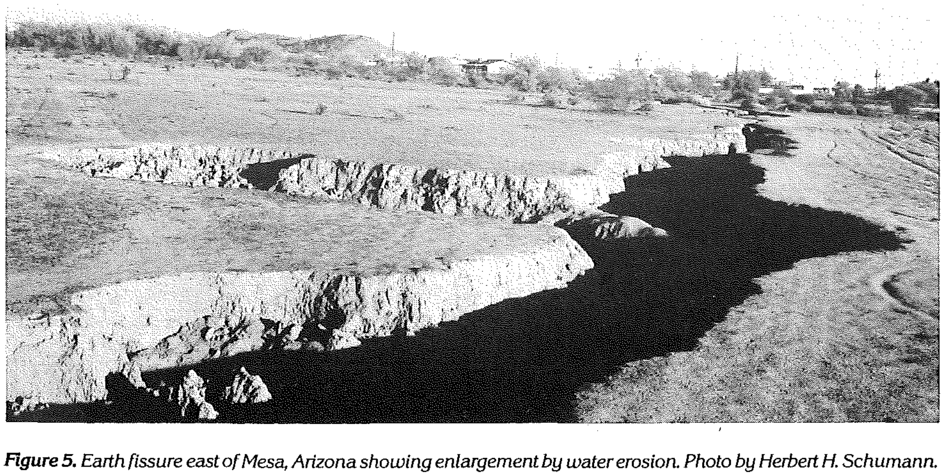


Figure 5. Earth fissure east of Mesa, Arizona showing enlargement by water erosion. Photo by Herbert H. Schumann.

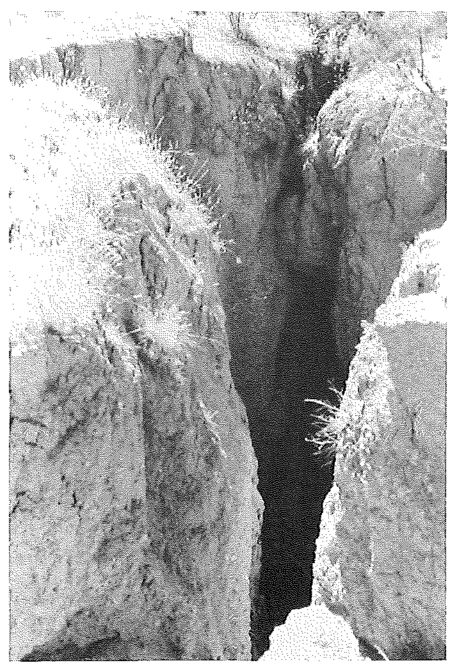


Figure 6. Earth fissure near Chandler Heights, Arizona. Fissure is 10 to 15 feet deep and 3 to 5 feet wide. Photo by Larry D. Fellows.

