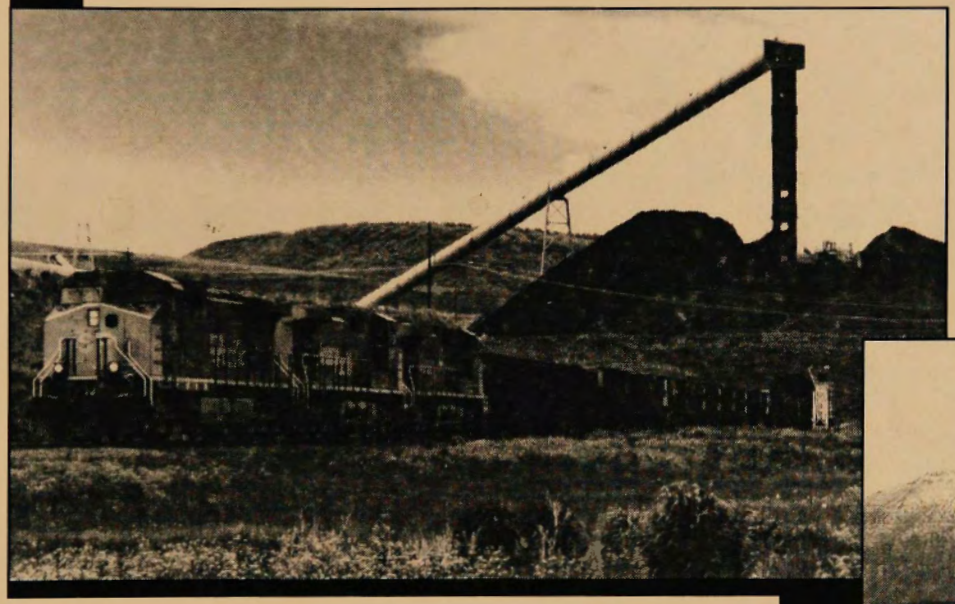
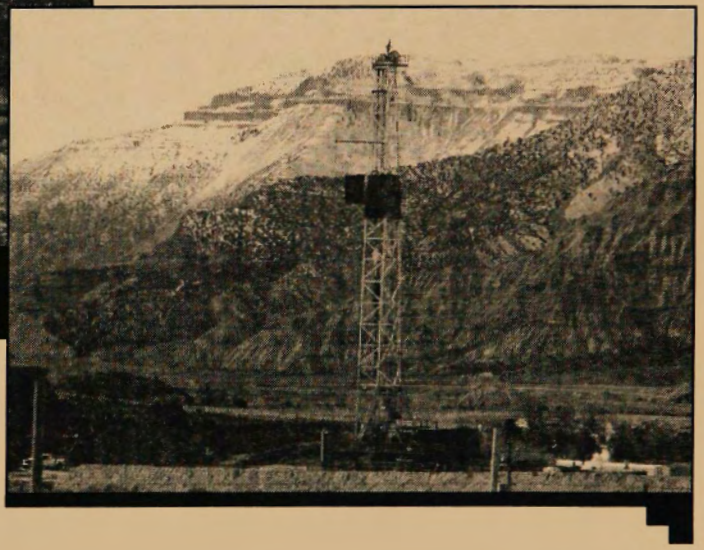
Information Series 44

Colorado Mineral and Mineral Fuel Activity, 1997

By James A. Cappa,
Wynn Eakins, and
H. Thomas Hemborg





Colorado Geological Survey
Department of Natural Resources
Denver, Colorado
1998

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Frontispiece: (1) Railroad load-out facility at Twentymile Mine, Routt County. Photo courtesy of Bob Lynn and Cyprus Amax Minerals Co.; (2) Barrett Resources development well drilling ahead, Rulison field, Garfield County. Photo courtesy of Jennie Hemborg.

INTRODUCTION AND ECONOMIC FACTORS

The Colorado Geological Survey Mineral and Mineral Fuels Section estimates the total value of 1997 mineral fuel production in Colorado to be $2,327 million dollars. The value of the coal production is estimated to be $356 million, oil at $457 million, natural gas at $1,433 million, carbon dioxide at $75 million, and uranium at $6 million.

Natural gas production in the state reached a new record of 625.9 billion cubic feet (BCF) in 1997. Oil production continued its gradual decline. Prices for natural gas increased some 39 percent during the year while crude oil prices declined about 7 percent. Coal production increased from the 1996 level of about 25 million tons to a new record of 27.4 million tons. The contract cost for a ton of coal continues to go down as productivity rises. Uranium production is increasing. Currently two mines in Colorado are producing uranium.

The U.S. Geological Survey's Mineral Information Office estimates the 1997 Colorado mineral production in 1997 at $523 million, up 2 percent from the 1996 value of $513 million. The increased value is mostly due to increased molybdenum, sand and gravel and crushed stone production. The total value of both mineral and mineral fuel commodities produced in the state during 1997 is $2,850 million (Fig. 1).

The value of Colorado's mineral and mineral fuel production is realized in many ways including employment, taxes, and royalties that flow back to the state and local governments. The value of Colorado's share of federal mineral royalties increased 36 percent to $43,982,442 in 1997 from $ 32,394,356 in 1996. A substantial portion of the Colorado share of royalties goes directly to public education and local governments (Fig. 2).

Severance taxes on mineral and mineral fuel production also provide revenue to state and local governments. According to state law, 50 percent of the severance tax revenue flows to local governments and 50 percent flows into a

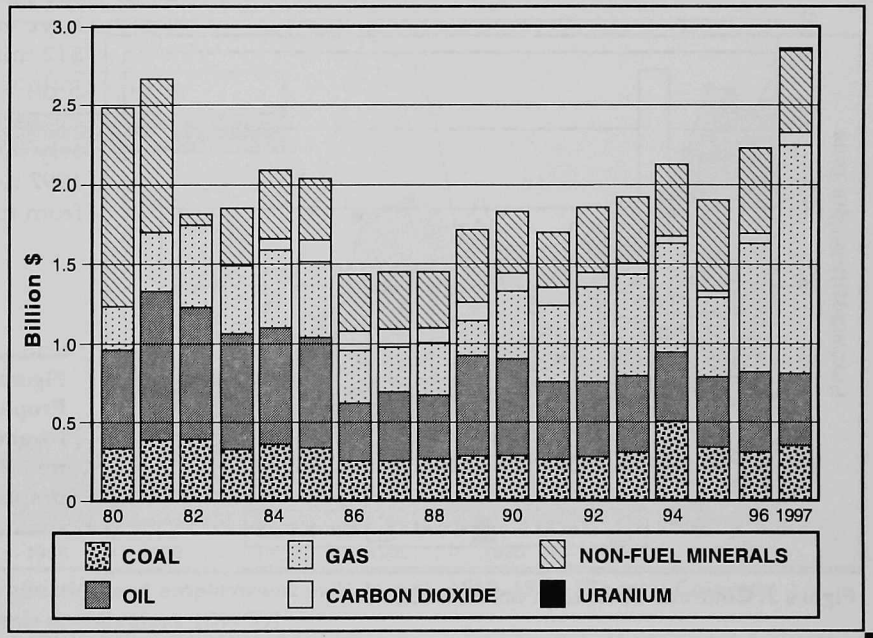

Figure 1. Value of Colorado mineral and mineral fuel production.

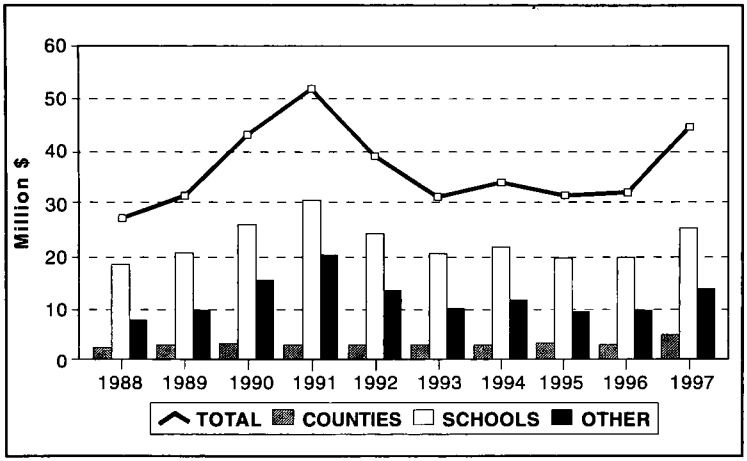

Figure 2. Federal mineral lease revenue distribution in Colorado.

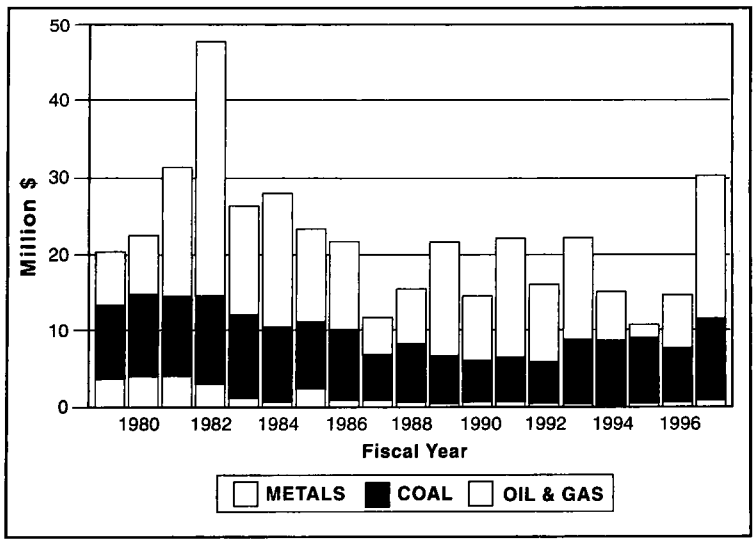

Figure 3. Colorado severance tax collections.

State trust fund to "replace" depleted natural resources and complete water projects. Legislation passed in 1996 allows some of the state share of severance tax to be used by agencies within the Department of Natural Resources that promote and regulate the mineral and mineral fuel industries. Severance tax collections for the past five years have varied between $12 million and $29 million (Fig. 3).

Estimated property taxes paid in 1997 to the counties from mineral and mineral fuel properties totaled an estimated $140 million (Fig. 4). La Plata, Weld, and Clear Creek counties all received over $10 million each in property tax revenue. Denver County was the only county that did not receive any revenue from mineral related property tax.

The University of Colorado College of Business Administration estimates employment in the mineral and mineral fuel industries in 1997 to be 13,400, down 1.5 percent from the 1996 level of 13,600. This sector of the economy continues a steady ten-year decline in employment from a 1988 level of 20,700 persons. The outlook for 1998 is more positive as employment levels are expected to increase by 300 jobs. The average annual wage of $49,000 for the mineral and mineral fuel industries is high in comparison to other sectors of the state's economy. The total contribution of mineral and mineral fuel employees' wages to the state's economy is about $656 million.

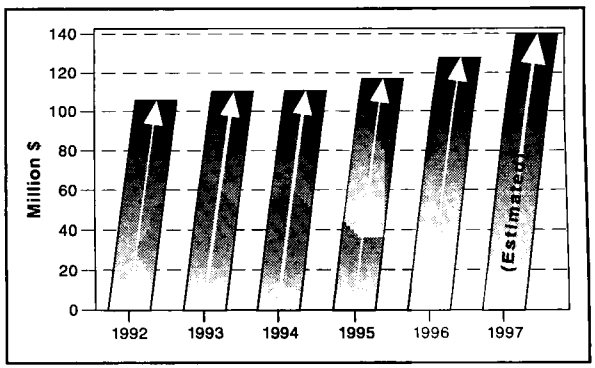

Figure 4. Property tax revenues from mineral properties.

COAL

PRODUCTION

The Colorado coal industry has exhibited an overall trend of production growth through the 1970s, 1980s, and 1990s (Fig. 5). In 1997, Colorado coal companies produced a record amount of coal and the Energy Information Administration (EIA) ranked Colorado 10th among coal producing states through the first ten months of the year. Production in 1997 was over 27.4 million tons, an 11 percent increase from the 24.7 million tons produced in 1996. During 1997, there were 14 mines producing coal in the state (Fig. 6), up from 13 mines in December of 1996. Most of the production was shipped to purchasers by rail.

Coal was produced from ten of Colorado's 63 counties in 1997—Delta, Fremont, Garfield, Gunnison, LaPlata, Mesa, Moffat, Montrose, Rio Blanco, and Routt (Fig. 7). Coal production from the ten underground mines was two-thirds of the total, with production from surface mines making up the remaining third. The three largest mines each produced over 5.5 million tons. Together, these three mines accounted for over two-thirds of the total state production. The state's largest producer was the Cyprus Amax Twentymile underground mine in Routt County with 7.2 million tons. ARCO's West Elk underground mine in Gunnison County was the next highest producer with 5.7 million tons (Fig. 8). Moffat County's Colowyo Mine was the third most productive mine in the state, and the most productive surface mine, at 5.5 million tons.

