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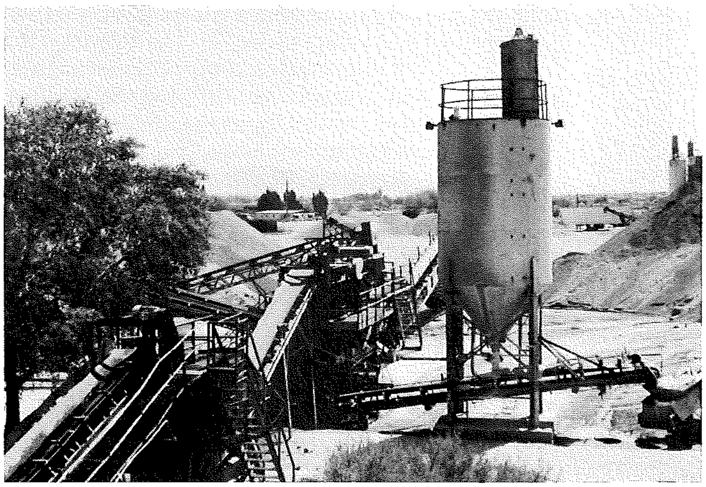

Figure 1. Processing plant for sand and gravel production, operated by the Tanner Companies, near Orange Grove Road and Interstate 10 north of Tucson. The four major steps to sand and gravel mining are site acquisition and clearing, mining, processing, and site reclamation. Strict geologic guidelines govern the selection of sand and gravel aggregate that gives concrete its bulk and strength. The deposit should be poorly sorted, i.e., it should contain a range of grain sizes from cobbles to sand. The particles must be durable; free of reactive alkalies, caliche, organic debris, and trash; and unindurated (not hardened or compacted). Photo by Alyce Pennington.

INDUSTRIAL MINERALS of SOUTHEASTERN ARIZONA

Gold, silver, copper -- When most people think of mining, they think of metallic minerals. Industrial minerals (sand and gravel, crushed stone, etc.), however, provide more dollars to the U.S. economy than do the more celebrated metals. In 1991, U.S. mines produced an estimated $11.2 billion worth of metals, compared with $19.6 billion worth of industrial minerals.

Because of the geologic setting of southeastern Arizona, various industrial minerals are exposed in areas that are within easy driving distance of Tucson. In April 1992, the Arizona Geological Society sponsored a 2-day field trip (organized by Brenda B. Houser) to examine several of these deposits, as well as commercial mining and processing operations. The following text is largely excerpted from the technical field-trip guidebook, *Industrial Minerals of the Tucson Area and San Pedro Valley, Southeastern Arizona*, edited by B.B. Houser and featuring the following authors: Daniel T. Eyde, Ted H. Eyde, John M. Guilbert, Robert L. Hockett, Dennis Mackovjak, Ken A. Phillips, and Jonathan D. Shenk. Much of the text is excerpted from the article, "Mineral Economics of Industrial Minerals in Southeastern Arizona," by K.A. Phillips of the Arizona Department of Mines and Mineral Resources. The guidebook may be purchased for $13.00 (includes shipping) from the Arizona Geological Survey, 845 N. Park Ave., Suite 100, Tucson, AZ 85719.

An industrial mineral is any rock, mineral, or other naturally occurring substance of economic value, excluding metallic ores and mineral fuels. Inhabitants of the Tucson basin have used industrial minerals since prehistoric times. Native Americans built low retaining walls from volcanic boulders on Tumamoc Hill, possibly to create agricultural terraces. In the late 1880's, Mexican laborers quarried the bouldery talus on the southern and northwestern sides of the hill for the walls and foundations of Tucson houses. Granitic boulders in the foothills of the Santa Catalina Mountains are used today as landscaping materials.

Industrial mineral deposits in southeastern Arizona range in age from Precambrian (more than 570 million years old) to Holocene (less than 10,000 years old). Sand and gravel, portland cement, stone (limestone, dolomite, marble, and landscape rock), clay, diatomite, gypsum, and asbestos have been mined or produced in southern Arizona.

In value, sand and gravel ranks second only to copper among the nonfuel minerals produced in Arizona. In 1991, 23.7 million tons[1] (about 6.5 tons per Arizona resident) of construction sand and gravel, worth $79.4 million, was produced in the State. (See related article on page 2 of this issue.) The urban areas of Maricopa and Pima Counties support the largest producers of construction sand and gravel in the State.

Sand and gravel is used in concrete aggregate for buildings, highways, dams, and airports, as well as in concrete products, such as blocks, bricks, and pipes. Including the requirements for pavement, pipes, drains, walls, and overpasses, each mile of urban freeway uses 400,000 tons of sand and gravel. A typical 1,600-square-foot house requires 100 tons of sand and gravel, a 24-story office building requires 36,000 tons, and a shopping mall requires 100,000 tons.

In Arizona, sand and gravel is largely produced from floodplains and terraces of the Salt River in Phoenix and the Santa Cruz River and Pantano Wash in Tucson, as well as from alluvial fans in outlying areas. After removal, sand and gravel must be processed -- crushed, screened, washed, and blended -- before it may be sold (Figure 1).

Portland cement is named after the Isle of Portland in southern England because of its resemblance to a limestone found there. Portland cement is a mixture of several industrial minerals, plus an iron additive. A favorite recipe lists the following ingredients and "cooking" instructions for portland cement: Blend 4 c. high-grade limestone, 3 tbl. high-alumina clay or shale, 1 tbl. silica (as sand, sandstone, or high-silica limestone), and

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[1] One short ton (abbreviated in this article as "ton") equals 2,000 pounds. One metric ton equals 2,200 pounds.

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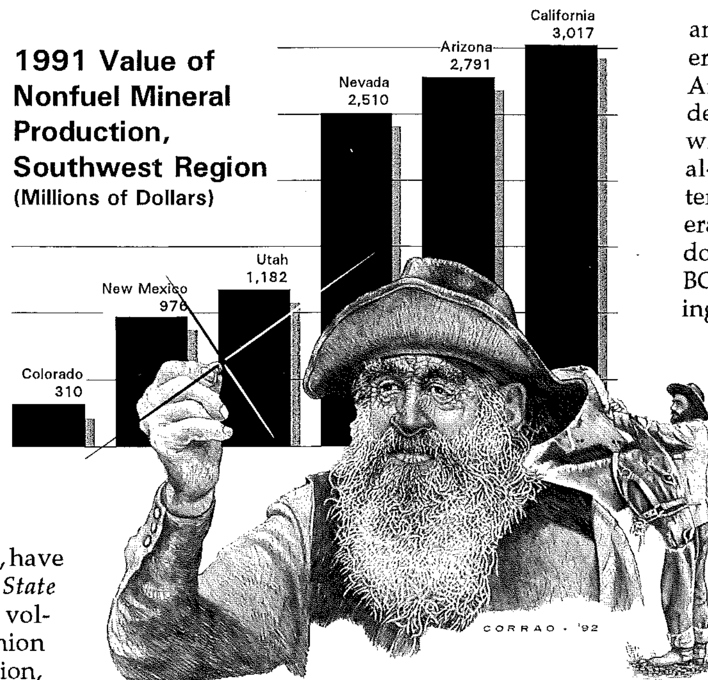
ALSO IN THIS ISSUE

THE NONFUEL MINERAL INDUSTRY OF THE SOUTHWEST
1991 SUMMARY

In 1991, the value of nonfuel mineral production declined by 4 percent in the Southwest. Preliminary figures show that the total value of production in this region was more than one-third of that of the United States. Mines in the six southwestern States of Arizona, California, Colorado, Nevada, New Mexico, and Utah produced $10.8 billion worth of mineral products; the national total was $30.8 billion (see figure at right; Table 1). California, Arizona, and Nevada ranked first through third, respectively, in U.S. nonfuel mineral production.



These preliminary figures were published by the U.S. Bureau of Mines (BOM), which has released individual State estimates of nonfuel mineral production for 1991. These estimates, generally yearend extrapolations based on 9 months of data, have been published in one volume: *State Mineral Summaries--1992*. This volume is designed to be a companion report to another BOM publication, *Mineral Commodity Summaries--1992*, which contains national statistics on 84 nonfuel mineral commodities. Single copies of each are free from the Publications Distribution Section, U.S. Bureau of Mines, Cochrans Mill Rd., P.O. Box 18070, Pittsburgh, PA 15236. Final production figures for 1991 are expected to be available in August.

The State summaries were prepared by BOM State Mineral Officers, in cooperation with the State mineral agencies. Individual summaries are also published separately as State Mineral Industry Surveys. Copies are available from the respective State Mineral Officers: Michael N. Greeley, 210 E. 7th St., Tucson, AZ 85705 (Arizona, New Mexico, and Utah); Fred V. Carrillo, 1605 Evans Ave., Reno, NV 89512 (California and Nevada); and Eileen Peterson, U.S. Bureau of Mines, Bldg. 20, Denver Federal Center, Denver, CO 80225 (Colorado).

ARIZONA

Arizona ranked second in the Nation in nonfuel mineral production in 1991, with an estimated total value of $2.8 billion, or more than 9 percent of the U.S. total (Tables 1 and 2). This amount reflected a decline of about 9 percent from 1990. The production of metallic minerals was valued at $2.6 billion, or 92 percent of the total mineral value in the State. Copper, gold, molybdenum, and silver were the major metallic commodities.

