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The Copperstone Mine: Arizona's New Gold Producer

Arizona's annual gold output will almost double in 1988 as a result of production from Cyprus Minerals Company's Copperstone gold deposit in La Paz County, west-central Arizona. During 6 years of expected mine life, the deposit is predicted to yield approximately 510,000 troy ounces of gold worth \$230 million, based on a value of \$450 per ounce. Unlike many recent gold discoveries in the Southwest, Copperstone is a new discovery in an area not previously identified as a mineral district. In this article, the geology and regional setting of the Copperstone deposit are described. Although the deposit is still not completely understood, enough is known to warrant reassessment of estimates of mineral-resource potential in west-central Arizona.

Regional Geologic Setting

West-central Arizona and adjacent areas of California and southern Nevada contain some of the most spectacularly exposed detachment faults in the world. The term "detachment fault" is commonly applied to large-displacement, gently dipping (inclined) normal faults. In this region, hanging-wall rocks, or rocks overlying the detachment faults, were displaced northeastward relative to footwall rocks, rocks that underlie the faults. The faults originally dipped to the northeast, but are now rotated and warped to form undulating surfaces that are nearly horizontal over large areas.

The north- to northeast-dipping Moon Mountains detachment fault, exposed at the northern tip of the eastern Moon Mountains, separates two large, geologically distinct areas: to the northeast lie numerous detachment faults, such as those in the Buckskin, Rawhide, and northern Plomosa Mountains; to the south, in the Dome Rock, southern Plomosa, and most of the Moon Mountains, detachment faults are absent. The Copperstone gold deposit lies within the hanging wall of the Moon Mountains detachment fault and flanks the area of pervasive faulting.

Miocene (5- to 24-million-year [m.y.]-old) detachment faults in west-central Arizona are associated with numerous copper, iron, and gold deposits, especially in the Buckskin and Rawhide Mountains, that have yielded metals worth many millions of dollars (Figure 1; Table 1; Wilkins and Heidrick, 1982; Spencer and Welty, 1986). Copper-gold deposits associated with detachment faults typically lie along or within a few tens of meters of the faults; a few, however, are hundreds of meters above the faults. Detachment-fault deposits contain fractures and thick, irregular zones that are commonly filled with the

minerals specular hematite, chrysocolla, quartz, barite, fluorite, calcite, and manganese oxides. Pyrite and chalcopyrite, which are commonly oxidized, are also present in many deposits.

The northeastern tip of the Moon Mountains is primarily composed of Mesozoic (63- to 240-m.y.-old) granitic rocks that form the footwall of the Moon Mountains detachment fault. Hanging-wall rocks are mostly metamorphosed Jurassic (138- to 205-m.y.-old) volcanic rocks. Older (Paleozoic; 240- to 570-m.y.-old) metamorphosed sedimentary rocks that are brecciated (composed of

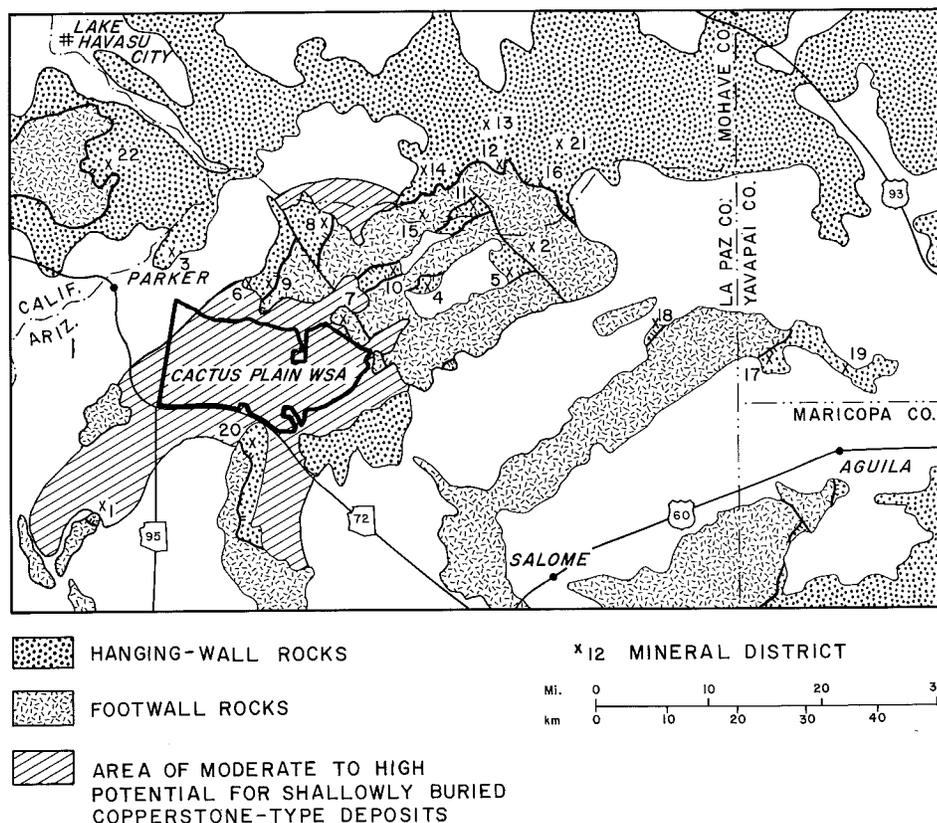


Figure 1. Map of part of west-central Arizona showing mineral districts where mineral deposits are known or suspected to be related to detachment faults. Middle Tertiary and older rocks are divided into hanging wall and footwall rocks, which lie above and below, respectively, regionally northeast-dipping detachment faults. Also shown is the outline of the Cactus Plain and Cactus Plain East Wilderness Study Areas. Numbers refer to mineral districts listed in Table 1.

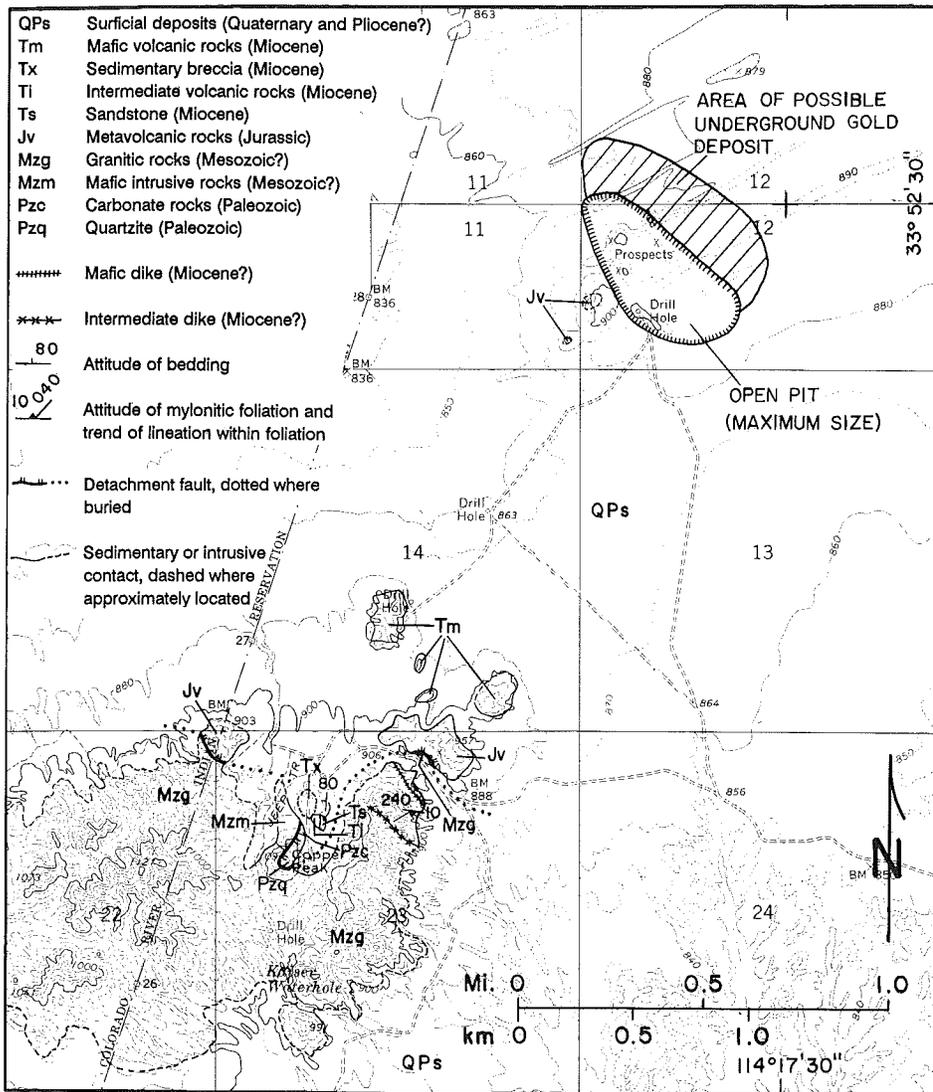


Figure 2. Geologic map of northeastern Moon Mountains showing location of Copperstone mine.

broken rock fragments) underlie Copper Peak; steeply dipping, younger (Miocene) volcanic and sedimentary rocks, including sedimentary breccias derived from the Jurassic volcanic rocks, are also present adjacent to Copper Peak (Figure 2). The copper-iron mineralization that characterizes detachment-fault deposits elsewhere in west-central Arizona is also evident in brecciated rocks along the Moon Mountains detachment fault at Copper Peak and at the edge of the Colorado River Indian Reservation.