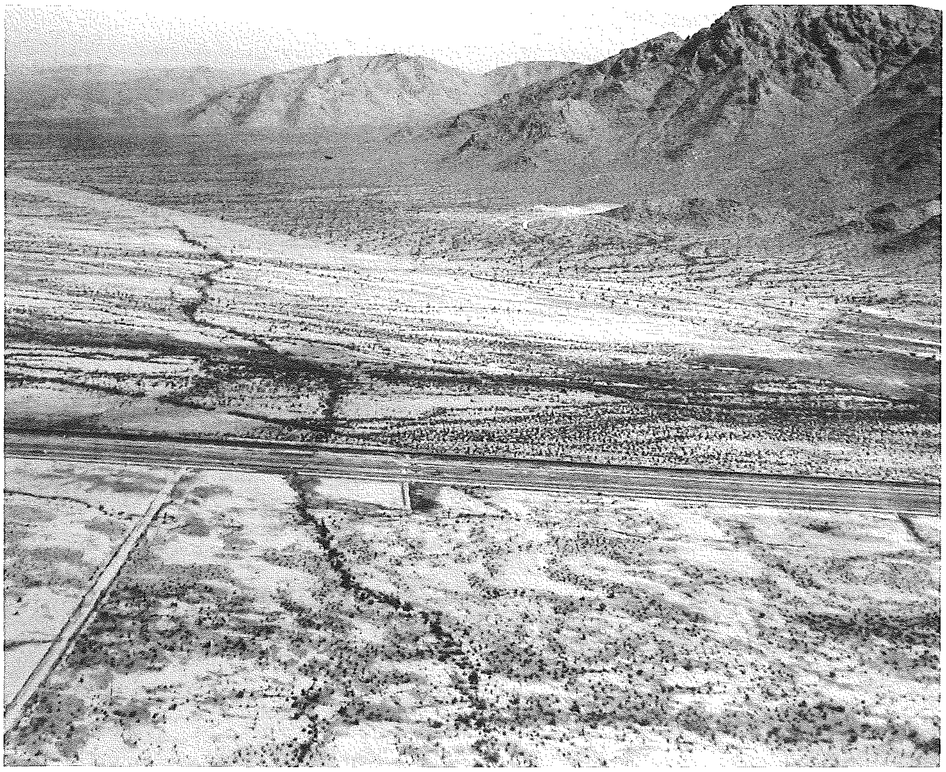
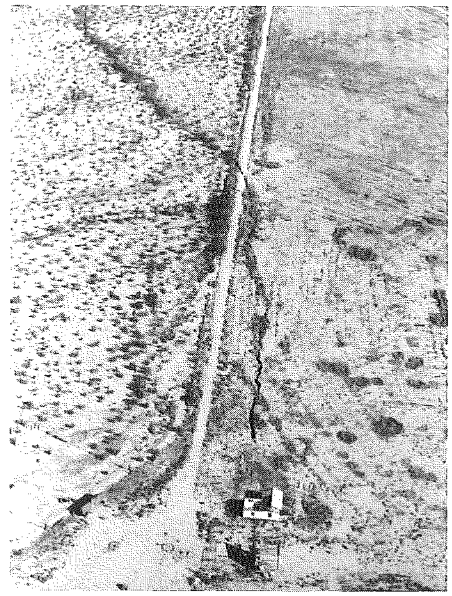


Figure 7. Earth-fissure zone that crosses Interstate Highway 10 (I-10) on west side of Picacho Mountains and east of Picacho, Arizona. Photo by Herbert H. Schumann.

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



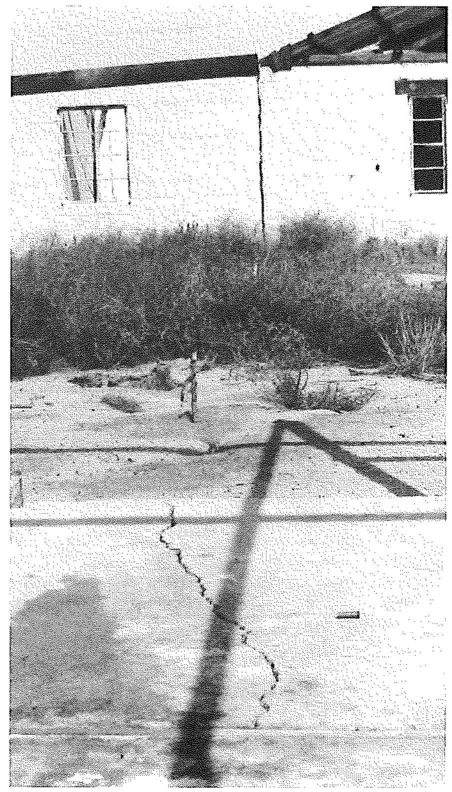


Figure 9. House damaged by earth fissure south of Stanfield, Arizona. (a, top) Aerial view. Note path of fissure darkened by vegetation. (b, bottom) Ground view. Note cracks in cement slab (foreground), yard, and house. Photos by the U.S. Geological Survey.