Arizona led the Nation in copper output, producing 62 percent of domestic copper in 1991. This output represented a 3-percent increase over that of 1990 and was the largest in the State since 1981. The producer copper price, however, continued to decline, dropping from a 1990 average of $1.23 per pound to $1.09.

Arizona was the eighth largest producer of gold in the Nation in 1991. The State ranked second in domestic production of molybdenum, sixth in silver, and tenth in construction sand and gravel and was among the leading producers of gem stones. Other important industrial-mineral commodities were cement and lime.

The BOM continued to investigate an area in northern La Paz and southern Mohave Counties (west-central Arizona) where gold is associated with detachment faults. The investigation will provide a comprehensive mineral-resource appraisal of this geologic terrane. It also evaluated known mineral deposits in the Coconino, Coronado, and Kaibab National Forests. The BOM continued its in-situ copper-mining research project with the Santa Cruz Joint Venture near Casa Grande. During the year, an injection and recovery test of the experimental well system, using a salt tracer, was conducted at the test site.

Federal legislative actions during 1991 delayed gold exploration and production activities in two areas of southern Arizona. Congressman James Kolbe introduced House bill 2790 to withdraw 13,000 acres in the Coronado National Forest from mineral development, thus blocking a gold-exploration project near Portal and the Chiricahua National Monument. Senator Dennis DeConcini and Representative Ed Pastor requested that the State director of the U.S. Bureau of Land Management (BLM) delay action on a plan to reopen the Old Yuma gold mine near Saguaro National Monument west of Tucson. The congressmen supported a proposal to expand the monument boundaries to encompass this and other mine sites.

Two companies were commended for their environmental and community efforts in 1991. Energy Fuels Nuclear received a BLM award for its $800,000 reclamation of the Hack Canyon uranium mine in Mohave County. ASARCO voluntarily funded the closure of several hazardous, abandoned mine shafts near an elementary school in Tucson, even though the company had never operated a mine on the property.

The Arizona Department of Commerce and several economic development councils in the State organized nine panels, or clusters, to create a long-range planning strategy for Arizona. The clusters held public hearings and submitted proposals for economic growth. In its yearend report, the Minerals and Mining Cluster made six recommendations that it considered essential to the minerals industry and Arizona's economic progress.

CALIFORNIA

California led the Nation in the value of nonfuel minerals produced in 1991, accounting for nearly 10 percent of the U.S. total. Production value was estimated at $3 billion, an increase of more than 8 percent from the 1990 value (Table 1). Metallic minerals, especially precious metals and molybdenum, as well as asbestos and pumice, were responsible for the rise in value.

Table 1. Value of nonfuel mineral production in the Southwest, measured by mine shipments, sales, or marketable production, including consumption by producers. Figures are from the U.S. Bureau of Mines; 1991 totals are preliminary estimates.

State	Value (thousands of dollars) 1990	1991e	Percent of Total Value in 1991 Southwest[1]	U.S.	1991 Rank in Nation	Principal Minerals
Arizona	3,065,448	2,790,830	25.9	9.1	2	copper, sand & gravel, cement, gold
California	2,779,799	3,017,185	28.0	9.8	1	sand & gravel, cement, boron, gold
Colorado	386,192	309,963	2.9	1.0	29	sand & gravel, cement, molybdenum, stone
Nevada	2,610,876	2,510,230	23.3	8.2	3	gold, sand & gravel, silver, diatomite
New Mexico	1,097,550	976,174	9.1	3.2	10	copper, potash, sand & gravel, stone
Utah	1,334,010	1,181,587	11.0	3.8	9	copper, gold, magnesium metal, cement
SOUTHWEST	11,273,875	10,785,969	100.2	35.0	---	
U.S. TOTAL	33,319,000	30,793,000	---	100.0	---	

e Estimated.
1 Percentages do not add to 100.0 because of rounding.

Increased gold production retained California's ranking as the second-largest gold-producing State. Precious-metals exploration occurred in several areas, despite lower silver and gold prices.

California led all other States in the production of asbestos, boron minerals, portland cement, diatomite, calcined gypsum, construction sand and gravel, rare earth concentrates, and tungsten. Industrial mineral production, however, mirrored the continuing decline in construction activity, with projected declines in portland cement, clays, crude gypsum, lime, construction sand and gravel, and crushed stone. Despite numerous complaints from homeowners and citizens groups throughout the State, some sand-and-gravel operations were started or enlarged during the year.

Assembly bill 213, passed by the California Legislature, clarified the type of mining wastes that are exempt from hazardous-waste management laws. San Benito County became the first county in the State to initiate a per-ton "business license" tax on minerals, imposing a 5-cent-per-ton tax on minerals mined in the county for use in road repair. The mineral tax was initiated last year under Senate bill 2557, which granted counties new authority to raise revenue.

A public-education project was opened in 1991. The self-guided, Mesquite Mine Overlook Trail in Imperial County introduces the hiker to the gold mine and its unique desert environment. It is a cooperative venture of the BLM and the Gold Fields Operating Company.

COLORADO

The value of nonfuel mineral production in Colorado was estimated at $310 million in 1991, down from the $386 million produced in 1990 (Table 1). Colorado's nonfuel mineral output has fallen significantly during the past decade, primarily because of the declining demand for molybdenum. Lower prices for base and precious metals contributed to the lower value of nonfuel mineral production in 1991. Lower values were also reported for clays, gypsum, lime, and perlite. Modest increases in the value of output of cement, crushed stone, and sand and gravel, which compose nearly two-thirds of the nonfuel mineral total in Colorado, were not sufficient to reverse the general decline. Colorado ranked 29th among the 50 States in nonfuel mineral production.

Lower gold prices left gold-mining companies in Colorado scrambling to stay afloat. Mine closures, layoffs, and mergers were common as gold production continued the decline of the 1980's. Increased production of gold from low-cost surface deposits in other States left Colorado's mostly underground deposits increasingly less competitive.

Production of construction sand and gravel, which constitutes nearly 30 percent of the total value of nonfuel mineral production in Colorado, was down slightly in 1991. Public concern over environmental issues remained a major hurdle to opening or expanding gravel-mining operations. Sand-and-gravel mining proposals faced stiff public opposition in Adams, Alamosa, Eagle, El Paso, Grand, Larimer, Montrose, and San Miguel Counties.

Cement was second in value of nonfuel mineral commodities; output increased moderately over 1990 levels. Output of crushed stone held its own in a continuing balancing act between construction needs for the material and public opposition to mining and its potential environmental impacts. The most vociferous controversy, which was still unresolved at yearend, was a proposed quarry in Clear Creek Canyon west of Denver. In a similar controversy over a stone quarry on State land north of Denver, the Colorado Supreme Court ruled that land administered by the State Board of Land Commissioners is subject to regulation by local authorities. Controversy and litigation continued over a proposal to mine black marble from claims on Conundrum Creek inside the Maroon Bells-Snowmass Wilderness in Pitkin County.

Removal of low-level radioactive tailings from an old uranium mill site in Grand Junction was delayed when a truck accident led to invocation of U.S. Department of Transportation regulations controlling movement of radioactive material by truck. About 1 million tons of contaminated material was used as construction fill in 6,500 sites in the Grand Junction area. To date, this material has been removed from 4,200 sites.

A U.S. Supreme Court ruling barred Colorado and other States from mandating toxic cleanup without approval from Federal regulators. The ruling prohibited Colorado from enforcing a $42-million cleanup plan for a mine site near Telluride and Ouray. It also affected cleanup plans in north Denver, where residents are suing a 100-year-old cadmium smelter, claiming damage to health and property values. The State earmarked nearly

Table 2. Value of nonfuel mineral production in Arizona, measured by mine shipments, sales, or marketable production, including consumption by producers. Figures are from the U.S. Bureau of Mines; 1991 totals are estimates.

Mineral	Value (thousands of dollars) 1990	1991e
Clays	2,318	1,436
Copper[1]	2,657,649	2,456,094
Gem stones	2,098	2,100
Gold[1]	62,191	67,247
Sand and gravel (construction)	92,166	79,400
Silver[1]	26,836	19,723
Stone (crushed)	13,500e	12,800
Other[2]	208,690	152,030
TOTAL	3,065,448	2,790,830

e Estimated.
1 Recoverable content of ores, etc.
2 Combined value of cement, diatomite (1990), gypsum (crude), iron oxide pigments (crude), lime, molybdenum, perlite, pumice (1990-91), pyrites, salt, sand and gravel (industrial), and stone (dimension).

$23 million to clean up mining wastes in Clear Creek and Gilpin Counties, one of the State's oldest mining districts. Superfund-site cleanup plans in Aspen and Leadville continued to draw heated opposition from residents.

The BLM proposed new rules that would expand the reclamation bonding requirements for mining operations that cause 5 acres or less of surface disturbance per year. The Colorado Legislature passed a bill that removes the ceiling on reclamation security-bond requirements from owners of small mining operations and allows local government and the public greater participation in the permitting process.

NEVADA

Nevada's 1991 nonfuel mineral production was estimated to be valued at $2.5 billion, a decrease of about $100 million from that of 1990 (Table 1). Gold production rose 4 percent, but silver production dropped nearly 40 percent because of mine closures due to lower prices. Nevada remained the leading State in the production of gold, silver, mercury, and barite; ranked second in the production of diatomite and lithium; and was the sole producer of mined magnesite. Nevada ranked third among the States in 1991 production value of nonfuel minerals.

