THE GEOLOGICAL SURVEY OF WYOMING
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THE WYOMING MINERAL INDUSTRY

A SUMMARY BY THE STAFF
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Focus:

Wyoming's mineral

by Daniel N. Miller, Jr.

The unparalleled affluence that Americans enjoy today is due primarily to an abundance of natural resources in the U.S. Foremost among these are the rocks and minerals that historically provided the materials to make the tools and machines which made it possible to raise our standard of living to its present level. Throughout its history and through the cooperative interaction of government and industry, the U.S. has encouraged exploration for new mineral resources and has fostered development of transportation systems capable of moving raw materials to processing facilities and markets in many parts of the country. In the early days, people in the mineral industries lived and worked at isolated locations and were primarily concerned with local markets and production from just one quarry or mine. But as interstate trade evolved, complex business arrangements and transportation systems developed, based on the production capability of many mines and cooperative efforts that lowered the unit costs of operation. Whole new industries and systems of marketing were created until extensive use of domestic mineral resources became the mainstay of the nation's economy.

The U.S. Bureau of Mines now estimates that each year Americans produce and consume four billion short tons of new mineral material valued at $68 billion. In addition, the nation reconstitutes $4 billion worth of metal scrap and imports mineral material valued at $30-35 billion. The use of mineral resources is fundamental to the production of almost every commodity; and directly or indirectly, almost every industry, and ultimately every person, in the country is affected.

Today, in response to expanded needs, we think and work on a gigantic scale of "resources" and "reserves," of exports and imports, of environmental impact studies, and of balance of payments deficits, as the needs of society grow and as government and industry attempt to manage distribution of the nation's

Minerals

legacy—a geological perspective

mineral wealth. Various research groups and congressional committees debate the pros and cons of new national mineral policies. Some factions advocate changes in interstate and intrastate systems of marketing. Others would alter the structures of big industries or press for greater control of antitrust violations. Still others want greater protection for the environment and historical and archeological sites. The issues are complex and the decisions eventually reached will have a pronounced effect on levels of government control, as well as on the nation's economic future.

Certainly the public has become more aware of its dependence on minerals and energy as local shortages occur, as agriculture gropes for ways to overcome the increased costs of equipment, fuel, and fertilizers, or as the costs of manufactured commodities escalate. Just how important are energy and mineral resources to Wyoming, and more generally, to our society as a whole?

Unlike most states, Wyoming is extremely fortunate in having a variety of rock types at or near the surface containing minerals and fluids useful to man. These resources will provide substantial business, employment and income to the state and its people for a long time to come. Some of these resources, such as petroleum and natural gas, coal, uranium, bentonite, and trona, are being developed at present and have established national and international markets.

But this has not always been the case. Market demands change. Rocks and minerals that are valuable today may not be in demand tomorrow, while other rocks and minerals that have no value today may have a ready market in the years ahead. As late as 1970, Wyoming crude oil sold for less than $3 per barrel, and natural gas was valued at 15 cents per thousand cubic feet if found near an established pipeline. Uranium ore was available, but processing facilities were controlled by the federal government. There was no demand for Wyoming coal. The soda ash industry at Green River was beginning to show signs of expansion, a taconite (iron ore) mining operation was developing near Atlantic City, and Amax was investigating a recently discovered copper deposit at Kirwin, west of Meeteetse. Supplies of bentonite and gypsum from the Bighorn and Powder River basins were keeping pace with a stable market demand, and known deposits of phosphate and aluminum ore were subjects of academic rather than economic discussions. Other minerals such as zeolites and diamonds were virtually unknown. In 1970, the total dollar value of all raw mineral production from Wyoming was about $650 million. At the same time, there was serious concern in government about national material and fuel shortages.

In just seven years, the value of Wyoming's raw mineral production has increased to $2 billion per year, due principally to the international oil embargo, but also to substantial increases in trona, uranium and coal production. Anticipated shortages came to pass, but for reasons quite different than those originally suggested.

Market demands for minerals change for a variety of reasons: because of advances in technology, because of actions taken by Congress, and in the case of some critical minerals, because of political or military activities in other nations. If, for example, a new method of making glass were developed that did not require soda ash, Wyoming's trona industry would experience an immediate drop in demand. Or if a practical economic means of removing sulfur from midwestern or eastern coal were developed, the mining of Wyoming coal would abruptly decline. An important point to remember is that factors influencing mineral markets are the result of many kinds of activity far removed from Wyoming. Whether a mining operation in the state expands, contracts, or ceases entirely has little to do with the volume of the resource at hand; but it does relate directly to the cost of mining, processing, and transporting the resource, and to the ultimate market value.

A second point to remember is that the diversity of Wyoming's mineral resources constitutes one of the state's greatest long-term economic assets. It will be comforting in the years ahead to know that if Wyoming's petroleum production declines, production in other areas will probably increase and help sustain the state's economy. Few other states have such a variety of potential economic resources with which to adjust to changing market demand.

At the national level, there are other factors that exert influence on mineral markets. It has become fashionable in recent years to discuss the depletion of the world's reserves and to emphasize the fact that mineral resources are "nonrenewable." There has always been concern with the question, "What will we do when this or that mineral resource is gone?" Those who tend toward pessimism think in terms of finite volumes and stagnated technology and assume that geologists, geophysicists, and engineers have discovered, or will discover, all of the resources that exist. While such reasoning has some philosophical merit, it is far more important to direct our efforts now toward the energy and mineral problems that are already obvious; toward the realities of changing markets, the development of more effective methods of exploration, and more efficient and less expensive techniques for processing and recycling materials. It must be emphasized that man in his pursuit of mineral technology really has just begun to understand and use the earth's mineral resources efficiently. Most of what we know about the chemistry and physics of minerals has been learned in the last 20 years, and that is only a small part of what we will learn in the future. The question is not whether man will deplete the earth's mineral resources as the needs of society change, but rather, "How much will it cost in terms of other values?"

In practice, the minerals industry is like any other complicated, competitive, and expensive business. Companies attempt to locate and obtain ownership of a resource, plan its development, borrow the necessary capital, conduct the operation, and recover costs and a reasonable profit within a given period of time. A few of these operations are successful. Many others are not, perhaps because they lack sufficient investment capital or simply because of unfortunate timing with respect to government intervention, market trends, or escalating costs.

There have always been enough economic hazards associated with just the exploration phase of the minerals business alone to deter investors from risking capital, and attempts to forecast costs and market demands years in advance can be mind-boggling. Of even greater concern today are the uncertainties and delays created by rapidly changing government regulations and court decrees that sometimes shut down multimillion dollar operations for seemingly inconsequential reasons. Lines of control are being drawn that regrettably and artificially pit federal and state governments against industry in terms of resource development. Society's dependence on minerals, fuels, and expanding technology sometimes seems to be forgotten as government extends its control into new social, environmental, and economic areas. The minerals industry, pressed with the responsibility of providing low cost raw materials, is sometimes hampered by a hodgepodge of temporary decisions from regulatory agencies that have extended their authority beyond the bounds of their responsibility. Widespread crises of fuel and material shortages, excessive costs, and economic hardships may ultimately occur before the necessities of a productive society are placed in clearer perspective. It remains in the nation's and Wyoming's best interests to develop mineral resources expeditiously and in concert with market demand. Industry responds to the needs of society in the market place, while government attempts to respond to society's aspirations. Neither can do its job successfully without the cooperation of the other.

In the future, minerals will continue to be the mainstay of Wyoming's economy. If there is any doubt, consider that in 1977 the mineral industry contributed more than $63 million in severance taxes alone to the state. Property taxes on mineral operations amounted to $85 million, and rental and royalty payments from state and federal lands totalled more than $79 million. Collectively, this amounted to $227 million. In addition, Wyoming's oil industry spent more than $560 million conducting its operations and employed approximately 18,700 people, who in turn redistributed more than $200 million from payrolls. The mining industry provided employment for about 10,000 people in Wyoming, with annual payrolls of $170 million. No other activity or combination of activities affects Wyoming's economy to such an extent.

In recent years, the mineral products and fuels produced as the result of activity in Wyoming have helped sustain thousands of businesses and industries and have provided heat, light, and fuel for millions of people throughout the U.S. More than 87 percent of the oil and 66 percent of the natural gas produced in the state flows into interstate pipelines for distribution throughout the nation. Wyoming coal, of which 74 percent is exported, is used as boiler fuel by public utility electrical generating plants in more than 25 cities, some as far away as Ohio and central Texas. Wyoming also exports 100 percent of its uranium yellow cake, 90 percent of its soda ash, more than 50 percent of its bentonite, 100 percent of its iron ore, and a dozen or so lesser mineral commodities.

How important are Wyoming's mineral resources? This series of articles is designed to let you judge for yourself, as we explore many facets of "Wyoming's Mineral Legacy."

Oil and gas remain dominant forces in minerals industry

Alan J. Ver Ploeg

Introduction and Historical Background

Wyoming's oil and gas industry is the state's largest mineral industry in terms of value of materials produced, income to the state, and employment. According to figures compiled by the Petroleum Association of Wyoming, the oil and gas industry provided 41.7 percent of the entire 1977 assessed valuation of the state and employed more than 18,700 people in 1976. All major aspects of the oil and gas industry are represented within the state, from seismic exploration and exploratory and development drilling, to transporting and refining the product. Oil and gas have played a major role in the state's economy since the turn of the century and should continue to do so into the next century.

The first recorded reference to the occurrence of oil within the state dates back to 1833 when Captain B.L.E. Bonneville visited the "Great Tar Spring" on the Popo Agie River near present-day Lander, Wyoming. The first commercial marketing of oil on record in Wyoming occurred in 1851 from an oil seep on Poison Spider Creek, west of present-day Casper. Records indicate that Jim Bridger, Kit Carson, Cy Iba, and others mixed the oil with flour and sold the product to emigrants for use as axle grease. The first oil field, Dallas Dome, originated in 1884 with the drilling of a 300-foot well near the "Great Tar Spring." About the same time, oil activity started in Natrona County in the area later to become famous as Salt Creek Field. Transportation of the oil from Salt Creek Field shifted from freight wagons to pipeline near the turn of the century. Pennsylvania Oil and Gas Company built the first small refinery in Casper in 1895. Early drilling efforts during the period 1900-20 revealed several very large fields, including Oregon Basin and Elk Basin in Park County, Garland in Big Horn County, and Lost Soldier in Sweetwater County (see map, fig. 2).

At that time evidence indicated tremendous oil reserves, but Wyoming had no nearby populous areas, and rail transportation to the population centers of the east and west was costly. Wyoming could not compete with midcontinent, eastern, and California oil. Crude prices dropped as low as 10 cents per barrel in the 1930's and it wasn't until the 1940's, with the demands brought on by World War II, that development moved back into full swing. The pace of development continued to increase into the 1970's.