ECONOMIC IMPACT

By the end of December 1997, Colorado's coal mines employed 1,591 miners (Table 1), an increase of 12 percent over the 1,416 miners at the end of 1996. The increase in employment reverses a generally downward trend in recent years. According to the Colorado Department of Labor and Employment,

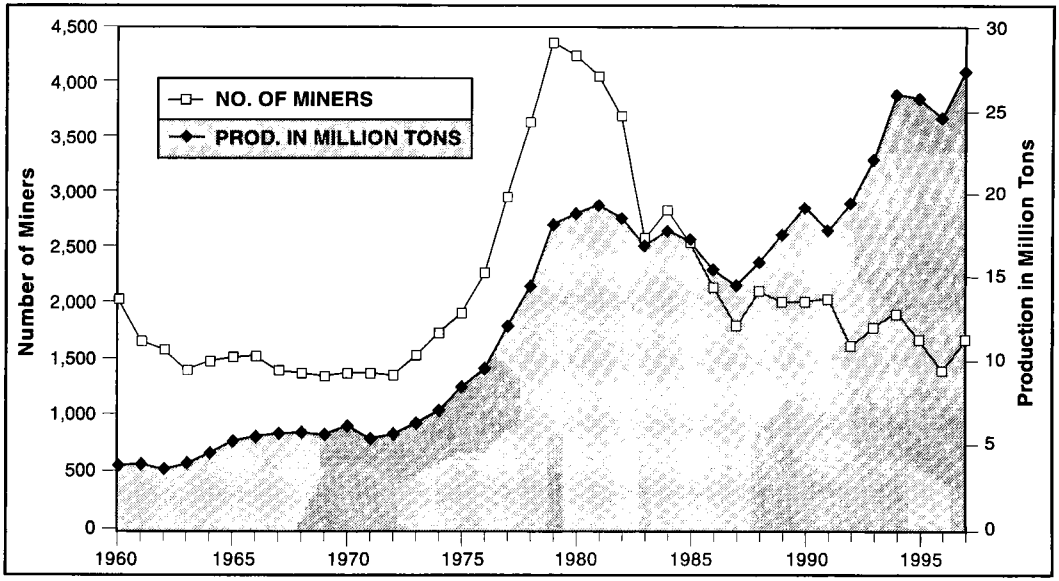

Figure 5. Coal production and employment in Colorado, 1960–1997. [Source: Colorado Division of Minerals and Geology (DMG)]

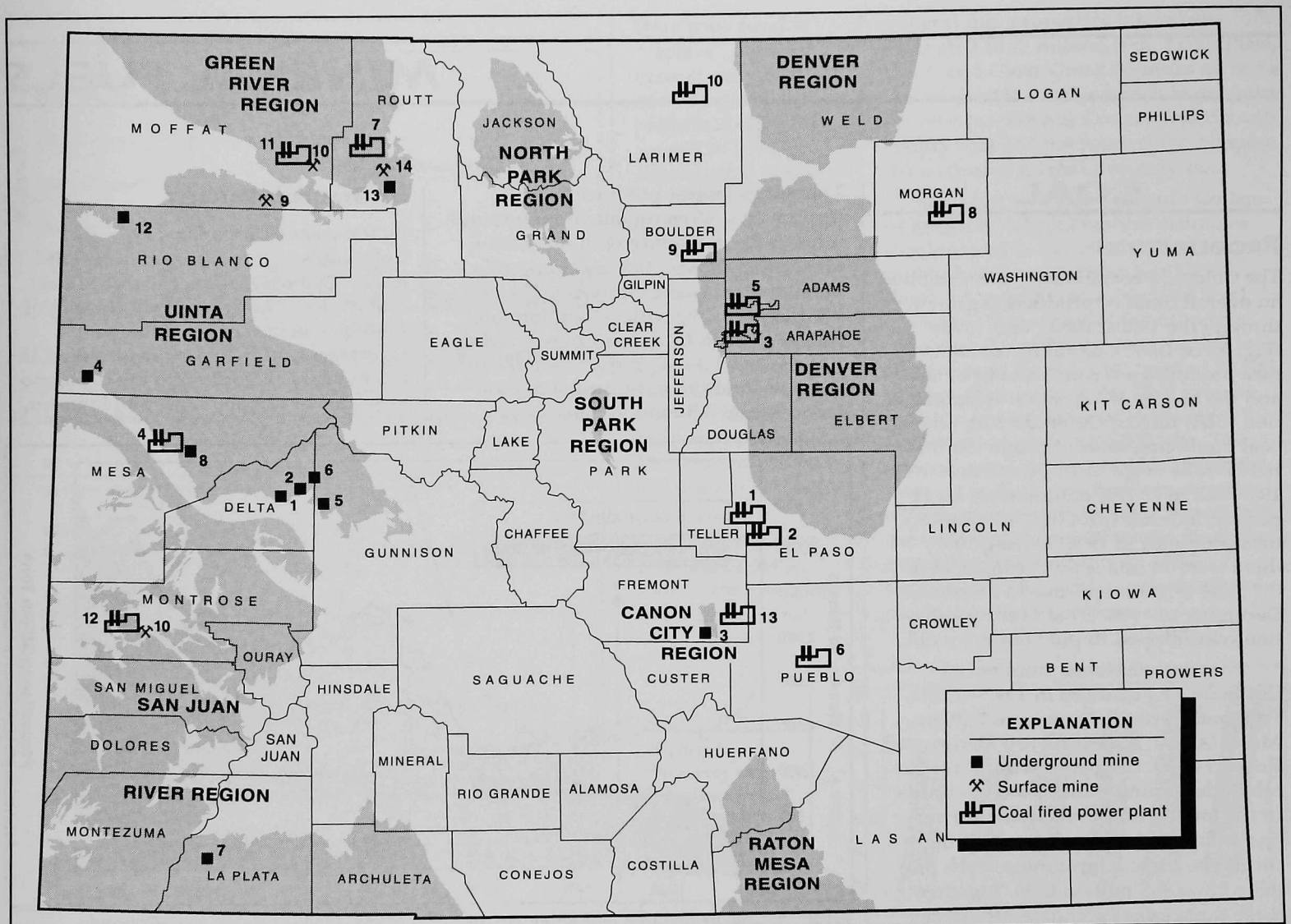

Figure 6. Coal mines and coal fired power plants in 1997. Mine numbers correspond to Table 1 and plant numbers correspond to Table 3.

Table 1. Colorado mines that produced coal in 1997. (Source: DMG)

Mine No.	County	Coal Region	Mine Name	Operator	Twp, Rge	Geologic Formation	Bed Names	Seam Thickness (ft)	BTU Avg	Mine Type	Mining Method	1997 Prod. (tons)	Dec. 1997 Miners	Shipment Method
1	Delta	Uinta	Bowie #1	Bowie Resources Ltd.	13S, 92W	Mesaverde	D	10–20	11,400	U	Continuous	758,181	11	Truck, rail
2	Delta	Uinta	Bowie #2	Bowie Resources Ltd.	13S, 91W	Mesaverde	D	8–16	12,000	U	Continuous	49,017	60	Truck, rail
3	Fremont	Canon City	Southfield	Energy Fuels Coal, Inc.	20S, 69W	Vermejo	Jack-O-Lantern Red Arrow	6 5.5	11,100	U	Continuous	216,043	35	Rail, truck
4	Garfield	Uinta	McClane Canyon	Grand Valley Coal Co.	7S, 102W	Mesaverde	Cameo	10–20	10,7000	U	Continuous	49,115	0*	Truck, rail
5	Gunnison	Uinta	West Elk	Mountain Coal Co. (ARCO)	13S, 90W	Mesaverde	B	16	11,700	U	Longwall, Continuous	5,721,549	246	Rail
6	Gunnison	Uinta	Sanborn Creek	Oxbow Carbon & Minerals, Inc. (Pacific Basin Resources)	13S, 90W	Mesaverde	B	18	12,375	U	Continuous	1,601,217	146	Rail
7	La Plata	San Juan River	King Coal	National King Coal, LLC	35N, 11W	Menefee (Mesaverde Group)	Upper bed	5.3–6	13,100	U	Continuous	221,960	59	Truck
8	Mesa	Uinta	Roadside (S. Portal)	Powderhorn Coal Co. (Peabody)	11S, 98W	Mesaverde	Cameo B	7–8	11,800	U	Continuous	436,317	47	Conveyor
9	Moffat	Uinta	Colowyo	Colowyo Coal Co. (Kennecott)	4N, 93W	Mesaverde	A-F, X,Y	8 beds–5.3–12.3	10,461	S	Dragline, shovels, dozers	5,544,254	289	Rail
10	Moffat	Green River	Trapper	Trapper Mining, Inc.	6N, 90W	Mesaverde	G,H,I, Q,R	4, 6,5, 13, 4	9,900	S	Dragline, dozers, hyd. excav.	2,002,097	113	Truck
11	Montrose	San Juan River	New Horizon	Western Fuels Assn.	46N, 15W	Dakota	1 & 2	1.6–3.3, 5.9–7.9	10,300	S	Shovels, dozers	387,330	22	Truck
12	Rio Blanco	Uinta	Deserado	Blue Mountain Energy, Inc.	3N, 101W	Mesaverde	D seam	8–9	10,930	U	Longwall, continuous	1,491,431	126	Rail
13	Routt	Green River	Twentymile (Foidel Creek)	Twentymile Coal Co. (Cyprus Amax)	5N, 86W	Mesaverde	Wadge	9.5	11,200	U	Longwall, continuous	7,258,575	352	Rail
14	Routt	Green River	Seneca II, Seneca II-W, Yoast	Peabody Western . Coal Co	5N, 87W	Mesaverde	Wadge, Wolf Cr., Sage Cr.	11.7, 20.4, 4.6	11,908–12,581	S	Dragline, loaders	1,684,641	85	Truck, rail
Total												**27,421,727**	**1,591**	

Abbreviations: MIne Type: **U**—underground; **S**—surface

* operated February to April, 1997

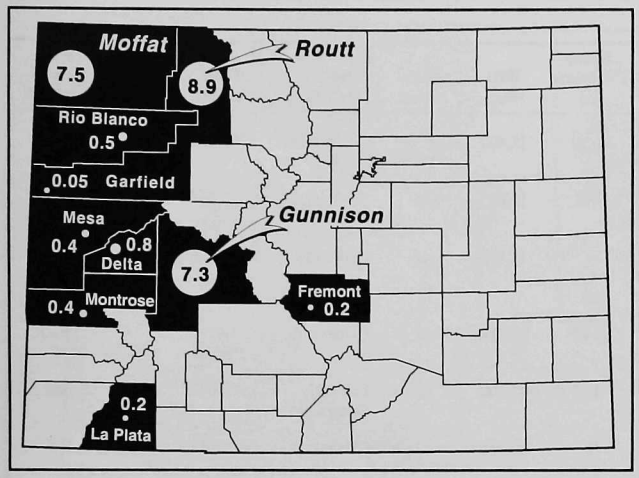

Figure 7. Colorado coal producing counties. Size of circle indicates relative amount of coal production in each county. (Source: DMG)

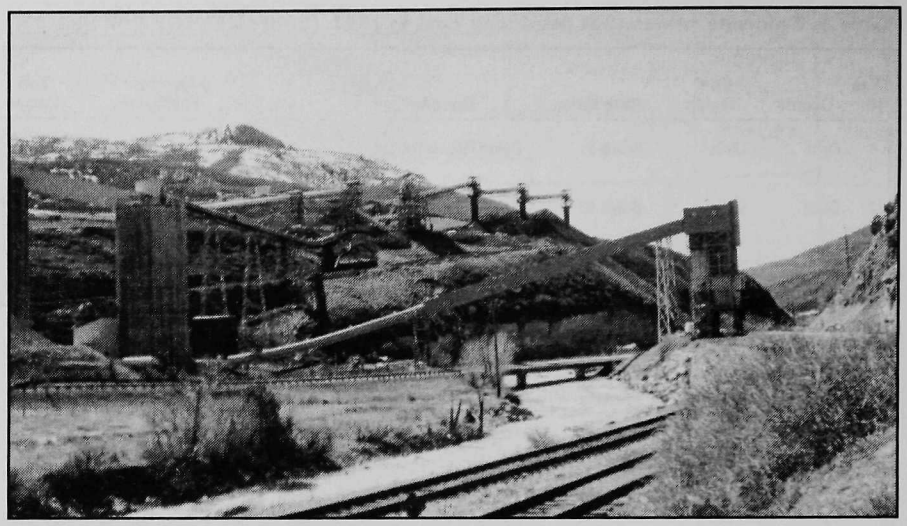

Figure 8. ARCO's West Elk Mine, Somerset Coal Field, Gunnison County.

the average wage of Colorado coal miners was $58,200-more than double the average wage in the state.

According to state mineral revenue auditors with the State Land Board and the Department of Revenue, about $31.6 million came to the state from taxes, royalties and rentals during the 1996-1997 fiscal year (Fig. 9). At an approximate average price of $13 per ton, the spot market average, 1997 production is valued at an estimated $356 million.

Coal Reserves and Geology

Coal underlies 29,600 square miles or 28 percent of Colorado, and the state has some of the highest quality coal in the world. Resources range in rank from

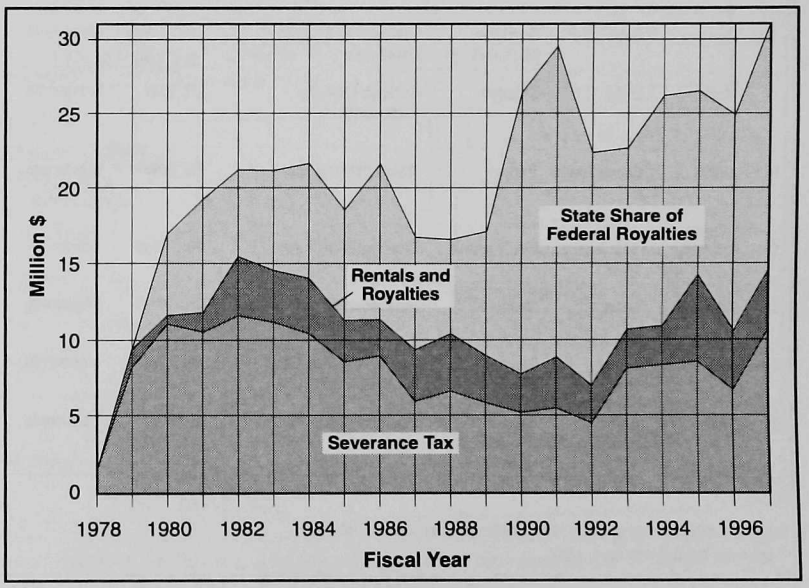

Figure 9. Coal income graph. (Sources: Colo. Department of Revenue, Colo. State Board of Land Commissioners, and U.S. Minerals Management Service)

lignite in the Denver Basin to anthracite near Crested Butte. However, more than 70 percent of the resource is bituminous.