Nevada's most valuable mineral commodity -- gold -- accounted for 88 percent of the State's total nonfuel mineral value, or about $2.2 billion. Construction sand and gravel and silver, which accounted for $63 million and $55 million, respectively, were the State's next most valuable minerals, followed by clays, diatomite, gypsum, lime, and lithium.

Precious-metals exploration declined as many gold producers shifted their exploration activities to foreign countries in response to increased regulations, lower prices, and more favorable conditions offshore. Exploration drilling, however, continued throughout Nevada, with most of the activity centered around known gold-producing properties.

The Nevada Legislature passed several laws in 1991 that affected mining, including the following: Assembly bill 78, which revises mining-reclamation regulations and requires each mining operation to file a yearly report on the status of mining, exploration, and reclamation activities; Assembly bill 351, which provides penalties for violating State hazardous-waste provisions; Assembly bill 535, which imposes annual assessments from $500 to $10,000 on developing a body of water that is injurious to wildlife; and Assembly bill 592, which revises requirements for mining-reclamation payments, fees, and verification. Enacted Senate bill 41 authorizes the State's Division of Environmental Protection to develop new rules governing hazardous chemicals. The law requires firms that deal with hazardous chemicals to register with the State, provide an inventory of their chemicals, list safety procedures, and complete a safety and risk evaluation.

NEW MEXICO

The total value of nonfuel mineral production in New Mexico was estimated at $976 million in 1991, a decrease of 10 percent from the previous year's total (Table 1). The State rose, however, to 10th place nationally in the output of nonfuel minerals.

The metals sector, which included copper, gold, molybdenum, silver, and zinc, contributed nearly $655 million, or 67 percent of the total value. New Mexico ranked second in the Nation in copper production. Most of New Mexico's gold and silver was produced as byproducts of base-metal output. Significant production of primary gold, however, is planned in 1992 from an area in the Ortiz Mountains south of Santa Fe, where ore reserves containing more than 1 million troy ounces of gold have been identified.

New Mexico's industrial mineral production in 1991 was valued at $321 million. Potash output furnished more than 24 percent of the total value of nonfuel mineral production in the State and nearly 90 percent of total U.S. output of potash in 1991. New Mexico mines also produced significant quantities of mica, perlite, construction sand and gravel, crushed stone, portland cement, and pumice. Perlite output was the highest in the Nation.

Environmental efforts in 1991 focused on pumice-mining operations at a site near the East Fork of the Jemez River in Sandoval County. To prevent the mine operator from obtaining a patent on its 1,700-acre parcel of mining claims, Congressman Bill Richardson introduced House bill 2502, which would include the mine in a 100,000-acre National Recreation Area. This designation would prohibit the patenting of mining claims and

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1 tsp. iron ore; grind blended ingredients; bake at 2,700°F for about an hour; add 2 tbl. gypsum to resulting clinker; grind to powder; package for sale.

Portland cement is used for a variety of construction projects. Dry cement is mixed with water and sand and gravel at batch plants to make wet cement (concrete), which is loaded into trucks for immediate transport to construction sites.

Portland cement is produced in only two plants in Arizona: One near Tucson in Pima County supplies the Tucson and south Phoenix areas (Figures 2 and 3); another in Cottonwood in Yavapai County supplies the north Phoenix and Flagstaff areas. The latter also provided the cement for the concrete in the Glen Canyon Dam. Maricopa County, the home of Phoenix, is deficient in limestone deposits that are suitable for portland cement.

Limestone, dolomite, and marble are calcium and calcium-magnesium carbonate rocks that are important to construction, chemical, and other industries. Marble is limestone or dolomite that has been metamorphosed (naturally heated) and recrystallized. These industrial minerals have many uses worldwide. Coarsely crushed stone is used for concrete aggregate, road material, and rail-

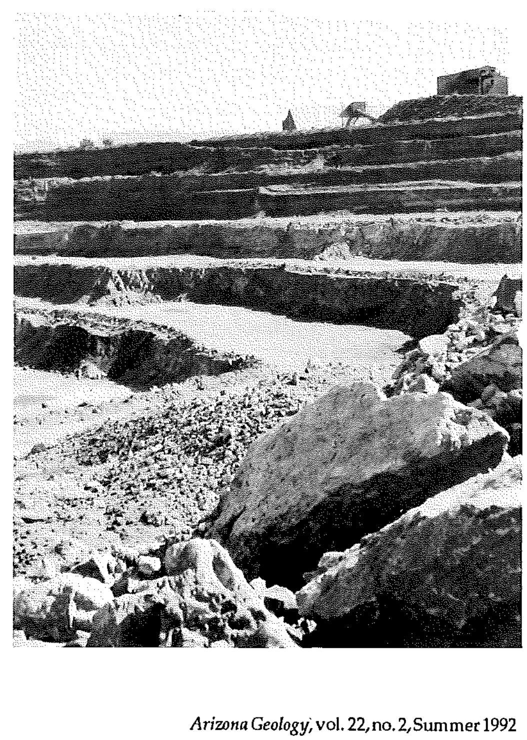

***Figure 2.** Rillito limestone quarry north of Tucson that is used to produce portland cement. Owned by the Arizona Portland Cement Company, this computerized cement operation includes a quarry; primary crusher and storage-surge building (right background); 3.9-mile conveyor-belt system from the quarry to the plant; stacker-reclaimer blending-storage building; kiln-feed composition-adjustment system; kiln; and cement milling, bagging, and shipping system. Photo by Alyce Pennington.*

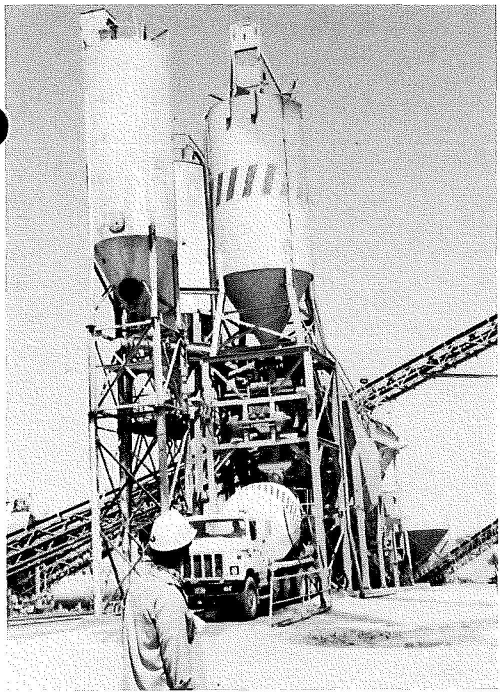

Figure 3. Processing plant for portland cement, operated by the Tanner Companies, near Orange Grove Road and Interstate 10 north of Tucson. The gray crushed cement rock is mixed with sand and gravel and water in the large metal cylinders and loaded into cement trucks. When water is added to cement, microscopic, tubular synthetic minerals quickly begin to grow. These needles intersect one another and bond tightly to the sand and gravel aggregate. Although additives, such as gypsum powder, can retard setting time, the concrete (the mixture of cement and aggregate) must be poured within 90 minutes of being mixed or it will solidify within the trucks. Laboratories, such as the Pima County Materials Testing Laboratory south of Tucson, run elaborate physical, chemical, and mechanical tests on samples to ensure that the concrete meets specifications. Strict quality control can prevent construction disasters. Photo by Alyce Pennington.

road ballast; finely crushed stone is used for poultry grit, livestock feed supplements, stucco, and fillers in paints and plastics. These minerals also serve as fluxing agents for smelting and refining metals; conditioners for acidic soils; raw materials for glassmaking; sources of lime; and decorative, monument, and building stones.

Arizona contains many deposits of limestone, dolomite, and marble, but because of location, size, and quality, only a few support commercial quarries. The best limestones in the State for chemical and industrial use are the Escabrosa and Redwall Limestones of Mississippian age, which were originally deposited 360 to 320 million years ago in shallow warm seas when the land mass that is now Arizona was near the equator. Two marble quarries in the Santa Rita Mountains south of Tucson supply local and regional markets. The white "scar" on the northwestern slope of the Santa Rita Mountains, which is visible from Interstate 19, is predominantly a natural outcrop of white marbleized Escabrosa Limestone.

Landscape rock includes decomposed, crushed, broken, and quarried blocks of rock as well as natural boulders used outdoors for ground cover and decorative purposes (Figure 4). The major markets for decomposed granite quarried in Arizona are the urban and suburban areas of Tucson, Phoenix, and Las Vegas. As ground cover, these materials control dust and weeds and reduce evaporation and water use. Decomposed granite packs well to make a smooth surface for driveways and play areas. Some "clay" tennis courts are, in fact, covered with finely crushed, screened, and rolled decomposed granite. In 1991, 5 million tons of crushed stone (limestone, dolomite, marble, and landscape rock), worth $12.8 million, was produced in Arizona.

Various clays are also produced in the State. One type is used for oil-refining catalysts; other types are used for floor and wall tiles, bricks, and miscellaneous clay products, as well as a portland cement additive. At least 10 companies operate at least 13 clay quarries in Arizona. In 1991, they produced 170,500 metric tons valued at $1.4 million. A high-alumina clay deposit in Cienega Gap southeast of Tucson supplies almost half of the clay quarried in Arizona (Figure 5). This clay is used as a cement additive and is hauled to Phoenix, where it is used to manufacture red brick.

