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New Mexico Geology, v. 24, n. 1 pp. 19-28, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
https://doi.org/10.58799/NMG-v24n1.19

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Introduction

New Mexico's mineral wealth has placed it among the richest states in the U.S. (Figs. 1, 2). In the year 2000 New Mexico ranked 18th in the U.S. in nonfuel minerals production, as compared to 21st in 1999 (Table 1). New Mexico also ranked 13th in coal production in the U.S. in the year 2000. In addition, significant reserves of coal, copper, potash, and molybdenum are identified in the state. Most of New Mexico's mineral production value comes from coal, copper, and potash (Table 2). Other commodities produced in the state include a variety of industrial minerals (including stone and aggregate), sulfuric acid, gold, uranium, and silver (Table 2).

This article summarizes production in the minerals industry in New Mexico, excluding oil and gas production, from 1998 through 2000. The data in this article were compiled by the authors and the employees of the Energy, Minerals and Natural Resources Department from a variety of company annual reports and personal tours of mine sites. Parts of this article are taken from reports published by the Energy, Minerals and Natural Resources Department, Mining and Minerals Division (1999, 2000, 2001) and the U.S. Geological Survey (Tanner and McLemore, 1999, 2001a, b). Most of the production statistics and reserves in this article are in English units as reported by the Energy, Minerals and Natural Resources Department and the company annual reports. However, the U.S. Geological Survey reports production statistics in metric units, which are retained in this article to avoid errors in the data as a result of conversion problems. Conversion factors are on page 28.

Coal

Coal is a readily combustible sedimentary rock that contains predominantly carbonaceous material. Coal is classified into four types, anthracite, bituminous, subbituminous, and lignite, based on carbon content and heating value (Table 3). The amount of energy that coal will release is typically expressed as British thermal units per pound (BTUs), the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Coal has been mined in New Mexico for centuries, beginning with the Native Americans and then the Spanish settlers who used coal from surface exposures as home heating fuel. The first significant coal

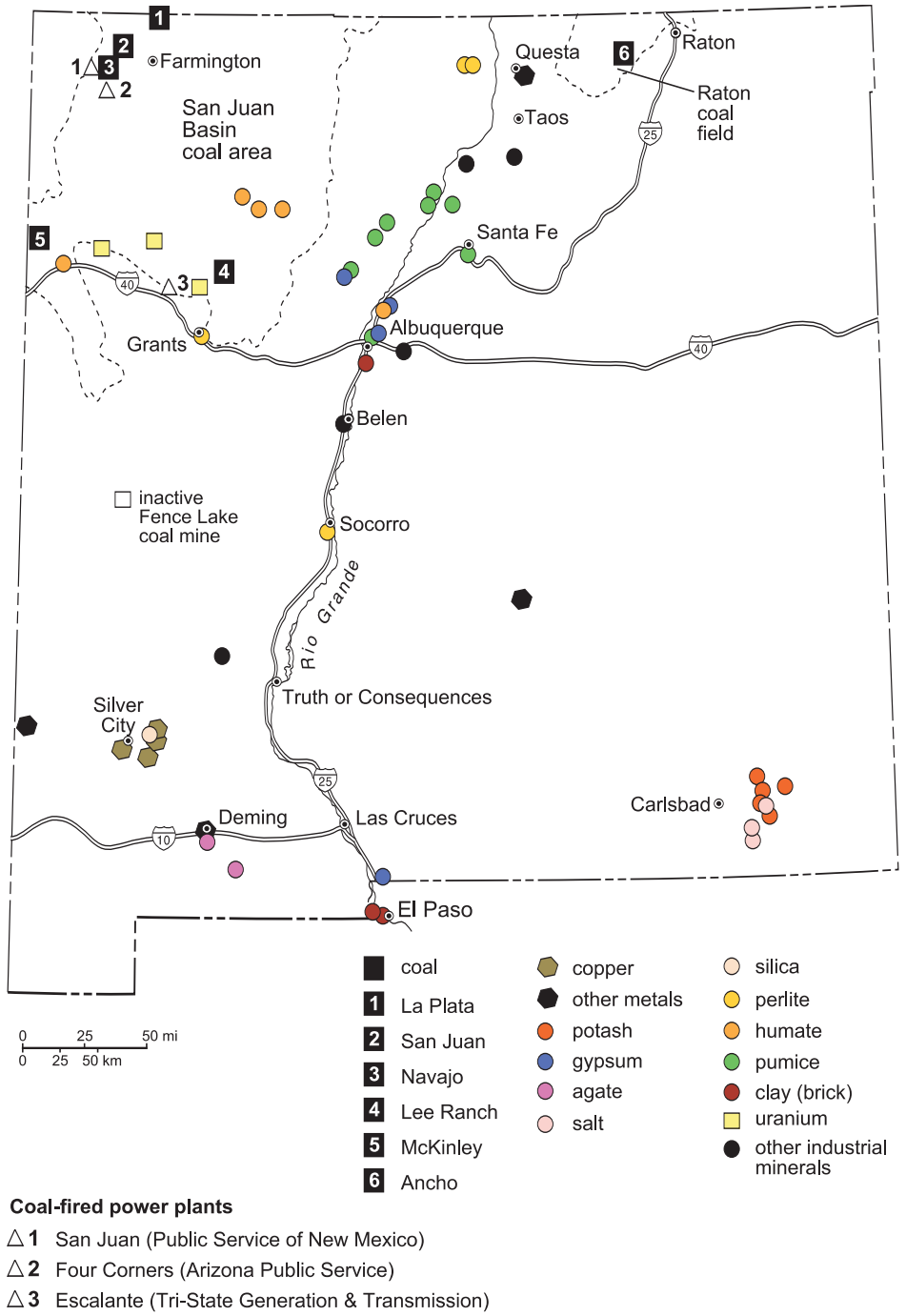

FIGURE 1—Major mines in New Mexico active in 1998–2000 and coal-fired power plants (from Pfeil et al., 2001).

mining in New Mexico began in 1861 near Carthage with an underground mine operated by the U.S. Army to supply coal to Fort Stanton (Hoffman, 1996). From the late 1800s to the 1950s New Mexico's coal production was primarily used for steam power by the railroads and for making coke used by southwestern copper smelters. In the early 1960s large-scale surface operations began producing coal for generation of electricity. Today, 56% of the nation's electricity is produced from coal-

TABLE 1—Total minerals production value in New Mexico from 1989 through 2000. [1]Data from Energy, Minerals and Natural Resources Department (1997–2000). [2]Data from U.S. Geological Survey, Mineral Yearbooks (1989–1998), Tanner and McLemore (1999, 2001a, 2001b), Smith (2000).

