INFORMATION SERIES 73

Colorado Mineral and Energy Industry Activities, 2005

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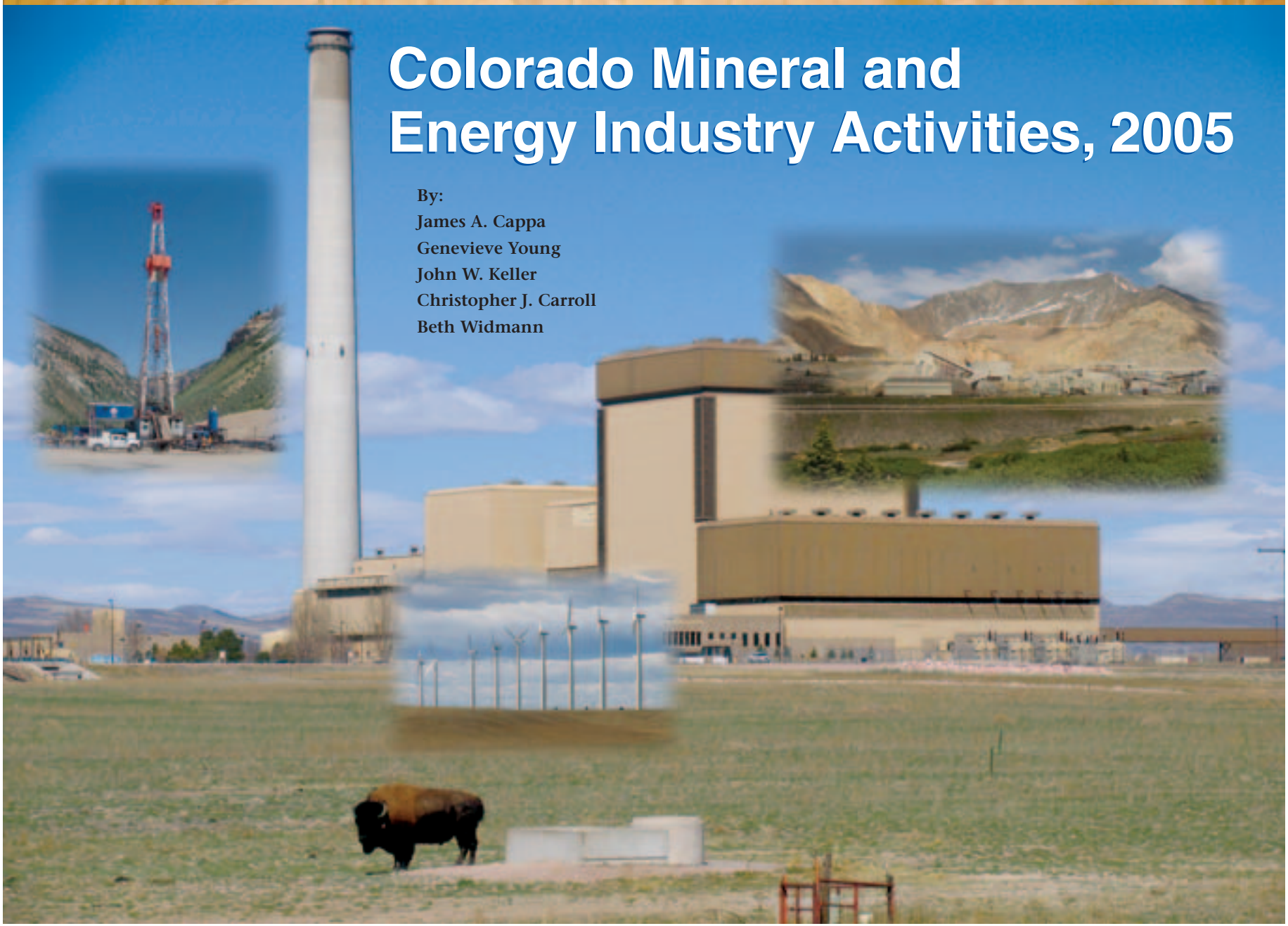

Colorado Geological Survey • Department of Natural Resources • Denver, Colorado • 2006

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State of Colorado

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Cover Figure Captions, starting from upper left

1. EnCana Oil and Gas drilling rig in the Piceance Basin (photo courtesy of Brian Macke, Colorado Oil and Gas Conservation Commission)
2. (Background image) Platte River Power Authority's Rawhide Energy Station, Weld County (photo by Christopher Carroll)
3. Climax Molybdenum Mine, Lake County (photo by John Keller)
4. Ponnequin Wind Farm, Larimer County (photo by Christopher Carroll)

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EXECUTIVE SUMMARY

The Colorado mineral and energy industries have enjoyed another year of spectacular growth; not only has production increased dramatically for most commodities, but prices for mineral and petroleum commodities have also increased. Employment levels have increased sharply.

The Colorado Geological Survey (CGS) estimates the total value of 2005 mineral and energy production in Colorado to be **$11.872 billion**—a 38 percent increase from the revised* 2004 total value of $8.610 billion (fig. 1, fig. 2, and table 1).

Mineral fuel, carbon dioxide, and nonfuel mineral production values for 2005 are estimated at:

- **Oil—$1,197 million**
- **Natural gas—$8,092 million**
- **Carbon dioxide—$241 million**
- **Coal—$813 million**
- **Nonfuel minerals—$1,521 million**
- **Uranium—$7.3 million**

The total estimated value of oil, natural gas, and carbon dioxide production in 2005 is $9.530 billion, which is up 39 percent from the 2004 value of $6.861 billion. Colorado natural gas production and the prices for oil and natural gas increased strongly during 2005. The production and price for carbon dioxide climbed during the year, increasing the value of production from $129 million in 2004 to $241 million in 2005—an 87 percent increase. Oil, gas, and carbon dioxide average prices are obtained from the Colorado Oil and Gas Conservation Commission.

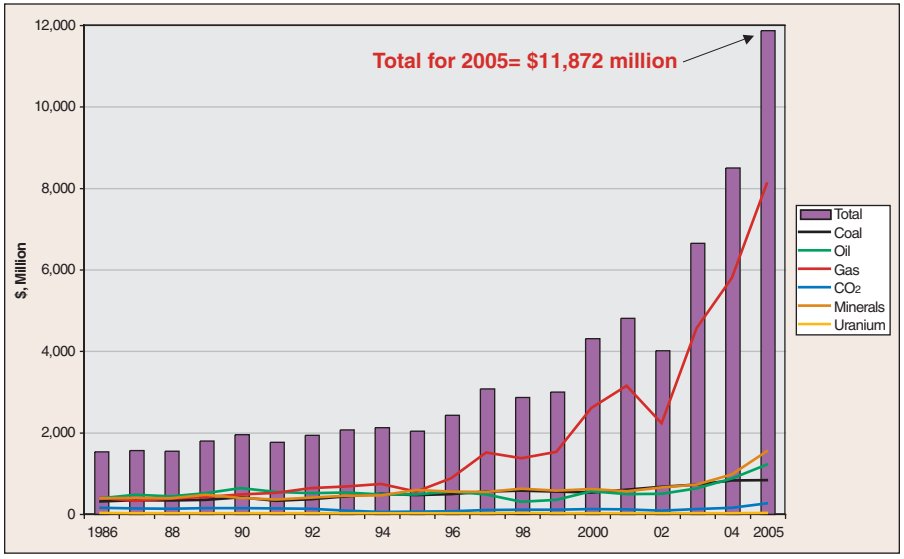

Figure 1. Colorado mineral and energy production value, 1986–2005.

Coal production decreased from the 2004 level of 39.8 million tons to 37.8 million tons in 2005, primarily due to production shortfalls at two coal mines. The average coal price on federal leases for 2005 is estimated at $18.14 per ton, up slightly from $18.09 in 2004. The average coal price is obtained from the federal Minerals Management Service; this price reflects both contract and spot sales of coal from federal leases, which are about 75 percent of the coal produced in Colorado. Spot prices for coal in Colorado for 2005 averaged about $33 per ton, an increase of 18 percent from the $28 average spot price for 2004, according to the U.S. Department of Energy/Energy Information Agency. CGS estimates the average price for all coal produced in Colorado to be $21.50 per ton. The value of the 2005 Colorado coal production is estimated at $813 million—up two percent from the revised* 2004 value of $796 million.

The CGS estimates the value of the 2005 nonfuel mineral production to be $1,521 million—a 60 percent increase from the revised 2004 value of $951 million. Dramatic price increases and increased production for molybdenum and continued high gold prices were a factor in the increase of nonfuel mineral value.

Uranium production value in 2005 increased 248 percent from $2.1 million in 2004 to $7.3 million in 2005. Uranium prices continued to rise in 2005; however, in spite of rising prices, all four producing uranium mines were shut down in November 2005.

Taxes and royalties from mineral and energy production flow directly back to the State of Colorado and local governments. The combined total of federal mineral lease revenues, state severance taxes, Colorado State Land Board mineral royalties and rentals, and county property taxes on mineral properties for 2005 was $530 million.

* Estimated production and values are obtained from other state agencies, federal agencies, company annual reports, press releases, mine operators, and other sources. Sources of data are explained in the appropriate section in the following chapters. The 2004 production value is revised to $8,610 million from the published value of $8,502 million (Colorado Geological Survey Information Series 70, *Mineral and Mineral Fuel Activity, 2004*.

Table 1. Colorado mineral and energy production and value, 2004 and 2005. Average price is annual average published price. Realized value is the amount received by companies, which is generally not equal to the average price times volume produced.

2005 (Estimated)	Volume Produced	Volume Sold	Average Price	Realized Value (Millions)	% Change in value from 2004
Hydrocarbon and Carbon Dioxide Production Statistics[1]					
Natural gas	1,129 Bcf	1,095 Bcf	$7.39/Mcf	$8,092	38%
Crude oil	22.5 MMbo	22.2 MMbo	$53.93/bbl	$1,197	38%
Carbon dioxide	399 Bcf	359 Bcf	$0.67/Mcf	$241	87%
Estimated Total Value of Hydrocarbons and Carbon Dioxide				$9,530	39%
Coal Production Statistics[2]					
Estimated Total Value of Coal Production	37.820 Mst	– –	$21.50/st	$813	2%
Mineral Production Statistics[3,4]					
Gold	355,168 oz	– –	$444.74/oz	$139	26%
Silver	169,189 oz	– –	$7.32/oz	$1.2	-6.7%
Molybdenum	32 million lbs	– –	$31.73/lb	$828	138%
Uranium	255,542 lbs	– –	$28.52/lb	$7.3	248%
Vanadium	1,374,518 lbs	– –	$17.52/lb	$24.1	1,507%
Industrial Minerals	– –	– –	– –	$529	8%
Estimated Total Value of Non-fuel and Uranium Minerals Production				$1,529	60%
Estimated Total Value of all Mineral and Energy Production in Colorado				**$11,872**	**38%**
2004 (Actual)	**Volume Produced**	**Volume Sold**	**Average Price**	**Realized Value (Millions)**	**% Change in value from 2003**
Hydrocarbon and Carbon Dioxide Production Statistics[1]					
Natural gas	1,091 Bcf	1,059 Bcf	$5.54/Mcf	$5,867	29%
Crude oil	22.5 MMbo	22.3 MMbo	$38.78/bbl	$865	43%
Carbon dioxide	341 Bcf	340 Bcf	$0.38/Mcf	$129	32%
Actual Total Value of Hydrocarbons and Carbon Dioxide				$6,861	31%
Coal Production Statistics[2]					
Actual Total Value of Coal Production	39.813 Mst	– –	$20.00/st	$796	13%
Mineral Production Statistics[3,4]					
Gold	343,350 oz	– –	$409.72/oz	$111	5%
Silver	199,057 oz	– –	$6.67/oz	$1.3	92%
Molybdenum	27.5 million lbs	– –	$18.30/lb	$348	170%
Uranium	112,803 lbs	– –	$18.55/lb	$2.1	600%
Vanadium	281,900 lbs	– –	$5.28/b	$1.5	650%
Industrial Minerals	– –	– –		$489	4%
Actual Total Value of Non-fuel and Uranium Minerals Production				$953	36%
Actual Total Value of all Mineral and Energy Production in Colorado				**$8,610**	**29%**

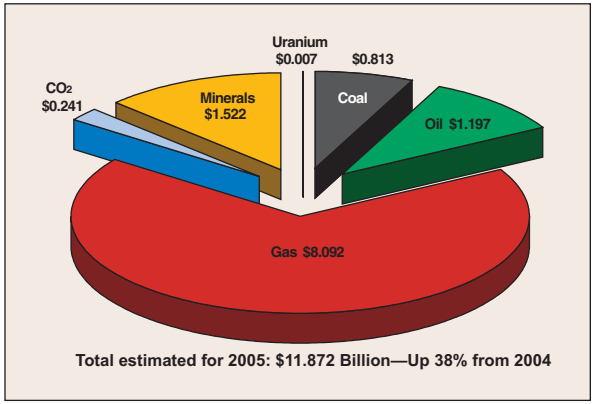

Figure 2. Mineral and energy production value ($ billion) by sector, 2005.

Table Sources: [1]Colorado Oil and Gas Commission, http://oil-gas.state.co.us/; [2]Colorado Department of Local Affairs, http://www.dola.state.co.us/LGS/FA/EMIA/miner/MinerWebTables.pdf; [3]U.S. Geological Survey Minerals Information, http://minerals.usgs.gov/minerals/pubs/mcs/; [4]Company reports and press releases.

Abbreviations: Bcf—billion cubic feet; Mcf—million cubic feet; MMbo—million barrels; bbl—barrels; Mst—million short tons; st—short tons; oz—ounces; lbs—pounds.

INTRODUCTION AND ECONOMIC FACTORS

The mineral and energy industries provide the essential elements of modern day life from gasoline for our cars; steel for our buildings, trucks, airplanes, and bridges; copper for wires and electrical parts; and aggregate for our roads. Every day, every citizen, in some way, touches or uses products provided by these industries. The Mineral Information Institute estimates that the average American will use 3.7 million pounds of minerals, metals, and fuels during an average life span of 77.6 years—that is over 47,502 pounds of materials every year for every American (fig. 3).

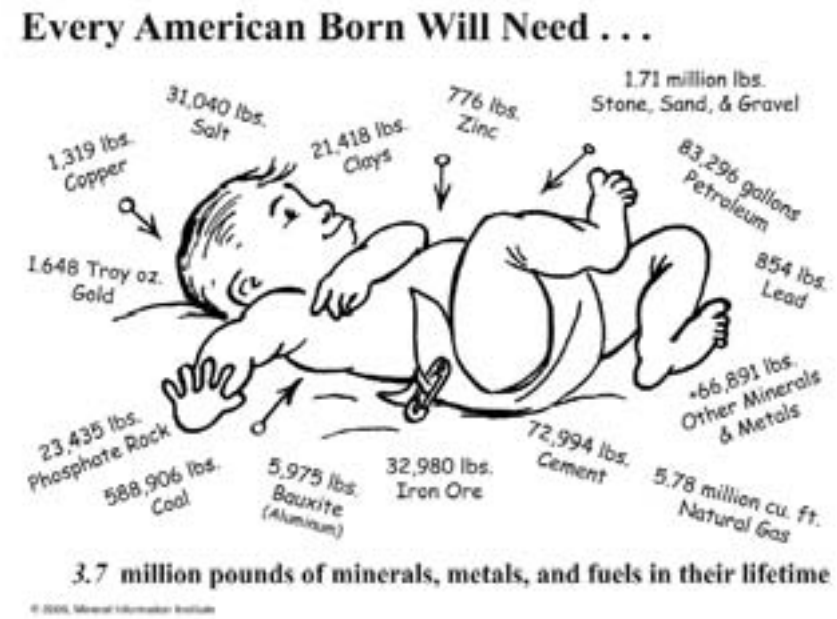

Figure 3. Mineral needs of the average American (Courtesy of the Mineral Information Institute).

The mineral and energy industries in Colorado produce a wide variety of materials essential to our daily lives; coal provides electricity, natural gas heats our homes, molybdenum hardens our steel. Sand and gravel are necessary for our homes, offices, roads, driveways, and many other uses.

The Colorado mineral and energy industries have enjoyed another year of spectacular growth; not only has production increased dramatically for most commodities, but prices for most mineral and petroleum commodities have also increased. Also, employment levels have increased sharply.

The Colorado Geological Survey (CGS) estimates the total value of 2005 mineral and energy production in Colorado to be **$11,872 million**—a 38 percent increase from the (revised*) 2004 total value of $ 8,610 million (fig. 1, fig. 2, and table 1).

The value of Colorado's mineral and energy production is realized in many ways including employment, taxes, and royalties that flow back to state and local governments. The value of Colorado's share of federal mineral royalties in 2005 is $114.791 million—a 28 percent increase from the 2004 value of $89.860 million. A substantial portion of the Colorado share of royalties goes directly to public education and local governments (figs. 4 and 5).

Severance taxes are state taxes that are collected on the production of oil, gas, coal and certain minerals. According to Colorado law, 50 percent of the severance tax revenue flows to local governments and 50 percent flows into a state trust fund to "replace" depleted natural resources and to 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 energy industries. Severance tax collections in fiscal year 2005 were $146.4 million—up 26 percent from the 2004 severance tax collection of $115.9 million (fig. 6).

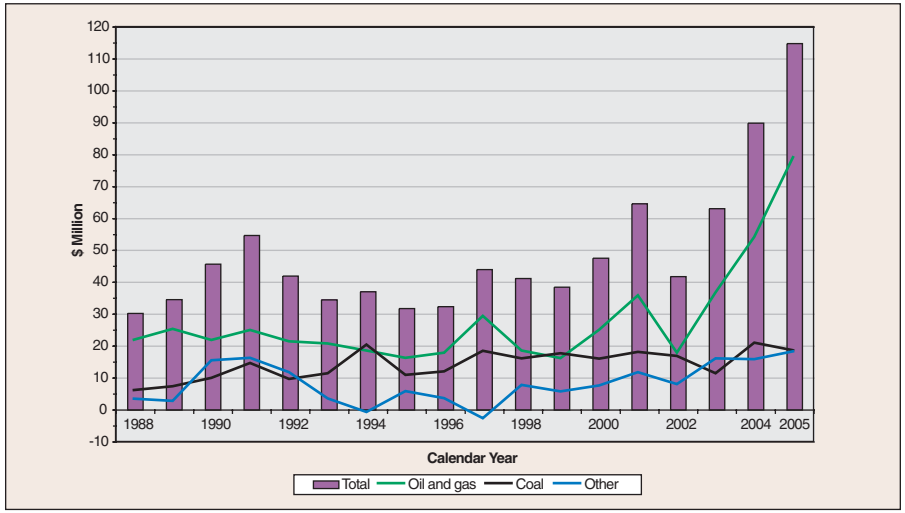

Figure 4. Federal mineral lease revenue by type, 1988–2005 (source: Colorado Department of Local Affairs).

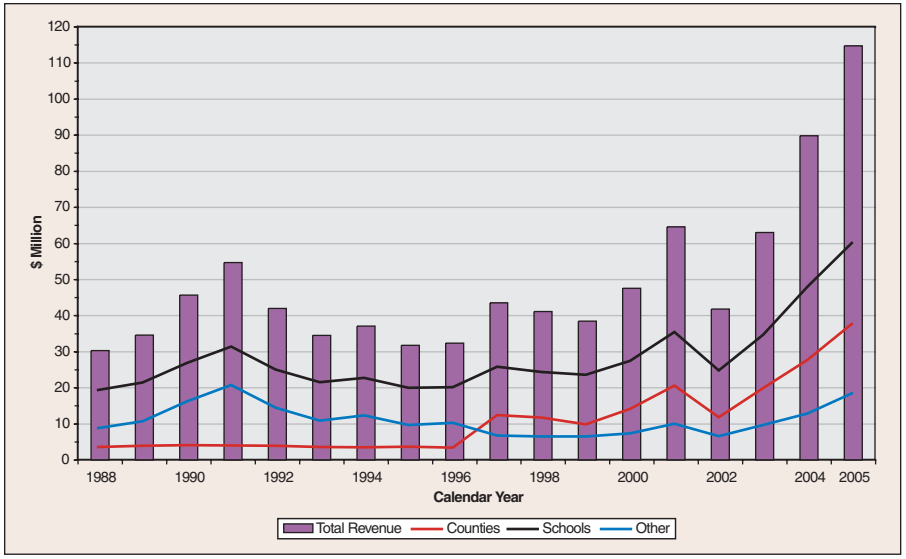

Figure 5. Federal mineral lease revenue and distribution, 1988–2005 (source: Colorado Department of Local Affairs).

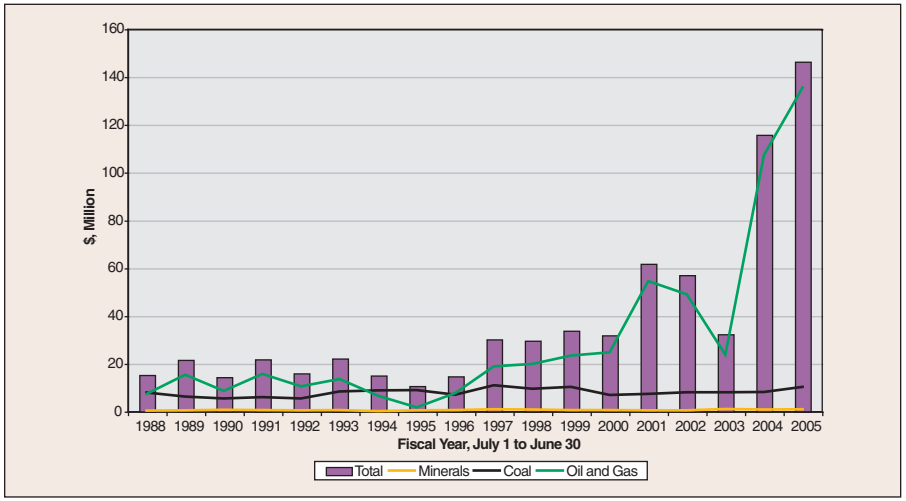

Figure 6. Colorado mineral severance tax revenue, 1988–2005 (source: Colorado Department of Local Affairs)

Estimated property taxes paid in 2005 to the counties from mineral and energy properties totaled $227 million up 68 percent from the $135 million collected in 2004 (fig. 7). Property taxes revenues lag about three years behind the actual year of production. All Colorado counties receive revenue from mineral related property taxes.

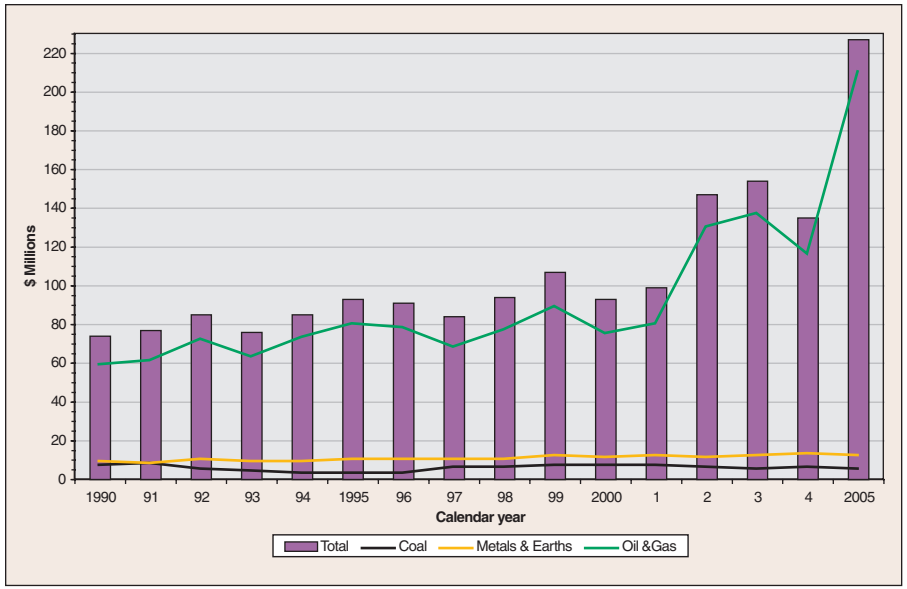

Figure 7. Property tax collections from Colorado mineral properties, 1990–2005 (source: Colorado Department of Local Affairs).

In the fiscal year ending on June 30, 2005, the Colorado State Land Board received $41.731 million from mineral royalties, bonuses, and rentals on state owned land, a new record and up 62 percent from the $25.785 million collected in fiscal year 2004. The State of Colorado owns over 4 million acres of mineral land and the revenues from these lands go to the Permanent Fund controlled by the State Land Board. Interest from this fund is distributed by the School Finance Act to the school districts of Colorado (figs. 8 and 9).

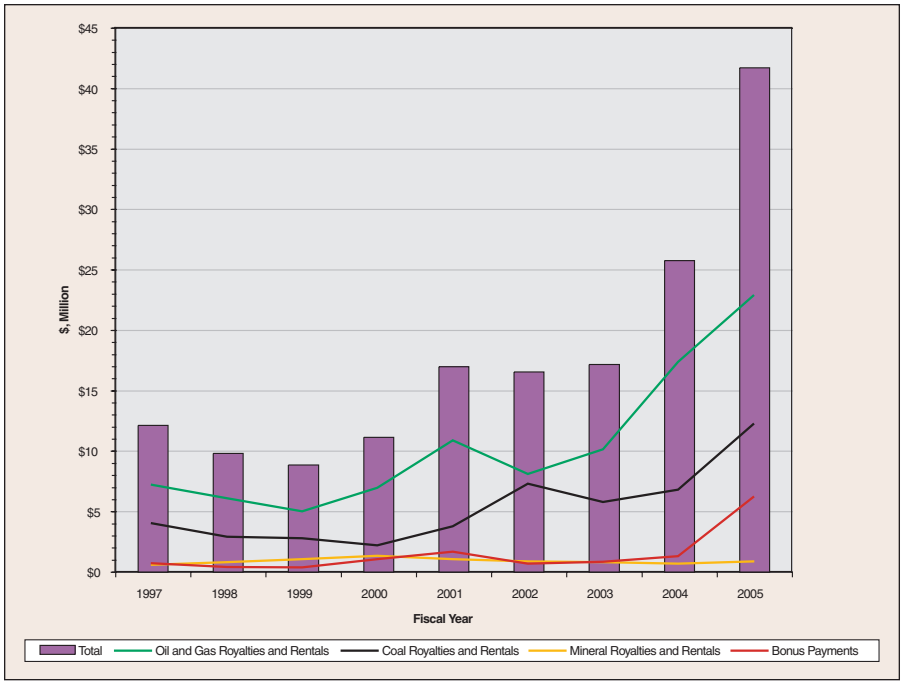

Figure 8. Colorado State Land Board Mineral Revenues, 1997–2005. Bonus payments are payments received from auctions of State mineral leases (source: Colorado State Land Board).

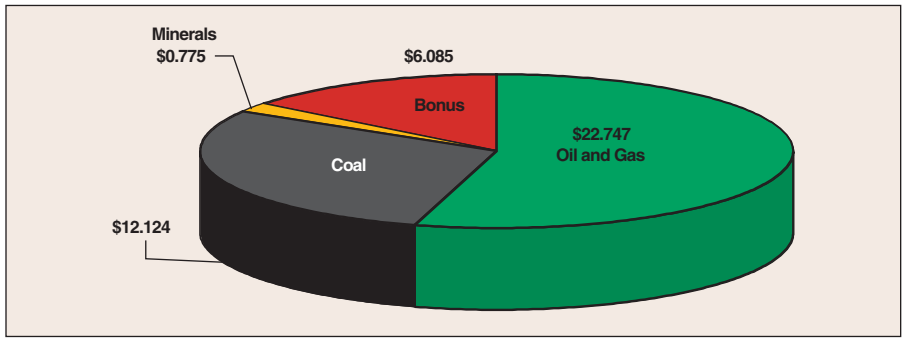

Figure 9. Colorado State Land Board mineral revenues, July 1, 2004–June 30, 2005. Bonus payments are payments received from auctions of State mineral leases (source: Colorado State Land Board).

The Colorado Department of Labor and Employment tracks employment trends for the state. Employment statistics for the mining and oil and gas extraction industries are included in their Mining category. This sector grew 38 percent (from 12,880 to 17,815) between 2000 and the 3rd quarter of 2005 (fig. 10). The Colorado Business Economic Outlook Forum annual report for 2006 states that about one-third of the employees in this supersector work in each of the following areas: oil and gas extraction, mining, and support activities related to both oil and gas and mining industries. The 24 percent growth in employment from 14,374 in 2004 to 17,815 in 2005 has resulted in a new ten-year high. Wages for workers in the oil and gas and mining businesses sectors are among the highest in the state and bring a much-needed source of wealth to the rural parts of Colorado. According to the Colorado Department of Labor and Employment, the average annual wage through the 3rd quarter of 2005 for workers in the oil and gas and mining industries was $82,316; about twice the average of $42,016 for all statewide job categories (fig. 10).

Figure 10. Colorado mineral and energy industry employment and wages, 1995–2005 (source: Colorado Department of Labor and Employment)

CONVENTIONAL ENERGY RESOURCES: OIL AND NATURAL GAS

Summary

The Rocky Mountain region, and in particular Colorado, continues to experience a boom in its oil and natural gas industry. Although briefly interrupted in 2002, this boom is currently in its sixth year and is showing no sign of slowing in the near future (fig. 11). The energy markets have also continued to experience a much greater than normal volatility in commodity prices during 2005. The combination of price volatility and growing demand has adversely impacted all business sectors in the state with higher energy costs.

The total value of oil and gas production in 2005 is estimated at $9.29 billion, a 38 percent increase over the 2004 value of $6.73 billion. This astonishing increase in value resulted primarily from the continued gains in both oil and gas commodity prices. Eighty-seven percent of 2005 production value resulted from the sale of natural gas where production has steadily grown for the past two decades.

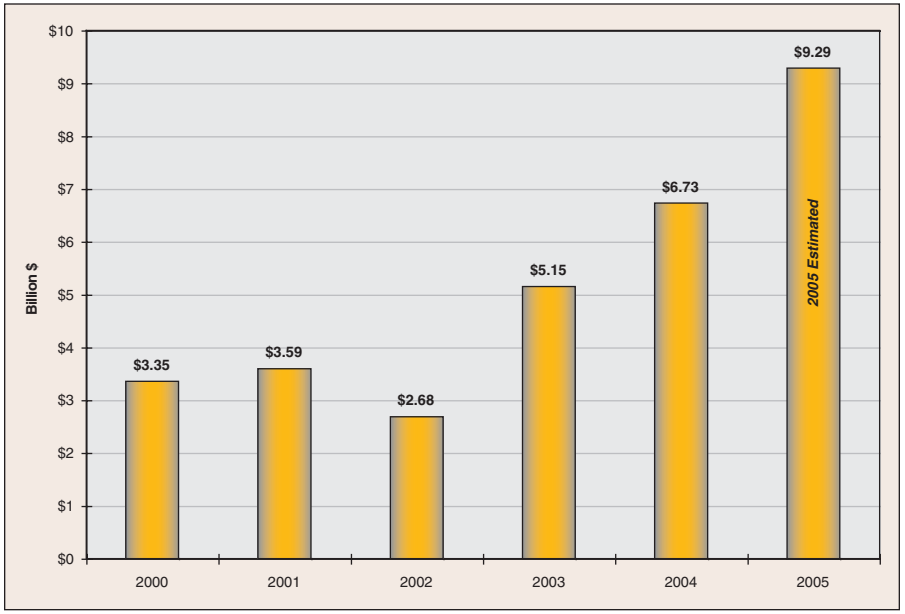

Figure 11. Annual production value for oil and natural gas in Colorado, 2000–2005 (Colorado Oil and Gas Conservation Commission, 2006).

Commodity Prices

Oil and natural gas prices for Colorado are tracked by the Colorado Oil and Gas Conservation Commission (COGCC) and made available via their website. Colorado's so-called "oil price" is actually a computed oil price composite index. This weighted index is based on the geographic quadrant of the state in which the production occurs (NW, SW, NE, or SE) and the refinery that is purchasing the production (Chevron Texaco, Shell, or Valero). Natural gas liquids, condensate, and crude oil are referred to in the aggregate as oil.

Colorado Weighted Average Oil Price Composite Index =
0.35 NW (Chevron Texaco) + 0.05 SW (Shell) + 0.40 NE (Valero) + 0.20 SE (Valero)

The state's oil index has shown strong growth in recent years. Since early 2002, oil prices have increased more than three-fold from about $17 per barrel to more than $60 during the Gulf of Mexico hurricane season of 2005 (fig. 12).

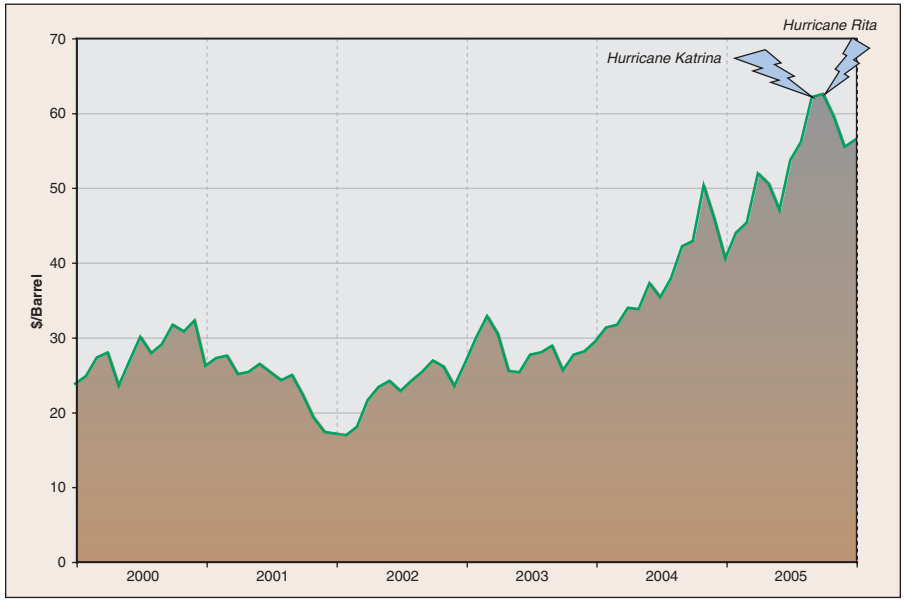

Figure 12. Colorado weighted average oil price composite index; monthly data for January 2000–December 2005 (Colorado Oil and Gas Conservation Commission, 2006).

As with Colorado's oil index, the often-quoted "gas price" is actually a computed composite index. This weighted index is based on the geographic area of the state in which the production occurs and the pipeline infrastructure that it will supply. The Northwest Pipeline System is a 4,000-mile, bi-directional transmission system that crosses through western Colorado and provides access to western Canada, U.S. Rocky Mountains and San Juan Basin gas supplies. More than 17,000 miles of El Paso Natural Gas pipeline connects gas supplies from Colorado's portion of the San Juan Basin to markets in California. The Colorado Interstate Gas pipeline system extends from producing areas in the Rocky Mountains and Anadarko Basin to the Colorado Front Range with multiple interconnects serving the Midwest, the Southwest, California, and the Pacific Northwest. Natural gas is priced based on its Btu-content (British thermal units), a price that decreases with increasing concentrations of non-methane contaminates.