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.

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

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.

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.

Theses and Dissertations, 1986

The following list includes theses and dissertations on Arizona geology, mineral technology, hydrology, and related subjects that were awarded in 1986 by Arizona State University, Northern Arizona University, and the University of Arizona. This list, however, is not a complete compilation of theses on such topics. Theses on the geology of other States are not listed, nor are theses awarded by out-of-State universities.

Most of the theses included here are not available in the Bureau library. Each thesis, however, may be examined at the main library of the university that awarded it. More detailed information may also be obtained from the respective departments, which are indicated in parentheses after each citation using the following codes:

Arizona State University, Tempe, AZ 85287; (602) 965-9011.
Gg-Geography; Gl-Geology; ME-Mechanical Engineering

Northern Arizona University, Flagstaff, AZ 86011; (602) 523-9011.
G-Geology

University of Arizona, Tucson, AZ 85721; (602) 621-2211.
CE-Civil Engineering; EE-Electrical Engineering; G-Geosciences; HWR-Hydrology and Water Resources; MGE-Mining and Geological Engineering; MS-Materials Science; RNR-Renewable Natural Resources

Arizona State University

Capobianco, C. J., Thermodynamic relations of several carbonate solid solutions: Ph.D. Dissertation, 223 p. (Gl)

Fairbank, J. A., Upstream and downstream influence of a 180° bend on fully developed laminar flow: M.S. Thesis, 113 p. (ME)

Greer, J. C., Dynamics of withdrawal from stratified magma chambers: M.S. Thesis, 180 p. (Gl)

Horn, Marty, Physical models of pyroclastic clouds, Maricopa County, Arizona: M.S. Thesis, 125 p. (Gl)

Hoyos-Patino, Fabian, Environmental geology of the Chandler quadrangle, Maricopa County, Arizona; part 1: M.S. Thesis, 87 p. (Gl)

Kenny, Ray, Reconnaissance environmental geology of the Tonto foothills, Scottsdale, Arizona: M.S. Thesis, 160 p. (Gl)

Kortemeier, W. T., Ongonite and topazite dikes in the Flying W Ranch area, Tonto basin, Arizona: M.S. Thesis, 94 p. (Gl)

Moyer, T. C., The Pliocene Kaiser Spring (AZ) bimodal volcanic field; geology, geochemistry, and petrogenesis: Ph.D. Dissertation, 320 p. (Gl)

Rhoads, B. L., Process and response in desert mountain fluvial systems: Ph.D. Dissertation, 288 p. (Gg)

Sykes, M. L., Ascent of granitic magma; constraints from thermodynamics and phase equilibria: Ph.D. Dissertation, 312 p. (Gl)

Zindel, Udo, Landscape evolution in the Clifton-Morenci mining district, Arizona, 1872-1986: M.S. Thesis. (Gg)

Northern Arizona University

Brathovde, J. E., Stratigraphy of the Grand Wash dolomite (Upper? Cambrian), western Grand Canyon, Mohave County, Arizona: M.S. Thesis, 140 p. (G)

Bremner Cramer, J. A., Micro-facies analysis of depositional and diagenetic history of the Redwall Limestone in the Chino and Verde Valleys: M.S. Thesis, 161 p. (G)

Carr, J. E., Sedimentary tectonics and the Cenozoic history of the Verde Valley near Camp Verde, Yavapai County, Arizona: M.S. Thesis, 197 p. (G)

Hopkins, R. L., Depositional environments and diagenesis of the Fossil Mountain Member of the Kaibab Formation (Permian), Grand Canyon, Arizona: M.S. Thesis, 224 p. (G)

Puls, D. D., Geometric and kinematic analysis of a Proterozoic foreland thrust belt, northern Mazatzal Mountains, central Arizona: M.S. Thesis, 102 p. (G)

