

THE MINERAL INDUSTRY OF ARIZONA

This chapter has been prepared under a Memorandum of Understanding between the U.S. Geological Survey and the Arizona Department of Mines and Mineral Resources for collecting information on all nonfuel minerals.

In 1998, the preliminary estimated value¹ of nonfuel mineral production for Arizona was \$2.82 billion, according to the U.S. Geological Survey (USGS). This was about a 20% decrease from the \$3.54 billion of 1997,² and followed a 1.7% decrease from 1996 to 1997. The State ranked third in the Nation (first in 1997), in total nonfuel mineral production value, of which Arizona accounted for about 7% of the U.S. total.

Arizona continued in 1998 as the top copper-producing State, accounting for about 65% of total U.S. copper mine production and value. Copper was the State's leading nonfuel mineral, representing 75% of Arizona's 1998 total nonfuel mineral production value.

In 1998, although copper mine production was down only about 4%, most of the State's decrease in nonfuel mineral value resulted from a 26% drop in the metal's unit value. Other mineral commodity values that decreased included those of lime, gold, crude gypsum, crushed stone, and salt, in descending order of change. Increases in all other commodities, especially those of molybdenum, construction sand and gravel, and portland cement, bolstered the State's overall total value. In 1997, drops in the values of copper, gold, construction sand and gravel, and molybdenum accounted for most of the State's decrease in value (table 1).

Based on USGS estimates of the quantities produced in the United States during 1998, Arizona rose to first² from second in the production of molybdenum, to second from third in gemstones, to fifth from sixth in construction sand and gravel, and to seventh from ninth in dimension stone. Brucite production commenced in the State in 1998, and Arizona was first of two producing States. Otherwise, the State remained 4th in silver and zeolites, 5th in pumice and pumicite, and 11th of the 12 U.S. gold-producing States. Additionally, Arizona was a significant producer of portland and masonry cements, lime, and gypsum.

¹The terms "nonfuel mineral production" and related "values" encompass variations in meaning, depending on the minerals or mineral products. Production may be measured by mine shipments, mineral commodity sales, or marketable production (including consumption by producers) as is applicable to the individual mineral commodity.

All 1998 USGS mineral production data published in this chapter are preliminary estimates as of February 1999 and are expected to change. For some commodities (for example, construction sand and gravel, crushed stone, and portland cement), estimates are updated periodically. To obtain the most current information, please contact the appropriate USGS mineral commodity specialist. A telephone listing for the specialists may be retrieved over the Internet at <http://minerals.usgs.gov/minerals/contacts/comdir.html>; by using MINES FaxBack at (703) 648-4999 from a fax machine with a touch-tone handset (request Document #1000 for a telephone listing of all mineral commodity specialists); or by calling USGS information at (703) 648-4000 for the specialist's name and number. All Mineral Industry Surveys—mineral commodity, State, and country—also may be retrieved over the Internet at <http://minerals.usgs.gov/minerals> or by way of MINES FaxBack.

²Values, percentage calculations, and rankings for 1997 may vary from the *Minerals Yearbook, Area Reports: Domestic 1997, Volume II*, owing to the revision of preliminary 1997 to final 1997 data. Data for 1998 are preliminary and expected to change, while related rankings may also be subject to change.

The Arizona Department of Mines and Mineral Resources³ (ADMMR) provided the following narrative information. ASARCO Incorporated's Arizona operations consist of the open pit mines at Ray and Silver Bell, an open pit and underground operation at Mission, the Hayden copper smelter, and the Santa Cruz experimental copper mine. Copper output at the Ray Mine rose to 152,000 metric tons, up from 138,000 tons in 1997. The Ray Mine replaced its remaining 11 150-metric-ton-capacity haul trucks with 5, 220-metric-ton-capacity trucks in late 1997. The leaching process at Ray was changed to use higher acid concentrations to increase recovery rates. A \$10 million electrowinning tankhouse expansion is underway that will add an additional 5,400 metric tons of capacity. When completed in mid-1999, total solvent extraction electrowinning capacity (SX-EW) will be 46,300 metric tons per year with a projected cash production cost of less than \$0.50 per pound. As part of a negotiated settlement with the U.S. Environmental Protection Agency and State agencies to resolve environmental issues, Asarco will extend the Mineral Creek diversion tunnel around the Ray Mine workings at a cost of \$55 million.