Geology

The Copperstone mine is approximately 1½ miles northeast of exposed bedrock in the northeastern Moon Mountains (Figure 2). Bedrock exposures in several very small hills surrounded by alluvium contain evidence of gold mineralization and led to the discovery of the Copperstone deposit. Mineral deposits are present above and along a gently dipping contact that is probably a fault; the contact separates Jurassic metamorphosed volcanic rocks

and overlying sedimentary breccias derived from them. The mineralized contact zone dips approximately 30° to the northeast, extends horizontally for 3,000 feet and at least 1,000 feet down dip, and is generally several tens of feet thick. The sedimentary breccia and a volcanic rock that contains vesicles (relict gas bubbles) are almost certainly Miocene in age and are mineralized, indicating that mineralization is Miocene or younger.

Drill-core samples reveal that some brecciation occurred after quartz veins were formed; however, numerous northwest-trending quartz-amethyst veins exposed in the mine pit are not brecciated. Steeply dipping, northwest-striking fractures and narrow shear zones exposed in the mine pit locally cut quartz-amethyst veins and contain subhorizontal slickenside lineations, which are smooth and polished striations that result from friction along a fault plane.

Gold is present where quartz and specular hematite are abundant in the breccia zone and locally within veins in the metamor-

phosed volcanic rocks. Chrysocolla, barite, earthy red hematite, and malachite are also common in the gold-mineralized zone. Fluorite, adularia, magnetite, calcite, chalcocopyrite, pyrite, and manganese oxides are present in smaller quantities. Gold, however, is rarely visible. The presence of quartz, hematite, and chrysocolla is a good indicator of gold mineralization.

Fluid-Inclusion Characteristics

Fluid inclusions are bubbles of liquid and gas that are commonly trapped inside minerals during mineral formation. The composition of fluid inclusions in mineral deposits reflects the composition of the aqueous fluids that formed the deposits. One can determine the salinity of the inclusions by determining the freezing temperature of the fluid within them. The minimum temperature of the fluid at the time it was trapped can be determined by heating the sample until the two phases (liquid and gas) in the inclusion become one. Fluid inclusions in quartz-amethyst from the Copperstone mine contain between 16 and 22 percent sodium-chloride equivalent (by weight) and were trapped at minimum temperatures between 200° and 260° C. These characteristics are similar to those of other mineral deposits along Miocene detachment faults in west-central Arizona, but are substantially different from those of most other types of deposits, such as epithermal-vein gold deposits (Figure 3; Wilkins and others, 1986).

Origin

The following characteristics of the Copperstone deposit suggest that it originated from the same processes that formed mineral deposits along numerous other Miocene detachment faults: (1) fluid-inclusion salinities and temperatures of entrapment; (2) abundant specular hematite with less abundant copper minerals such as chrysocolla, malachite, and chalcocopyrite; (3) geographic proximity to a detachment fault; and (4) probable Miocene age. Two characteristics of the Copperstone deposit, however, differ from those of other detachment-fault deposits: abundance of quartz-amethyst veins and abundance of gold. These authors believe that most evidence at the Copperstone deposit supports a relationship between mineralization and detachment faulting.

A working model for the origin of the Copperstone deposit is as follows: hot, saline, aqueous fluids containing dissolved gold, copper, iron, and other elements moved up-dip along the north- to northeast-dipping Moon Mountain detachment fault. These fluids encountered highly porous and permeable sedimentary breccias in the hanging wall of the detachment fault and began ascending through the breccia zone. As a result of cooling or mixing with more oxygen-rich, shallow-level ground water, largely within the sedimentary breccias, gold and

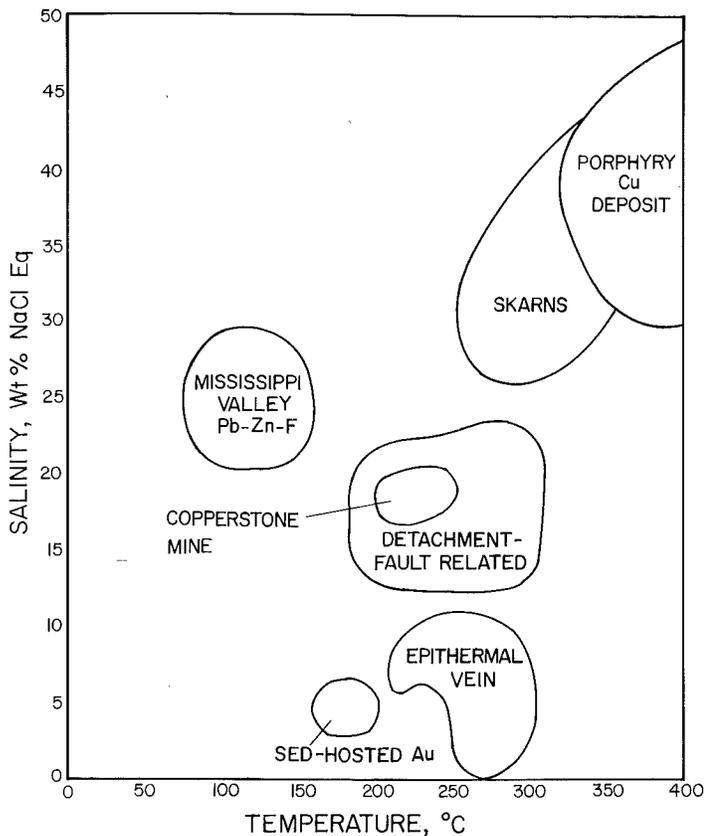


Figure 3. Diagram of salinity and homogenization temperature fields for fluid inclusions from several major mineral deposits, including those associated with detachment faults. Fluid inclusions from the Copperstone deposit clearly fall within the field of other detachment-fault-related deposits. Many geologists suspected that the Copperstone deposit was an epithermal-vein deposit, as are many other gold deposits in the Southwest; fluid-inclusion data, however, strongly suggest otherwise. Modified from Wilkins and others (1986), with additional data from the Copperstone mine.

other elements precipitated from the fluids to form the Copperstone deposit.

Implications for Land-Use Planning and Management

The presence of the Copperstone gold deposit in a geologic setting that is characteristic of large areas of west-central Arizona indicates that the mineral-resource potential of this area in the State is greater than previously suspected.

The Copperstone deposit was probably not discovered until recently because it was almost entirely concealed by young surficial deposits. Undiscovered mineral deposits similar to Copperstone may also be concealed beneath other surficial deposits, such as those covering nearby Cactus Plain (Figure 1). Application of more sophisticated geophysical techniques may eventually result in discovery of such deposits. Many areas in west-central Arizona, such as the Cactus Plain and Cactus Plain East Wilderness Study Areas, are presently under consideration for Federal wilderness-area status. If designated to be managed as wilderness, these areas would no longer be open to mineral exploration or mining activity.

Mineral deposits associated with detachment faults have only been recognized as a distinct deposit type during the past 10 years. The recent discovery of the Copperstone deposit and recognition of its association with a detachment fault are generating renewed interest in detachment-fault-related deposits and in areas where such deposits might be located. Future improvements in our understanding of Arizona geology and future mineral-deposit discoveries will undoubtedly lead to renewed interest in areas that presently receive little attention from research or exploration geologists.

References

Spencer, J.E., and Welty, J.W., 1986, Possible controls of base- and precious-metal mineralization associated with Tertiary detachment faults in the lower Colorado River trough, Arizona and California: *Geology*, v. 14, p. 195-198.

Wilkins, Joe, Jr., Beane, R.E., and Heidrick, T.L., 1986, Mineralization related to detachment faults; a model, in Beatty, Barbara, and Wilkinson, P.A.K., eds., *Frontiers in geology and ore deposits of Arizona and the Southwest*: Arizona Geological Society Digest, v. 16, p. 108-117.

Wilkins, Joe, Jr., and Heidrick, T.L., 1982, Base and precious metal mineralization related to low-angle tectonic features in the Whipple Mountains, California and Buckskin Mountains, Arizona, in Frost, E.G., and Martin, D.L., eds., *Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada*: San Diego, Cordilleran Publishers, p. 182-203.

Table 1. Value of production for commodities from mineral districts in west-central Arizona that are known or suspected to be related to detachment faults. Manganese mineral deposits, although not clearly understood, are suspected to be related to detachment faults. District locations are shown on Figure 1.

District	Commodities*	1986 Value**
1. Copperstone	Au (reserves)	\$189,306,900
2. Alamo	Cu, Pb, Ag, Au	72,303
3. Cienega	Cu, Ag, Au	5,571,167
4. Clara	Cu, Ag, Au	3,066,661
5. Lincoln Ranch	Mn	18,960,000
6. Mammon	Cu, Ag, Au	93,913
7. Midway	Cu, Ag, Au	43,743
8. Planet	Cu, Ag, Au	12,771,828
9. Pride	Cu, Ag, Au	37,679
10. Swansea	Cu, Ag, Au	17,471,085
11. Black Burro	Mn	261,490
12. Cleopatra	Cu, Pb, Ag, Au	1,118,459
13. Lead Pill	Cu, Pb, Ag, Au	303,365
14. Mesa	Mn	47,400
15. Owen	Cu, Pb, Zn, Ag	107,561
16. Rawhide	Cu, Pb, Zn, Ag	116,573
17. Bullard	Cu, Ag, Au	1,763,481
18. Burnt Well	(unknown)	(minor)
19. Harris	Mn	79,395
20. Northern Plomosa	Cu, Pb, Ag, Au	2,123,413
21. Artillery	Mn	75,135,320
22. Whipple	Cu, Pb, Zn, Ag, Au	683,550
TOTAL		\$329,135,287

* Ag = silver; Au = gold; Cu = copper; Mn = manganese; Pb = lead; Zn = zinc.