Of the coal currently being mined, the average heat value is high—ranging from 9,900 to 13,100 Btu/lb. Over 70 percent of the mined coal is bituminous; the remainder is subbituminous in rank. All the coal being produced is low sulfur. The ash content of most mined coals is also low at 6 to 10 percent: Figure 10 is a comparison of Colorado coal quality factors with those of several other coal producing states. Much of the coal is clean enough to burn without any washing; however, coal preparation plants serve five of the mines in the state (Table 2). Although some Colorado coal is coking quality, the current production is almost exclusively being used as steam coal.

All the mines in 1997 produced Cretaceous age coals from the Mesaverde, Dakota, or Vermejo Formations. Eleven of the fourteen mines, accounting for about 98 percent of the production, are located in the Uinta or Green River coal regions of northwest Colorado (Fig. 6) and produced Mesaverde coal. Seams mined by surface mining methods in the state ranged from 1.6 to 20 feet thick. Underground-mined seams were anywhere from 5 to over 20 feet thick (although the actual maximum thickness recovered was 12 feet). Overburden depths to mined seams reach a maximum of 2,100 feet.

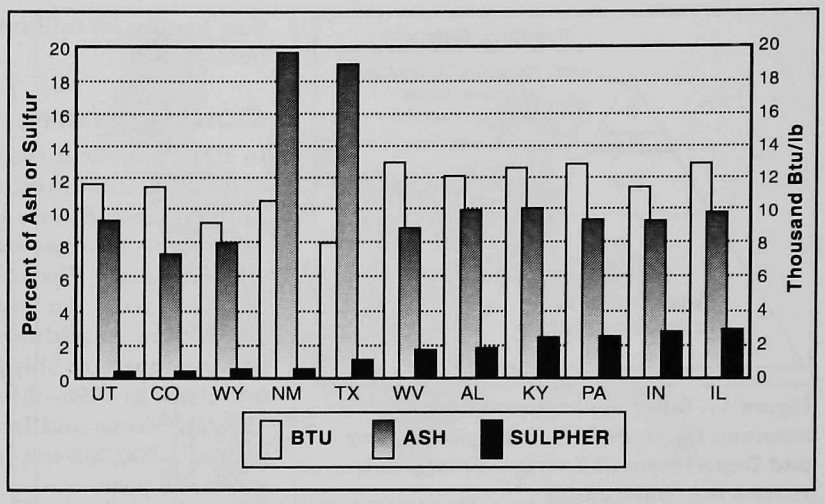

Figure 10. Quality comparison of coal produced in Colorado and selected states. (Source: Analyses from *Keystone Coal Industry Manual*, 1997)

Table 2. Coal preparation plants in Colorado. (Source: 1998 *Keystone Coal Industry Manual*)

Company	Name	Location	Type	Raw Feed (tph)	Year Built
Basin Resources, Inc.	New Elk Prep Plant	Weston	Heavy-media washer, spirals, wash tables	550	1984
Cyprus Amax	Twentymile Coal Co.	Oak Creek	Heavy-media cyclones	250	1995
Energy Fuels Coal, Inc.	Southfield Mine	Canon City	Heavy-media washer and cyclones	240	1979
Powderhorn Coal Co. (Peabody)	Powderhorn Prep Plant	Palisade	Heavy-media washer and cyclones, wash tables	400	1978
Blue Mountain Energy, Inc.	Deserado Mine	Rangely	Heavy-media cyclones, jigs, spirals	900	1983

The Energy Information Administration (EIA) estimates Colorado's demonstrated coal reserves (see Fig. 11) at about 16.8 billion tons (as of January 1, 1995) placing Colorado 8th among the states in demonstrated reserves. Furthermore, of the 16.8 billion ton total, more than 11 billion tons are low sulfur (<0.6 pounds of sulfur per million Btu).

Unfortunately, according to the EIA, about 10 percent of the underground reserves and 11 percent of the surface reserves are inaccessible. In addition, recovery factors for the 90 percent of reserves that are accessible are about 88 percent for the surface reserves and around 50 percent for underground reserves in the state. The overall recovery factor applied to accessible coal in

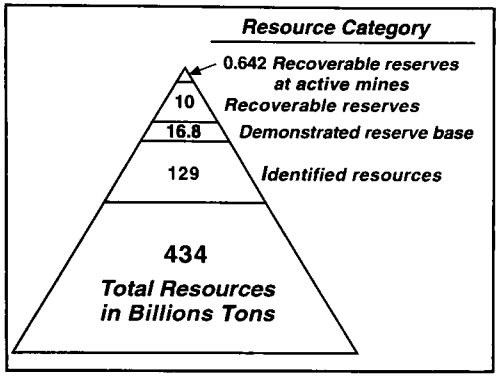

Figure 11. Colorado coal resources and reserves. (Sources: U.S. Geological Survey and Department of Energy—Energy Information Administration)

place was 66 percent in 1995. This gives Colorado an estimated recoverable reserve base of over 10 billion tons remaining as of January 1, 1995-a 350+ year supply at current production rates. (For comparison, production of Colorado coal from the 1860s to the present has been just under a billion tons.)

Recoverable reserves under lease at active mines were 642 million tons in 1996. At current production rates, this is a 23-year recoverable coal supply at operating mines. Colorado's low sulfur and high BTU coal should continue to be in demand from American and foreign electricity producers in the future. Based on planned or recent expansions and previous increases in production, the Colorado Mining Association (CMA) predicts an increase in production to over 30 million tons within the next decade.

Consumption

In 1996, approximately forty percent of Colorado's coal production was burned in the state and sixty percent was shipped to 18 other states (Figs. 12 and 13). Tennessee, Texas, Kansas, Utah, and Missouri were the largest out of state consumers. In addition, a total of 1.4 million tons was shipped to five foreign countries in 1996—Mexico, Japan, Taiwan, Korea and Israel. This represented a 500,000-ton increase over the previous year.

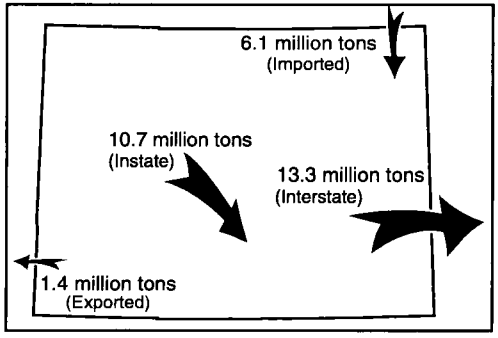

Figure 12. Colorado coal distribution diagram. (Source: Department of Energy-Energy Information Administration)

According to the EIA, total coal consumption in the state in 1996 was about 17 million tons. A dozen Colorado power plants consumed the majority of the total, about 16.4 million tons (Table 3); this coal originated in Colorado's Western Slope mines (Fig. 14) and Wyoming's Powder River Basin. In fact, 95 percent of the energy input at Colorado's electric utilities comes from coal (Fig. 15). Nationwide, 56 percent of electric utility energy input is from coal. Other coal consumers in Colorado were comparatively minor; several industrial plants burned 367,000 tons in 1996. Residential and commercial consumption was only 13,000 tons.

Productivity and Capacity

The larger underground coal mines in the state have been increasing their production by the use of more efficient technology such as longwall mining (See mining method, Table 1). Colorado longwall mines broke state and world underground production records for the third consecutive year. In 1995 and 1996, ARCO's West Elk Mine and the Twentymile Mine, operated by Cyprus Amax, had traded these production records. *Coal Age* magazine reports that in June 1997 the Twentymile Mine established the current world record for monthly underground coal production of 1,001,401 tons, surpassing its previous world record of 944,443 tons set in May 1997. During 1996, the Twentymile Mine completed a $50 million modernization program, which included installation of a state-of-the-art, computerized longwall mining system. This mine has panels over 3 miles long—the longest in the world.

Table 3. Coal-fired power plants in Colorado. (Source: 1998 *Keystone Coal Industry Manual*)

No.	Plant	Utility	Location	1996 Consumption Thou. Tons
1	Drake	Colorado Springs	Colorado Springs	645
2	Nixon	Colorado Springs	Colorado Springs	677
3	Arapahoe	PSC of Colorado	Denver	645
4	Cameo	PSC of Colorado	Cameo	256
5	Cherokee	PSC of Colorado	Denver	1,943
6	Comanchee	PSC of Colorado	Pueblo	2,696
7	Hayden	PSC of Colorado	Hayden	1,525
8	Pawnee	PSC of Colorado	Brush	1,820
9	Valmont	PSC of Colorado	Boulder	506
10	Rawhide	Platte River Power	Wellington	1,195
11	Craig*	Tri-State G&T Assn., Inc.	Craig	4,025
12	Nucla*	Tri-State G&T Assn., Inc.	Nucla	374
13	Clark*	Utilicorp United, Inc.	Canon City	143
Total				**16,450**

*1996 consumption not available. 1995 consumption shown. Based on data for coal received during 1996, 1995 consumption is representative of 1996 consumption.

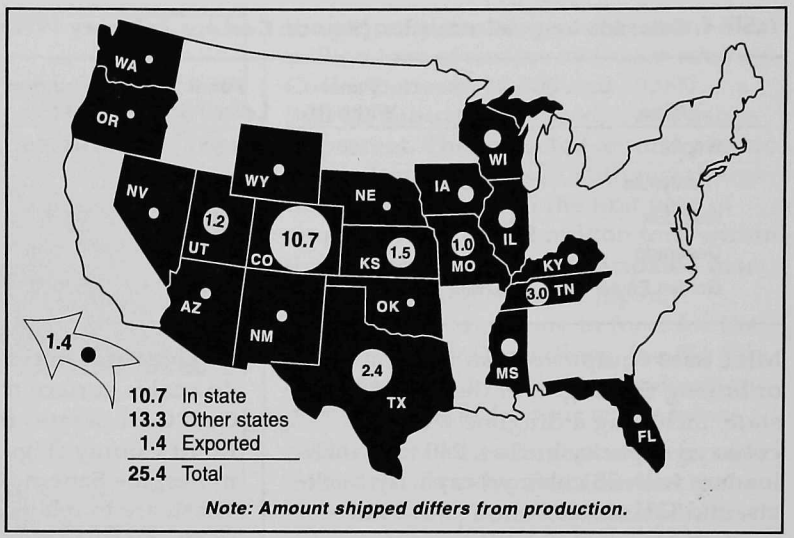

Figure 13. Distribution of Colorado coal in 1996. (Source: Department of Energy—Energy Information Administration)

The longwall systems operating in Colorado in the past five years had panel widths ranging from 650 to 950 feet, panel lengths from 6,000 to 17,600 feet, and cutting heights from 7 to 12 feet (Table 4). The longwall shearers cut a volume of coal equivalent to the panel width multiplied by the cutting height and a cutting depth of approximately 30 to 36 inches each time they pass over the longwall face. The cut coal falls on to a conveyor below (Fig. 16) and the entire longwall system advances to make the next pass. In this manner, a longwall can advance as much as 50 feet a day in the direction of the panel length. The EIA stated that productivity of longwall mines in Colorado was the highest in the country during 1994 at 5.92 tons per worker hour. This productivity compares to 3.84 tons per worker hour for mines using continuous mining machines. Smaller underground mines in the state which use continuous miners or conventional mining methods, have a difficult time competing with the efficient longwall operations. The use of increasingly larger equipment at surface mines is a major factor in increased productivity. For example, the Colowyo

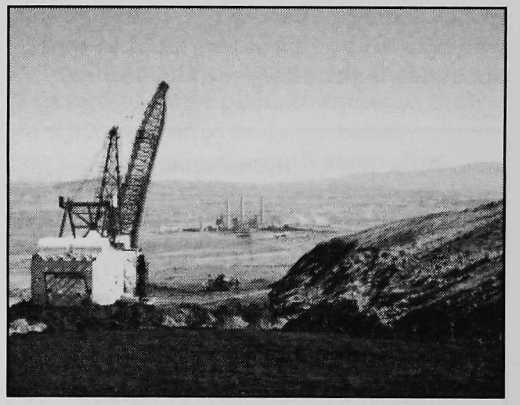

Figure 14. Trapper Mine dragline, Moffat County, with Craig Power Station in background.

Table 4. Colorado longwall statistics. (Source: *Coal Age*, February 1998)

Mine	Seam	Panel Width (ft)	Panel Length (ft)	Overburden (ft)	Seam Height (in.)
Empire	E	750	7,500	600–1,200	126–138 (cut 120)
Twentymile	Wadge	840	17,600	600–1,300	96–114 (cut 102)
West Elk	B	950	9,000	600–1,400	276 (cut 144)
Deserado	D	800	6,000	1,600–2,100	96–102
Golden Eagle	Maxwell	650	8,900	600	96 (cut 84)

Mine uses equipment that is the largest or among the largest of their kind in the state, including a dragline with a 60 cubic yd capacity bucket, 240 ton trucks, loaders with 35 cubic yd capacity buckets, and D11 dozers.

According to the EIA, the overall productivity of Colorado mines, including surface mines, was 7.32 tons per worker hour in 1996. Colorado coal mines are more productive than coal mines in all but six states. Coal in these six states is primarily surface mined, whereas only about one-third of Colorado coal is surface mined. The Seneca Coal Co. operates three surface mines in Routt County (Figs. 17a and b). These mines, the Seneca II, Seneca II-W and Yoast, are in relatively close proximity to one another and their production is not segregated. In this report, these mines are considered to be a single mine.