Year	Minerals production value[1] (including coal production) (dollars)	Payroll[1] (including coal production) (dollars)	Minerals production value[2] (excluding coal production) (dollars)	Rank in U.S.[2] (excluding coal production)	Minerals production value in U.S.[2] (excluding coal production) (dollars)	Percentage of U.S. total[2] (excluding coal production)
2000	1,377,411,947	260,609,375	812,000,000	18		
1999	1,453,066,873	277,708,501	715,000,000	21	39,100,000,000	1.72
1998	1,504,795,624	310,550,710	853,000,000	17	39,600,000,000	2.25
1997	1,621,513,947	300,851,045	1,040,000,000	14	40,500,000,000	2.56
1996			992,000,000	13	38,700,000,000	2.56
1995			1,130,000,000	11	38,500,000,000	2.94
1994			930,,000,000	12	35,200,000,000	2.64
1993			804,049,000	12		
1992			871,279,000	15	31,714,000,000	2.75
1991			985,510,000	10	30,793,000,000	3.20
1990			1,103,481,000	10	33,432,000,000	3.30
1989			1,122,303,000	10	31,811,000,000	3.53

fired generation, and New Mexico gets 58% of its electricity from coal (Energy, Minerals and Natural Resources Department, 2000, pp. 48–49). More than half of all coal produced in New Mexico is used at three generating stations within the state (Fig. 1). All but a small portion of the remaining production is shipped by rail to generating stations in Arizona and Wisconsin.

New Mexico ranks 10th in demonstrated reserves (Energy Information Administration, 2000, table 33) in the U.S. and 11th in recoverable reserves (1997 statistics; Energy Information Administration, 1999). Within permitted mine areas, the state ranks 3rd in recoverable reserves with 1.3 billion short tons of coal (2000 statistics; Energy Information Administration, 2000, table 25). Most of New Mexico's coal reserves are in the northern half of the state in the San Juan and Raton Basins (Fig.1). Within the San Juan Basin, there are three Late Cretaceous coal-bearing units, the Crevasse Canyon, Menefee, and Fruitland Formations. The McKinley mine (Pittsburg and Midway) and Lee Ranch mine (Lee Ranch Coal) produce from the Menefee Formation. The Navajo (BHP World Minerals), San Juan (San Juan Coal, subsidiary of BHP World Minerals), and La Plata (San Juan Coal) mines produce coal from the younger Fruitland Formation (Fig. 1). Both the Menefee and Fruitland coals are subbituminous in rank with low sulfur (0.5–0.8%). The Fruitland coals have a greater ash content (19–22%) than the Menefee coals (8–11%). There are two coal-bearing units in the Raton Basin, the Late Cretaceous Vermejo Formation and the Late Cretaceous–Tertiary Raton Formation. The Vermejo Formation was a major producer in the past. Currently the Ancho mine (Pittsburg and Midway), which is the only operating mine in the New Mexico part of the Raton Basin, produces from coal beds in the Raton Formation. Raton Formation coals are bituminous in rank, low in sulfur (0.6%), and have a moderate ash content (13%). The Ancho mine is scheduled to close in 2003.

From 1998 through 2000 New Mexico ranked 12th in coal production in the nation. In 2000 the Navajo mine west of Farmington and the McKinley mine near Gallup were the 17th and 33rd largest coal producers in the nation (Table 4). Total production for the state in 1998 was 28.38 million short tons. In 1999 New Mexico's coal production was 28.84 million short tons (Energy, Minerals and Natural Resources Department, 2000, p. 13), and in 2000 production was 27.34 million short tons (Energy, Minerals and Natural Resources Department, 2001, p. 16). The average price of New Mexico coal in 1998 was $20.68 per short ton, and the average price for coal in the U.S. was $17.67 per short ton (Energy, Minerals and Natural Resources Department, 2000, p. 13). Although the New Mexico price is much higher than the national average, it has been on the decline for the past 3 yrs in part because of renegotiations of contracts.

The coal industry in New Mexico has been stable during 1998–2000 as a result of a few developments. The greatest change in the industry has been with San Juan Coal Company's (subsidiary of BHP World Minerals) San Juan mine. The San Juan surface mine has been producing since 1973, but the cost of production became prohibitive in the 1990s. In 1997 production began from an underground pilot mine at the south end of the San Juan property. The pilot mine closed in early 1999, and the San Juan Coal Company applied to the state for a permit revision to develop a longwall mine. The proposed underground mine is adjacent to the existing surface mine and includes 9,600 acres for the underground operation. BHP World Minerals requested an additional lease of 4,300 acres from the BLM for this operation. The lease was denied by the BLM in May 2000; they stated that the proposed bid did not meet fair market value. The bid was resubmitted, and the lease was approved in late 2000. With the additional acreage the mine has reserves that will last until 2017 (Al Putzig, pers. comm. 2001). Both the San Juan and La Plata surface mines (both operated by the San Juan Coal Company) will close at the end of 2002 if the longwall mine's annual production of 6.5 million short tons is met (Paydirt, 2000b). It will be the sole source of coal for the San Juan Generating Plant.

In April 1998 the New Mexico Coal Surface Mining Commission upheld the decision of the Mining and Minerals Division director to issue a permit for Salt River Project's Fence Lake mine in west-central New Mexico (Fig. 1). The permit was issued in July 1996 but was appealed to the commission. This matter is now under appeal before the State District Court. Lee Ranch mine north of Grants submitted a permit revision in early 1998 to add approximately 7,000 acres to the existing permit (Hoffman and Pfeil, 2001). This revision for the Lee Ranch mine has been granted. In the Raton Basin, Pittsburg and Midway submitted a permit revision application for a new area adjacent to their Ancho operations, the Gachupin–Brackett area. This permit was approved in October 1999 and is in production (Hoffman and Pfeil, 2001).

Copper

Copper is one of the oldest metals ever used and has been important in the development of civilization because of its properties: high ductility, malleability, thermal and electrical conductivity, and resistance to corrosion. Electrical and electronic uses dominate copper markets, but copper also is used in pipes, tools, machinery, coins, and ornaments. Copper prices began to

stabilize in 2000 after the drop in 1998–1999 that led to layoffs, cutbacks, and mine closures. Copper averaged $1.09/lb in 1996, $1.07/lb in 1997, $0.79/lb in 1998, $0.76/lb in 1999, and $0.89/lb in 2000 (Edelstein, 2000).

The Phelps Dodge Corporation continues to mine copper at Santa Rita (Chino) and Tyrone. The Chino mine at Santa Rita is the largest porphyry copper deposit in New Mexico and is one of the ten largest copper mines in the U.S. in terms of mine production (Edelstein, 2000). Copper sulfides are found in the upper, fractured granodiorite and adjacent sedimentary rocks. Adjacent copper skarns are becoming increasingly more important economically. Mine production for 1998–2000 is in Table 5. Estimated milling reserves in 2000 are 310 million short tons of 0.6% copper, and estimated leaching reserves are 476.2 million short tons of 0.3% copper (Phelps Dodge Corporation, 2001). Phelps Dodge Corporation owns 66.7% of the reserves at Chino. The company developed a first-of-its-kind control system to guide the processing of the wide variety of ore found in the Chino deposit. The system saves costs by analyzing the ore as it comes into the concentrator and continually adapting processing conditions. Phelps Dodge announced in October 2001 that it will temporarily close the Chino mine and Hurley smelter in early 2002, affecting 650 employees.