** Values do not add to total because of rounding.

GSA Centennial Field Guides

The Geological Society of America (GSA) has published two Centennial Field Guides that include areas in Arizona: the Cordilleran Section and the Rocky Mountain Section (volumes 1 and 2, respectively). The first volume contains field-guide articles and maps to 100 outstanding geologic locations in Alaska, British Columbia, California, Hawaii, Nevada, Oregon, and Washington, as well as Arizona. The second volume contains 100 guides for Alberta, Arizona, Colorado, Idaho, Montana, New Mexico, South Dakota, Utah, and Wyoming. These two volumes are part of the 71-item GSA publishing project, the Decade of North American Geology (DNAG). To obtain copies, send \$43.50 for each volume to The Geological Society of America, Publication Sales, P.O. Box 9140, Boulder, CO 80301; tel: (800) 472-1988.

Three Questions about Arizona's Mineral Resources

by Larry D. Fellows

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Arizona Geological Survey

Mineral resources have had, and continue to have, a significant impact on Arizona's economy. Minerals were exploited on a limited scale for three centuries before the Arizona Territory was established in 1863. Accelerated settlement of the Territory, due in large part to discovery and mining of metallic mineral resources, began after the Civil War. By the late 1870's and early 1880's, many mining communities had been established and were thriving. Reported production of metallic minerals from the late 1800's through 1981 is shown in Table 1.

Arizona was the Nation's leading nonfuel mineral producer until 1983. In 1987 Arizona ranked second in the Nation, with a total value of \$1.76 billion in metallic and nonmetallic mineral production. The value of nonfuel mineral production from 1980 through 1987, inclusive, as reported in U.S. Bureau of Mines' Yearbooks and Mineral Industry Surveys, totalled nearly \$14.5 billion. These estimated values are for the mineral commodities only and do not include wages paid to miners or processors; taxes paid to local, State, and Federal governments; or value of products manufactured from the mineral commodities.

The Arizona Geological Survey (AGS) is directed by statute to (1) inform the public about the geologic environment and the development and use of mineral resources in Arizona and (2) encourage the wise use of land and mineral resources in the State. This article addresses this mandate by answering three questions that are commonly asked and frequently misunderstood.

Where are Arizona's mineral resources?

Metallic mineral districts include mineral deposits that formed under a variety of conditions and at many different times. Districts were defined by Keith and others (1983) on the basis of types and amounts of

Table 1. Reported production of metallic minerals in Arizona from the late 1800's through 1981 (Keith and others, 1983).

Commodity	Production
Copper	66,619,200,000 lb
Gold	14,043,000 oz
Lead	1,387,561,000 lb
Manganese	413,000,000 lb
Molybdenum	489,000,000 lb
Silver	482,836,000 oz
Uranium	18,427,000 lb
Vanadium	45,261,000 lb
Zinc	2,264,300,000 lb

metals produced and geologic origin (Figure 1). Mineralization occurred millions of years ago and, for almost all deposits, at considerable depths below the land surface. Today the mineral deposits are exposed at or near the surface because overlying rocks have been stripped away by erosion. Some mineral deposits have been completely removed. Others are hidden, perhaps only a few feet or tens of feet below the surface.

It is difficult to define precisely the boundaries of mineral districts because of inadequate subsurface information. As additional drilling is completed and other information becomes available, the boundaries will be adjusted accordingly.

Nonmetallic resources (clay, gypsum, limestone, salt, sand and gravel, zeolites, etc.), which are scattered throughout the State, are not shown in Figure 1. Neither are the energy resources such as coal, natural gas, and petroleum.

Have all of Arizona's mineral resources been discovered?

Emphatically, no! A great deal of potential still exists. Prospectors have walked virtually every square foot of Arizona. In so doing, they have found most of the obvious deposits, those exposed directly at the surface. Discovery of the subtle and hidden deposits has become progressively more difficult.

The opening of the Cyprus Copperstone gold mine in La Paz County in late 1987 is proof that all deposits have not been found. The Copperstone deposit was discovered by a prospector who noticed a few very small, isolated outcrops of mineralized rock and staked a claim. This mine will produce 50,000 to 60,000 troy ounces of gold per year during its projected life span of 5 to 6 years. In 1985 Arizona's gold production totalled 52,000 troy ounces. The new mine, therefore, will double Arizona's gold production.

Where will future mineral discoveries be made?

Some discoveries will be made within or adjacent to the mineral districts shown in Figure 1. Others will be made far from known mineral districts.

To make an accurate assessment of mineral-resource potential, one must define the geologic framework by doing field investigations, mapping rock formations, conducting laboratory analyses and geophysical or geochemical studies, and drilling to obtain more detailed information. Geologic mapping in Arizona, a major responsibility of the AGS, is incomplete. Large areas have not been mapped in detail (Figure 2), and others must be remapped or reinterpreted. Knowledge of rocks and minerals in the subsurface is practically nonexistent.

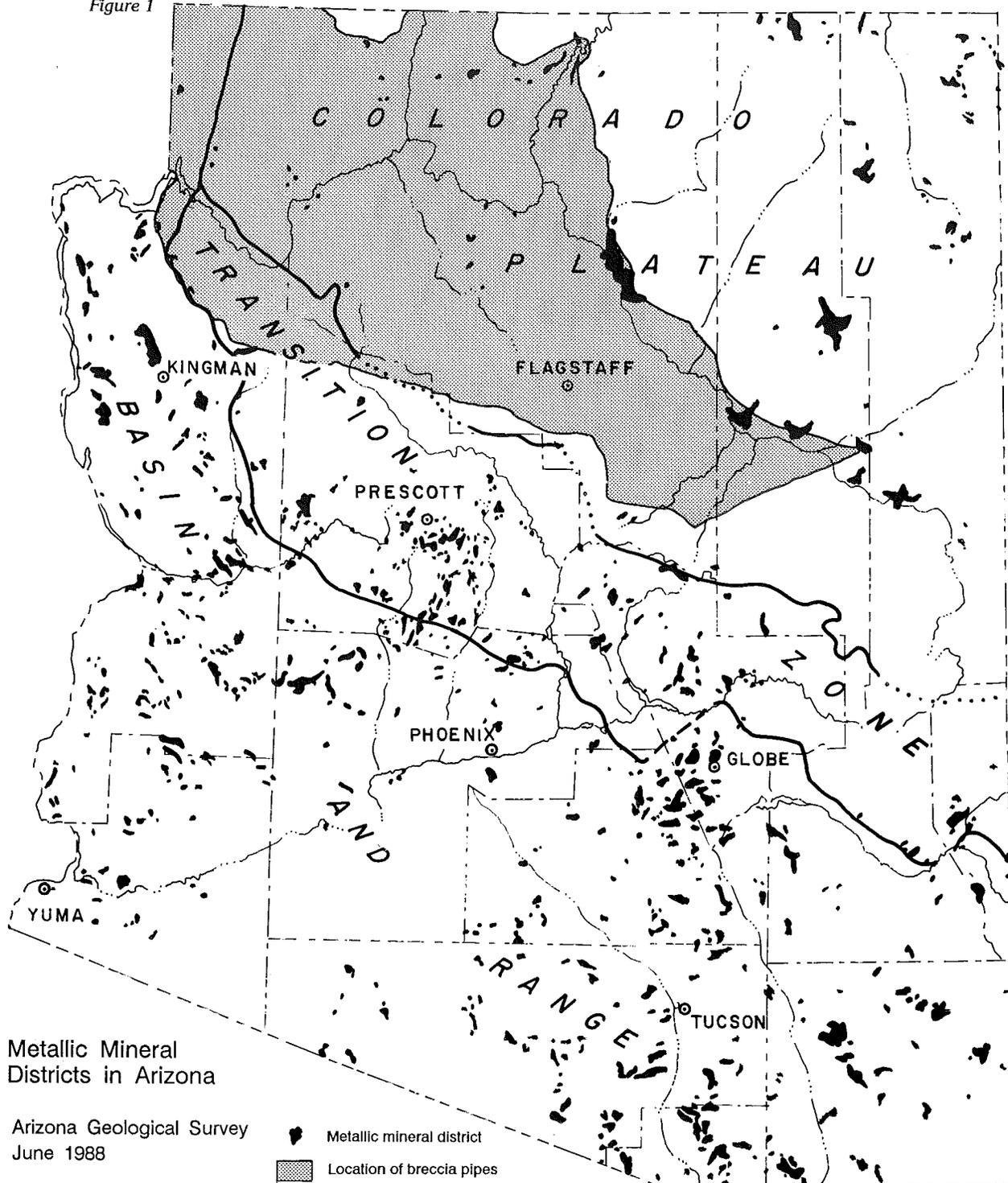
New geologic concepts are constantly being developed to help explain the relationships between mineral deposits and the geologic framework. New geologic maps are being prepared to show detail that was previously unavailable. Because of new geologic mapping in portions of western Arizona, the geologic framework is much better known than it was 10 years ago. Mineralized areas along low-angle detachment faults that are favorable for exploration can now be identified. Extensive exploration, however, will be necessary to determine if economic mineral deposits are present.