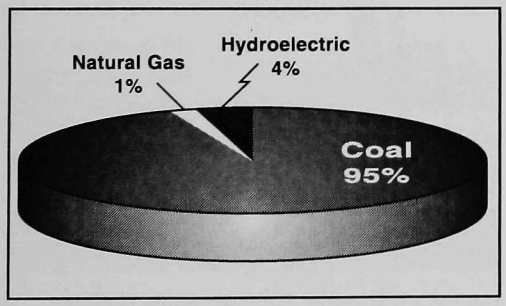

Figure 15. Energy input at Colorado electric utilities. (Source: Department of Energy—Energy Information Administration)

The CMA reported in their January/February 1998 newsletter that Colorado coal production of 17.6 million tons through July put the state on pace for an annual production of just over 30 million tons. Railroad service problems during the last half of 1997 appear to be a primary reason for the annual production falling significantly short of this projected level (see News and Developments Section below). The rate of production during the last five months of 1997 was less than 80 percent of the rate through July.

According to the EIA, the productive capacity of Colorado mines in 1996 was over 29.3 million tons. Given the 1996 production of 24.7 million tons, the capacity utilization of Colorado coal mines was approximately 84 percent in 1996.

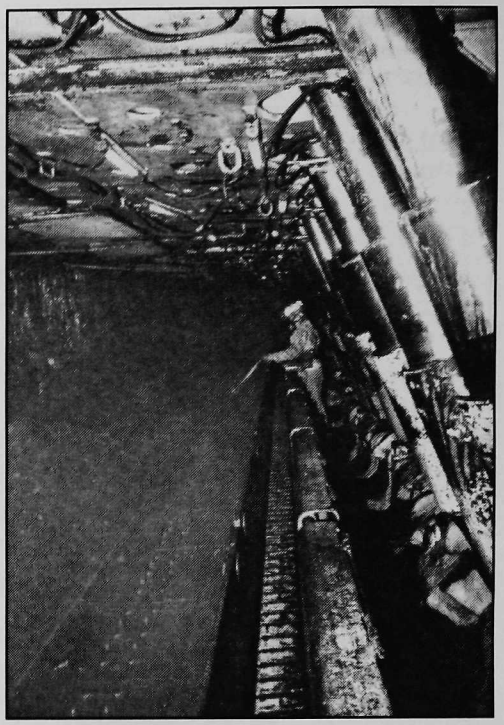

Figure 16. Longwall machine at the West Elk Mine, Gunnison County. (Photo courtesy of Wendell Koontz, Mountain Coal Co.)

News and Developments

Two mines opened during the year, but one of them also shut down. The Bowie No. 2 Mine in Delta County began coal production in October 1997 from the

D seam of the Mesaverde Formation. Development work to support a longwall operation has started. The McClane Canyon Mine in Garfield County reopened, with coal production reported only from February through its shut down in April. *Coal Week* reports that the coal produced from the McClane Canyon Mine supplemented coal from the Deserado Mine in meeting requirements of the Bonanza power plant in Utah. The Deserado Mine produced coal for an entire year for the first time since 1995. Its 1997 production represents almost a million ton increase in production over 1996, when $32 million dollars in mining equipment, including a longwall system, were lost to a fire.

The Colorado Division of Minerals and Geology received no new permit applications for coal mines during 1997; however, the Big Elk and Lorencito Mines are two prospective new operations. *Coal Outlook* reported in May 1996 that Peabody is exploring the possibility of opening a new longwall mine, the Big Elk, in Routt County to produce from 5 to 8 million tons of coal per year from the Wadge seam of the Mesaverde Formation. The mine could be operating soon after the year 2000 if Peabody continues to proceed with the project.

Coal Age reported in July 1997 on the Lorencito operation in Las Animas County. The owners plan to purchase the old Basin Resources New Elk preparation plant and take over the Trinidad railroad that serves the plant, then construct a 0.5 mile spur to the plant to support the operation. Sources from the Colorado Division of Minerals and Geology indicate that a haul road has not yet been built and there has been an ownership change: Tahieyo Enterprises, a Japanese coal producer, is now the sole owner of the Lorencito operation. *Coal Outlook* had reported in May 1996 that the property contains an estimated 175 million tons of surface and deep reserves. Coal is between 12,500 and 13,000 Btu/lb, sulfur is 0.6 percent, and ash is 10 percent. The projected annual production is 1 million tons of both metallurgical and steam coal in the first year of operation and over 2 million tons within three years of startup. Anticipated markets include the U.S. and Japan. Exploration permits are in force for the two prospective operations, the Big Elk and Lorencito. In addition, exploration permits are held for four active mines.

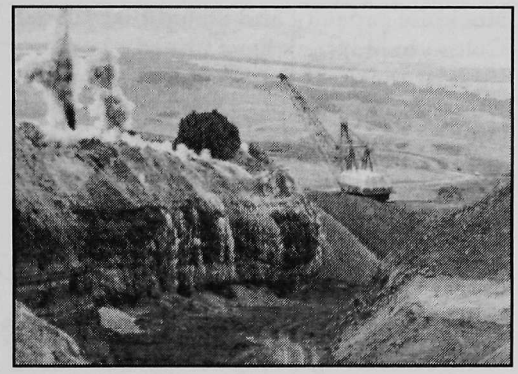

Figure 17a and b. Blasting operation in progress at Seneca Mine, Routt County. (Photos courtesy of Roy Karo, Seneca Coal Co.)

The state's two largest underground mines, the Twentymile Mine and the West Elk Mine, both encountered difficult mining conditions during 1997. In the Twentymile Mine, problems associated with mining in steep grades (10 to over 15 percent) during the last quarter of the year caused a significant decrease in productivity. Regulatory approval has been obtained by Cyprus Amax for the redesign of mine plans to increase both safety and productivity by better accounting for areas with steep dips. Despite this problem with steep grades, the mine produced more than a million tons more than during the previous year.

In January, the West Elk Mine began dealing with water inflow from a fault system. Development sections were shut down as a result of the water inflow. In May, a high ash parting was encountered in the area being mined by the longwall. Mountain Coal Company's approach to dealing with this ash layer

was increasing the number of passes before advancing the shields and segregating materials at the longwall face. The West Elk Mine ultimately produced about 4 percent less coal than in 1996. The unavailability of sufficient rail transport was also a major contributor to decreasing the production from what it might otherwise have been.

Railroad service limitations, in part caused by the merger of the Union Pacific and Southern Pacific (UP/SP) railroads, had adverse affects on most mines that depend on rail transport of their coal to markets. An October *Coal Week* article reported that rail transportation problems had limited West Elk's longwall production to "a couple days a week", due to their limited stockpile capability. The November *Coal Age* reports on Surface Transportation Board hearings in which the UP/SP proposed service cutbacks for delivery of Twentymile Mine exports to Mexico. The CMA reports that the production for many companies would have been higher in 1997 except for the impacts in Colorado of "a virtually unprecedented nationwide rail crisis." Colorado producers in northwest and west-central Colorado report that they sold more coal for delivery in the latter months of 1997 than the UP/SP railroad was able to ship. Governor Romer wrote a letter to Union Pacific Chairman Richard Davidson, dated December 31, 1997, expressing strong concern about the matter. In the letter, Romer cited limited stockpile capacity and stated that "some Colorado shippers have already had to limit or cease production — affecting jobs throughout Colorado."

ARCO announced their likely withdrawal from the worldwide coal business in April 1997 issues of *Coal Week* and *The Mining Record*. A March 1998 article in the *Rocky Mountain News* reports the announcement of the sale of ARCO Coal's North American operations to Arch Coal, Inc. Because Arch Coal is headquartered in St. Louis, there is speculation that ARCO Coal's 65-person Denver headquarters will close.

Four active Colorado coal mines received safety and reclamation awards in 1997. Two mines, the Colowyo and Trapper mines, were recognized by the CMA and Colorado Division of Minerals and Geology for their commitment to safety. At the end of 1997, the Colowyo Mine had completed almost 2.5 million worker hours without a lost time injury. The McClane Canyon, Twentymile, and Trapper Mines were given reclamation awards for environmental and reclamation achievements.

OIL AND GAS

PRODUCTION

Colorado hydrocarbon production in 1996 totaled 25.6 million barrels of oil (MMBO) and 583.3 billion cubic feet (BCF) of natural gas. Carbon dioxide production totaled 329.3 BCF. In 1996 Colorado ranked tenth of all the states in daily crude and lease condensate production with 70,006 barrels of oil per day (BOPD) and seventh in daily gas production with 1.59 BCF per day. Consumption of natural gas in the state in 1996 was 307.4 BCF. Accordingly, Colorado in 1996 consumed 52.7 percent of its produced volume.

Extrapolation of the state's 1997 January through November hydrocarbon and carbon dioxide production volumes provided by the Colorado Oil and Gas Conservation Commission (COGCC) suggests full year production figures will be 23.7 MMBO, 625.9 BCF of natural gas, and 324.8 BCF of carbon dioxide (Fig. 18). The projected 1997 oil volume of 23.7 MMBO is a 7 percent decline from 1996. This continues the long term slide in Colorado oil production that began in 1977. The projected 1997 natural gas volume, if correct, will establish a new annual state production record for this commidity. The projected carbon dioxide volume of 324.8 BCF is off by 4.5 BCF from last year's annual state production record for carbon dioxide of 329.3 BCF.

Colorado coalbed methane production in 1996 totaled 274.6 BCF. This placed Colorado in second place in the U.S. behind New Mexico's 575 BCF. Colorado coalbed methane production in 1997 is expected to total 320.3 BCF. This anticipated "new" record volume would represent 51.2 percent of the

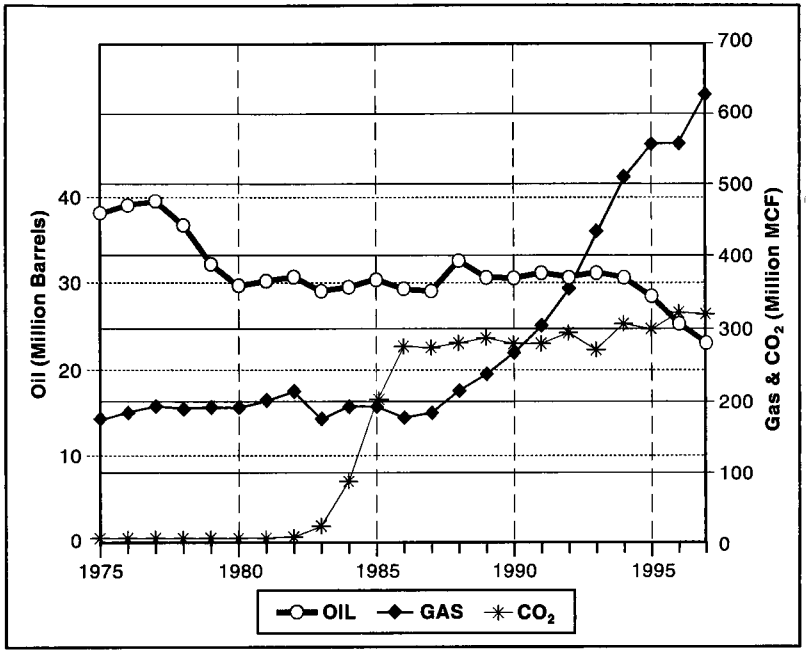

Figure 18. Colorado oil, gas, and carbon dioxide production 1975–1997.

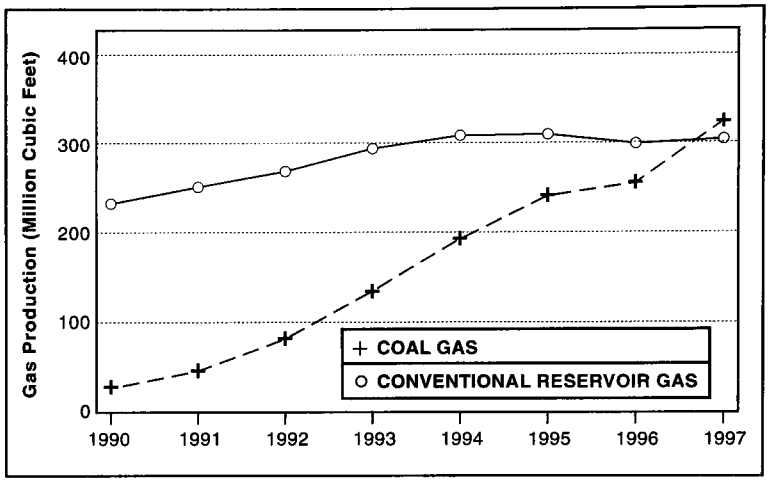

Figure 19. Annual volumes of coal gas and conventional reservoir gas in Colorado, 1990–1997.

state's total natural gas production, up from a 47 percent contribution in 1996. This would the first year that annual coalbed methane production exceeded natural gas production from the state's conventional reservoirs (Fig. 19).

Nationally, coalbed methane production grew 5 percent in 1996 to 1,003 BCF. Most of the increase occurred in the Basin and Ignacio-Blanco fields of the San Juan Basin, which lies in southwest Colorado and northwest New Mexico, and in the Oakwood and Nora fields of southern Virginia. This is the first time that U.S. annual coalbed methane production has exceeded 1 trillion cubic feet. Coalbed methane in 1993 represented about 3 percent of the nation's total dry gas production. By 1996, this proportion had grown to 5.3 percent. Colorado's 1996 coalbed methane volume accounted for just over 32 percent of this component of the U.S. gas supply.

In 1996, Rio Blanco County led all counties in oil production with 8,635,078 barrels of oil. The Rangely field's Weber pool (Permian and Pennsylvanian in age) produced 8,267,285 barrels of oil (BO) which provided 95.7 percent of the county total. Second and third place in county oil production went to Weld County (7,307,632 BO) and Cheyenne County (3,837,521 BO). Wattenberg field was the major contributor in Weld County (79.9 percent).

The top three natural gas producing counties in 1996 were La Plata (298.3 BCF), Weld (110.3 BCF), and Garfield (42.4 BCF). La Plata County's Ignacio Blanco field Fruitland Formation coalbed methane reservoir (Late Cretaceous) contributed 266.0 BCF (89 percent) of La Plata County's natural gas production. Wattenberg field provided just over 90 percent of the Weld County natural gas total. La Plata County achieved a significant milestone in 1996 by becoming the first county in the state to exceed 2 trillion cubic feet (TCF) in

cumulative natural gas production. Cumulative natural gas production at the end of 1996 in La Plata County stood at 2.258 TCF.