Diatomite, or "fossil flour," is an unusual sedimentary rock composed of the microscopic siliceous remains of single-celled, water-dwelling plants called diatoms. The skeletons contain holes and channels that make the diatomite porous and permeable, qualities that are excellent for sophisticated filtration systems. Diatomite deposits worldwide are also used in thermal insulation, absorbents, pesticide carriers, lightweight aggregates, ceramic materials, and anticaking agents. They are also a source of silica for glass and metallurgical applications.

Diatomite deposits are numerous in the western United States, but only a few are commercially quarried because impurities, such as volcanic ash, sand, and clay, affect the potential end uses, processing requirements, and value. In Arizona, diatomite deposits are present in Pinal, Cochise, Yavapai, Graham, and Greenlee Counties. The White Cliffs deposit in the San Pedro Valley has been the focus of the most activity in Arizona and has yet to be adequately investigated (Figure 6). Although this deposit was intermittently quarried for more than 60 years, diatomite is not currently being produced in Arizona.

Gypsum is a hydrous (water-containing) calcium sulfate that forms a soft, compact granular rock; a fine-grained, massive, translucent rock called alabaster; and crystalline minerals, such as selenite. Alabaster has been used for centuries for carved bowls, lamp bases, and similar objects. Crude gypsum is added to portland cement to retard setting time and to alkaline soils to help minimize the accumulation of sodium. Calcining (roasting) gypsum produces either plaster of paris if heated at 250°F to 600°F or "dead-burned gypsum" if heated at 900°F to 1,000°F. When mixed with water, plaster of paris forms a pliant plaster that recrystallizes to gypsum. It may be used directly as plaster or molded into casts or between sheets of heavy paper to form gypsum board (also called wallboard, sheetrock, and plaster board). Plaster of paris is also used as a binder, filler, and chemical agent. Dead-burned gypsum is used

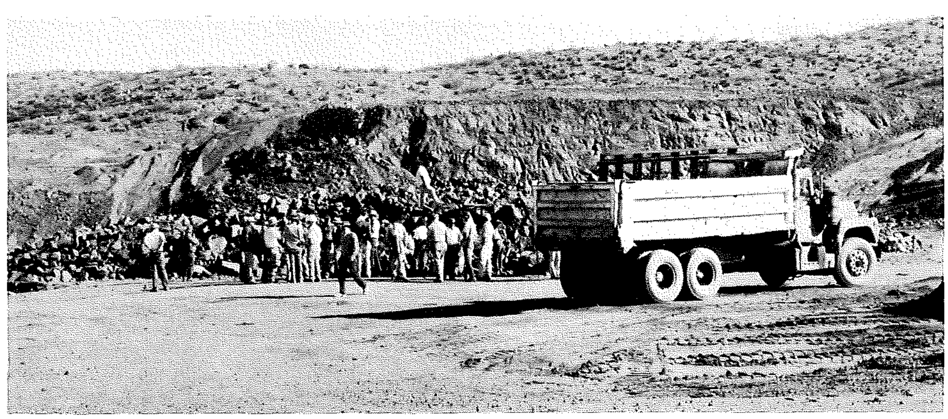

Figure 4. Kalamazoo Materials quarry southwest of Mammoth. This exposure of Oracle Granite has produced 4,000 to 8,000 tons of landscaping materials per month. The quarry overlies an underground copper sulfide deposit that is being mined. Photo by Alyce Pennington.

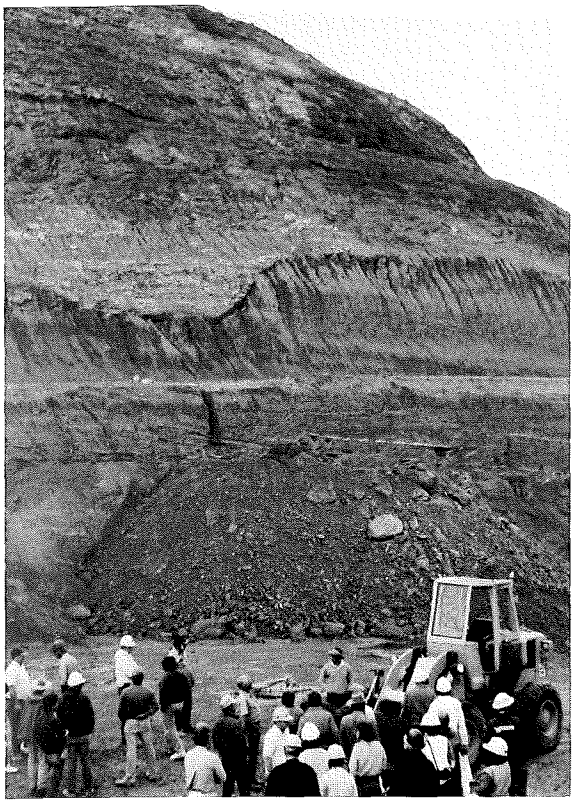

Figure 5. *Pantano Clay Pits at Cross Hill southeast of Tucson. This clay deposit, which is enriched in aluminum oxides, is quarried from the Pantano Formation. The Phoenix Brick Yard uses the clay to make bricks and tiles, and the Arizona Portland Cement Company uses the clay as a source of alumina for cement production. Clay is obtained from the beds in the lower half of the outcrop. The upper half of the exposure is a large rock-avalanche deposit that may have slid from the area of the Rincon Mountains when the crust in that area was uplifted and extended 20 to 30 million years ago. Photo by Alyce Pennington.*

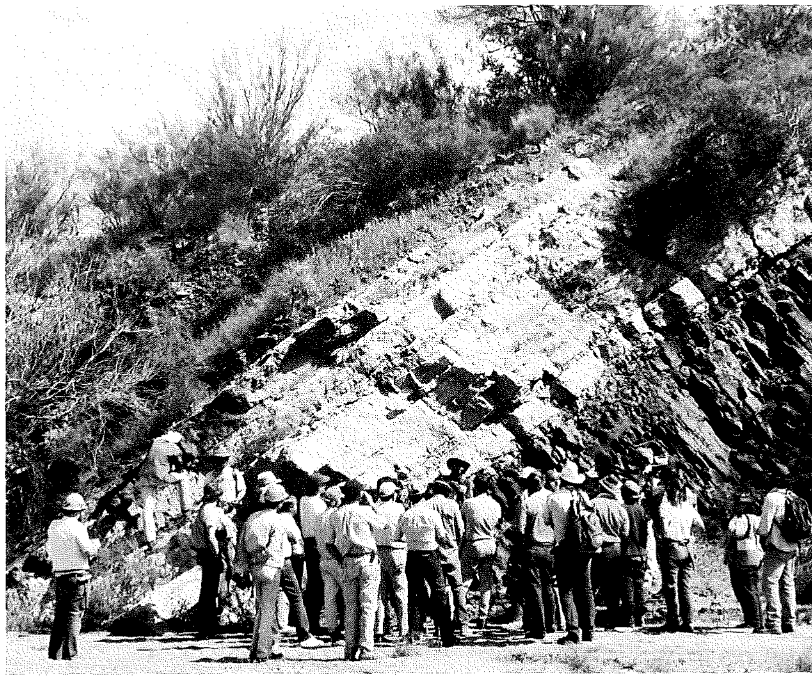

Figure 7. *Asbestos outcrop along Putnam Wash opposite the mouth of Aravaipa Creek north of Mammoth. The dark-colored rock at the base of the tilted rock units is a diabase sill, which formed when magma from the Earth's interior was forced upward and intruded preexisting rocks. The light-colored rock above the diabase sill is Mescal Limestone, which was partially metamorphosed by solutions from the hot magma and altered to serpentine and chrysotile. Although this outcrop has never been developed, larger deposits in the Salt River Canyon were extensively quarried because of their exceptionally long (up to 45 centimeters), low-iron fibers. Photo by Alyce Pennington.*

as a desiccant and dehydrator and in specialty cements.

Gypsum has been quarried in Arizona since 1880 but increased substantially in commercial value in the mid-1950's, when its demand in agriculture and construction rose with Arizona's population. At least five companies produce gypsum in Arizona from areas near Camp Verde, Littlefield, Winkelman, Mammoth, and the Harquahala Mountains. The National Gypsum Company, the largest gypsum producer in Arizona, is the only operation in the State that calcines gypsum. Its product supports a wallboard manufacturing plant in Phoenix.