New exploration, mining, and processing techniques are also being developed to find more effective or efficient ways to locate and produce the resources. Exploration is driven by economics. The prevailing price of the potential resource must be high enough so it can be extracted profitably. Land must also be available for exploration.

Selected References

- Burgin, L.B., 1988, The mineral industry of Arizona in 1987: U.S. Bureau of Mines Mineral Industry Surveys, 2 p.
- Canty, J.M., and Greeley, M.M., 1988, History of mining in Arizona: Tucson, Mining Club of the Southwest Foundation, 280 p.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
- Dummett, Hugo, and Colburn, Nora, comp., 1988, Visit to the Bighorn, Socorro, and Copperstone gold mines, Arizona: Arizona Geological Society Field-Trip Guidebook, 276 p.
- Fellows, L.D., 1984, Mineral and energy resources: assessing Arizona's potential: Arizona Bureau of Geology and Mineral Technology Fieldnotes, v. 14, no. 1, p. 1-9.
- Keith, S.B., Gest, D.E., DeWitt, Ed, Woode Toll, Netta, and Everson, B.A., 1983, Metallic mineral districts and production in Arizona: Arizona Bureau of Geology and Mineral Technology Bulletin 194, 58 p., scale 1:1,000,000.
- McColly, R.A., and Anderson, N.B., 1987, Availability of federally owned minerals for exploration and development in western States; Arizona, 1986: U.S. Bureau of Mines Special Publication, 27 p., scale 1:500,000, 2 plates.
- Marsh, S.P., Kropschot, S.J., and Dickinson, R.G., 1984, Wilderness mineral potential; assessment of mineral-resource potential in U.S. Forest Service lands studied 1964-1984: U.S. Geological Survey Professional Paper 1300, v. 1, 550 p.
- Peirce, H.W., ed., 1987, Proceedings of the 21st Forum on the Geology of Industrial Minerals; aggregates to zeolites (AZ) in Arizona and the Southwest: Arizona Bureau of Geology and Mineral Technology Special Paper 4, 134 p.
- Phillips, K.A., 1987, Arizona industrial minerals: Arizona Department of Mines and Mineral Resources Mineral Report 4, 185 p.
- U.S. Bureau of Mines, 1982-87, Minerals Yearbooks, 1980-85; v. 2, area reports, domestic: U.S. Government Printing Office.
- Welty, J.W., Reynolds, S.J., Keith, S.B., Gest, D.E., Trapp, R.A., and DeWitt, Ed, 1985, Mine index for metallic mineral districts of Arizona: Arizona Bureau of Geology and Mineral Technology Bulletin 196, 92 p.
- Wenrich, K.J., and Sutphin, H.B., 1988, Recognition of breccia pipes in northern Arizona: Arizona Bureau of Geology and Mineral Technology Fieldnotes, v. 18, no. 1, p. 1-5, 11.

Figure 1



Metallic Mineral Districts in Arizona

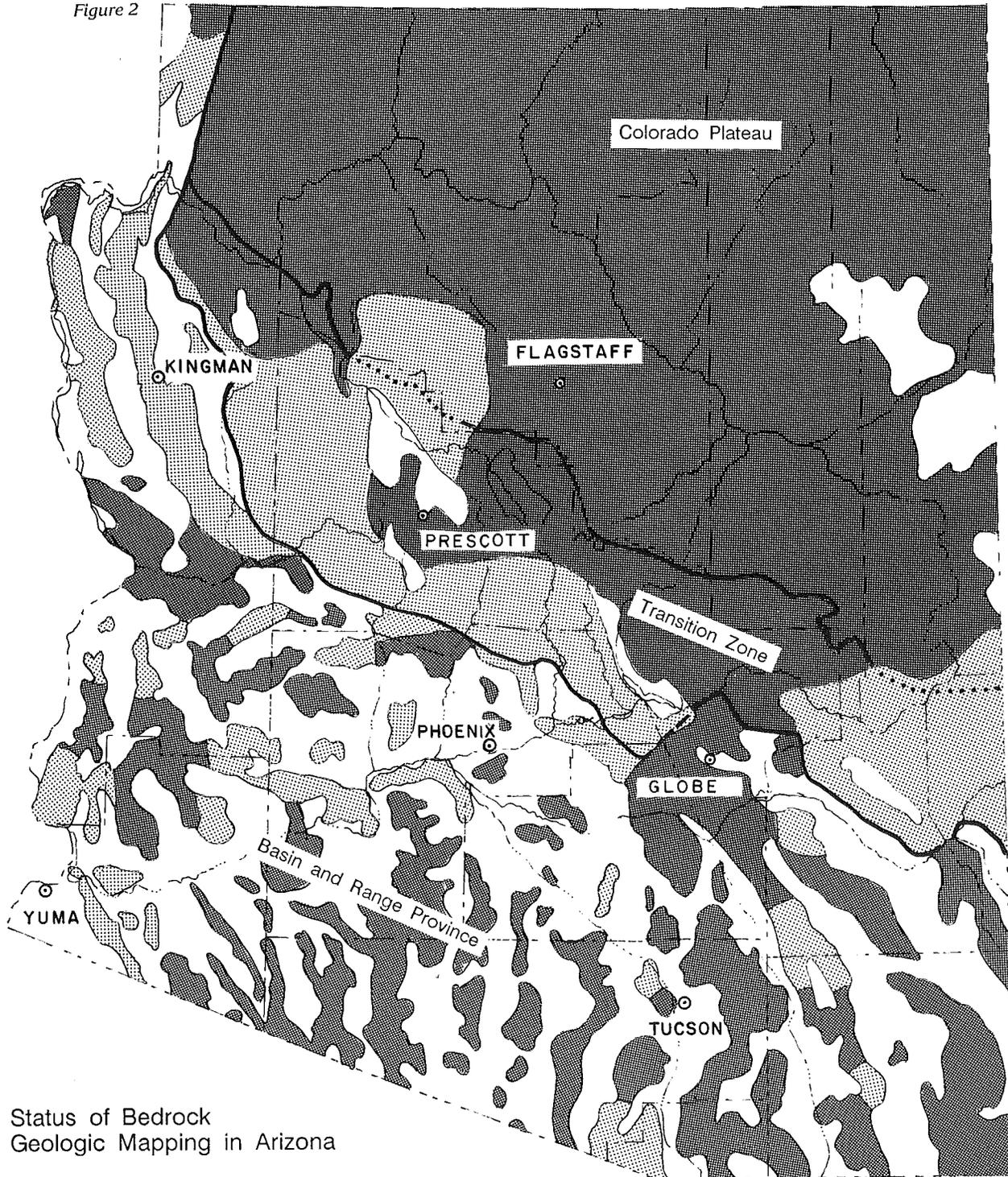
Arizona Geological Survey
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 Metallic mineral district
 Location of breccia pipes

Metallic mineral occurrences in each district are of similar age and origin. Geologic controls of many individual mineral occurrences are poorly understood, however. District boundaries will, therefore, be modified as geologic knowledge increases. Districts shown on the map were defined by Keith and others (1983a). Their report, which includes a 1:1,000,000-scale color map and cumulative production for each district through 1981, may be purchased from the Arizona Geological Survey. A 1:500,000-scale black-and-white map is also available (Keith and others, 1983b). Nonmetallic resources (cinders, clay, gypsum, limestone, salt, sand and gravel, zeolites, etc.) are not shown on this map. Neither are the energy resources, such as coal, natural gas, and petroleum. Breccia-pipe deposits were described by Wenrich (1988). Although thousands of pipes are present within the lined map area, probably less than 8 percent were mineralized and less than 10 percent of the latter have economic value. Future metallic mineral deposits will be discovered both within and outside the districts shown on the map.

Keith, S.B., Gest, D.E., DeWitt, Ed, Woode Toll, Nella, and Everson, B.A., 1983a, Metallic mineral districts and production in Arizona: Arizona Bureau of Geology and Mineral Technology Bulletin 194, 58 p., scale 1:1,000,000.
 Keith, S.B., Schnabel, Lorraine, DeWitt, Ed, Gest, D.E., and Will, Jan, 1983b, Map, description, and bibliography of the mineralized areas of the Basin and Range Province in Arizona: U.S. Geological Survey Open-File Report 84-86, 129 p., scale 1:500,000.
 Wenrich, K.J., and Sutphin, H.B., 1988, Recognition of breccia pipes in northern Arizona: Arizona Bureau of Geology and Mineral Technology Fieldnotes, v. 18, no. 1, p. 1-5, 11.

Figure 2



Status of Bedrock
Geologic Mapping in Arizona

Arizona Geological Survey
June 1988

-  Mapped at 1:100,000-scale or larger
-  Mapping in progress or mapped at scales smaller than 1:100,000
-  Bedrock covered by sedimentary deposits of late Cenozoic age
-  Geologic province boundary

The Nonfuel Mineral Industry: 1987 Summary

by Evelyn M. VandenDolder
Arizona Geological Survey

In 1987 the value of nonfuel mineral production in the Southwest reached \$7.5 billion, a 21.6-percent increase from the 1986 value of \$6.2 billion (Figure 1; Table 1). Production value in the Southwest accounted for 29.4 percent of the total value for the Nation, estimated to be \$25.5 billion in 1987. For the purposes of this article, the Southwest includes Arizona, California, Colorado, Nevada, New Mexico, and Utah.