In 1996, the total producing well count in Colorado was 16,565. This total included 69 carbon dioxide producers, 967 coalbed methane producers, and 15,529 wells producing natural gas and/or oil from conventional reservoirs. The well count increased in 1997 to 17,351. The break down by category is: 69 carbon dioxide producers, 1,058 coalbed methane producers, and 16,224 conventional wells. Weld County led all counties in number of active wells in 1996 and 1997 with totals of 8,145 and 8,273, respectively. For both years these Weld County totals represented nearly half of the state's active wells.

In 1996, 31 of Colorado's 63 counties were oil productive, 34 produced natural gas from conventional reservoirs, six coalbed methane, and three produced carbon dioxide. Five fields account for all of Colorado's carbon dioxide production: Dike Mountain and Sheep Mountain fields in the northwestern part of the Raton Basin in Huerfano County; McCallum and McCallum South fields in the northeastern part of the North Park Basin in Jackson County; and McElmo field in the eastern part of the Paradox Basin in Montezuma County. Two of these fields accounted for 99 percent of the 1995 Colorado carbon dioxide production stream: McElmo with 258.6 BCF and Sheep Mountain with 65.5 BCF. There are 15 Colorado fields that produced coalbed methane in 1995 and 1,065 fields that produced oil and/or natural gas from conventional reservoirs.

Value and Pricing

The total value of 1996 oil, gas, and carbon dioxide production in Colorado was $1,542 million dollars: oil $534 mil-

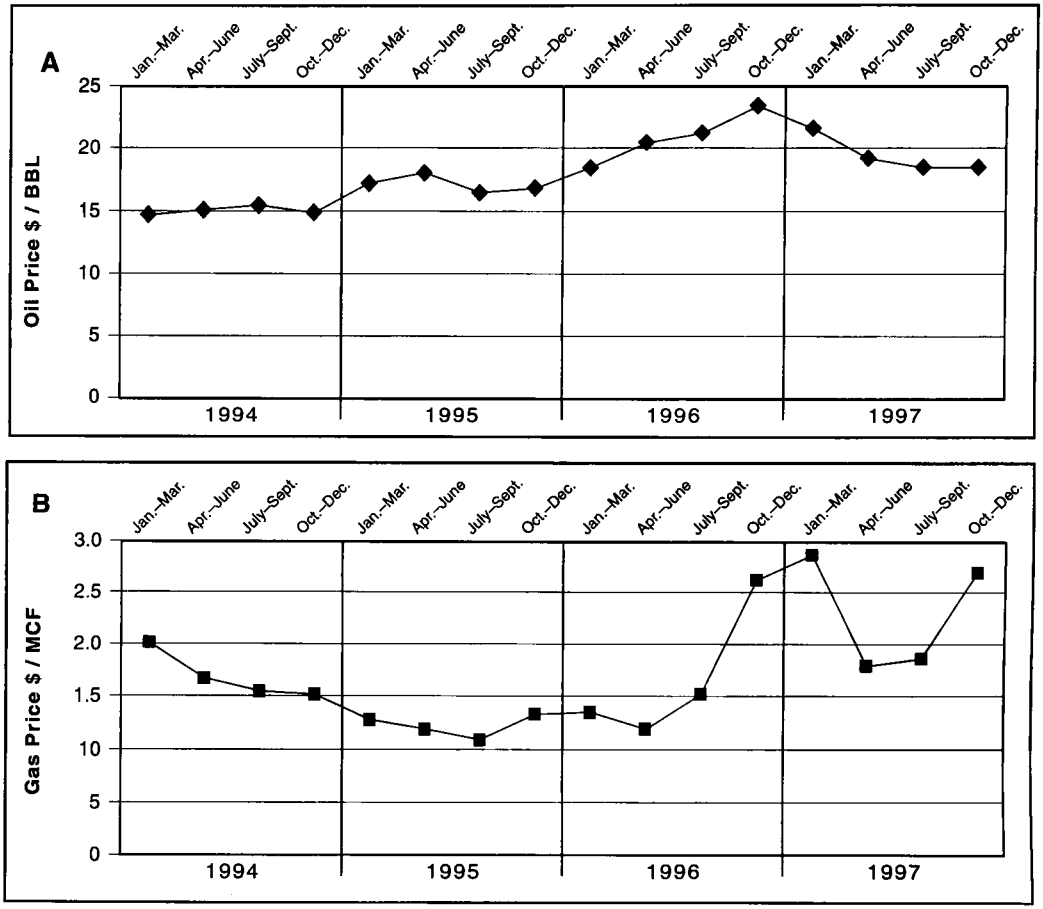

Figure 20a and b. Colorado oil and gas prices by quarter, 1994–1997. (Data from Colorado Oil and Gas Conservation Commission)

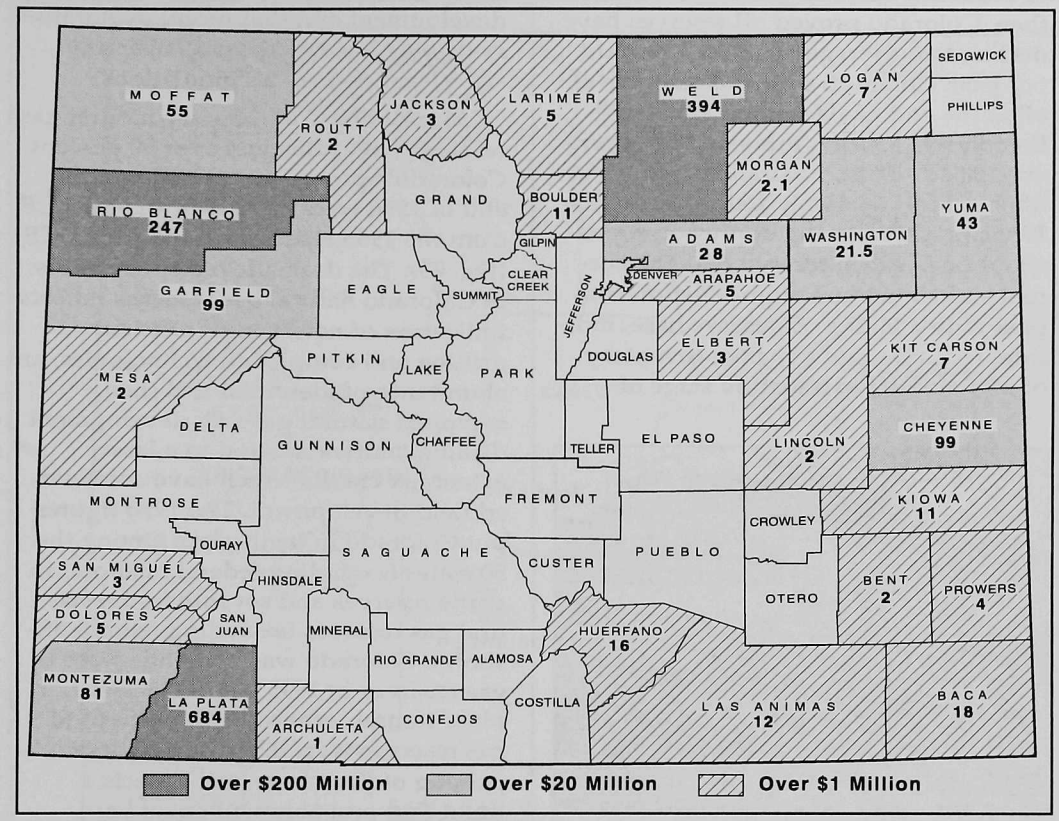

Figure 21. Colorado county oil and gas production values, 1996. (Data from Colorado Oil and Gas Conservation Commission)

lion, natural gas $962 million, and carbon dioxide $ 46 million. The total value in 1997 for these commodities should be approximately $1,965 million dollars: oil $457 million, natural gas $1,433 million, and carbon dioxide $75 million.

1996 values were derived by using an average wellhead price of $20.84 for a barrel of oil (BO), $1.65 for a thousand cubic feet (MCF) of natural gas, and $0.14 for a MCF of carbon dioxide.

The average wellhead price in Colorado for oil in 1997 decreased by 7.4 percent to $19.29 per BO. The average wellhead price for gas in the state 1997 increased by nearly 39 percent to $2.29 per MCF. Figure 20 displays the variation of Colorado oil and gas wellhead prices by quarter for the last four years. The wellhead price for carbon dioxide in 1997 increased by 64 percent to $0.23 per MC. Figure 21 shows 1996 Colorado oil, gas, and carbon dioxide production value by county. Ten of Colorado's 63 counties attained over $20 million in 1996 production value of oil and/or gas.

Drilling Permits

In 1997, 1,136 permits were processed by the COGCC (1,002 drilling and 124 recompletion) This compares to 1,002 drilling permits and 161 recompletion permits processed in 1996. The three counties that led in 1997 permit applications were Weld (367), Garfield (146), and Las Animas (136). Weld County also led in 1996 with 305 permits. Garfield County moved up to second place in ranking from fourth in 1995 as a result of accelerated development of natural gas from the Williams Fork Formation tight sandstones in the east-central portion of the Piceance Basin of northwestern Colorado. Figure 22 is a view of a development well in the Piceance Basin's Rulison gas field in March 1977. Figure 23 is a view of a Rulison field gas well completed from the Williams Fork Formation in July 1995.

Las Animas County was in second place in 1995 as result of active coalbed methane development from Vermejo and Raton formation coal seams in the central area of the Raton Basin of

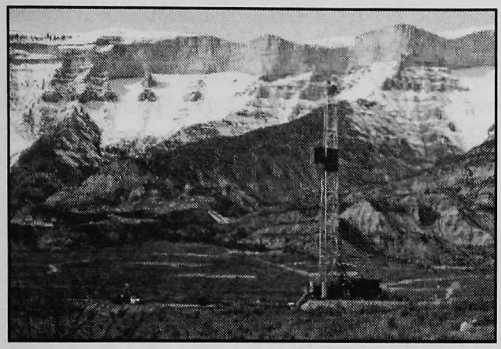

Figure 22. Nabors Drilling Company Rig No. 457 on a Barrett Resources development well located about 6 miles southwest of Rifle. The RMV 99-28 Vassar/Heath is planned as a 7,150 foot Williams Fork Formation test in the Rulison field—one of the Piceance Basin's more prolific basin centered tight gas sand accumulations.

south-central Colorado. This play continued into 1997 at a level comparable to the previous year.

Daily rig counts in Colorado were up slightly in 1997 to an average of 16.3 from 13.8 in 1996.

Table 5 is the final list of the oil and gas wildcat discoveries in 1996 and a preliminary list of the 1997 oil and gas discoveries. This data has been derived from COGCC files. Fig. 24 locates these wells in map view.

Reserves

Colorado's proved oil reserves peaked at 359 million barrels in 1989. Since then, Colorado proved oil reserves have declined an average of about 5 percent per year. Colorado's proved reserves of oil at the end of 1996 stood at 231 million barrels. During this same time period (1989 to 1996), Colorado's oil reserve life has been relatively stable-averaging 10 years with a swing of plus or minus about one year in reserve life. The current slide in annual oil production coupled with a falling oil reserve base, indicates that the state's current inventory of oil fields are in a mature stage of development and that recent exploratory drilling has failed to discover any significant new oil accumulations.

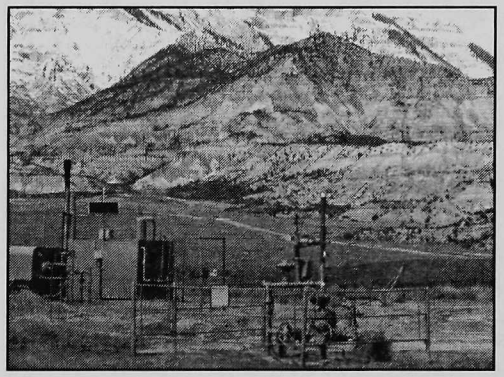

Figure 23. Barrett Resources gas well, Rulison field, Garfield County. The RMV 27-28 Clough was completed in July 1995 from selected perforations in the Mesaverde Group Williams Fork Formation over a gross interval from 5,283 to 7,088 feet. By the end of January 1998 the well was flowing at a rate of 413 MCF of gas and 1.5 barrels of condensate per day. Cumulative production at the end of January 1998 was 695 MMCF of gas and 2,400 barrels of condensate.

Since 1989, Colorado dry natural gas reserves have risen just over 80 percent. Colorado's proved gas reserves at the end of 1996 were 7,710 BCF, up 454 BCF from the 1995 reserve total of 7,256 BCF (Fig. 25). The dramatic recent increases in Colorado natural gas reserves reflects utilization of newer more efficient drilling and completion technologies, an abundance of identified and then exploited natural gas-rich development drilling "fairways", and to a lessor extent tax credits which have accelerated field development. The 1996 figures put Colorado in tenth place among the 50 states (excluding federal offshore) in crude reserves and seventh in dry natural gas reserves (excluding federal offshore). Colorado was in eighth place in gas reserves in 1995 behind seventh place Kansas, whose 1995 dry natural gas reserves were 8,571 BCF. Colorado's passing of Kansas in 1996 reflects a trend that probably will never be reversed as Kansas gas reserves have been in near constant annual decline from a modern peak of 10,509 BCF established in 1986. Kansas dry gas reserves at the end of 1996 stood at 7,694 BCF, down 877 BCF from the previous year.