Geologic Setting

Occurrence of oil and gas in Wyoming is tied quite closely to the locations of the state's large sediment-filled basins. The most important basins in terms of oil and gas production are the Powder River Basin, Greater Green River Basin, Bighorn Basin, and Wind River Basin (see map, fig. 2). Two smaller basins, Washakie Basin and Great Divide Basin, are becoming important as a result of recent gas discoveries there.

Wyoming's oil and gas normally occur in either structure-controlled or stratigraphy-controlled concentrations called "traps." In a typical oil and gas trap, because of differences in specific gravity, gas is found at the top (or crest) of the trap, oil immediately beneath the gas, and water beneath the oil.

Most of the recent discoveries in the Powder River Basin are stratigraphic traps in which the oil and gas are concentrated by a decrease in porosity in an updip or upslope direction, which thus stops the migration of the oil and gas and causes an accumulation. Most of Wyoming's stratigraphic traps occur in relatively undisturbed portions of the basins.

Structural traps, characteristic of the early fields, usually occur on the highly deformed margins of basins. Many of the fields in the Bighorn Basin are excellent examples of this type of concentration, with the oil and gas usually trapped in the crests of upwarped or anticlinal rock configurations. Because of their obvious surface expression, features of this type were often the targets of early exploration ventures. Unfortunately, industry has tested nearly all the obvious structures and only more subtle, deeply buried structural traps remain as exploration targets. Industry now relies on new high-resolution seismic techniques, supplemented by the older field mapping techniques, to locate deep structures, such as those recently discovered in the Overthrust Belt region (see map, fig. 2). The newer seismic techniques have proven instrumental in Overthrust Belt exploration and have been valuable in the search for stratigraphic traps as well.

In rocks younger than Jurassic (see time scale, fig. 1), paraffin-rich, low sulfur, light oils with American Petroleum Institute (API) gravities of 34° or higher are common. Because of their characteristic greenish color, these oils are referred to as "green oils." Crude oils in formations older than Jurassic are generally asphaltic, higher sulfur, heavier oils with API gravities 34° or lower. These oils, which are relatively dark in color, are termed "black oils." Both types are found in Jurassic formations which seem to form the transition zone between the two general types.

Reservoir rock (rock containing oil and gas) ranges in age from Tertiary to Cambrian (see time scale, fig. 1) and is

TIME (Millions of Years Before the Present)	ERA	PERIOD	EPOCH	GEOLOGIC EVENT
0.01	CENOZOIC	Quaternary	Holocene (Recent)	
2			Pleistocene	Regional mountain glaciation and redistribution of thick sand and gravel deposits.
12		Tertiary	Pliocene	
22.5			Miocene	Major volcanic activity in the Absaroka Plateau.
38			Oligocene	Copper mineralization in the Absaroka Mountains. Formation of bentonite from volcanic ash derived from the Absaroka Mountains.
55			Eocene	Major coal deposits. Trona deposition in ancient Lake Gosiute. Deposition of Wyoming's major uranium deposits. Oil shale deposition in Green River Basin. Formation of bentonites. (Major Mountain Building)
65			Paleocene	Major coal deposits. Large accumulations of natural gas.
141	MESOZOIC	Cretaceous		Major uranium deposition in the Black Hills region. North American continent overrides Pacific Ocean Basin. Numerous bentonite deposits are formed from volcanic ash reacting with sea water. Major coal deposits and large accumulations of oil and natural gas.
195		Jurassic		Accumulations of gas and oil in Nugget Formation
230		Triassic		Deposition of iron-rich red beds.
280	PALEOZOIC	Permian		Deposition of phosphates and iron-rich red beds. Accumulation in Phosphoria Formation.
325		Pennsylvanian		Copper mineralization in the northern Laramie Mountains and Hartville uplift. Major accumulations of oil and gas in Tensleep, Minnelusa, and Weber Formations.
345		Mississippian		Accumulation of black oil in Madison Limestone.
395		Devonian		Intrusion of diamond-bearing ultrabasic igneous diatremes.
435		Silurian		
500		Ordovician		
570		Cambrian		
4500	PRECAMBRIAN			Deposition of uraniferous conglomerates. Major copper mineralization. Formation of iron-taconites and hematite, feldspar, and jade.

Fig. 1 Geologic time scale showing major geologic events discussed in text.

most often composed of various types of relatively porous sandstone or limestone. In general, fields in stable interior basin areas are characterized by stratigraphic traps which produce from Tertiary and Cretaceous reservoirs. Conversely, those in the deformed margins of the basins are characterized predominately by structural traps and produce from older rocks (Jurassic, Permian, Pennsylvanian, Mississippian, etc.). Bighorn Basin fields fall in the latter category, while the Powder River and Greater Green River Basin fields fall predominately in the former. Wind River Basin fields occur in both categories.

TABLE 1. Drilling activity in Wyoming. 1970-1977.

Year	Number of Wells Drilled for: Oil	Gas	Dry	Total	Total Footage Drilled (millions)	Average Depth	Average Number of Active Rotary Rigs
1970	662	35	699	1,396	9.7	6,930	71
1971	435	51	464	950	5.7	5,959	45
1972	349	53	566	968	6.5	6,702	60
1973	385	64	446	895	5.8	6,490	70
1974	428	40	533	1,001	6.8	6,769	107
1975	611	75	570	1,256	8.9	7,114	107
1976	431	81	466	978	7.0	7,124	87
1977	598	149	530	1,277	9.4	7,331	118

(Information gathered from Petroleum Information's *Rocky Mountain Region Report*, selected years; and the *Oil and Gas Journal*, January 31, 1977.)

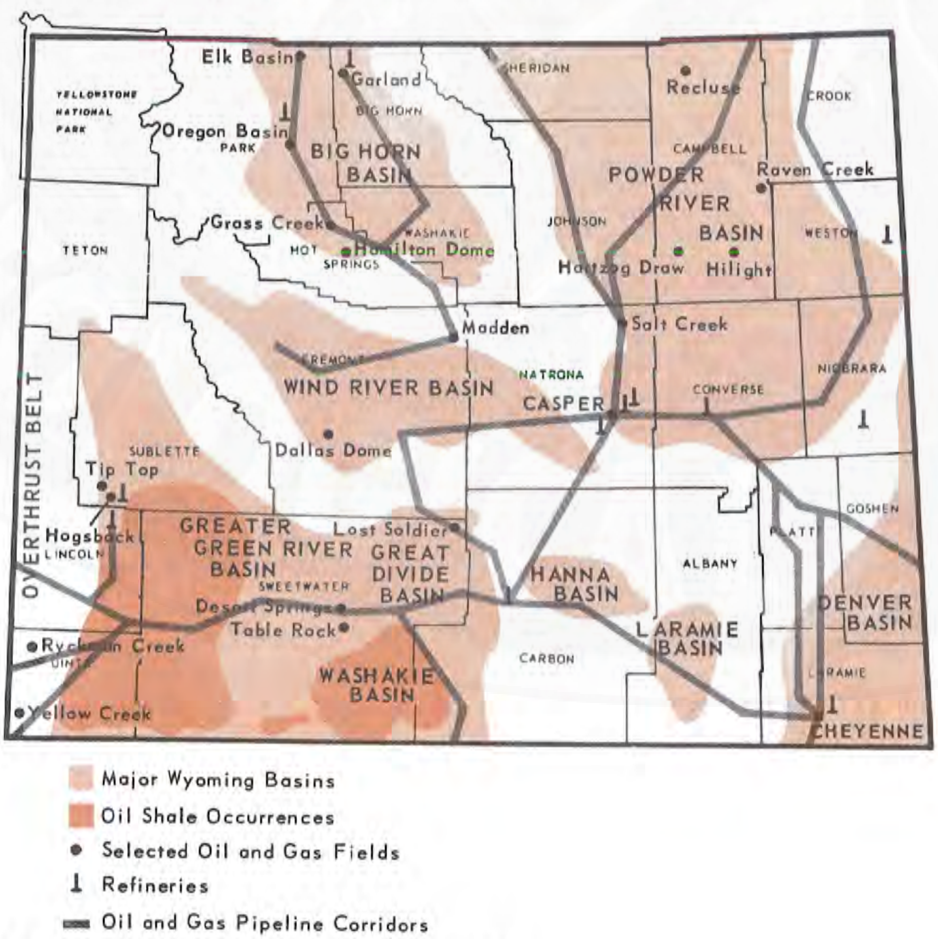


Fig. 2. Generalized oil and gas index map of Wyoming.

Drilling and Production

Drilling activity in Wyoming fluctuated during the period 1970-77, as shown in table 1. Rotary rig activity in Wyoming reached a 14-year high in 1974 (107) and continued at that rate into 1975 when a five-year high of 1,256 wells were drilled. These totals, however, were surpassed in 1977 when rig activity averaged 118, and industry drilled 1,277 wells, indicating a distinct increase in activity.

The breakdown of development wells (drilled to expand production within a field) versus exploration wells (drilled to find new production) averaged only 50-55 percent in favor of development during the period 1966 to 1974. However, in 1975 and 1976, with recently enacted and impending tax legislation unfavorable to exploration efforts, the percentage of exploration wells dropped from nearly 50 percent to 35 percent.

Most of the exploration and development drilling during the last 10 years has occurred in the Powder River Basin, and it appears that this trend will continue for several years. Statistics for 1976 indicate that 57 percent of all exploration wells and 65 percent of all development wells were drilled in the Powder River Basin. The second most active area, the Green River Basin, accounted for 20 percent of all exploration wells and 17 percent of the development wells in 1976. The overall success ratio for 1976 ran 17 percent for exploration wells and 77 percent for development wells.

When compared to the larger oil and gas producing states, Wyoming's role in domestic production seems relatively insignificant. Wyoming ranks fifth among the 50 states in crude oil production, following Texas, Louisiana, California, and Oklahoma, and seventh in marketed production of natural gas after Texas, Louisiana, Oklahoma, New Mexico, Kansas, and California (based on 1976 API statistics). However, Wyoming dominates oil and gas activity in the Rocky Mountain area, as shown in the first column of table 2.

Early crude oil production in Wyoming (see graph, fig. 3) peaked in 1923 after discovery and development of large fields such as Salt Creek, Elk Basin, Oregon Basin, and Hamilton Dome. A long decline in production followed, coinciding with the "Great Depression" and failure to compete with Midwest and West Coast oil. World War II initiated a long period of increasing production which finally leveled off in 1961. Production stabilized with very little fluctuation from 1961 to 1968. Discovery and development of large stratigraphic traps in the Powder River Basin led to the resurgence in the late 1960's and early 1970's, giving Wyoming its highest yearly production to date in 1970 (155,743,349 barrels).

More recently, however, production has returned to the level of the early 1960's because of rapid depletion of large older fields such as Salt Creek in Natrona County. Production in 1976 totalled 134,148,510 barrels, a one percent decline from 1975. A similar drop is expected in 1977, although new production from Hartzog Draw Field in the Powder River Basin could counteract at least part of this anticipated decline.