The Tyrone porphyry copper deposit in the Burro Mountains also is one of the top ten mines in the U.S. in terms of mine production (Edelstein, 2000). The deposit is found within a quartz-monzonite laccolith and adjacent Proterozoic rocks. Several orebodies, sometimes considered separate porphyry copper deposits, have been found. The concentrator processed approximately 300 million short tons of ore grading 0.81% copper from 1969 to 1992. The mill closed, and mining for leach began. In the year 2000 leaching reserves (recoverable copper) are estimated as 460.7 million short tons of ore grading 0.3% copper (Phelps Dodge Corporation, 2001). In addition, the Niagara deposit contains 500 million short tons of mineralized material grading 0.29% copper as of December 2000. This mineralized material could be brought into production should market conditions warrant. Copper production by solvent solution extraction-electrowinning process (SX/EW) in 1998–2000 is in Table 5.

On February 3, 1998, the Phelps Dodge Corporation acquired Cobre Mining Company, Inc. for approximately $115 million. The acquisition included the open-pit mine, two underground mines, two mills, and surrounding 11,000 acres of land. Then on October 21, 1998, Phelps Dodge suspended underground mining at Cobre because of low copper prices. By March 17, 1999, the remaining operations were suspended. The entire operation remained on care and maintenance status through the rest of the year. Estimated milling reserves in the year 2000 are 132.4 million short tons of 0.73% copper, and estimated leaching reserves are 97.9 million short tons of 0.35% copper (Phelps Dodge Corporation, 2001). Most of the copper reserves at the Cobre mine are in the Syrena and upper part of the Lake Valley limestones north of the Barringer fault. Chalcopyrite is the chief ore mineral, with minor magnetite and iron-rich sphalerite. Orebodies are associated with the garnet-magnetite skarn, downdip of the Barringer fault. Supergene copper mineralization west of the main pit within the Colorado Formation is associated with the Hanover Mountain copper porphyry deposit. Hydrothermal fluids from the Hanover–Fierro stock migrated updip in adjacent sediments and were dammed against the Barringer fault, forming the copper skarns and replacement bodies.

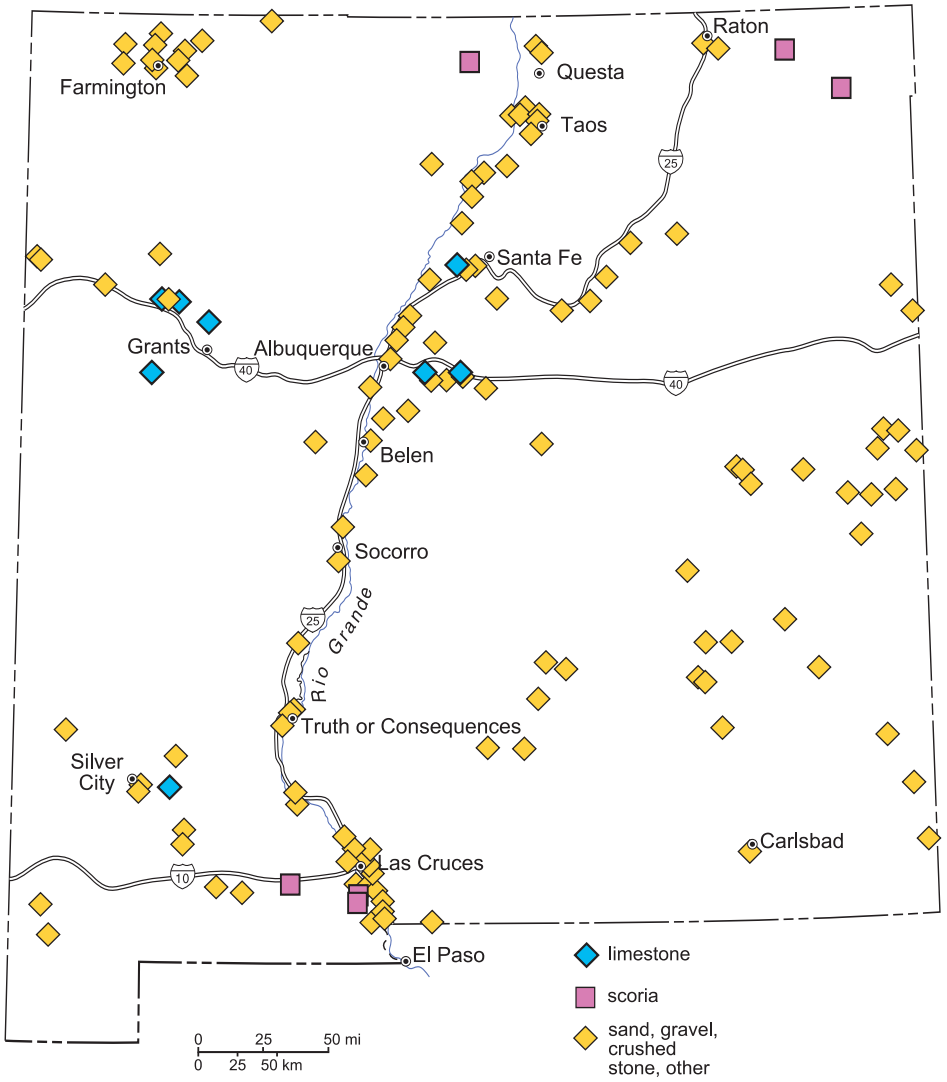

FIGURE 2—Major aggregate pits and quarries active in 1998–2000 (from Pfeil et al., 2001).

The Phelps Dodge Corporation closed the Hidalgo smelter south of Lordsburg on September 3, 1999. The smelter may be reconfigured to an acid conversion facility. In addition, Phelps Dodge acquired Cyprus Amax on October 16, 1999. The primary assets acquired include the Bagdad, Sierrita, Miami, El Abra, and Cerro Verde copper mines; the Henderson and Climax molybdenum mines; a copper smelter, refinery, and two rod plants; and three molybdenum roasting operations and three molybdenum conversion facilities. None of the operating Cyprus Amax acquisitions are in New Mexico.

Environmental Impact Statements (EIS) are being prepared for expansions at Chino and Cobre mines. In addition, Phelps Dodge, in voluntary cooperation with the New Mexico Environment Department, is beginning reclamation at six sites in the Silver City area impacted by historic mining: Whitewater Creek, Hanover Creek, Lampbright area, Hurley smelter, town of Hurley, and tailings area south of the smelter. The first stage is to develop a background report defining the problems.

TABLE 2—Minerals production data in New Mexico 1998 through 2000 (Energy, Minerals and Natural Resources Department, 1999, 2000, 2001). [1]Quantity of copper, molybdenum, and uranium are in pounds; gold and silver are in ounces, other commodities are in short tons. — not available.