Sherlock, S. M., Structure and stratigraphy of early Proterozoic rocks, McDonald Mountain—Breadpan Mountain area, northern Sierra Anchas, Gila County, Arizona: M.S. Thesis, 81 p. (G)

Sutphin, H. B., Occurrence and structural control of collapse features on the southern Marble Plateau, Coconino County, Arizona: M.S. Thesis, 139 p. (G)

Vonderharr, Jerry, Sedimentology and paleoecology of the De Chelly Sandstone (Permian) of northeastern Arizona: M.S. Thesis, 137 p. (G)

Weisman, M. C., Geology of the Pine and Northern Buckhead Mesa quadrangles, Mogollon Rim region, central Arizona: M.S. Thesis, 126 p. (G)

Weiss, G. C., A depositional analysis of the arkose member (middle Proterozoic) of the Troy Quartzite in central Arizona: M.S. Thesis, 191 p. (G)

Winkler, F. E., Analysis of gravity data from the Aubrey Valley area, Coconino and Yavapai Counties, Arizona: M.S. Thesis, 122 p. (G)

University of Arizona

Abe, J. M., Economic analysis of artificial recharge and recovery of water in Butler Valley, Arizona: M.S. Thesis. (HWR)

Aguirre, Gerardo, An appraisal of the electrically thin conductive sheet model in geophysical probing: M.S. Thesis. (EE)

Anderson, Phillip, The Proterozoic tectonic evolution of Arizona: Ph.D. Dissertation, 416 p. (G)

Anthony, E. Y., Geochemical evidence for crustal melting in the origin of the igneous suite at the Sierrita porphyry copper deposit, southeastern Arizona: Ph.D. Dissertation, 79 p. (G)

Armaleh, S. H., Analysis of single and group piles in cohesionless soils: M.S. Thesis, 134 p. (CE)

Armin, R. A., Red chert-clast conglomerate in the Earp Formation (Pennsylvanian-Permian), southeastern Arizona; stratigraphy, sedimentology, and tectonic significance: Ph.D. Dissertation, 310 p. (G)

Arnold, A. H., Geologic implications of a geochemical study of three two-mica granites in southern Arizona: M.S. Thesis, 147 p. (G)

Awad, Barre, Application of the simplex method to slope stability analysis: M.S. Thesis, 86 p. (CE)

Baseghi, Behdad, Three-dimensional seepage through porous media with the residual flow procedure: Ph.D. Dissertation, 204 p. (CE)

Blau, J. B., Parameter identifiability of an erosion simulation model: M.S. Thesis. (HWR)

Borkan, R. E., Simulating the effects of dam releases on Grand Canyon River trips: M.S Thesis. (RNR)

Catallini, L. E., Arizona Superconducting Super Collider; rock mass classification for preliminary tunnel design—Sierrita site: M.S. Thesis. (MGE)

Cunningham, W. D., Superposed thrusting in the northern Granite Wash Mountains, La Paz County, Arizona: M.S. Thesis, 108 p. (G)

Ervin, M. T., The origin of chert in the Concha Limestone (Permian) of southeastern Arizona: M.S. Thesis, 87 p. (G)

Faulds, J. E., Tertiary geologic history of the Salt River Canyon region, Gila County, Arizona: M.S. Thesis, 308 p. (G)

Gaudette, M. V., Influence of Ogallala groundwater and distilled water on the hydraulic conductivity of bentonite borehole plugs: M.S. Thesis. (MGE)

Hayes, M. J., Sedimentology, stratigraphy, and paleogeography of the Fort Crittenden Formation (Upper Cretaceous), southeastern Arizona: M.S. Thesis, 117 p. (G)

Helmick, W. R., The Santa Cruz River terraces near Tubac, Santa Cruz County, Arizona: M.S. Thesis, 90 p. (G)

Hess, N. J., Petrology and crystal chemistry of the Ruby Star Granodiorite, Pima County, Arizona: M.S. Thesis, 69 p. (G)