These preliminary figures were recently published by the U.S. Bureau of Mines (USBM), which has released State-by-State estimates of nonfuel mineral production for 1987. Excerpts from the preliminary summaries for the Nation and the southwestern States appear below. Additional details on the national statistics are given in the USBM's 1988 *Mineral Commodity Summaries*. Single copies are free from the Publications Distribution Section, U.S. Bureau of Mines, Building 149, P.O. Box 18070, Pittsburgh, PA 15236. The Mineral Industry Surveys for individual States were prepared by State mineral specialists from the USBM, in cooperation with the respective State mineral agencies. Lorraine B. Burgin, USBM State mineral specialist in Denver, compiled the Arizona summary, in cooperation with the Arizona Department of Mines and Mineral Resources. For copies of the preliminary reports, write to Mineral Industry Surveys, U.S. Bureau of Mines, Washington, DC 20241.

U.S. Summary

In 1987 decreasing imports, low inventories, and a steady demand for many goods increased commodity prices and improved the output and profits of many industrial firms, including mineral and mineral-material producers. Prices and output for most mineral commodities rose during 1987. The value of nonfuel mineral production in the Nation increased 8.5 percent, from \$23.5 billion in 1986 to \$25.5 billion in 1987. Metals and industrial minerals accounted for 29 and 71 percent of the total value, respectively. The value of metal production rose 28 percent in 1987 to \$7.4 billion, whereas the production value of industrial minerals rose only 2 percent to \$18 billion.

Reduced production costs, increased byproduct production, and higher metal prices in 1987 led to increased mine output of copper and zinc in the United States. Mine production of lead, however, declined to the lowest level since 1968, despite good market growth and a 60 percent increase in the average price of lead. This apparent paradox in lead mining was believed to be partly the result of a continuing trend of high grading

at some mines because of low prices during 1982-86.

Productivity improvements and restructuring efforts of the domestic copper industry, such as the construction of efficient flash-smelting facilities, led to higher metal output despite the closing of two smelters. Increased demand for aluminum, copper, and lead and concomitant price hikes were chiefly due to improved economic activity, especially in the electrical and construction sectors, increases in the per-unit use of copper in motor vehicles, and a higher percentage of registered vehicles needing lead replacement batteries. The drop in domestic output of automobiles was believed to be the principal cause of slightly lower domestic zinc demand. U.S. import reliance for the major nonferrous metals declined slightly in 1987, reversing the trend of recent years.

Work continued at the Environmental Protection Agency (EPA) on the development of a mining-waste regulatory program. EPA is addressing the need to regulate smelting and refining wastes from the lead, zinc, copper, and aluminum industries.

The prices of gold and platinum-group metals (PGM) continued a 2-year trend of sharp increases and these metals remained a major focus of exploration and development worldwide. The reserve positions of both gold and PGM were improved significantly as a result of these activities during the past 3 to 4 years. The average price of silver also rose dramatically, reversing a 3-year downward trend. Domestic mine output of the precious metals increased except for refinery output of PGM, which declined slightly. The increase in domestically mined

silver was due to increased byproduct silver production from almost 40 gold mines and the opening or reopening of several silver mines. Reported domestic industrial consumption of gold and silver rose slightly.

The Comprehensive Anti-Apartheid Act of 1986 (Public Law 99-440) restricted or banned U.S. importation of gold coins minted in the Republic of South Africa and materials produced by parastatal organizations (organizations of which the government has some ownership), such as iron and steel products, coal, and crude oil. U.S. exports of refined petroleum to the Republic of South Africa were also banned. Importation of strategic minerals deemed "essential for the economy or defense of the United States" that are "unavailable from reliable and secure suppliers" has not been banned, however. These minerals include andalusite, antimony, chromium, chrysotile asbestos, cobalt, industrial diamonds, manganese, PGM, rutile, and vanadium.

Demand for building materials, such as construction aggregate, gypsum, and cement remained strong. Consumer demand for cement slightly exceeded the 1986 record level. U.S. reliance on imported cement reached a record high level of 18 million short tons, which accounted for 20 percent of consumption compared with just 4 percent in 1981. Mexico continued to capture a large share of the import market with 28 percent of the total, exceeding imports from Canada for the second consecutive year. Crushed-stone production exceeded 1 billion short tons for the third consecutive year; construction sand-and-gravel production totaled 883 million tons.

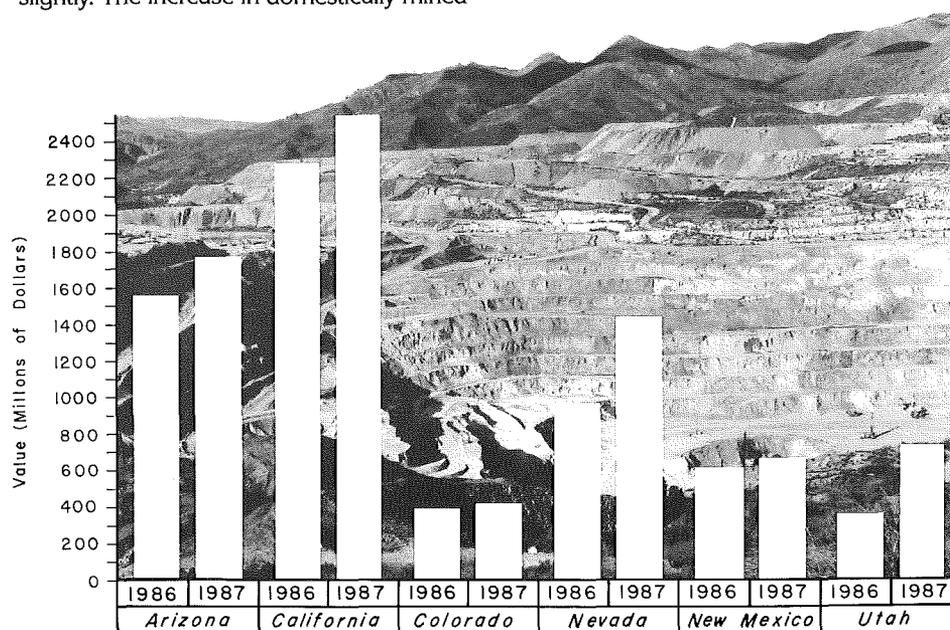


Figure 1. Value of nonfuel mineral production in the Southwest, 1986 and 1987.

Foreign acquisition of cement, crushed stone, and sand-and-gravel operations continued to grow during 1987. By year-end, approximately 54 percent of domestic cement capacity had been acquired by foreign firms, mostly western European countries, compared with 22 percent in 1981. Foreign-owned crushed-stone and sand-and-gravel operations produced about 3 to 5 percent of the total 1987 output.

Production of salt for chloralkali manufacture increased because of a strong demand for chlorine and caustic-soda-based products. Because of declining sales in certain markets, one major salt company announced it was available for acquisition. Another major domestic salt producer signed a letter of intent to purchase its competitor, pending U.S. Department of Justice approval.

Environmental issues, mergers, acquisitions, international trade, and government legislation all had significant impacts on the production of industrial minerals. EPA continued its impact analysis of the proposed ban and phase-out of asbestos and asbestos products. It reviewed the National Emission Standards for Hazardous Air Pollutants and surveyed producers of garnet,

gold, kyanite, limestone, taconite, talc, tungsten, and vermiculite to determine the asbestos and total mineral fiber content of mine emissions. The Occupational Safety and Health Administration (OSHA) extended an administrative stay on the regulation governing exposure to nonasbestiform amphiboles while it continued studying the economic impact of the regulation on the mining and construction industries.

The framework for a U.S.-Canada free-trade agreement was completed in October 1987. The pact will eliminate all tariffs and most nontariff barriers between the two countries by 1999, thereby creating the world's largest open market. The expansion of trade is expected to generate 5 percent higher growth for Canada and up to 1 percent higher growth for the United States by the end of the century. Currently, the U.S. trade deficit with Canada is second only to its deficit with Japan. Canada is the largest supplier of nonfuel minerals to the United States.

Arizona

The value of nonfuel mineral production in Arizona increased 13 percent in 1987 to an estimated \$1.8 billion, about two-thirds of the

peak production value reached in 1981. The value of metals output, which accounted for 84 percent of the total value, substantially increased from \$1.2 billion in 1986 to \$1.5 billion in 1987.

Arizona, with nearly two-thirds of U.S. output, continued to rank first in the Nation in copper production. Copper accounted for more than three-fourths of the State's nonfuel mineral value. The year's depressed markets resulted in a slight decline in the quantity of copper produced; however, shortages developed and a dramatic increase in the price of copper the last quarter of 1987 brought a 19-percent rise in the value of copper output. Still striving to recoup losses incurred since 1981, copper companies were restructured and innovative mining and processing methods were introduced to reduce costs.

With the rise in gold prices, output and value of Arizona's gold production soared. At the \$13.9-million Copperstone complex near Parker, about 6,000 troy ounces of gold were produced in 1987. Annual output, expected to reach 60,000 ounces, will more than double Arizona's gold production.