	1998		1999		2000				
	Quantity[1]	Production value (dollars)	Quantity[1]	Production value (dollars)	Quantity[1]	Production value (dollars)	Payroll (dollars)	Employment	Production rank in U.S.
Coal	28,382,364	614,263,863	28,845,336	632,968,729	27,337,832	554,009,565	99,996,625	1,710	13
Copper	554,188,543	419,451,218	433,569,905	315,240,601	429,698,323	365,411,301	62,225,858	1,860	3
Potash	1,330,341	231,079,006	1,342,026	235,202,181	1,377,801	215,737,596	58,539,874	967	1
Industrial minerals	3,299,061	148,974,895	3,703,430	176,750,513	2,925,926	162,402,617	17,678,535	756	—
Aggregates	12,285,797	50,182,561	13,404,230	60,677,102	13,752,251	66,810,485	11,252,483	1,030	—
Sulfuric acid	997,183	2,380,724	781,895	12,998,174	300,473	1,735,205	—	—	—
Molybdenum	7,339,117	24,000,091	2,855,000	12,778,888	1,504,236	5,918,114	10,000,000	195	6
Gold	32,337	9,454,651	18,263	5,098,683	—	15,613	4,355,075	—	10
Uranium	264,057	2,600,000	248,752	—	21,548	—	—	—	—
Silver	433,596	2,408,615	259,174	1,352,002	207,788	1,031,989	—	—	10

Successive stages will involve remedial investigations, a feasibility study, and remedial action.

The Copper Flat deposit in Sierra County, discovered in 1975, consists of copper, gold, molybdenum, and silver disseminated in a quartz-monzonite stock and in quartz veins (Dunn, 1982, 1984; McLemore et al., 1999). Unlike the Santa Rita and Tyrone deposits, there is no major supergene enrichment zone at Copper Flat; Copper Flat is a medium-grade hypogene deposit with relatively low pyrite. In the three months before the mine closed, from March through June 1982, Quintana Minerals Corporation produced approximately 7.4 million pounds of copper, 2,301 ounces of gold, and 55,966 ounces of silver (Alta Gold Company, 2000). Gold Express Corporation, currently known as StarTronix International, Inc., acquired the property soon after. Alta Gold Company acquired Copper Flat in June 1994. The Copper Flat deposit has proven and probable reserves of 50,210,000 short tons of ore at a grade of 0.45% copper, 0.004 ounces/ton gold, 0.066 ounces/ton silver, and 0.015% molybdenum as of December 31, 1998. Contained metal is approximately 447,872,000 pounds of copper, 223,900 ounces of gold, 3,299,500 ounces of silver, and 14,762,000 pounds of molybdenum. The deposit has internal continuity and an estimated stripping ratio of less than 0.9:1 (Alta Gold Company, 2000). On March 8, 2000, Alta Gold Company filed a motion to convert case to Chapter 7 with the U.S. Bankruptcy Court in Reno, Nevada. As of April 14, 1999, Alta Gold had been operating as a debtor in possession, pursuant to a voluntarily filed petition under Chapter 11 of the Bankruptcy Code, in an attempt to reorganize the business and to restructure its debt and other liabilities. It is anticipated that Alta Gold's remaining assets will be liquidated under the direction of the bankruptcy court or in some similar forum.

In July 1998 Summo Minerals Corporation of Vancouver dropped the Champion mine claims at the Copper Hill deposit in the Picuris district near Dixon in Taos County. Preliminary reserves estimated that the deposit contains 46.5 million short tons of ore grading 0.42% copper. The BLM and the Picuris Pueblo are opposed to the mine because it sits between two canyons that drain into the Rio Grande and Rio Embudo—both of which may receive Wild and Scenic River designations.

Molybdenum

In New Mexico molybdenum is produced from the Questa mine in Taos County and as a byproduct of copper smelting in Grant County. Molybdenum is a refractory metallic element used principally as an alloying agent in steel, cast iron, and superalloys to enhance hardness, strength, toughness, and wear and corrosion resistance. Molybdenum also is used in fire retardants and in catalysts. The mineral, molybdenite, is used as a lubricant. The annual average prices per kilogram in 1999 were: molybdenum concentrates, $3.840; molybdic oxide, $5.861; and ferromolybdenum, $8.157 (Blossom, 2000).

Molycorp, Inc.'s (a subsidiary of Unocal) Questa molybdenum mining development and exploration continuously operated from 1923 through 1986 when soft market conditions caused the temporary shutdown of the mine until 1989. Mining operations again were placed on standby in 1992 and then resumed in 1995.

Between 1965 and 1983 the company mined some 81 million short tons of ore at a grade of 0.191% molybdenum from their open pit. Underground block caving of ore commenced in 1983 and continues to this day. At present, ore grade ranges between 0.3% and 0.5% molybdenum. Crude ore processed in 2000 was 413,501 short tons, which resulted in 1,290,210 pounds of molybdenite concentrate (molybdenum disulfide, MoS_2) recovered (773,294 pounds of molybdenum; Molycorp, Inc., pers. comm. 2001). Reserves and resources at Questa as of November 1999 (Molycorp, Inc., pers. comm. 2001) are as follows:

Proven reserves: 16,344,898 short tons of 0.343% MoS_2 at a cutoff grade of 0.25% MoS_2

Probable reserves : 47,198,409 short tons of 0.315% MoS_2

Possible reserves: 3,223,000 short tons of 0.369% MoS_2.

When proven and probable reserves are considered, the mine life is 25–35 yrs, and when resources are included the mine life is 50–80 yrs. Approximately 195 people worked at the mine in the year 2000. A proposed expansion plan was announced in September 1998 that would mine an estimated 70 million short tons of ore reserves. However, as a result of a drop in molybdenum prices at the end of 1998, Molycorp announced that it would cut back production at the Questa mine and lay off employees in 2002 (Molycorp, Inc., pers. comm. 2001).

Molycorp, Inc. also continued with a reclamation and re-vegetation program to cover overburden dumps at the inactive open pit site. In 2000 Molycorp posted a $129 million cleanup bond in response to the New Mexico Environment Department's concerns about reclamation of the mine site (Paydirt, 2000c). In May 2000 the U.S. Environmental Protection Agency proposed the Questa mine for the National Priorities List. As a result, the U.S. Geological Survey and the state of New Mexico are conducting additional hydrologic studies.

Precious metals

Royal Minerals, Inc. shipped 5 short tons of concentrate containing gold, silver, copper, lead, and zinc to a company in Utah from the Center mine in the Steeple Rock district, Grant County in 2000 (Doug Hansen, pers. comm. February 21, 2001).

The Center mine had been acquired by the Mt. Royal Mining and Exploration Company in 1985. They leased it in 1987 to R and B Mining Company, who drove a decline below the old Center shaft and produced until 1994. In 1998 Royal Minerals, Inc. acquired the mine from Mt. Royal Mining and Exploration Company and built a mill at the mine to process mine-waste piles and remaining ore reserves. The base-metal veins in the district were emplaced exclusively along the Carlisle fault and consist of 5–20% sulfides (galena, sphalerite, and chalcopyrite) with typically 34–274 ppm silver and 0.34–171 ppm gold, and local secondary sulfide and carbonate minerals in a gangue of quartz, pyrite, chlorite, illite/sericite, rare adularia, and a few additional accessory minerals. The ore at the Center mine consists of (1) coarse-grained, massive sulfides (as much as 20% base metals total), locally with little quartz, and (2) medium- to fine-grained sulfides disseminated throughout brecciated quartz veins and fault gouge. Massive sulfides form streaks, irregular masses, and veinlets in zones as wide as 12 ft. Ore shoots 1–5 ft thick can be found in bends and splays of the Carlisle fault.