Colorado Weighted Average Gas Price Composite Index =
0.20 RM (NW P/L) + 0.50 SJB (El Paso) + 0.30 Rockies (CIG)

The state's gas index has shown strong recovery in recent years. Although there is considerable price fluctuation, the average gas price increased from about $3.50 per million Btu in 2000 to nearly $7.00 in 2005. This is a two-fold increase in the last six years (fig. 13).

The opening of the Kern River pipeline expansion in mid-2003 provided Colorado operators (among others in the Rockies) the opportunity to compete with markets in California. This increased competition provided stronger gas prices for Colorado (fig. 13). Prior to the opening of the Kern River expansion, Colorado gas prices were falling because more gas was being produced in the state than there was pipeline capacity to transport it to other markets. The post-Kern River pipeline period saw a significant expansion in the gas market, yielding more favorable prices for Colorado producers. Hurricane Katrina made landfall on August 29, 2005 and Hurricane Rita made landfall on September 24, 2005; two major storms only a month apart. The resulting disruption to production and facilities infrastructure in the Gulf of Mexico resulted in a significant spike in gas prices across the country (fig. 13).

Oil and Gas Production Volume and Value

Since 2002, the energy industry has benefited from rising prices and production volumes of oil and natural gas. As a result, the combined value of oil and natural gas production in Colorado hit an all-time high in 2005 at an estimated $9.3 billion. Of this value, $8.1 billion (87 percent) is from the sale of natural gas, with about 45 percent of this value from coalbed methane. At the same time, costs have also risen dramatically.

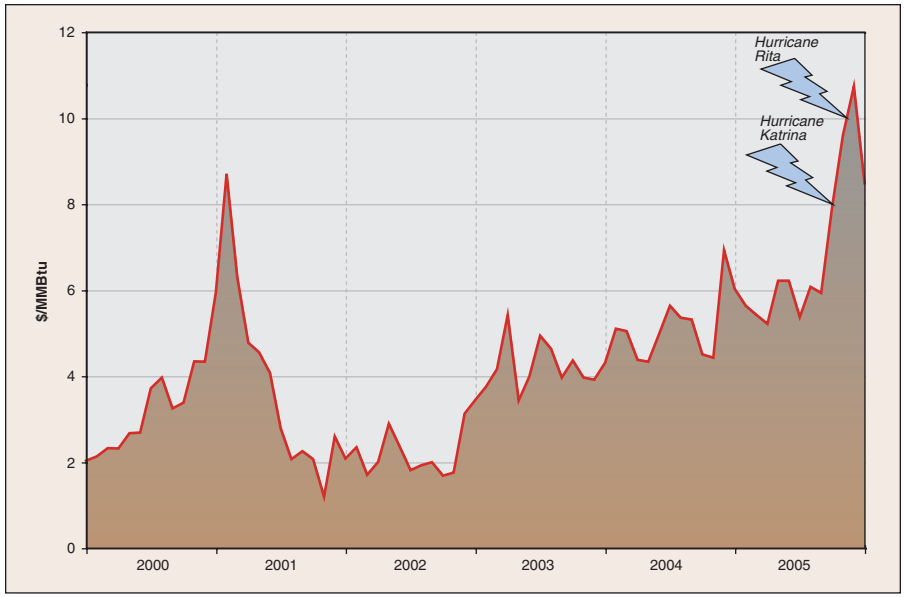

Figure 13. Colorado weighted average gas price composite index; monthly data for January 2000–December 2005; MMBtu = Million British Thermal Units (Colorado Oil and Gas Conservation Commission, 2006).

For the third consecutive year, natural gas production in Colorado exceeded 1 trillion cubic feet (Tcf) (fig. 14). Natural gas production in 2005 is estimated to be 1.13 Tcf which is a 3.5 percent increase over the 1.09 Tcf produced in 2004. Since separate reporting for coalbed methane began in 1990, coalbed methane production has grown to represent about one-half of the state's natural gas production until the last couple of years. Since 2003, growth in coalbed methane production has slowed while conventional and other non-conventional gas production has continued to grow steadily (fig. 14). In 2005, coalbed methane production is estimated to remain at the 2004 level of 501 billion cubic feet (Bcf) which is a 2.5 percent below the peak of 514 Bcf reported in 2003.

Because of the tremendous boom in Rockies' gas exploration and development, Colorado's annual gas production has grown an average of 7.5 percent per year since 2000; from 772 Bcf to an estimated 1.13 Tcf for 2005 (fig. 14). By contrast, the value of that production has increased from $2.8 billion to an estimated $8.1 billion during the same period, almost a three-fold increase in the value of the state's gas production (fig. 15).

Oil production in Colorado dropped sharply to a low of 19.3 million barrels from 1995 to 1999. Since then strong commodity prices and increased natural gas production reversed this downward trend, resulting in a gradual (but steady)

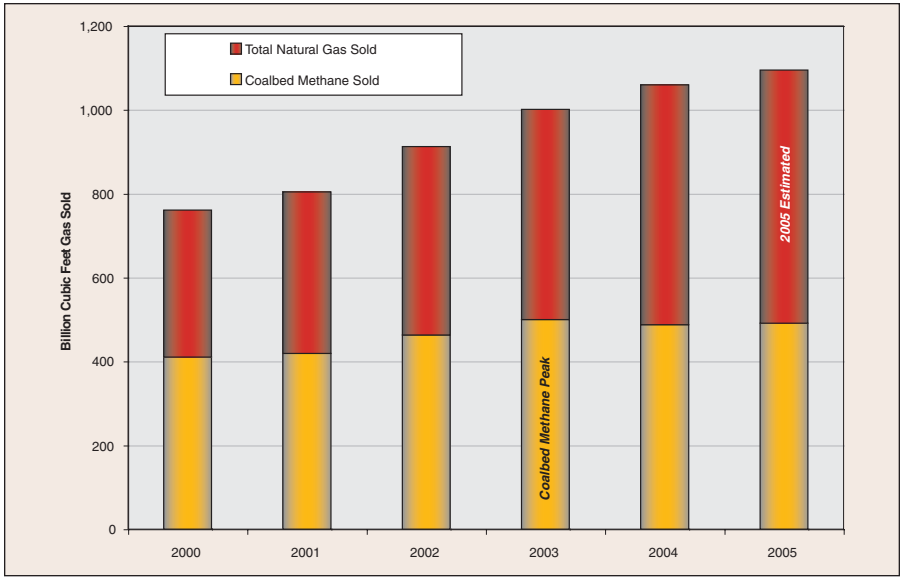

Figure 14. Colorado natural gas production and value (Colorado Oil and Gas Conservation Commission, 2006).

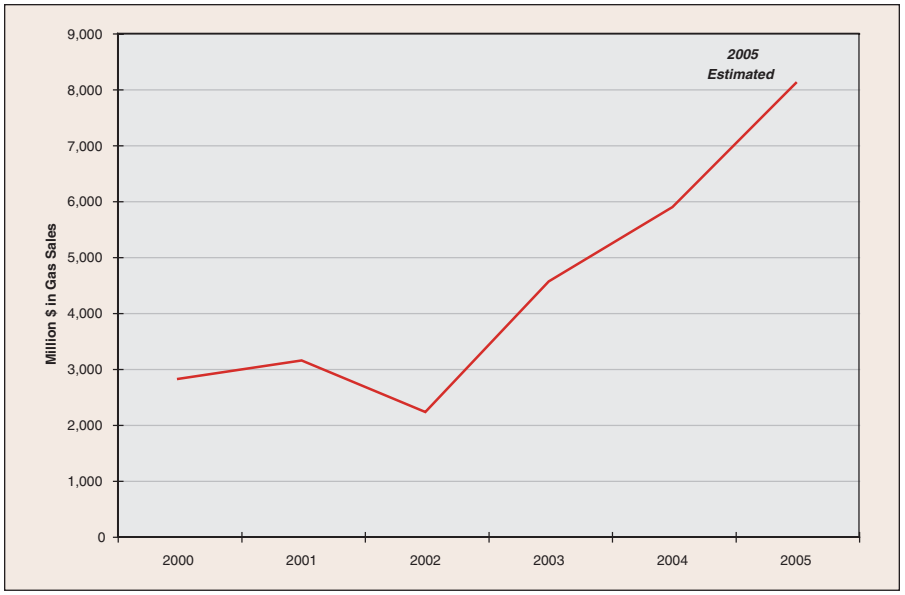

Figure 15. Value of Colorado natural gas production (Colorado Oil and Gas Conservation Commission, 2006).

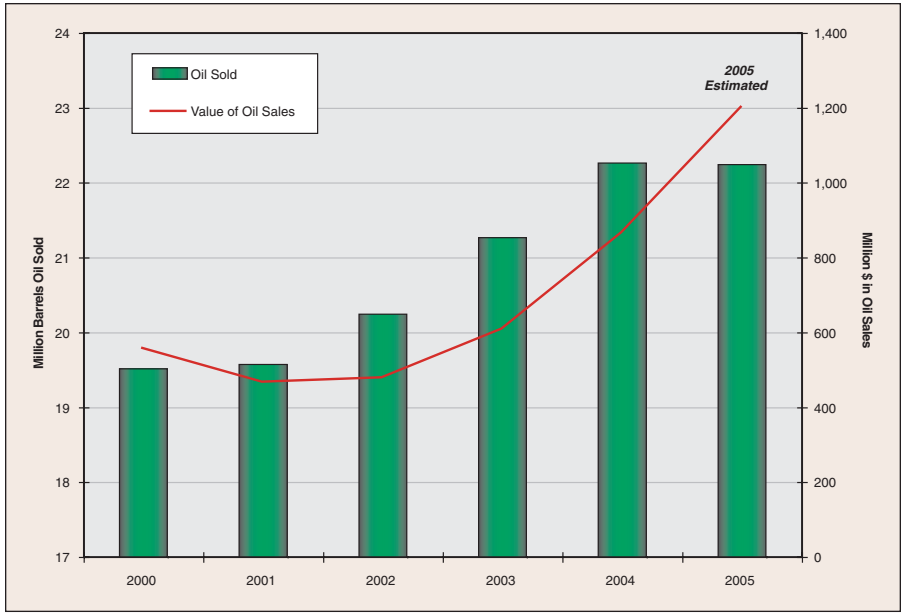

Figure 16. Colorado oil production and value (Colorado Oil and Gas Conservation Commission, 2006).

increase in oil production through 2004 (fig. 16). Oil production in 2005 is estimated to remain at the 2004 level of 22.5 million barrels. Although growth in oil production has slowed, strong oil prices continue to drive up its value, reaching an estimated $1.2 billion in 2005 or an increase of nearly 40 percent over the 2004 value of $863 million (fig. 16).

County Rankings

Thirty-seven (or 58 percent) of Colorado's 64 counties produce either oil or natural gas, often both. For the purpose of ranking each county's contribution to the total value of the state's production, the sales volumes for each county have been assigned a value using the average annual composite oil and gas price indices ($53.93 per barrel oil and $7.39 per thousand cubic feet gas [Mcf], respectively). Based on the resulting production values computed for 2005, Colorado has three counties in which the annual production value is estimated to exceed $1 billion (La Plata, Garfield, and Weld) and five counties in which the annual production value is estimated at $100 million or more but less than $1 billion (Las Animas, Rio Blanco, Yuma, Moffat, and San Miguel) (fig. 17). The combined production value for these eight counties represents 95 percent of the total production value for Colorado.

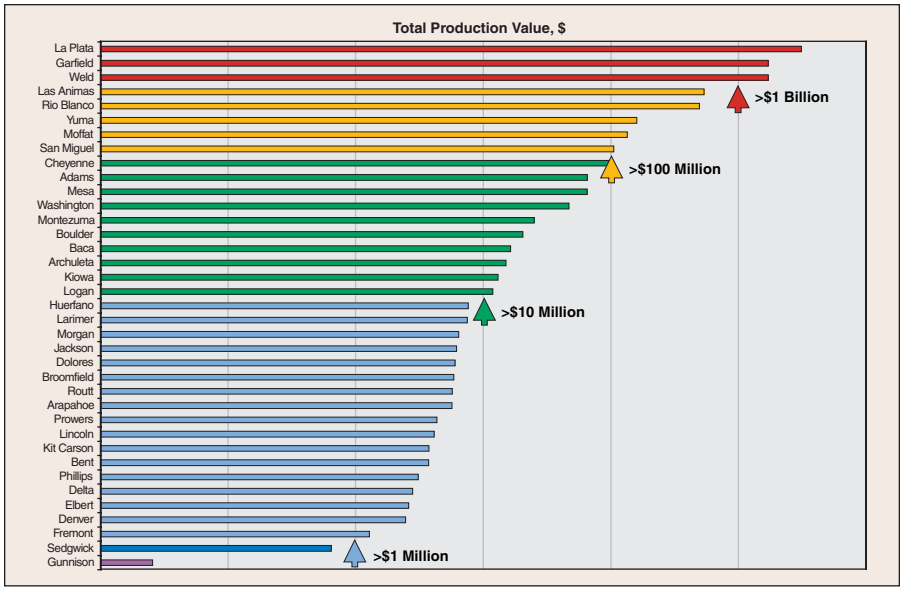

Figure 17. Oil and natural gas production value by county for 2005 (Colorado Oil and Gas Conservation Commission, 2006).

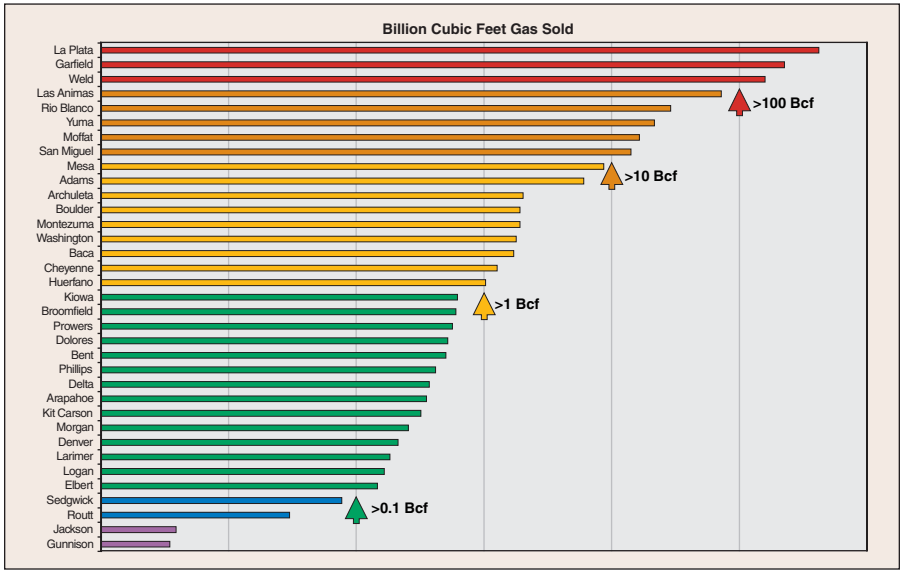

Figure 18. Total natural gas production sold by county in 2005 (Colorado Oil and Gas Conservation Commission, 2006).

A significant portion of this value results from the production of natural gas. The same eight counties that top the rankings in total production value account for 97 percent of the total natural gas production sold for the state and nearly 80 percent of the total oil production sold. The top ranking counties in the sale of natural gas production for 2005 are La Plata, Garfield, and Weld, each with sales in excess of 100 Bcf for the year; Las Animas, Rio Blanco, Yuma, Moffat, and San Miguel counties each had sales of natural gas production in excess of 10 Bcf during the same period (fig. 18). The top ranking counties in oil production sold in 2005 are Weld, Rio Blanco, and Cheyenne with each reporting the sale of more than 1 million barrels of oil or 83 percent of the oil sold in the State of Colorado (fig. 19).

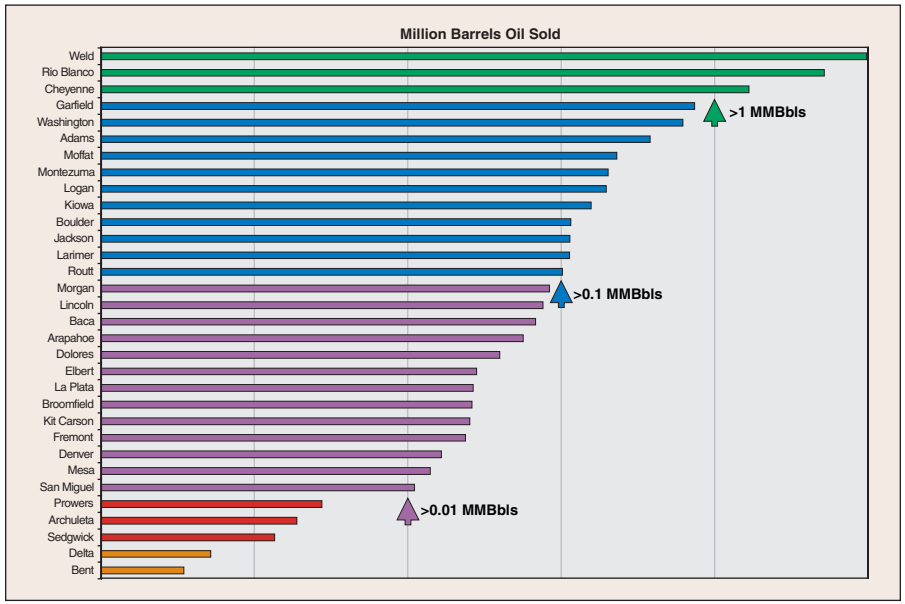

Figure 19. Total oil production sold by county in 2005 (Colorado Oil and Gas Conservation Commission, 2006).

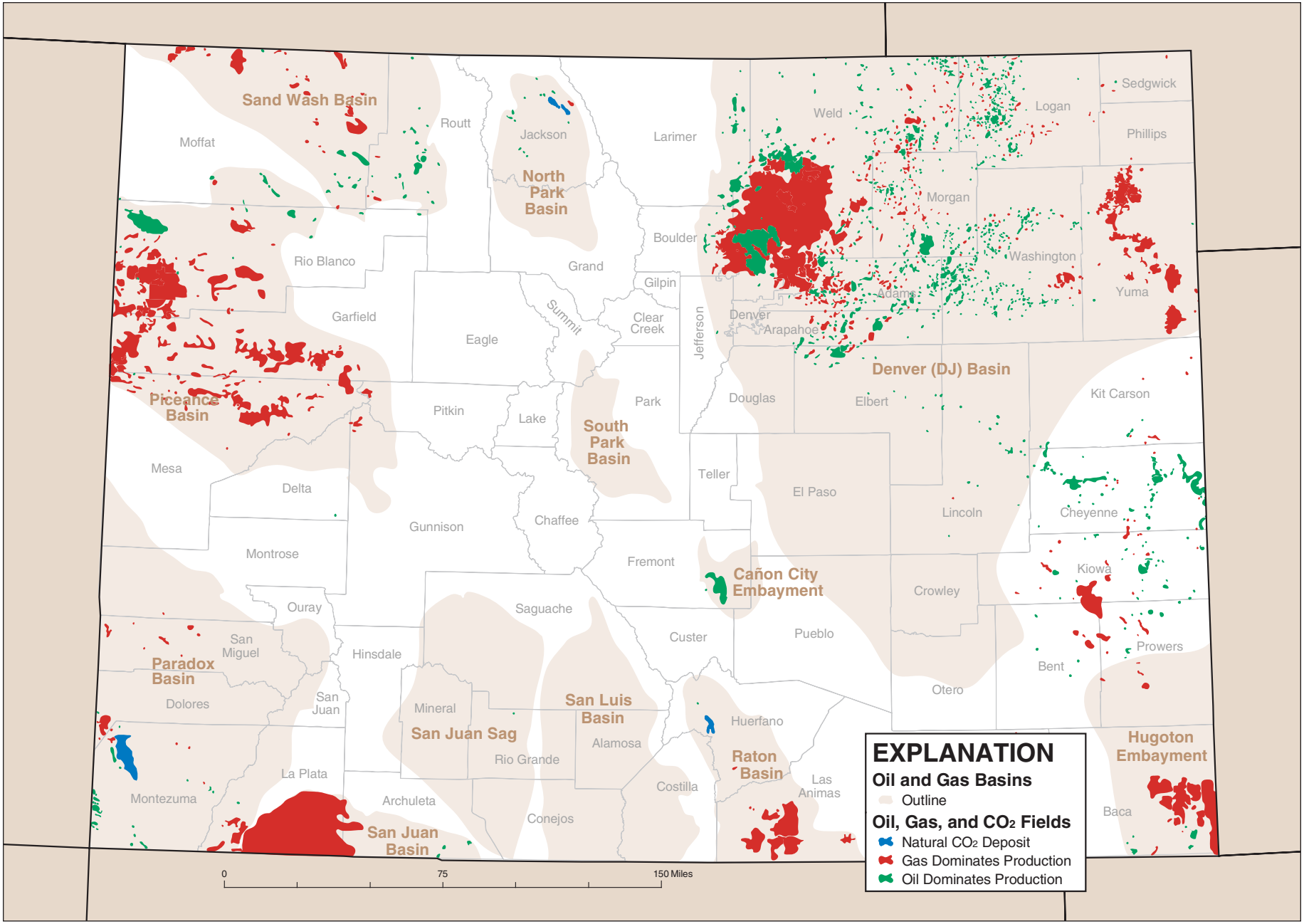

Figure 20. Oil, gas, and carbon dioxide (CO_2) producing fields in Colorado.

Field Rankings and Activity

The county rankings reflect the diversity in Colorado's oil and gas resource base. La Plata County is home to Ignacio-Blanco, the largest gas producing field in Colorado (fig. 20). Ninety percent of the gas sold in La Plata County is produced from coal beds of the Late Cretaceous Fruitland Formation. Oil and gas production also occur from deeper horizons within the basin's Cretaceous sequence, including the Lewis Shale, Mesaverde Group, Mancos Shale, and Dakota Sandstone. The San Juan Basin Gas Area of Colorado and New Mexico ranked as the leading U.S. natural gas area in both production and proved reserves in 2004 (Energy Information Administration, 2005).

The Wattenberg field in the Denver Basin ranked as the 8th largest field in the U.S. in terms of both gas production and gas proved reserves in 2004 (Energy Information Administration, 2005). Wattenberg is also the largest oil field west of the Mississippi River, outside of Texas and California. It ranked 22nd in both oil production and oil proved reserves in 2004. Although the Wattenberg field straddles several counties within the Denver Basin, a significant portion of the field's production is located in Weld County (fig. 20). The western part of the basin, which is located along the eastern edge of the Front Range, is rich in both oil and gas resources. The vast majority of production comes from the Cretaceous Dakota Group's Muddy J Sandstone and the Niobrara-Codell sequence. Production also occurs from the D Sandstone and the fractured Pierre Shale. During 2005, the Wattenberg field's production averaged nearly 27,000 barrels of oil and 0.5 Bcf of gas each day. The liquid production is comprised of approximately 45 percent crude oil, 23 percent gas condensate, and 32 percent natural gas liquids (Wally O'Connell, Kerr-McGee, personal communication). Within the eastern portion of the Denver Basin, the relatively shallow Cretaceous Niobrara Chalk is now making a significant contribution through the production of biogenic gas—a play that is centered in Yuma County.

The Piceance Basin has recently been referred to as the "Persian Gulf of natural gas" (*Denver Post*, March 10, 2006). This remarkable center of natural gas drilling activity is located in Garfield and Rio Blanco counties and is receiving nationwide attention because of its strategically important gas resources (fig. 20). The Piceance Basin hosts four fields with natural gas proved reserves in the nation's "Top 50" list of fields (Energy Information Administration, 2005). All four are located along Interstate Highway 70 in Garfield County. Significant gas production occurs from the Paleocene–Late Cretaceous Fort Union Formation and the Late Cretaceous Mesaverde Group sandstones and coalbeds. In addition, significant oil production occurs from a thick interval spanning the Cretaceous to Pennsylvanian, including the Mancos Shale, Morrison Formation, Entrada Sandstone, the Shinarump Member of the Chinle Formation, and the Weber Sandstone. The Rangely field, which is located in the northwestern Piceance Basin, produces from the prolific Permo-Pennsylvanian Weber Sandstone and accounts for Rio Blanco County ranking second in the sale of oil production for the state. Rangely is one of the largest oil fields in the Rocky Mountains, ranking 57th in the U.S. in terms of oil proved reserves and 60th in terms of oil production in 2004 (Energy Information Administration, 2005).

There is also intense development activity in southern Colorado. Oil (and some associated gas) production in Cheyenne County occurs from Mississippian- and Pennsylvanian-age sandstone and limestone reservoirs along the Las Animas Arch that separates the Hugoton Embayment from the Denver Basin (fig. 20). The Raton Basin located in western Las Animas County is the site of an aggressive coalbed methane play within the Late Cretaceous Raton and Vermejo Formations. The Raton Basin Gas Area of Colorado and New Mexico ranked 11th in the nation in proved gas reserves in 2004 (Energy Information Administration, 2005). San Miguel County in the northern Paradox Basin reports the sale of more than 10 Bcf of gas produced from the Permo-Pennsylvanian Cutler and Hermosa Groups and the deeper Mississippian Leadville Limestone.

Moffat County includes both the northernmost part of the Piceance Basin and the western two-thirds of the Sand Wash Basin. The county could be more easily described by what it does ***not*** produce from, as oil and gas sales are reported from numerous intervals from the Paleocene to deeper Pennsylvanian-age rocks. These include the Paleocene–Cretaceous Wasatch–Fort Union formations, Cretaceous Lance–Fox Hills–Lewis–Almond interval, Mesaverde Group sandstones, Mancos–Niobrara–Mowry shales, Dakota Group, Jurassic Morrison–Sundance–Entrada–Nugget sequence, Permo–Triassic Shinarump–Moenkopi–Phosphoria formations, Permo–Pennsylvanian Weber–Minturn formations.

Drilling Activity

The COGCC reports 5,148 applications for permit to drill (APDs) were received during 2005, representing a 57 percent increase over the 3,284 APDs received in 2004 (fig. 21). Of those received in 2005, 214 were withdrawn and 4,573 of the remaining applications were approved; 361 remained to be processed at year-end. The vast majority of the applications received during 2005 were for drilling new wells or sidetracking existing wellbores; that is, 94 percent or 4,314 permits were approved for drilling new wells (fig. 22). The remaining 259 permits consisted of requests for deepening, recompleting, or re-entering existing wellbores.

The three counties for which the most drilling permits were approved in 2005 are Garfield, Weld, and Las Animas (fig. 23) and reflect the strong focus of exploration and development efforts in the Piceance, Denver, and Raton basins, respectively. Of the total 4,573 applications that were approved in 2005, 93 percent or 4,252 were for drilling activity in the Piceance, Denver, and Raton basins (fig. 24).

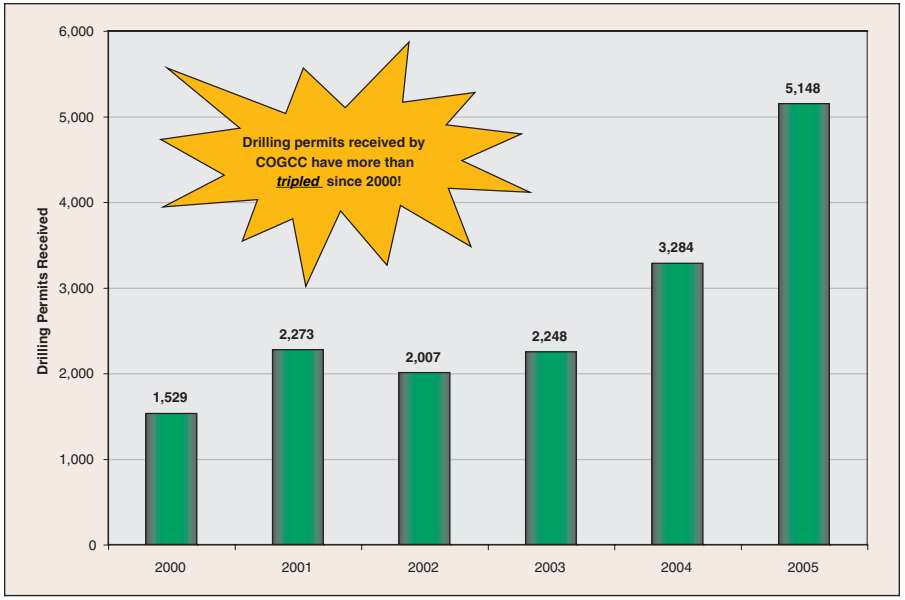

Figure 21. Drilling permits received by the Colorado Oil and Gas Conservation Commission since 2000.

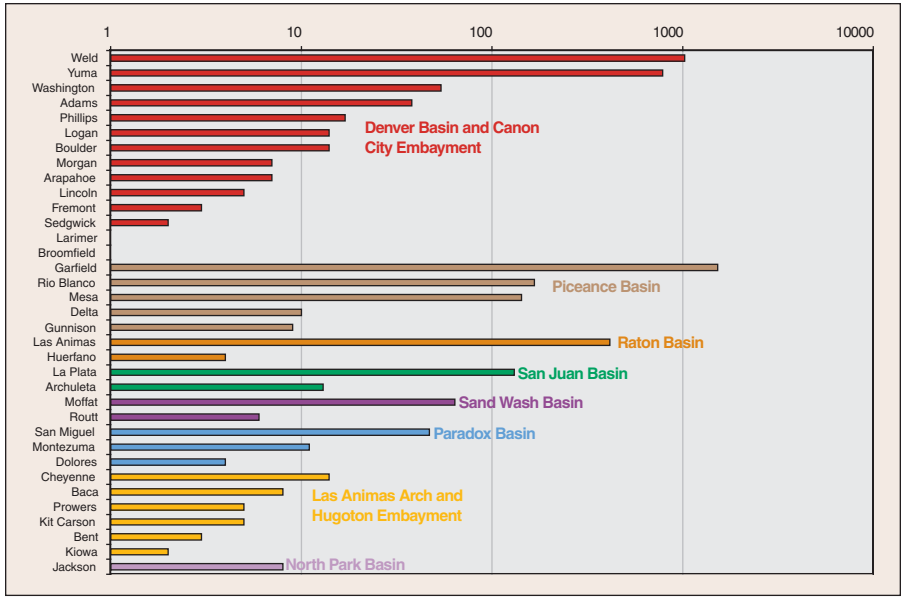

Figure 23. APDs approved in 2005 by county and basin (Colorado Oil and Gas Conservation Commission, 2006).

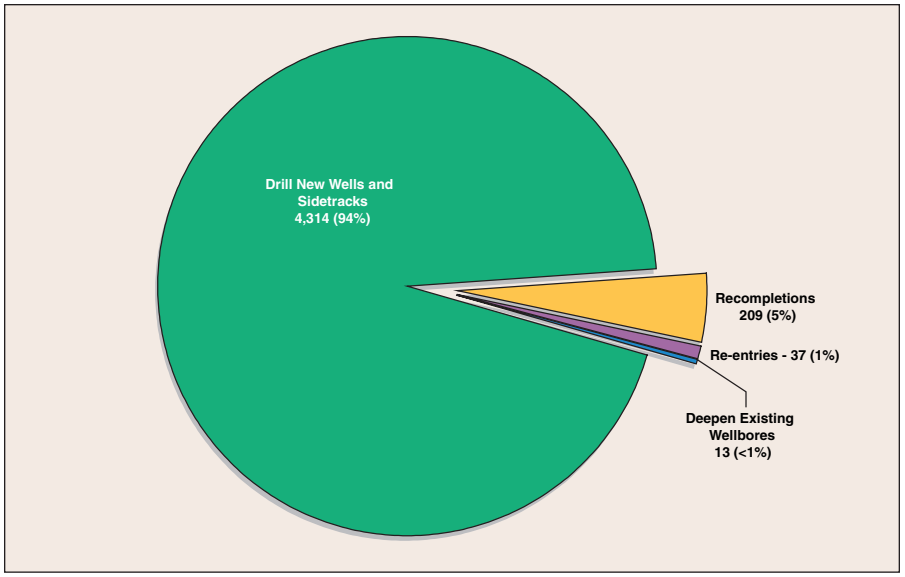

Figure 22. Applications for permit to drill (APD) approved during 2005 by type (Colorado Oil and Gas Conservation Commission, 2006).

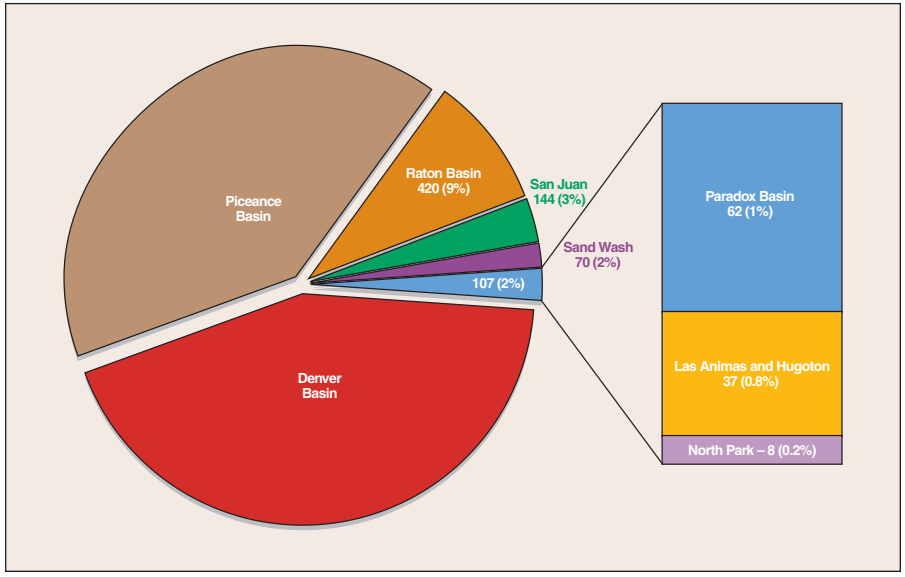

Figure 24. APDs approved in 2005 by basin (Colorado Oil and Gas Conservation Commission, 2006).

In addition to the proposed drilling activity in Colorado's more mature areas such as the San Juan and Paradox basins, applications were also approved in 2005 for emerging resource areas such as the coalbed methane potential in the Sand Wash and North Park basins.

The average weekly rotary drill rig count for Colorado was 74 during 2005, up 37 percent from the average of 54 for 2004 (Baker Hughes, 2006). This average represents about 5.7 percent of the total 1,290 onshore rigs operating in the U.S. during 2005.