Mission copper production declined slightly in 1997 as harder ore was milled. Offsetting this, however, average ore grade increased as the underground mine contributed higher grade material for all of 1997. Production totaled 114,000 metric tons of copper. Mission was Arizona's largest silver producer with 67,500 kilograms recovered as a byproduct.

The Hayden smelter, an Inco Ltd.'s flash furnace rated at 653,000 metric tons of charge per year, processed a record amount of concentrates during 1997 producing 192,000 metric tons of copper. Improvements to the smelter's gas handling and process controls began during 1997. They are expected to lower operating costs and increase throughput upon completion in 1998.

Silver Bell's \$70 million SX-EW plant was developed as a joint venture with Mitsui & Co. U.S.A. (25% share) and began production in July 1997. In 1998, the plant produced more than 18,000 tons of copper. Asarco reports cash costs to be \$0.50 per pound.

At Santa Cruz, an experimental insitu leach research project, injection of leach solutions ceased after 22 months with many of the technical and environmental goals achieved along with the recovery of 16 metric tons of copper. Asarco and joint venture partner Freeport McMoran Copper & Gold Inc. have applied for permits for additional testing (without federal funds) at another site about 1.6 kilometers south of the initial test site. Information gathered there will provide data on the economics of insitu leaching the deposit.

Broken Hill Proprietary (BHP) Copper Co. reacted strongly to the lower copper prices early in 1998 by closing the sulfide portion of Pinto Valley's operations and delaying startup of the

³Nyal J. Niemuth, Mining Engineer, authored the text of State minerals information provided by the Arizona Department of Mines and Mineral Resources.

Florence insitu leach. During the year, BHP also wrote down \$388 million against the smelter and \$543 million against its Arizona copper mines. The February 25 action at Pinto Valley resulted in the laying off of 447 workers, 75% of the workforce. Sulfide production was not scheduled to resume until solid and sustained improvements in price occur. In 1997, Pinto Valley produced 61,700 metric tons of copper in concentrate. In November, BHP reported that the San Manuel smelter would be operating at reduced capacity due to a shortfall in concentrate from the Pinto Valley closing. On October 22, 1997, a portion of the tailings dam failed at Pinto Valley, spilling tailings into Pinto Creek. By September 1998, a majority of the cleanup and restoration work was completed at a projected cost of over \$30 million. BHP's San Manuel Mine is the largest underground operation in the United States and during its life has hoisted over 540 million metric tons of ore. It is the fourth largest copper mine in Arizona and produced 114,000 metric tons of copper in the fiscal year that ended May 31, 1998. The company is considering the resumption of mining oxide ore from the open pit developed in the subsidence area. Approximately 180 million metric tons would be heap leached, and the pregnant solutions fed to the existing solvent extraction electrowinning (SX-EW) plant. That plant continues to operate, but at reduced capacity, on solutions derived from insitu leaching.

In mid-1998, BHP reported discovery of the Magma Porphyry east of Superior. It is the first major copper discovery announced in Arizona in many years. The deposit, buried nearly 1.6 kilometers beneath the surface, was first intersected by drilling from the underground workings of the Magma Mine in 1995. Five holes drilled to date all showed significant mineralization and terminated in mineralized rock. Though its dimensions are incompletely defined, it is at least 460 meters high, 640 meters long, and 180 meters wide. Assays from the bottom 306 meters of the longest intercept yielded arithmetic mean grades of 1.75% copper and 0.029% molybdenum. The last 189 meters assayed 2.18% copper and 0.028% molybdenum. BHP is evaluating options for future exploration.