When examining crude oil production on a county basis, Park, Campbell, Natrona and Hot Springs counties emerge as leaders in the state (see table 3). Large old structural traps such as Oregon Basin and Elk Basin fields in Park County, Grass Creek and Hamilton Dome Fields in Hot Springs County and Salt Creek Field in Natrona County, greatly influence production in these counties. However, the large recently discovered stratigraphic traps (Hilight and Raven Creek fields, and most recently, Hartzog Draw Field) are chiefly responsible for Campbell County's production. Wyoming's reliance on the large fields for its oil production is evidenced by the fact that over 63 percent of the state's total production comes from the 25 largest fields (according to statistics compiled by the Wyoming Oil and Gas Conservation Commission). Any sudden decline in production from one of these fields will greatly affect production from the county in which it is located. Natrona County experienced this recently with the abrupt decline in production from Salt Creek Field.

Total gas production in Wyoming has followed essentially the same pattern as oil production, peaking in 1971 at 384,313,989 thousand cubic feet (mcf) as a result of large discoveries in Campbell County in the mid to late 1960's (see graph, fig. 4). With declining production from some of the large older gas fields, overall production started to decline in 1973. New discoveries during 1974 and

TABLE 2. Wyoming's role in domestic production.

Indicator	Percentage of Rocky Mountain Total	Percentage of U.S. Total
Crude Oil Production	34.1%	3.9%
Crude Oil Reserves	38.3	2.6
Marketed Natural Gas Production	13.6	1.2
Natural Gas Reserves	18.6	1.7
Total Wells Drilled	25.5	2.5
Footage Drilled	33.4	3.9
Average Rig Count	33.7	5.3
Petroleum Refinery Capacity	25.0	1.2

(Calculated from statistics in *Oil and Gas Journal*, January 31, 1977 and March 21, 1977.)

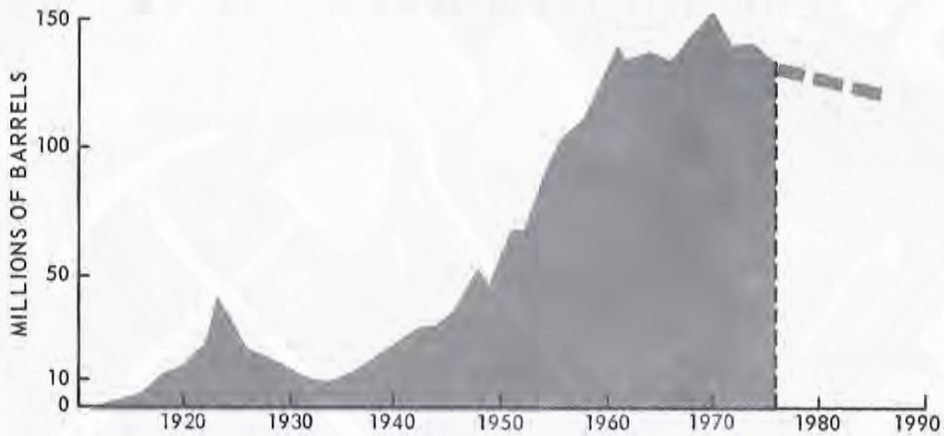


Fig. 3. Annual oil production in Wyoming (from Wyoming Oil and Gas Conservation Commission).

Fig. 4. Annual natural gas production in Wyoming 1917-1976 (from Wyoming Oil and Gas Conservation Commission).

1975 in Sweetwater and Fremont counties led to the upturn indicated for 1976 (see graph, fig. 4).

Gas production totals on a county basis show that the leaders are Sweetwater, Fremont, Sublette, Campbell, and Park counties (see table 2). In general, gas production in Park and Sublette counties comes from large older fields (structural traps) such as Elk Basin and Oregon Basin in Park County and Hogsback and Tip Top in Sublette County. Campbell, Sweetwater, and Fremont counties owe most of their production to stratigraphic traps discovered relatively recently. These include Hilight and Recluse fields in Campbell County, Desert Springs and Table Rock fields in Sweetwater County, and Madden Field in Fremont County. Again, as with oil production, Wyoming relies heavily on large fields for its gas production, with over 69 percent of the total coming from the 25 largest gas fields.

Wyoming's oil and gas production by company shows some interesting features, as reflected in table 4. First, out of nearly 400 companies operating in Wyoming, the top 20 account for 80 percent of the oil production and nearly 73 percent of the gas production. Second, although the major companies (led by Amoco Production) play a very important role in Wyoming's production, the contribution of the smaller independent companies is impressive. As shown by recent important field discoveries, the smaller independents are playing an ever-increasing role. Hartzog Draw, where the most active operators are Woods Petroleum, Davis Oil, Diamond Shamrock, and others is a prime example.

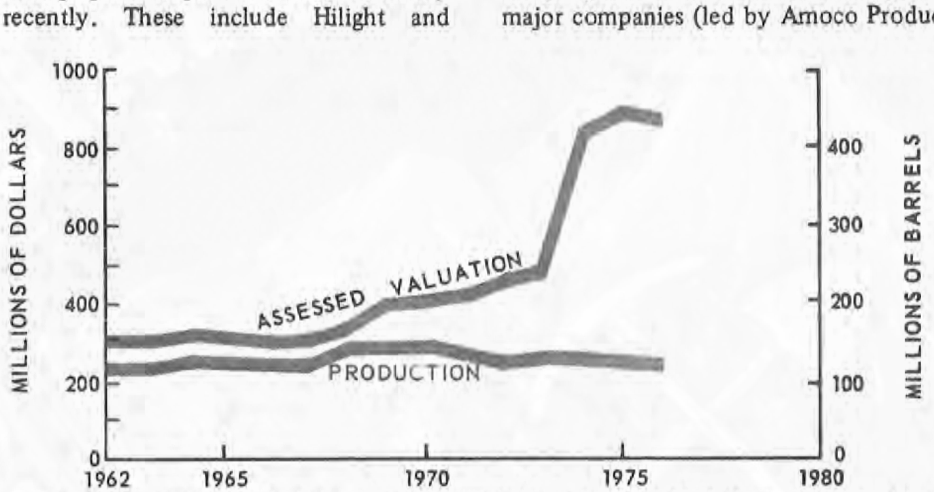


Fig. 5. Annual assessed valuation of oil production in Wyoming 1962-1976 (from Mineral Division, Department of Economic Planning and Development, *1976 Wyoming Mineral Yearbook*).

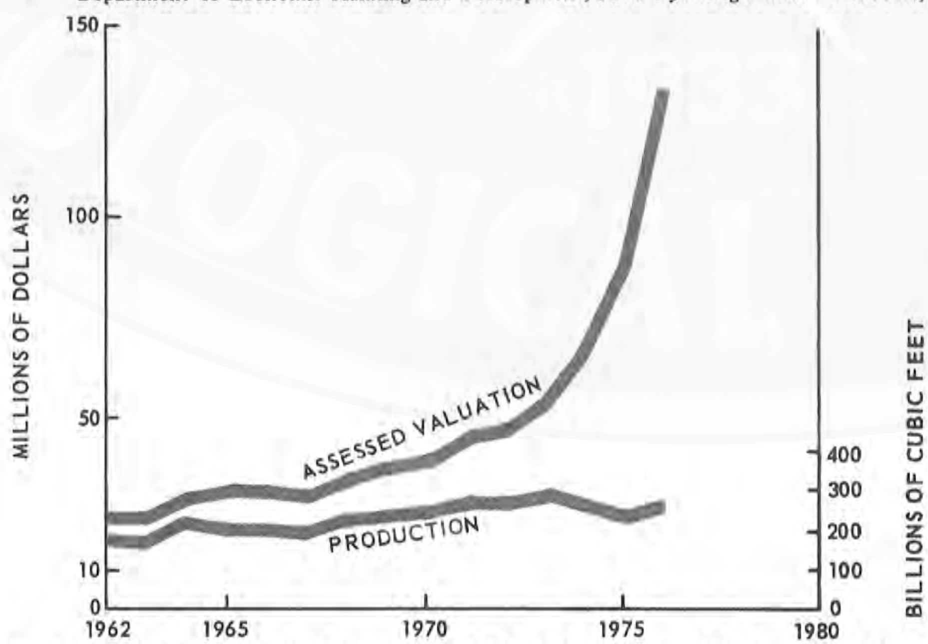


Fig. 6. Annual assessed valuation of natural gas production in Wyoming 1962-1976 (from Mineral Division, Department of Economic Planning and Development, *1976 Wyoming Mineral Yearbook*).

Much less than one-half the oil within a field is ever recovered by normal production methods; and as a result, efforts are eventually geared toward very expensive enhanced recovery techniques. One of the original "secondary recovery" methods, and one that is still used extensively, involves water flooding, or injecting water into a reservoir to force the oil out. A variation on this technique substitutes natural gas or steam for water. A method known as "tertiary recovery" includes techniques using detergents to "wash" the oil from the rock or solvents to dissolve the oil. Both secondary and tertiary techniques are used in Wyoming. Secondary recovery methods, however, are more common, as industry strives to prolong production from the large older fields. According to 1976 statistics compiled by the Wyoming Oil and Gas Conservation Commission, industry is involved with 246 water injection projects, 13 gas injection projects, two hydrothermal or steam injection projects, and one combustion project (tertiary recovery) in various fields in Wyoming.

Although oil and gas production is apparently leveling off or slightly declining, assessed valuation has risen dramatically since the early 1970's due to the rise in prices caused by Organization of Petroleum Exporting Countries (OPEC) price increases and decreasing domestic supplies (see graph, fig. 5).

The assessed valuation of oil would be considerably higher if the federal government did not regulate the prices on "old" and "new" oil. Simply stated, "old oil" is oil from wells drilled prior to 1973 and "new oil" is oil from wells drilled after 1973.

Prior to the enactment of the Energy Policy and Conservation Act on December 22, 1975, old oil cost $5.50 per barrel.

The Energy Act fixed the average price for all oil at $7.66 per barrel. The ceiling on new oil prices was lifted by the Energy Act, but the previous price was held at $11 per barrel.

The relative amounts of old oil and new oil produced in a county affect the assessed valuation for each county. For example, the average price per barrel in Park County, a county with older established fields, increased from $3.30 per barrel in 1973 to $6.05 per barrel in 1975, an increase of 83 percent. At the same time in Converse County, a county containing several large new fields, the average price per barrel went from $4.55 in 1973 to $11.25 in 1975, an increase of 147 percent. This 64 percent difference in increase is directly proportional to the greater percentage of "new oil" produced in Converse County.*

A similar price regulation system has been applied to natural gas in Wyoming. Recent price increases yielded a dramatic rise in assessed valuation (129 percent) for the period 1971 to 1976 (see graph, fig. 6). During the same period, overall production declined 12 percent. New regulations set by the Federal Power Commission in July 1976 provide that: 1) gas discovered after December 31, 1974 may be sold in interstate commerce at up to $1.42 per thousand cubic feet (mcf); 2) gas from wells discovered between January 1, 1973 and December 31, 1974 has a ceiling of $1.01 per mcf; and 3) gas in production before January 1, 1973 will continue at a maximum rate of $0.295 per mcf, although when current contracts expire the price may be raised to as high as $0.52 per mcf.* Here again, a county's relative percentages of "new" and "old" gas production will greatly affect its assessed valuation.