Hiller, J. W., Seismic refraction study of the southeastern Arizona crust between Globe, Arizona and Cananea, Sonora: M.S. Thesis, 177 p. (G)

Holden, P. W., Pesticides and ground-water quality in four states; issues and problems: M.S. Thesis. (HWR)

Holt, W. E., Crustal structure from 3-D gravity modeling of a metamorphic core complex; a model for uplift, Catalina-Rincon Mountains, Arizona: M.S. prepublication manuscript, 23 p. (G)

Hussain, Fida, The relative effects on in-situ drying and sample preparation disturbance on the compressibility of a copper mine tailing: M.S. Thesis. (CE)

Ibarra-Encinas, German, Cantilever sheet pile analysis for stratified cohesive soil deposits: M.S. Thesis, 107 p. (CE)

Janecke, S. U., Structural geology and tectonic history of the Geesaman Wash area, Santa Catalina Mountains, Arizona: M.S. Thesis, 143 p. (G)

Johnejack, K. R., Sediment transport in step-pool mountain streams: M.S. Thesis, 116 p. (CE)

Jones, D. M., The effect of nitrogen gas and particle size on the selective separation of molybdenite from chalcopyrite: M.S. Thesis. (MS)

Krantz, R. W., The odd-axis; orthorhombic fault patterns and three-dimensional strain fields: Ph.D. Dissertation, 97 p. (G)

Kuo, C. (James), Factors affecting particle growth and related organic matter removal during alum coagulation: Ph.D. Dissertation. (CE)

Lang, J. R., A geochemical study of alteration and mineralization in the Wallapai mining district, Mohave County, Arizona: M.S. Thesis, 142 p. (G)

Lee, H. Y., Garnet-orthopyroxene equilibria in the FMAS system; experimental and theoretical studies and geological applications: Ph.D. Dissertation, 118 p. (G)

(continued on page 12)

Recent Publications on the Geology of Arizona

The following publications were recently added to the Bureau library, where they may be examined during regular working hours. Copies may also be obtained from the respective publishers.

U.S. Bureau of Mines

Mineral Land Assessment Reports

MLA-57-86—Lane, M. E., 1986, Mineral investigation of a part of the New Water Mountains Wilderness Study Area (AZ-020-125), La Paz County, Arizona, 25 p., scale 1:62,500.

MLA 62-86—Kreidler, T. J., 1986, Mineral investigation of a part of the Signal Mountain Wilderness Study Area (AZ-020-138), Maricopa County, Arizona, 9 p.

MLA 64-86—Kreidler, T. J., 1986, Mineral investigation of a part of the Cactus Plain Wilderness Study Area (AZ-050-014A/B), La Paz County, Arizona, 11 p., scale 1:62,500.

MLA 66-86—Ryan, G. S., 1986, Mineral investigation of the Mount Wilson Wilderness Study Area (AZ-020-001A), Mohave County, Arizona, 15 p., scale 1:62,500.

U.S. Geological Survey

Bulletins

1703-A—Simons, F. S., Theobald, P. K., Tidball, R. R., Erdman, J. A., Harms, T. F., Griscom, Andrew, and Ryan, G. S., 1987, Mineral resources of the Fishhooks Wilderness Study Area, Graham County, Arizona, 6 p., scale 1:50,000.

1703-B—Simons, F. S., Theobald, P. K., Tidball, R. R., Erdman, J. A., Harms, T. F., Griscom, Andrew, and Ryan, G. S., 1987, Mineral resources of the Needles Eye Wilderness Study Area, Gila County, Arizona, 8 p., scale 1:24,000.

Circular

973—Fischer, J. N., 1986, Hydrogeologic factors in the selection of shallow land burial sites for the disposal of low-level radioactive waste, 22 p.

Maps

HA-663—Freethey, G. W., Pool, D. R., Anderson, T. W., and Tucci, Patrick, 1986, Description and generalized distribution of aquifer materials in the alluvial basins of Arizona and adjacent parts of California and New Mexico, scale 1:500,000.