The Cyprus Climax Metals division of Cyprus Amax Minerals Co. is Arizona's second largest producer of copper and the world's largest producer of molybdenum. In response to low copper prices during 1998, Cyprus planned to reduce copper production by 27,000 metric tons from Bagdad and Sierrita. These cutbacks were made by reducing the use of their highest cost equipment. Additionally, expenditures were to be reduced by \$10 million by deferring equipment purchases and holding other expenses to sustaining levels.

Cyprus Sierrita Corp. reported that 19 quarterly production and cost records were achieved by yearend 1998 (Cyprus Sierrita Corp., 1999). Cyprus Sierrita completed construction of two new in-pit crushers and a conveyor system to reduce haulage costs. Sierrita, recognized as one of the most efficient mines in the world, operates with the lowest average copper grade, 0.28%, of any milling operation. A contributing factor to this success is the mine's byproduct molybdenum credit of 9,000 metric tons, the largest in Arizona.

The Bagdad Mine in Yavapai County produced 112,000 metric tons of copper in 1997, a new production record. This resulted from mining higher grade sulfide ore, improved recovery, and increased equipment availability. Cyprus reports

that Bagdad has nearly a 900-million-metric-ton proven and probable ore reserve of 0.38% copper and 0.021% molybdenum.

The Miami Mine consists of an openpit copper mine, a SX-EW, a 590,000-metric-ton-per-year capacity smelter with acid plant, an 172,000-metric-ton-annual-capacity electrolytic refinery, and an 122,000-metric-ton-per-year rod plant. The mine and SX-EW plant produced a record 71,000 metric tons of copper in 1997. The final Environmental Impact Statement and Record of Decision was issued by the U.S. Bureau of Land Management (BLM) and the Tonto National Forest for the Cyprus Miami Leach Expansion project. The project covers three new leach facilities and one waste rock dump. Total copper production through the life of the proposed expansion facilities is 1.3 million metric tons.

Phelps Dodge Corp. completed an \$81 million expansion of the Morenci Mine adding 1,900 metric tons to monthly production beginning July 1998. The Southwest expansion project replaced an antiquated solvent extraction plant with a new one, constructed a new leach field in Stargo Canyon, and modernized the central electrowinning tankhouse to use stainless steel starter sheets. Use of these sheets saves making and shipping 35,000 copper starter sheets per week from the company's El Paso, TX, refinery as well as improving cathode quality.

Silver production in Arizona totaled 185 metric tons (table 1) recovered as a byproduct of copper mining. Arizona's only operating primary gold mine, Gold Road, produced 1,092 kilograms in 1997. Lower gold prices combined with other operating conditions caused Addwest Minerals Inc. to cease mining and milling in June 1998. Despite the closure, Addwest continued to add to its holdings in the Oatman district, acquiring rights to the United Western and United Eastern Mines adjacent to the Gold Road. Ore from these mines could be treated by the company's 450-metric-ton-per-day mill.

The BLM released the Yarnell gold mine's draft Environmental Impact Statement in June 1998. Bema Gold Corp., doing business in Arizona as Yarnell Mining Co., anticipates that construction could begin by mid-1999 if the record of decision and other permits are received. The mine will be operated as an open pit, heap-leach system producing 1,000 kilograms of gold per year over a 6-year mine life.

Unlike the metals segment, construction materials were in high demand as Arizona continued to enjoy robust population growth and a strong economy. The Arizona Department of Transportation's construction budget jumped 26% in 1998 and is expected to increase 13% in 1999 (Rock Products, 1998). Both cement producers in Arizona are considering expansion. During the next 5 years, Arizona portland cement's plant capacity will probably increase to 2.1 million metric tons per year. In the initial phase, capacity will increase to 1.42 million metric tons per year and involves installing a new raw feed roller mill and converting the existing raw feed mill into a finish mill. The second phase, planned for completion in 2003, requires installing a second pre-calcining tower. Phoenix Cement Co. has announced they have entered the planning stage for modernization of their Clarkdale operation. Plans include an increase in plant capacity from the current 570,000 metric tons of cement per year to 1 million metric tons per year.

After several years of development work, RMc Industries Inc. of Fort Collins, CO, will bring a brucite (natural magnesium hydroxide) deposit in Arizona into production in early 1998.