Exploration and Reserves

During the past seven years, industry has concentrated its exploration effort in the Powder River Basin. The second most active area during this period was in Greater Green River Basin. Most of the drilling represented an attempt to locate new stratigraphic reservoirs based on indications from seismic profiles.

*Mineral Division, Department of Economic Planning and Development. *1976 Wyoming Mineral Yearbook*, Cheyenne, Wyoming.

TABLE 3. Oil and gas production for 1975 by county.

County	No. of Fields	No. of Wells	1975 Oil Production–bbls*	1975 Gas Production–mcf*
Albany	7	31	217,125	
Big Horn	18	382	6,414,028	4,959,609
Campbell	133	1,391	29,835,014	36,930,901
Carbon	30	169	637,356	12,708,875
Converse	39	780	9,565,125	16,701,328
Crook	42	273	3,172,644	382,892
Fremont	45	703	7,619,231	50,161,815
Goshen	2	3	7,803	
Hot Springs	22	682	11,453,054	492,923
Johnson	23	319	4,086,175	1,241,559
Laramie	8	46	250,281	120,990
Lincoln	9	73	57,421	3,380,502
Natrona	44	1,708	12,702,804	11,186,096
Niobrara	17	136	640,898	670,142
Park	36	1,116	30,566,104	21,583,318
Platte	2	40	481,952	59,238
Sheridan	4	15	154,363	2,238
Sublette	27	603	3,456,236	40,117,123
Sweetwater	56	587	8,047,359	87,936,838
Uinta	3	12	12,496	5,002,930
Washakie	17	165	1,717,004	10,826,245
Weston	30	765	2,814,675	1,293,528

*bbls–barrels, mcf–thousand cubic feet

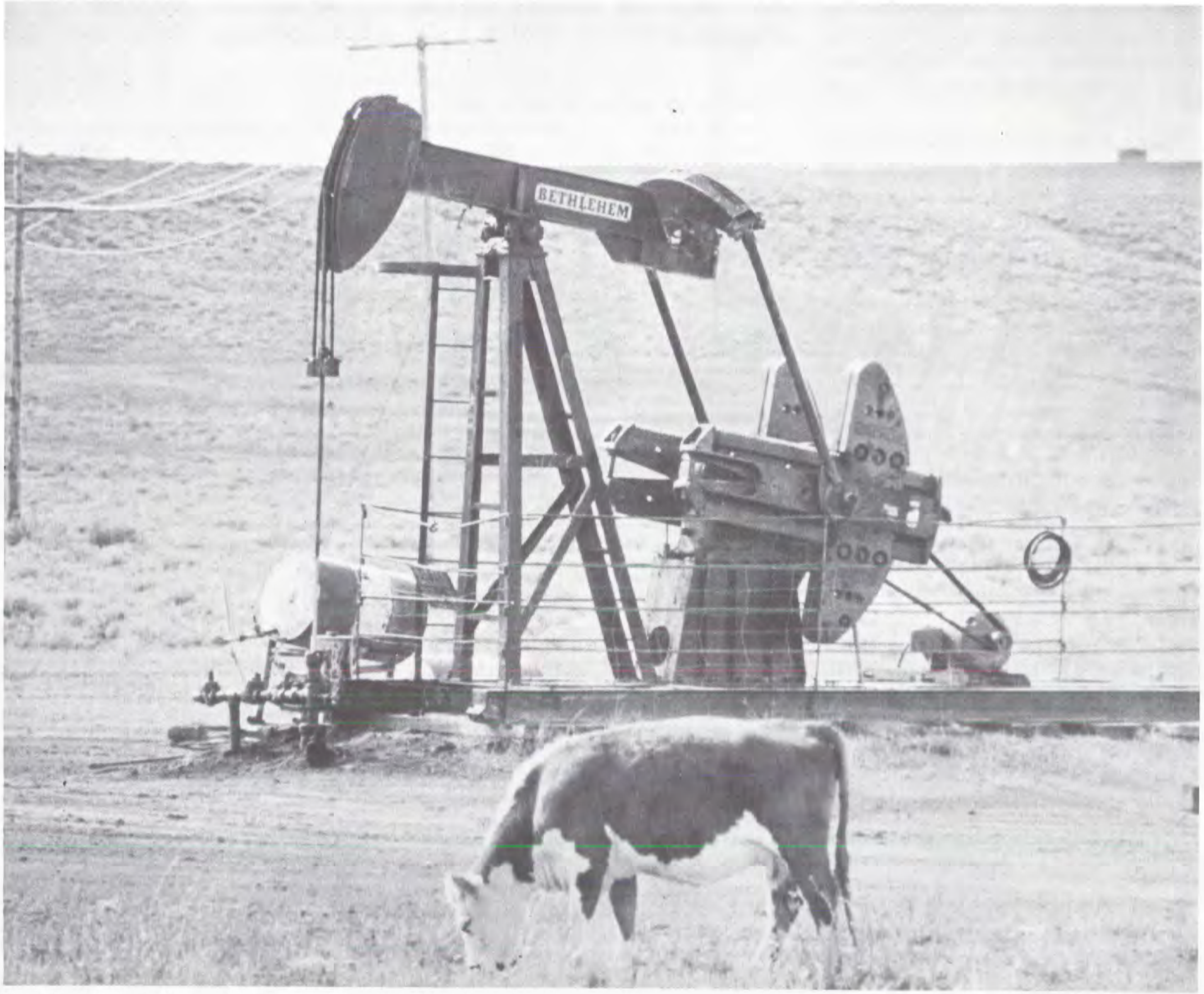
(Statistics compiled by the Wyoming Oil and Gas Conservation Commission for 1975.)

TABLE 4. Wyoming's oil and gas production by company.

Company Name	Percent of Wyoming's Total Oil Production	Percent of Wyoming's Total Gas Production
Amoco Production	21.9%	13.3%
Marathon Oil Co.	16.8	3.4
Continental Oil	6.7	2.1
Inexco Oil Co.	5.8	3.4
Atlantic Richfield Co.	4.0	2.3
Mobil Oil Co.	3.2	7.3
Texaco Inc.	2.3	4.0
Terra Resources	2.0	1.9
Davis Oil Co.	1.9	2.4
Champlin Petroleum Co.	1.8	6.9
Ashland Oil Co.	1.8	0.02
Chevron Oil Co.	1.8	2.6
Mountain Fuel Supply Co.	1.7	10.7
Gulf Oil Corp.	1.7	.4
Union Oil Co. of California	1.2	4.0
Tennaco Oil Co.	1.2	.3
Farmers Union Cent. Exch.	1.2	.06
Diamond Shamrock Corp.	1.0	1.2
Buttes Oil and Gas Co.	1.0	.02
Belco Petroleum	1.0	6.3
TOTAL	80.0%	72.6%

(Statistics compiled for 1975 by the Wyoming and Gas Conservation Commission.)

The discovery of Pineview Field in Utah (1975) and Yellow Creek Field



Pumping unit at the Osage oil field, Weston County, Wyoming. (Wyoming Travel Commission Photo)

(1976) and Ryckman Creek Field (1976) in Wyoming, initiated accelerated exploratory work in the Overthrust Belt. Thanks to improved high-resolution seismic techniques, these highly complicated, deep structural traps were recognized and successfully drilled. Industry uses seismic surveying as the prime form of predrilling exploration, and seismic crews remain very active today in the Overthrust Belt. The fact that a very large portion of the Overthrust Belt is still untested places it high on industry's list in terms of potential for exploration.

Recent gas discoveries in the Washakie and Great Divide basins have spurred exploration drilling and seismic work in that region. Recent deep drilling in the interior of the Wind River Basin has encountered vast new gas reserves and prompted industry to consider the untested interior portion of the Bighorn Basin for the same type of potential.

The maintenance of adequate reserves depends quite heavily on exploration success. Many variables are involved with estimating "discovered" and "undiscovered" oil and gas reserves, and values arrived at are quite subjective and vary considerably depending on the parameters and definitions used. This is especially true with estimates of "undiscovered" reserves. For example, 1974 U.S. Geological Survey estimates of "undiscovered" reserves in the U.S. ranged between 200 and 400 billion barrels of oil, while Mobil Oil Corporation's best estimate was 68 billion barrels of oil.

Estimates of "discovered" reserves are much less tentative because they are based on actual drilling results. However, problems still exist with assumptions that must be made concerning size, shape, and uniformity of discovered reservoirs.

Estimated discovered oil and gas reserves in Wyoming for the period 1969-77 are shown in table 5. As might be expected, the trends in the above oil and gas reserve totals correlate with those for production during the same time period. For example, the increase in oil reserves from 1970 to 1971 resulted largely from discoveries in the Powder River Basin during that period. The increase in gas reserves from 1973 to 1974 corresponds to discoveries made in Sweetwater and Fremont counties in 1973 and 1974. The decline in reserve totals for oil should continue, although new discoveries in the Overthrust Belt and unexplored interior basin areas undoubtedly will effect the rate of decline. Gas reserves will decline more slowly and may even increase slightly as a result of continuing exploratory success in Sweetwater and Fremont counties.

Refining and Transportation

The 12 refineries currently operating within the state (see table 6) employ more than 1,900 people and are capable of processing 188,630 barrels of crude oil per day, slightly more than one-half of Wyoming's daily production. Capacity is expected to jump to over 200,000 barrels per day when Little America's refinery in Sinclair, already the largest in the Rocky Mountain region, completes expansion of its facilities to a 70,000 barrel-per-day capacity. Recent figures indicate that major refineries in the state are operating at between 80 and 90 percent capacity. Wyoming's refineries obtain between 95 and 100 percent of their crude within the state. Although no precise data is kept on refinery yields in Wyoming, indications are that it is quite close to the Rocky Mountain area average shown in table 7.

Products are normally extracted from crude oil through a complex process of heating, catalyst action, molecular alternation, distillation, and several other techniques, any combination of which may be used by a refinery in its operation. Techniques of vacuum distillation, catalytic cracking, catalytic hydrotreating, and catalytic reforming predominate in Wyoming refineries.

If crude oil production declines sharply within the state, refineries will have to cut back. However, refining companies in Wyoming are hopeful that new discoveries in the Overthrust Belt and growing fields like Hartzog Draw in Campbell County will maintain their supply of crude oil.

Recent substantial increases in the price of natural gas liquids have stimulated construction of new processing plants within the state for extracting marketable liquid petroleum (LP) products from unprocessed natural gas. In 1976, 36 natural gas processing plants operated in Wyoming, processing 265,681,231 mcf of natural gas to produce 423,235,207 gallons of liquid petroleum fuels (based on 1976 Wyoming Oil and Gas Conservation Commission statistics). The trend in production of liquid petroleum fuels essentially has paralleled that of natural gas production in the state over the last 10 years. A breakdown of 1976 LP yields in Wyoming according to U.S. Bureau of Mines statistics is shown in table 8.