Reserves

The Energy Information Administration (EIA) defines "proved reserves" as those volumes of oil and gas that geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions. Proved reserves are either proved producing or proved non-producing. Non-producing reserves are those that remain in the reservoir because they were not drilled during the report year. Non-producing reserves may represent a substantial fraction of total proved reserves.

Crude Oil

It is estimated that Colorado had 220.5 million barrels of proved reserves of crude oil as of December 31, 2004, which represents an increase of 1.6 percent or 3.5 million barrels from the end of 2003 (fig. 25; Energy Information Administration, 2005; Colorado Oil and Gas Conservation Commission, 2006). Nationally, crude oil proved reserves declined 2.3 percent during the same period, from 21.9 billion barrels at the end of 2003 to 21.4 billion barrels at the end of 2004.

Colorado's increase in crude oil proved reserves resulted primarily from acquisitions and extensions to existing oil fields; no new field discoveries or new reservoir discoveries in old fields were reported for 2004 (Energy Information Administration, 2005). There was a minor adjustment to previously reported reserves which is common as infill wells are drilled, well performance is analyzed, new technology is applied, or economic conditions change. The largest upward move in oil reserves is related to the continued development efforts in the Greater Wattenberg Area of the Denver Basin.

Not all proved reserves of crude oil reported in 2004 were producing. Colorado reported 62 million barrels of proved reserves in non-producing status, 1.6 percent more than the 61 million barrels reported in 2003 (Energy Information Administration, 2005; Energy Information Administration, 2004). Non-producing reserves are those awaiting well workovers, the drilling of extensions or additional development wells, installation of production or pipeline facilities, and depletion of other zones or reservoirs before recompletions in reservoirs not currently open to production.

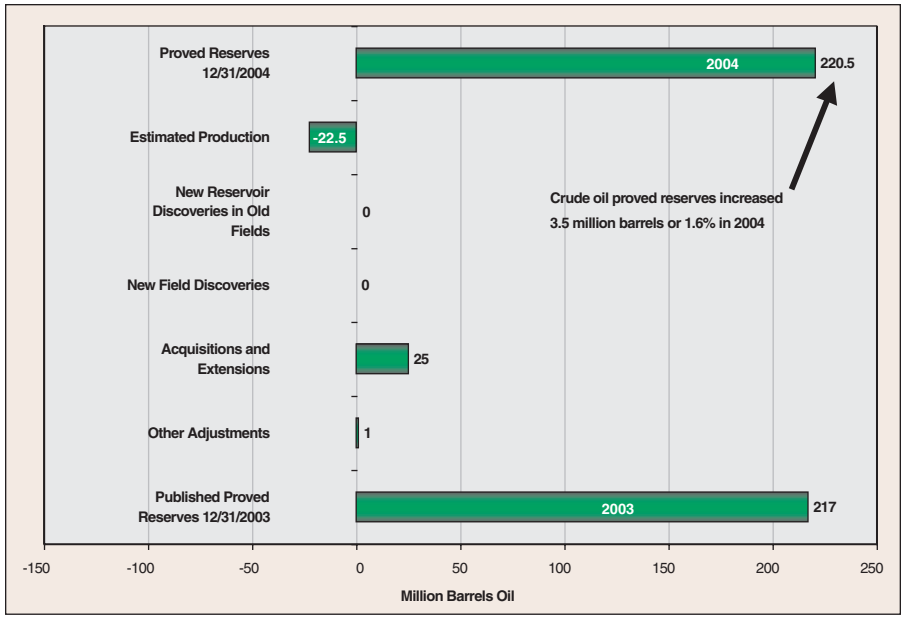

Figure 25. Colorado crude oil proved reserves, reserves changes, and production for 2004 (Energy Information Administration, 2005; Colorado Oil and Gas Conservation Commission, 2006).

There are more than 45,000 oil and gas fields in the U.S. with the top 100 fields accounting for two-thirds of U.S. crude oil proved reserves. The Energy Information Administration (2005) ranked the top 100 oil and gas fields based on reserves and 2004 field level production data. Colorado has two fields in the top 100—Wattenberg and Rangely. The Wattenberg field, discovered in 1970 in the Denver Basin, ranked as the 22nd largest oil field in the nation based on liquids proved reserves (liquids includes both crude oil and lease condensate) and 22nd based on liquids production of 10.8 million barrels in 2004. The Rangely field, discovered in 1902 in the Piceance Basin, ranked as the 57th largest oil field based on liquids proved reserves and 60th based on liquids production of 5.0 million barrels in 2004.

Natural Gas

EIA defines "dry" natural gas as the actual or calculated volumes of natural gas that remain after: (1) the liquefiable hydrocarbon portion has been removed from the gas stream (i.e., gas after lease, field, and/or plant separation), and (2) any volumes of non-hydrocarbon gases have been removed where they occur in sufficient quantity to render the gas unmarketable.

Proved reserves of U.S. natural gas increased by two percent in 2004, making it the sixth year in a row that the nation's natural gas reserves have increased (Energy Information Administration, 2005). Total discoveries for the onshore lower 48 States were almost 18 Tcf, resulting in total U.S. reserves additions replacing 118 percent of 2004 dry gas production. Six areas account for 75 percent of the nation's dry natural gas proved reserves; among this list is Colorado with eight percent of total U.S. gas reserves (table 2). The EIA (2005) reports that Colorado dry natural gas proved reserves declined by 0.7 Tcf during 2004, which represents a 4.8 percent decrease from the 15.4, Tcf reported for 2003 (fig. 26). This downward adjustment in gas reserves is primarily related to the re-assessment of the state's recoverable coalbed methane resources.

Table 2. Colorado ranks 6th in gas reserves in the U.S. in 2004.

Area	Percent of U.S. Gas Reserves	Proved Gas Reserves, Tcf
Texas	26	50.0
Wyoming	12	22.6
Gulf of Mexico Federal Offshore	10	18.8
New Mexico	10	18.5
Oklahoma	9	16.2
Colorado	8	14.7
Area Total	**75**	**190.8**

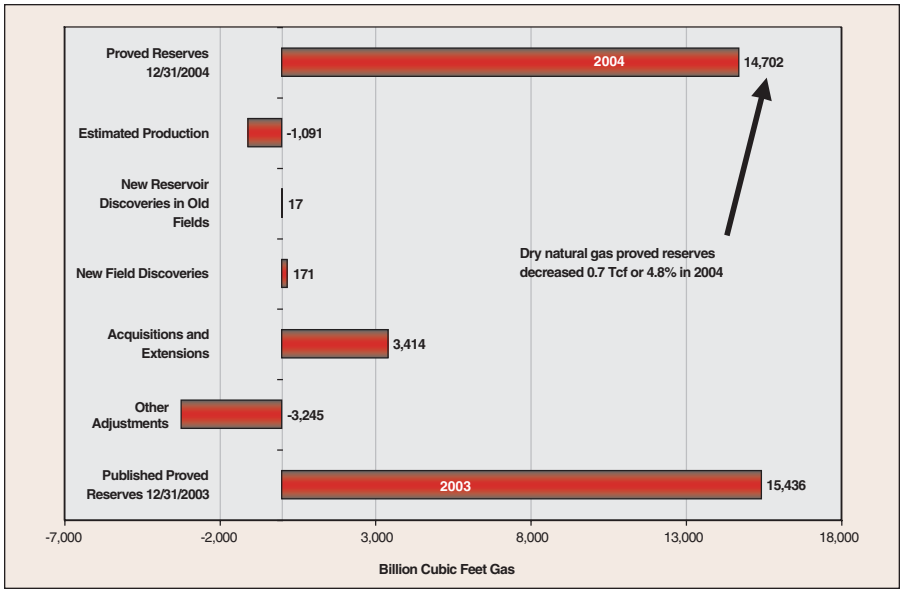

Figure 26. Colorado dry natural gas proved reserves, reserves changes, and production for 2004 (Energy Information Administration, 2005; Colorado Oil and Gas Conservation Commission, 2006).

The majority of natural gas reserves growth in 2004 resulted from extensions to existing gas fields. Nationally, extensions added 18.2 Tcf in gas reserves; this represents 11 percent more than 2003 and 66 percent more than the prior 10-year average of 11 Tcf (Energy Information Administration, 2005). Colorado ranked 7th in extension-reporting areas with 1.0 Tcf or 5.5 percent of the total U.S. reserve extensions for 2004. The estimated 2004 U.S. dry natural gas production is 19.2 Tcf; down from the 19.4 Tcf estimated for 2003. Colorado's annual gas production of 1.1 Tcf during the same year represents 5.7 percent of total U.S. production.

Nationally, new field discoveries added 759 billion cubic feet of new gas reserves in 2004—38 percent less than in 2003 (Energy Information Administration, 2005). Colorado ranked in the top areas with 171 billion cubic feet in new field discoveries or 22.5 percent of the U.S. total. Nationally, reserves from new field discoveries in 2004 were the lowest since 1992 and 59 percent less than the prior 10 year average of 1.8 billion cubic feet.

Colorado reported 4.4 Tcf of total gas as proved reserves in non-producing status in 2004, 12.8 percent more than the 3.9 Tcf reported in 2003 (Energy Information Administration, 2005; Energy Information Administration, 2004). These "behind pipe" reserves consisted of 3.8 Tcf of non-associated gas and 0.6 Tcf of associated-dissolved gas. Non-associated natural gas is that which is not in contact with significant quantities of crude oil in the reservoir. Associated-dissolved natural gas is the combined volume of natural gas, which occurs in crude oil reservoirs either as free gas (associated) or as gas in solution with crude oil (dissolved).

Parts of seven of the nation's largest 100 gas fields are in Colorado—San Juan Basin Gas Area, the Wattenberg field in the Denver Basin, Raton Basin Gas Area, and the Mamm Creek, Grand Valley, Rulison, and Parachute fields in the Piceance Basin (Energy Information Administration, 2005; table 3). Two of these—the San Juan and Raton Basin Gas Areas are shared with New Mexico. Of these gas-rich areas, the San Juan Basin Gas Area and Wattenberg field rank in the top 10 in the U.S. Most notably, the Ignacio Blanco/Blanco gas fields of the San Juan Basin Gas Area in Colorado and New Mexico represent the largest gas proved reserves for the entire nation and also had the highest gas production of 1.5 Tcf estimated for 2004.

Table 3. Colorado gas fields ranked in top 100 U.S. by gas proved reserves and gas production in 2004.

Field Name	Location	Discovery	Reserves Rank	Production Rank	Production Volume, Bcf
San Juan Basin Gas Area	CO & NM	1927	1	1	1,450.8
Wattenberg	CO	1970	8	8	192.0
Raton Basin Gas Area	CO & NM	1998	11	19	101.8
Mamm Creek	CO	1959	19	23	95.7
Grand Valley	CO	1985	23	60	42.3
Rulison	CO	1958	30	68	37.9
Parachute	CO	1985	35	81	32.5

Coalbed Methane

Nationally, proved reserves of coalbed methane declined to 18.4 Tcf in 2004, a 1.6 percent decrease from the 2003 level of 18.7 Tcf (Energy Information Administration, 2005). These reserves are included in the natural gas reserves discussed in the previous section. Coalbed methane accounted for 10 percent of all 2004 dry natural gas reserves in the U.S. Five states (Colorado, New Mexico, Wyoming, Alabama, and Utah) account for 86 percent of the U.S. coalbed methane proved reserves. ***Colorado ranks first in the nation for coalbed methane proved reserves with 31.5 percent of the U.S. total.*** Colorado, Wyoming, and Utah reported declines in proved coalbed methane reserves in 2004. Colorado reported 5.8 Tcf in coalbed methane reserves in 2004, down 10.8 percent from 6.5 Tcf reported in 2003. This is the second continuous year that Colorado coalbed methane reserves have declined since peaking in 2002 at 6.7 Tcf.

U.S. coalbed methane production increased eight percent in 2004 to 1,720 billion cubic feet and accounted for nine percent of the U.S. dry gas production (Energy Information Administration, 2005). Colorado coalbed methane production was 501 Bcf in 2004, representing a decrease of 2.6 percent from the 514 Bcf reported for 2003 (Colorado Oil and Gas Conservation Commission, 2006). The state's coalbed methane production was second only to that of New Mexico in 2004 (Energy Information Administration, 2005).

Trends, Developments and Forecasts

Drilling in the Rocky Mountains now equals and likely exceeds drilling in the Permian Basin of west Texas, according to a drilling-industry newsletter (*Land Rig Newsletter,* Lubbock, Texas, November 2005). For the last four or five decades, the Permian Basin has remained the most intensely drilled region in the U.S. in terms of drill footage. However, drill footage in the Rockies has increased 156 percent since the first quarter of 2003, while increasing only 44 percent over the same period in the Permian Basin. Both regions have logged more than 11 million drilled feet since 2003. This rapid change in regional footage is a clear indicator that unconventional gas resource development (coalbed methane, tight sands, and gas shales) is gaining share as a target for the drill bit. Overseas drilling interests have taken notice of the demand for drilling in the Rockies, with China, Russia, and Italy scrambling to provide everything from drill rigs to crews to operate them.

It is estimated that energy companies spent more than $1 billion in 2005 to drill oil and gas wells in the Rocky Mountain region. With energy prices reaching new record highs, most companies see the gas-rich Rocky Mountains as a strategic opportunity to expand their production and reserves base. The Bush Administration has facilitated this boom by enabling the region to be opened to further development. Nationally, proved reserves of natural gas increased for the sixth consecutive year in 2005 with the majority of natural gas discoveries resulting from extensions of existing conventional and unconventional gas fields—much of which took place in the Rockies.

The fast pace of energy development in Colorado has raised concerns however, where it has led to an increase in the potential for land-use conflicts. Public and local governments have become increasingly more concerned about issues such as noise, traffic, dust, and well site reclamation resulting from this development. This in turn has placed additional pressure on the Colorado Oil and Gas Conservation Commission to educate and inform the public about the comprehensive body of rules and regulations that already exist to protect public health and safety with respect to oil and gas development in the state.

Development Plans

It has been an amazing year for companies with operations in Colorado in 2005. Eight oil and gas firms each completed 100 or more new wells for production during 2005; five of those firms completed in excess of 200 new wells during the same period (fig. 27).

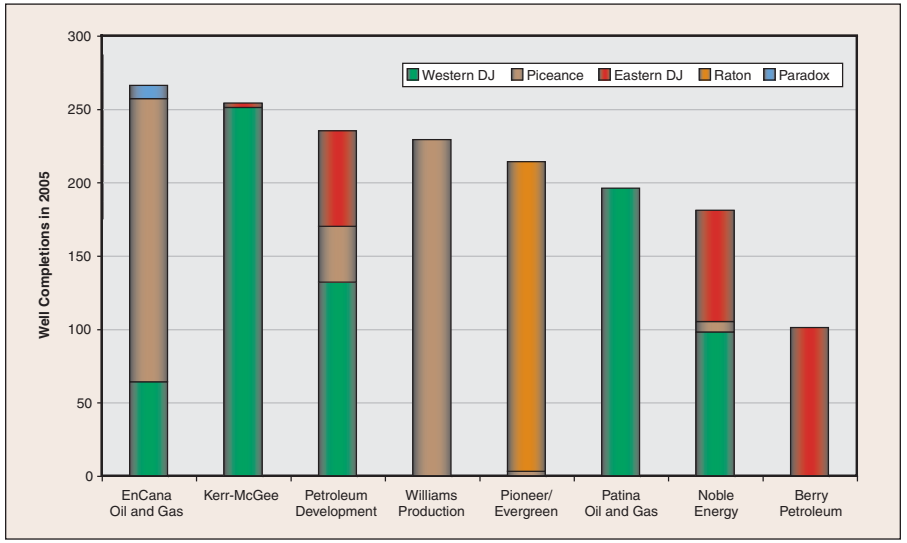

Figure 27. Operators that completed 100 or more wells in 2005 (PI/Dwights, 2006).

Canadian giant EnCana Corporation, whose U.S. headquarters are located in Denver, invested about $480 million in the Piceance Basin to drill nearly 200 new wells in 2005. EnCana acquired Denver's Tom Brown Inc. for $2.2 billion in 2004 to further consolidate its position in Garfield County. As a result, the Piceance Basin accounted for about 30 percent of EnCana's $1.6 billion capital expenditure in 2005.

The Bureau of Land Management (BLM) approved EnCana's proposal to drill 327 wells from 120 pads on the border between Garfield and Rio Blanco Counties. These wells are planned for Figure Four federal unit, an area encompassing 17,385 acres located southwest of Meeker and northwest of Parachute. Drilling is expected to take place over a three- to four-year period, beginning in 2005. About 6,700 acres are federal land, about 9,200 acres are privately owned with federal mineral rights, and the balance consists of private surface lands with private mineral rights. EnCana also gained BLM approval to drill up to 100 natural gas wells on Grass Mesa south of Rifle over the next two to three years. That planning area includes nearly 10,000 acres, with more than 40 percent of it public and nearly 60 percent private.

Kerr-McGee Corporation planned to invest $120 million to drill 220 wells in Weld County's Wattenberg oil and gas field in 2005—$10 million more than in 2004; by year end, they had actually completed 251 wells in Weld County. Their operations in the Rockies are part of a $660 million capital budget to develop onshore oil and gas fields. The Oklahoma City-based company bought Westport Resources Corporation, a Denver company for $3.4 billion in April 2004.

Williams, another Oklahoma company, budgeted $525 million to $575 million for capital investment in 2005 with most of that committed to Colorado's Piceance Basin and Wyoming's Powder River Basin. This compares with the $400 million to $450 million that Williams invested in 2004. Williams announced in late March 2005 that it had entered into a contract with Helmerich & Payne for the operation of 10 new FlexRig4® drilling rigs, each for a term of three years. This agreement paves the way for Williams to increase the pace of developing its natural gas reserves in the Piceance Basin while utilizing a new rig design that adds efficiency and increased environmental sensitivity to its operations. At year-end 2004, Williams' ownership in the Piceance Basin accounted for 61 percent of the company's 3 trillion cubic feet equivalent (Tcfe) of total proved domestic reserves and more than half of its estimated 7 Tcfe of proved, probable and possible reserves.

Williams planned to drill approximately 300 new wells in the Piceance Basin in 2005. The new FlexRig4® rigs are planned for use in the 2006 drilling season when the company expects to drill up to another 450 wells in the Piceance Basin with 500 wells planned for 2007. Williams reported 229 well completions in Garfield County in 2005. The vast majority of additional wells are planned in established areas of the Piceance versus step-out opportunities that Williams is developing in the basin. By the end of the first quarter 2005, Williams had 13 rigs operating in the Piceance Basin; as new rigs are added, Williams is expecting to operate approximately 20 rigs in the Piceance Basin in 2006 and 22 rigs in 2007. Since the new rigs will be built for optimal performance in Piceance Basin drilling conditions, the company expects to be able to drill more wells per rig in a given time frame.

Williams also announced an increase in planned capital spending in exploration and production by approximately $430 million over the three years from 2005 to 2007, with $400 million of the increase divided equally between 2006 and 2007. About three-quarters of the additional capital is planned for drilling. The remainder is targeted for expanding gathering and processing facilities to handle increases in the company's Piceance Basin production.

Houston-based Noble Energy Incorporated closed its $3.4 billion purchase of Denver-based Patina Oil and Gas Corporation in May 2005. This acquisition allowed Noble to consolidate its position in the Denver–Julesburg Basin (DJ) where Patina was a major operator. Noble increased their development activity for 2005 in the Wattenberg Field. They increased their drilling rigs from two to three with plans to add a fourth rig sometime in the fall. Noble has stated that they probably have thousands more projects left to do in the Wattenberg area.

BP America, one of Colorado's top gas producers with fields in La Plata County, completed 47 wells in 2005. As with many other companies operating in Colorado, the inability to secure more rigs has reshaped anticipated drilling schedules.

Denver-based Bill Barrett Corporation acquired Calpine's Piceance Basin properties for $137 million in 2004. Following this acquisition, Bill Barrett planned to drill up to 80 wells in Garfield County in 2005 and another 60 wells in 2006. They plan to drill on a 10-acre down hole spacing using directionally drilled wells. Operating four drilling rigs by the summer of 2005, Barrett reported 38 well completions in 2005.

Changing Trends

The Piceance Basin is one of the largest gas provinces in the lower 48 states with an estimated 100 Tcf of natural gas resources in-place. This compares to consumption for the entire U.S. of about 22 Tcf per year. The play covers well over one million acres and is relatively young in its development with 2,000 to 3,000 wells to date and tens of thousands yet to be drilled. Williams and EnCana are the two largest operators in the Piceance Basin.

For the first time, the number of drilling permits for natural gas wells issued in Garfield County—which is at the center of this "hot" play—has surged ahead of the number of permits issued in Weld County, home of the venerable Denver–Julesburg Basin northeast of Denver. For the second consecutive year, Garfield County outpaced Weld County in terms of daily natural gas production in 2005, a trend that started in 2004. Of the 70 to 80 drill rigs working in Colorado, about half of them are operating in Garfield County.

The Denver Basin has led the nation on rig count and fracture stimulation jobs for the last 10 to 20 years. The decline in the number of permits in Weld County is partially due to the maturity of the Denver Basin where the focus is on reworking older wells to improve production. This type of remediation work does not require a new well permit from the state. However, recent changes in well spacing in the Denver Basin will likely stimulate APD submittals over the next several years.

Roan Plateau

The Roan Plateau rises 3,000 to 3,500 feet above the Colorado River valley about 150 miles west of Denver and north of Interstate Highway 70 between Rifle and Parachute in Garfield County (fig. 28). It is already the site of an unprecedented drilling boom because of its vast natural gas resources. The Bureau of Land Management (BLM) estimates gas reserves to be about 15 Tcf. The BLM oversees 73,602 acres of federal leases; 44,267 acres of which are on top of the plateau. Forty percent of the land on the plateau is privately owned.

In November 2004, the BLM released a draft Roan Plateau Management Plan and Environmental Impact Statement, followed by a 90-day public comment period ending early March 2005. Along with energy development, the plan is intended to manage off-road vehicle use, backcountry and wilderness-oriented recreation and habitat protection, livestock grazing, and other uses. Final environmental analysis by the BLM is expected in early 2006, followed by a 30-day public comment period and a 60-day review by the Governor's office to determine if the plan is consistent with state objectives. A final record of decision on the Roan Plateau Management Plan by the BLM is expected in the summer of 2006.

The draft plan consisted of five alternatives for management of the Roan Plateau, ranging from one that allows nearly 1,600 natural gas wells to be drilled, including 200 on top of the plateau, to an alternative that maintains the status quo of limiting drilling to 855 wells, with 10 of those on top of the plateau. BLM's "preferred alternative" would have deferred mineral leasing until 80 percent of the anticipated wells beneath the cliffs had been drilled, which they estimated to occur in 16 years. At that time, only 51 additional wells would be drilled over the remaining 20-year life of the preferred alternative.

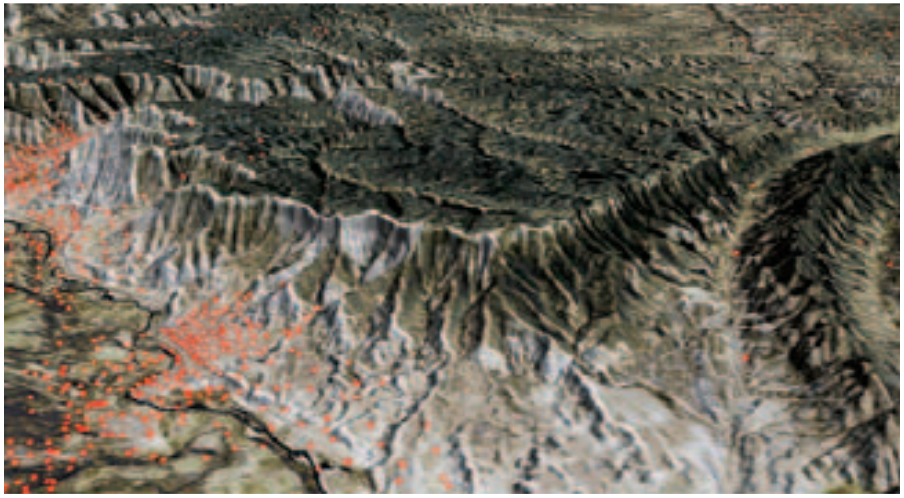

Figure 28. Oblique view of the Roan plateau looking northwest and showing the location of existing well pads (red dots). Along Interstate Highway 70, below the Plateau are four of the top 50 natural gas fields in the nation: Parachute (35th), Grand Valley (23rd), Mamm Creek (19th), and Rulison (30th).

BLM utilized a 2001 drilling rate to determine when the 80 percent threshold would be reached; however, the current drilling rate, which is considerably higher, would move that threshold to 6–8 years. If the threshold had been reached sooner than 16 years, it would likely have resulted in more than 51 wells being drilled on top of the plateau.

DNR Proposal

The Department of Natural Resources (DNR) is a cooperating agency for the 20-year plan along with Garfield County, Rio Blanco County, City of Rifle, City of Parachute, and City of Glenwood Springs. DNR's multidisciplinary team includes representatives from the Division of Wildlife, State Parks, Oil and Gas Conservation Commission, Geological Survey, and the Executive Director's Office. In August of 2005, the DNR team submitted a proposal to BLM and the other Cooperators that combined aspects of several of the original alternatives. The goal of the DNR Proposal was to develop the resources beneath the Plateau in a manner that gives strong protection to the other resources in the planning area. Initial reaction by the other cooperators and BLM to the DNR plan was positive, even though some still do not want any drilling on top of the Plateau. The key elements of the DNR plan were tentatively approved by BLM management in Washington D.C. in December 2005, and as of the end of April 2006, BLM is close to completing evaluation of the DNR plan.

The DNR plan proposes leasing the entire plateau at one time with a maximum lease size of 2,500-acres. All successful bidders would be required to immediately join an undivided federal unit. The effect of the unit would be to have only one operator for the top of the plateau. This will facilitate communication and planning between BLM and the operator, eliminate the need for redundant facilities, pipelines, etc, and reduce the need for a race to get individual lease tracts drilled because all lease winners would share in the costs and proceeds of all wells on top of the plateau. Drilling would be confined to the ridge tops of the plateau in areas of existing roads. Surface disturbance would be limited to one percent of the total acreage at any one time, so the operator would have to reclaim an area before moving on to another ridge. The DNR plan proposes that well pads be spaced no closer than ½ mile to each other.

The DNR plan proposes the use of a concept of "staged or clustered" drilling, in which only one section of the plateau top would undergo development at a time. This approach has appeal because it would concentrate drilling, completion, pipeline construction, surface facility construction, truck traffic, and other natural gas development activity on a limited number of well pads in the same general area, leaving most of the land above the rim available for wildlife habitat and other surface uses. The staged development concept would operate in harmony with the other resources on the plateau and yet allow an orderly, phased development of the oil and gas resources with minimal environmental impact.

Increasing Well Density

Increasing well density (the number of wells per unit area) is a common technique for extracting additional resources from oil and gas fields. In many cases, these "infill" wells target resources that could not otherwise be recovered or could not be recovered in a profitable time frame. In La Plata County, the state's production leader with 1.3 billion cubic feet of coalbed methane produced each day, BP America and Tulsa-based Samson Resources propose doubling the well density across more than 100 square miles of the northern San Juan Basin. The impact of this increased well density is often mitigated by using directional drilling technology, which allows several wells to be drilled from a single well pad, thus minimizing surface disturbance and environmental impact.

Representing about 75 percent of the natural gas production in the Wattenberg Field, three operators—EnCana Oil and Gas (USA) Inc., Kerr-McGee Rocky Mountain Corp., and Noble Energy Production, Inc., along with the Colorado Oil and Gas Association, submitted an application to revise COGCC Rule 318A in mid-2005. The proposed rule change outlines a responsible, planned development strategy to maximize production while minimizing surface disturbance and extending the life of the Wattenberg Field.

The Denver–Julesburg (DJ) Basin is located in northeast Colorado and is one of the nation's most important oil and natural gas provinces. As the state's second largest gas field, the Wattenberg Field covers parts of Adams, Boulder, Broomfield, Larimer, and Weld counties (fig. 29). There are nearly 12,000 oil and gas wells in the basin that supply about 30 percent of the natural gas consumed by communities along the Front Range. Production occurs from the Sussex, Niobrara, Codell and J Sand formations, where a typical J Sand well can provide enough natural gas to heat or cool 600 Colorado homes for 10 years.

Figure 29. Wattenberg Field is located in an urbanized area of northeastern Colorado (Colorado Oil and Gas Association, 2005)

In 1998, the COGCC established Rule 318A to promote responsible, efficient development of the gas resources in the Wattenberg Field. Rule 318A created five surface "drilling windows" in each quarter section (160 acres) for the purpose of establishing well pads for the production of natural gas. This rule in effect established a 32-acre well spacing or "downhole" well density for each producing formation (fig. 30).

Figure 30. Overview of drilling windows for a quarter section and new well locations under the proposed revision of Rule 318A (Colorado Oil and Gas Association, 2005).

Ongoing scientific and engineering evaluations have provided compelling evidence that the current well density as set forth in Rule 318A is leaving valuable resources behind in the subsurface. The revision to the existing rule, which was approved by COGCC in late 2005, enables companies to increase the number of wells in each quarter section from five to eight wells per formation to increase gas recovery. Under the revised rule, operators are required to directionally drill the additional wells from previously established drilling windows unless another drilling location is authorized by the surface owner (fig. 30). Operators are further required to reduce the distance between the existing well and the new "twinned" well to 100 feet from the current 150 feet.

As an accommodation to the surface owners under the proposed rule revision, operators will incur the additional cost to directionally drill the new wells from existing drilling windows. This means the wells will be drilled directionally to a target location that is not directly beneath the surface location of the wellbore, which minimizes the impact to the surface (fig. 31).

The Greater Wattenberg Area, which encompasses an area larger than the actual Wattenberg Field is reduced by more than 30 percent from 2,916 square miles to 2,016 square miles under the revised rule. This reduction in area was requested by the applicants to further reduce surface disturbance while continuing to maintain high recovery efficiencies with the application of directional drilling technology. Wattenberg is a multi-pool field (seven pools total) with depths ranging from 4,000 to 8,500 feet. It is estimated that the Greater Wattenberg Area had 2.4 Tcf recoverable gas reserves under the previous Rule 318A. ***The amendment to Rule 318A is estimated to add an incremental 1.6 Tcf to the recoverable reserve base, which then elevates Wattenberg to the status of a "giant" gas field; that is, a field with more than 3 Tcf in recoverable gas reserves.***

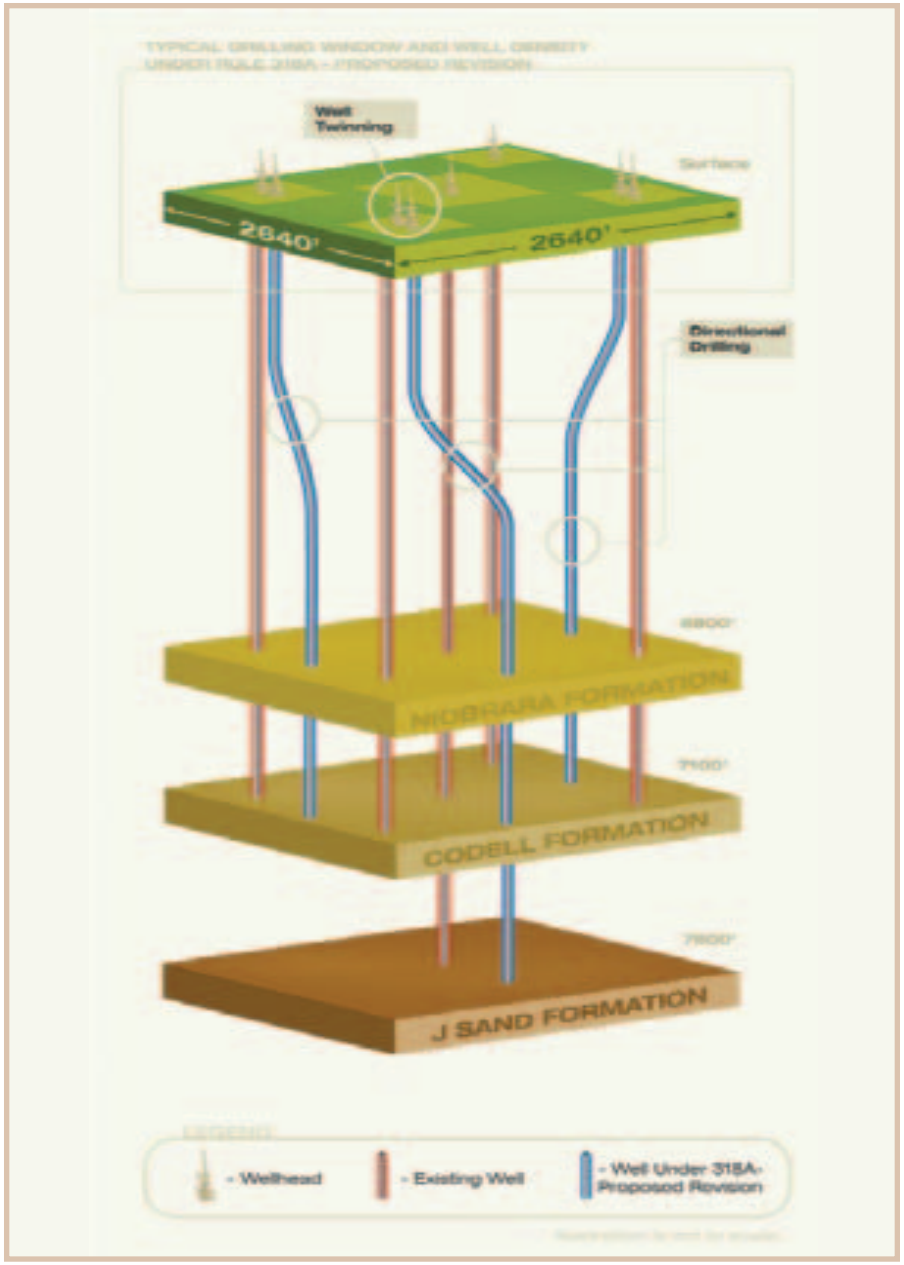

Figure 31. Cross sectional view of downhole well density under the proposed revision to Rule 318A (Colorado Oil and Gas Association, 2005).

Development plans under the revised rule are expected to be on the order of 200 to 300 new wells drilled per year over the next 20 years. Growth will be limited by shortages of drill rigs, qualified personnel, cement supplies, and pipeline capacity. The new wells are expected to flatten (not increase) the recent decline in oil and gas production from the Greater Wattenberg Area. It is predicted that this play will become marginal if gas prices drop to $4 per Mcf and uneconomic at $3 per Mcf.

Volume, Value, and Prices for 2006

Natural gas production volumes reported for 2005 are expected to increase an average of 3 to 3.5 percent over the next year or two due to the continuation of aggressive drilling programs throughout the state. Based upon price increases observed in 2004 and 2005, the value of that production may increase by as much as 30 to 40 percent in 2006. Estimated production value for crude oil and natural gas in 2005 is $9.29 billion; this value is forecast to exceed $12 billion and could possibly be as high as $13 billion for 2006 (table 4). This growth results primarily from Colorado's increasing natural gas resource base rather than the relatively stagnant growth in crude oil production. As a result, this value will be closely tied to the emerging LNG (liquefied natural gas) market over the next few years.