The underground mine, near Kingman, will have a capacity of about 23,000 metric tons per year (Industrial Minerals, 1997).

In 1998, Salt River Sand & Rock Co., in Maricopa County, again operated one of the largest sand and gravel plants in the United States. Vulcan Materials Co. acquired Calmat Co. in November 1998 for \$760 million and the assumption of Calmat's debt of \$130 million. Calmat of Arizona has 479 employees at its seven Phoenix area plants. The merger further solidifies Vulcan's position as the nation's largest producer of construction aggregates (Vulcan Materials Co., November 16, 1998, press release, accessed April 20, 1999, at URL <http://www.vulcanmaterials.com/press/calmat.htm>). Omya Arizona Inc. continued work on plans and permits for a new calcium carbonate processing plant at Superior in Pinal County. The Drake and Ashfork sandstone quarries and processing plant of Western States Stone were acquired by American Sandstone. Western States' schist quarries in the Mayer area were acquired by Apache Stone and their marketing and stone yards were combined into Garden State Stone.

Arizona is the leading State in the value of mined gemstones in the United States. Although best known for turquoise and petrified wood, amethyst from the Four Peaks Mine in Maricopa County has been coveted by faceters and collectors since the turn of the century. The mine, inactive for over 10 years, was purchased in late 1997 and reactivated. The amethyst is mined by hand, flown by helicopter to Phoenix (the property is surrounded by the U.S. Forest Services' Four Peaks Wilderness Area), and shipped to Bangkok for faceting.

Mine fraud is of increasing concern to stock exchanges and government security regulators. Some scandals with connections to Arizona were reported by the Toronto Stock Exchange and the Ontario Securities Commission, and included International Platinum (IP) and Delgratia and Naxos (Toronto Stock Exchange and the Ontario Securities Commission, 1998). In early 1998, International Precious Metals (successor to IP who was delisted by the Toronto Stock Exchange), was delisted by the NASDAQ stock exchange. Other examples reported during 1998 include the Arizona Corp. Commission issuing a cease and desist order to Black Diamond Mining and Federal grand jury indictments of four Phoenix area individuals on 30 charges involving activities at the Henrietta Mine.

These types of activities were the impetus for the Ontario Securities Commission and the TSE to form the mining standards task force to review standards governing the conduct of mineral exploration programs and reporting of results. The task force's interim report, made four key recommendations: 1) designate a qualified person to sign off on exploration disclosures, 2) establish best exploration and field practices to ensure integrity of results, 3) raise disclosure standards, and 4) improve regulatory oversight.

According to the ADMMR, a common occurrence is the reporting of gold or other precious metals where none exists. Investors seem vulnerable to promotions that claim to be able to detect or recover gold that reputable laboratories cannot detect. Despite regulatory agencies investigations and shutdowns, investors should remain wary as the proposed improvements are expected to discourage, but not stop, mine fraud.

In August 1998, the U.S. District Court in Phoenix approved a \$100 million settlement to clean up damage to Pinal Creek, Gila County, caused by acid mine drainage. The settlement, the largest environmental agreement in Arizona's history, involves Cyprus Miami Mining Corp., BHP Copper Inc., and Inspiration Consolidated Copper Co. (Mining Week, 1998).

The Arizona legislature established the abandoned mines safety fund. Administered by the Arizona Mine Inspector, the only use of such funds is for actual abatement costs to close or fence shafts and adits on State trust lands. Donations to the fund may be matched by appropriations from the legislature.

For a more complete discussion of Arizona's Mineral Industry along with a detailed listing of the mines and operators see Directory 47, *Active Mines in Arizona 1999* available from the Arizona Department of Mines and Mineral Resources.

References Cited

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- Mining Week, 1998, National Mining Assoc.: Mining Week, August 24.
- Rock Products, 1998, [Untitled]: Rock Products, v. 101, no. 12, December, p. 60.
- Toronto Stock Exchange and the Ontario Securities Commission, 1998, Setting new standards, Interim Report: Toronto Stock Exchange.