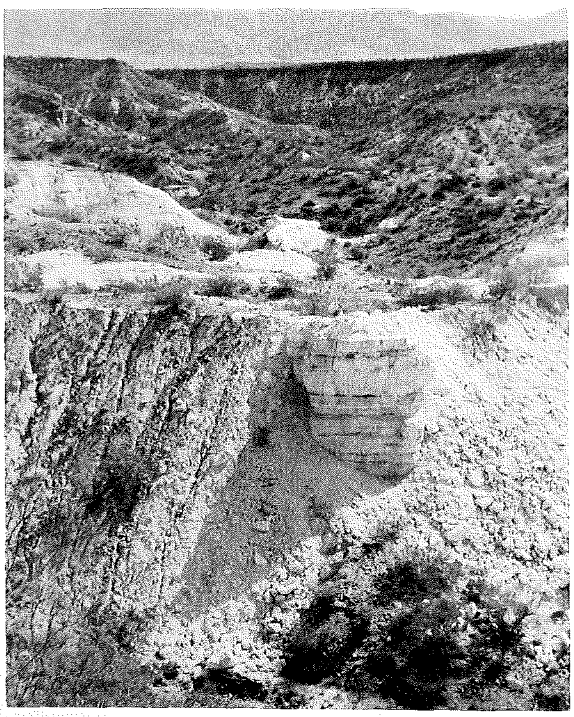

Figure 6. *Camel Canyon, informally named by University of Arizona paleontologists for the abundant fossilized camel bones discovered there, is the southern limit of the White Cliffs diatomite deposit. This lacustrine (lake) deposit, which consists of interbedded silt, gypsum, marl, diatomite, chert, and volcanic ash, is within the Quiburis Formation. The small quarries in this area were probably not developed until the late 1960's or early 1970's. North of the canyon, however, exposures of the White Cliffs diatomite were quarried as early as the 1920's. Photo by Alyce Pennington.*

Asbestos is a commercial term applied to a group of highly fibrous, silicate minerals that readily separate into long, thin, strong, flexible fibers. The fibers are heat resistant, chemically inert, and electrically insulating and may be woven together. These qualities make asbestos suitable for manufacturing noncombustible, chemically resistant, and nonconducting materials (e.g., yarn, cloth, paper, paint, brake linings, tiles, insulation, cement, and filters). High-grade deposits of the serpentine mineral chrysotile ("white asbestos") were quarried in the Salt River Canyon and processed in the Globe area for international markets. The chrysotile along Putnam Wash (Figure 7) is a microcosm of the Salt River Canyon chrysotile, although the fibers are shorter than those of the canyon deposits.

Society relies on industrial minerals for making products as diverse and essential as food, medicine, buildings, and computers. Their importance to modern civilization, though generally unappreciated compared with that of metals, is undeniable. As long as humans require food and shelter, human civilizations will require industrial minerals.

Summary of Earthquake Activity in Arizona for 1990 and 1991

by David S. Brumbaugh, Director
Arizona Earthquake Information Center

Earthquake activity in northern Arizona during 1990 and 1991 mainly occurred in two regions: the Grand Canyon and Mogollon Plateau (Table 1; Figure 1). Several earthquakes had also been recorded in these areas in 1989 (Brumbaugh, 1990).

Earthquake activity in the Grand Canyon area greatly increased in 1988, when a swarm of events shook the South Rim in September. This trend continued in 1989, capped in March by two tremors with a local magnitude (M_L) of 4.0. In 1990 and 1991, the earthquakes at the South Rim were of lower magnitudes: a total of 11 events of M_L 1.8 to 3.0 were recorded.

The largest earthquake in Arizona in 1990 and 1991 was an M_L 4.0 event that occurred in April 1991 at Jacob Lake, approximately 40 kilometers north of the Grand Canyon's North Rim. This earthquake was felt at Fredonia, Kanab, Big Springs, and Jacob Lake. Although Big Springs and Jacob Lake were the communities closest to the epicenter, the highest intensity (V on the Modified Mercalli scale) was felt at Fredonia. Reports of the tremor's effects in Fredonia included windows, doors, and dishes rattling; pictures swinging; and small objects (e.g., dishes) moving. The earthquake appears to be associated with the West Kaibab fault zone. Seismic events in this area have been well documented since 1980 (Kruger-Knuepfer and others, 1985; Bausch and Brumbaugh, 1992).

The Mogollon Plateau had been an area with little historical earthquake activity: only two tremors (M_L 4.0 in 1953 and M_L 4.1 in 1967) had been located in the region before 1989. This changed in April 1989, when an M_L 3.4 earthquake was recorded at Chavez Mountain and was followed that same year by 18 more events on the plateau, two of which were M_L 3.0 to 3.5. Twelve events occurred in this region in 1990 near Sunset Mountain, but no events were detected in 1991. None of the earthquakes on the Mogollon Plateau were reported as being felt.

Other earthquake activity in northern Arizona during 1990 and 1991 included scattered events from the Utah border to the southern part of the Mogollon Rim. There were two events in 1991 (in January and November) in Chino Valley, which is just south of the Mogollon Rim. The second event (M_L 3.5) shook residents in Prescott and Prescott Valley. Local police and fire departments reported numerous calls about the tremor. Some callers thought they had felt an explosion. The ground shaking was especially noticeable to those on the second and third floors of buildings, such as the Prescott County Annex. The events in this area ended a period of quiescence that followed an M_L 5.1 earthquake in 1976.

The Northern Arizona Seismic Network, operated by the Arizona Earthquake Information Center (AEIC), continued to expand and upgrade during 1990 and 1991. The network grew to seven stations when the newest station at Blue Ridge (BRDG) on the Mogollon Plateau began operating in 1990. The station at Flagstaff was upgraded in 1991 by conversion to broadband digital recording for its three seismometers. A new seismic alarm system being installed in Flagstaff will notify AEIC personnel whenever a significant earthquake ($M_L \geq$ 4.0) occurs in Arizona.

References

Bausch, D.B., and Brumbaugh, D.S., 1992, Catalogue of historical activity: Arizona Earthquake Information Center Report 92-1, 9 p., 2 sheets, scale 1:3,500,000.

Brumbaugh, D.S., 1990, Summary of earthquake activity in Arizona for 1989: Northern Arizona: Arizona Geology, v. 20, no. 1, p. 6-7.

(continued on next page)

Table 1. Arizona earthquakes (M_L > 1.0) detected in 1990 and 1991 by the AEIC network.

Date (1990)	Latitude (°N)	Longitude (°W)	Depth (km)	Origin Time	M_L[1]	Epicenter
2-25	34.95	111.13	3	17:38:19.5	1.9	Sunset Mtn.
3-1	35.10	111.08	21	2:10:38.7	2.0	Sunset Mtn.
3-1	36.02	112.22	12	20:22:29.5	1.9	Grand Canyon
4-1	35.04	111.04	5	19:58:4.0	1.8	Sunset Mtn.
4-12	34.91	110.99	15	20:15:38.8	2.2	Sunset Mtn.
4-13	35.02	111.10	4	8:54:3.4	1.9	Sunset Mtn.
4-15	36.10	110.99	18	7:25:37.1	1.8	Coal Mine Mesa
4-18	35.08	111.63	18	0:29:29.2	2.2	Coulder Mtn.
4-25	35.02	110.99	3	22:45:29.9	2.1	Sunset Mtn.
5-7	36.06	112.28	14	5:2:59.2	2.2	Grand Canyon
5-7	36.07	112.16	14	6:35:6.7	2.1	Grand Canyon
5-19	35.10	111.13	3	5:5:44.2	1.9	Sunset Mtn.
5-20	34.99	110.98	11	3:1:1.4	2.3	Sunset Mtn.
5-26	36.04	111.99	8	3:46:6.0	1.8	Grand Canyon
5-27	34.99	110.97	2	21:11:36.7	2.4	Sunset Mtn.
5-29	34.90	110.94	14	17:34:53.8	2.6	Sunset Mtn.
6-8	35.49	111.61	11	21:11:53.2	2.3	S P Crater
6-13	35.19	110.98	8	2:0:23.5	2.5	Sunset Mtn.
6-13	34.99	111.07	11	4:59:9.7	2.0	Sunset Mtn.
6-13	36.41	112.54	12	6:46:20.4	2.2	Steamboat Mtn.
6-22	36.05	112.22	2	16:24:57.4	2.2	Grand Canyon
7-18	37.06	113.46	1	1:33:6.7	2.8	west of Fredonia
10-17	36.53	111.13	3	11:48:23.5	2.9	Kaibito Plateau
(1991)						
1-25	34.76	112.17	8	17:9:42.0	1.7	Prescott/Jerome
1-30	35.35	111.72	16	4:11:37.5	1.7	Flagstaff
4-26	36.60	112.40	4	13:8:30.0	4.0	Jacob Lake
5-16	35.97	112.27	22	0:47:13.9	1.8	Grand Canyon
5-25	36.20	112.39	10	20:57:26.9	1.8	Grand Canyon
7-10	36.95	111.59	5	6:14:14.0	3.0	Glen Canyon
8-14	35.94	112.21	20	12:19:50.7	2.9	Grand Canyon
8-14	36.05	112.16	11	19:48:21.7	2.0	Grand Canyon
8-22	36.00	112.13	2	16:41:1.0	3.0	Grand Canyon
11-13	34.60	112.30	5	21:37:26.8	3.5	Prescott Valley

[1] M_L = Local magnitude.

Kruger-Knuepfer, J.L., Sbar, M.L., and Richardson, R.M., 1985, Microseismicity of the Kaibab Plateau, northern Arizona, and its tectonic implications: Bulletin of the Seismological Society of America, v. 75, no. 2, p. 491-506.