Table 4. Oil and gas production value forecasted for 2006.

Year	Oil and Gas Production Value[1], Billion $	Annual Growth, %
2000	3.35	79
2001	3.59	7
2002	2.68	-25
2003	5.15	92
2004	6.73	31
2005 *Estimated*	9.29	38
2006 *Forecasted*	12.1–13.0	30–40

[1]CO_2 value is not included

Oil prices for the next year or two are forecasted to remain in the range of $50 to over $60 per barrel with the potential for price spikes in excess of $70. Factors that continue to drive near-term oil prices higher include (1) continued unrest in the Middle East and potential instability in other member nations of the Organization of the Petroleum Exporting Countries (OPEC) (such as Venezuela and Nigeria) and Russia, (2) concerns that OPEC may not be able to significantly increase production to meet further demand particularly from China and India, (3) the threat of demand destruction at higher price levels, and (4) extreme weather events such as the record 2005 hurricane season that continues to disrupt an

already tight refining capacity in the US Gulf Coast and effect the infrastructure required to transport product.

Natural gas prices are expected to continue in the range of $5 to $8 per thousand cubic feet (Mcf) through the end of 2006. However, natural gas prices are expected to be even more volatile than oil due to deliverability obstacles, increasing demand from electric generation, and uncertainties in the weather and oil markets. The 2005 hurricane season resulted in Henry Hub natural gas prices spiking to more than $15 per Mcf in late September and again in mid-December. Deliverability obstacles include weather-related disruptions and shut downs, a distribution system already filled to capacity in many areas, and a need for more storage and distribution of liquefied natural gas.

The COGCC expects drilling permits to increase by another 10 percent in 2006, setting a new record of nearly 5,700 APDs.

Oil Shale

For more than one hundred years, scientists, engineers and prospectors have searched for ways to recover oil from the kerogen in oil shale in a way that is economically viable and environmentally responsible. Kerogen is a naturally occurring, solid, insoluble organic matter that occurs in rocks, which can yield oil upon heating—a process known as pyrolysis. The typical organic constituents of kerogen are algae and woody plant material.

The estimated resource of oil in the oil shale in Colorado's Piceance Basin (fig. 32) is about one trillion barrels, with recovery rates of up to one million barrels per acre. Current U.S. oil usage is about 20 million barrels per day. If oil shale could provide 25 percent of our current demand, 5 million barrels, the estimated Colorado recoverable resource of 800 billion barrels would last 400 years (Bartis and others, 2005).

A new era of oil shale exploration, testing, and development in Colorado began in June 2005, when the BLM announced a request for Research, Development, and Demonstration (RD&D) proposals on oil shale tracts in Colorado, Utah, and Wyoming. Nineteen nominations were received by the BLM and were evaluated by an interdisciplinary team of representatives from the BLM, the Departments of Energy and Defense, and the governments of the three States. In the 1st quarter 2006, the BLM announced that five proposals in Colorado were accepted to advance to the next phase of the process. The successful applicants are Chevron Shale Oil Company; EGL Resources, Inc.; and Shell Frontier Oil & Gas, whose three separate nominations were all judged eligible for further consideration.

Each nomination identifies the 160 test–site acres allowed in the call for proposals, along with an additional contiguous area of 5,600 acres to be reserved for a preferential right to convert to a commercial lease at a future time after additional BLM review. All five proposals in Colorado plan to use an in situ type of process rather than conventional mining and retorting techniques.

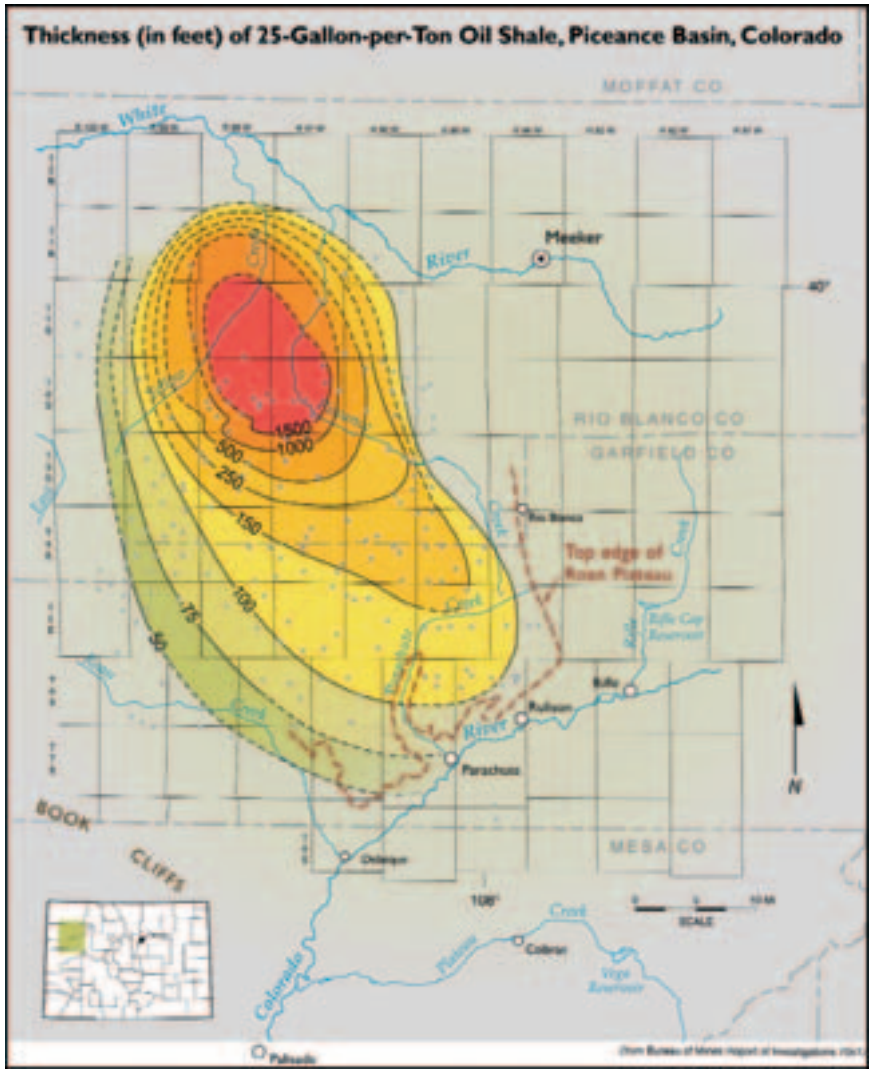

Figure 32. Isopach map of 25-gallon-per-ton oil shale in the Piceance Basin, Colorado.

The BLM is in the process of performing a Programmatic Environmental Impact Statement on the proposed commercial oil shale lands leasing program that should be available in draft form by fall, 2006, and be finalized by the summer of 2007.

Shell Exploration & Production Company has been conducting an in situ oil shale research program on the company's private acreage in Colorado's Piceance

Basin for several years. In general, Shell's in situ shale oil recovery process involves drilling holes and inserting electric heaters to depths up to 2,000 feet. Over a period of years, the oil shale layers are gradually heated and convert the kerogen in the oil shale into high quality crude oil suitable for transportation fuels. The products are recovered at the surface through conventional means where they require less refining than conventionally produced oil.

Shell's In Situ Conversion Process (ICP) (fig. 33) has several steps:

- Forming of an underground ice barrier, known as a "freeze wall," around the production area. This keeps groundwater out of the production reservoir and petroleum products within the production area.
- Drilling of heater holes to a depth of approximately 2,000 feet. Inserting heaters to heat the oil shale formation to a temperature of about 650° to 700° F for a period of years. This slow pyrolysis converts the kerogen in oil shale into light oil and gas products.
- Recovery of oil and gas using a traditional production well.
- Remediate production reservoir through conventional steam stripping.
- Thaw out "freeze wall" and monitor groundwater.
- Surface reclamation.

Several issues remain to be resolved before oil shale can be commercially recovered using Shell's ICP:

- Reliability of heaters over a long period of time.
- Protection of ground water.

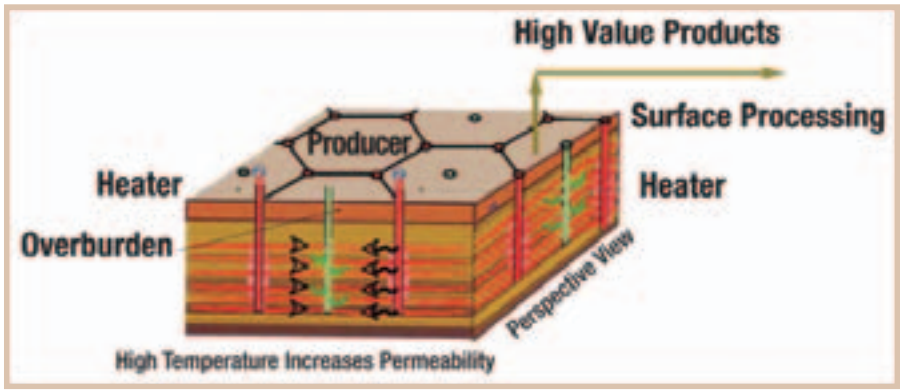

Figure 33. Diagram of Shell's ICP process. (*Image courtesy of Shell Exploration & Production Co.*)

COAL

Introduction

In the past year, there has been much discussion about what resources we will have in the future to maintain our high standard of living. MSN Money Online recently stated that coal is the "fuel of the future." This prediction is based on the fact that coal is inexpensive, the supply is stable and large, and demand is increasing worldwide. In the last year, the spot price for coal has increased two-fold, so only long-term contracts have lower fuel price structures. The spot price of natural gas peaked at $15.50 per million Btu in December 2005. Electricity from steam coal sells for the equivalent of electricity from natural gas if gas were priced at $3.50 per million Btu. Even at $7 per million Btu for gas, electricity from coal will still be about half the price of natural gas. The unreliability of natural gas-fired electrical power is now creating pressure on the home-heating and industrial markets since last summer's hurricane season. Coal can also play a role in the future development of coal gasification, liquid transportation fuels, and the production of ethanol.

Although Colorado coal mines were set to break the 40 million ton statewide production mark in 2005, they fell just short when West Elk, Elk Creek, and McClane Canyon mines reported combustion-related events, roof-fall problems, and an explosion that halted production at these mines in December. The year-end total was 37,820,153 short tons of coal, marking 2005 as the second most productive year on record (fig. 34). The high production rates brought increased employment (1,991 miners employed as of December 2005), and higher spot prices for coal sales that topped the $37 per ton mark. *CoalAge* magazine, in a recent survey of industry executives, predicts that 2006 will be a healthy year for coal production nationally, and the Colorado coal industry should also fare well. In 2005, Colorado ranks seventh among coal-producing states in the U.S.

For over six consecutive years, the states west of the Mississippi River have produced more coal than the traditional eastern coal-producing states (fig. 35). In 2004, over 627 million tons were produced from coal states west of the Mississippi River. This is due primarily to demand for low-sulfur western coal, most of which is produced in Wyoming's Powder River Basin.

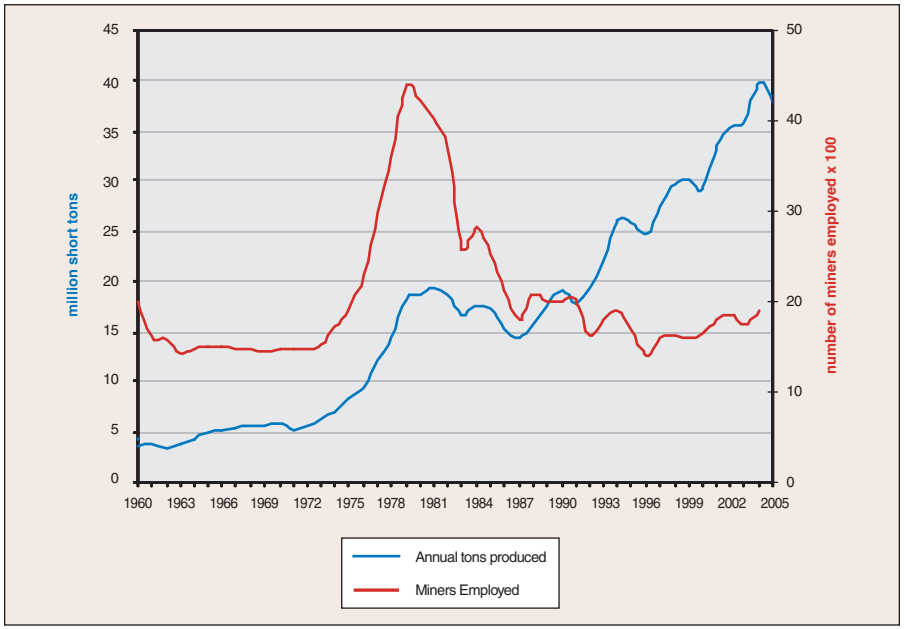

Figure 34. Coal production and employment of miners in Colorado, 1960–2005 (Source: Colorado Division of Minerals and Geology (CDMG) data).

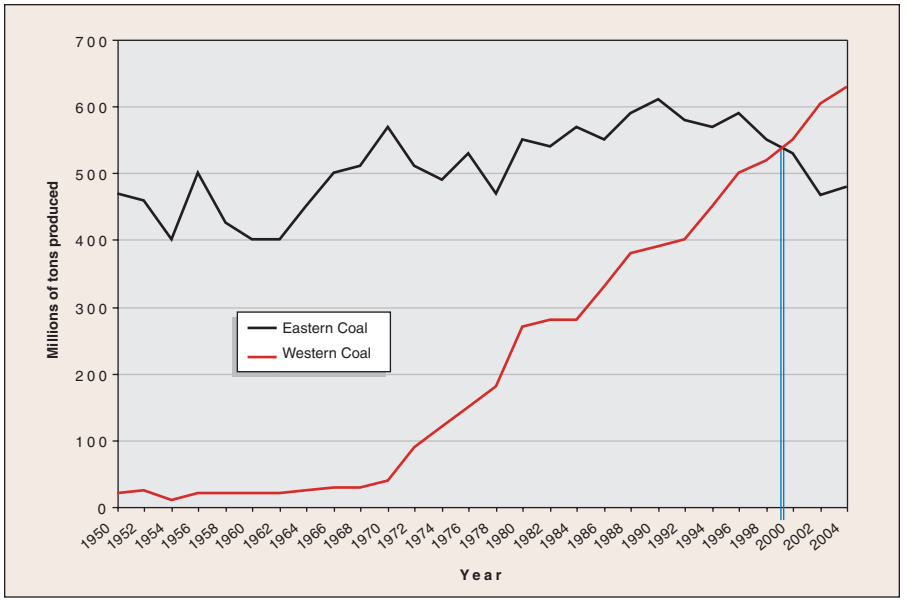

Figure 35. Chart comparing western and eastern U.S. coal production trends, 1950–2004 (Source: Mine Safety and Health Administration (MSHA) data).

The last few years have reversed a long trend for the coal industry in terms of economic development. Factors relating to increased demand for Colorado coal include:

1) Requests for air-quality compliance coal from the western states as eastern supplies diminish. Colorado has the second largest demonstrated reserves of compliance coal in the nation.
2) A shortage of inexpensive coal as the spot price for eastern coal increases.
3) Baseload electrical power in metropolitan Denver can be increased with coal to offset growing electricity demand that impacts the peak-power storage capacity not met with natural gas because of the recent closure of the Leyden gas storage facility in Arvada.
4) High-Btu, low-sulfur Colorado coal is blended with large volumes of low-sulfur, low-Btu Powder River coal at power plants in the southern states.

Coal prices and growth of the industry

Spot market prices for U.S. coal increased considerably in the last two years. According to the U.S. Department of Energy's Energy Information Administration (EIA) the spot price of Uinta Basin (Colorado and Utah) bituminous coal increased from $29 per ton in 2004 to $37 per ton in 2005, a 28 percent increase (fig. 36). Most Colorado coal is within the Uinta Basin group and has remained level at roughly $36 per ton through early 2006. Illinois, Central, and Northern Appalachian coal spot prices decreased slightly in 2005, but are still higher than Uinta Basin coal prices. Powder River Basin coal spot prices were stable and low at $6 per ton until March 2005. Then prices increased markedly to over $20 per ton in January 2006. If these high prices stabilize, it will significantly affect the long-term market.

Although $37 per ton for spot coal is high, most of the Colorado coal sells at much lower contract prices. The Minerals Management Service tracks the sales of coal from federal leases, which are about 75 percent of the active coal producing areas in Colorado. The average price per ton from these leases for 2005 was $18.14. However, an undetermined amount of Colorado coal is sold on the spot market for values of up to $37 per ton. The CGS estimates an average of $21.50 per ton for the year to account for contract and some spot sales, resulting in a coal production value of $813 million for 2005.

At the February 2006 National Western Mining Conference in Denver, Bob Burnham of Hill & Associates discussed the current and future status of the Colorado coal market. He suggested that Colorado coal production level has peaked and may remain at this level for the next ten years. By 2015, demand for compliance coal will probably decrease because of implementation of the Clean Air Interstate Regulations (CAIR II and III) rules. At that time, all of the U.S. power plants will have air pollution controls and emissions technologies retrofitted to their boilers and high-sulfur coal allowances will be used again. Long-term forecast for

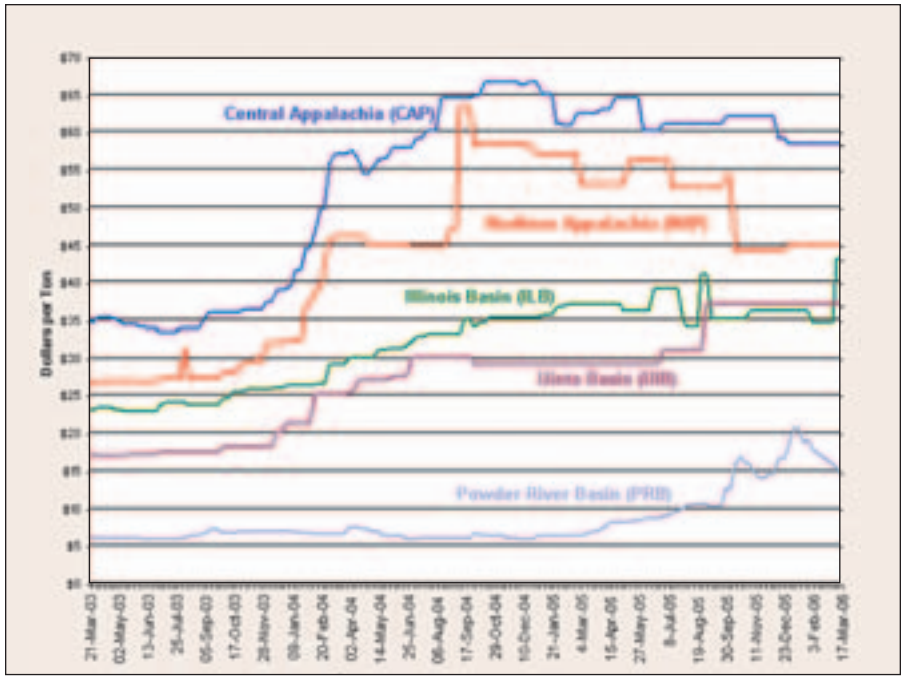

Figure 36. Spot sales price for domestic coal by region and type, 2003–2006 (Source: EIA, March 2006).

Colorado coal production is 43 million tons per year by 2012, but may decline thereafter. EIA suggests that the maximum productive capacity at Colorado's coal mines today is 43.9 million tons.

Clean Coal Technologies

"Clean coal" is defined as coal that is chemically washed of mineral impurities and sometimes gasified and burned. President Bush, in his January 2006 State of the Union Address, outlined a program for a near-zero emissions coal-based power plant. Called the FutureGen project, it is a $1 billion coal-fired power plant that will produce electricity and hydrogen from coal, while capturing and sequestering carbon emissions. Hoping to be the first such power plant in the world, the U.S. Department of Energy (DOE) has published a draft request for proposals to potential builders. In the new federal budget for 2007, an additional $300 million more has been allocated for FutureGen research and to support other clean coal technologies. Bush hopes that clean coal technologies will play an important role in reshaping American energy consumption.

FutureGen will combine the latest in technology from coal gasification, electricity generation, emissions controls, carbon dioxide capture and storage, and hydrogen production into a single power plant for commercial power generation. The plant will produce electricity, hydrogen-rich synthetic gas, and other byproducts for use by other industries. The process begins with coal, steam, and hot air mixed so that the coal is gasified and its carbon is converted to synthetic gas of mostly hydrogen and carbon monoxide. New technologies will allow the synthetic gas to react with steam to increase the amount of hydrogen and carbon dioxide produced. This carbon dioxide captured from the combustion process will be liquefied and permanently stored in deep geologic formations. A partnership of allied corporations has been formed to create the project, which includes Kennecott Energy/Rio Tinto, CONSOL Energy, BHP-Billiton, and Peabody Energy. The hydrogen can be used as a clean fuel for electric generation, fuel cells, or hybrid combinations. Other byproducts of the process include fertilizers, hydrogen, liquefaction, and synthetic recycled gases. Other clean coal technologies are envisioned for industrial use and as a liquid transportation fuel of the future.

Xcel Energy is seeking partners to build a demonstration plant in Colorado to prove technology for burning coal with the lowest possible emissions. The technology is called "integrated gasification combined cycle," or IGCC. It is used at several power plants in the eastern U.S. to reduce carbon dioxide emissions by converting coal into gas before combustion. To date, the technology is new and untested at higher elevations. Xcel has proposed legislation in Colorado to finance a feasibility study on IGCC. If the study shows success in Colorado then federal funding may be available to build a demonstration plant. This plant would produce at least 300 megawatts of electricity and cost roughly $1 billion. Federal funding under the Energy Act of 2005 could reach $200 million for the project.

DOE is focusing research on cost-effective controls of mercury, nitrogen oxides, sulfur dioxide, and fine particulate emissions. Technologies under development include coal gasification, advanced turbines, combustion technologies, and distributed generation and fuel cells. This project is also supported by Environment Colorado, a group that also supports minimizing rate impacts through appropriations from excess severance tax revenues.

There has been much interest lately in converting coal to liquid diesel fuel. This revived technology would augment the nation's conventional diesel fuel supply. A Denver-based company, KFx Inc., is working on a pilot project for coal gasification and liquefaction in the Powder River Basin in Wyoming using subbituminous high moisture coal. Colorado coal, with its high heat value and low moisture content, makes gasification technology attractive.

Approximately three barrels of diesel fuel equivalents can be generated per ton of coal. Coal liquefaction and gasification technologies were developed by Germany in the 1940s. Fischer-Tropsch technology, developed in South Africa during the apartheid years, today produces over 25 percent of that country's diesel fuel from coal.

2005 Colorado Coal Production

Colorado coal mines produced coal at the second highest level in history in 2005. This demand is attributed to the significant interest in clean Colorado coal, favorable mining conditions, larger mining equipment, and high coal prices. Of the 37.8 million tons produced, 28.5 million tons came from eight underground mines, while 9.3 million tons came from four surface mines (see Figure 37 for mine locations; Tables 5 and 6 for mine statistics). Most of the coal mined in Colorado is bituminous (approximately 79 percent of the state's production); only two mines produced sub-bituminous products (Trapper and Colowyo mines). Twentymile Coal's Foidel Creek Mine, Oxbow Mining's Elk Creek Mine, and Mountain Coal's West Elk Mine all rank in the top ten largest underground mines in the nation.

Four Colorado mines set new monthly and yearly records in 2005. The Foidel Creek Mine broke its own statewide record for monthly coal production by producing 1.069 million tons in December 2005. Foidel Creek also broke its own statewide annual coal production mark for a single mine by producing 9.37 million tons in 2005. Western Fuels New Horizon Mine in Nucla set its all-time annual coal production mark in 2005 with 420,730 tons produced. Bowie #3 also set their own annual production record in 2005 with 3.27 million tons for the year. King Coal in La Plata County also set an all-time monthly coal production record with 45,605 tons produced in November 2005, and a new annual production record with 467,378 tons.

Coal was produced in eight Colorado counties in 2005. For the first time in four years, Routt County was the state's top coal producer (table 6), with over 10.5 million tons. Gunnison County dropped to second with 8.4 million tons produced, primarily because Mountain Coal Company's West Elk Mine was shut down for the last two months of 2005, and Oxbow Mining Co's Elk Creek Mine partially crossed over into Delta County in the middle of 2005. Delta County surpassed Moffat County for the third most coal production, and claimed the most miners employed (537) as of December 2005.

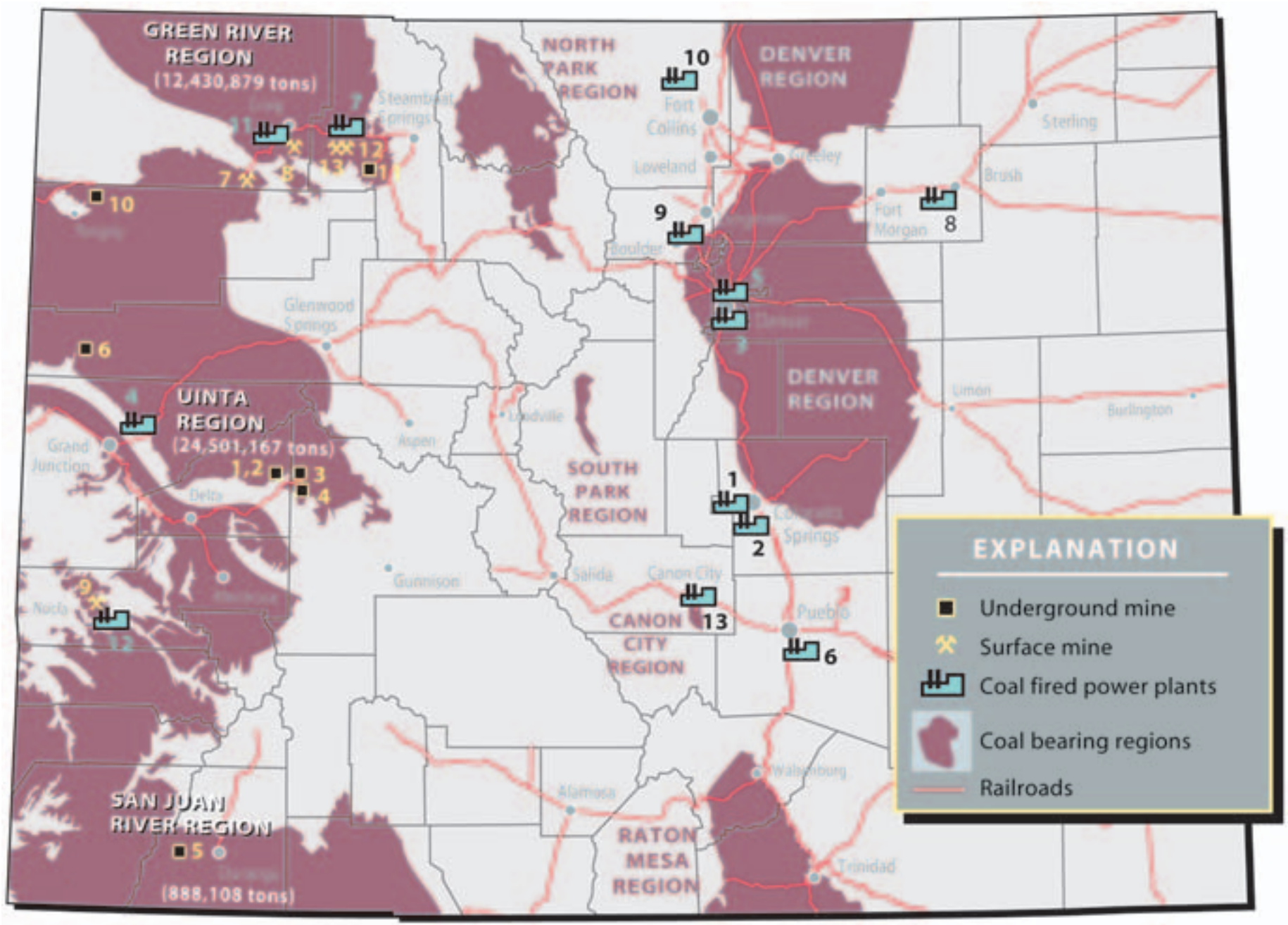

Figure 37. Locations of coal mines, power plants, railroads, and coal-bearing regions in Colorado, 2005. See Table 5 for mine information, and Table 8 for power plant names.

Table 5. Colorado coal mine statistics, 2005. Source: Colorado Division of Minerals and Geology 2005 production data. See Figure 37 for mine locations.

Mine # (fig. 37)	County	Parent Company	Operator	Mine Names	Coal Region	Coal Field	Twp., Rng.	Geologic Formation	Producing Bed Names	Seam Thickness	BTU Avg.	Mine Type	Mining Method	2005 Prod. (tons)	Dec 2005 Miners	Shipment Method
1	Delta	Colorado Energy Investments, LLC; Sentient Coal Resources, LLC	Bowie Resources Ltd.	Bowie #2	Uinta	Somerset	13S, 91W	Mesaverde	D	7–12 ft	12,053	U	Longwall, continuous	819,468	0	Rail
2	Delta	Colorado Energy Investments, LLC; Sentient Coal Resources, LLC	Bowie Resources Ltd.	Bowie #3	Uinta	Somerset	13S, 91W	Mesaverde	B	12–20 ft	11,650	U	Longwall, continuous	3,272,130	254	Rail
3	Gunnison	Oxbow Carbon and Minerals Holdings, Inc.	Oxbow Mining, LLC	Elk Creek	Uinta	Somerset	13S, 90W	Mesaverde	D2	D=6–19 ft. D2 seam minable is 14 ft.	12,375	U	Longwall, continuous	6,545,486	283	Rail
4	Gunnison	Arch Coal Inc.	Mountain Coal Company, Inc.	West Elk	Uinta	Somerset	13S, 90W	Mesaverde	E	12 ft	11,650	U	Longwall, continuous	5,584,151	347	Rail
5	La Plata	Alpha Natural Resources	National King Coal, LLC	King Coal	San Juan River	Durango	35N, 11W	Upper Menefee	Upper Bed	52–72 in.	12,800	U	Continuous	467,378	55	Truck
6	Garfield	Central Appalachian Mining (CAM)	CAM	McClane Canyon	Uinta	Book Cliffs	7S, 102W	Mesaverde	Upper Cameo, Lower Cameo	Upper Cameo= 5–9 ft; Lower Cameo= 8–10 ft	10,475	U	Continuous	260,891	22	Truck
7	Moffat	Kennecott Energy Co.	Colowyo Coal Company, L.P.	Colowyo	Uinta	Danforth Hills	4N, 93W	Williams Fork—Fairfield Coal Group	A–F,X,Y	52.2 ft total; Y=4 ft, X=10.7 ft, A=2 ft, B=6.8 ft, C=6.4 ft, D=10.1 ft, E=6.8 ft, F=5.4 ft	10,453	S	Dragline, Shovels, Dozers	5,869,561	247	Rail
8	Moffat	PacifiCorp/Tri-State G&T/Salt River	Trapper Mining, Inc.	Trapper	Green River	Yampa	6N, 90W	Williams Fork—Upper Coal Group	H, I, K, L, M, Q	H=6 ft, I=5 ft, K=4 ft, L=4 ft, M=6 ft, Q=10 ft	9,850	S	Dragline, Shovels, Hyd. Excav.	1,914,642	126	Truck
9	Montrose	Tri-State G&T Assoc.	Western Fuels Colorado, LLC	New Horizon	San Juan River	Nucla-Naturita	46N, 15W	Dakota	1, 2	Kd Upper= 0.80–1.5 ft; Kd Lower= 5.0–7.5 ft	11,680	S	Shovels, dozers	420,730	23	Truck
10	Rio Blanco	Deseret Generation & Transmission	Blue Mountain Energy, Inc.	Deserado	Uinta	Lower White River	3N, 101W	Williams Fork	B Seam	B= 7–16 ft., D= 6–8 ft.	10,000	U	Longwall, continuous	2,149,481	142	Rail
11	Routt	Peabody Energy	Twentymile Coal Co.	Twentymile (Foidel Creek)	Green River	Yampa	5N, 86W	Williams Fork—Middle Coal Group	Wadge	8.5–9.5 ft	11,250	U	Longwall, continuous	9,369,969	451	Rail, Truck
12	Routt	Peabody Energy	Seneca Coal Co.	Seneca II-W	Green River	Yampa	5N,87W	Williams Fork—Middle Coal Group	Wadge, Wolf Cr., Sage Cr.	Wadge= 8.9–12.2 ft (avg. 11.7 ft); Wolf Creek= avg. 20.4 ft; Sage Creek= 3.4–5.4 ft (avg. 4.6 ft)	11,908–12,581	S	Dragline, loaders	573,134	21	Truck
13	Routt	Peabody Energy	Seneca Coal Co.	Yoast	Green River	Yampa	5N,87W	Williams Fork—Middle Coal Group	Wadge, Wolf Cr.	Wadge= 0.39–14.2 ft (avg. 12.2 ft); Wolf Creek= 15.8–16.7 ft (avg. 16.0 ft)	11,908–12,581	S	Dragline, loaders	573,134	20	Truck
Total				**Shaded part indicates new annual production record.**										**37,820,154**	**1,991**	
				Mine Type abbreviations: U—underground mine, S—surface mine. Shaded section of production is a record for that mine.												

Table 6. Colorado coal production by county, type of production, and employment as of December 2005. All coal production in tons (Source: Colorado Division of Minerals and Geology).

County	2005 Production Total	Underground Production	Surface Production	Miners Employed	Surface/ Underground Mines
DELTA	7,813,300	7,813,300		537	0/2
GARFIELD	260,891	260,891		22	0/1
GUNNISON	8,407,934	8,407,934		347	0/2
LA PLATA	467,378	467,378		55	0/1
MOFFAT	7,784,203		7,784,203	373	2/0
MONTROSE	420,730		420,730	23	1/0
RIO BLANCO	2,149,481	2,149,481		142	0/1
ROUTT	10,516,236	9,369,969	1,146,267	492	2/1
TOTALS	**37,820,153**	**28,468,953**	**9,351,200**	**1,991**	**4/8**

Exploration

Most active coal mines in Colorado had exploration activities in 2005. Peabody Energy, with their recent acquisition of the RAG American mines and reserves in northwest Colorado has been researching ways to continue coal mining at 10 million tons per year in Routt County. With Yoast and Seneca II-W closed they now will deplete their reserves in Twentymile Park faster than anticipated. Nearby, Peabody owns reserves south of Hayden (Big Elk lease area) and near Craig (Empire Mines), which will help supply the Hayden Power Plant for years to come. Peabody recently requested a lease by application (LBA) in Twentymile Park to add to their reserves. Increased numbers of coal exploration permits have been filed through the Colorado Division of Minerals and Geology (CDMG) offices in the last year. Several companies are drilling on their existing leases to extend operations, including Bowie, Elk Creek, and Deserado. National King Coal, Central Appalachian Mining, and Kennecott Energy have all filed permits to explore for coal at King

Coal, McClane Canyon, and Colowyo mines respectively. Northfield Partners, LLC is exploring a site called Northfield in Fremont County, which is north of the Energy Fuels Southfield Mine that closed in 2001.