News and Developments

Union Pacific Resource Company disclosed plans in April 1997 to invest $100

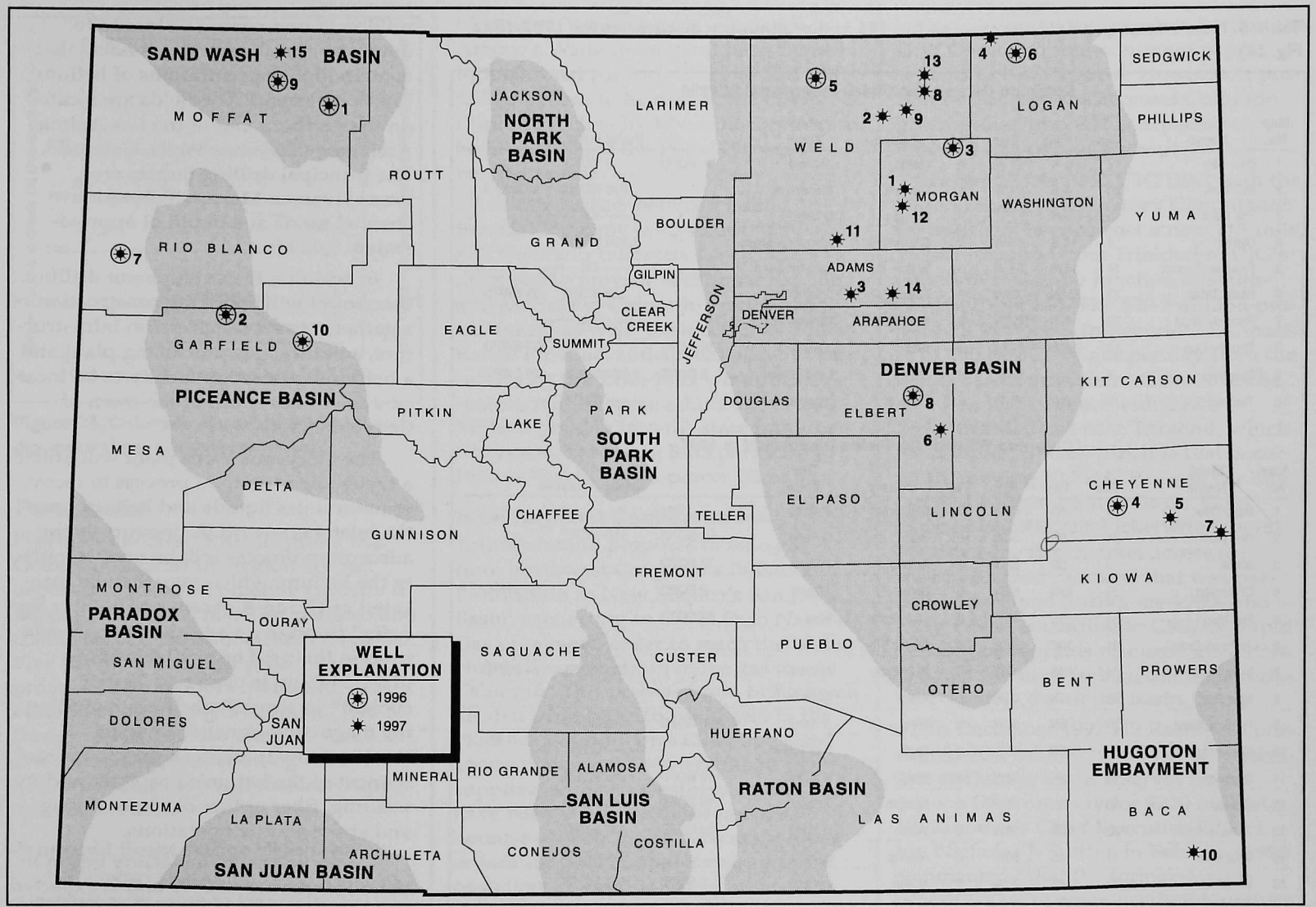

Figure 24. Location map of 1996 and 1997 wildcat oil and gas discoveries in Colorado. See Table 5 for name and date. Data from Colorado Oil and Gas Conservation Commission files.

Table 5. New oil and gas fields discovered in 1996 and preliminary discoveries for 1997. (See Fig. 24)

Colorado Oil and Gas Fields Discovered in 1996

Map No.	Field Name	Sec	Twp	Rge	PM	County	Pay Zone	Initial Potential	
1	Blue Sky	12	9 N	91 W	6	Moffat	Almond	34 BCPD	5 MCFD
2	Bull Fork	20	4 S	97 W	6	Garfield	Mesaverde	970 MCFD	50 BWPD
3	Fox Field	13	6 N	57 W	6	Morgan	D Sand	—— Oil ——	
4	Oyster	9	14 S	47 W	6	Cheyenne	Morrow & Keyes	1,530 MCFD	
5	Pawnee Pioneer	14	10 N	64 W	6	Weld	Richard Sand	—— Oil ——	
6	Peetz Table	23	11N	53W	6	Logan	J Sand	8 BOPD	55 BWPD
7	Rangely West	29	1 N	102 W	6	Rio Blanco	Castlegate	—— Gas ——	
8	Stanley Cup	36	8 S	59 W	6	Elbert	J Sand	125 BOPD	307 BWPD
9	Teardrop	5	10 N	93 W	6	Moffat	Lewis Shale	9 BCPD	1,500 MCFD 10 BWPD
10	Timberline	8	6 S	91 W	6	Garfield	Mesaverde	—— Gas ——	

Colorado Oil and Gas Fields Discovered in 1997

Map No.	Field Name	Sec	Twp	Rge	PM	County	Pay Zone	Initial Potential	
1	Baby Doe	34	4N	59W	6	Morgan	D Sand	Gas	
2	Bird Heaven	31	8N	60W	6	Weld	D Sand	54 BOPD	150 MCFD
3	Brook	9	3S	62W	6	Adams	J Sand	12 BOPD	
4	Champion	36	12N	55W	6	Logan	J Sand	8 BOPD	160BWPD
5	Full Moon	34	15S	45W	6	Cheyenne	Miss.	55 BOPD	
6	Jayhawk Draw	31	10S	57W	6	Elbert	J Sand	—— Oil ——	
7	Marguerite	34	16S	42W	6	Cheyenne	Morrow	1,000 MCFD	24 BWPD
8	New Day	28	9N	58W	6	Weld	Niobrara	12 BOPD	
9	Pommel West	20	8N	59W	6	Weld	D Sand	200 BOPD	340MCFD
10	Spelunker	24	33S	44W	6	Baca	Red Cave	—— Gas ——	
11	Spenson	13	1N	63W	6	Weld	D Sand	419 BOPD	886 MCFD
12	Stump	30	3N	59W	6	Morgan	J Sand	10 BOPD	100 MCFD
13	Terrace South	32	10N	58W	6	Weld	D Sand	28 BOPD	137 MCFD
14	Wildflower	11	3S	60W	6	Adams	J Sand		731 MCFD
15	Windsock	32	11N	93W	6	Moffat	Lewis	6 BOPD	685 MCFD

Abbreviations: BOPD—barrels of oil per day; **BCPD**—barrels of condensate per day; **MCFD**—thousands of cubic feet of gas per day; **BWPD**—barels of water per day

million in east-central Colorado to develop several natural gas fields that contain high concentrations of helium (up to 3 percent). The fields are located on the northern end of the Las Animas Arch near Cheyenne Wells, Colorado. The principal drilling targets are Pennsylvanian Morrow Formation channel sands at a depth of approximately 5,000 feet.

In addition to development drilling, the project will entail the construction of a gathering and compression infrastructure, a natural gas processing plant and a helium liquefaction facility-to be located a few miles south of the town of Cheyenne Wells.

The Cheyenne Wells plant will utilize a cryogenic extraction process to recover natural gas liquids and helium from the inlet gas stream. A pressure swing adsorption process will be used to purify the helium, which may then be marketed as Grade-A gaseous helium or liquefied through an additional cryogenic process that will be available at the plant. Helium is used as a "super coolant" in several machines including the magnetic resonance imaging machine now in use as a diagnostic tool in most of the nation's hospitals, and in welding, fiber optics, deep sea diving and space shuttle operations.

Construction of the facility began in the third quarter of 1997 and is expected to be completed in the second quarter of 1998.

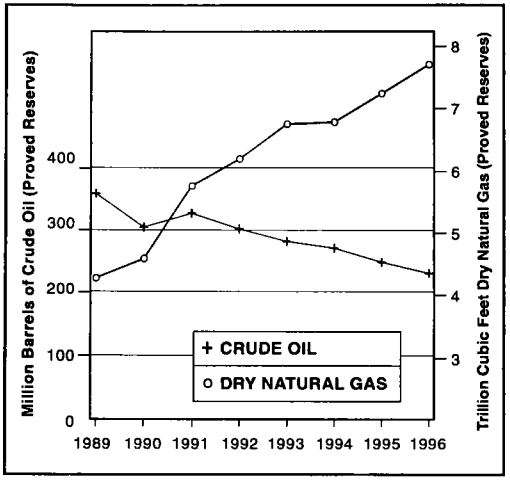

Figure 25. Colorado historical crude oil and dry natural gas reserve estimates.

PIPELINES

Pipelines are critical to gas prices in Colorado because the region is a net exporter of gas, and pipeline capacity to move gas to major midwest markets and California has traditionally been limited. Five newly announced pipeline projects promise to bring more marketing flexibility for Colorado gas supplies. Two of these projects are also likely to result in lower consumer prices along the Front Range because they will increase supply to local markets.

Proposed Front Range Pipelines

KN Energy has announced plans to construct a pipeline to transport 250,000 million British thermal units (MMBtu) per day of gas from the Rockport Hub in Cheyenne, Wyoming for redelivery to Amoco's Wattenberg plant near Denver International Airport. The planned 109 mile pipeline, to be named the Front Runner Pipeline by KN, is anticipated to be in service for the 1998-1999 winter heating season.

A joint project between Public Service Company of Colorado (PSCo) and Colorado Interstate Gas (CIG) is designed to provide additional supplies and services to Colorado Front Range customers as well. Their so called Front Range Pipeline, anticipated also to be in service by the 1998–1999 winter heating season, will bring an additional 269,000 MMBtu per day into the state from the Cheyenne, Wyoming Rockport Hub to PSCo's Fort St. Vrain power plant.

New Regional Configurations

TransColorado proposes to take gas from northwest Colorado's Piceance Basin south to New Mexico's San Juan Basin, connecting to the El Paso Natural Gas pipeline in order to reach the Waha Hub in Texas that can move gas to California. This project would bring much needed price relief to producers in the Piceance Basin by providing increased access to markets. Western Slope gas supplies, while increasingly abundant, have been at a price disadvantage because of their Rocky Mountain interior location and limited access of transportation to major markets.

KN Energy recently acquired Natural Gas Pipeline Company of America. The primary route of this pipeline is from the Gulf Coast and mid-continent supply regions to the Midwest. However, a portion of this pipeline accesses Colorado gas supplies, and KN is expected to enhance this part of the route.

In September 1997 CIG filed with the Federal Energy Regulatory Commission for approval to construct a new 115-mile, 16 inch pipeline from Trinidad to CIG's mainline at Campo Junction in southeastern Colorado. The $20.7 million project will provide a transportation capacity of 100 MMCF of gas per day from the Raton Basin in southern Colorado. The new line will connect with CIG's Picketwire Lateral near Trinidad, which is a 25-mile, 10 inch pipeline that is currently moving 30 MMCF of gas per day out of the central Raton Basin. Constructed in 1994, the Picketwire Lateral provided the first market access for shut-in coalbed methane that was partially developed during the 1980s and early 1990s. According to CIG, the rapid development of this resource since 1994 dictated the need to increase transportation capacity out of the basin.

In December 1997 HS Resources purchased 70.2 million barrels of oil equivalent of Denver Basin reserves from Amoco Oil Company for $330 million. HS Resources Chief Executive Officer, Mr. Nicholas J. Sutton, in February 1998 commented "that the former Amoco properties were strategically interwoven with existing HS Resource properties and contribute more than 2,100 specifi-

cally identified new low-risk, high-return development projects. Combining these with nearly 1,800 development projects owned by HS Resources prior to the Amoco acquisition provides the company with a broad menu for many years of Denver Basin development." In 1998 the company has announced that it will undertake more than 500 exploitation activities, including restimulations, deepenings, and development and infill locations. The 804 operated and 1,100 non-operated wells acquired from Amoco bring the HS Resources base of producing wells in the Denver Basin to more than 4,000.

In 1997, Total Petroleum North America was acquired by Ultramar Diamond Shamrock (UDS) for $811 million. As a result, the Total brand name was changed to Diamond Shamrock. UDS now owns and operates 290 retail stores in Colorado. The Total refinery in Commerce City and two terminal facilities were also part of the acquisition.

UDS also operates a crude oil products pipeline from Texas to serve the Colorado market.

The capacity of the Commerce City refinery is 28,000 BO per day, and the pipeline transports 15,000 barrels of gasoline and 6,200 barrels of jet fuel per day from Amarillo, Texas to Colorado Springs.

The Commerce City refinery is particularly important to crude producers in the Denver Basin since most Denver Basin crude is refined at the Total/UDS refinery (which means low transportation charges for producers). Closure of the refinery, as a cost cutting move for UDS, would force producers to transport their crude longer distances. The concern has surfaced because of UDS's ability to import substantial amounts of reformulated gasoline through their Texas pipeline to serve Colorado markets. Current Denver Basin daily crude oil production is approximately 26,000 barrels. At present, UDS does not appear to have plans to close the refinery.

URANIUM AND VANADIUM

Because of increased worldwide demand and ever decreasing inventories, prices for uranium oxide rose from a low of $7 per pound in the early 1990s to over $15 per pound in early 1997. Prices for uranium oxide have since settled in the $10 to $11 range.

Cotter Corporation, a subsidiary of Commonwealth Edison Corp., owns the Schwartzwalder Mine, the largest operating underground uranium mine in the United States. The uranium deposit at the Schwartzwalder Mine was discovered in the mid-1940s and is located just a few miles north of Golden in Jefferson County (Fig. 26). Uranium mineralization, primarily as pitchblende, occurs within steeply dipping and flat hydrothermal veins within a Precambrian garnet-biotite gneiss and quartzite unit.