As in petroleum refining, there are several methods used either alone or in combination for extracting LP from natural gas. The most common method applied at Wyoming plants is a refrigeration process in which gas temperature is reduced to -10° F., causing the majority of the liquid within the gas to condense.

To maintain their operations, gas plant operators (like oil refinery operators) are heavily dependent on new discoveries of large reserves like those recently found in the Wind River Basin.

Nearly all Wyoming's crude oil is transported by pipeline. Simply stated, the crude oil is transported from the well via gathering lines which link with larger trunk line systems that move the oil to refineries. In newly discovered oil fields, transportation is limited to tank trucks until gathering lines are constructed to connect with the nearest large trunk line system. Product lines carry more than one-half of the refined products; the remainder is transported by truck or railroad tank car.

Natural gas is transported to processing plants in much the same manner as crude oil; that is, gathering lines converge on larger transmission lines which lead to the processing plant. After the LP products are extracted at the processing plant, the dry residue gas is sent into transmission lines which carry it to various marketing areas. The majority of the natural gas liquids are transported by motor freight.

Average costs for pipeline construction in Wyoming can vary from $40,000 to over $100,000 per mile depending on

TABLE 5. Estimated discovered oil and gas reserves in Wyoming, 1969-1977.

Date	Oil Reserves (Thousands of barrels)	Gas Reserves (Millions of cubic feet)
1-1-69	1,101,288	3,768,535
1-1-70	999,550	3,937,045
1-1-71	1,017,359	4,243,331
1-1-72	996,985	4,131,492
1-1-73	949,779	4,088,728
1-1-74	916,763	4,109,523
1-1-75	903,360	3,917,387
1-1-76	877,385	3,703,159
1-1-77	827,769	3,704,383

(Oil data from American Petroleum Institute; gas data from American Gas Association.)

TABLE 6. Refineries in Wyoming.

Location	Company Operating	Rated Capacity*
Casper	Amoco Oil Co.	43,000
Casper	Texaco, Inc.	21,000
Casper	Little America Refining	24,500
Cheyenne	Husky Oil Co.	23,600
Cody	Husky Oil Co.	10,800
Cowley	Sage Creek Refining Co.	1,140
LaBarge	Mountaineer Refining Co.	300
LaBarge	Southwestern Refining Co.	500
Lusk	C&H Refinery	190
Newcastle	Tesoro Petroleum Co.	10,500
Osage	Glacier Park Co.	4,100
Sinclair	Sinclair Oil Co.	49,000
	TOTAL	188,630

*Rated Capacity is the number of barrels of crude oil per calendar day that a refinery can process based on a year's operation.

Source: *Oil and Gas Journal* and *National Petroleum News.*

terrain, size of pipe, and so on. Normally, 4-inch diameter pipe is used for gathering lines, 8-inch for trunk lines and oil product lines, and 16-20-inch or more for gas transmission lines. With the recent rises in steel prices and greatly increased labor costs, the cost of installing a pipeline has risen dramatically and in many cases has more than doubled over the last 10 years. Major pipeline corridors in Wyoming are shown on the map in figure 2. Amoco Pipeline Company operates the most extensive crude oil pipeline system and product pipeline in Wyoming. The largest gas pipeline system is operated by Colorado Interstate Gas Company.

Of the 134,148,510 barrels of crude oil produced in Wyoming in 1976, slightly under 50 percent went to in-state refineries and the remainder moved by pipeline to refineries in other states in the Rocky Mountain area and the Midwest. As an example of the outflow pattern of crude oil from Wyoming, note the statistics for 1975 and December 1976 shown in table 9.

Crude oil receipts from Wyoming are quite important to the states of Michigan, Colorado, Montana, and Utah. For example, in May 1977 Montana received 58 percent of its total refinery receipts from Wyoming; Colorado received 47 percent; Michigan received 31 percent; and Utah received 18 percent. These percentages have remained fairly constant over the last five years.

Of the total gas production in the state during the last five years, a decreasing percentage has been consumed within the state. In 1972, for example, 38 percent of the state's total production was consumed within the state; in 1974, according to U.S. Bureau of Mines statistics, only 33 percent was consumed in Wyoming. This trend is becoming quite alarming to many Wyoming residents as nearly all the newly discovered gas is transported out-of-state, creating a situation where in-state shortages of gas are already evident in some communities. In 1974, the interstate pattern of natural gas flow from Wyoming was as follows: 50.2 percent of total exports to Colorado, 27 percent to Utah, 13.8 percent to Nebraska, and 8 percent to Montana.

As with crude oil, receipts of gas from Wyoming represent a large portion of total receipts in Colorado (66 percent), Utah (35 percent), Montana (25 percent), and Nebraska (2 percent) (1974 U.S. Bureau of Mines statistics). This pattern has remained essentially the same during the past five years.

Forecast

Wyoming's role as the Rocky Mountain area's leader in petroleum production should continue well into the future. Overall production of oil and gas should remain relatively unchanged for the next 5-10 years, followed by a decline as reserves are gradually depleted. The length of the static period and the rate at which the decline occurs will depend greatly on industry's ability to continue discovering new fields similar to Hartzog Draw and Ryckman Creek, thereby offsetting rapidly declining production in the large older fields which have historically carried Wyoming's overall production.

Exploration efforts will continue in the Powder River Basin, in search of large new stratigraphic traps for the most part. Deep drilling will be stepped up in the Wind River Basin in order to better define the extent of recently discovered gas reserves. This trend toward increased deep drilling should carry over into the interior portion of the Bighorn Basin, which, except for a recent deep gas success, is relatively untested. Similarly, recent successes in the Green River, Washakie, and Great Divide basins should stimulate increased exploraton for gas there. The area now receiving the most exploratory interest, the Overthrust Belt, undoubtedly will continue to headline activity in the Rocky Mountain area as industry increases its efforts to identify deep structural traps in complex geologic areas.

Greatly improved high resolution seismic techniques will continue to serve as the most successful method of searching for the extremely subtle and deep structural and stratigraphic traps that remain to be found. New remote sensing techniques employing satellite imagery may prove to be an important exploration tool.

It would appear that, except in the Overthrust Belt area, the majority of the remaining oil and gas in the state will be found in relatively deep stratigraphic traps in the interior untested portions of basins. The upward trend in drilling activity noted in 1977 should continue as more and more wells are needed to maintain production; that is, oil and gas will be much harder to find. Movement into the interior portions of basins will necessitate the drilling of much deeper wells, accompanied by large increases in drilling costs.

Disposition of crude oil and gas should follow the same trends noted for recent years, with the percentage of export probably increasing. The problem of natural gas shortages within the state will need to be dealt with as nearly all new gas discoveries are earmarked for interstate transport. Refinery expansion should level off with production.

In general, reserve totals for the state will follow the same trends expected for production. Continued experimentation with fracturing tight gas sands in the Pinedale Unit in the northern part of the Green River Basin, if successful, could add significantly to the state's gas reserves. Also, the vast oil reserves represented by the state's oil shale should bolster production in the future as new technology and a more favorable economic climate develop.

It is obvious that exploration for new reserves is quite sensitive to government legislation and new regulations which affect interest rates on capital, and timing. Projected trends could vary drastically in either a positive or negative sense, depending on steps taken by government. Federal designations of roadless areas could become a serious problem in the future as environmental groups attempt to have large segments of the Overthrust Belt designated off limits to motorized vehicles. Additional regulations affecting drilling procedures and exploration techniques also will add to drilling costs and eventually will lead to cutbacks in exploration effort. On the other hand, legislation decontrolling oil and gas prices would stimulate exploratory drilling efforts.

Oil Shale – Resource of the Future

Oil shale is in effect kerogen-rich marlstone. When heated to 900° F, kerogen can be distilled into a type of crude oil. It contains all of the ingredients normally found in crude petroleum; hence, it may someday become an important supplementary source.

Essentially all the potentially economic oil shale in the U.S. is contained in a relatively small area that includes parts of southwestern Wyoming, northwestern Colorado, and northeastern Utah. The deposits are extensive and have been investigated for their possible economic potential by many governmental and industrial organizations. Obviously, as the nation's supplies of oil and gas become more critical, interest in oil shale increases.

Unfortunately, the major problems related to commercial development of oil shale remain unsolved, although many hundreds of millions of dollars and an immeasurable amount of energy have been expended in research efforts. The richest and best known deposits are located near Rifle, Colorado, where industry is actively pursuing pilot plant operations.

Wyoming's oil shale occurs in the Green River Formation of Tertiary Eocene age (fig. 1). The richest deposits are in the central and eastern Green River Basin (fig. 2). Studies completed by the U.S. Bureau of Mines in 1972 and 1973 indicate potential yields of up to 25 gallons of crude per ton of rock for the richer portions of the oil shale sequence. However, the overall average for the sequence was only 10-15 gallons per ton.

To date, the Green River Basin deposits have not been fully evaluated, but general estimates run as high as 430 billion barrels of reserves in rock of 10 gallons per ton or more.

Development of Wyoming's oil shale appears to be many years in the future. Industry interest and efforts are now concentrated on Colorado where yields run as high as 25-65 gallons per ton, more than double the quality of Wyoming's oil shale. In 1974, the State of Wyoming offered two 1,280-acre tracts of the state's best oil shale land for lease and received no bids from industry. However, as petroleum reserves are depleted, economics and improved technology may dictate that Wyoming's deposits be developed.

TABLE 7. Northern Rocky Mountain area* refinery yields for 1976.

Product	Percent of Total Yield
Gasoline	49.1%
Distillate fuel oil	26.9
Residual fuel oil	8.2
Jet fuels	5.5
Asphalt	4.3
Still gas for fuel	2.5
Coke	1.6
Others	1.9
TOTAL	100.0%

*Includes Wyoming, Utah, Montana, and Colorado.

Source: U.S. Bureau of Mines, March 1977 petroleum statement.

TABLE 8. Breakdown of 1976 natural gas processing plant yields in Wyoming.

Type of Natural Gas Liquid	Percent of 1976 Production
LPG (includes butane, propane, etc.) and ethane	69%
Natural gasoline and isopentane	29
Plant condensates	2
TOTAL	100%

Source: U.S. Bureau of Mines, February 1977 petroleum statement.

TABLE 9. Distribution of total crude oil exported from Wyoming.

State	Annual 1975	Annual 1976
Illinois	17.3%	12.4%
Indiana	10.1	17.2
Kansas	19.7	19.5
Michigan	8.1	9.3
Missouri, Nebraska	1.1	1.0
Ohio (west)	4.2	4.1
Colorado	8.7	8.0
Montana	20.3	18.6
Utah	7.1	8.5
TOTAL	96.6%	98.6%

Source: U.S. Bureau of Mines, February 1976 and March 1977 petroleum statement.