St. Cloud Mining Company (a subsidiary of The Goldfield Corporation) owns claims in the Chloride mining district in Sierra County where indicated reserves are estimated as 349,500 short tons averaging 0.70% copper, 5.95 ounces of silver/short ton, and 0.031 ounces of gold/short ton (The Goldfield Corporation, 2000). Production occurred from 1981 through early 1992; the property has remained inactive since 1992.

St. Cloud also owns claims in the Lordsburg mining district in Hidalgo County where indicated reserves are estimated to be 103,800 short tons averaging 0.53% copper, 1.0 ounces of silver/short ton, and 0.097 ounces of gold/short ton. The company produced and sold 8,365 short tons of construction aggregate in 2000, compared to 5,152 short tons in 1999, 16,547 short tons in 1998, 24,553 short tons in 1997, and 14,070 short tons in 1996 (The Goldfield Corporation, 2000). In 1996, 17,190 short tons of barren, siliceous flux was sold to copper smelters; there have been no siliceous flux sales since 1996.

Industrial minerals

Potash and salt

The Carlsbad potash district is the largest potash producing area in the nation. Mississippi Potash, Inc. (a subsidiary of Mississippi Chemical Corporation) and IMC Kalium Potash Mines (a subsidiary of IMC Global, Inc.) operate mines in the district. Potash is used as fertilizer and as a chemical in specialty and industrial markets. Langbeinite ($K_2SO_4 \cdot 2MgSO_4$) and sylvite (KCl) are the primary potash minerals found in Permian evaporites of the Permian Basin in New Mexico (Barker and Austin, 1996). Mining is by underground methods; locally solution mining is used as well. The estimated potash reserves in the district are more than 745 million short tons. Sodium salt also is produced locally as a byproduct; New Mexico ranks 11th in salt production. Salt is used in oil field drilling, animal feed, and to de-ice roads.

In 1999 IMC Kalium Potash Mines completed construction of a new langbeinite refinery at a cost of approximately $77 million; it began production during 1999. IMC acquired the Western Ag-Minerals mine and its annual production capacity of 400,000 short tons in 1997. Production at the Western Ag mine was temporarily discontinued in 1999 to connect the mine to IMC's Carlsbad mine and redirect the ore to the new refinery. The total reserves at IMC mines include an estimated 223.3 million short tons of potash ore in four mining beds at thicknesses ranging from 4.5 ft to more than 11 ft. These ore reserves are estimated to yield 16 million short tons of concentrate from sylvinite (KCl + NaCl) with an average grade of 60% K_2O and 41.1 million short tons of langbeinite concentrate with an average grade of approximately 22% K_2O. Total production in 1999 was over 1.7 million short tons of finished product (IMC Global, Inc., 2000).

Mississippi Potash, Inc. (formerly New Mexico Potash Corporation and Eddy Potash, Inc.) began an expansion project of its facilities in Carlsbad in 1998, which was completed in 1999 at a cost of $8.2 million. Production capacity of red granular potash increased from 445,000 to 545,000 short tons per year (Paydirt, 2000a). There are two facilities at Carlsbad, the East and West mines. The estimated total reserves as of 1999 are 522 million short tons with a grade of 15.2% K_2O. The recoverable reserves are estimated to be 467 million short tons at a grade of 14.5% K_2O (Mississippi Chemical Corporation, 2000). The production capacity is estimated at 1.1 million short tons a year; 1,012,000 short tons was sold in 2000 (Mississippi Chemical Corporation, 2000). Two types of ore are processed. Flotation is used to produce red potash, and hot leach crystallization is used to produce the more pure white potash. In the year 2000 Mississippi Potash's West mine was presented with a Sentinels of Safety Award in the underground non-metal division by the Mine Safety and Health Administration (MSHA) and the National Mining Association for its exceptional safety record.

Zeolites

Zeolites are minerals formed by alkaline alteration of volcanic ash. Clinoptilolite is the predominant mineral having unique physical, chemical, and cation-exchange properties for agricultural, industrial, and environmental applications. Markets include odor control and hygiene products (cat litter), absorbents, filtration media, environmental products, animal feed supplements, soil conditioners, floor-drying agents, mineral fillers, water- and wastewater-treatment products, air filtration media, and cation-exchange products.

St. Cloud Mining Company (a subsidiary of The Goldfield Corporation) operates the largest zeolite mine in the U.S., the Stone House mine in Sierra County. The company has operated the open pit since 1990. The mining properties consist of approximately 1,500 acres and contain 18.3 million short tons of reserves (The Goldfield Corporation, 2000). Clinoptilolite is found in the altered Tertiary tuff of Little Mineral Creek (White et al., 1996). Clinoptilolite is mined, crushed, dried, and sized without beneficiation and shipped packaged to meet customers' specifications. In the year 2000 St. Cloud produced 16,422 short tons of natural zeolite, compared to 15,013 short tons in 1997, 14,095 short tons in 1998, and 14,456 short tons in 1999. St. Cloud Mining Company has made several modifications to its zeolite operation, including the addition of cation-exchange capacity for value-added products and additional classification capabilities to expand markets for their products. The modern facility can crush and size as much as 500 short tons per day.

Pumice

New Mexico ranked 4th in pumice production in 1999 and 3rd in 2000 out of six pumice-producing states. The main use for pumice is as an aggregate in lightweight building blocks and assorted building products. Other major applications for pumice and pumicite include abrasives, absorbents, concrete aggregates and admixtures, filter aids, horticulture (including landscaping), and the stonewashing of denim.

Pumice is found in the Jemez Mountains and the Mogollon–Datil volcanic field (Hoffer, 1994); however, only six operations are currently active in New Mexico. El Cajete pumice mine expansion in the Jemez Mountains (Copar Pumice Company) was delayed until preparation of an EIS (draft released early 1997). The mine opened in 1997 and will operate for 10 yrs. Reserves are estimated at 100,000 short tons of pumice that will be used in making stonewashed jeans. Other pumice mines are active in the region.

Mica

New Mexico ranked 4th in scrap-mica production out of six mica-producing states. Mica is used as a functional filler in building materials because of its unique physical characteristics, including its light color, flexibility, durability, thermal properties, and weight. It is used in the manufacture of many other industrial and consumer

TABLE 3—Characteristics of coal (from Energy, Minerals and Natural Resources Department, 2000).

Coal type	Carbon content (%)	Heat value (BTUs/lb)	Use	Where found
Anthracite	86–98	over 15,000	home heating	NE Pennsylvania
Bituminous	45–86	10,500–15,500	electric power generation; coke production	Eastern and midcontinent coal fields
Subbituminous	35–45	8,300–13,000	electric power generation	Western states, Alaska and New Mexico
Lignite	25–35	4,000–8,300	electric power generation	Primarily Texas, but also Montana, North Dakota, and some Gulf Coast states

products such as joint compound, paints, automotive sound deadening materials, thermoplastics, coatings, and cosmetics.