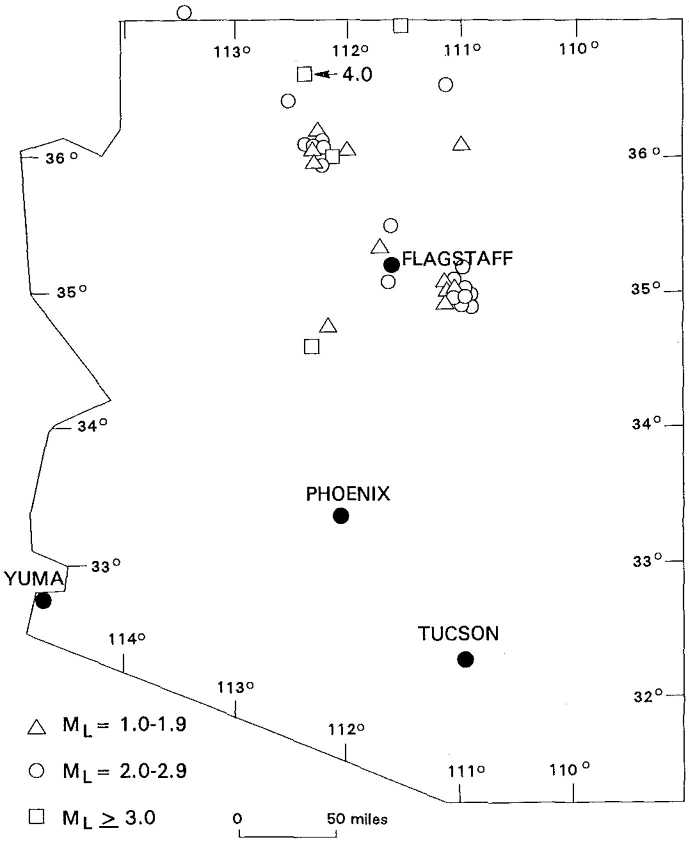

Figure 1. Epicenters of earthquakes of $M_L > 1.0$ that occurred in Arizona during 1990 and 1991. The earthquake of M_L 4.0 at Jacob Lake is identified. See Table 1 for more precise magnitudes of these earthquakes.

NONFUEL continued from page 4

would severely restrict all natural-resource development. In December, the bill was passed by the House of Representatives and sent to the Senate. Late in the year, a controversial proposal to ban cyanide heap-leach gold mining in New Mexico was initiated by the State Attorney General and the State Land Commissioner. These officials urged the Governor to take whatever steps possible to prevent such gold-extraction procedures until the State enacts a comprehensive, noncoal-mining law.

The New Mexico Legislature attempted to enact a noncoal-mine reclamation statute through House bill 564. Although generally supported by the minerals industry, the bill failed to pass primarily because some environmental groups opposed parts of the bill that concerned effective dates of regulation and citizen suits. Other citizen-suit bills related to environmental laws also failed to pass. House bill 348, which established a new Environment Department, was passed and signed by the Governor. The director of this agency is appointed by the Governor and serves as a member of the executive cabinet.

The Santa Fe County Board of Commissioners adopted a new mining law that regulates mineral development in the county. The regulations have been described as the most stringent in New Mexico and among the most restrictive in the Nation. The new law established a nine-member Mining Plans Review Board that will evaluate all applications for mineral exploration and mine operation.

The BOM, in conjunction with the U.S. Geological Survey and the New Mexico Bureau of Mines and Mineral Resources, continued to investigate mineral deposits near the margin of the Great Plains in New Mexico. This investigation was designed to evaluate a variety of mineral deposits, including rare earths associated with alkaline intrusive complexes along the margin. Two other BOM studies that were nearly completed at yearend were a mineral appraisal of the 14.5-million-acre Roswell Resource Area in southeastern New Mexico and a mineral-resource evaluation of the 100,000-acre, Valle Vidal addition to the Carson National Forest in the northern part of the State.

UTAH

Nonfuel mineral production in Utah in 1991 was estimated at $1.2 billion (Table 1). This amount reflected a decline of about 11 percent from the previous year. The State, however, maintained its ninth-place ranking nationally in the output of nonfuel minerals.

Approximately 81 percent ($960 million) of the total value of production was attributed to the metals sector, which included copper, gold, iron, magnesium, molybdenum, and silver. Utah mines also produced significant quantities of beryllium, portland cement, magnesium compounds, salt, construction sand and gravel, and vanadium.

Utah ranked third among States in the production of copper, gold, magnesium metal, and iron ore and was the only U.S. source of mined beryllium in 1991. The production of magnesium compounds rose about 28 percent over that of 1990.

Controversy over the cause of salt loss in the Bonneville Salt Flats continued in 1991. Since 1960, the amount of salt in this area has declined by 30 percent; researchers estimate that the annual loss is 1 percent, or 1.6 million short tons. Possible causes include the hydrologic effects of the railroad and I-80 highway and the removal of saline ground water by a nearby mining operation, which recovers potash, magnesium compounds, and salt from ground water through solar evaporation. The BLM is trying to determine how much loss is due to natural causes and how much is due to human activities.

Through Senate bill 34, the Utah Legislature established a new Department of Environmental Quality. The director of the new agency will be appointed by the Governor and serve as a member of the Governor's executive cabinet. Supported by the Governor, the State legislature passed House concurrent resolution 13, which urged Congress to add no more than 1.4 million acres of BLM land in Utah to the National Wilderness Preservation System.

Congressional hearings were held during the year to consider various wilderness proposals. Although the BLM has recommended approximately 2 million acres of its land be designated for wilderness protection, the congressional delegation was not unified in its recommendation. One faction proposed 1.4 million acres be classified as wilderness; another recommended 5.5 million acres.

The BOM continued a study begun in 1988 under the auspices of the Inventory of Land Use Restraints Program (ILURP). The goal of this long-term program is to inventory Federal land-use restrictions to assess the availability of Federal lands for mineral entry. In 1991 the BOM prepared draft computer plots that show the availability status for locatable and leasable minerals.

The U.S. Environmental Protection Agency presented Geneva Steel and the citizens of Utah County with its Outstanding Achievement Award for their cooperative effort in developing one of the Nation's first State Implementation Plans designed to control fine-particulate pollution.

OIL AND GAS NOTES

by Steven L. Rauzi
Arizona Geological Survey

Oil production in Arizona totaled 110,772 barrels from 22 producing wells in 1991, down from 121,855 barrels in 1990. Gas production totaled 1.3 billion cubic feet from six producing wells, down from 2.1 billion cubic feet in 1990. Fifteen wells were idle at the end of 1991, including two shut-in helium wells at the Dineh-Bi-Keyah Field.

Refineries produced 2.5 million barrels of product in 1991, up from 2.0 million barrels in 1990. Individual products mostly consisted of asphalt, diesel fuel, and jet fuel. The Sunbelt Refining Company at Coolidge processes heavy crude oil from California that is shipped to the refinery in the All American Pipeline. The Intermountain Refining Company at Fredonia processes crude oil shipped in trucks from the Grant Canyon and Trap Springs Fields in Nevada.

Products transferred through LPG storage-well facilities near Litchfield Park and Adamana in 1991 included about 55 million gallons in receipts and about 67 million gallons in deliveries. About 24.3 million gallons were in storage at yearend. Stored products included propane; iso-, normal, and mixed butane; and propylene. A natural-gas storage-well facility in subsurface salt north of Kingman is still in the planning stages.

Dry Mesa Corporation of Farmington, New Mexico, reentered* an abandoned well just north of the Dry Mesa Field where the company is testing the Pennsylvanian Paradox Formation for a gas completion*. The Dry Mesa Field, located in northeastern Arizona about 12 miles west of Teec Nos Pos trading post, was first drilled for oil production from the Mississippian Leadville Limestone in 1959. Through February 1992, the field had produced 795,611 barrels of oil from the Leadville Limestone. In early 1991, a pipeline was laid to the Dry Mesa Field and connected to the one gas well there, which was recompleted* from the Leadville Limestone to the Paradox Formation in July 1969. Until this well was connected to the pipeline, all gas produced from it was used as fuel for the pumping units on the field's three Mississippian oil producers, one of which was converted to a water-disposal well in May 1990. Late last year, the company recompleted one of the two remaining oil wells to a gas well from the Paradox Formation. Through February 1992, production from the two recompleted gas wells totaled 534 million cubic feet of natural gas, of which 50 million cubic feet was produced in February.

Gas production from the Paradox Formation in northeastern Arizona became economic in 1989 when Western Gas Processors, Ltd. connected the Black Rock Field to the El Paso natural-gas pipeline that traverses the northern part of the State. Shortly thereafter, Chuska Energy Company initiated gas sales from the field by connecting three shut-in wells to the pipeline. Two of the three wells were drilled by Cities Service Oil Company in 1971 and 1972; the other was drilled by American Fuels Corporation in 1973. The wells had been shut-in since the early 1970's because no pipeline existed to deliver the gas to market. In September 1989, Chuska Energy Company applied for 160-acre spacing in the Black Rock Field, which the Arizona Oil and Gas Conservation Commission approved for gas wells drilled in the Black Rock Field and portions of the adjacent Dry Mesa Field. The company drilled two additional wells in January and February 1990 and abandoned the American Fuels Corporation well in May 1991. Through February 1992, production from the five gas wells in the Black Rock Field totaled 5.3 billion cubic feet, of which 43 million cubic feet was produced in February.

In addition to their regular meetings, the Oil and Gas Conservation Commission heard two petitioned hearings from industry in 1991. In the first hearing, the Commission approved Dry Mesa Corporation's application to amend their water-disposal permit to accept water produced from the Paradox Formation in the Dry Mesa Field. In the second hearing, the Commission approved Merrion Oil and Gas Corporation's application to amend their water-disposal permit to accept water produced from the Leadville Limestone in the East Boundary Butte Field.

Rules governing the drilling and completion of oil, gas, helium, and geothermal wells are being amended to update and clarify language, edit for consistency, and account for new technology and practices in the regulated industry. These rules are being reviewed by the Governor's Regulatory Review Council. After the rules are approved by the Council, accepted by the Oil and Gas Conservation Commission, and certified by the Attorney General, they will replace the existing rules in Title 12, Chapter 7 of the *Arizona Administrative Code*.