HA-664—Freethey, G. W., and Anderson, T. W., 1986, Predevelopment hydrologic conditions in the alluvial basins of Arizona and adjacent parts of California and New Mexico, scale 1:500,000.

I-843-E—Myrick, R. M., and Aldridge, B. N., 1985, Delineation of flood hazards in the Ruelas Canyon quadrangle, Pima County, Arizona, scale 1:24,000.

I-1310-F—Richter, D. H., Sharp, W. N., Watts, K. C., Raines, G. L., Houser, B. B., and Klein, D. P., 1986, Maps showing mineral resource assessment of the Silver City 1° x 2° quadrangle, New Mexico and Arizona, scale 1:1,150,000.

MF-1183-E—Watts, K. C., Hassemer, J. R., Forn, C. L., and Siems, D. F., 1986, Geochemical maps showing distribution and abundance of molybdenum in two fractions of stream-sediment concentrates, Silver City 1° x 2° quadrangle, New Mexico and Arizona, scale 1:250,000.

MF-1183-F—Watts, K. C., Hassemer, J. R., Forn, C. L., and Siems, D. F., 1986, Geochemical maps showing distribution and abundance of silver in two fractions of stream-sediment concentrates, Silver City 1° x 2° quadrangle, New Mexico and Arizona, scale 1:250,000.

MF-1465-C—Machette, M. N., Personius, S. F., Menges, C. M., and Pearthree, P. A., 1986, Map showing Quaternary and Pliocene faults in the Silver City 1° x 2° quadrangle and the Douglas 1° x 2° quadrangle, southeastern Arizona and southwestern New Mexico, scale 1:250,000.

MF-1602-B—Simpson, R. W., Gage, T. B., and Bracken, R. E., 1986, Aeromagnetic and isostatic gravity maps of the Crossman Peak Wilderness Study Area, Mohave County, Arizona, scale 1:48,000.

MF-1834-A—Peterson, J. A., and Tosdal, R. M., 1986, Mineral occurrence map and tabulation of geologic, commodity, and production data, Ajo and Lukeville quadrangles, southwestern Arizona, scale 1:250,000.

MF-1860-A—Billingsley, G. H., Antweiler, J. C., Beard, L. S., Lucchitta, Ivo, and Lane, M. E., 1986, Mineral resource potential map of the Pigeon Canyon, Nevershine Mesa, and Snap Point Wilderness Study Areas, Mohave County, Arizona, scale 1:50,000.

MF-1860-B—Lucchitta, Ivo, Beard, L. S., and Rieck, H. J., 1986, Geologic map of the Pigeon Canyon, Nevershine Mesa, and Snap Point Wilderness Study Areas, Mohave County, Arizona, scale 1:50,000.

MF-1873-A—Abrams, G. A., 1986, Geophysical maps of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona, scale 1:24,000.

MR-94—Beikman, H. M., Peterson, J. A., Huber, D. F., and Butler, W. C., 1986, Metallic mineral and mineral-fuel resource potential map of Arizona showing major mineral deposits, scale 1:1,000,000.

Open-File Reports

86-184—Miller, R. J., Gray, Floyd, Hassemer, J. R., Detra, D. E., Briggs, P. H., and Brice, John, III, 1986, Analytical results and sample locality maps of stream-sediment, heavy-mineral-concentrate, and rock samples from the Big Horn Mountains Wilderness Study Area (AZ-020-099), Maricopa County, Arizona, 27 p., scale 1:48,000, 3 plates.

86-422W—U.S. Geological Survey, 1986, Annual summary of ground-water conditions in Arizona, spring 1984 to spring 1985, scale 1:250,000.

86-510—Chenoweth, W. L., 1986, The Orphan Load mine, Grand Canyon, Arizona; a case history of a mineralized collapse-breccia pipe, 126 p.