In 1995 and 1996, Cotter Corporation began development and pre-production work on the mine, which had been on standby since 1989. In 1997, the Schwartzwalder Mine produced approximately 500,000 pounds of uranium oxide. At present the ore is trucked to Cotter's Canon City mill and stockpiled. In addition to the existing acid leach recovery system, a new alkaline leach recovery system for the Schwartzwalder ore is being installed at the Canon City mill. The mill is scheduled to reopen in late 1998.

Underground exploration drilling in 1997 from the lowest working level at 1,900 feet below the surface continued at the mine. Drilling has intercepted a favorable band of rocks containing veins with uranium mineralization at depths of 300 feet below this lowest working level. The mine plan includes moderate production from about ten stopes. A few significant veins remain to be developed; however, most production will come from small lower grade areas left over from the closure in 1989.

International Uranium Corporation reopened the Sunday Group mines in the Big Gypsum Valley, San Miguel County (Fig. 26) in July. Vanadium and uranium mineralization at this site is located in sandstones of the Salt Wash Member of the Jurassic Morrison Formation. The average ore grade is

1.5 percent vanadium oxide and 0.25 percent uranium oxide.

About 90 percent of worldwide vanadium production is used to produce ferrovanadium, a steel alloy which imparts additional hardness and strength. Other applications include pigments, catalysts, electronics, and titanium-aluminum-vanadium alloys for the aerospace industry.

As of 1971 the Sunday Group had produced 1,111,000 pounds of vanadium oxide and 143,000 pounds of uranium oxide. The economics of production at the Sunday Group mines are greatly enhanced by the current high price of vanadium at $5 to $7 per pound.

Production began in November with two shifts of 35 persons. As of February 1998 over 10,000 tons of ore have been shipped to the company's White Mesa Mill in Blanding, Utah.

The total value of the produced uranium in the state is $6 million. The vanadium has an estimated value of about $2 million.

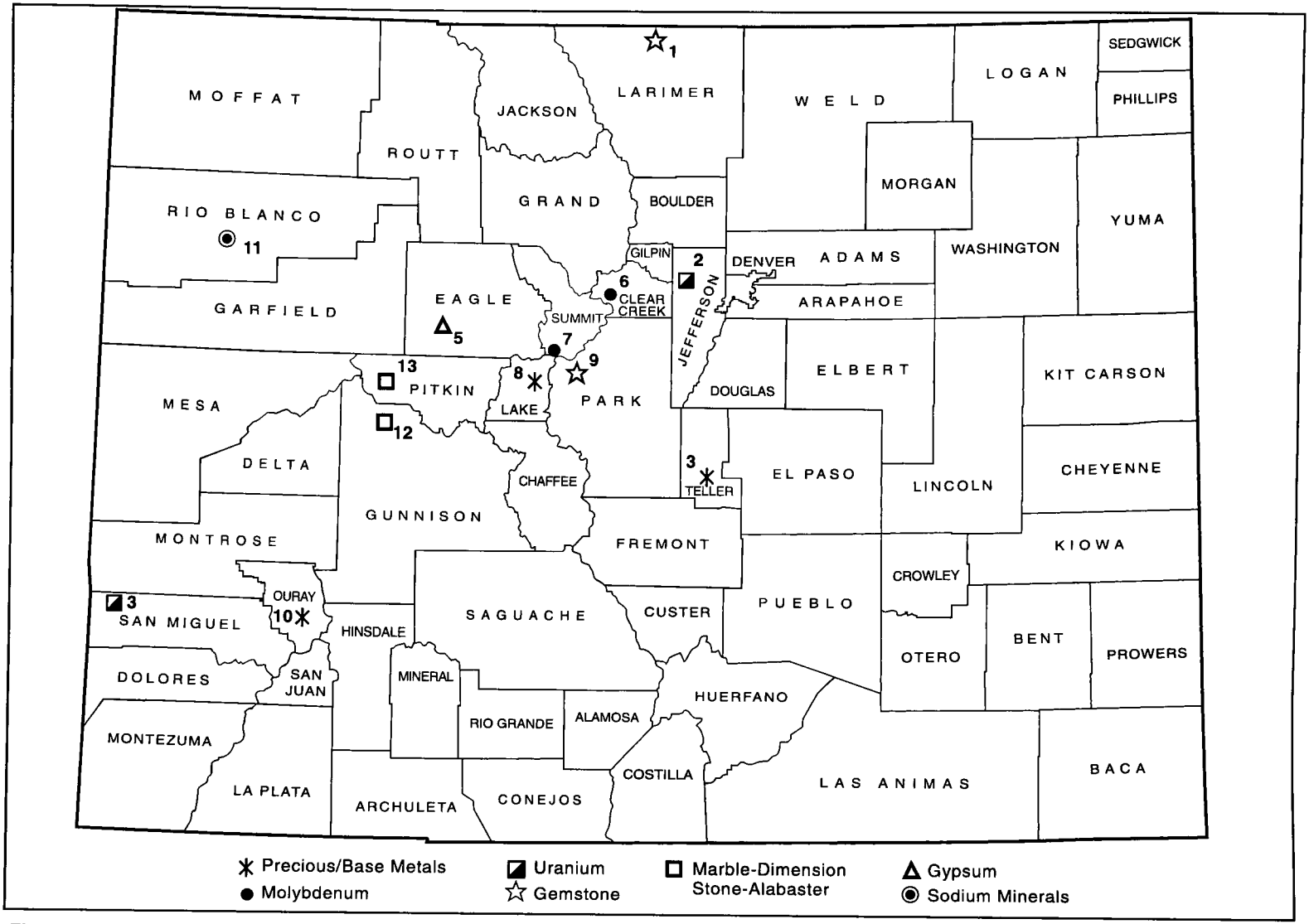

Figure 26. Map showing location of major mineral producers and prospects in Colorado.

METALS

MOLYBDENUM

The Henderson Mine in Clear Creek County is the nation's top producer of primary molybdenite. In 1997, the mine and mill produced an estimated 38 million pounds of molybdic oxide from about eight million tons of ore (Fig. 26 and 27). The average realization per pound of molybdic oxide is $5.50 (Cyprus Amax Minerals Co. Press Release, January 21, 1998) which equals an estimated $210 million production value for 1997. The Henderson mine and mill complex employs approximately 460 people.

The company began a modernization program called "Henderson 2000." At present, ore is hauled by an underground train system through a 9.5-mile tunnel under the Continental Divide to the mill site. "Henderson 2000" includes replacement of the train system by a 10-mile long underground conveyor belt; ore crushing facilities will be moved from the mill to an underground site at the mine.

Table 6. Major mineral producers and prospects in Colorado. Numbers refer to mines located in Figure 26.

Map No.	Mine Name	Commodity	Type	Owner/Operator
1	Kelsey Lake	Diamonds	OP	Diamond Co. N.L.
2	Schwartzwalder	Uranium	UG	Cotter Corp.
3	Sunday Group	Uranium	UG	International Uranium Corp>
4	Cresson	Gold	OP	Pikes Peak Mining Co.
5	Eagle Gypsum	Gypsum	OP	Centex Contstruction Prod.
6	Henderson	Molybdenum	UG	Cyprus Amax Minerals Co.
7	Climax	Molybdenum	UG, OP	Cyprus Amax Minerals Co.
8	Black Cloud	Zinc, lead, gold, silver	UG	Asarco, Inc.
9	Sweet Home	Rhodochrosite	UG	Sweet Home Rhodo, Inc.
10	Revenue-Virginius	Gold and Silver	UG	Sunshine Mining & Refining Co.
11	White River	Sodium bicarbonate	SOL	White River Nahcolite Co.
12	Yule Quarry	Marble	UG	Colorado Yule Marble Co.
13	Avalanche Creek	Alabaster, marble	UG	Crystal Valley Mining Co.

Abbreviations: TYPE: **UG**—underground; **OP**—open pit; **SOL**—solution

GOLD AND SILVER

The precious metal industry in Colorado set a modern era (post World War II) production record in 1996 with approximately 250,000 ounces of gold and 312,000 ounces of silver (Fig. 28). Gold production in 1997 declined six percent to an estimated 239,000 ounces of gold and 410,000 ounces of silver. Gold production in Colorado remains near record levels in spite of the late 1996 closure of the San Luis Gold Mine in Costilla County.

The Cripple Creek and Victor Gold Mining Company had a successful third

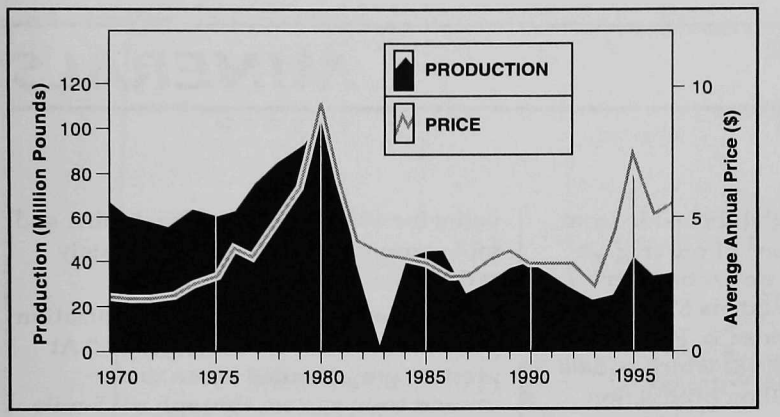

Figure 27. Colorado molybdenum production.

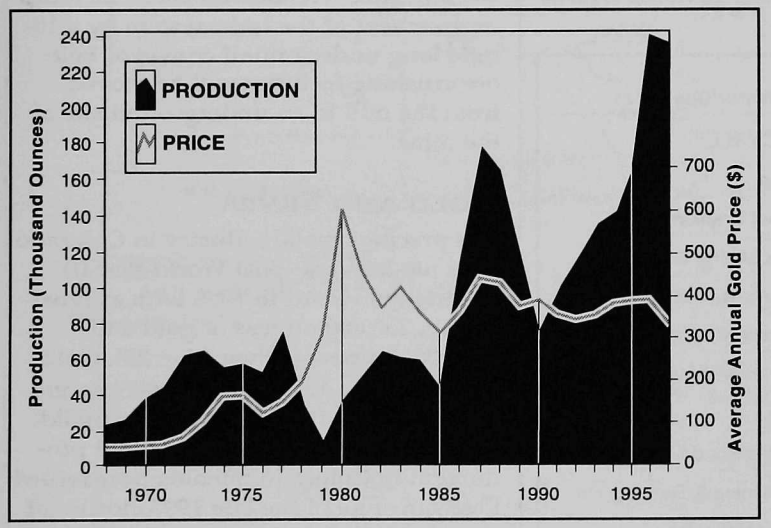

Figure 28. Colorado gold production.

year of operation at the Cresson Mine in the famed Cripple Creek district, Teller County (Fig. 26). The Cresson Mine has a 1994 proven and probable reserve of 73 million tons at a grade of 0.03 ounce of gold per ton for a total of 2.2 million ounces. Production at the Cresson Mine for 1997 is estimated at 228,000 ounces of gold and 47,000 ounces of silver from about 10 million tons of ore. The deposit has an overall strip ratio of 1.7:1 and a leach pad recovery of 71 percent. Operating (cash) costs projected over the life of the mine are about $200 per ounce of gold.

The Cripple Creek mining district is located within a Tertiary (32 million years old) alkaline volcanic-diatreme complex, which was intruded into Precambrian granites and metamorphic rocks. Gold mineralization is found in quartz and telluride veins and as disseminated low-grade deposits in the phonolite breccia (Fig. 29). Bob Womack discovered gold in the district in 1891. By the early 1900s, Cripple Creek was a boomtown with a population of over 60,000 people. Most of the underground mines in the district were producing high-grade ores of one to two ounces per ton. To date, the district has produced over 21 million ounces of gold, about half the total production for the entire state of Colorado.

Leadville Mining and Milling Corp. announced commencement of mining operations at their Comstock-Hopemore-Hunter Mine in the Leadville district, Lake County. The B Zone at the mine is a wide high-grade gold-bearing structure within the Dyer Dolomite and Manitou Formation, both of which are found below the Leadville Limestone.

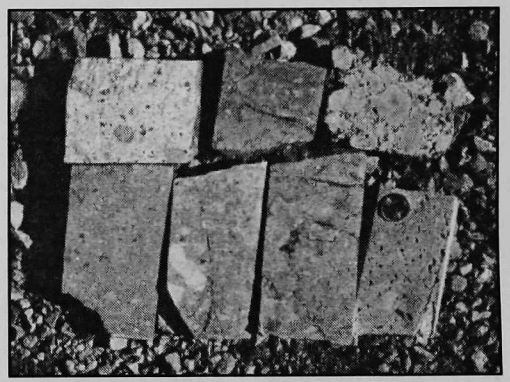

Figure 29. Core samples from the Cresson Mine, Cripple Creek district, Teller County.

Gold and silver are also produced as a by-product of base metal mining at the Black Cloud Mine in the Leadville district. In 1997, the Black Cloud Mine produced an estimated 10,700 ounces of gold and 363,000 ounces of silver.

Base Metals

Asarco's Black Cloud Mine near Leadville is the state's sole significant base metal producer. The mine and mill have a capacity of 875 tons per day and operates from two underground shafts. Production in 1997 totaled 202,000 tons of ore with an average grade of 0.05 ounce per ton gold, 1.8 ounce per ton silver, 3.5 percent lead, 8.5 percent zinc, and 0.13 percent copper. Estimated amounts of base metal production are 14 million pounds of lead, 34 million pounds of zinc, and 0.5 million pounds of copper. The mine is an underground room and pillar, cut and fill operation. The orebody is a complex massive sulfide replacement deposit in the Mississippian Leadville Limestone.

From August to December 1996 the mine was closed because of mechanical problems and stagnant commodity prices. The mine and mill recalled all 130 employees and resumed full operations in January 1997. Development work in 1997 included the installation of an underground hoist over a 6-foot diameter borehole, driving sub-levels off of a winze, and drifting along vein systems. Underground drilling was used for exploration and resource delineation.