January and February 1992 were relatively active months for oil and gas leasing on State land. State acreage under lease as of April totaled 81,224, up from 60,131 in October 1991. The northwestern and southeastern parts of the State were the most active areas of leasing. State land may be leased noncompetitively, upon payment of a $100 application fee and a 1-year advance rental fee. The leases carry a 5-year primary term at $1-per-acre annual rental fee and may be extended for one additional 5-year term at $2-per-acre annual rental fee. The State royalty is 12.5 percent.

Oil and gas leasing on Federal land was also relatively active. Federal acreage under lease as of April totaled 201,981, up from 197,642 in October 1991. Premco Western, Inc., of Dallas, Texas, acquired two leases in northwestern Mohave County at the Bureau of Land Management's competitive lease sale in December 1991. They acquired eight tracts noncompetitively after the sale. Tracts in Coconino, Maricopa, Mohave, and Yuma Counties were offered in the May 1992 sale.

The oil source-rock potential of the Precambrian Chuar Group, which is exposed in northern Arizona near the Colorado River, continues to attract interest among explorationists. Two abstracts on this subject appeared in the U.S. Geological Survey's 8th McKelvey Forum on Mineral and Energy Resources, which was held in February 1992. The first abstract, *Petrography and Rock-Eval Studies of Organic Matter in Precambrian Rocks, U.S.A. and U.S.S.R.*, by Mark Pawlewicz and James G. Palacas, compared vitrinitelike particles from widely scattered Precambrian terrains. Their study showed that the Kwagunt Formation of the Chuar Group is mature with respect to liquid hydrocarbon generation. In the second abstract, *The Lake Superior Oronto Group, a Middle Proterozoic Exploration Model for the Late Proterozoic Chuar Group of the Grand Canyon*, by Albert B. Dickas and M.G. Mudrey, Jr., the exploration philosophy applied to the Oronto Group is presented as a model for Chuar Group hydrocarbon evaluation. A recent M.S. thesis from Northern Arizona University, *Sedimentology and Shale Petrology of the Upper Proterozoic Walcott Member, Kwagunt Formation, Chuar Group, Grand Canyon, Arizona*, by David A. Cook, describes

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***Reentry:** the entry of any abandoned well, usually by drilling out cement plugs across hydrocarbon and water-bearing formations.

Completed well: a well that has produced or is ready to produce hydrocarbons.

Recompleted well: a well that has been deepened, partially filled, perforated, or reperforated in a different zone.

New AZGS Publications

The following publications have been released since November 1991. They may be purchased from the Arizona Geological Survey (AZGS), 845 N. Park Ave., #100, Tucson, AZ 85719. Orders are shipped by UPS; a street address is required for delivery. All orders must be prepaid by check or money order payable in U.S. dollars to the Arizona Geological Survey. Add shipping and handling charges, listed below, to your total order:

In the United States:	20.01 - 30.00, add 5.75	50.01 - 100.00, add 10.25
$1.01 - $5.00, add $2.00	30.01 - 40.00, add 6.50	Over 100.00, add 12%
5.01 - 10.00, add 3.00	40.01 - 50.00, add 8.00	Other countries: Request price quotation
10.01 - 20.00, add 4.50		

Spencer, J.E., 1992, Radon gas: A geologic hazard in Arizona: Down-to-Earth Series 2, 17 p. $2.50

Radon is a colorless, odorless, radioactive gas produced by the decay of uranium, which is present in virtually all rocks and soils. Because it can endanger life, radon is considered a geologic hazard. This educational booklet describes the areas in Arizona that contain anomalous amounts of uranium and that may consequently pose a health hazard from emanation of radon. Other sections of the report describe how radon forms, how it enters homes, how it is measured, how hazardous it is to humans, and how residents of Arizona can reduce radon levels in their homes. The project was done in cooperation with the Arizona Radiation Regulatory Agency.

Reynolds, S.J., Spencer, J.E., Laubach, S.E., Cunningham, Dickson, and Richard, S.M., 1991, Geologic map and sections of the Granite Wash Mountains, west-central Arizona: Map 30, scale 1:24,000, in color. $6.00

The Granite Wash Mountains in west-central Arizona are among the most geologically complex mountain ranges in the southwestern United States. This range is part of the Maria fold-and-thrust belt, a west-trending belt of large folds and major thrust faults in west-central Arizona and southeastern California. Several discrete episodes of deformation occurred during the late Mesozoic that produced folds, refolded folds, folded and refolded thrust faults, and complex repetition, attenuation, and truncation of stratigraphic sequences. Greenschist-facies metamorphism accompanied deformation; both were followed by emplacement of two Late Cretaceous granitic intrusions and numerous dikes. Some deposits of gold, copper, and the industrial mineral kyanite are present in the range.

Scott, E.A., 1991, Geologic map of the central Gila Bend Mountains, west-central Arizona: Open-File Report 91-7, 11 p., scale 1:24,000. $4.00

This map covers approximately 40 square miles of the central Gila Bend Mountains. The geology of this area is characterized by a lithologically diverse sequence of Tertiary volcanic rocks and minor amounts of sedimentary rocks that overlie pre-Tertiary crystalline rocks. Abundant northwest-trending normal faults bound numerous tilt blocks. This mapping project was funded by the U.S. Geological Survey (USGS) Cooperative Geologic Mapping (COGEOMAP) program.

Field, J.J., and Pearthree, P.A., 1991, Surficial geology around the White Tank Mountains, central Arizona: Open-File Report 91-8, 7 p., scale 1:24,000, 9 sheets. $12.50

The nine maps contained in this report depict the distribution and general ages of Quaternary and upper Tertiary geomorphic surfaces and associated alluvial deposits surrounding the White Tank Mountains, which are west of Phoenix. By indicating the ages of alluvial surfaces and deposits, the maps provide a basis for evaluating the geologic history of the area and assessing potential geologic hazards. Relative topographic positions of each surface, surface characteristics, and degree of soil development in underlying deposits are the principal criteria used to assess surface age. The project was supported by the Arizona Geological Survey, USGS (through the COGEOMAP program), Maricopa County Flood Control District, and Arizona Department of Water Resources.

Duncan, J.T., and Spencer, J.E., 1991, Investigations of uranium and radon in the greater Phoenix metropolitan area, Arizona: Open-File Report 91-9, 12 p. $2.00

Radon gas is considered a potential health hazard when it accumulates in indoor air in concentrations above a specified level. Radon is produced by the radioactive decay of uranium. Knowledge of the distribution of rock types that contain high levels of uranium is therefore useful to government agencies, home buyers, and builders who are interested in reducing radon exposure to humans. Areas with high, or anomalous (greater than 6 parts per million), uranium concentrations are rare in the Phoenix area, but some do exist and are the focus of this report. The anomalous areas were surveyed with a portable gamma-ray spectrometer, and representative samples of the more anomalous rocks were analyzed for uranium using neutron-activation analysis. The report also includes an analysis of the relationship between aquifer geology and radon in ground water in the Cave Creek-Carefree area. This project was funded by the U.S. Environmental Protection Agency through the Arizona Radiation Regulatory Agency.

Field, J.J., and Pearthree, P.A., 1992, Geologic mapping of flood hazards in Arizona: An example from the White Tank Mountains area, Maricopa County: Open-File Report 91-10, 16 p., scale 1:24,000, 4 sheets. $10.00

Assessment of the character of flood hazards and the extent of flood-prone areas on the piedmonts of mountain ranges in Arizona is an increasingly important concern to floodplain managers as urban areas continue to expand. Geomorphic analyses and geologic mapping of piedmonts provide the best data for determining which portions of a given piedmont may be subject to alluvial-fan flooding. This report explains the methods used to map and characterize flood-hazard zones on piedmonts around the White Tank Mountains. The report was prepared in cooperation with the Maricopa County Flood Control District and the Arizona Department of Water Resources.

Spencer, J.E., and Reynolds, S.J., 1992, Mineral deposits of the Bullard mineral district, Harcuvar Mountains, Yavapai County, Arizona: Open-File Report 92-1, 18 p. $3.00

This report contains the results of several drilling and gold-assaying studies, as well as an analysis of the geologic setting and potential for future mineral discoveries. Mineral deposits are related to the Bullard detachment fault.

Richard, S.M., 1992, Detailed geologic map of the upper Apache Wash area, central southern Plomosa Mountains, west-central Arizona: Open-File Report 92-2, 11 p., scale 1:12,000. $3.00

This detailed geologic map depicts a complex and poorly understood sequence of Mesozoic faulting and clastic sedimentation, followed by Tertiary normal faulting and volcanism. The report includes descriptions of 16 mineral deposits, most of which are quartz veins or shear-zone-hosted quartz and iron oxides, with or without copper minerals.

Spencer, J.E., Gilbert, W.G., and Richard, S.M., 1992, Geologic map of the eastern Eagletail Mountains, Maricopa, La Paz, and Yuma Counties, Arizona: Open-File Report 92-3, 13 p., scale 1:24,000. $4.00

In the eastern Eagletail Mountains, a thick sequence of early Miocene volcanic rocks and northwest-trending dikes overlie and intrude, respectively, a diverse array of probable Jurassic granitoid rocks and their foliated equivalents. This detailed geologic map was partially funded by the USGS through the COGEOMAP program. The report includes descriptions of several mines and mineralized areas, most of which consist of quartz-hematite veins or shear-zone-hosted iron oxides with sparse copper minerals.