86-521—Flanigan, V. J., Mohr, Pam, Tippens, Charles, and Senterfit, Michael, 1986, Electrical character of collapse breccia pipes on the Coconino Plateau, northern Arizona, 50 p.

86-522—Gusa, Sharon, 1986, Recognition of the Peach Springs Tuff, California and Arizona, using heavy mineral suites, 11 p.

86-585—DeWitt, Ed, and Waegli, Jerome, 1986, Gold in the United Verde massive sulfide deposit, Jerome, Arizona, 41 p.

86-592-A—Wenrich, K. J., Billingsley, G. H., and Van Gosen, B. S., 1986, The potential for breccia pipes in the National Tank area, Hualapai Indian Reservation, Arizona, 45 p.

Professional Paper

1241-D—Hedge, C. E., Houston, R. S., Tweto, O. L., Peterman, Z. E., Harrison, J. E., and Reid, R. R., 1986, The Precambrian of the Rocky Mountain region, 17 p.

Water-Supply Paper

2300—Moody, D. W., Chase, E. B., and Aronson, D. A., comp., 1986, National water summary 1985; hydrologic events and surface-water resources, 506 p.

Other Publications

Amos, R. C., 1986, Sunset Crater, Arizona; evidence for a large-magnitude strombolian eruption: Tempe, Arizona State University, M.S. Thesis, 165 p.

Anderson, T. W., and Johnson, A. I., eds., 1986, Regional aquifer systems of the United States, southwest alluvial basins of Arizona: American Water Resources Association Monograph Series No. 7, 116 p.

Annis, D. R., 1986, Petrochemical variations in post-Laramide igneous rocks in Arizona and adjacent regions; geotectonic and metallogenic implications: Tempe, Arizona State University, M.S. Thesis; v. 1, 142 p.; v. 2, 550 p.; scale 1:1,000,000, 5 plates.

Bowie, M. R., 1985, Geology of the Dripping Spring Valley chabazite and related zeolite deposits, southeast Arizona and southwest New Mexico: Socorro, New Mexico Institute of Mining and Technology, M.S. Thesis, 54 p.

Brittingham, P. L., 1985, Structural geology of a portion of the White Tank Mountains, central Arizona: Tempe, Arizona State University, M.S. Thesis, 106 p.

Lacy, J. C., 1986, Manual for determination of status and ownership of Arizona mineral and water rights, 2nd ed.: Arizona Department of Mines and Mineral Resources, 50 p.

Reeter, R. W., and Remick, W. H., 1986, Maps showing groundwater conditions in the west Salt River, east Salt River, Lake Pleasant, Carefree, and Fountain Hills sub-basins of the Phoenix Active Management Area, Maricopa, Pinal, and Yavapai Counties, Arizona, 1983: Arizona Department of Water Resources Hydrologic Map Series Report No. 12, scale 1:125,000, 3 sheets.

Robertson, J. A., 1986, Environmental geology of the Chandler quadrangle, Maricopa County, Arizona; pt. 2: Tempe, Arizona State University, M.S. Thesis, 102 p., scale 1:24,000, 13 plates.

Roddy, M. S., 1986, K-metasomatism and detachment-related mineralization, Harcuvar Mountains, Arizona: Tucson, University of Arizona, M.S. prepublication manuscript, 84 p.

U.S. Bureau of Land Management, 1986, Paiute and Beaver Dam Mountains Wilderness Areas, Arizona-Utah, draft wilderness management plan: 69 p.