Distribution

The main transportation method for coal in the West is rail. Both the Union Pacific and the Burlington Northern/Santa Fe (BNSF) railroads transport coal through Colorado. The Union Pacific Railroad moves most of the coal out of western Colorado through the Moffat Tunnel, and BNSF rails Wyoming coal to the Rawhide Power Plant north of Ft. Collins and to other plants along the Front Range. Over 77 percent of all rail shipments originating in Colorado are coal products. Over 51 percent of the rail shipments terminating in Colorado are coal, by far the single most important rail commodity in the state. Coal rail freight growth is expected to increase nationally and the Colorado railroad infrastructure, while currently supplying mines that are under producing, is inadequate for future growth.

The constraint of the existing rail infrastructure in Colorado is a limiting factor for coal production in the state. In 2005, over 17.4 million tons of coal moved from the Somerset Coal Field to the Front Range and further east. Stockpiles at the three Somerset mines were at times over one half million tons each because not enough rail cars were available. In 2005, over 30 million tons of coal were transported through the Moffat Tunnel between Winter Park and Denver.

About 25 percent of the coal produced in-state is consumed in Colorado. This is down substantially from 50 percent in 2000. Most coal is shipped by rail to 27 other states (fig. 38), and is sold as far away as Massachusetts and Florida. According to EIA the average distance shipped for coal from the Western U.S. (Colorado, Utah, and Wyoming) is 1,097 miles by train but only 17.6 miles by truck. Most of Colorado's coal is shipped to states east of Colorado where it is blended with high-sulfur Eastern coals to reduce pollution at minimally compliant power plants. The leading Colorado coal exports (2004 data) were to Kentucky, Texas, Tennessee, Mississippi, Utah, and Illinois. In addition to coal shipped for use in power plants, over 4.6 million tons coal are shipped to industrial plants in Texas, Mississippi, Arkansas, and Illinois for cement manufacturing and other industrial uses. Foidel Creek shipped about 500,000 tons to Mexico and another 450,000 tons to Canada last year.

Consumption

Coal is consumed in Colorado at coal-fired power plants, commercial industries, and manufacturing plants. According to EIA, a total of 19.817 million tons of coal were consumed in Colorado in 2004 (table 7). This is down 1.7 percent over 2003. Of this total, 19.251 million tons were consumed at power plants, which is 97.1 percent of Colorado's total coal consumption. Over 37.3 million megawatt-hours

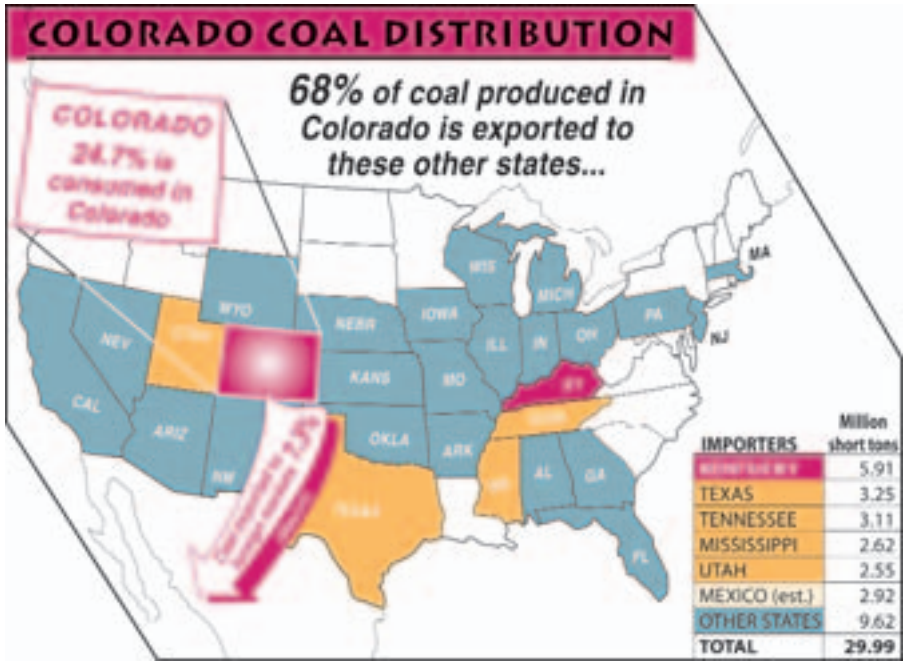

Figure 38. Distribution of Colorado coal, 2004 (Source: EIA, 2004, most recent data).

(Mw-h) of gross power are generated by Colorado coal-fired plants annually. Gross electric generation is the product of megawatts of power generated times the number of hours in a year (8,760). Some of these plants also use natural gas or fuel oil as additional power sources.

Table 7. Colorado coal consumption by sector 2003–2004. W = withheld to avoid disclosure of individual company data (Source: EIA, 2004, most recent data).

2003 (million tons)				2004 (million tons)				
Electric Power	Other Industrial	Residential and Commercial	2003 Total	Electric Power	Other Industrial	Residential and Commercial	2004 Total	% Change
19,596	W	W	20,153	19,251	W	W	19,817	-1.7

Xcel Energy owns or operates seven coal-fired power plants in Colorado and is the largest utility consumer of coal in the state. The Craig Power Station in Moffat County consumed over 5 million tons of coal in 2005, generating over 10.8 million Mw-h of electricity (Table 8). This was the largest electricity production from a single source in state history. Craig Station receives coal from Trapper and Colowyo mines, both in Moffat County.

Table 8. Electric generation and fuel consumption at coal-fired power plants in Colorado, 2005. Refer to fig. 37 for locations on map. PRB = Powder River Basin, Wyoming. Mw = Megawatts, MCF = Million cubic feet, BBLS = Barrels (Source: Data from utility company annual reports).

Map No. Fig. 37	Power Plant	Utility	Nameplate Rating (Mw)	2005 Gross Electric Generation (Mw-h)	Coal (tons)	Gas (MCF)	Fuel Oil (BBLS)	Origin of Coal
1	Martin Drake	Colorado Springs Utilities	273	1,205,734	1,054,485	200,942	– –	75% Foidel Creek, 25% Wyoming PRB
2	Nixon	Colorado Springs Utilities	225	1,628,027	893,698	0	181,275	Wyoming PRB
3	Arapahoe	Xcel Energy (partly gas)	144	971,901	543,148	32,863	– –	Wyoming PRB
4	Cameo	Xcel Energy	66	531,942	312,425	36,912	– –	McClane Canyon Mine
5	Cherokee	Xcel Energy	710	5,457,818	2,316,609	255,710	– –	99 % Foidel Creek Mine, 1% Colowyo Mine
6	Comanche	Xcel Energy	700	4,709,267	2,610,300	101,802	– –	Wyoming PRB
7	Hayden	Xcel Energy/ Pacifcorp/Salt River Project	447	3,973,253	1,830,905	44,781	1,712	80% Seneca Mines, 20% Foidel Creek
8	Pawnee	Xcel Energy	547	3,139,143	1,842,127	150,167	– –	Wyoming PRB
9	Valmont	Xcel Energy	166	1,588,084	649,226	56,071	– –	73% Foidel Cr, 26% Colowyo, 1% Elk Cr
10	Rawhide	Platte River Power Auth.	270	2,121,749	1,114,521	265,337	5,295	Wyoming PRB
11	Craig	Tri-State G & T Assn.	1264	10,855,000	5,019,447	37,000	432,700	58% Colowyo, 39% Trapper, 3% Foidel Cr
12	Nucla	Tri-State G & T Assn.	100	825,699	404,899	– –	– –	New Horizon Mine
13	W.N. Clark	Aquila Inc.	38	306,928	171,096	– –	– –	Foidel Creek Mine
		State Totals		**37,314,545**	**18,762,886**	**1,181,585**	**620,982**	

Xcel has also begun construction on its new coal-fired power plant in Pueblo. This is a super-critical pulverized unit that will be added to the existing Cherokee Station. It will add 750 Mw of capacity to the plant. Coal will be supplied from Wyoming's Powder River Basin.

Coal consumption in Colorado is mostly for electric generation, but about two percent is consumed in the manufacturing and commercial sectors. Major manufacturers using coal for boilers in Colorado include Cemex, Inc. and Holcim, Inc. for cement-manufacturing; TXI, Inc. for lightweight shale aggregates; Western Sugar for their sugar beet refining; and the Coors Brewery. Some of this coal is from Colorado but some is from Wyoming and Pennsylvania. While no Colorado coal was used at coke plants in 2005, there has been renewed interest in the product. According to the National Mining Association's publication *Mining Week* (February 17, 2006), total U.S. coal exports for 2005 was 49.5 million tons, or 4 percent higher than in 2004. This was due to an upswing in metallurgical coal exports. Total metallurgical coal exports in 2005 were 28.7 million tons, or 6.9 percent higher than in 2004. Most U.S. coal exports are to Europe. Colorado has over 2 billion tons of coking coal resources in the Trinidad and Somerset coal fields, but none were produced for that purpose in 2005.

Colorado utilities also receive coal from other states, but in 2004 the supply declined over 2003. Over 6.8 million tons of subbituminous Powder River coal was imported from Wyoming in 2004, down from 9.3 million tons in 2003 (EIA data). The Platte River Power Authority's Rawhide Plant in northern Colorado is close to the Wyoming border and uses only Powder River Basin coal. Five other plants from Denver to Pueblo and Brush also use imported Wyoming coal. Over 22,000 tons of anthracite were imported from Pennsylvania in 2004, mostly for industrial purposes, but some was for residential and commercial sectors. Some coal from Utah was used for electricity generation in our state in 2004 as well.

Employment, safety, and productivity

Based on the CDMG monthly listing of coal mining data, a nine percent increase in employment from December 2004 to December 2005 indicates a growing market for coal miners in western Colorado. The number of employees at Colorado coal mines is about 2,200, of which 1,991 are miners. Coal is the biggest component of Colorado's mining industry today. This increase in employment is a result of the increased production at the large coal mines.

Colorado's coal miners produce more coal per man-hour than most other states. Coal mining productivity is defined as the total state coal production divided by the total direct labor hours worked by all mine employees. In 2004, the average production per miner-hour was 9.1 tons, up 5.8 percent from 2003 (EIA coal most recent data), and much higher than the U.S. average of 6.8 tons per miner-hour. In general, underground miners in Colorado produced at a rate of 9.52 tons per miner-hour (the second highest rate in the nation), up from the 9.48 tons per miner-hour in 2003.

The U.S. Department of Labor's Mine Safety and Health Administration (MSHA) reports that 2005 was a year for the least number of coal mining fatalities nationally. Only 22 miners were killed in coal mining last year, 14 of which were underground miners. In Colorado coal mines, no fatalities have occurred in over five years, which is a tribute, in part, to the CDMG's Mine Safety Program, and to the individual mine safety development programs. The injury incidence rate at Colorado coal mines is well below the national average. The Colorado coal mine injury rate has been reduced by 58 percent since 1995; even while coal production has increased by 50 percent.

In the first two months of 2006, there have been 21 deaths at coal mines in the U.S. On February 6, 2006, in response to West Virginia's Sego Mine disaster and other alarming fatalities across the country early in 2006, MSHA requested all coal mines across the country to conduct one-hour safety stand downs to give miners and mine operators the chance to conduct safety reviews. All of the Colorado mines participated in the event. On February 16, 2006, Senator Arlen Spector (R-PA) introduced

federal legislation that would require all underground mines to use specific wireless technologies, conduct surprise rescue drills, and construct oxygen stations in response to several West Virginia coal mine accidents this year. Called the Mine Safety and Health Act of 2006, this bill would require operators to equip miners with text messaging to communicate in the event of an underground emergency. Secondary telephone communication service would also be required between underground and surface locations.

Coal Mining Reclamation and Safety Awards

At the 106th National Western Mining Conference held in Denver this February several coal companies and contractors received pollution prevention and safety awards from the Colorado Mining Association and the CDMG. Among the winners were Kennecott Energy Company's Colowyo Coal Mine for employees working 580,000 man-hours without a lost time or restricted duty injury in 2005, and Trapper Mine employees working over 911 days and over 784,000 man-hours without a lost-time injury.

Trapper Mining Co., along with Kennecott and Seneca Coal companies, all received recognition for their five-year collective efforts in continuing a native shrub establishment study in northwest Colorado. Among the pollution prevention awards were the Colowyo Mine for developing an automated system for recycling energy consumption, Trapper Mine for adding drinking water conservation measures, innovative reclamation practices, and recycling. Mountain Coal Company was awarded for the West Elk Mine developing an environmental, health, and safety plan for all employees and a plan for methane energy recovery, recycling, and water management. Peabody Energy's Twentymile Mine operation was awarded for recycling all groundwater drainage to the mine and minimizing both water supply and discharge. Oxbow Mining's Elk Creek Mine won junior level recognition for developing used oil, solvent, drum, and metal recycling programs. Bowie Mine was honored for evaluating mining-related seismic effects at the Bowie #2 Mine. The study determined the impact of longwall mining near the Terror Creek Reservoir. Kaiser Ventures and Greystone Environmental Consultants received recognition for final reclamation and bond release at the Chimney Rock Mine. Rimrock Coal and Landmark Reclamation received an award for reclamation at the Rimrock Mine as well.

Underground Longwall Mining Activity

The 2005 *U.S. Longwall Census* reports five active longwall machines in Colorado (table 9). Longwall machinery is important to Colorado because of its safety and productivity records. Longwall technology is an important reason why Colorado's coal production from its geologically thick coal beds has doubled since 1982 (fig. 39). Nationally, 47 mines operate 53 longwall faces. The average longwall face in Colorado mines is now over 9,000 feet long. The biggest shearer and set of shields

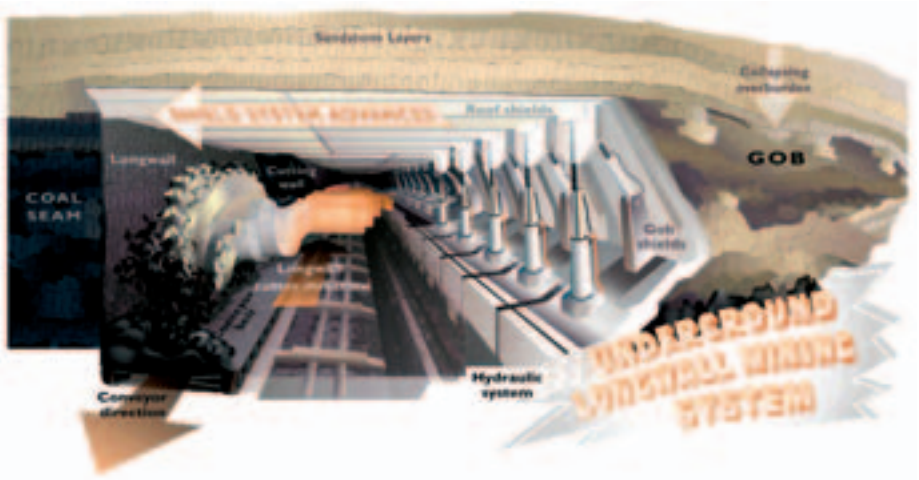

Figure 39. Diagrammatic cross-sectional view of a longwall machine in action.

is the new DBT longwall at Peabody Energy's Foidel Creek Mine in Routt County. According to *CoalAge*, the EL3000 shearer has 2,980 horsepower and the supports have a yield of 1,328 tons. All of the longwall parameters increased in size for the average U.S. longwall last year. The average cutting height measured 85 inches; the average longwall length is now 945 feet, up from last year's 922 feet; and the average panel length is 9,912 feet, up from 9,724 feet a year ago. The average rating for the shearer grew to 1,447 horsepower, up from 1,295 horsepower in 2004; the average yield grew to 909 tons from 870 tons.

Table 9. Colorado underground mine longwall data in 2005 (Source: *CoalAge* magazine, Feb. 2006).

Company Name (Mine)	Seam	Seam ht. (in)	Cutting ht. (in.)	Panel width (ft)	Panel length (ft)	Overburden (ft)	Depth of cut (in)	Shearer
Bowie Resources (Bowie Mine #3)	B	108–120	96–120	845	7,000	1,100	36	DBT America EL2000 DDR 2,980
Blue Mountain Energy (Deserado)	B	84–168	132	800	11,000	400–900	32	Joy 4LS-5 DDR 1,030
Oxbow Mining (Elk Creek)	D	108–180	132	805	6,800	500–2,000	30	Joy 7LS-3A DDR 1,720
Peabody Energy (Foidel Creek)	Wadge	96–114	96–114	1,000	12,000–15,000	600–1,400	36	DBT EL3000 DDR 2,980
Arch-Mt Coal Co (West Elk)	B	276	144	950	3,500–9,000	600–1,400	40	Joy 6LS-2 DDR 1,720

Coal quality

Four components are important in determining whether a certain coal is highly desired or less desired: ash, sulfur, and mercury content, as well as the heat value (Btu). These, along with transportation costs, determine the price that can be obtained for a particular coal. The amount of ash determines how much impurities such as clay particles are mixed in with the coal. The lower the ash content, the lower the waste products after burning. The amount of sulfur and mercury determines how much removal treatment is required to comply with Clean-Air standards. The Btu value determines how much heat can be generated with a pound of coal. The average coal mined in Colorado today is 10,952 Btu, 0.6 percent sulfur, and 10.55 percent ash. This is characterized as a high Btu, low sulfur, and moderate ash coal. Colorado is second only to Illinois in bituminous coal reserves, but is by far the leader in bituminous clean air compliant coal reserves. According to EIA data, the average quality of coal received at manufacturing plants in Colorado for 2005 was 11,620 Btu, 0.51 percent sulfur, and 9.77 percent ash. Btu of Colorado coal increased from the 11,336 Btu reported for 2004.

Colorado steam coal is attractive because of its high quality for Clean-Air compliance with power plant emission standards (table 10). The San Juan and Raton Mesa Coal Regions have the highest heat values, averaging over 12,500 Btu. The Denver Coal Region has the lowest sulfur coal averaging 0.3 percent. The South Park and Uinta Coal Regions have less than seven percent ash. Colorado coal produced in 2005 ranges between 0.4 and 0.8 percent sulfur, which is about two or three times lower than the average eastern bituminous coal. The average quality of coal received at electric utilities in Colorado is compliant with Clean Air Act standards.

Table 10. Average quality values for mineable coal beds from all coal mines in Colorado by coal region. Mercury values are from the USGS National Coal Quality Inventory at active mines in 2001 (Source: Colorado Geological Survey Information Series 58).

Analyses	Denver Region	Green River Region	North Park Region	Raton Mesa Region	San Juan Region	Uinta Region	South Park Region	Cañon City Region
Ash (percent)	11.2	9	12.4	16.1	12.7	6.8	6.4	9.8
Sulfur (percent)	0.3	0.6	0.5	0.7	0.8	0.6	0.5	0.8
Btu (per lb.)	9,072	10,973	9,483	12,541	12,758	11,879	9,780	11,130
Mercury (ppm)	—	<0.02	—	0.035	0.03	0.02	—	0.185

Reserves

About 75 percent of Colorado coal leases are federally owned. Nearly 50,000 acres are currently under lease. For 2004, EIA (2004 is most recent data) reported that Colorado had 415 million tons of recoverable coal reserves under lease at active mines, a 2.9 percent decrease over 2003. EIA's Demonstrated Reserve Base (DRB) data show Colorado with 16.293 billion tons of coal; 11.53 billion tons underground mineable and 4.76 billion tons surface mineable. Recoverable reserves (9.8 billion tons) are defined as that part of the DRB that can be mined using today's mining technology. In 2004, the average recovery at Colorado coal mines was 69.34 percent

Over 1,700 Colorado coal mines have produced 1.265 billion tons of coal since 1864 (fig. 40). Most of the historic coal has been produced in the Uinta Coal Region (35.2 percent) and the Green River Coal Region (26.6 percent), which are both actively mined today.

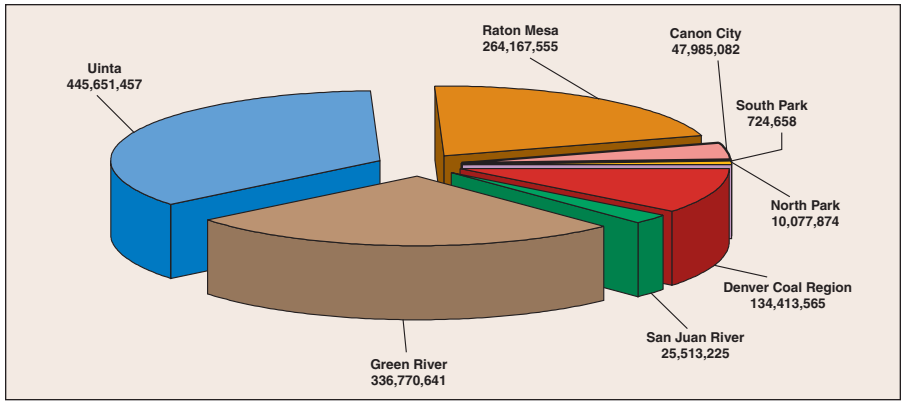

Figure 40. Historic Colorado coal production in cumulative tons produced by coal regions. Total coal production for Colorado as of January 1, 2006 is 1.265 billion tons.

Colorado coal mine news 2005

Northwest Colorado coal mining news

Peabody Energy closed its Seneca mines near Hayden (Yoast and Seneca II-W) on December 31, 2005 and these are now in reclamation. These surface mines have faced high mining costs due to steeply dipping coal beds for several years. The coal beds of the lower Williams Fork Formation are up to 40 feet thick and dip up to 17 degrees (fig. 41). Both mines were at the end of their economic reserves and steeply dipping terrain played a large part in their closing. To continue supplying the Hayden Power Plant, Peabody has increased production from the nearby Foidel Creek Mine. Coal is hauled over the road between the mine and the power plant. The Seneca coal mines have supplied the Hayden Station since 1964 and more than 45 million tons of coal were mined from the Seneca, Seneca II, Seneca II-W, and Yoast mines.

Peabody Energy and the Twentymile Coal Company had an exceptionally good year at the Foidel Creek Mine in 2005. In December, the mine broke both the annual and the monthly coal production records for the state. The company hopes to be the first Colorado coal mine to produce over 10 million tons annually in 2006. Foidel Creek will now supply the Hayden Station with coal trucked over the Twentymile Road. Other customers for the 11,400 Btu low sulfur coal include power plants in Mississippi, Texas, Arizona, Canada, and Mexico. The mine will install a new longwall operation in April 2006. Peabody now has over 500 employees at the mine and hopes to produce 10.5 million tons of coal this year.

The Trapper Mine near Craig in Moffat County encountered thinning coal beds toward the eastern end of their surface pits. Three drilling rigs are currently being used for exploration to expand the mine along the Williams Fork Mountains. Possibilities for new reserves include more surface mining of the Upper Coal Group of the Williams Fork Formation, or possibly moving underground into the Middle Coal Group coals in the future. Trapper currently has another eight years of reserves under lease.

The Colowyo Mine in Moffat County is the state's largest surface coal mine. In 2005, the mine produced 5.87 million tons of coal. The ADDCAR Highwall Mining System was employed in both the West and East pits in 2005 and produced 900,000 tons. The mining system cut into the hillside as far as 1,100 feet, leaving 7- to 10-foot pillars. The coal is cut with a conventional miner and conveyed to the surface on segmented feeder cars with conveyors (fig. 42). Due to variability of the wavy coal beds encountered the work was sometimes challenging for the highwall machinery at the East Pit. Production at the East Pit has ceased and the pit is currently being reclaimed.

Figure 41. View of the Seneca II-W coal mine excavating in steeply dipping terrain, November 2005.

Figure 42. Diagrammatic representation of a highwall mining system.

Kennecott is exploring their Collum and South Taylor Pit areas near Colowyo Mine for future mining operations. South Taylor will be the next surface operation after the West Pit is exhausted. Kennecott hopes to have the South Taylor Pit operational by the end of 2007. Currently, the draglines and truck/shovel operations in the West Pit are moving toward the south end. Many of the coal seams are thinning toward the south. Keith Haley is the new manager of mine operations at Colowyo.

The Deserado Mine in Rio Blanco County near Rangely produced 2.15 million tons of Mesaverde Group coal in 2005. Coal production for 2006 will be less than in previous years due to lower consumption rates of stockpiled coal at the Bonanza Power Plant. In 2005, the company drilled nine exploration holes, two monitoring wells, and three de-gas wells to the north of the current mining location. One target is to determine accurately where the axis of the Red Wash Syncline is located. The longwall is now mining the 7-to 16-foot thick B-seam at a depth of over 900 feet.

The McClane Canyon Mine in Garfield County reported an explosion over Thanksgiving weekend while the mine was closed. Ventilation was minimal over that time and methane built up and exploded. No fire occurred, but a front-end loader at the mine entrance had windows blown out. The mine was shut down for six weeks while MSHA inspectors and mine personnel worked to repair equipment and secure safety in the mine.

Central Appalachian Mining (CAM) announced in 2005 an intention to greatly expand mining operations on the permit area. CAM would like to extend operations to over 5 million tons per year. To accommodate the efforts they would install a coal loading facility and rail line to Mack. In addition, CAM is looking into opening a new mine along the Book Cliffs that would be three miles southeast of the current mine.

Somerset coal field news

In the North Fork Valley there are three active operations mining coal from the Paonia Shale Member of the Mesaverde Group. On the north side of the valley are the Oxbow Mining Company's Elk Creek Mine and the Bowie Coal Company's Bowie #3 Mine. Elk Creek mines the 14-foot thick D2 seam; Bowie #3 mines the 12-to 20-foot thick upper and lower split B-seams. The third mine, Arch Coal/Mountain Coal Company's West Elk Mine, is the only mine on the south side of the valley. This mine produces coal from the 13-foot thick E-seam. These mines all produce low-sulfur and high-Btu bituminous coal. All of the coal produced at these mines is hauled by Union Pacific Rail from the valley to Grand Junction and then to various destination points as far away as Florida and Massachusetts. All three mines set coal production records in 2004, but late in 2005 geologic constraints to mining set production back.

Oxbow Mining Company's Elk Creek Mine was fully operational and ranked as the second most productive underground mine in the nation in 2005. The longwall is currently mining in both Delta and Gunnison counties. In mid-December, the longwall encountered roof fall on the head gate from a fractured claystone roof rock. This unexpected condition resulted from a complex stress regime due to the proximity of the abandoned Blue Ribbon Mine, which mined the E-seam. The result was a longwall that loaded up with shear stress and could only operate at about ten percent capacity. For a time the shields were stuck, and Oxbow is now retreating the longwall to another panel. The mine hopes to start in a new panel by April 2006. As a result production slowed considerably.

Bowie Resources produced coal from two mines in 2005, the Bowie #2 and the #3 mines. The main production shifted from the D-seam in the #2 Mine to the B-seam in the #3 Mine in early 2005. Production continued without major interruption at the 5-million ton per year level. The new preparation plant built to clean the B-seam coal is used part of the time. East of the Mains Fault zone the lower B-seam contains a fractured mudstone parting causing out-of-seam dilution. Bowie #3 Mine produced 3.2 million tons in 2005, with a monthly high of 509,381 tons produced in September. Some coal is still produced from the D-seam by conventional miners at the North Mains section of the #2 Mine. The two mines are connected via ventilation tunnels along the Mains Fault. Currently the Bowie #3 Mine is 1,200 feet deep, and in February the longwall was slowed due to tailgate difficulties as mining near the Mains Fault became difficult. Bowie #3 Mine crossed the fault in 2005 and miners cannot remove coal within 300 feet of the fault zone due to rock instability. Mine geologists have mapped the fault as it crosses both mines.

Arch Coal's West Elk Mine on the east end of the North Fork Valley had a below average year. Arch reported a "very significant heating and combustion-related event" in the gob area behind the longwall section in early November 2005 and shut down the mine. MSHA inspectors oversaw the mine for two months in order to reduce methane gas buildup and a potential fire. The recovery team drilled ten holes into the heating zone area for gas sampling purposes, monitoring, and thermal-event control. A turbine engine was used to pump large quantities of carbon dioxide into the mine to smother the smoldering coal. By late January 2006, the mine's ventilation system was restarted, and continuous miner production was resumed in February after a two and a half month shutdown. The longwall will restart in another section of the 13 foot thick E-seam.

Southwest Colorado coal mining news

For the second year in a row, National King Coal's 70-year old mine near Durango set a new coal production record in 2005 with 460,611 tons produced. Originally opened in 1936, King Coal is Colorado's oldest and longest continually operating coal mine, having produced over 5.6 million tons of coal from the Menefee Formation of the Mesaverde Group. The high Btu coal is sold to cement manufacturers in New Mexico and Arizona. Much of the coal mined at King Coal is hauled by truck to rail lines in Gallup, New Mexico.

The New Horizon Mine in Montrose County near Nucla broke their annual coal production record again. The surface mine that supplies the Tri-State Generation and Transmission Nucla Power Plant produced 420,730 tons of coal in 2005. Increased electricity demands on the power plant in 2005 was the main driving force behind the coal production record. The plant is operating at near capacity with its fluidized bed configuration that can handle high ash content coal up to 22 percent. The coal operation produces from both the lower and upper Dakota Group coal seams. The upper bed is only one foot thick, but the main seam is the 5.5–foot-thick lower seam. New Horizon is mostly a truck and shovel operation but also uses cast-blasting and a dozer-push operation. The pit highwall varies from 20 to 120 feet high. Currently the mine has six years of reserve life remaining on the existing permit and is looking for future reserves to the north and west of the current pit.

URANIUM

Summary

Increased uranium demand for electric generation at nuclear power plants worldwide has tightened the supply and driven prices sharply higher over the past three years. In 2005, the annual average spot price for U_3O_8 rose sharply to $28.52 per pound (fig. 43). This is the highest it has been since the early 1980s and is 54 percent higher than the average 2004 price of $18.55 per pound. The price is continuing to soar and it hit $41.00 per pound in April 2006. Higher prices have prompted increased production and exploration efforts for the radioactive metal. Cotter Corporation produced uranium ore from four mines on Colorado's Western Slope in 2005, but shut down all four operations in November. Most of the new unpatented mining claims staked in Colorado in the last two years are uranium claims in the western part of the state.

In 2004 (the most recent year for worldwide data), mines around the world produced about 102 million pounds of uranium oxide (U_3O_8) while consumption was 160 to 180 million pounds (source: Ux Consulting Company). Uranium derived from "downblending" highly enriched uranium from decommissioned Russian nuclear weapons made up most of the difference, but that source is predicted to run out by 2013. Imports accounted for 81 percent of the 64 million pounds of U_3O_8 purchased for use in U.S. nuclear power reactors in 2004 (source: U.S. Energy Information Agency, EIA). Australia, Canada, and nations of the former Soviet Union are the world's largest uranium producers. According to the EIA, Colorado ranks third among the states for uranium reserves, behind Wyoming and New Mexico.

In late 2003, the Chinese government announced plans to build 30 or more new nuclear power plants by 2020. Russia plans to build 24 new plants also by 2020, and India plans to build 17 new plants by 2012. The U.S. currently has 104 licensed commercial nuclear reactors. Nuclear energy generates about 20 percent of the electricity used in the U.S. No new commercial reactors have come on line since 1996, and no new nuclear power plants have been licensed in the U.S. since 1973.

Serious interest in nuclear electric generation in the U.S. is being renewed as concern rises over global climate change and emissions of carbon dioxide from coal, oil, and gas-fired power plants. In April 2005, Greenpeace co-founder Dr. Patrick Moore told the U.S. House Subcommittee on Energy and Resources that "nuclear energy is the only non-greenhouse gas-emitting power source that can effectively replace fossil fuels and satisfy global demand … There is now a great deal of scientific evidence showing nuclear power to be an environmentally sound and safe choice." Moore believes his former colleagues at Greenpeace are unrealistic in their call for a phasing out of both coal and nuclear power worldwide.

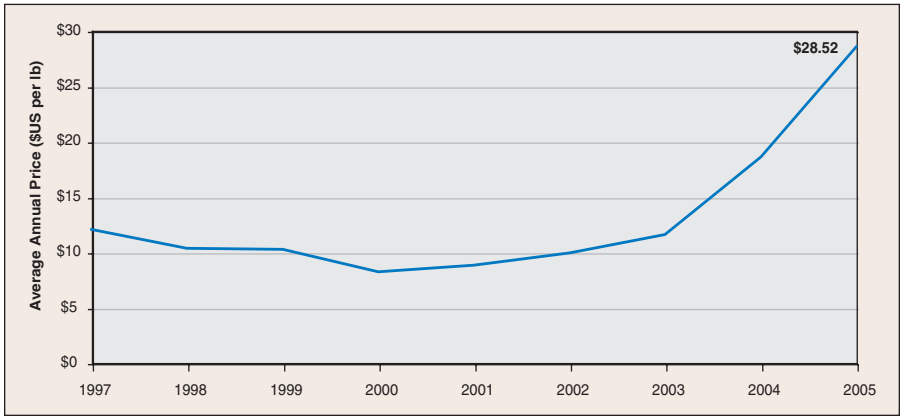

Figure 43. Average annual spot prices for uranium oxide (U_3O_8), 1997–2005. Data source: The Ux Consulting Company, LLC, **http://www.uxc.com/**.

Uses of uranium

Uranium is a heavy, radioactive metal that is used mainly to generate electricity in nuclear power plants. Other uses for enriched uranium include powering nuclear-propelled military ships and submarines and as X-ray targets in making high-energy X-rays. Uranium is also used to manufacture plutonium in breeder reactors. Plutonium use is decreasing as fewer nuclear weapons are being manufactured by developed nations. Depleted uranium, the uranium that is left over after the most radioactive isotopes have been removed, is used in some helicopters and airplanes as wing counterbalances, as bullets or artillery shells, and as tank armor by some militaries.

Cotter Corporation mines, Montrose County: Englewood-based Cotter Corporation, a subsidiary of General Atomics Corporation of San Diego, produced uranium and vanadium ore from four mines near Nucla and Naturita in Montrose County in 2005. These are the JD-6, JD-8, JD-9, and SM-18 mines. The production from these mines is shown in Table 11. Unfortunately, the company closed all four of these mines in November 2005, laying off 49 workers at mine sites on the Western Slope and more workers at its ore processing mill in Cañon City. Jerry Powers, Cotter's Manager of Administration, was quoted in the *Montrose Daily Press* in November 2005, saying the mines were closed because the company was

not able to make them profitable despite high prices for uranium and vanadium. Higher energy costs and the long haulage distance (about 300 miles) from the mines to the Cañon City mill played a large role in the economic difficulties of the operations. Powers said the decision to close the mines was not a "full closure," but the company did not have a schedule for re-opening the mines or mill site. Cotter's Cañon City uranium ore mill is one of only four uranium mills in the U.S.