Only one mine produces mica in New Mexico, the MICA mine in Taos County, operated by KMG Minerals Division of Franklin Industries, Inc. from 1990 through 1999. Mica is produced from a muscovite quartz schist of Proterozoic age (Nelson, 1996). Reserves are estimated as exceeding 4 million short tons (Nelson, 1996). The mine announced expansion plans in early 1999. The current mine is the 4th largest scrap-mica mine in the U.S. and covers approximately 15 acres. The expansion calls for an increase to 90 acres within 20 yrs. The nearby Picuris Pueblo opposes any expansion of the mine. Oglebay Norton Company acquired the mine in December 1999 from Franklin Industries.

Cement

Cement commonly refers to hydraulic cement, especially portland cement. Hydraulic cements are those that have the property of hardening under water and are the chief binding agents for concrete and masonry. Portland cement was patented by Joseph Aspdin of Leeds, England, in 1824, and today, it is the predominant variety of hydraulic cement. The name "portland" was chosen because when set the cement resembled a building stone quarried from the Isle of Portland off the southern coast of England. Portland cement concrete is a principal construction material. Most of the cement produced in the U.S. is portland cement; however, some masonry cement, a finer mixture of portland cement and other constituents, used for stucco and mortar, is also produced. Portland cement shipments from New Mexico to the final customer amounted to 732,000 metric tons in 1998 and 777,000 metric tons in 1999. Shipments of masonry cement are reported as 7,000 metric tons in 1998 and 5,000 metric tons in 1999 (van Oss, 2000).

Gypsum

New Mexico ranked 7th in gypsum production out of the 20 states that mine it (Olson, 2000b). Gypsum ($CaSO_4 \cdot 2H_2O$) is a soft mineral with a hardness of 1.5–2 on the Mohs scale and is typically formed in sedimentary environments. Gypsum is used primarily in the manufacture of wallboard for homes, offices, and commercial buildings; other uses include the manufacture of portland cement, plaster of paris, and as a soil conditioner.

Perlite

New Mexico ranks 1st in perlite production of the six U.S. perlite-producing states. Perlite is weathered (hydrated) natural glass that is formed by the rapid cooling of viscous, high-silica rhyolite lava. In New Mexico, perlite is found in lava flows and lava domes that are typically 3.3–7.8 Ma (Chamberlin and Barker, 1996; Barker et al., 1996). The distinguishing feature of perlite from other volcanic glasses is that when heated above 1,600º F, it expands or pops to 4–20 times its original volume to form lightweight, glass foam. This expansion is due to the presence of 2–6% combined water in the mined perlite. This expansion also results in a white color. Whereas the mined perlite may range from waxy to pearly, light gray to black or even brown, blue, or red, the color of expanded perlite ranges only from snowy white to grayish white. Perlite is used in building-construction products, horticultural aggregates, filter aids, and fillers. Perlite is produced from four mines in New Mexico (Chamberlin and Barker, 1996; Energy, Minerals and Natural Resources Department, 2000): the Socorro Perlite mine, Socorro County; No Agua mine and El Grande mine, Taos County; and United States Gypsum mine, Cibola County.

Crushed and dimension stone

Crushed stone is one of the most accessible natural resources and is a major basic raw material used in construction, agriculture, and other industries. Despite the low value of its basic products, the crushed stone industry is a major contributor to and an indicator of the economic well being of any city, county, state, or country. Crushed stone is quarried throughout New Mexico (Fig. 2), and its uses include concrete aggregate, bituminous aggregate, roadstone and coverings, riprap, and railroad ballast (Tepordei, 2000). Common rock types in New Mexico include basalt, granite, rhyolite, limestone (includes dolostone and marble), sandstone, shale, scoria, and volcanic cinder. The average 1999 value for crushed stone produced in New Mexico was $5.98 per metric ton as compared to $4.25 in 1998 (Tanner and McLemore, 2001b).

Dimension stone is natural rock quarried as blocks or slabs that meet specifications as to size (width, length, thickness), hardness, and shape. Color, grain texture and pattern, and surface finish of the stone are typically specified as well. Durability (essentially based on mineral composition, hardness, and past performance), strength, and the ability of the stone to take a polish are other important selection criteria. Dimension stone is used primarily in blocks, building construction, monuments, civil structures, curbing, rubble, and landscaping. Dimension stone may be quarried in large blocks that are later cut for final finishing, or it may be sold in natural or broken pieces that remain unfinished. In general, commercial dimension stone is quarried from deposits of durable rock with few fractures. The most important dimension stone quarry in New Mexico is the Belen travertine mine, operated by the New Mexico Travertine Company

The average 1999 value for dimension stone produced in New Mexico was $204 per metric ton—an increase of 3.6% from that of 1998 (Dolley, 2000). The average unit values for different types of dimension stone throughout the U.S. were: granite, $263 per metric ton; limestone, $168 per metric ton; sandstone, $132 per metric ton; marble, $237 per metric ton; and slate, $490 per metric ton. Available price data show considerable variation, not only among the different types of stone, but also among different appearances of the same type of stone. Color, grain structure, and finish contribute significantly to price and marketability (Dolley, 2000).

Sand and gravel

Sand and gravel, like crushed stone, are readily accessible natural resources and major basic raw materials used for construction, agriculture, and industry. Sand and gravel also have a low value, yet they too are major contributors to and indicators of economic well being. Sand and gravel are quarried throughout New Mexico (Fig. 2) and are used for concrete aggregate and concrete products, plaster and gunite sands, asphalt concrete aggregates, road base and coverings, fill, railroad ballast, and snow and ice control. The average 1999 value for sand and gravel produced

TABLE 4—Coal production in New Mexico 1998–2000 (from Energy, Minerals and Natural Resources Department, 2000). — not available. [1]Data from Energy Information Administration, 2000a, table 14. [2]Data from Energy Information Administration, 2000a, table 10.

Mine	County	1998		1999		2000	
		Coal production (short tons)	U.S. rank by size	Coal production short tons)	U.S. rank by size	Coal production (short tons)	U.S. rank by size
Navajo	San Juan	8,417,120	18	9,374,060	16	8,489,100	17[1]
McKinley	McKinley	6,923,700	21	7,183,365	23	5,247,623	33[1]
Lee Ranch	McKinley	4,790,614		4,929,848		5,080,835	
La Plata	San Juan	3,880,268		4,285,457		4,757,674	
San Juan	San Juan	2,884,262		1,906,228		2,625,419	
Ancho	Colfax	1,486,400		1,166,378		1,137,181	
Total		28,382,364	12	28,845,336	12	27,337,832	12[2]

in New Mexico was $4.99 per metric ton (Tanner and McLemore, 2001b). Most of the quarries are located along I–25, I–10, I–40, and in populated areas, such as Albuquerque, Las Cruces, Santa Fe–Taos, and Farmington.

Clay

Two types of clay are mined in New Mexico: common and fire clay. Common clay is used for making bricks, roofing granules, and quarry tile. In northern New Mexico commercial adobe yards produce adobe bricks from local alluvial materials. In 1999 New Mexico ranked 6th in the production of fire clay out of six producing states; production amounted to 1,000 metric tons (Virta, 1999). Fire clay for use in the Hurley copper smelter is quarried from Luna and Grant Counties.