The value of industrial minerals output was led by construction sand and gravel, portland cement, crushed stone, and lime. Declines were posted for masonry and portland cement, pumice, and crushed stone.

California

California continued as the leading State in the Nation in production value of nonfuel minerals for 1987. Value increased to an estimated \$2.5 billion from the \$2.3 billion reported in 1986. California led all States in the production of asbestos, boron minerals, portland cement, diatomite, calcined gypsum, rare-earth metal concentrates, construction sand and gravel, and tungsten ore and concentrates. It was second in the production of natural calcium chloride, magnesium compounds from seawater, sodium compounds, wollastonite, and gold. Exploration and gold production increased significantly during the year.

Colorado

The value of nonfuel mineral production in Colorado in 1987 was estimated at \$386.5 million. Although still far below the peak of \$1.2 billion in 1981, the value increased 4 percent over that of 1986. A major factor in the increase was the continued large output and higher price of gold. Molybdenum output fell about one-third, as demand for this steel-hardening metal remained low, eliminating many mine jobs. The mining sector of the State's economy continued to lose jobs for the seventh year in a row. Colorado ranked 22nd in the Nation in nonfuel mineral production in 1987, compared with 7th place in 1981.

In 1987 Colorado's gold mines produced nearly 60,000 more ounces of gold than they

Table 1. Value of nonfuel mineral production in the Southwest, measured by mine shipments, sales, or marketable production, including consumption by producers. All figures are from the U.S. Bureau of Mines; totals for 1987 are preliminary estimates.

State	Value (thousands of dollars)		Percent of Total Value in 1987		Major Commodities
	1986	1987	Southwest	United States	
Arizona	1,556,035	1,761,633	23.5	6.9	copper, construction sand and gravel, portland cement, molybdenum, gold, silver
California	2,269,417	2,509,501	33.5	9.9	portland cement, construction sand and gravel, boron minerals, gold, crushed stone, natural sodium carbonate
Colorado	370,008	386,459	5.2	1.5	molybdenum, gold, construction sand and gravel, portland cement, crushed stone, zinc
Nevada	977,331	1,426,963	19.1	5.6	gold, silver, construction sand and gravel, portland cement, gypsum, crushed stone
New Mexico	612,075	678,021	9.1	2.7	copper, potassium salts, construction sand and gravel, portland cement, perlite, crushed stone
Utah	374,056	727,528	9.7	2.9	copper, gold, portland cement, magnesium, construction sand and gravel, salt
SOUTHWEST	6,158,922	7,490,105	100.0	29.4	
U.S. TOTAL	23,457,000	25,462,000	—	100.0	

Table 2. Value of nonfuel mineral production in Arizona, measured by mine shipments, sales, or marketable production, including consumption by producers. All figures are from the U.S. Bureau of Mines; totals for 1987 are preliminary estimates.

Mineral	Value (thousands of dollars)	
	1986	1987
Clays	1,366	1,482
Copper	1,149,193	1,370,924
Gem stones	2,533	2,836
Gold	W	W
Gypsum	1,820	1,832
Lead	W	—
Lime	21,016	22,431
Molybdenum	75,607	51,802
Pumice	30	26
Sand and gravel (construction)	140,004	140,500*
Silver	22,987	23,161
Stone (crushed)	25,100*	22,400
Other**	116,379	124,239
TOTAL	1,556,035	1,761,633

W Withheld to avoid disclosing company proprietary data; value included in "Other" figure.

* Estimated.

** Combined value of cement, perlite, salt, industrial sand and gravel, dimension stone, and values indicated by symbol W.

had in 1986. This dramatic rise in gold production is expected to continue through 1988. More than a dozen new or rejuvenated mines are preparing to add their output to the gold flow.

Construction sand-and-gravel output decreased slightly from that of 1986, but total value rose an estimated 11.6 percent. New residential and commercial construction and the concomitant demand for sand and gravel, stone, and other industrial minerals continued to decline for the third consecutive year. The value of new construction dropped 34 percent to \$249 million between September 1986 and September 1987. Non-building construction (bridges, roads, and water and sewer systems), however, showed a 6-percent gain over the same period in 1986. The overall decline was attributed to weakness in the economy, rising interest rates, and overbuilding in the early 1980's.

Nevada

Nevada's 1987 nonfuel mineral production was estimated to be valued at \$1.4 billion, an increase of \$450 million from that recorded in 1986. The increase resulted from a 32-percent rise in gold production to 2.7 million troy ounces and a 64-percent rise in silver production to 12.6 million troy ounces. Construction and expansion projects were underway at most major gold facilities in the State. Nevada was the leading State in the Nation in the production of gold, silver, and barite and was the sole producer of mined magnesite and mercury. Nevada ranked fourth in the Nation in value of nonfuel mineral production.

New Mexico

The value of nonfuel mineral production in New Mexico for 1987 was estimated to be \$678 million, about 11 percent higher than in 1986. Leading commodities were copper, potash, construction sand and gravel, portland cement, perlite, crushed stone, and silver. Increases were reported for all nonfuel minerals except clay, masonry cement, gold, molybdenum, salt, and crushed and dimension stone.

Metals output accounted for more than half of the total value of the State's production of nonfuel minerals. New Mexico ranked second nationally in the production of copper. Gold production, however, declined substantially. Molybdenum production ceased because of low prices and continued depressed demand.

Although potash production increased about 20 percent, its value rose a comparatively small amount because of reduced prices throughout most of the year. Several New Mexico potash producers filed an antidumping petition with the International Trade Commission of the U.S. Department of Commerce, contending that Canadian potassium chloride was dumped on the U.S. market, thereby forcing U.S. prices down substantially. The department's preliminary findings confirmed that Canadian producers sold the product in U.S. markets at prices from 9 to 85 percent below the fair market value. When the department set preliminary dumping duties, Canadian potash producers raised their prices to cover the extra costs. As a result, U.S. producers reported some sales increases.

Utah

The value of nonfuel mineral production in Utah in 1987 was estimated at \$728 million, a 94-percent increase over that of 1986.

Leading commodities included copper, gold, portland cement, magnesium metal, construction sand and gravel, salt, silver, crushed stone, and phosphate rock. Metals accounted for about one-third of the total value of nonfuel mineral output, a substantial gain over the one-fifth recorded for 1986. The principal factor in the rise in value of Utah's nonfuel mineral output was the return to production of a major copper operation, which was shut down in 1985.

Magnesium metal production declined as one major producer was forced to purchase brine salts for its primary magnesium plant after a mid-1986 storm destroyed its solar evaporation ponds on Great Salt Lake. Although several uranium operations reopened in late 1987, the continued depressed conditions of the uranium industry led one corporation to announce the permanent closure of its uranium-vanadium mines and mill.

The total value of industrial minerals rose one-fifth. Increases were posted for all nonmetals, except native asphalt (gilsonite) and masonry cement.

ADMMR Receives New Director

Leroy E. Kissinger has been appointed the new director of the Arizona Department of Mines and Mineral Resources (ADMMR). Kissinger, 59, succeeds John H. Jett, who retired in March. Kissinger holds a bachelor's degree in geological engineering from the University of Oklahoma and has more than 20 years of experience in the mineral industry. He is a registered professional geologist in Arizona. ADMMR is chartered to promote the development of mineral resources in the State.

Arizona's State Fossil and Bicentennial Stone

In May Governor Rose Mofford signed Senate Bill 1455, sponsored by State Senator Doug Todd (Tempe) and passed by the Arizona Legislature, making petrified wood, or *Araucarioxylon arizonicum*, the official State fossil of Arizona. This 225-million-year-old fossil from the Triassic Chinle Formation in northeastern Arizona is a primitive and extinct conifer that was a significant link in the evolution of vascular plants. Arizona's multicolored petrified wood is also prized as a semi-precious gem stone.

Tourists no longer have to visit Arizona, however, to see petrified wood from the Chinle Formation. It is displayed in many museums throughout the world. Tourists can also visit Independence Mall in Philadelphia, Pennsylvania. "We the

People 200," the group that organized the 1987 bicentennial celebration of the U.S. Constitution, requested rock specimens from each State to construct a monument called the Freedom Foundation Wall on Independence Mall. The monument is made of 50 2x2x4-foot blocks placed in five rows of 10 blocks each. On the front of the wall, metal reproductions of the Constitution and Declaration of Independence are mounted; on the back of each stone, its State of origin and the date the State ratified the Constitution is carved. The stones are laid in order, with those from the first States to ratify the Constitution in the bottom row. Arizona's stone, a cross section of a large petrified log, is in the top row; Arizona became the 48th State on February 14, 1912.