______ 1987, Paria Canyon-Vermilion Cliffs, Arizona-Utah, final wilderness management plan: 57 p.

(continued from page 10)

Lombard, J. P., Provenance of sand temper in Hohokam ceramics, Arizona: M.S. prepublication manuscript, 35 p. (G)
Long, Junsheng, Determination of unit watershed size for use in small watershed hydrological modeling: M.S. Thesis. (RNR)
Matthews, D. W., Thermally induced countercurrent flow in unsaturated rock: M.S. Thesis. (HWR)
Meldahl, K. H., Sedimentologic, stratigraphic, and taphonomic implications of biogenic stratification: M.S. prepublication manuscript, 21 p. (G)
Miller, K. M., Interpretive scheme for modeling the spatial variation of soil properties in 3-D: M.S. Thesis. (MGE)
Rader, D. L., The depositional environment of the Permian Scherrer Formation in southeastern Arizona: M.S. Thesis, 69 p. (G)
Rahi, K. A., Hydraulic conductivity assessment for a variably saturated rock matrix: M.S. Thesis. (HWR)
Roddy, M. S., K-metasomatism and detachment-related mineralization, Harcuvar Mountains, Arizona: M.S. Thesis, 84 p. (G)
Rosko, M. J., A comparison study of the petrology of fine-grained clastics in mid-Cenozoic age basin deposits, Pima and Cochise Counties, Arizona: M.S. Thesis, 77 p. (G)
Silliman, S. E. J., Stochastic analysis of high-permeability paths in the subsurface: Ph.D. Dissertation. (HWR)
Smith, C. F., Evaluating three fitting criteria for the calibration of the U.S. Geological Survey precipitation runoff modeling system (PRMS): M.S. Thesis. (HWR)
Southworth, R. K., Spatial variation modeling of regularly spaced soil property data in one dimension: M.S. Thesis. (MGE)
Strauss, L. J., Geochemical constraints on the dynamics of flow in the upper San Pedro basin, southeastern Arizona: M.S. Thesis, 23 p. (G)
Sumpter, L. T., Stratigraphy and sedimentology of the Willow Canyon Formation, southeastern Arizona: M.S. Thesis, 124 p. (G)
Turin, H. J., Carbon dioxide and oxygen profiles in the unsaturated zone of the Tucson basin: M.S. prepublication manuscript, 67 p. (G)
Wald, D. J., A seismically active section of the southwest Indian Ridge: M.S. prepublication manuscript, 33 p. (G)

Fieldnotes

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Geologic Place Names

Globe, Gila County, Arizona. Population 6,685.

Although there are several fascinating legends concerning the origin of the name "Globe" for the mining community that is the county seat of Gila County, the name probably came from the Globe mine. The Maricopa Book of Mines shows that the Globe Ledge was recorded on September 19, 1873. The first settlement in the newly opened mining area was at the Ramboz mine. Here the Globe mining district was organized in November 1875 in the Globe Hills. Ramboz settlement was moved before 1878 to Globe, probably because there was ample water at the latter place and because it was also better situated as a general distributing point.

As for the origin of the name "Globe," one story relates that D. B. (Gip) Chilson and Henry Wagner were prospecting in the Apache Peaks for a large silver mine they were told was the source of the silver bullets reputedly used by Apache Indians. They found such a place and called it Globe because of its immense size. One of its locators said after its discovery that it was as big as the globe.

A second version states that a small settlement was barely begun where Globe is today when cavalry men, traveling near land that later became the Old Dominion mine, found a large and perfectly round boulder, hence the name. Still another legend says that at the site of the new community a globe-shaped boulder of nearly pure silver was found. This story, however, probably originated from the discovery of "Munson's chunk," which was actually found after the community was a going concern. The first story, that the community took its name from the Globe Ledge and Globe mine, seems the most tenable.

When the community was established, it was referred to as Globe City, a name that continued until the publication of the *Arizona Silver Belt* on May 2, 1878 (the first edition), in which the editor suggested that the word "city" be dropped.

In October 1880, Globe was incorporated as a village. This fact, however, seems to have been forgotten after 1884 because the town was again incorporated in 1905. Its citizens found city government too expensive and disbanded the incorporation within a year. Globe was reincorporated as a city in 1907.

—Excerpted from Granger, B. H., 1960, Will C. Barnes' Arizona place names: Tucson, University of Arizona Press, p. 103.

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