Coal – the rebirth of an industry

Gary B. Glass

If Wyoming were a country, its one trillion tons of coal resources would rank it fourth in the world. To help visualize such a large resource, imagine that Wyoming is asked to provide all the energy needs of the U.S. Assuming that the nation continues to consume energy at the current rate of 74,000 trillion Btu's per year, the coal in Wyoming could sustain that rate of consumption for more than 240 years.

But in reality, anyone can justifiably argue that not all the state's coal is recoverable. Consider, then, that just 5 percent of one trillion tons of coal would still sustain an annual production rate of 100 million tons for 500 years. Literally, the present as well as many succeeding generations can no more than scratch the surface of Wyoming's colossal coal resource.

So where are Wyoming's vast coal deposits? Why are they so large? What have they meant to Wyoming, and what will they mean in the future?

Wyoming's Vast Coal Deposits

Coals are found in all the major basins of the state, as well as in the folded and faulted Overthrust Belt of extreme western Wyoming and in the Black Hills of northeasternmost Wyoming (fig. 7). The state's coal-bearing areas, which are variously called regions, basins, or fields, occupy more than 40,000 square miles, or approximately 41 percent of the state. More than half of the total resource is located in the Powder River Basin of northeastern Wyoming. Most of the remaining 500 billion tons are found in the Green River Region and Hanna Coal Field of southcentral Wyoming, in the Hams Fork Region of western Wyoming, and in the Bighorn and Wind River basins of northcentral and central Wyoming. Smaller deposits in the Jackson Hole, Rock Creek, and Goshen Hole Coal fields, as well as in the Black Hills region, complete the resource.

In all these coal-bearing areas, coals are found in rock sequences deposited during either the Cretaceous period (66-135 million years ago) or during the more recent Tertiary period (38-66 million years ago). The most widespread coal-bearing rocks in Wyoming are Cretaceous in age and usually crop out as narrow bands of upturned rock around the margins of the basins and the margins of uplifted areas of the state. These same rocks lie thousands of feet deep in the central portions of the basins. Cretaceous rocks also crop out as irregular, linear bands in the Overthrust Belt. Relatively flay-lying, thick sequences of Tertiary rocks, on the other hand, occupy the central portions of most coal-bearing areas, where they overlie the older Cretaceous rocks.

Approximately half of Wyoming's estimated coal resource lies between 1,000 and 6,000 feet below the surface. An unestimated resource lies even deeper. At present, only a portion of the mapped and explored resources under less than 1,000 feet of cover are considered economically recoverable (table 10). For this reason, only 7 percent of Wyoming's total resource, or 53 billion tons, is officially regarded as minable. This estimate is very conservative and will probably double or triple in the next five years as new reserves are identified by geologic studies. New reserves, incidentally, continue to be found much faster than the older reserves are depleted. For example, in 1977 the U.S. Geological Survey delimited 1.8 billion tons of previously undescribed strippable coal reserves in the northwestern corner of the Powder River Basin. This single new strippable deposit contains three times more coal than the entire state has produced after more than 116 years of mining.

Geologic Origin

In the geologic past, conditions remained conducive to the growth of densely vegetated swamps over large expanses of the state for nearly 100 million years, thus allowing time for the accumulation of Wyoming's significant coal deposits. But the question might be asked, "How could swamps similar to those on the lower Mississippi River Delta or the Florida Everglades exist in Wyoming?"

Obviously, they don't today. But Wyoming's present topography and climate bear little resemblance to conditions 38-135 million years ago when the coals were deposited. The state's large basins and intervening mountain ranges did not begin to take shape until the end of Cretaceous time, about 66 million years ago. During the Cretaceous period, the nearest mountains were west of the state in Utah and Idaho. All of Wyoming was a low, flat area covered by an inland sea. Periodically, the sea would retreat northward or eastward, allowing rivers to flow through coastal swamps and marshes that followed the retreating shoreline.

In these coastal swamps and marshes, dying trees, grasses, and reeds continually sank to the bottom where swamp waters prevented their destruction. Year after year, the dead vegetation accumulated. Eventually, the sea returned and flooded the coastal swamps, causing the shoreline to retreat westward.

This cycle was repeated time after time, the shoreline shifting and returning, converting the flooded portions of the coastal swamps into peat as they were buried by mud and sand. While the weight of these added sediments compressed the peat beds, heat associated with increasing depth of burial transformed the peat into coal. The final result was a thick sequence of rock, which consists of relatively thin layers of coal separated by various thicknesses of intervening sandstones and shales.

The origin of Wyoming's Cretaceous coals is very similar to the formation of older coals found in the Appalachian and midcontinent coal fields of the U.S. Like the older Pennsylvanian age coals (270-310 million years old) of these eastern

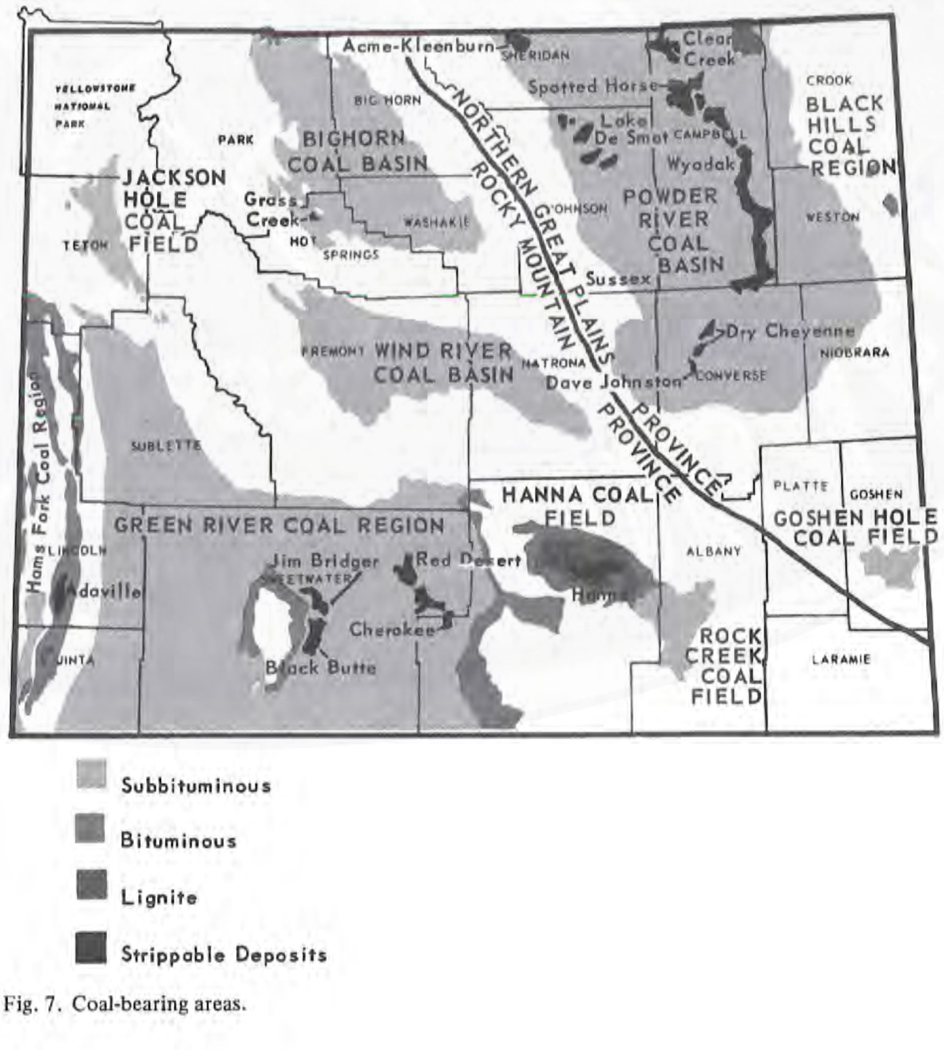


Fig. 7. Coal-bearing areas.

TABLE 10. Estimate of Wyoming's remaining coal resource and reserve base to January 1, 1978 (millions of tons).

Categories of Original Resource	Mapped and Explored Areas (0-3000 ft. of cover)	Mapped and Estimate of Unexplored Areas (0-6000 ft. of cover)
Original resource[1]	136,891.43	936,891.43
Production from deep mining[2]	386.05	
Production from strip mining[2]	210.61	
Total production	596.66	596.66
Losses due to deep mining (equals production)	386.05	
Losses due to strip mining (20% lost)	42.12	
Total production and mining losses	1,024.83	1,024.83
Remaining resources	135,866.60	935,866.60
Underground reserve base[3]	29,487.75	
Strippable reserve base[3]	25,516.20	
Total reserve base[3]	55,003.95	

[1] Source: U.S. Geological Survey and U.S. Bureau of Mines.
[2] Source: U.S. Geological Survey, U.S. Bureau of Mines, and Wyoming State Inspector of Mines.
[3] Minable portion of the total resource; modified from U.S. Bureau of Mines' estimates.

TABLE 11. Coal production by states (thousands of tons).[1]

Western States	1974	1975	1976[P]
Alaska	700	766	706
Arizona	6,448	6,986	10,242
Arkansas	455	488	598
Colorado	6,896	8,219	9,248
Iowa	590	622	522
Kansas	718	479	698
Missouri	4,623	5,638	5,415
Montana	14,106	22,054	26,106
New Mexico	9,392	8,785	9,784
North Dakota	7,463	8,515	11,119
Oklahoma	2,356	2,872	3,299
Texas	7,684	11,002	14,215
Utah	5,858	6,961	7,880
Washington	3,913	3,743	4,111
WYOMING	20,703	23,804	31,086
Subtotal	91,905	110,934	135,209
Eastern States			
Alabama	19,824	22,644	21,605
Georgia	--	74	72
Illinois	58,215	59,537	57,974
Indiana	23,726	25,124	24,136
Kentucky	137,197	143,613	140,000
Maryland	2,337	2,606	2,695
Ohio	45,409	46,770	45,484
Pennsylvania	80,462	84,137	83,654
Tennessee	7,541	8,206	8,755
Virginia	34,326	35,510	36,765
West Virginia	102,462	109,283	108,863
Subtotal	511,501	537,504	530,003
TOTAL UNITED STATES	603,406	648,438	665,212

[1] Source: U.S. Bureau of Mines
[P] Preliminary

and central states, most Cretaceous coals in Wyoming are seldom more than 10 feet thick. Notable exceptions are some 30 to 100 feet thick Cretaceous coals mined near Kemmerer in westernmost Wyoming.

Coal-forming conditions during Tertiary time, which began 66 million years ago, were significantly different from those in the earlier Cretaceous period. By then, the rudiments of Wyoming's present geography had taken form. The Cretaceous seaway had disappeared as the entire region was uplifted. Various ranges of the Rocky Mountains rose to form intervening basins that filled with debris from the very mountains that partitioned them off. Within these enclosed or semi-enclosed basins, freshwater swamps and marshes formed adjacent to meandering rivers, and along the shores of lakes.