Gilbert, W.G., and Spencer, J.E., 1992, Geology of Cemetery Ridge, Clanton Hills, and westernmost Gila Bend Mountains, La Paz and Yuma Counties, Arizona: Open-File Report 92-4, 16 p., scale 1:24,000. $4.50

Cemetery Ridge consists of crystalline rocks intruded by northwest-trending dikes and overlain by middle Tertiary volcanic rocks. The Clanton Hills and westernmost Gila Bend Mountains consist of early Miocene volcanic rocks and tuffaceous limestone. This report describes nine mines or mineralized areas, most of which consist of shear zones that host iron oxides and copper minerals. The detailed geologic map was partially funded by the USGS through the COGEOMAP program.

Gilbert, W.G., Laux, D.P., Spencer, J.E., and Richard, S.M., 1992, Geologic map of the western Gila Bend and southern Eagletail Mountains, Maricopa and Yuma Counties, Arizona: Open-File Report 92-5, 17 p., scale 1:24,000. $4.75

The study area depicted on this detailed geologic map is composed of Proterozoic igneous and metamorphic rocks intruded by the early Miocene Columbus Wash granodiorite. These crystalline rocks are overlain by a thick sequence of early Miocene volcanic rocks. Scattered mineral deposits, some of which have been mined, largely consist of fracture-filling iron oxides commonly associated with quartz, as well as minor amounts of relict (oxidized) pyrite, chrysocolla, and malachite. Some deposits are associated with middle Tertiary mafic dikes. This detailed geologic map was partially funded by the USGS through the COGEOMAP program.

Fridrich, C.J., 1991, Geologic map of Sierrita caldera fragment, Sierrita Mountains, Pima County, Arizona: Contributed Map CM-91-L, scale 1:24,000. $2.00

Parts of the southern Sierrita Mountains are thought to contain a Late Cretaceous caldera margin. A thick sequence of tuffs, lavas, and breccias is interpreted as caldera infill deposited during caldera formation. This map shows the distribution and types of caldera-fill and adjacent rock units.

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the depositional environments of the hydrocarbon-rich Walcott Member of the Chuar Group. This study includes detailed section descriptions from Nankoweap Butte and Sixtymile Canyon, as well as clay-mineralogy data used to predict oil generation. In 1990, the Oil and Gas Conservation Commission published *Distribution of Proterozoic Hydrocarbon Source Rock in Northern Arizona and Southern Utah*, by Steven L. Rauzi, which defines the possible areal extent of the ancient Chuar basin. This report includes a 1:500,000-scale map of the subcrop and structure of the Precambrian erosional surface. It may be purchased from the Arizona Geological Survey for $12.50 (includes shipping).

Lerch, Felix, 1992, Geologic map of part of the Southern Plomosa Mountains, west-central Arizona: Contributed Map CM-92-A, scale 1:12,200. $2.00

This map covers approximately 10 square miles in the southwestern Plomosa Mountains, an area of complex structure and stratigraphy. Proterozoic crystalline rocks are overlain by Jurassic sedimentary and volcanic rocks, both of which are unconformably overlain by the Jurassic(?) to Cretaceous McCoy Mountains Formation. Normal and thrust faults have displaced various units, including Paleozoic sedimentary rocks.

Yarnold, J.C., and McDaniel, B.J., 1992, Preliminary geologic map of Tertiary sedimentary rocks in the northern Rawhide Mountains, Mohave County, Arizona: Contributed Map CM-92-B, scale 1:18,000. $3.00

This map covers several square miles at the southern end of the McCracken Mountains and the northern edge of the Rawhide Mountains. Tertiary sedimentary and volcanic units are extensively subdivided in this area of Miocene detachment faulting and rotational normal faulting.

Dickinson, W.R., 1992, Geologic map of Catalina core complex and San Pedro trough: Contributed Map CM-92-C, scale 1:125,000, in color. $8.00 [For rolled map, add $1.00 to shipping and handling charges.]

This map is a compilation and reinterpretation of dozens of previously released geologic maps, supplemented by reconnaissance studies by the author. The map covers the Santa Catalina, Rincon, Tucson, Tortolita, Tortilla, Black, and Dripping Spring Mountains; the western flank of the Galiuro Mountains; and the Johnnie Lyon Hills. This map was originally published as part of Geological Society of America Special Paper 264. It may be purchased rolled or folded.

Evensen, C.S., Gray, I.B., Meador, J.R., and Ciesiel, Robert, with a text by W.L. Chenoweth, 1992, Map and geologic sections of the underground workings of the Monument No. 1 and Mitten No. 2 uranium-vanadium mines, Navajo County, Arizona: Contributed Report CR-92-A, 9 p., various scales. $3.00

This report describes the location, geologic setting, and production history of the Monument No. 1 and Mitten No. 2 uranium-vanadium mines, which are approximately 17 miles north of Kayenta, Arizona, within the Navajo Indian Reservation. The original mapping was done in the mid-1950's, when the mines were being prospected. (Both mining permits expired in the 1960's.) The text is based on Atomic Energy Commission (AEC) files. The channel-fill sediments of the Shinarump Member of the Triassic Chinle Formation that form the Monument No.1-Mitten No. 2 mesa have been very productive for uranium and vanadium. They represent the second largest concentration of oxidized uranium and vanadium minerals in Monument Valley.

Chenoweth, W.L., 1992, Location, geologic setting, and production history of the Harvey Blackwater Nos. 1, 3, and 4 uranium mines, Apache County, Arizona, and San Juan County, Utah: Contributed Report CR-92-B, 8 p. $1.50

During the uranium boom of the early 1950's, Harvey Blackwater, a Navajo from Mexican Water, Arizona, held five claims in Cane Valley, within the Navajo Indian Reservation. This report describes the location, geologic setting, and production history of three of these claims. The ore deposits are in channel-fill sediments of the Shinarump Member of the Triassic Chinle Formation. The three mines produced significant amounts of uranium but have been idle since the mid-1950's. The information in this report is based on AEC files.

Mining Publications

Arizona, "the Copper State," produces 60 percent of the Nation's copper. Total direct contributions by the copper industry to the State's economy reached more than $1.51 billion in 1991. The total combined impact on the economy of Arizona was $5.65 billion, an amount projected from industry spending during 1991 as revenues were circulated throughout Arizona businesses, households, and government agencies. These statistics were compiled by economist George F. Leaming and summarized in *The Copper Industry's Impact on the Arizona Economy 1991*, a new report published by the Western Economic Analysis Center in Marana, Arizona. Copies of this informative 52-page book may be obtained from the Arizona Mining Association, 2702 N. Third St., Suite 2015, Phoenix, AZ 85004; tel: (602) 266-4416.

A recently published, two-volume mining history describes important persons, places, and events in Arizona. The first volume, published in 1987, contains 11 articles in 278 pages. The second volume, published in 1992, includes 10 articles and 4 short stories in 293 pages. Each volume is illustrated with more than 150 pages of old photographs. Edited by Michael N. Greeley and J. Michael Canty, *History of Mining in Arizona* was published by the Mining Club of the Southwest Foundation. Softcover copies may be purchased for $31.00 per volume; a limited number of hardcover copies of Volume 2 are available for $52 per copy. (Both prices include postage and handling.) Write to the MCSW Foundation, P.O. Box 27225, Tucson, AZ 85726.

President Signs National Geologic Mapping Bill

On May 18, President Bush signed H.R. 2763, the National Geologic Mapping Act of 1992. The U.S. House of Representatives passed the bill in November 1991. In March 1992, the U.S. Senate passed a companion bill, S. 1179. Funding, however, has not yet been appropriated.

The purpose of the act is to expedite production of a geologic-map information base for the Nation. Geologic maps provide information that is used to resolve issues related to land-use management, including assessment, use, and conservation of natural resources; ground-water management; and environmental protection. Information about the purpose and objectives of the act was included in the Winter 1991 issue of *Arizona Geology* (v. 21, no. 4, p. 7-8).

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From Minerals to Fireworks

The 4th of July would be a dud without chemical elements derived from minerals. Each color in a fireworks display is produced by a specific element: bright greens are made with barium; deep reds are a product of strontium; blues come from copper; yellows require sodium. Other colors may be created by mixing elements. Strontium and sodium together produce brilliant orange. Titanium, zirconium, and magnesium alloys make silvery white. Copper and strontium create lavender.

Elements and compounds are also used for special effects. Iron filings and small particles of charcoal produce gold sparks. Aluminum powder creates a loud bang and bright flash. Larger particles, such as small flakes or granules, give a longer, showerlike effect. Magnalium, a magnesium-aluminum alloy, produces a series of silvery-white flashes. Antimony sulfide and perchlorate compounds are other components of flash mixtures.

Fireworks date back to ancient China and continue to grow in popularity. From 1980 to 1990, their use in the United States doubled to nearly 60 million pounds per year. Of this amount, consumers buy two-thirds; the remainder are bought for professional fireworks displays. About 85 percent of consumer fireworks and half of the display variety are imported from China, Japan, Korea, and European countries, such as France and Italy.

As the United States prepares to celebrate the 216th anniversary of its Declaration of Independence, take a moment to consider the importance of minerals in the festivities.

-- U.S. Bureau of Mines press release

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