The 2005 total Colorado production of 255,544 pounds of U_3O_8 was 127 percent higher than the 2004 production of 112,803 pounds. CGS estimates that the 2005 uranium production has a gross value of $7.3 million based on the average 2005 uranium (U_3O_8) price of $28.52 per pound. The uranium-vanadium ore was trucked from the mines to Cotter's mill in Cañon City where it was processed to yellowcake uranium concentrate and vanadium concentrate. The yellowcake is sold to an enrichment plant in Illinois for further processing.

Cotter's mines are located in the famous Uravan mineral belt, the oldest uranium mining area in the U.S. and historically the most productive uranium and vanadium region in Colorado. The uranium and vanadium deposits are hosted in sandstone, primarily that of the Salt Wash Member of the Jurassic Morrison Formation. The Uravan mineral belt has about 1,200 historic mines that produced over 63 million pounds of uranium and 330 million pounds of vanadium from 1948 to1978.

Table 11. 2005 uranium and vanadium production at Cotter Corporation's mines in western Colorado. Source: personal communication, Cotter Corporation.

Mine name	tons of ore mined	grade U_3O_8 (percent)	U_3O_8 mined (lbs)	grade V_2O_5 (percent)	V_2O_5 mined (lbs)
JD-6	10,471	0.24	50,261	1.28	268,058
JD-8	5,918	0.59	69,832	3.19	377,568
JD-9	10,560	0.27	57,024	1.40	295,680
SM-18	18,673	0.21	78,427	1.16	433,214
TOTALS	45,622	0.28	255,544	1.51	1,374,520

RENEWABLE ENERGY RESOURCES

Introduction

Colorado is situated in a unique location for alternative energy technology. The mountainous elevation and high plains are good territory for hydroelectric, wind, geothermal, and solar energy. The National Renewable Energy Laboratory (NREL) is located in Golden and is considered the nation's number one source for alternative energy technology. The State of Colorado passed Amendment 37 in 2004, which establishes a ten percent renewable energy requirement for Colorado's electric utilities by 2015. Powered by tax credits and the future promise of Green Credits, the alternative energy industry is growing in Colorado. Many of the large utilities offer rebates and incentives to customers who install solar panels or wind turbines.

On February 21, 2006, President Bush toured the facilities at NREL to observe ethanol and biomass research efforts on corn stover, corn stalks, switch grass, and poplar trees. He asked three questions: is there enough biomass to make a significant difference in fuel supply?; what is the energy cost to produce cellulose ethanol?; and how cost effective is it? NREL officials said that yes, there is enough biomass to keep up with fuel demand and that ethanol gives off five times the energy it takes to produce it. The President has vowed to break the nation's addiction to oil. American's concerns about high utility bills and gasoline prices are a national priority.

Wind Energy

Wind power is a growing segment of the global electric generation market. According to the American Wind Energy Association (AWEA), 2005 was a record year worldwide for production of wind energy. Wind energy generation capacity increased from 8,207 megawatts (Mw) to 11,769 Mw worldwide, a 43 percent increase last year. More than 2,400 Mw of potential power was added in the U.S. in 2005. The AWEA supports a balanced energy policy that fully taps wind power for domestic electricity production through improved access, upgrades to existing and new transmission lines, and tax credits to encourage investment in the industry.

Xcel Energy is the nation's leading wind power purchaser. The Minneapolis-based company and its independent partners produced 1,048 Mw of power generated from wind in 2005. Xcel has wind farms in Minnesota, Texas, and Colorado. They now purchase more electricity from wind power than the California-based energy companies, Southern California Edison and Pacific Gas and Electric.

Figure 44. Ponnequin Wind Farm, Weld County, showing old and new wind power technology.

Colorado is quickly becoming one of the nation's top wind producing states. Xcel purchased or generated 282 Mw of wind power in Colorado last year. The company hopes to generate up to 1,057 Mw of wind power in Colorado by the end of 2007. Xcel Energy owns and operates a wind farm on State Land Board property in Weld County near the Wyoming border. The 44-turbine Ponnequin Wind Farm (fig. 44) generated 54 million Megawatt-hours (Mw-h) of electricity in 2005. Two types of turbines are used at Ponnequin, Vestas and NEG Micons (table 12). Xcel owns 37 of the turbines and EUI owns seven of the turbines on the wind farm.

Cinergy Global Power owns the Peetz Table Wind Power Plant in Logan County. This plant has 33 turbines (NEG Micon) and generated 78,301 Mw-h of electricity in 2005. Xcel Energy purchases the power through their Windsource program for peak electrical usage. Each unit consists of a 170-foot diameter rotor and turbine, set on a 237-foot high tower.

Table 12. Wind energy development in Colorado (Source: AWEA).

Project	Owner	Online Date	Mw Capacity	Power Purchaser	No.Units/ Turbine Type
Ponnequin EIU 1	K/S Ponnequin Windsource & Energy Resources	1999	5.1	Xcel Energy	7 NEG Micon
Ponnequin Xcel 2	Xcel	1999	16.5	Xcel Energy	22 NEG Micon
Ponnequin EIU 3	New Century	2001	9.9	Xcel Energy	15 Vestas
Peetz Table Wind Farm	New Century	2001	29.7	Xcel Energy	33 NEG Micon
Colorado Green, Lamar (Prowers Co)	Xcel/GE Wind Corp.	2003	162	Xcel Energy	108 GE Wind 1500
Prowers Co (Lamar)	Arkansas River Power Authority	2004	1.5	Arkansas River Power Authority	1 GE Wind 1500
Baca Co (Springfield)	Arkansas River Power Authority	2004	1.5	Arkansas River Power Authority	1 GE Wind 1500
Prowers Co (Lamar)	Lamar Utilities Board	2004	4.5	Lamar Utilities Board	3 GE Wind 1500
Aurora WalMart	Bergey Windpower	2005	0.05	WalMart	1 Bergey Windpower 50 kW

There are four new proposed wind projects in Colorado for 2006. These include a 40-turbine extension to the Peetz Table Wind Farm at Spring Canyon. Three other projects are planned by the Wray School District, Washington County Green Light project (200–300 Mw capacity), and Quixote Wind in southeastern Colorado. Colorado is set to become the fourth largest wind power producing state in the nation by the end of 2007.

Hydroelectric power

Due to our mountainous terrain, Colorado has great potential for hydroelectric power and has maintained a substantial amount of hydroelectric power generation. Approximately five percent of our total electrical output comes from hydroelectric power. Aspen, Telluride, Durango, Ouray, Nederland and other mountain towns supply much of their power from several nearby hydroelectric stations. The Colorado-Big Thompson Project brings large volumes of western slope water via tunnels under the Continental Divide to the Front Range (fig. 45). Along the way hydroelectric power is generated at several substations.

The Ames Power Station in Ophir supplied the power for the world's first alternating current in 1891. Table 13 lists Colorado's hydroelectric stations, nameplate ratings, and electric generation in 2004.

Figure 45. Dam and reservoir in the Colorado-Big Thompson Project near Loveland.

Solar Energy

Colorado has excellent opportunities for solar power because of our over 300 days of sunshine each year. Xcel Energy has a program for solar energy development. Individual homeowners can get electric rebates for installing a photovoltaic solar system on their homes or businesses. These rebates for solar installation are an incentive to grow the solar energy industry. Photovoltaic cells are placed on the roof to collect light and convert the energy to direct current in batteries. A solar array of cells can make the electric meter run backward during the sunny daylight hours.

The City of Denver recently announced that they plan a municipally-owned solar power plant that would generate electricity to supply 1,000 homes near the Stapleton area. This unique idea would be one of the first government-run, solar plants within an urban area in the U.S. The plan calls for Xcel Energy to purchase the power from the city as part of an Amendment 37 renewable requirement. The revenue generated by the plant would provide enough funding to pay for construction and maintenance of the plant.

Table 13. Hydroelectric generating stations in Colorado, 2004.

Plant Name	Parent Company	Plant Address	Nameplate Rating (Mw)	Electric Generation (Mw-h)
Mount Elbert	US Bureau of Reclamation	Twin Lakes Field Office, Granite Star Route, Granite, CO 81228	200	344,142
Flatiron	US Bureau of Reclamation	11056 West County Road 18E, Loveland, CO 80537-9711	94.5	227,386
Morrow Point	US Bureau of Reclamation	Montrose, CO	120	195,118
Pole Hill	US Bureau of Reclamation	11056 West County Road 18E, Loveland, CO 80537-9711	38.2	179,448
Cabin Creek Station	Xcel Energy	6276 County Road 381, Georgetown, CO 80444	324	175,383
Blue Mesa	US Bureau of Reclamation	Gunnison, CO	60	142,539
Estes	US Bureau of Reclamation	PO Box 960, Estes Park, CO 80517-0960	45	106,625
Tesla	Colorado Springs Utilities	690 W. Monument Creek Rd., USAFA, Colorado Springs, CO 80840	28	44,457
Shoshone Hydro	Xcel Energy	60111 Hwy. 6&24, Glenwood Canyon, P.O. Box 1067, Glenwood Springs, CO 81602	14.4	42,681
Mary's Lake	US Bureau of Reclamation	PO Box 960, Estes Park, CO 80517-0960	8.1	38,304
Green Mountain (Reservoir)	US Bureau of Reclamation	Building 17, 170, County Road 1813, Silverthorne, CO 80498	26	26,975
Tacoma Station	Xcel Energy	North of Rockwood, CO	8	26,631
Upper Molina	US Bureau of Reclamation	Molina, CO	8.6	25,612
Lakewood	City of Boulder	WTP Hydro, 1094 Betasso Rd, Boulder, CO 80302	3.4	19,622
Roberts Tunnel	Denver Water	Grant, CO	6	17,757
Towaoc	US Bureau of Reclamation	Cortez, CO	11.5	16,486
Lower Molina	US Bureau of Reclamation	Molina, CO	4.9	14,797
Ames Hydro	Xcel Energy	650 Ames Road, P.O. Box 668, Ophir, CO 81426	3.6	13,362
Ptarmigan/Vallecito	Ptarmigan Resources and Energy	Vallecito Reservoir	5	11,674
Ruedi Reservoir	City of Aspen	Aspen, CO	5	10,833
Silver Lake	City of Boulder	WTP Hydro, 1094 Betasso Rd, Boulder, CO 80302	3.2	10,000
Big Thompson	US Bureau of Reclamation	11056 West County Road, Loveland, CO 80537-9711	4.5	9,900
Foothills	Denver Water	Littleton, CO	3.1	9,400
Dillon (Lake Dillon)	Denver Water	Dillon Dam, CO	1.9	9,366
Palisade	Xcel Energy	PO Box J, Palisade, CO 81526	3	9,213
Boulder Hydro	City of Boulder	37788 Boulder Canyon Dr., P.O. Box 1728, Nederland, CO 80466	20	8,140
Williams Fork	Denver Water	Williams Fork Dam, CO	3.2	8,109
Hillcrest	Denver Water	Denver, CO	2	6,771
Betasso	City of Boulder	Betasso, WTP Hydro, 1094 Betasso Rd, Boulder, CO 80302	2.4	6,200
Strontia Springs	Denver Water	Waterton Canyon, CO	1.1	6,195
Redlands	Redlands Water and Power Co.	2216 S. Broadway, Grand Junction , CO 81503	1.4	5,200
Salida	Xcel Energy	Poncha Springs, CO	1.3	4,962
Crystal	US Bureau of Reclamation	Montrose, CO	28	4,705
Manitou	Colorado Springs Utilities	540 Manitou Springs, CO 80829	5	4,066
Idylwilde	City of Loveland	Loveland, CO	0.9	3,807
Ouray	Eric Jacobson	Ouray, CO	0.9	3,700
Sunshine	City of Boulder	WTP Hydro, 1094 Betasso Rd, Boulder, CO 80302	0.8	3,565
Georgetown Hydro	Xcel Energy	6276 CR 381, Georgetown, CO 80444	1.4	2,952
John Fetcher Power Plant, Stagecoach Reservoir	Upper Yampa Water Cons. Dist.	Oak Creek, CO	0.8	2,893
Longmont Hydro Plant	City of Longmont	Lyons Canyon	0.5	2,704
McPhee	US Bureau of Reclamation	Cortez, CO	1.3	2,655
Sugarloaf	STS Hydropower, Ltd.	Sugarloaf Dam, Turquoise Lake, Leadville, CO	2.5	2,600
Maroon Creek	City of Aspen	Aspen, CO	0.45	1,978
Bridal Veil Power Station	Eric Jacobson	Telluride, CO	0.3	1,300
Kohler	City of Boulder	Betasso, WTP Hydro, 1094 Betasso Rd, Boulder, CO 80302	0.136	736
Orodell	City of Boulder	WTP Hydro, 1094 Betasso Rd, Boulder, CO 80302	0.18	727
Maxwell	City of Boulder	WTP Hydro, 1094 Betasso Rd, Boulder, CO 80302	0.08	572
Ruxton	Colorado Springs Utilities	Manitou Springs, CO	1	56
		Total	**1,105.5**	**1,812,304**

Biomass

The Colorado Biomass Information Clearinghouse is the source of data about biomass. It defines biomass as any organic matter other than coal that can be processed into energy for heat, liquid fuels, or electricity. Sources include wood, plants, agriculture and residue, animal waste, and industrial wastes. Biomass consumed directly to produce electricity was demonstrated at Aquila's W.N. Clark power plant by direct burning of tree slash. Biomass can be converted into ethanol or biodiesel gasification from animal waste. In Lamar, anaerobic biomass waste from a hog farm produced 45 kilowatt-hour (kWh) to run a turbine for local energy consumption. Colorado Swine Partners raises piglets and sows for finishing farms. The hogs produce 12,500 gallons of waste every day, and the company uses the hog waste to produce electricity from a reciprocating engine and a Capstone 30 kWh microturbine fueled directly from methane produced from animal waste.

Renewable Fuels: Ethanol and Bio-Diesel

Ethanol is made by fermenting a biomass source high in carbohydrates and is used as a fuel additive to reduce emissions. The feedstock is corn, but researchers have found that cellulose materials such as wood, paper, and crop residues can also be converted to ethanol. Currently there are 42 new ethanol plants under construction nationwide. This industry was a farmers cooperative share program, but new private investment is now taking hold.

The U.S. produces 4.3 billion gallons of ethanol annually. The Energy Policy Act of 2005 sets a new standard of 7.5 billion gallons of renewable fuels usage by 2012. This includes biodiesel and ethanol. In Colorado, there are two operating ethanol plants: Coors Brewery produces 1.5 million gallons annually, and Sterling Ethanol produces 50 million gallons per year. There are currently four additional ethanol plants in design or under construction in Colorado. The U.S. Department of Energy (DOE) Clean Cities initiative supports blending of ethanol and gasoline to reduce air pollutants in our cities. Ethanol is blended with gasoline at about ten percent.

Bio-diesel is another alternative fuel source. In Denver, many city vehicles use a mixture of 20 percent biodiesel and 80 percent diesel. Bio-diesel is a cleaner air emissions type of fuel made from domestic byproducts such as vegetable oil. Many Colorado towns like Boulder and Breckenridge use biodiesel fuels in their busses. John Ghist, a school teacher at Platte Valley High School, has started a program to educate students about biodiesel. The students are converting gasoline and diesel powered vehicles to vegetable oil biodiesel. Students at Platte Canyon High School are engaged in a biodiesel project wherein their goal is to provide five percent of the fuel for the district's buses.

Geothermal

Colorado has abundant geothermal resources. Ninety-three geothermal wells and springs, ranging in outflow temperature from 20° C to 83° C at Mount Princeton, Chaffee County, have been documented by the CGS. Most of the current direct geothermal usage is for spas and resorts, aquaculture, and greenhouses. The cities of Ouray and Pagosa Springs utilize waste geothermal water from hot springs resorts to heat sidewalks and public buildings.

Areas of high heat flow in the upper Arkansas Valley and other regions of the state indicate the potential for high temperature geothermal resources at depth. High temperature geothermal resources (greater than 100° C at the surface) can be utilized directly to create electricity. Binary systems can utilize low temperature geothermal resources (less than 100° C at the surface) to create electricity.

Direct-use, geothermal heat exchange systems (heat pumps) have recently been installed in school buildings in the following districts: Cañon City, Colorado Springs, Denver, Frenchman, Lewis-Palmer, and Poudre Valley. Additional government buildings with new heat exchangers are in the City of Northglenn, Montrose County, and at the Air Force Academy. Many private facilities in western Colorado have installed heat exchangers under an incentive program by the Delta-Montrose Electric Association, including the new car museum at Gateway.

The Colorado Office of Energy Management and Conservation is in the process of receiving funding from DOE to create a State Geothermal Working Group to promote increased usage of geothermal resources. In 2006, the CGS received funding from DOE to collect, assess, and publish (in a GIS format) geothermal data from Colorado.

NON-ENERGY RESOURCES

Summary

Colorado's non-energy minerals-mining industry enjoyed a record-breaking year in 2005. Nonfuel mineral production in Colorado includes metals, industrial minerals, and construction materials such as sand and gravel aggregate. CGS estimates that the total value of nonfuel minerals produced in Colorado in 2005 is $1.52 billion, which breaks the previous record of $1.3 billion set in 1980 (fig. 46). Of the 2005 total, $1.00 billion is from metal mining. These estimates are compiled from information obtained by CGS from mine operators, news articles, corporate press releases, annual reports of public companies, and from preliminary estimates released by the U.S. Geological Survey (USGS) Minerals Information Team. The 2005 production value is a 60 percent increase over the revised 2004 CGS estimate of $950.5 million. Colorado now ranks 9th among the states in nonfuel mineral value, moving up from 17th in 2004.

The primary reason for the record-high production value in 2005 is that molybdenum prices were sharply higher compared to previous years. Molybdenum production increased in response to the higher prices for the metal. Higher gold prices also significantly contributed to the increase in production value.

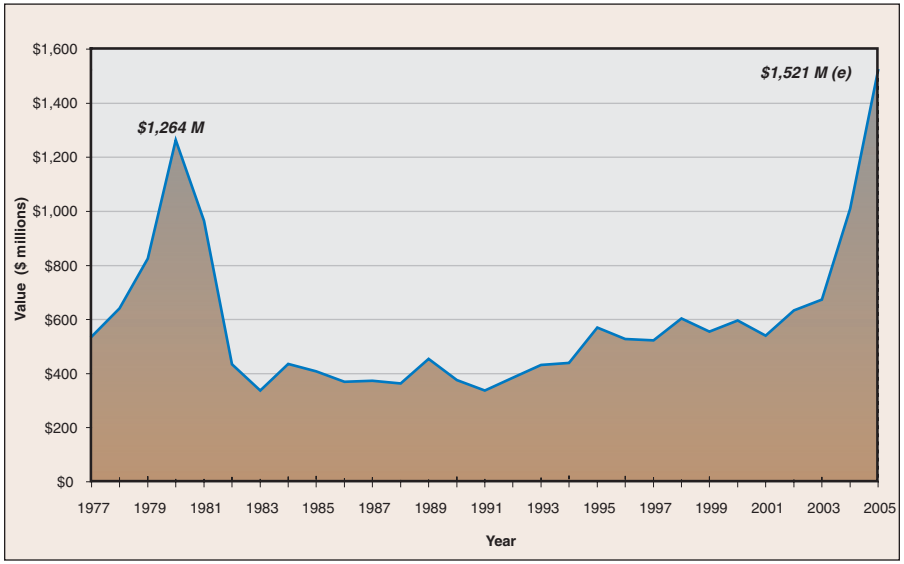

Figure 46. Colorado nonfuel mineral production value, 1977 to 2005. (e=estimated)

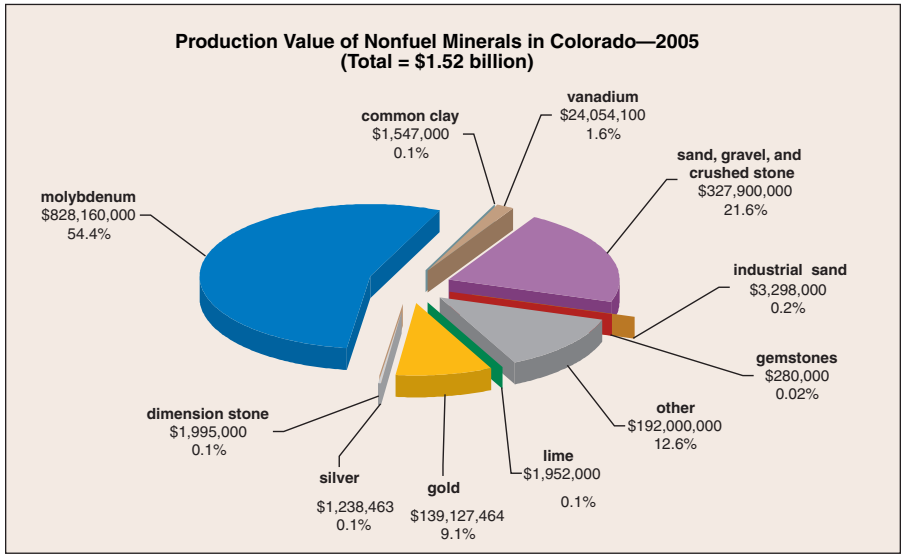

Figure 47. Estimated production value of nonfuel minerals in Colorado, 2005. "Other" includes cement, soda ash, sodium bicarbonate, gypsum, helium and bentonite.

Figure 47 shows the relative contribution of the various commodities to the total production value, and Figure 48 is a map showing selected metal and industrial mineral mines that were active in 2005.

As a result of higher prices for most mineral commodities, exploration activity increased in 2005. In Colorado, the number of active unpatented mining claims on public lands declined from 1995 to 2003, but increased in both 2004 and 2005 (fig. 49). Most of this increase is due to new mining claims in the uranium-rich areas of the Colorado Plateau. Further testimony to the resurgent mining industry in the state is that the 2006 National Western Mining Conference and Exhibition, an annual event organized by the Colorado Mining Association and held in Denver, drew 15 percent more attendees than the previous year's event. The 575 registered participants and 63 exhibitors were the most since 1997.

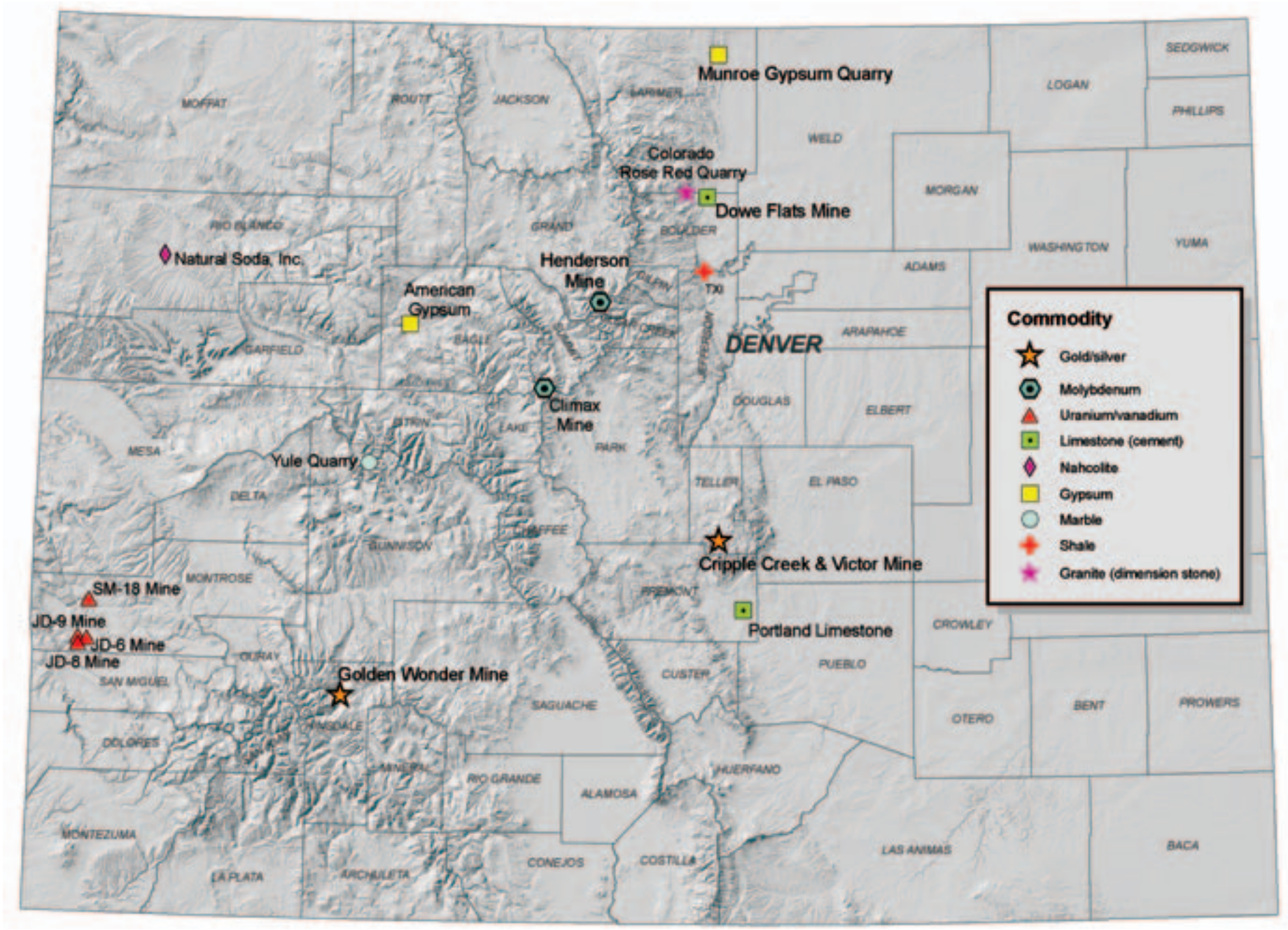

Figure 48. Map showing the locations of significant metal and industrial mineral mines in Colorado in 2005. Clay and aggregate mines are not shown.

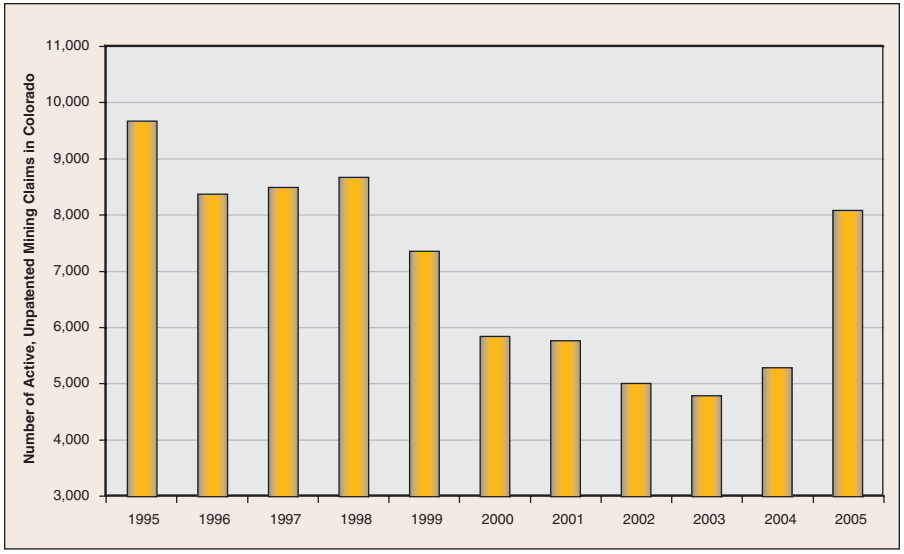

Figure 49. Active unpatented mining claims in Colorado, 1995–2005. Source: U.S. Bureau of Land Management.

Metal Mining

The metals mining industry is continuing to enjoy its first boom cycle of the 21st century. Continuing the trend that began in 2002, the quantity and value of metals produced in Colorado rose significantly in 2005. CGS estimates that the gross value of metals mined in Colorado in 2005 rose to $1.00 billion, a 115 percent increase compared to the 2004 value of $463.6 million. Colorado is the leading molybdenum-producing state in the U.S. and is ranked 4th in gold production. Colorado mines also produced silver and vanadium. Although uranium is a metallic element, its production value is not included in the total for metals because it is an energy mineral.

Worldwide, metal price increases have stimulated exploration and development of new deposits. The current price boom is fueled largely by steadily increasing demand from developing nations, particularly China and India, which continue to rapidly industrialize. Many mining industry leaders expect the current boom to last for at least the next ten years. The annual survey of nonferrous metal exploration expenditures shows that exploration budgets in 2005 totaled $5.1 billion worldwide, a 44 percent increase over 2004 and nearly triple the $1.9 billion spent in 2002 (source: Metals Economic Group).

Molybdenum

Colorado is now the leading molybdenum-producing state in the U.S. All of Colorado's molybdenum production is from one large underground mine—the Henderson Mine near Empire in Clear Creek County. The price of molybdenum skyrocketed from around $8 per pound at the end of 2003 to historical highs of over $30 per pound in 2005. The price peaked at $40 per pound before beginning to decline later in 2005. As of mid-March 2006, the molybdenum price is around $25 per pound, which is still high compared to the 20-year average of about $5.60 per pound. The spectacular price rise was attributed to increasing demand in China and a tight supply of high-quality western molybdenum. The high price has stimulated increased production of the metal. Because of the high price and increased production, molybdenum is now the largest segment of Colorado's mining industry in terms of production value. Figure 50 shows molybdenum production in Colorado and the average yearly price per pound of molybdic oxide from 1970 through 2005.

Uses of molybdenum: Molybdenum is an important, versatile, and widely used metal. Molybdenum's largest use is as an alloy agent in stainless steel, other specialty steels, and cast iron. It increases hardenability, toughness, corrosion resistance, and weldability of steel. High-temperature superalloys are used in jet engines, among other things. Molybdenum is also used in titanium alloys for products where low weight, high strength and corrosion resistance are important, such as

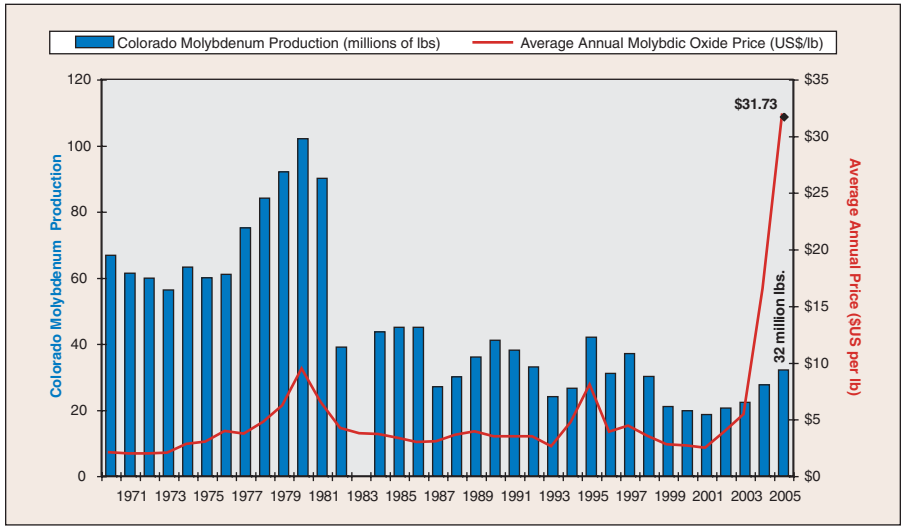

Figure 50. Molybdenum production in Colorado and average annual molybdenum prices, 1970–2005. Data for recent years based on prices quoted in Platts Metal Week as reported by Phelps Dodge.

high-performance bicycle frames (International Molybdenum Association, IMAO). When combined with cobalt and nickel, molybdenum is used in the petroleum industry for its ability to remove sulfur from the organic sulfur compounds usually found in crude oil. As the world supply of crude oil is further extended and low-sulfur crude oils become scarce, molybdenum-based catalysts will increase in use. In a similar manner, molybdenum is used in "scrubbers" to remove sulfur from flue-gases. Molybdenite, the soft, shiny, bluish-gray mineral, is widely used as a lubricant to reduce friction between metal parts. Some automotive oils and greases have molybdenum additives.

Henderson Mine, Clear Creek County: The Henderson Mine in the Front Range west of Idaho Springs (fig. 51) is North America's largest primary producer of molybdenum. This large, underground block-cave mine is owned by Climax Molybdenum Company, a subsidiary of Phelps Dodge Corp. The mine produced 32 million pounds of molybdenum metal in 2005, a 16 percent increase from the 27.5 million pounds produced in 2004. Phelps Dodge reported that it received an average of $25.88 per pound for molybdenum produced in 2005. The estimated gross value of this production is $828.2 million, an increase of 138 percent over the 2004 value of $348.1 million. In 2006, Henderson expects to increase production to over 35 million pounds. Henderson's maximum production capacity is 40 million pounds per year, and the company expects to reach that level by 2007. In 2005, the mine and mill complex added 157 people to its work force, which now stands at about 560.

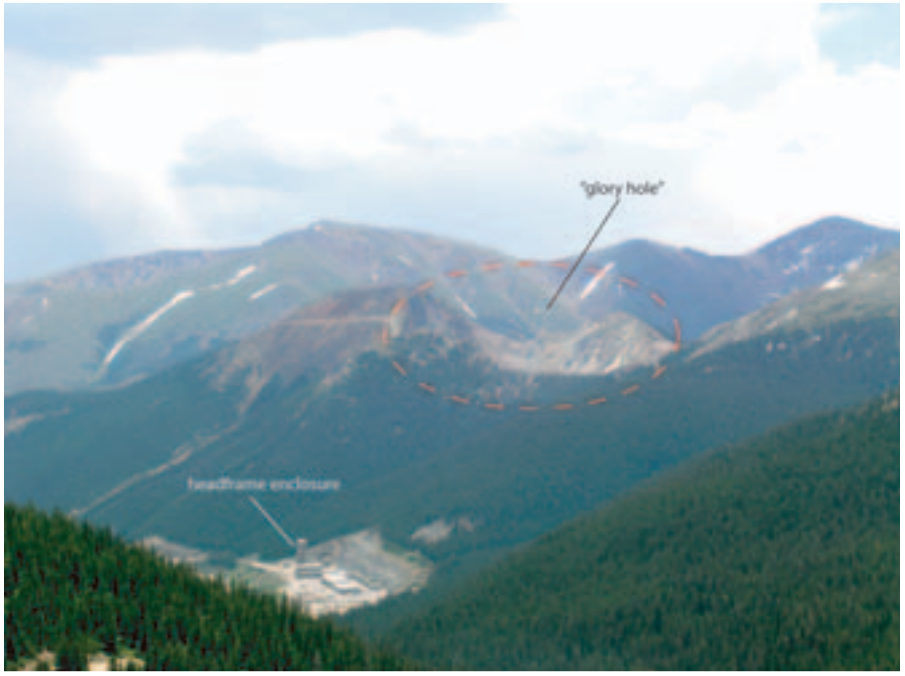

Figure 51. Overview of the Henderson Mine, Clear Creek County, Colorado. The headframe for the main shaft is housed in the tall tower in the lower left part of the photo. Red Mountain rises behind the mine. The large "glory hole" (a sinkhole-like feature above the production area) is to the right of the summit of Red Mountain. *(Photo by Jim Cappa)*

Ore from the Henderson Mine is transported to the mill in Grand County by a conveyor belt through a 10.5-mile-long tunnel under the Continental Divide. The sulfide concentrator at the Henderson mill is capable of treating 32,000 tons of ore per day. The mine ships most of its high-purity, chemical grade molybdenite concentrate to Fort Madison, Iowa for further processing. Henderson has produced more than 170 million tons of ore and over 800 million pounds of molybdenum since opening in 1976.