Construction Materials and Industrial Minerals

Introduction

The most economically significant segment of the construction material industry in the state is sand and gravel and crushed stone. Other important construction materials and industrial minerals produced in Colorado include gypsum, dimension stone, silica sand, sodium minerals, and gem stones. Other construction materials and industrial minerals produced in the state during 1997 but not discussed in this report include peat, bentonite clay, common clay, and kaolin.

Sand, Gravel, and Aggregate

The sand, gravel, and aggregate industry produced approximately 47 million tons of material in 1997, up slightly from the 46 million tons in 1996. The value of the 1997 production is estimated to be $209 million (Fig. 30). Continued residential building in Colorado, especially in the Front Range counties, is largely responsible for the growth in construction material production. Figure 31 shows current mining activities at a large quarry just south of Golden, Colorado.

Silica Sand

Colorado Silica Sand Inc. of Colorado Springs produces approximately 200,000 tons a year of specialty sand that is used for fracturing of oil and gas wells, filter

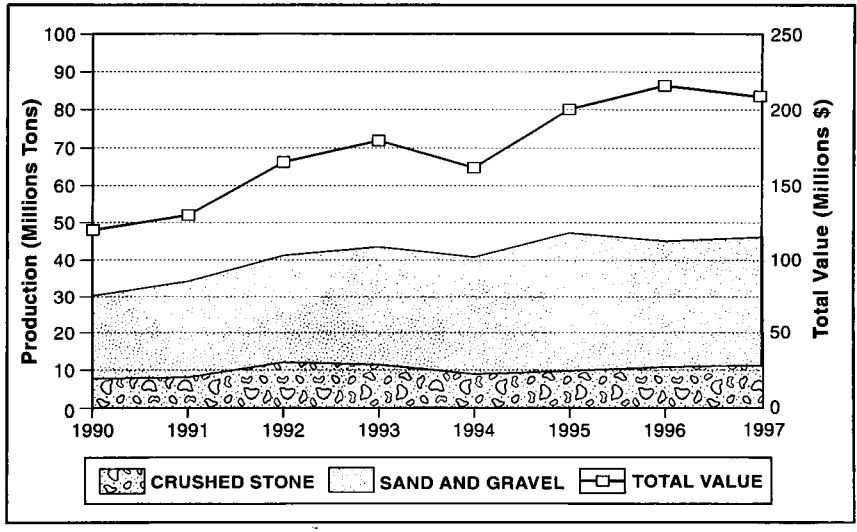

Figure 30. Colorado crushed stone, sand and gravel production.

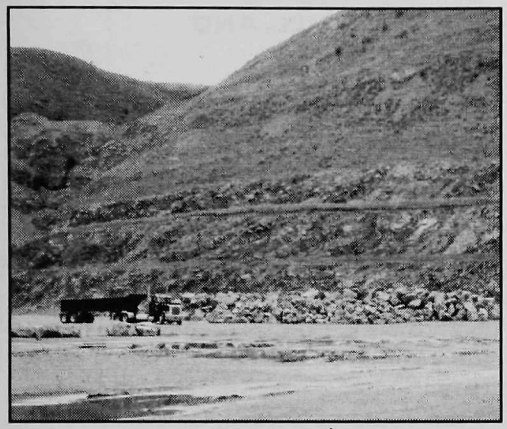

Figure 31. Active crushed stone mining operation at the Heritage Square quarry near Golden, Jefferson County.

media for water purification plants, gravel packs around water wells, and other applications where roundness, permeability, and strength are important parameters.

Dimension Stone

The Colorado Yule Marble Company is mining white marble from the historic Yule Marble Quarry near Marble, Colorado. In 1997 the company produced about 50,000 cubic feet of marble, down from the 1996 production of 75,000 cubic feet. The mine was shut down during October and November. Currently, the mine is in the process of an ownership change. All the marble produced at the Yule quarry goes to the domestic market as large blocks and cemetery monuments. Market conditions have been changing for the Colorado Yule Marble Company; in the early- and mid-1990s about half of the quarry's production was sent to European and Asian destinations. The quarry employs six persons. The company has no new development plans for 1998.

Gem and Specimen Minerals

Colorado Diamond Co., a subsidiary of Redaurum Ltd. of Toronto, began production in May 1996 at the Kelsey Lake Mine in the State Line district of Larimer County, becoming North America's first large-scale, commercial diamond mine (Fig. 32). The mine is producing about 40,000 to 50,000 metric tons of kimberlite ore per month. During the summer Redaurum announced that it would sell all of its diamond prospects and mines in the U.S. and Africa. Since the announcement, the mine has been on a standby and maintenance basis. The plant produced about 9,000 carats in 1997. Two kimberlite pipes were being mined in the open pit operation. The total acreage of the two ore bodies is about 9 hectares. The stripping ratio is between 1.5:1 and 2:1. The total resource in the current mine plan is 16.9 million metric tons to a depth of 100 meters.

Over 60 percent of the diamonds recovered at Kelsey Lake are of gem quality, including a 28.3 carat light yellow diamond discovered in 1996, the largest ever recovered in the State Line district and the fifth largest found in North America. In 1997 the company recovered two large gem quality stones, a 28.2 carat diamond and a 16.3 carat white diamond. The larger stone has been cut into a "cushion" or soft square shape of 16.8 carats making it the largest cut stone ever found in the United States. The previous record holder was the "Uncle Sam" stone found in Arkansas in 1924; it weighed 40.42 carats before being cut into a 12 carat polished stone.

In April Redaurum announced that it had acquired exclusive rights to the Maxwell kimberlite prospect, located about two kilometers west of the Kelsey Lake Mine. The Maxwell kimberlite has a surface expression of 5.6 acres and is diamondiferous. Evaluation work completed during the first exploration period in the State Line district in 1982 included 85 drill holes, geophysical surveys, and a 78 metric ton bulk sample, which yielded diamonds of similar

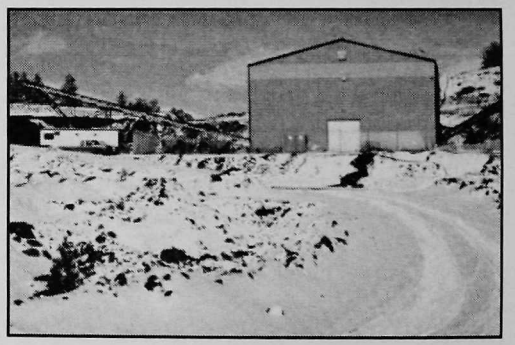

Figure 32. Diamond processing plant at the Kelsey Lake Mine, Larimer County.

quality to those being recovered at the Kelsey Lake Mine. Plans for 1997 included processing of a 10,000 metric ton bulk sample.

The Sweet Home Mine, an old silver prospect, in Park County was reopened as a rhodochrosite mine in 1991. Over the past six years the mine has produced several world class specimens of cherry red rhodochrosite crystals including one thought to be the largest in the world. Some of the larger crystals set in a quartz and sulfide mineral matrix have commanded prices in the hundreds of thousand dollars. Production of rhodochrosite in 1997 was down from 1996. The company plans to sink a winze in 1998.

Gypsum

The Eagle Gypsum Mine, Eagle County produced about 375,000 tons of gypsum in 1997. The gypsum ore is mined from an open pit mine using pavement profiler machines that cut a trench 12 feet wide by 0.5 feet deep. The gypsum is manufactured into wallboard and other products at the plant in the town of Gypsum. Approximately 50 percent of the wallboard produced at the plant goes to the Colorado construction industry and the remainder is marketed throughout the U.S. In February 1997, the company was sold to Centex Construction Products of Dallas and changed its name to Centex Eagle Gypsum Co., LLC. In 1998 the company started on a two-year expansion project

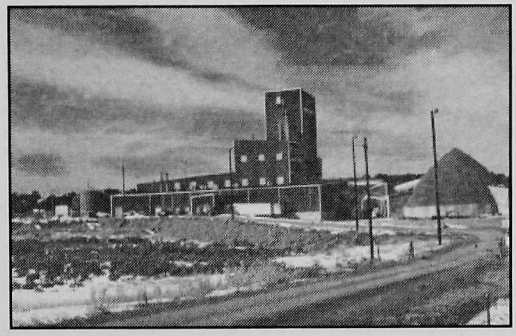

Figure 33. Processing plant at the White River Nahcolite Company Mine, Rio Blanco County.

to increase the production capacity of the plant and the mine to an annual rate of 600,000 tons.

Sodium Minerals

The White River Nahcolite Company produced approximately 70 percent of the plant's nameplate capacity of 125,000 tons a year of nahcolite, sodium bicarbonate, at their solution mine in the Piceance Basin, Rio Blanco County (Fig. 33). In April the company was purchased by IMC Global Inc., an Illinois based producer of potash and related crop nutrients. The company produces both food and industrial grade sodium bicarbonate (baking soda) from the 20 to 25 feet thick "Boies Bed", a Tertiary age lacustrine deposit at a depth of 2,000 feet. Current production is from solution cavity number four. The plant has a staff of twenty-two persons.

METAL EXPLORATION ACTIVITIES

Hendricks Mining Co. completed several core drill holes on their holdings in the Caribou district, Boulder County. The Cross Mine in the district is thought to be a stockwork vein gold deposit associated with the contact of a Tertiary age quartz monzonite and surrounding Precambrian rocks. Preliminary reserve calculations by Hendricks Mining indicate 1.6 million tons at a grade of 0.14 ounce of gold per ton including a high grade zone of 387,000 tons at a grade of 0.21 ounce of gold per ton. Some of the 1997 drill holes reached depths of 2,000 feet and intercepted veins with significant gold values and lesser amounts of silver and base metals.

Because of the recent increase in silver prices, Sunshine Mining and Refining Co. is reevaluating its Revenue-Virginius Mine in Ouray County. The Revenue-Virginius is estimated to contain 6.2 million ounces of silver with an inferred resource of at least the same amount. Historically, the Virginius vein contains some of the highest grade silver ore in the state, averaging about 125 ounces per ton. Locally, gold values are about 0.08 ounce per ton. Mineralogy and grades of the tetrahedrite-galena-quartz vein persist over 3,500 feet of depth, based upon exposures in the old mine workings and in drill core.

Sunshine will be conducting prefeasibility studies on the Virginius vein this summer.

Anvil Resources Ltd. acquired kimberlite prospects in the Chicken Park area of the State Line district. The company drilled 12 exploration holes on the property in 1996. Eleven of the drill holes encountered kimberlite. According to a report prepared by M.E. McCallum the drilling program recovered chromite and ilmenite minerals that have chemical compositions indicating an origin in the diamond pressure-temperature stability region. G-10 garnets, a known indicator of diamondiferous kimberlite, were also encountered. Previous testing in this area during the early 1980s by Cominco produced 19.7 carats from a sample of 296 metric tons. A 10,000 metric ton bulk sample is scheduled for the summer of 1998.

Royal Gold Inc. of Denver, through its agreement with Union Pacific Resources, focussed its 1997 exploration activities on Union Pacific lands in the State Line diamond district (Fig. 34). The company conducted a reverse circulation-drilling program at twenty prospective sites identified from the previous year's stream sediment sampling and geophysical programs. Ten out of fifty stream sediment samples yielded positive results for kimberlite minerals including locally abundant G-10 garnets. Royal Gold is evaluating the results of the drilling program and plans to complete follow up exploration in 1998.

Royal Gold is the largest U.S. based gold royalty company and is headquartered in Denver. The company acquires and creates royalty interests by acquisition, exploration, and development of gold properties.

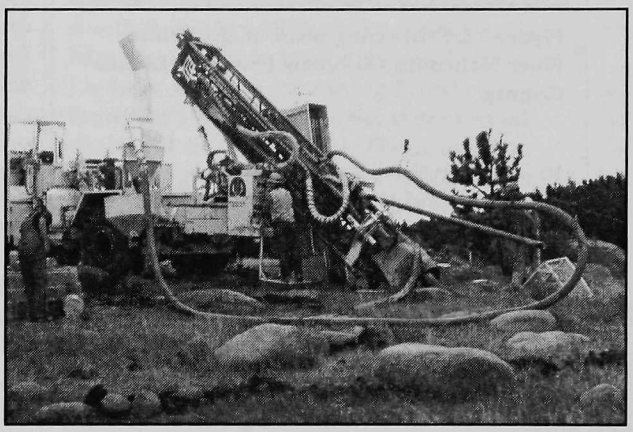

Figure 34. Royal Gold's drilling program for diamonds is being conducted on Union Pacific Resource lands in the State Line district of Colorado and Wyoming. (Photo courtesy of Royal Gold, Inc.)

Summo USA Corporation has two sediment-hosted copper prospects in Colorado; the Cashin prospect in Montrose County and the Copper Spur prospect in southern Routt County. Summo acquired the Copper Spur prospect in September 1996. Copper mineralization at this prospect is in the Devonian Parting Formation and is associated with hydrocarbons. The prospect was mined around the turn of the century and in the 1950s. Historically, the grades were 2 to 4 percent copper with small amounts of lead. Summo reopened the old workings, conducted channel sampling, and obtained an average grade of 1.75 percent copper. Some surface mapping and sampling was completed in 1997 on the prospect.

The Powderhorn district in Gunnison County is estimated to contain approximately 500 million tons of titanium ore. Most of the titanium resource is in perovskite, a mineral that presents unique processing problems. Teck Resources has been conducting an evaluation program on the titanium resource called the White Earth Project since 1990. In 1997, Teck continued the second phase of pilot metallurgical tests, which consist of converting the perovskite concentrate to titanium dioxide pigment for the paint and chemical industry. The pilot plant is expected to provide enough titanium dioxide for test pigment marketing purposes.

American Soda Company operated a pilot solution-mining project for nahcolite in the Piceance Basin near the White River Nahcolite Mine in Rio Blanco County. The company is using a special single-hole, solution-mining process developed by Shell Oil.