Theses and Dissertations, 1987

The following list includes theses and dissertations on Arizona geology, mineral technology, hydrology, and related subjects that were awarded in 1987 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 library of the Arizona Geological Survey. 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; G-Geology

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

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

Arizona State University

- Dehn, Jonathan, Model of cinder cone formation: M.S. Thesis, 85 p. (G)
Estrada, J.J., Geology of the Four Peaks area, Arizona: M.S. Thesis, 76 p. (G)
Faith, Karen, Land use change at Interstate 10 interchanges in Goodyear and Avondale, Arizona: M.S. Thesis, 84 p. (Gg)
Jagiello, K.J., Structural evolution of the Phoenix basin, Arizona: M.S. Thesis, 157 p. (G)
Lacey, Michael, The role of vegetation in slope erosion and sediment yield, central Arizona: M.S. Thesis, 82 p. (Gg)
Miller, E.J., The Buckeye pluton; a peraluminous two-mica granite: M.S. Thesis, 106 p. (G)

Northern Arizona University

- Bayne, B.J., Depositional analysis of conglomerates in the Mazatzal Group and related strata, central Arizona: M.S. Thesis, 186 p. (G)
Brady, T.B., Early Proterozoic structure and deformational history of the Sheep Basin Mountain area, northern Sierra Anchas, Gila County, Arizona: M.S. Thesis, 122 p. (G)
Burns, B.A., The sedimentology and significance of a Middle Proterozoic braidplain; Chediski Sandstone Member of the Troy Quartzite, central Arizona: M.S. Thesis, 143 p. (G)
Richards, A.M., Gravity analysis of the Tonto and Payson basins, central Arizona: M.S. Thesis, 162 p. (G)

- Roller, J.A., Geometric and kinematic analysis of the Proterozoic Upper Alder Group and Slate Creek movement zone, central Mazatzal Mountains, central Arizona: M.S. Thesis, 105 p. (G)
Sydow, M.W., Seismicity and crustal structure of north-central Arizona: M.S. Thesis, 92 p. (G)

University of Arizona

- Ali, M.M., A probabilistic analysis of the distribution of collapsing soil in Tucson using Kriging method: Ph.D. Dissertation, 252 p. (CE)
Amer, S.A., Spectral reflectance measurements of salt-affected soil: M.S. Thesis, 69 p. (SWS)
Beatty, Barbara, Correlation of some mid-Mesozoic redbeds and quartz sandstones in the Santa Rita Mountains, Mustang Mountains, and Canelo Hills, southeastern Arizona: M.S. prepublication manuscript, 30 p. (G)
Boling, J.K., Earth-fissure movements in south-central Arizona, U.S.A.: M.S. Thesis, 99 p. (HWR)
Bradley, M.A., Vein mineralogy, paragenetic sequence and fluid inclusion survey of the silver district, La Paz County, Arizona: M.S. Thesis, 131 p. (G)
Brod, L.G., Jr., Geology and speleogenesis of Colossal Cave, Pima County, Arizona: M.S. Thesis, 68 p. (G)
Clark, Susanmarie, Potential for use of cottonwoods in dendrogeomorphology and paleohydrology: M.S. prepublication manuscript, 52 p. (G)
Davies, B.E., Water movement in nonisothermal tuff: M.S. Thesis, 82 p. (HWR)
Epstein, V.J., Geologic and hydrologic factors affecting land subsidence in Eloy, Arizona: M.S. prepublication manuscript, 68 p. (G)
Fuller, J.E., Paleoflood hydrology of the alluvial Salt River, Tempe, Arizona: M.S. prepublication manuscript, 70 p. (G)
Glynn, M.E., Geotechnical investigations of two potential sites for the proposed Arizona Superconducting Super Collider: M.S. Thesis, 133 p. (MGE)
Grondin, G.H., Transport of MS-2 and f2 bacteriophage through saturated Tanque Verde Wash soil: M.S. Thesis, 188 p. (HWR)
Grubensky, M.J., Structure, geochemistry, and volcanic history of mid-Tertiary rocks in the Kofa region, southwestern Arizona: M.S. Thesis, 107 p. (G)
Gustin, M.S., A petrographic, geochemical, and stable isotope study of the United Verde orebody and its associated alteration, Jerome, Arizona: Ph.D. Dissertation, 249 p. (G)
Haile, A.B., Possible water pollution sources in Sabino Creek, Santa Catalina Mountains, Arizona: M.S. Thesis, 79 p. (HWR)
Handler-Ruiz, Andrea, Correlation between channel changes and sand and gravel mining: M.S. prepublication manuscript, 90 p. (G)
Haverland, R.L., Soil development on a granite catena in southeastern Arizona: Ph.D. Dissertation, 265 p. (SWS)
Hay, L.E., The automatic calibration of the SRP's long-term forecasting model: M.S. Thesis, 88 p. (HWR)
Kalin, R.M., Stable isotopic composition of atmospheric water vapor and its relationship to precipitation in Tucson: M.S. prepublication manuscript, 22 p. (G)

- Katz, L.T., Steady state infiltration processes along the Santa Cruz and Rillito Rivers: M.S. Thesis, 119 p. (HWR)
Khanchoul, Kamel, Relationship between lithology and slope form in the Tucson Mountains, Pima County, Arizona: M.S. Thesis, 78 p. (Gg)
Koterba, M.T., Differential influences of storm and watershed characteristics on runoff from ephemeral streams in southeastern Arizona: Ph.D. Dissertation, 291 p. (HWR)
Krebs, C.K., Geochemistry of the Canelo Hills Volcanics and implications for the Jurassic tectonic setting of southeastern Arizona: M.S. prepublication manuscript, 38 p. (G)
Levine, S.J., Genesis of soils derived from the Kaibab Formation of the Colorado Plateau: Ph.D. Dissertation, 160 p. (SWS)
McIntosh, B.J., A simplified probability approach to the design and analysis of uranium tailings impoundments: M.S. Thesis, 143 p. (MGE)
Marozas, D.C., The effects of mineral reactions on trace metal characteristics of groundwater in desert basins of southern Arizona: Ph.D. Dissertation, 114 p. (G)
Miller, P.S., Performance of drainage channels in Pima County, Arizona: M.S. Thesis, 118 p. (CE)
Murphy, E.M., Carbon-14 measurements and characterization of dissolved organic carbon in ground water: Ph.D. Dissertation, 180 p. (HWR)
Nagaraj, B.K., Modelling of normal shear behavior of interface in dynamic soil-structure interaction: Ph.D. Dissertation, 285 p. (CE)
Naruk, S.J., Kinematic significance of mylonitic foliation: Ph.D. Dissertation, 72 p. (G)
Olson, K.L., Urban stormwater injection via dry wells in Tucson, Arizona, and its effect on ground-water quality: M.S. Thesis, 151 p. (HWR)
Osborn, M.D., Modeling nitrates in projecting the future ground-water quality of the Cortaro area, Arizona: M.S. Thesis, 114 p. (HWR)
Pool, D.R., Hydrogeology of McMullen Valley, west-central Arizona: M.S. Thesis, 86 p. (HWR)
Poulton, M.M., Extraction of surface and subsurface geologic information from digital images of the proposed Arizona Superconducting Super Collider sites: M.S. Thesis, 54 p. (MGE)
Richardson, T.C., A risk analysis approach to managing groundwater quality in the upper Santa Cruz basin: M.S. Thesis, 117 p. (HWR)
Roberts, L.K., Paleohydrologic reconstruction, hydraulics, and frequency-magnitude relationships of large flood events along Aravaipa Creek, Arizona: M.S. Thesis, 40 p. (G)
Robison, L.C., Geology and geochemistry of Proterozoic volcanic rocks bearing massive sulfide ore deposits, Bagdad, Arizona: M.S. Thesis, 142 p. (G)
Rose, S.E., Dissolved oxygen systematics in the Tucson basin aquifer, Arizona: Ph.D. Dissertation, 153 p. (G)
Rosenthal, R.H., The interaction of parent material and eolian debris on the formation of soils in the Silverbell desert biome of Arizona: M.S. Thesis, 84 p. (SWS)
Ruf, A.S., Effects of strain and magnetic fabric in the mylonite zones of the Santa Catalina Mountains and Pinaleno Mountains metamorphic core complexes, Arizona: M.S. prepublication manuscript, 31 p. (G)
Stach, L.A., Inversion for source parameters of moderate-size earthquakes in the western U.S. using regional waveforms: M.S. Thesis, 101 p. (G)

STAFF NOTES

- Suchomel, K.H., Carbon isotopes, and carbon dioxide and oxygen behavior in the uncontaminated and contaminated unsaturated zone, Phoenix, Arizona: M.S. prepublication manuscript, 81 p. (G)
- Swift, P.N., Early Proterozoic turbidite deposition and melange deformation, southeastern Arizona: Ph.D. Dissertation, 134 p. (G)
- Tanbal, K.M., A gravity survey over late Quaternary fault scarps west of the Santa Rita Mountains: M.S. Thesis, 55 p. (G)
- Tinney, J.C., Trading quality for quantity; an assessment of salinity contamination generated by groundwater conservation policy in the Tucson basin: Ph.D. Dissertation, 229 p. (RNR)
- Trapp, R.A., Geochemistry of the Laramide igneous suite of the Santa Rita and Empire Mountains, southeastern Arizona: M.S. Thesis, 118 p. (G)
- Wagner, D.V., Isotopic and chemical characterization of ground waters in the vicinity of Flagstaff, Arizona: M.S. Thesis, 111 p. (HWR)
- Whitehead, T.W., Sorption and desorption of volatile alkyl halides in a desert soil: M.S. Thesis, 117 p. (HWR)
- Wiese, B.M., Open-space planning guidelines for Tucson, Arizona: M.S. Thesis, 209 p. (RNR)
- Williams, Derrick, Geostatistical analysis and inverse modeling of the upper Santa Cruz basin, Arizona: M.S. Thesis, 149 p. (HWR)
- Worthington, M.A., Thermal anomalies and the ground-water flow system south of the Narrows, upper San Pedro Valley, Arizona: M.S. Thesis, 80 p. (HWR)

New Report Outlines Mineral Potential on Federal Lands

A new report by the U.S. Bureau of Mines (USBM) identifies lands in Arizona where the Federal government owns all or part of the mineral estate and assesses the likelihood that valuable mineral deposits are present on those lands. Two 1:500,000-scale maps that show Federal land status and mineral favorability are included with the report. By comparing the availability of Federal land for mineral exploration and development with mineral favorability, the USBM hopes to determine how much Federal land-use restrictions limit access to the Nation's mineral wealth.