Gemstones and semi-precious stones

Gemstones and semi-precious stones produced in New Mexico include turquoise, geodes, agate, azurite, fluorite, onyx, smithsonite, barite, moonstone, and peridot. Production statistics for 1998–2000 are withheld because many non-commercial collectors do not report their income. In 1993 the value of gemstone production was $22,000, and the average over the previous 5 yrs was approximately $76,000, mostly from turquoise (Austin, 1994). However, depletion of the known deposits and difficulty in and expense of adhering to federal, state, and local environmental regulations have closed most of the commercial mines.

Turquoise ($Al_2(OH)_3PO_4 \cdot H_2O$) is an opaque, cryptocrystalline mineral, with a hardness of 5–6 on the Mohs scale. Turquoise was mined from deposits in the Cerrillos Hills, Santa Fe County; Burro Mountains, Grant County; Orogrande district, Otero County; Little Hatchet Mountains, Luna County; and Guadalupe Mountains, Eddy County before 1993 (Austin, 1994). Today, mostly non-commercial collectors mine only small amounts from these areas. A new deposit of turquoise has been found in Lincoln County; the exact location is withheld. Unusual scalenohedral forms of massive turquoise, most likely pseudomorphs after calcite, have been found in southwestern New Mexico. The average length is 3.1 inches. As very few of these forms are known to exist, specimens are valued at several hundred dollars a piece. Two specimens are at the New Mexico Mineral Museum in Socorro, and one is on display in the Mineral Museum of Royal Scepter Gems and Minerals in Silver City. Also see photos at http://www.zianet.com/RoyalScepter/ (accessed on March 28, 2001).

Agate, jasper, chert, and petrified wood (all varieties of quartz) are found in many different geological settings in 15 counties throughout New Mexico. Mining claims in Luna County remain active, and commercial mining occurs periodically (McLemore et al., 2001). Agate from Luna County wholesaled for $50 per 100 pounds and retailed at $1 per pound. "Picture" and dendritic jasper are found south of Gage in Luna County. The dendritic-type jaspers in these deposits are sold for $1–$12. Amethyst quartz is found throughout New Mexico; specimens from the Steeple Rock district, Grant County sell for $5–$200.

Geodes are found throughout southern New Mexico (Colburn, 1999; McLemore and Dunbar, 2000; McLemore et al., 2001). Geodes are hollow or near-hollow, crystal-lined cavities found in igneous and sedimentary rocks. "Thundereggs," also known as spherulites, are solid or near-solid nodules formed by magmatic and volcanic processes and are found only in volcanic rocks. The high-grade rough (uncut) thundereggs wholesale for $8 per pound, and select cut specimens range as high as several hundred dollars.

Many smaller localities in the state yield gems, semi-precious stones, and mineral specimens. Azurite is collected from a number of copper deposits throughout New Mexico. Azurite roses have been found at the Nacimiento mine in Sandoval County and average $8–$12 a piece. Fluorite, galena, linarite, smoky quartz, and a variety of other minerals are collected from the Bingham district in Socorro County. Smithsonite and barite are collected from the Magdalena district in Socorro County. The pegmatite at the Harding mine in Taos County is a favorite collecting locality for lepidolite, beryl, muscovite, and other minerals. Selenite and alabaster are collected in southeastern New Mexico. Clear to gray to brown moonstone, a sanidine gemstone, is found in the Black Range, Grant County. Gem quality, green to brown peridot is found at Buell Park, McKinley County, and in Kilbourne Hole and the Potrillo volcanic field, Doña Ana County. Champagne-colored bytownite feldspar from Pueblo Park in Catron County is being sold as cut pieces or set in sizes of approximately 8 carats.

Mineral collectors are advised to personally ask for permission to collect on private and state-owned land.

Other industrial minerals

Silica flux is used in copper smelting to lower the melting temperature of the ore, make fluid slag, and allow the molten metal to settle to the bottom of the furnace. Silica flux is mined from two quarries near the copper smelter at Hurley. Silica flux was mined in the Little Hatchet Mountains near the Hidalgo smelter at Playas, but operations ceased when the smelter closed in 1999. A silica flux mine in Luna County at Goat Ridge also has operated in the past but is now closed.

Sulfuric acid is produced as a byproduct of copper smelters in Grant County. It is an important chemical used in many industrial applications, including copper recovery from SX-EW plants.

Helium is produced from the Shiprock and Ute Dome fields in the San Juan Basin. Helium is used in cryogenic applications, welding cover gas, pressurizing and purging, controlled atmospheres, leak detection, gas mixtures, and other uses.

Humates are weathered coal or highly organic mudstone that is found in coal-bearing sequences. New Mexico has significant concentrations of humates, predominantly in the Fruitland and Menefee Formations in the eastern San Juan Basin. Humate is produced from five mines in New Mexico. One of the oldest humate operations is Mesa Verde Resources, which operates two pits in the basin and a mill east of Bernalillo. Menefee Mining operates one pit and a mill near Cuba; however, Agronics' mine and mill south of Cuba are now closed. A mine processing site and transportation facility are operated by U-Mate International, Inc., in the Gallup area. Humate is used as a soil conditioner and as

TABLE 5—Copper production in New Mexico 1998–2000 (as total recoverable copper, from Phelps Dodge Corp. Annual Report, 2000, 2001).

Mine	1998		1999		2000	
	Concentrate and precipitate production (short tons)	Leached production (short tons)	Concentrate and precipitate production (short tons)	Leached production (short tons)	Concentrate and precipitate production (short tons)	Leached production (short tons)
Chino	85,500	72,400	74,300	55,800	87,000	48,600
Tyrone	—	82,600	—	80,100	—	79,300

an additive to drilling muds (Hoffman et al., 1996). Approximately 12.1 billion short tons of humate resources are within the San Juan Basin (Hoffman et al., 1996).

Iron ore as magnetite is shipped from the magnetite tailings at Phelps Dodge's Cobre mine in Grant County and is used by cement plants to increase the strength of their cement. An operation is being developed at the Smokey mine in the Capitan Mountains, Lincoln County, to produce magnetite–hematite from contact-metasomatic deposits.

Although garnet has not been produced in New Mexico from 1998 through 2000, at least one company is examining areas in the state for potential resources of garnet that could be used as an abrasive. Garnet typically is found in skarn deposits in southern and central New Mexico, and in some areas, garnet is a major constituent of waste rock piles remaining after recovery of metals (Lueth, 1996). For example, approximately 135,000 metric tons of 20–36% garnet is estimated to be in four tailings piles at Hanover in Grant County (Cetin et al., 1996). Average values for crude garnet concentrates ranged from approximately $55 to $120 per metric ton in 1999 (Olson, 2000a).