In these gradually filling basins, peat accumulations, which were periodically buried under floodplain sediments, were much thicker than most accumulations left by the coastal swamps of the Cretaceous. This is evidenced by the fact that Tertiary age coals often exceed 10 feet in thickness, with 30-100 feet thick coals common. Locally, at least one Tertiary coal reaches 220 feet in thickness. Even on a worldwide scale, Wyoming's thick Tertiary coals are nearly unique.

A second reason for Wyoming's large coal resource is thus apparent. Many of the state's coals, particularly Tertiary age coals, are unusually thick. A single acre of land underlain by a coal bed 100 feet thick contains about 177,000 tons of coal. It stands to reason that resources very quickly total into the billions of tons when virtually hundreds of thousands of acres are underlain by coals of such thickness. Couple these exceptionally thick coal resources with an uncounted number of coals of more conventional thickness, and it becomes clear that one trillion tons may still be a conservative estimate of coal in Wyoming.

Wyoming's Coal Industry

Although it is probably still debatable whether coal brought the railroad to Wyoming or whether the railroad merely triggered coal mining activity, the result was the same: coal became Wyoming's first significant mineral industry. Large-scale underground coal mining began in the late 1860's even before the first transcontinental railroad was completed. Many Wyoming towns owe their existence as much to the coal industry as to the railroad. Railroads that crossed the state remained the dominant users of Wyoming coal for more than 90 years. It wasn't until the 1950's that Wyoming's first coal era ended, almost as abruptly as it had begun.

By then, diesel engines had replaced obsolete steam locomotives. This conversion crushed not only Wyoming's coal industry but also many of the smaller towns dependent on the mines that had supplied fuel to the railroads. Annual production in 1958 slumped to 1.6 million tons, far below the traditional railroad demands of 6-9 million tons. Similarly, the number of coal miners, usually more than 4,000, had dwindled to a few hundred.

Coal mining in the state continued to struggle for more than a decade. Then in the late 1960's, demands for low sulfur coal to fuel power plants provided a new market that not only revived the state's coal industry but also surpassed all previous demands. In the last decade, Wyo-

TABLE 12. Selected coal characteristics.

Geographic Area	Rank	Bed Thickness (feet)[1]	Average (As Received Basis)[1] Moisture (%)	Ash (%)	Sulfur (%)	Heat Value (Btu/lb.)
Northeastern Wyoming	Subbituminous	Range: 12-125 Avg.: 70	26.3	7.9	0.5	8,300
Southern Wyoming	Subbituminous	Range: 4-35 Avg.: 20	12.4	7.1	0.5	10,500
Western Wyoming	Subbituminous	Range: 5-90 Avg.: 16.5	20.8	4.5	0.6	9,600
Eastern Kentucky	Bituminous	Range: 2-6 Avg.: 3.5	4.1	6.2	1.1	13,400
Northwestern West Virginia	Bituminous	Range: 3-15 Avg.: 4	3.1	7.0	2.2	13,800
Southeastern Illinois	Bituminous	Range: 3-8 Avg. 4	15.0	8.0	3.5	11,000

[1]Coal beds currently mined

TABLE 13. Wyoming coal production by mine.[1]

Company	Mine Name	Employees 1976	Production 1976	Employees 1977	Production 1977
Amax	Belle Ayr (strip)	224	7,233,000	339	13,303,000
Arch Mineral	Seminoe No. 1 (strip)	160	2,715,723	174	2,242,137
	Seminoe No. 2 (strip)	100	2,660,931	232	2,543,900
Ash Creek Mining	PSO No. 1 (strip)	–	–	23	Under Construction
Big Horn	Big Horn No. 1 (strip)	100	730,678	132	2,394,532
Black Butte	Black Butte (strip)	–	–	16	Under Development
Bridger	Jim Bridger (strip)	129	3,567,058	196	5,448,953
Carter Mining	Rawhide (strip)	191	Under Construction	131	1,096,240
	Caballo (strip)	–	–	129	Under Construction
Columbine Mining	Rainbow No. 8 (deep)	94	119,086	102	6,377
Dusky Diamond	Grass Creek (strip)	2	1,686	1	1,607
Energy Development	Vanguard No. 2 (deep)	220	303,155	231	387,936
FMC	Skull Point (strip)	78	84,524	60	718,789
Kemmerer	Elkol (strip)	169	1,845,658	183	1,654,409
	Sorensen (strip)	285	2,276,799	313	2,730,656
Kerr-McGee	Jacobs Ranch	–	–	106	Under Construction
Medicine Bow	Medicine Bow (strip)	152	2,773,856	183	1,200,000
NERCO	Dave Johnston (strip)	132	2,714,326	133	3,236,616
Prospect Point	Commercial stockpile and tipple	–	–	12	Unknown
Resource Exploration	Rimrock (strips)	82	829,372	82	1,017,003
Rosebud Coal Sales	Rosebud (strips)	165	2,270,894	197	2,806,239
Stansbury	Stansbury (deep)	82	101,652	135	230,000
SUNEDCO	Cordero (strip)	66	10,338	56	2,128,545
Thunder Basin (ARCO)	Black Thunder (strip)	41	Under Construction	110	42,865
Welch	Welch (strip)	2	8,640	0	CLOSED
Wyodak Resources	Wyodak (strip)	37	838,216	38	857,038
	TOTAL	2,511	31,085,592	3,314	44,046,842

[1]Source: State Inspector of Mines

ming has catapulted from one of the smallest to the sixth largest of 26 coal-producing states in the nation (table 11). Since 1969 alone, annual production has increased more than ninefold – from 4.6 million tons to more than 44 million tons in 1977 – about 6 percent of total U.S. production.

As mentioned earlier, Wyoming's expanding coal industry is meeting new needs of power plant customers. Whereas the railroad judged a coal by its heat value, utility companies judge a coal by its sulfur content. Utilities must burn low sulfur coals to keep sulfur dioxide emissions in compliance with new air quality standards. To meet this demand for low sulfur coal, industry interest has shifted from Wyoming's bituminous coals with high heat values to subbituminous coals with lower heat values; but most importantly, these subbituminous coals have much lower sulfur contents, often averaging less than 0.5 percent sulfur. The low sulfur content of Wyoming coals, which usually have four to six times less sulfur than eastern and midcontinent coals, allows them to compete even though the heat values of Wyoming coals are 1,800-4,000 Btu's less per pound (table 12). Wyoming's coals also contain lower concentrations of various toxic elements than many other U.S. coals.

Because subbituminous coals occur in close proximity to bituminous coals in southern and western Wyoming, many traditional mining districts are about where they were during the railroad era. The big difference is unparalleled activity in the subbituminous coal fields of the Powder River Basin of northeastern Wyoming; in particular, the coal deposits of Campbell County. The low sulfur Wyodak-Anderson coal bed of that region, which is 25-125 feet thick, suddenly has come into its own. Almost ignored for more than a century of mining, production from that coal bed alone now ranks Campbell County first in the state. Even more spectacular, production from the Wyodak-Anderson coal bed will account for more than 70 percent of the state's annual production by the 1980's.

Along with this change in demand came a change in mining technique. The underground mines of the railroad era were replaced with substantially larger strip mines, most of which now produce in excess of two million tons each year (table 13). Because of the size of these mines, four strip mines accounted for more than 50 percent of the state's production in 1977. Strip mines as a group now produce 99 percent of Wyoming's annual tonnage. Wyoming also can lay claim to the largest strip mine in the U.S., since Amax Coal Company's Belle Ayr mine, which produced 7.2 million tons in 1976, increased production to 13.3 million tons last year.

In northeastern Wyoming, shallow overburden and flat-lying, thick coals allow most strip mining companies to use electric power shovels for both overburden and coal removal. The buckets on some of these shovels can lift up to 44 tons of coal. Large shovels such as these are dominant, since these machines must often load from coal faces over 70 feet high. In contrast, the dipping, thinner coals of southern Wyoming require electrically powered draglines for overburden removal (fig. 8). These medium-sized draglines have huge 70-130 ton capacity buckets dangling from booms the length of football fields. Coal is then loaded with power shovels or smaller

Fig. 8. Typical strip mine in southern Wyoming. (In the background note the dragline removing overburden.)

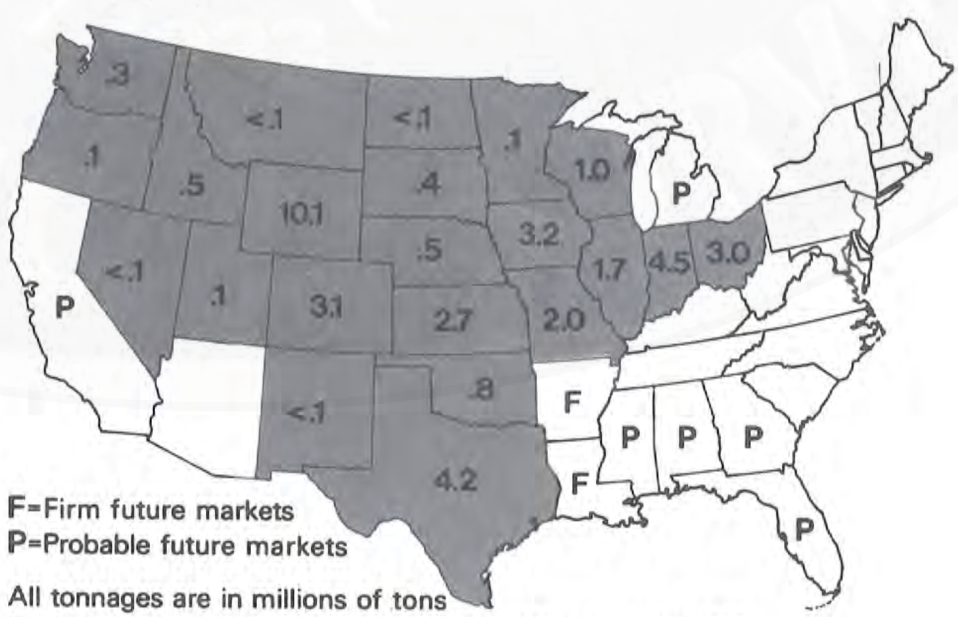


Fig. 9. Estimated distribution of marketed tonnages of Wyoming coal in 1977.

front end loaders. Unique open-pit techniques are applied in the mines of western Wyoming where each mining operation removes numerous, closely spaced, steeply dipping coal beds. Shovels, draglines, and scrapers are used to dig the deep, multiple-terraced pits common to that mining technique.

In most Wyoming strip mines, 100 to 150-ton dump trucks or bottom dump trailers transport coal from the mine to the loadout or tipple areas. At the tipples, Wyoming companies limit processing to occasional blending and more or less routine crushing operations. Where blending is necessary to satisfy contract specifications, selective mining of a single coal bed or several beds allows blending at the truck dump areas. Crushers then reduce the coal to sizes that are optimal for railroad loading and shipment. Because of the large mine capacities and the need to minimize transportation costs, most coal companies are installing elaborate, 190-feet high concrete silos that hold 10,000-12,000 tons of coal. A silo like this can load an 11,000-ton unit train in several hours as the train passes through a tunnel in the base of the silo.