In Arizona, for example, the Federal government owns mineral rights on about 32 million acres, or 44 percent of the State. These Federal lands include 795,000 acres that the USBM deems "highly favorable" for metallic minerals—60 percent of all Arizona land in that category. Mineral exploration and development are prohibited or severely restricted on 167,000 acres or 21 percent of these "highly favorable" lands.

To obtain a copy of *Availability of Federally Owned Minerals for Exploration and Development in Western States: Arizona*, send \$3.25 to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; tel: (202) 783-3238.

Laurette E. (Lauri) Colton has been hired as Publication Sales Manager. She formerly worked for the Resource Center of Tucson Unified School District #1 in language arts library services. Born in Hot Springs, South Dakota in Black Hills country, she is a graduate of Sunnyside High School in Tucson.

Larry D. Fellows has served as President-Elect of the Association of American State Geologists (AASG) since July 1, 1987. In this position, he served as chairman of the AASG Federal Liaison Committee, which met in Washington, D.C. in September 1987 and March 1988. This committee acts as a liaison between the State geological surveys and Federal agencies and congressional committees that deal with natural-resource issues.

Thomas G. McGarvin received a Faculty of Science Distinguished Service Award from the University of Arizona. He also conducted two spring field trips for Tucson-area teachers. Approximately 20 primary- and secondary-school teachers attended both trips. The first trip, conducted on April 16, focused on the geology of the Tucson basin and Tucson Mountains and included a guided tour of the Earth Sciences Center at the Arizona-Sonora Desert Museum. The second trip on April 30 to the northern and eastern Tucson basin and the Saguaro National Monument-East continued the discussion on the geologic history of the Tucson area.

Philip A. Pearthree has joined the Arizona Geological Survey as Assistant Research Geologist. He has extensive experience in geomorphology, Quaternary geology, geophysics, tectonics, and seismology and has significantly increased the understanding of seismic hazards in Arizona and Nevada, including neotectonic fault behavior and large earthquake occurrences. His research at the Survey will focus on earth materials, geologic processes, and natural hazards in Arizona and their impact on land-use planning and management. Pearthree obtained a B.A. degree in geology and history from Oberlin College and M.S. and Ph.D. degrees in geosciences from the University of Arizona.

Stephen J. Reynolds participated in a symposium titled "Applied Extensional

Tectonics," hosted by the Australian Bureau of Mineral Resources, Geology, and Geophysics in Canberra, Australia in November 1987. Reynolds, an invited speaker whose expenses were paid by the Australian government, presented three talks on the geology of the Basin and Range Province of Arizona. He also gave invited lectures at the University of Melbourne, Monash University, University of Adelaide, South Australian Department of Mines and Energy, and Western Mining Corporation. In April 1988 Reynolds organized a short course on the origin of gold deposits, sponsored by the Arizona Geological Survey and the Arizona Geological Society. The course, which was attended by about 45 persons, featured Professor Robert Kerrich of the University of Saskatchewan.

Jon E. Spencer presented a paper at the 117th annual meeting of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME), held in Phoenix in January 1988. The paper, titled "Control of Mineralization by Mesozoic and Cenozoic Low-Angle Structures in West-Central Arizona," was coauthored by **S.J. Reynolds** and **John W. Welty** and released as Society of Mining Engineers Preprint Number 88-46. Spencer also gave an oral presentation at the Cordilleran Section Meeting of the Geological Society of America (GSA), held in Las Vegas in March 1988: "Role of Crustal Flexure in Initiation of Detachment Faults; Inferences Based on Airy Stress Functions." An abstract for the talk was printed in volume 20 (page 234) of GSA Abstracts with Programs.

Arizona Geological Survey geologists also helped lead the Spring 1988 Arizona Geological Society field trip, which was attended by more than 100 persons. The first day of the two-day excursion included a trip to the Vulture Mountains, where **S.J. Reynolds** and **Michael J. Grubensky** gave an overview of the regional geology, a visit to the recently opened Big Horn gold mine, and a stop in the western Harquahala Mountains. On the second day, which was devoted to examination of the Copperstone gold mine, **J.E. Spencer** summarized for participants fluid-inclusion studies of the gold deposit and recent geologic mapping of the nearby Moon Mountains.

Nonmetallic-Mineral Map Available

The Arizona Geological Survey (AGS) has several copies of Miscellaneous Investigations Series Map I-845-J available for purchase. This publication, titled "Maps Showing Nonmetallic Mineral Deposits in the Phoenix Area, Arizona," consists of two maps at scales of 1:250,000 and 1:500,000. It was com-

plied by Richard T. Moore and Robert J. Varga of the Arizona Bureau of Mines, a former name of the AGS, and published by the U.S. Geological Survey in 1976. A copy may be purchased for \$2.00, plus \$1.75 for shipping and handling, from the AGS, 845 N. Park Ave., Tucson, AZ 85719.

New Publications from the Arizona Geological Survey

The following publications may be purchased over the counter or by mail from the Arizona Geological Survey, 845 N. Park Ave., Tucson, AZ 85719. For price information on these and other Survey publications, contact the Survey offices.

Brooks, S.J., 1988, Hydrogeology of the basins encompassing the Maricopa Superconducting Super Collider site: Open-File Report 88-6, 29 p., scale 1:24,000 and 1:62,500.

Thorough and accurate descriptions of the ground-water and surface-water hydrology are vital in choosing the best site for the Superconducting Super Collider (SSC), a proton-antiproton particle accelerator proposed by the U.S. Department of Energy (DOE). Hydrologic aspects are important parameters in estimating construction costs, scheduling, long-term operational costs, and environmental impacts. The arid climate, deep water table, and remote uninhabited location of the Maricopa site are hydrologically ideal for construction of the SSC. This report integrates past geologic studies, drilling data, geophysical analyses, and remote-sensing information.

Childs, O.E., Knepp, R.A., Reynolds, S.J., Haxel, G., Thompson, S., III, and Wright,

J., 1988, Correlation of Stratigraphic Units of North America (COSUNA) documentation records for southern Arizona and vicinity: Open-File Report 88-3, 99 p.

COSUNA was a project of the American Association of Petroleum Geologists that resulted in the publication of 16 correlation charts based on modern concepts of the stratigraphy of the North American continent. This open-file report includes the documentation records used to compile the stratigraphic columns for southern Arizona and the Big Hatchet Mountain area of New Mexico.

Dickinson, W.R., 1988, Geologic map of the Catalina core complex and San Pedro trough, Pima, Pinal, Gila, Graham, and Cochise Counties, Arizona: Miscellaneous Map 88-C, scale 1:125,000.

This general geologic map was derived from the 15 map sheets of Miscellaneous Map 87-A, which, in turn, were derived from more than 80 geologic maps prepared by more than 60 individuals and from reconnaissance, remapping, and reinterpretation by the author from 1980 to 1988. New data and reinterpretation, which were not incorporated in MM-87-A, were also used in this compilation. The map area includes the Rincon, Santa Catalina, Tortolita, Tucson, Black, Tortilla, and Dripping Spring Moun-

tains, Johnnie Lyon Hills, and western flank of the Galiuro Mountains.

Nowatzki, E.A., Muller, Eugene, DeNatale, J.S., Ibarra-Encinas, G.A., Al-Ghanem, A.H., and Welty, J.W., 1988, Additional geotechnical engineering investigations for Arizona's Maricopa SSC site: Open-File Report 88-5, 223 p.

Arizona's Maricopa site is among seven finalists for the Superconducting Super Collider (SSC). Geotechnical data, such as laboratory analyses and field studies, compiled for the final proposal are included in this open-file report.

Santa Fe Pacific Railroad Company, 1981, Geologic map of Santa Fe Pacific Railroad Company mineral holdings in northwestern Arizona: Miscellaneous Map 88-A, scale 1:250,000.

This geologic map covers all of Mohave County, plus bordering areas of La Paz, Yavapai, and Coconino Counties and bordering areas of California and Nevada. The map incorporates original mapping, aerial-photograph interpretation, and maps from theses and various publications. Previously unmapped areas are shown with a variety of rock units, especially in the Black Mountains and ranges flanking the Big Sandy River Valley between Kingman and Wikieup.

Fieldnotes Will Have "New" Publisher

This is the last issue of *Fieldnotes* to be published by the Arizona Bureau of Geology and Mineral Technology. July 1 the Geological Survey Branch of the Bureau officially becomes the Arizona Geological Survey (AGS), an independent State agency, and the Mineral Technology Branch becomes part of the University of Arizona. Senate Bill 1102, enacted in 1987, mandates this administrative change, but specifies that the AGS be located in proximity to the University of Arizona in Tucson. No office relocation is planned.

Fieldnotes

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State of Arizona	Governor Rose Mofford
University of Arizona	President Henry Koffler
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