Addwest Minerals, Inc.'s Wind Mountain nepheline syenite project in southern Otero County is for sale. The nepheline syenite was to be used as a constituent in amber-colored beverage containers, ceramics, and flatglass (McLemore and Guilinger, 1996; McLemore et al., 1996). The nepheline syenite contains high iron compared to other commercial sources of nepheline syenite, but, when the Wind Mountain nepheline syenite is crushed and passed through a specialized rare-earth magnet, the resulting nonmagnetic product is similar in composition to Grade B product specified by Unimin Canada Ltd. The magnetic fraction can be sold as millite, an iron-rich additive required for controlling the color of glass. Several other consumers have tested the nepheline syenite and found it suitable for use in ceramics, fiberglass, and flatglass. The lack of free silica as quartz also enables use of the Wind Mountain nepheline syenite as a silica-free abrasive. Interesting textural variations in the main mass of the syenite, wisps of finer grained material waving through the rock, also make it an attractive building stone. Mining will be by underground, room and pillar methods. An adit was started in early 1995. Processing will involve crushing, grinding, magnetic separation, and screening. At full production, Wind Mountain is expected to process 3,000 short tons per day or 700,000 short tons per year. Current proven, probable, and inferred reserves total 200 million short tons for a mine life of more than 100 yrs.

Uranium

Uranium is used as a fuel for nuclear reactors and has limited industrial applications as a heavy metal. Only one company in New Mexico, Quivira Mining Company owned by Rio Algom Ltd. (successor to Kerr McGee Corporation), produced uranium during 1998–2000 from waters recovered from inactive underground operations at Ambrosia Lake, Grants (mine-water recovery). Billiton Copper Holdings, Inc., a wholly-owned subsidiary of Billiton, purchased Rio Algom Ltd. in late 2000. Mine-water recovery had ceased in 1992 because of the decline in the price of uranium, but it resumed in 1994. Approximately 232,000 pounds of uranium oxide ($U_3O_{8)}$ was produced from mine-water recovery in 1999, and 200,000 pounds was recovered in 1998. In the year 2000, 21,548 pounds of U_3O_8 was produced. New Mexico ranks 2nd in uranium reserves in the U.S., which amount to 15 million short tons of ore at 0.277% U_3O_8 (84 million pounds of U_3O_8) at $30 per pound (Energy Information Administration, 2000b).

Other operations in New Mexico remained inactive during 2000. Hydro Resources, Inc. has suspended plans to mine uranium by in situ leaching at Churchrock until the uranium price increases. Reserves at Churchrock are estimated as 15 million pounds of U_3O_8. NZU, Inc. also is planning to mine at Crownpoint by in situ leaching. Rio Grande Resources Company is maintaining the closed facilities at the flooded Mt. Taylor underground mine in Cibola County. In late 1997 Anaconda Uranium acquired the La Jara Mesa uranium deposit in Cibola County from Homestake Mining Company The sandstone uranium deposit was discovered in the late 1980s in the Morrison Formation and contains approximately 8 million pounds of 0.25% U_3O_8.

State Mine Inspector's annual mine safety awards

Each year the State Mine Inspector (Bureau of Mine Inspection) recognizes excellence in mine safety in New Mexico. Gilbert Miera (State Mine Inspector) presented mine safety awards for 2000 in the following seven categories:

- **Small sand, gravel, or stone**–Bar J Sand and Gravel, Sandoval County
- **Small surface operation**–Mississippi Potash, Inc., North, Eddy County
- **Medium underground operation**–Mississippi Potash, Inc., West, Eddy County
- **Large surface operation**–Phelps Dodge Tyrone, Inc., Grant County
- **Large underground operation**–Mississippi Potash, Inc., East, Eddy County
- **Mining contractor**–Bowen Industrial Contractors, Inc.
- **Non-producing mine operations**–Cobre Mining Company, Continental surface mine, Grant County

In addition, the following 10 producers received Accident-Free Year Certificates for no loss-time accidents in 2000:

- Phelps Dodge Mining Company, Chino Mines Company, Grant County
- Certified Sand Company, Inc., Bill Inman pit, Doña Ana County
- Gallup Sand and Gravel Company, San Antone pit, McKinley County
- Burn Construction Company, Inc., Picacho Peak, Doña Ana County
- Doug Foutz Construction Company, Inc., Foutz pit, San Juan County
- City of Roswell, Roswell pit, Chaves County
- American Minerals, Inc., Deming mill, Luna County
- Agronics, Inc., Clod Buster mine and mill, Sandoval County
- Dial Oil Company, San Juan County
- Badger–Western Exploration, Inc., Grant County

New Mexico Mining and Minerals Division reclamation awards

Each year, the New Mexico Mining and Minerals Division (NMMMD) recognizes exemplary reclamation of mined lands in New Mexico. Award nominations are accepted in a number of different categories depending on the size of the mine, the nature of the operation, and its resulting disturbance. The 2000 reclamation

awards were presented by Jennifer Salisbury, Secretary of the Energy, Minerals and Natural Resources Department at the New Mexico Mining Association annual convention in Farmington on September 19, 2000. The three award winners were:

1. St. Cloud Mining Company, Sierra County, for their successful reclamation of the San Pedro mine, Santa Fe County, and outstanding efforts in meeting the needs of the state, county, and concerned citizens.
2. Smith and Aguirre Construction Company, Doña Ana County, for their successful safeguarding and reclamation practices performed at abandoned mines near Albemarle and Bland, Sandoval County.
3. Phelps Dodge Mining Company for their innovative and successful reclamation practices at the Pinos Altos mine, Grant County.

Outlook

Minerals production in New Mexico has continued to decline since maximum annual production was achieved in 1989 (Table 1). This decline is a result of many complex and inter-related factors; two of the more important ones are declining commodity prices and declining quality of ore. Other factors have hampered new mines from opening in the state: water rights issues, negative public perceptions toward mining, the state land moratorium, and the complexity of the entire regulatory process and the length of time required at local, state, and federal levels. All of these factors add to the cost of mining, not only in New Mexico but also throughout the world. A healthy mineral industry is vitally important to the economy of New Mexico and to maintenance of public education and services. The minerals industries also provide property and corporate income taxes, and their 7,021 direct employees (excluding oil and gas) contribute personal income taxes from approximately $278 million in earnings (Table 2). The multiplier effect of the dispersal of these wages through local economies increases their impact many fold.

Acknowledgments. Special thanks to the company personnel for discussions and information on the status of their mines. Robert Colburn and Susan Brians were particularly helpful in providing information on the market for gems and semi-precious stones in New Mexico. Robert North provided information on Phelps Dodge Corporation, and Bruce Walker provided information on Molycorp. James Barker, Virgil Lueth, and Jim O'Hara reviewed an earlier version of this manuscript, and their comments are appreciated. Mike Breese and Kelly Donahue are acknowledged for technical assistance. Peter Scholle, Director, New Mexico Bureau of Geology and Mineral Resources and State Geologist, is acknowledged for his support and encouragement of this project. The New Mexico Bureau of Geology and Mineral Resources Cartography Department drafted the figures.

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Appendix 1

Conversion factors from English to metric units.

To convert	Multiply by	To obtain
ounces	3.1103×10^{1}	grams
pounds	4.536×10^{-1}	kilograms
short tons	9.078×10^{-1}	metric tons