Henderson is continuing development work on the new 7,210-foot production level. This deeper production area is expected to help the mine achieve its production goal of 40 million pounds of molybdenum per year by early 2007. Seven miles of development drifting have been completed since 2003. The 7,700-foot level, which has been the source of most ore production since 1991, is being depleted. Reserves at year-end 2004 were 158.7 million tons of ore at a grade of 0.21 percent, containing 575 million pounds recoverable molybdenum.

Climax Mine, Lake and Summit Counties: The Climax Mine, also owned by Phelps Dodge, was the first major molybdenum mine in the U.S. It is located on the Continental Divide at Fremont Pass between Leadville and Copper Mountain (fig. 52). The mine has been on care-and-maintenance since 1995. The recent high prices for molybdenum prompted the company to look into the economics of re-starting the mine. In April 2006, Phelps Dodge announced that its board of directors approved re-opening the mine pending completion of a final feasibility study and obtaining regulatory permits. The recently completed pre-feasibility study indicates the mine could produce 20 to 30 million pounds of molybdenum annually. The mine, which would employ approximately 300 workers, is expected to start production at the end of 2009. Meanwhile, reclamation of rock stockpiles and the large valley-fill tailings areas is continuing at the site.

Phelps Dodge reports that the Climax deposit contains proven millable reserves of 156.4 million tons of ore grading 0.19 percent molybdenum, containing 500 million recoverable pounds of the metal. Additionally, identified mineralized material estimated at 87 million tons grading 0.25 percent molybdenum containing 350 million pounds adds substantially to the total resource.

Henderson DUSEL (Deep Underground Science and Engineering Laboratory): The Henderson Mine is one of two candidate sites selected in 2005 by the National Science Foundation to produce a detailed conceptual design for the Deep Underground Science and Engineering Laboratory, or DUSEL. The other potential site is the Homestake Mine in South Dakota. HUSEP (Henderson Underground Science and

Figure 52. The Climax molybdenum mine and mill at Fremont Pass, Lake and Summit Counties, Colorado. The mine is currently on care-and-maintenance status. *(Photo by John Keller)*

Engineering Project) is the collaboration of university scientists, engineers, the Climax Molybdenum Company, and local communities that was formed to coordinate the establishment of a DUSEL at Henderson. If realized, a DUSEL at Henderson will provide a comprehensive science and engineering program that is expected to result in fundamental discoveries with far reaching impact in physics, geoscience, and bioscience. It will also have a substantial impact on the local economy and will become a magnet for prominent scientists from all over the world. The expected lifespan for the DUSEL facility will be at least 30 years and will cost $300–$400 million for construction and initial experiments. The annual budget is expected to around $50 million and about 200 persons will be employed on a permanent basis.

The possibility for Colorado to host this important national research facility has attracted support not only from academic institutions but also from the local community and state leadership. U.S. Sen. Wayne Allard and Congressman Mark Udall have provided letters of support and have expressed their intent to follow further developments. Newly elected U.S. Sen. Ken Salazar recently expressed his strong support. Colorado state government has also provided strong support for this initiative.

The idea of a DUSEL grew out of the need for scientists in several disciplines to have access to a deep underground laboratory for sophisticated experiments in their respective fields. Physicists require a deep underground location in order to shield their experiments from bombardment by cosmic rays from space. The cosmic rays interfere with the high sensitivity detectors that are needed for many experiments. Geoscientists require access to deep underground environments in order to solve questions regarding the deformation of rock, changes in fluid flow and chemistry and other properties that vary with depth. Engineers need access to such environments to develop technology to efficiently and safely produce deep excavations to store fuels and wastes, and to possibly sequester CO_2 and other greenhouse gases.

Gold

Colorado is currently the 4th leading gold-producing state in the U.S. behind Nevada, Utah, and Alaska, respectively. Total Colorado gold production in 2005 was 355,168 ounces, a 3.4 percent increase over 2004 production. All of the stated 2005 production is from two mines: the Cripple Creek and Victor Mine in Teller County, and the Golden Wonder Mine in Hinsdale County. CGS estimates the gross value of 2005 gold production is $139.1 million. Small amounts of additional gold production may have occurred from small placer (gravel) or lode mines that do not publicly disclose production figures. The cumulative average spot gold price averaged $444.74 per ounce in 2005 (London PM Fix; data from Kitco Inc). Figure 53 shows Colorado gold production along with the average annual gold price from 1968 to 2005. In January 2006, the gold price reached a 25-year high of $567 per ounce.

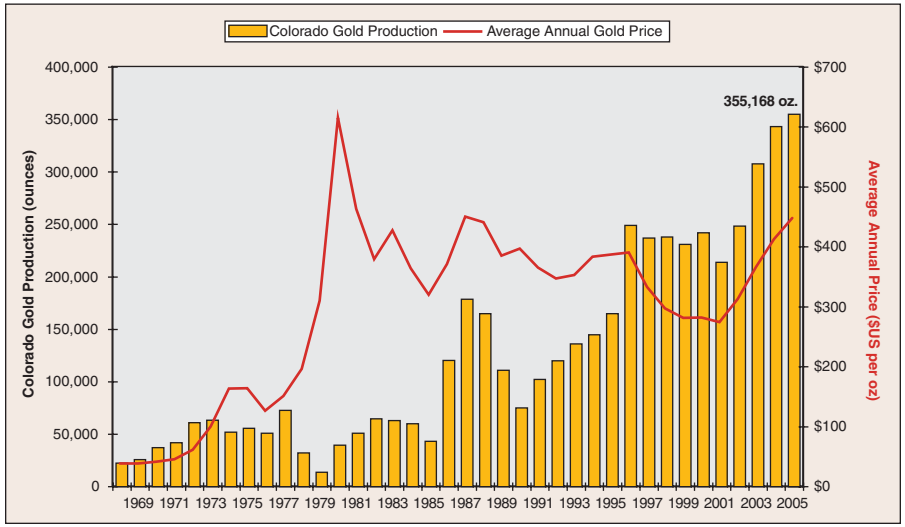

Figure 53. Colorado annual gold production and average annual gold price, 1968–2005. Source for gold price information: Kitco.com.

Uses of gold and silver: Gold is used in jewelry and gold bullion is held as an investment, but gold also has numerous industrial and medical applications. Gold has superior electrical conductivity, resistance to corrosion, and other physical and chemical properties that make it an exceptionally useful metal. The main industrial uses for gold are in electronics and as an electrolyte in the electro-plating industry. The largest medical use for gold is as a dental filling.

Cripple Creek & Victor Mine, Teller County: The Cripple Creek & Victor (CC&V) Mine (fig. 54) is a joint venture between AngloGold Ashanti Ltd. of South Africa and Golden Cycle Gold Corporation of Colorado Springs. The mine is one of the most productive gold mines in the U.S. It produced 329,625 ounces of gold from 21.2 million tons of ore in 2005, up slightly from the 329,030 ounces produced in 2004. Total cash costs of production were $230 per ounce. Based on AngloGold's realized sales price of gold from the CC&V Mine ($388 per ounce), the gross value of gold produced at the mine in 2005 was $127.8 million.

There are three active and two inactive surface mining areas at CC&V. The grade is low but high mining volume makes up for it. Mining proceeds at a rate of 164,000 tons per day (ore + waste). 64,000 tons per day of ore is processed per day. At the end of 2004, the company's stated ore reserve was 134.3 million ore tons containing 2.37 million ounces of gold, having an average grade of 0.018 ounces per ton and a cutoff grade of 0.007 ounces per ton. Exploration and reserve replacement made up for 2005 mining depletion. These reserves are sufficient to keep the mine operating until at least 2013. Geologic resource estimates of additional mineralized material, combined with the proven ore reserves stated above, yield a total mineral resource of 274 million tons containing 7.68 million ounces of gold. AngloGold Ashanti forecasts that 2006 gold production will remain between 323,000 and 337,000 ounces with expected total cash costs of $238 to $248 per ounce. Capital expenditure is planned to rise to $12 million for exploration, haul truck purchase, major mine equipment rebuilds, and engineering for load-out bin relocation.

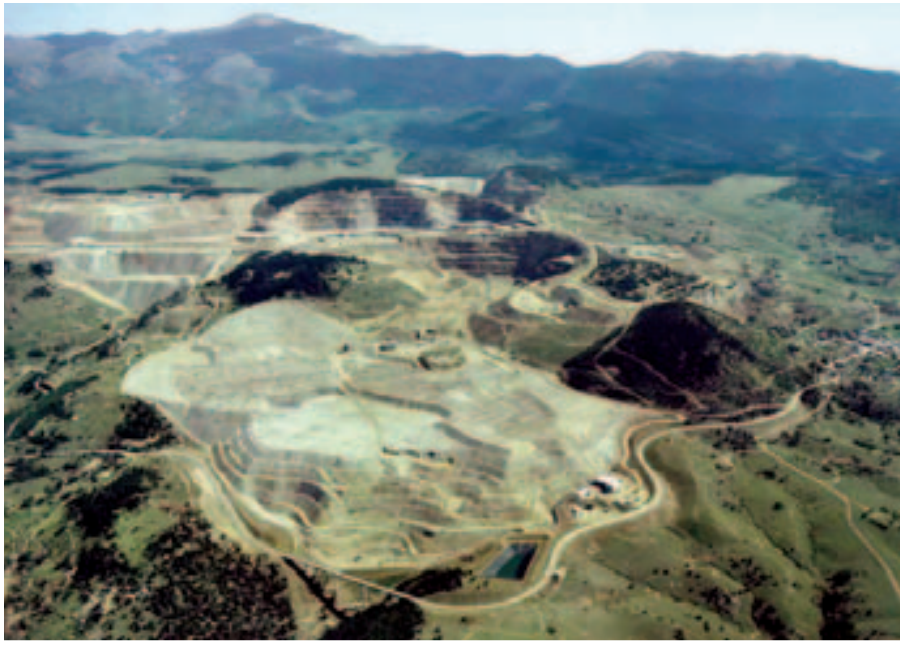

Figure 54. Overview of Cripple Creek & Victor Mining Company operations in Teller County, Colorado. The heap leach pads and State Highway 67 are in the foreground, the open-pit mines are behind and above the pads. The town of Victor is to the right of the mine, and Pikes Peak is in the background. *(Photo courtesy of AngloGold Ashanti (Colorado) Corp.)*

Since its discovery in 1891, the Cripple Creek district has produced over 23 million ounces of gold. Gold mineralization is hosted by veins and breccias within an alkaline volcanic complex of mid-Tertiary age. The mineralized volcanic complex is centered near the intersection of three major rock types of the much older Precambrian basement.

Golden Wonder Mine, Hinsdale County: The Golden Wonder is a small but high-grade underground gold mine near Lake City in the San Juan Mountains. According to press releases by mine owner LKA International Inc., 2005 production (net ounces gold received) was 25,543 ounces. This is a 78 percent increase from 2004 production. The average grade of ore mined in 2005 was an amazingly rich 19.74 ounces of gold per ton! In January 2005, LKA announced that it is planning to permit and develop a new adit and drift below the current workings. The proposed drift will be located approximately 1,000 vertical feet below the deepest current workings. The horizontal distance of the new drift will be approximately one mile. The drift is intended to intersect the high-grade vein structure at the deeper level, which will significantly increase the production potential of the mine.

The Golden Wonder was initially discovered in 1880 and has been worked sporadically since that time. Since modern operations began in 1997, the mine has produced approximately 120,000 ounces of gold. High-grade crushed ore from the mine is trucked in "super sacks" to a facility in Nevada for milling and processing.

The Golden Wonder is an epithermal vein system hosted in volcanic rocks of the San Juan volcanic field. The vein system consists of several en echelon quartz veins ranging in width from a few inches to 5.5 feet. Both fracture-fill and replacement textures are present in the veins, and hydrothermal breccia occurs locally. Two main ore assemblages have been identified: gold-bearing chert (chert-type), and pyrite-marcasite-sulfosalt (sulfide-type). Gold-bearing telluride mineralization is present as well, and this is often very high grade.

Silver

Silver is currently produced in Colorado only as a byproduct of gold mining at the Cripple Creek and Victor (CC&V) Mine. The value of silver production is very small compared to that of gold. In 2005, AngloGold Ashanti Ltd. reported that CC&V produced 169,189 ounces of silver. Based on the annual average 2005 silver price of $7.32 per ounce, the gross value of silver produced was over $1.2 million. Silver, like gold and most other metals, has been experiencing a price boom over the last three years. Figure 55 shows the average annual price of silver from 1984 to 2005. The price continues to rise and topped $12 per ounce for the first time in over 22 years in April 2006.

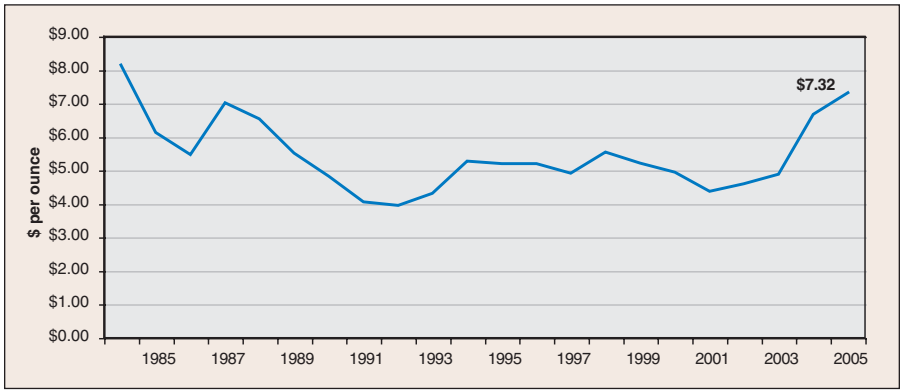

Figure 55. Average annual price of silver, 1984–2005. Based on London PM fix. Data source: Kitco.com.

Uses of silver: Silver, like gold, is used mostly for jewelry but also has many other applications including photographic film, dental alloys, medical, and scientific equipment, mirrors, electrical contacts, and in high-capacity silver-zinc and silver-cadmium batteries.

Vanadium

Colorado was the only state to produce vanadium ore in 2005. Vanadium is a co-product of uranium production at Cotter Corporation's mines in Montrose County in western Colorado. Cotter opened four mines in that area of the Colorado Plateau over the last two to three years. The company, unfortunately, closed all of the mines for economic reasons in November 2005. Jerry Powers, Cotter's Manager of Administration, told the *Montrose Daily Press* in November 2005 that the mines were closed because the company was not able to make them profitable despite high prices for uranium and vanadium.

Figure 56. Miners and ore-hauling rail cars outside the portal of the JD-6 vanadium and uranium mine, Montrose County, Colorado. *(Photo courtesy of Jerry Powers, Cotter Corp.)*

Although these mines are known mainly for their uranium, they actually produced more vanadium by volume and value than uranium (fig. 56). In 2005, Cotter's four mines produced 45,622 tons of ore containing 1,374,520 pounds of vanadium measured as V_2O_5. Production from the individual mines is shown in Table 11 in the "Uranium" section of this report. The USGS reports that the average annual price for V_2O_5 skyrocketed from $5.28 per pound in 2004 to about $17.50 per pound in 2005. However, as of February 2006, the price had retreated to $11–12 per pound. Based on the average 2005 price, CGS estimates the value of vanadium metal production in Colorado in 2005 to be $24.1 million. This is 15 times the estimated production value of $1.5 million in 2004.

Uses of vanadium: About 90 percent of vanadium is used as a metallurgical agent, primarily as an alloy to strengthen specialty steel. The metal also helps to make steel resistant to corrosion. Vanadium is also used as a chemical catalyst.

Base Metals

Colorado does not currently produce base metals (lead, zinc, and copper) but the state was a major producer of lead and zinc in the past, and had moderate copper production mainly as byproduct. The Leadville district in Lake County was by far the most prolific base metal district in the state. The last mine to produce base metals in Colorado was the Black Cloud Mine in Leadville, which produced lead, zinc, silver and gold. The Black Cloud shut down in 1999 after 30 years of production. Mines in other areas of Colorado produced base metals also,

particularly in the Sawatch Range, the San Juan Mountains, and the central Front Range. With the prices of lead, zinc, and copper increasing steadily over the past two years (fig. 57), interest in exploring and developing base metal deposits in Colorado may be renewed. Active exploration and resource-definition drilling is presently occurring at the Cashin copper deposit in Montrose County.

Uses of base metals: All base metals have numerous uses. About 80 percent of lead is used to make batteries. The main uses of zinc are anti-corrosion coatings on steel (galvanizing), and in precision metal components (die casting). Most copper is used to make electrical generators and motors, electrical transmission wire, and electronic goods.

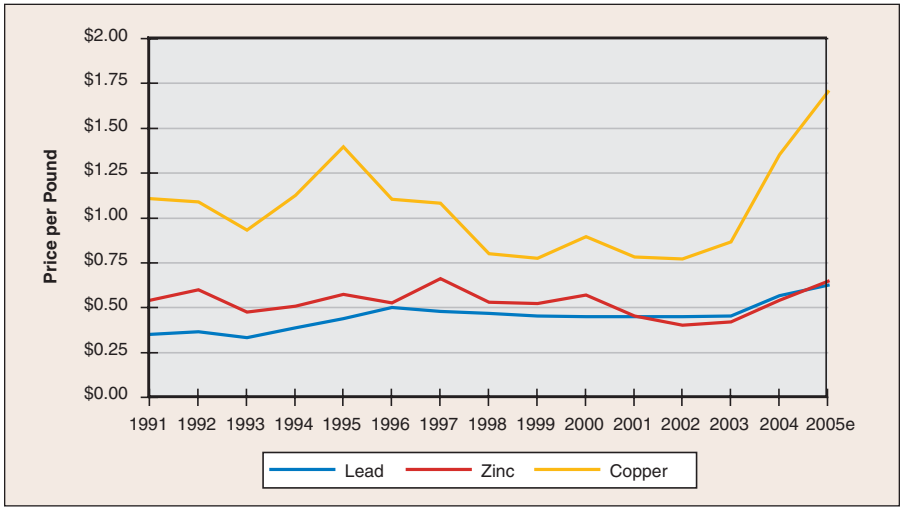

Figure 57. Average annual prices for lead, zinc, and copper, 1991 through 2005. Data compiled from U.S. Geological Survey Mineral Commodity Summaries. e=estimated

Metal Exploration and Development News

Gold Hill district, Boulder County (gold, silver): Consolidated Global Minerals, Ltd. of Vancouver, B.C., through its Colorado subsidiary Mount Royale Ventures, LLC, continued development and testing work in 2005 at its Front Range Gold Project in the Gold Hill district west of Boulder. As of March 2006, the property was not yet in production but work toward that goal is ongoing and results have so far been encouraging. Mine development work has been focused at the Cash Mine. Over 500 feet of new drift was completed and the old workings along the Cash and Freiberg veins were accessed. Stopes are being developed and old drifts are being enlarged and improved to accommodate modern mining equipment. A new refuge chamber and secondary escapeway have been developed. The mine portal was constructed, as was a new ore bin at the portal. Development is now focused on upgrading the existing mine workings to meet regulatory standards and allow for future exploration and mining.

Over 770 feet of core drilling was completed and extensive geological mapping and channel sampling of new and old workings was performed. In July 2005, the company announced results of systematic channel sampling of the first 105 feet along the Freiberg vein. Twenty-two samples on the vein averaged 1.922 ounces per ton gold and 10.505 ounces per ton silver over an average width of 2.3 feet. During new drift development, two previously unknown veins were encountered and both contain gold grades over one ounce per ton. Core drilling showed that veins are laterally persistent and have a consistent orientation.

There are no "official" mineral reserves on the property as defined under National Instrument 43-101 of the Canadian Security Administrators, according to Consolidated Global Minerals. However, the company believes that the most reliable of previous mineral resource estimates conducted on the property was one done in 1964 that used 1,580 samples from underground workings of the Cash and Rex mines. This study concluded there were 15,948 tons at 1.71 ounces per ton gold and 14.8 ounces per ton silver "proven," and an additional "indicated" 8,000 tons at 1.31 ounces per ton gold and 10.1 ounces per ton silver. The mines were shut down in 1964 although it was known that ore remained in the mine. The mine owners at that time were awaiting higher gold prices.

The project's 50-ton-per-day flotation mill (the Gold Hill mill), was originally built in 1987 to process material from old mine waste piles. Mount Royale Ventures reconditioned and tested the mill in 2005. A Knelson gravity concentrator and finishing table were purchased for the mill and added to the circuit. Bulk-sampling of material from the Freiberg vein was processed through the mill over several test runs. Test work has been completed; demonstrating a recovery in the mid-90 percent range with high-grade gravity concentrates and bulk flotation concentrates being produced. Gravity concentrates have been sent to a lab for refining and additional testing.

The company's land position consists of 85 patented and 21 unpatented lode-mining claims, totaling 480 acres that include the Cash, Rex, Who Do, St. Joe, and Black Cloud mines. The project is situated just east of the town of Gold Hill. Mines in the area produced gold and silver from narrow, but high-grade, quartz veins hosted by Proterozoic gneiss and granitic rocks. Gold locally occurs in telluride minerals.

Bates-Hunter Mine, Gilpin County (gold): Wits Basin Precious Metals Inc. of Minneapolis, Minnesota continued exploration and development work on the Bates-Hunter Mine in Central City. In January 2006, the company announced that de-watering of the mine was proceeding 24 hours per day and that the water level was below the 300-foot level of the mine. The de-watering is intended to provide access to the vein for sampling at the 300-level and below, and for underground drilling in the future. The Bates-Hunter Mine is permitted for mining 70,000 tons

per year. The mine and the Golden Gilpin Mill are also covered by a water discharge permit. The company plans to rehabilitate the existing shaft at the mine.

In late 2005 and early 2006, the company announced the results of channel, grab, and muck-pile sampling on the 112-foot and 163-foot levels, the 120-foot-sublevel, and the surface. Several very high-grade values were attained, including one sample that assayed 6.01 ounces per ton gold. Out of 54 total samples reported, six assayed over 1.0 ounce per ton and four of these were over 2.0 ounces per ton gold.

The Bates-Hunter Mine was a gold and silver producer in the 1800s and early 1900s. It closed in 1936. The shaft is 800 feet deep and the company believes there is excellent potential for high-grade mineralization at deeper levels. Other mines in the area were productive to depths of 2,200 feet or more. There are nine principal veins within the Bates-Hunter property, according to company press releases.

Cashin Deposit, Montrose County (copper): The Cashin deposit is a sandstone-hosted copper prospect near the Colorado–Utah border that is currently being explored by Constellation Copper Corporation. If eventually developed into a mine, Cashin would be a satellite operation to Constellation's Lisbon Valley Mine, located 15 miles to the southwest in San Juan County, Utah. The Lisbon Valley Mine and processing facilities began copper production in early 2006. The Cashin deposit could add several years of copper production to the Lisbon Valley operation. In 2005, Constellation focused most of its attention on readying that mine for production. In 2006, the company will begin baseline environmental studies at Cashin in advance of the mine permit application process.

Mining reserves at the Cashin deposit were calculated by SRK Consulting and announced by Constellation in March 2006. Using a conservative copper price of $1.25 per pound, SRK calculated that Cashin contains 5.705 million tons or proven and probable ore grading 0.547 percent copper and containing 62.4 million pounds of copper. As of late-March 2006, copper is trading at around $2.55 per pound.

Copper was originally discovered in the Cashin area in 1896, and was mined from 1899 to the 1950s. Mineralization consists principally of malachite and azurite. Chalcocite, neoticite, and chrysocolla are also present. Native copper (and some native silver) was occasionally found in high-grade parts of the historic mine. Copper mineralization at Cashin is hosted by the Wingate Sandstone of Triassic age.

Little Hope Mine, Teller County (gold): Minerex Corp. is continuing their efforts to secure permits from Teller County for this proposed small gold mine near Mineral Hill just north of the town of Cripple Creek. The company is also continuing their exploratory core drilling activities on the property. In 2005, the company received mining permits from the State of Colorado's Division of Minerals and Geology. The mine, if it becomes active, would produce gold ore to be processed at a custom mill located elsewhere.

Burro Canyon project, San Miguel County (uranium and vanadium): U.S. Energy Corporation and Uranium Power Corporation are exploring the Burro Canyon project in San Miguel County, southwestern Colorado. In March 2006, U.S. Energy announced the results from 20,303 feet of exploration drilling that tested the Salt Wash Member of the Morrison Formation. Numerous intercepts with significant uranium mineralization were encountered. The project area consists of 143 unpatented mining claims totaling nearly 3,000 acres. The project is located adjacent to the currently inactive Sunday Mine complex which produced about 1.5 million pounds of uranium and 10 million pounds of vanadium.

Hansen deposit, Fremont County (uranium): The Hansen uranium deposit in the Tallahassee Creek area of Fremont County is once again being examined for its uranium potential. In March 2005, Quincy Energy Corp. entered into an option agreement with NZ Uranium LLC to explore the Hansen deposit. No additional exploration or development work has so far taken place on the property. Quincy first wishes to further compile and evaluate the large existing database for the property.

Previous resource estimates for the deposit range between 18 and 33 million pounds of U_3O_8. A 1980 study by Kilborn Engineering estimated 27.7 million pounds of U_3O_8 in mineralized material grading 0.102 percent U_3O_8. In the late 1970s, Cyprus Mines Corp. designed an open pit mine and milling facility capable of processing 4,500 tons per day of ore and yielding 2 million pounds of uranium per year. It was projected to employ 550 people by 1983. The plan was abandoned, however, in 1980 when the price of uranium crashed because of decreased demand for nuclear fuel after the Three Mile Island incident.

Los Ochos deposit, Saguache County (uranium): In November 2005, Laramide Resources Ltd. of Toronto, Canada acquired the Los Ochos uranium property in Saguache County from its former owner, Homestake Mining Company. It was part of a larger deal that included two other uranium properties in other states. As part of the deal, Laramide committed to spend $1.5 million over the next two years toward exploration and development of the properties.

Little Maverick Mining Company, Whirlwind claim, Mesa County (uranium): In early 2005, the Little Maverick Mining Company submitted a mining plan to the U.S. Bureau of Land Management for a small-scale operation using an existing shaft at a site near Gateway in Mesa County. The site is on the Whirlwind claim near Lumsden Canyon. It was last mined about 20 years ago and is presently reclaimed. Fewer than 12 workers would be employed at the mine, which would produce about 500 tons of uranium ore per month.

Caribou Consolidated District project, Boulder County (gold, silver, and base metals): Calais Resources Inc., continued work at its Caribou Consolidated project in 2005. Although no new drilling or major mine development work was completed, work continued on 3-D geologic modeling of the several deposits within the project area. The modeling is based on drilling completed in 2004 and in prior years, and underground geologic mapping and channel sampling in the existing workings. The new modeling will help Calais Resources complete a new resource estimate

under National Instrument 43-101 guidelines of the Canadian Security Administrators. "43-101" reporting is required for stating mineral reserves for companies whose shares are traded on Canadian stock exchanges. Tom Hendricks, Vice President of Exploration and Corporate Development at Calais, continues to provide educational tours and lectures about the mining project and the importance of good environmental stewardship to interested groups. Mr. Hendricks has 34 years of working experience in the Caribou mining district. In early 2006, David Young, formerly an executive with Apollo Gold Corporation, became the company's new President and CEO.

Industrial Minerals and Construction Materials

Important industrial minerals and construction materials currently being produced in Colorado include sand, gravel, crushed stone, silica sand, dimension and decorative stone, cement, clay, gypsum, sodium bicarbonate, and peat. The total value for all nonmetallic, non-energy materials produced in Colorado in 2005 is estimated to be $529 million. This is an increase of 8.2 percent over the 2004 revised total value of nearly $489 million. These numbers include the values of gemstones and helium produced in the state.

Construction Sand, Gravel, and Crushed Stone

Colorado produced an estimated 60.4 million tons of aggregate in 2005, 78 percent of which was sand & gravel (47 million tons). The total value of Colorado aggregate was nearly $327.9 million, which is 7.5 percent more than the 2004 value of $305 million. Sand & gravel production was up 4.5 percent from last year's revised production of 45 million tons (fig. 58), ranking Colorado 10th in the nation. Crushed stone production increased by 13.3 percent from 12.1 million tons (revised) in 2004 to 13.3 million tons (estimated) in 2005. Average unit values for sand & gravel and crushed stone are $5.90 and $6.27 per ton, respectively (fig. 59).

The top uses for sand & gravel are concrete aggregate, road base and coverings, construction fill, and asphaltic concrete aggregate. Although the use of sand & gravel predominates in Colorado, nationally, the use of crushed stone as an alternative to sand and gravel is gaining momentum. Crushed stone quarries typically operate within a smaller footprint and can be located further from high-density urban areas and scenic and environmentally contentious river valleys, so are preferred over sand & gravel operations. Although higher operating costs equate to higher prices for crushed aggregate, the cost differential is slowly decreasing because of escalating conflict over environmental and land use issues associated with sand & gravel operations.

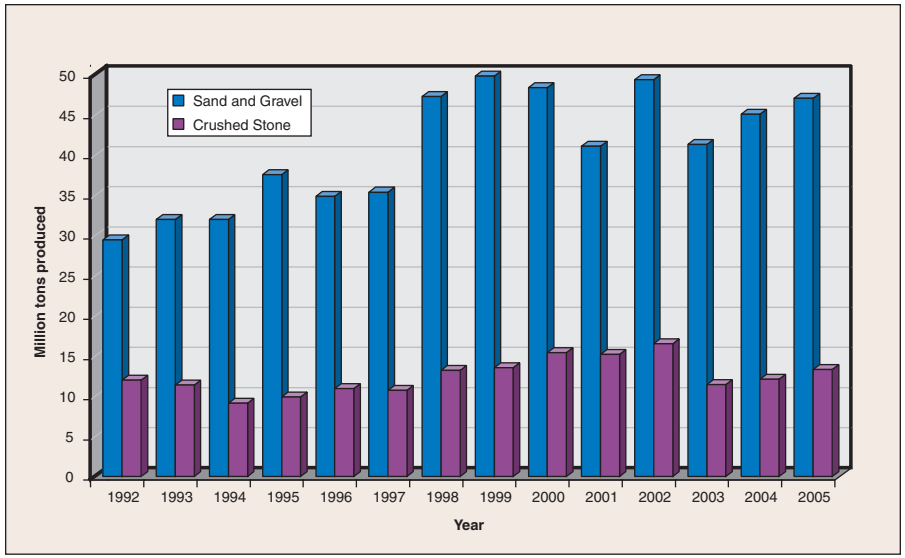

Figure 58. Production of sand & gravel vs. crushed stone in Colorado. 2005 data are U.S. Geological Survey estimates.

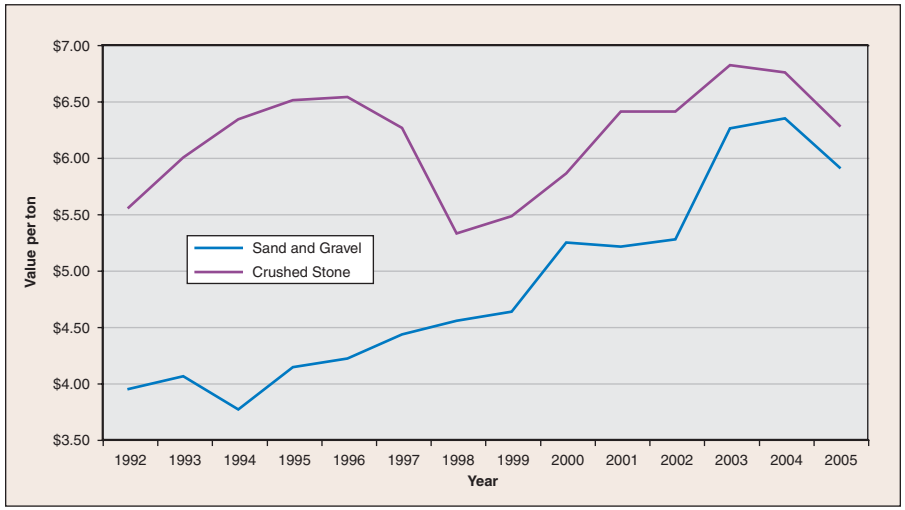

Figure 59. Average estimated value per ton of sand & gravel vs. crushed stone produced in Colorado. 2005 data are U.S. Geological Survey estimates.

Industrial Sand and Gravel

Data are not available for production of industrial sand and gravel for 2005. However, production is estimated to be over 70,000 tons based on average production values for the years 2004 and 2003. Colorado's leading industrial sand company is the Ohio-based Oglebay Norton Company. The local division office, Oglebay Norton Industrial Sands (ONIS), is located in Colorado Springs and supports 25 to 30 employees. ONIS markets "Colorado Silica Sand," a specialty industrial sand that is used primarily as filter media for water purification plants and as a construction material, largely for stucco. Some of their smaller markets include hydraulic fracturing material for oil and gas wells, gravel packs around water wells, and other applications where roundness, permeability, and strength are important parameters. Additionally, the sand is used as a landscaping material. The majority of product is exported outside of Colorado. Currently, ONIS extracts (essentially recycles) its silica sand from waste material cut from new developments in El Paso County where much of the surface cover is removed or scraped off before construction begins. The surface materials are generally Quaternary-age alluvial and/or eolian deposits consisting mostly of well-sorted and well-rounded grains of quartz. ONIS is actively exploring for other silica sand resources in Colorado.

Dimension and Decorative Stone

Dimension stones are quarried slabs or blocks of attractive rock that are used for decorative construction, facing panels, flagstone, sculptures and monuments, and many other projects requiring large, competent masses of stone. Many dimension stone producers may also crush and market some of their stone for landscaping purposes. Colorado produced an estimated 18.5 million tons of dimension stone in 2005 with an estimated value of $1.99 million. This is a 3.8 percent increase over the revised 2004 production estimate of 17.8 million tons. The principal Colorado dimension stones include marble, sandstone, granite, and rhyolite.