TABLE 1
NONFUEL RAW MINERAL PRODUCTION IN ARIZONA 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	1996		1997		1998 p/	
	Quantity	Value	Quantity	Value	Quantity	Value
Clays: Common	104	W	W	W	W	W
Copper 3/	1,240	2,980,000 r/	1,250	2,940,000	1,200	2,120,000
Gemstones	NA	2,360	NA	2,360	NA	2,780
Gold 3/ kilograms	2,990 r/	37,500 r/	2,140	22,800	2,100	20,000
Molybdenum do.	W	W	14,400	W	16,700	W
Sand and gravel:						
Construction	41,900	199,000	39,500	187,000	46,900	229,000
Industrial	323	2,890	330	3,160	337	3,940
Silver 3/ metric tons	189 r/	31,500 r/	190	29,900	185	30,300
Stone: Crushed	6,800	40,600	7,490	44,000	7,400	43,300
Zeolites metric tons	(4/)	NA	(4/)	NA	NA	NA
Combined values of brucite (1998), cement, clays (bentonite), gypsum, (crude), iron oxide pigments (crude), lime, perlite (crude), pumice and pumicite, salt, stone (dimension sandstone), and values indicated by symbol W	XX	308,000	XX	312,000	XX	374,000
Total	XX	3,600,000 r/	XX	3,540,000	XX	2,820,000

p/ Preliminary. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; value included with "Combined values" data. XX Not applicable.

1/ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Recoverable content of ores, etc.

4/ Withheld to avoid disclosing company proprietary data.

TABLE 2
ARIZONA: CRUSHED STONE SOLD OR USED, BY KIND 1/

Kind	1996				1997			
	Number of quarries	Quantity (thousand metric tons)	Value (thousands)	Unit value	Number of quarries	Quantity (thousand metric tons)	Value (thousands)	Unit Value
Limestone	6	4,110	\$23,000	\$5.60	6	4,590	\$23,300	\$5.07
Granite	12	1,540	8,580	5.57	12	1,580	10,700	6.74
Marble	3	W	W	8.24	3	W	W	11.69
Sandstone and quartzite	2	W	W	12.58	2	W	W	16.10
Volcanic cinder and scoria	5	238	542	2.28	4	115	135	1.17
Miscellaneous stone	2	W	W	9.04	4	948	6,010	6.34
Total	XX	6,800	40,600	5.97	XX	7,490	44,000	5.86

W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

1/ Data are rounded to three significant digits, except unit value; may not add to totals

TABLE 3
ARIZONA: CRUSHED STONE SOLD OR USED BY PRODUCERS
IN 1997, BY USE 1/ 2/

Use	Quantity (thousand metric tons)	Value (thousands)	Unit value
Coarse aggregate (+1 1/2 inch), riprap and jetty stone	W	W	\$3.18
Fine aggregate (-3/8): Stone sand, concrete	W	W	11.10
Coarse and fine aggregates:			
Graded road base or subbase	63	\$72	1.14
Unpaved road surfacing	35	43	1.23
Terrazzo and exposed aggregate	109	2,010	18.47
Crusher run or fill or waste	1	11	11.00
Other coarse and fine aggregates	4	59	14.75
Other agricultural uses 3/	10	152	15.20
Chemical and metallurgical:			
Cement manufacture	W	W	5.62
Lime manufacture	W	W	4.04
Flux stone	W	W	13.19
Sulfur oxide removal	W	W	11.42
Special:			
Whiting or whiting substitute	W	W	11.44
Roofing granules	3	63	21.00
Other miscellaneous uses not listed: Unspecified: 4/	3	27	9.00
Actual	1,310	10,300	7.87
Estimated	996	6,020	6.05
Total	7,490	44,000	5.86

W Withheld to avoid disclosing company proprietary data; included in "Total."

1/ Includes granite, limestone, marble, miscellaneous stone, sandstone and quartzite, and volcanic cinder and scoria.

2/ Data are rounded to three significant digits, except unit value; may not add to totals shown.

3/ Includes poultry grit and mineral food.

4/ Includes reported and estimated production without a breakdown by end use.