Decorative stone has become a more important part of the Colorado minerals industry in recent years. Both crushed rock and whole boulders are used. Granite, gneiss, sandstone, volcanic rock, obsidian, marble, and quartz pegmatite are some of the rock types currently being mined in the state for decorative use. Natural boulders that have a covering of lichen on them are commonly known as "moss rock" in the landscaping industry. Usually, the larger the percentage of the rock covered with the colorful lichen, the more valuable it is. Numerous small decorative stone mines and quarries are located throughout Colorado. No specific production figures are available for statewide decorative stone production.

Colorado Quarries, Custer, Chaffee, Fremont, Teller Counties: Colorado Quarries operates several quarry operations that produce decorative, pre-cast, and landscape stone. In 2005, they produced 50,254 tons of stone. Marketed products include *White Quartzite* from Howard; *Ruby Spar, RG Rose Quartz,* and *Flamingo Quartz* from near Cañon City; *Green* and *Indian Rhyolite* and *Black Obsidian* from near Westcliffe, *Red Granite* from near Guffey; and *Gray Granite* from near Texas Creek. These materials are used principally in the landscape industry as decorative boulders, building stone, and crushed stone. Their materials are also used in the pre-cast market (panels on buildings and other structures). Standard stone mining equipment is used at all quarries. Stone from Colorado Quarries has been used on the Pepsi Center and Colorado Convention Center in Denver and the Colorado Springs Airport and U.S. Air Force Academy in Colorado Springs. Colorado Quarries received the MSHA Sentinels of Safety award in 2005 for both of their portable crushing units.

Arkins Park Stone, Larimer County: Arkins Park Stone Corporation employs about 40 people and operates three quarries near the town of Masonville. Annual production typically averages just over 8,000 tons. The company produces buff (light pinkish-brown) sandstone as well as "Berthoud Pink" and "Berthoud Sunset" sandstone from the Permian Lyons Sandstone. Approximately 80 percent of the product is sold or used in Colorado. Much of the stone is used as flagstone and facing in the construction of buildings. Recently, the company also began producing rip-rap for commercial uses such as riverbed linings, dams, and bridge abutments.

Yule Quarry, Gunnison County: Colorado Stone Quarries, a subsidiary of Polycor, Inc. of Quebec, Canada owns and operates the Yule Marble Quarry. Polycor operates a number of marble and granite quarries in North America, has a number of fabricating facilities, and has a substantial presence in international stone markets. In 2005, the company brought expert management to the quarry with quarry manager Francois Darmayan. A Fantini floor saw was purchased from Italy and several wire saws were added to the operation, thus allowing production to rise significantly. Approximately 60,000 cubic feet (5,100 tons) of stone were produced with 9 to 12 employees on site, which is an increase over 2004 production of about 40 percent. Although some Yule marble is still used for sculpting, the majority is now being made into slab and tile for international sales. Approximately 99 percent of production is exported outside of Colorado, with destinations including Italy, Indonesia, China, India, Quebec, and Georgia.

Other Stone Operations: The Colorado Red Rose Quarry in Larimer County produces blocks of red granite for use as countertops and monuments. Alabaster is quarried from the Permian Lykins Formation at a small mine near Fort Collins by Colorado Alabaster Supply. Their alabaster is used mainly for sculpting and is marketed both locally and nationwide. The White Banks Mine in Pitkin County also produces alabaster, as well as dark-colored marble, and quartz. The Eocene-age

Wall Mountain Tuff, known in industry as Castle Rock rhyolite, is quarried by the Ames Construction Company near the town of Castle Rock. The Castle Concrete Company operates the Table Mountain quarry (fig. 60) in Fremont County and produces 150,000 tons of hard, dense, high-silica Dakota Sandstone annually for use as riprap, road base, aggregate, and dimension stone. Numerous other small operations quarry various sandstone units throughout the state.

Figure 60. Highly siliceous Dakota Sandstone from the Table Mountain quarry in Fremont County is used as riprap, road base, aggregate, and dimension stone. *(photo: Colorado Geological Survey)*

Cement

Cement is a manufactured product consisting primarily of lime (which is derived by roasting limestone) and shale. Other ingredients may include gypsum and silica sand. The main cement manufacturers in Colorado are Holcim (US) Inc. and CEMEX, Inc. The two companies produced a combined total of roughly 2.3 million tons of cement in 2005. Nationwide, cement consumption rose 5.7 percent in 2005 and is expected to continue rising in 2006 according to the Portland Cement Association. At least 32 states, including Colorado, experienced tight cement supplies in 2005. Although housing construction is expected to plateau or decline in 2006, ongoing commercial construction and public works construction will continue to strain cement supplies (Reed Business Information). In Colorado, demand for cement will also increase because of our booming oil and gas industry. For example, recent legislation has increased well spacing in the Wattenberg field from 5 to 8 wells per 160 acres per producing formation. This could potentially result in the completion of an additional 24,000 wells or more. Tight cement supplies will make it difficult to keep pace with industry demand for new well completions.

Cemex, Inc., Boulder County: Portland and masonry cement are produced at the Cemex, Inc. mine and processing plant near Lyons. The plant uses the dry processing method and employs about 100 people. Cement production in 2005 was 478,000 tons, most of which was utilized in the Front Range urban corridor. Cement ingredients (limestone and shale) are mined locally from the Niobrara Formation and the overlying Pierre Shale. Mexico-based Cemex purchased Britain-based RMC Group in March of 2005, making Cemex the world's largest supplier of ready mix concrete and third in cement production behind Lafarge and Holcim.

GCC Rio Grande, Inc., Pueblo County: GCC Rio Grande, Inc., a subsidiary of Grupo Cementos de Chihuahua, has been planning and permitting a new cement plant in Pueblo during the past several years. Construction of the plant and mining facilities began in mid-2005 and is continuing at a good pace. The raw materials storage building has been built and mining should commence in 2006. The proposed mine and processing plant is expected to produce about one million tons of cement per year and will employ nearly 100 workers. The Fort Hays Member of the Niobrara Formation will be mined as the main cement ingredient. Gypsum, another ingredient of cement, will be mined locally as well.

Holcim (US), Inc., Fremont County: The Portland Plant near Florence is operated by Holcim (US), Inc. In 2005, the plant employed about 180 people and produced more than 1.8 million tons of cement. The majority of their product is used in the metropolitan Denver area and throughout Colorado, although some cement is also distributed to neighboring states such as New Mexico, Wyoming, Kansas, and Nebraska. Limestone from the Fort Hays Member of the Niobrara Formation of Upper Cretaceous age is mined by Holcim as the principle raw ingredient for their cement. The Codell Sandstone, also Cretaceous, is mined for use as a silica additive. Most of the company's gypsum is imported from Oklahoma; some gypsum is produced as a byproduct of Holcim's lime calcining plant. In January 2005, parent company Holcim Ltd. purchased U.K.-based Aggregate Industries. Holcim is the second largest cement producer in the U.S.

Sodium Bicarbonate and Soda Ash (nahcolite)

Natural Soda, Inc., Rio Blanco County: Natural Soda Inc. uses solution mining to recover naturally occurring sodium bicarbonate from nahcolite on its U.S. Bureau of Land Management leases in the Piceance Basin in northwest Colorado. In 2005, the solu-

Figure 61. Aerial view of Natural Soda Inc's sodium bicarbonate plant in Rio Blanco County. Pipes that transport nahcolite-bearing solution from wells to the plant can be seen in the upper left. *(Photo courtesy of Natural Soda, Inc.)*

tion mine and recovery plant produced 84,304 tons of sodium bicarbonate, a six percent increase over the 79,375 tons produced in 2004. The facility has a production capacity of over 110,000 tons per year. Both food-grade (baking soda) and industrial-grade sodium bicarbonate products are produced at the plant (fig. 61). Worldwide production capacity for sodium bicarbonate is about 1.7 million tons per year.

Prices for sodium bicarbonate increased in 2005 in response to rising energy costs and other production costs. Chemical Market Reporter shows that the current market price for sodium bicarbonate varies from $22.50 per 100 lbs (industrial grade) to $34.80 per 100 lbs (USP food grade, coarse, bagged), with other grades in between. According to Linda Abolt, Quality Compliance Manager for Natural Soda's plant, "the average net back price enjoyed by sodium bicarbonate producers is approximately $100 per ton." Using that as a rough guideline, the estimated value of Colorado's sodium bicarbonate production in 2005 was about $8.4 million.

Natural Soda began development of a new set of injection and recovery wells in August 2005. The wells will create a new production cavity from which the company has been authorized to recover an additional 320,000 tons of nahcolite. These wells should be completed sometime in 2006, though there have been some technical difficulties relating to solution flow between the wells. Currently, the company has approved access to about 460,000 tons of sodium bicarbonate from existing cavities.

High-grade (>80 percent) nahcolite is recovered from the "Boise Bed" of the Green River Formation. Dissolution of the nahcolite is through drill holes along the base of the Boise Bed. The nahcolite-bearing solution is pumped to the surface via separate recovery wells. Natural Soda also owns the Rock School lease, an undeveloped nahcolite property nearby. The two properties, both leased from the Bureau of Land Management, together comprise over 9,500 acres in the Piceance Creek Basin. These leases contain in situ nahcolite resources estimated to exceed 4 billion tons.

American Soda LLP, Garfield County: American Soda, owned by Solvay Chemicals, Inc., produces sodium bicarbonate using soda ash feedstock from Solvay's trona processing facility near Green River, Wyoming. The soda ash is railed to the American Soda plant in Parachute. From 2001 to 2004, American Soda produced soda ash as well as sodium bicarbonate from nahcolite extracted from the Green River Formation in Rio Blanco County, Colorado. The company controls over 7,000 acres of nahcolite mineral leases in Rio Blanco County on land managed by the U.S. Bureau of Land Management.

Uses of sodium bicarbonate: Food, 32 percent; animal feed, 24 percent; cleaning products, 9 percent; pharmaceuticals and personal care, 9 percent; chemicals, 8 percent; water treatment, 6 percent; fire extinguishers, 2 percent; paint blast media, 2 percent; miscellaneous, 8 percent (source: Chemical Market Reporter).

Clay and Shale

The majority of the clay mined in Colorado is common clay, which is used mainly to make bricks and tiles or in the manufacture of cement and lightweight aggregate. Common clay is mined primarily in eastern Colorado, especially near the Front Range in Jefferson, Elbert, Douglas, El Paso, Pueblo, and Fremont Counties. In 2005, Colorado clay mines produced an estimated 333,172 tons of clay valued at over $2 million. This represents an increase of about 19.3 percent over the 2004 production of 279,173 tons (fig. 62). In eastern Colorado, clay is mined principally from three formations: the Laramie Formation (Upper Cretaceous), the Dakota Sandstone (Lower Cretaceous), and the Dawson Formation (Upper Cretaceous to Tertiary). Elsewhere in the state, clay deposits within the Lykins, Morrison, Benton, Niobrara, Mesaverde and Vermejo Formations (ranging in age from Triassic to Cretaceous) have also been exploited.

Higher quality clays have also been produced from the Dakota and Dawson Formations. Both formations locally contain resources of refractory clay, which is used in the manufacture of refractory ware, such as crucibles and high temperature firebricks for kilns. Current market demands have not warranted active mining of these deposits. Additionally, bentonite clay layers are found in altered volcanic ash in Fremont County, and locally in the Jurassic Morrison Formation

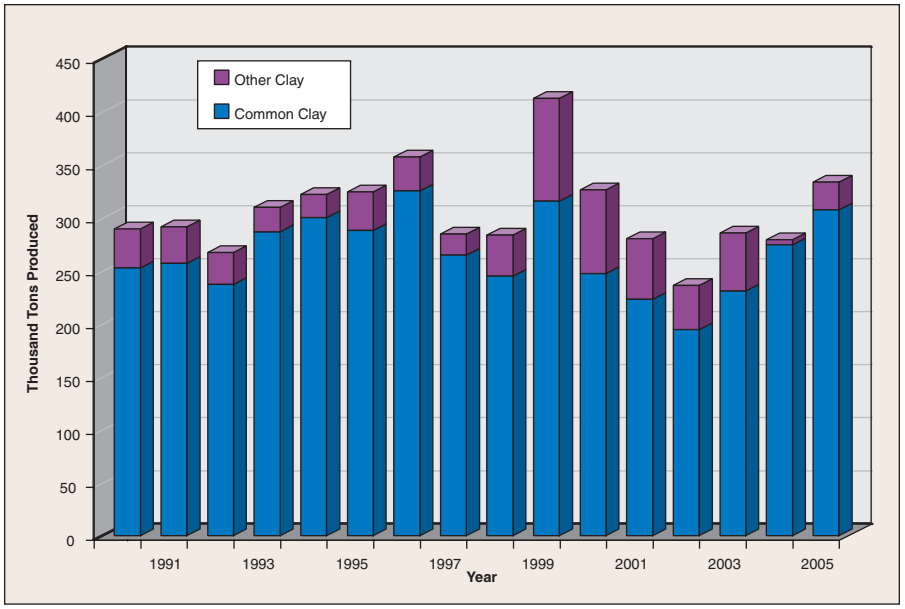

Figure 62. Total clay production in Colorado increased by about 19 percent from 2004 to 2005. Most of the clay mined in Colorado is common clay, which is used primarily for making bricks. Other clays may include bentonite, refractory clay, or other specialty clays. 2005 figures are U.S. Geological Survey estimates.

and the Cretaceous Pierre Shale. Bentonite is frequently used as an absorbent (such as in kitty litter or to clean up hazardous fluid spills) and as a containment barrier (such as in clay liners for landfills). Colorado typically produces approximately 1,500 to 5,000 tons of bentonite annually, although, actual production and value data for bentonite mined in Colorado is withheld by the U.S. Geological Survey.

Acme Brick: The Acme Brick company mines approximately 110,000 tons of clay per year and in 2005 manufactured 60 million bricks, most of which were sold outside of Colorado. Acme owns and operates five clay mines in Jefferson, Elbert, and Douglas Counties: two mines produce clay from the Cretaceous Dakota Group, two produce from the lower Dawson (Denver) Formation (Paleocene), and one produces from the upper Dawson Formation (Eocene). Standard open-pit mining methods are utilized at all five mines.

Lakewood Brick and Tile Co.: Lakewood Brick owns and operates two clay pits, Doughty and Church, in Jefferson County near Rocky Flats. In 2005, they mined over 23,000 tons of clay from these two pits. Additionally, Lakewood Brick supplements its stockpiles with clay purchased from other local suppliers. At their brick processing facility, 37 employees manufacture an average of 17 million bricks per year. Half of this production remains in Colorado, while the remainder is exported to other states.

Summit Brick and Tile Co.: In 2005, approximately 46,800 tons of clay was produced from 10 Summit Brick mines in El Paso, Fremont, and Pueblo Counties. This represents a 25 percent decrease compared to 2004. Approximately 27 million brick are manufactured annually at the plant, about 35 percent of which are sold within Colorado and the remainder of which are shipped throughout the U.S. Raw clay costs average about $10 per ton delivered to the plant yard. The average price for face brick is about $325 per 1000 units. Summit's mines and plant employ approximately 85 people. One of the Summit mines produces common clay for brick manufacturing from the Cretaceous Pierre Shale. Three other mines produce fire clays from the Cretaceous Dakota Group, which are used to manufacture white brick. Summit's red-burning clays are derived from the Morrison Formation and from the contact zone between Precambrian Pikes Peak Granite and the Pennsylvanian Fountain Formation (fig. 63). Standard open-pit mining techniques are used at all the mines. This involves removal and stockpiling of overburden material, excavation of the clay deposit, and then back-filling and planting to reclaim the area. Summit Brick has participated in the Occupational Safety and Health Administration Safety and Health Achievement Recognition Program (SHARP) since 2001, and has received Certificates of Recognition from Colorado State University and the U.S. Department of Labor.

Figure 63. Bright-red clays of the Fountain Formation at one of Summit Brick's fire clay mines. *(Photo courtesy of Summit Brick)*

TXI Operations: The Pierre Shale in northern Jefferson County is mined by TXI for use as lightweight aggregate. The raw shale is kiln-fired to the point where it expands in size and becomes low in density and weight (like popcorn). Lightweight aggregate is used in place of regular sand, gravel, or crushed stone in applications where excessive weight is undesirable, such as floors and walls in multi-story buildings. Cinder blocks are commonly made with lightweight aggregate.

TXI employs 43 people at their mine and processing facility. In 2005, approximately 410,000 tons of shale were mined to produce 370,000 cubic yards of lightweight aggregate. Roughly, half of their finished product is sold within Colorado; the remainder is sold to other western states, particularly California.

Gypsum

Most gypsum production goes towards the manufacture of wallboard and plaster products. Gypsum is also used as a cement ingredient, as a soil conditioner, and in other industrial uses such as glassmaking and smelting. The principal producer of gypsum in Colorado is American Gypsum. Colorado Lien and a few other small operations produce gypsum for cement or soil conditioners.

American Gypsum, Eagle County: The American Gypsum mine and wallboard plant, located near the town of Gypsum, produced 636,000 tons of gypsum in 2005. This represents a 2.6 percent increase in production over 2004. Approximately 600 million square feet of wallboard are manufactured annually at the plant. About 50 percent of the wallboard goes to the Colorado construction industry, and the remainder is marketed throughout the U.S. The gypsum is excavated from evaporite deposits in the Pennsylvanian Eagle Valley Formation using a surface (or pavement) grinder. The company is in the process of developing a new mining area northeast of the current site. Over a span of a few years, mining will shift to the new site as reserves are depleted at the original site. The future mining area ensures that the wallboard plant can operate for at least another 20 years. The mine and plant employ approximately 125 people.

Colorado Lien, Larimer County: Colorado Lien, subsidiary of Pete Lien & Sons, Inc. of South Dakota, produces gypsum from the Munroe Quarry north of Fort Collins near Livermore. Gypsum is extracted from the Permian Lykins Formation using a portable crusher. Annual production averages about 50,000 tons. The majority of the material quarried is sold within the state to the cement industry. In 2005, the National Stone, Sand and Gravel Association awarded the About Face Award to the Munroe Quarry for its outstanding work in reclamation.

Peat

Peat is a mixture of decomposed organic matter, the quality of which is determined by the level of decay. Sphagnum moss is the least decomposed and highest quality. Hypnum moss, reed-sedge, and humus are progressively more decomposed and of decreasing quality. Peat promotes plant growth and has widespread use as a soil additive in the agricultural and horticultural industries. It can also be used to filter or absorb contaminated water or hazardous material spills. There are three active permitted peat mines in Colorado, although only one of the mines is currently producing. This small, intermittent operation near Alamosa produces humus-grade peat to fill local landscaping needs. The peat is extracted from a dry bog as opposed to wetland areas typical of other worldwide peat resources. Colorado demand for peat is met primarily through imports, mostly from Canada.

Gem and Specimen Minerals

Colorado is home to a large variety of gemstones and specimen-quality minerals. Some of these are produced by small commercial mining operations, and some are found by amateur collectors, or "rockhounds." Small commercial gem and mineral mining operations are typically owned and operated by truly dedicated and successful rockhounds.

According to preliminary USGS estimates, the total reported value of 2005 gemstone production in Colorado was $280,000. This is a decrease of 22 percent compared to the revised 2004 value of $360,000. The decrease may be attributable to the October 2004 closure of the Sweet Home rhodochrosite mine near Alma in Park County. The USGS ranked Colorado as the 10th leading gemstone-producing state in 2005.

Colorado is renowned for several types of gemstones and specimen minerals. Table 14 lists a few of the better-known of these minerals. Figures 64 through 68 are photographs of some fine specimens.

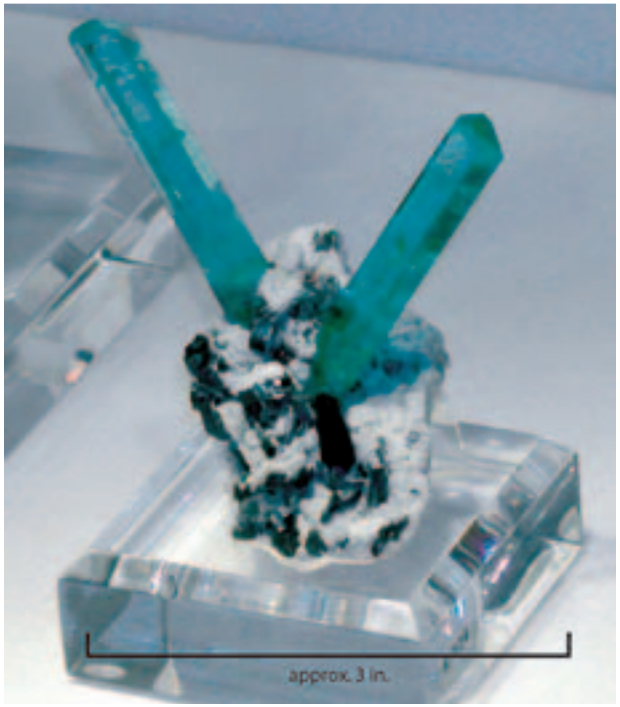

Figure 64. Aquamarine from a miarolitic cavity, or "pocket," on the east flank of 14,276-foot Mount Antero. Specimen is 3.7 inches tall. The pocket was discovered in July 2004 by Steve Brancato of Salida, Colorado. *(Photo courtesy of Robert Spomer, Buena Vista Gem Works)*

Table 14. Partial listing of gemstones and specimen-quality minerals found in Colorado.

Specimen mineral/ gemstone name	Some Colorado occurrences	Comments
Aquamarine	Mount Antero, Chaffee County	Colorado's official State Gemstone. Significant new discoveries on Mt. Antero recently. Found in cavities in the granite.
Rhodochrosite	Rhodochrosite is found in at least 17 counties in Colorado. The best-known locations include: Sweet Home Mine, Park County; Sunnyside Mine, San Juan County; Moose Mine, Gilpin County; Urad Mine, Clear Creek County.	Colorado's official State Mineral. The Sweet Home Mine produced the finest red transparent specimens in the world. The mine closed in 2004.
Diamond	State Line district, Larimer County	The Kelsey Lake diamond mine operated sporadically from the mid-1990s until 2002. It was the only commercial diamond mine in the U.S.
Amazonite	Crystal Peak area, Park and Teller Counties; Harris Park, Park County; Cameron Cone, Specimen Rock, and Crystal Park in El Paso County.	Spectacular blue-green feldspar occurs in miarolitic cavities in Pikes Peak Granite. Often found with smoky quartz.
Topaz	Devils Head, Douglas County; Spruce Grove campground area, Jefferson County; Crystal Park, El Paso County; Specimen Rock, El Paso County; Crystal Peak and Glen Cove areas, Teller County; Ruby Mountain, Chaffee County; Mt. Antero, Chaffee County.	Large quantities have been cut into gems and many others are on display around the world. Found in miarolitic cavities in granite or rhyolite.
Smoky quartz	Lake George and Florissant area, Park and Teller Counties; Devils Head, Douglas County; Harris Park, Park County; Wigwam Creek, Jefferson County; Specimen and Sentinal Rocks, Teller County.	Often found in association with amazonite in miarolitic cavities in Pikes Peak Granite.
Turquoise	Hall Mine near Villa Grove, Saguache County; Cripple Creek area, Teller County; King Mine, Conejos County; Turquoise Chief Mine, Lake County.	Colorado was at one time second only to Nevada in turquoise production. Currently being mined in the Cripple Creek area.
Lapis lazuli	Italian Mountain, Gunnison County	Italian Mountain is probably the best locality in North America for lapis. Lapis lazuli is a rock composed of several minerals. The main component is lazurite.
Peridot (gem-quality olivine)	Badger Creek area, Park and Fremont Counties.	This is a relatively recent discovery (1990s). Small pieces of gem-grade peridot are present in Tertiary-age basalt.

Figure 65. Wire wrap pendant with sky blue turquoise from the Villa Grove deposit in Saguache County. *(Pendent by Denise Zarecor; photo courtesy of Robert Spomer, Buena Vista Gem Works)*

Figure 66 (below). Amazonite (blue-green) and smoky quartz (black) from the Lake George/Florissant area, Park and Teller Counties, Colorado. Discovered and mined by Joseph Dorris, Glacier Peak Art, Gems, and Minerals. *(Photo courtesy of Robert Spomer, Buena Vista Gem Works)*

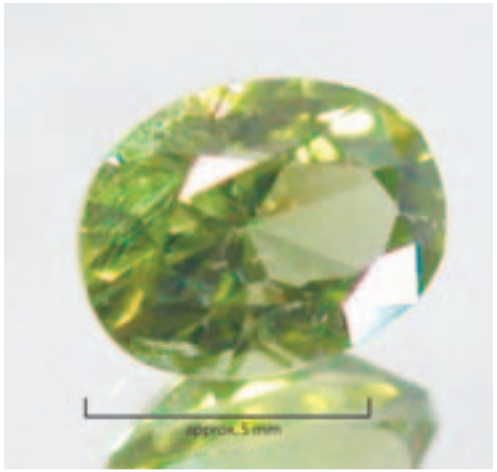

Figure 67. Faceted peridot from the Badger Creek area of southwestern South Park, Park and Fremont Counties, Colorado. The gem was faceted by Robert Spomer, Buena Vista Gem Works. *(Photo courtesy of Robert Spomer, Buena Vista Gem Works)*

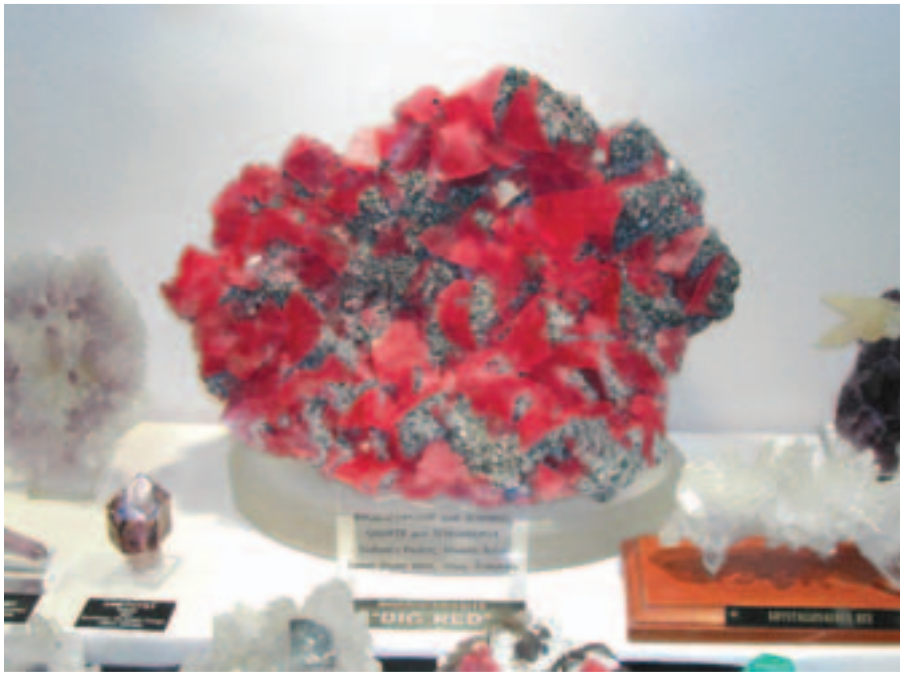

Figure 68. "Big Red": rhodochrosite (red) with quartz and tetrahedrite. This "plate" is about a foot in diameter. It was mined from Graham's Pocket in the Sweet Home Mine in Park County, Colorado. The mine stopped production in 2004. The specimen is owned and displayed by collector Keith Proctor. *(Photo courtesy of Robert Spomer, Buena Vista Gem Works)*

Non-Energy Gases

Carbon Dioxide (CO_2)

As one of several techniques for enhancing oil recovery, carbon dioxide (CO_2) flooding projects have been consistently and increasingly successful over the past 25 years. The number of CO_2 floods in the U.S. tripled in that time to over 70 in 2004 (source: Petroleum Technology Transfer Council). During this same period, CO_2 enhanced recovery production increased twenty fold, with most of the growth taking place in the 1980s prior to the 1986 price collapse. According to a recent *Oil & Gas Journal* survey of enhanced recovery projects, about four percent, or nearly 206,000 barrels per day, of U.S. oil production in 2004 came from CO_2 flood projects.

The Rangely Weber Sand miscible CO_2 flood in the northern Piceance Basin in northwestern Colorado is considered the third largest enhanced oil recovery (EOR) producing project worldwide and in the U.S. The Rangely project produces about 14,000 EOR barrels of oil per day. The most active CO_2 flooding area in the U.S. is the Permian Basin located in west Texas and eastern New Mexico. Here, more than 50 projects produce an incremental 145 million barrels of oil per day, more than 80 percent of the current North American enhanced oil produced from CO_2 floods. An extensive CO_2 pipeline and re-injection infrastructure system exists throughout the Permian Basin, making it attractive for expanding or starting new projects. High-pressure pipelines supply CO_2 from natural source fields at Bravo Dome in northern New Mexico, and McElmo Dome and Sheep Mountain in southern Colorado. Shell's completion of the pipeline out of McElmo Dome in 1983 significantly increased the value of the naturally occurring CO_2 reserves in Colorado (fig. 69). In addition to EOR applications, CO_2 is used in welding gases, the manufacture of dry ice, and the food and beverage industry.

CO_2 flooding is also emerging as the leading process for sequestering CO_2 that would otherwise be vented to the atmosphere. In recent work completed by the Colorado Geological Survey, it is forecasted that Colorado has an estimated CO_2 storage capacity of 157 billion metric tonnes. Storage options are diverse for the state and widely distributed. They include geologic options such as injecting CO_2 into oil, gas, and coalbed methane reservoirs with incremental recovery to offset project costs, as well as deep saline aquifers unlikely to be needed for future potable water supplies. In addition, Colorado offers numerous localities in which advanced mineralization techniques such as mineral carbonation of silicate minerals using CO_2 may be applied as the technology becomes available for commercial application.

Kinder Morgan CO_2 Company is the largest transporter and marketer of naturally occurring CO_2 in the U.S., supplying more than 400 million cubic feet a day to its customers (Petroleum Technology Transfer Council, 2006). The company says that CO_2 flood costs have declined dramatically since the 1980s, from

more than $1 million per pattern to less than half that. CO_2 prices have also fallen by 40 percent with flood costs between $2–3 per barrel, excluding injectant costs. In addition, CO_2 can be captured and recycled multiple times during the lifetime of the flood, further offsetting costs.

The largest natural CO_2 reserves are located at LaBarge-Big Piney field in Wyoming (~55 Tcf), Bravo Dome in New Mexico (~16 Tcf), and McElmo Dome in Colorado (~17 Tcf). Sheep Mountain in the northern Raton Basin in southeastern Colorado has an estimated 2.5 Tcf in ultimate CO_2 recovery. The CO_2 from McElmo and Sheep Mountain fields is very high quality; that is, 95 and 97 percent CO_2, respectively.

The total value of CO_2 production in Colorado was about $241 million in 2005, an increase of 87 percent over the value of $129 million in 2004. Montezuma County produced 344 Bcf or 96 percent of Colorado's total CO_2 in 2005 (fig. 69). The Mississippian Leadville Limestone at the McElmo Dome field supplies CO_2 for EOR applications in the Permian Basin. Dike Mountain and Sheep Mountain fields in the northwestern part of the Raton Basin in Huerfano County produced four percent of the state's total carbon dioxide in 2005. McCallum and McCallum South fields in the northeast part of the North Park Basin in Jackson County contributed less than one percent of the state's total carbon dioxide production in 2005.

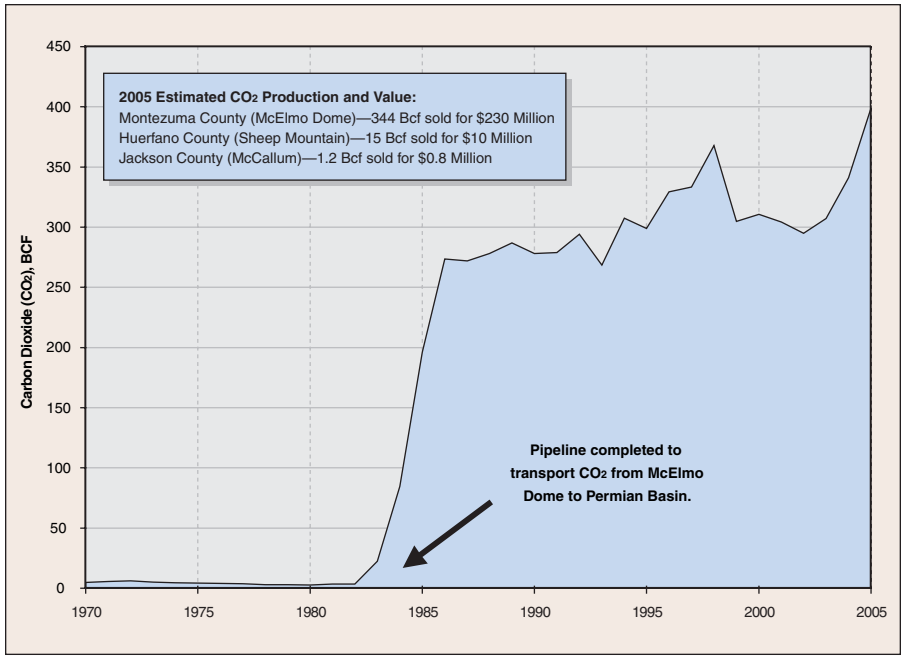

Figure 69. Carbon dioxide production, annual data for 1960–2004 (Colorado Oil and Gas Conservation Commission, 2006).

Helium

Grade-A helium is produced at Duke Energy Field Service's Ladder Creek natural gas processing plant near Cheyenne Wells in eastern Colorado. The helium is liquefied at minus 458° F to separate it from the natural gas produced in the process. Helium is used for many purposes including medical imaging, welding, pressurizing and purging rockets, scientific and party balloons, fiber-optic cable production, production of metal alloys, and many others. The Ladder Creek plant produced 95.2 million cubic feet of Grade-A helium from local sources in 2005. The plant also produces helium from material that is trucked in from elsewhere. The USGS estimates that the price range for privately produced Grade-A helium in 2005 is $67 to $73 per thousand cubic feet (6 to 7 cents per cubic foot). The USGS also estimates that the total Grade-A helium extracted from natural gas in the U.S. in 2005 was 2.97 billion cubic feet (bcf), slightly less than the 3.04 bcf extracted in 2004. Kansas, Texas, New Mexico, Oklahoma, Utah, and Wyoming also produce helium from natural gas.

INFORMATION SOURCES AND ACKNOWLEDGEMENTS

The Colorado Geological Survey wishes to acknowledge the many people and organizations that contributed information presented in this report. Numerous individuals at mineral and energy resource companies, state and federal government agencies, and trade organizations have provided us with the information necessary to create this annual summary of Colorado's mineral and mineral fuel activity. Listed below are some of the companies, agencies, and publications that contributed information for this report:

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Calais Resources Inc., **http://www.calaisresources.com/colorado.html**

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