TABLE 4
ARIZONA: CRUSHED STONE SOLD OR USED BY PRODUCERS IN 1997,
BY USE AND DISTRICT 1/ 2/

(Thousand metric tons and thousand dollars)

Use	District 1		District 2		District 3		Unspecified districts	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Construction aggregates:								
Coarse aggregate (+1 1/2 inch) 3/	--	--	W	W	W	W	--	--
Fine aggregate (-3/8 inch) 4/	--	--	W	W	W	W	--	--
Coarse and fine aggregate 5/	W	W	W	W	W	W	--	--
Agricultural 6/	--	--	--	--	W	W	--	--
Chemical and metallurgical 7/	W	W	--	--	W	W	--	--
Special 8/	--	--	--	--	W	W	--	--
Unspecified: 9/								
Actual	W	W	--	--	W	W	879	5,380
Estimated	W	W	--	--	W	W	--	--
Total	2,350	11,600	3	9	4,260	27,000	879	5,380

W Withheld to avoid disclosing company proprietary data; included in "Total."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes granite, limestone, marble, miscellaneous stone, quartzite, sandstone, and volcanic cinder and scoria.

3/ Includes filter stone.

4/ Includes stone sand (concrete).

5/ Includes terrazzo and exposed aggregates, crusher run (select material of fill), and other coarse and fine aggregates.

6/ Includes poultry grit and mineral food and other agricultural uses.

7/ Includes cement manufacture, lime manufacture, flux stone, and sulfur oxide removal.

8/ Includes whiting or whiting substitute and other uses.

9/ Includes reported and estimated production without a breakdown by end use.

TABLE 5
ARIZONA: CONSTRUCTION SAND AND GRAVEL SOLD OR USED IN 1997,
BY MAJOR USE CATEGORY 1/

Use	Quantity (thousand metric tons)	Value (thousands)	Value per ton
Concrete aggregate (including concrete sand)	12,700	\$66,200	\$5.20
Plaster and gunite sands	1,270	4,740	3.73
Concrete products (blocks, bricks, pipe, decorative, etc.)	24	195	8.13
Asphaltic concrete aggregates and other bituminous mixtures	4,130	23,200	5.63
Road base and coverings 2/	10,500	39,700	3.78
Fill	731	1,940	2.65
Snow and ice control	13	138	10.62
Other miscellaneous uses 3/	249	1,040	4.16
Unspecified: 4/			
Actual	5,110	26,600	5.21
Estimated	4,750	23,600	4.96
Total or average	39,500	187,000	4.74

1/ Data are rounded to three significant digits, except value per ton; may not add to totals shown.

2/ Includes road and other stabilization (cement and lime).

3/ Includes filtration and railroad ballast.

4/ Includes reported and estimated production without a breakdown by end use.

TABLE 6
ARIZONA: CONSTRUCTION SAND AND GRAVEL SOLD OR USED IN 1997,
BY USE AND DISTRICT 1/

(Thousand metric tons and thousand dollars)

Use	District 1		District 2		District 3		Unspecified districts	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Concrete aggregate and concrete products	846	5,340	288	1,820	11,600	59,300	--	--
Plaster and gunite sands	72	788	20	155	1,180	3,800	--	--
Asphaltic concrete aggregates and other bituminous mixtures	654	4,980	128	631	2,930	16,700	419	924
Road base materials 2/	752	3,650	168	1,080	8,800	33,700	799	1,320
Fill	22	63	197	678	513	1,200	--	--
Other miscellaneous uses 3/	2	13	15	158	5,090	27,200	--	--
Unspecified: 4/								
Actual	--	--	W	W	W	W	265	438
Estimated	1,210	5,720	607	2,260	2,940	15,600	--	--
Total	3,560	20,500	1,420	6,780	33,100	157,000	1,480	2,680

W Withheld to avoid disclosing company proprietary data; included with "Other miscellaneous uses."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes road and other stabilization (cement and lime).

3/ Includes filtration, railroad ballast, and snow and ice control.

4/ Includes reported and estimated production without a breakdown by end use.