The few active underground mines in the state, which are small even by western standards, are nevertheless at least partially automated with machines called continuous miners. These electrically powered machines have rotating drums armed with carbide teeth that literally rip the coal loose as the machine is driven against the exposed face of a coal bed. Shuttle cars then move the coal to conveyor belts that carry it through the mine to tipples outside the mine entrance.

All Wyoming mines, and particularly the strip mines that sell coal on the open market, use equipment and techniques that keep mining costs to an absolute minimum. This has become increasingly important since mining costs must remain low enough to offset the high transportation costs of moving Wyoming coal to distant markets. For example, coal in the Powder River Basin, which sells for $5 to $7 a ton at the mine, costs some utility companies between $15 and $20 a ton by the time it reaches its destination. Similarly, coal selling for $8 to $18 a ton in southern Wyoming costs some companies $19 to $24 a ton when it is delivered.

Along with production, the number of miners also has increased from a few hundred in the 1960's to 3,314 in 1977 – more than a tenfold increase. Although this is only about three-quarters of the average work force of the railroad era, the productivity advantage of strip mines

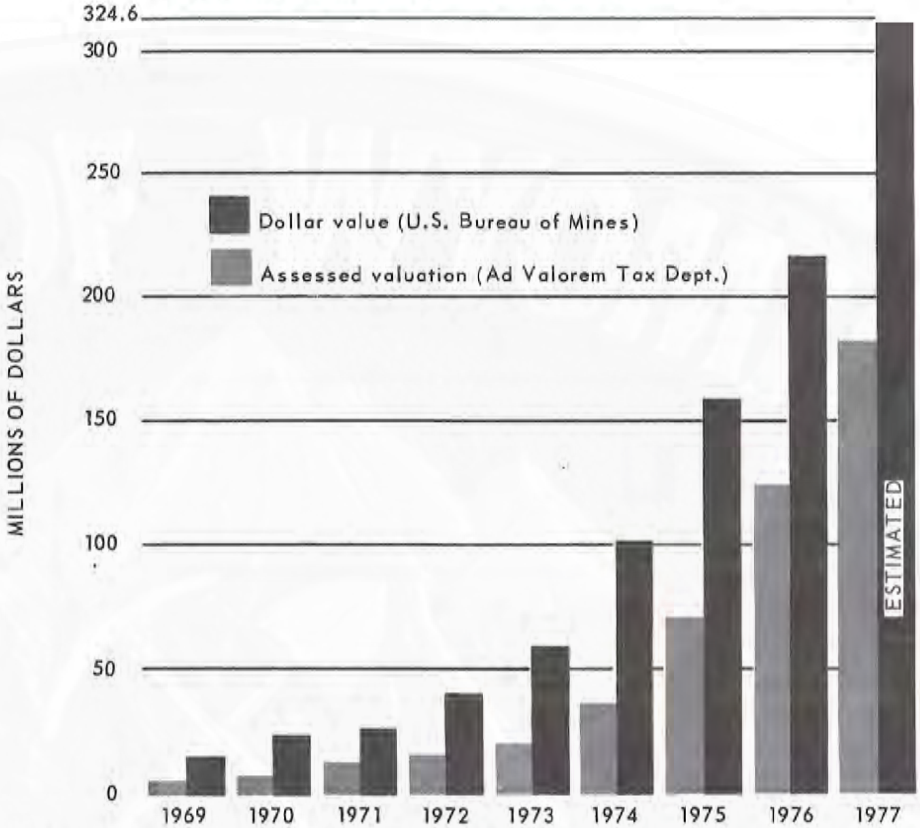


Fig. 10. Dollar value and assessed valuation of Wyoming coal, 1969-1977.

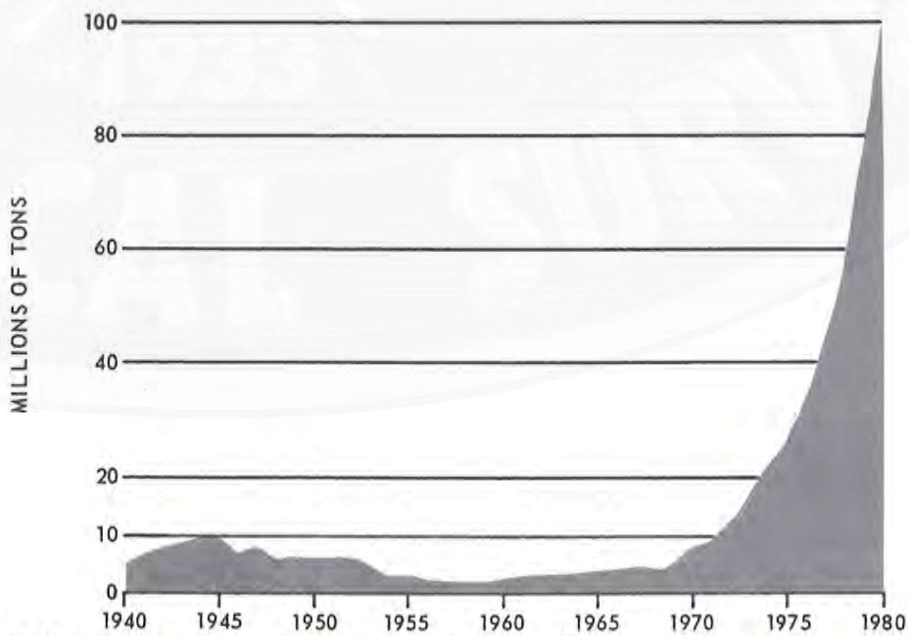


Fig. 11. Annual Wyoming coal production with forecast to 1980.

over deep mines enables modern miners to produce four times more coal per year than the peak production of that past era. In fact, this productivity advantage has increased steadily. Productivity already has gone from about 11,000 tons per man in 1971 to an estimated 13,300 tons per man in 1977 – a 21 percent increase. In contrast, Wyoming's deep mine productivity has remained below 2,000 tons per man for many years.

About 67 percent, or 29.9 million tons, of the coal mined in Wyoming now goes to power plants in at least 19 other states, located as far west as Washington, as far south as Texas and Oklahoma, and as far east as Indiana, Illinois, and Ohio (fig. 9). Another 26 percent, or 11.3 million tons, is burned in Wyoming power plants. Industrial customers use the remaining 7 percent. The beet sugar, cement, and phosphate industries are the major out-of-state industrial users, with about 0.8 million tons shipped to various plants throughout the Rocky Mountain region. Another 2.1 million tons is used to manufacture trona, cement, and synthetic coke in Wyoming.

In terms of dollar value, Wyoming's coal industry has grown from a $27.3 million industry in 1971 to one valued at more than $324 million in 1977 – almost a twelvefold increase (fig. 10). Taxes, royalties, and rentals also have increased. In 1976, coal companies paid over $14,690,000 to the State of Wyoming in the form of state taxes, rentals and royalties on state lands, and federal royalty income to Wyoming. These contributions were equivalent to 8 percent of the total taxes, royalties, and rentals paid by the mineral industry and rank coal second only to the oil industry. Last year, coal's contributions exceeded $32.8 million, which increased coal's share of mineral revenues to 14 percent of the mineral industry.

In a different vein, the impending new coal era first prompted the Wyoming legislature to pass the Open Cut Reclamation Act of 1969. This act, administered by the State Land Board, was Wyoming's first mining and reclamation law. In 1973, the legislature enacted the Wyoming Environmental Quality Act, which among other things created a Department of Environmental Quality with air, water, and land divisions. The act also rescinded the Open Cut Reclamation Act of 1969 and transferred responsibility for mining and reclamation to the new department's Division of Land Quality.

In short, the administrator of the Division of Land Quality has the authority to grant, deny, or revoke mining permits and licenses, to implement and enforce rules and regulations, to invoke penalties for noncompliance, to set and collect performance bonds, and to reclaim land if bonds are forfeited. In regard to permits and licenses, all surface and underground mines in Wyoming require a mining permit, even mines that extract minerals and rocks other than coal. Each application requires several volumes of legal and technical information, including maps and mining and reclamation plans. Permit applications are advertized for four consecutive weeks and can be taken before public hearings if any written objections are made. Written consent or waiver by a surface owner is also necessary before a mining permit is granted. While a mining license is required for each separate mining permit, a similar license is required for exploration activities that use bulldozers. Additionally, the act required all companies with valid permits under the old 1969 law to modify their older permits to conform with new requirements.

Minimum reclamation standards require: restoration of mined lands to a use equal to or greater in value than before mining; a schedule of reclamation activities; stockpiling and reuse of topsoil; prevention of water pollution, erosion, landslides, acid water, and flooding; and revegetation of affected lands. Failure to comply with these regulations can result in stiff fines and even imprisonment.

By law, mine operators must provide estimates of reclamation costs. The Land Quality Division then sets performance bond requirements high enough that the state can reclaim affected lands if the bonds are forfeited. At the conclusion of mining, no less than $10,000 is held for a minimum of five years in case revegetation is unsuccessful. As an additional precaution, the 1973 act prohibits a company from mining in Wyoming if it ever forfeits a performance bond.

Forecasts of Future Development

Wyoming coal production is expected to more than double in the next three years, going from 44.1 million tons in 1977 to an estimated 100 million tons by 1980 (fig. 11). By 1985, annual production should top 125 million tons, about 12 percent of the predicted national tonnage for that year.

Just three years from now, Wyoming could have more than 30 operating coal mines, compared to the 20 mines on line in 1977 (fig. 12). There could be more than 50 mines by 1985. Most of these new operations would be strip mines, with an average large mine producing about six million tons per year. Even by 1980, each of the state's three largest mines could easily strip 10-20 million tons annually. By comparison, only three strip mines in the nation mined more than eight million tons in 1977.

Miners' ranks will grow to well over 4,000 by 1980. By 1985 there could be over 6,000 coal miners in the state. Even with substantial increases in numbers of employees, strip mine productivity will continue to increase into the 1980's when productivity should exceed 35,000 tons per man – 15-20 times the productivity of deep mines.

Additional markets will include power plant or industrial customers in Louisiana, Mississippi, Arkansas, Oregon, and possibly Alabama, Georgia, Florida, California, and Arizona.

Although it is difficult to project dollar value, the next three years could see Wyoming's coal industry grow to a $600-$700 million business. To reach this level, coal prices need not exceed the $7.37-per-ton average that was achieved in 1977. Carrying this same average price into the future, a $1 billion industry could be a reality before 1985.

If taxable valuation of coal remains at an estimated 67 percent of its dollar value, taxes (which are now equal to about 16 percent of the taxable valuation) would be almost $68 million by 1980. Since taxes will undoubtedly continue to increase, this tax estimate is conservative. It is difficult to project what royalties and rentals may be in the 1980's; but without doubt, they will be substantially larger than at present.

Of course, forecasts such as these are easy to make but difficult to substantiate. Already, the optimism of 1976 has been tempered, especially as a result of various government actions. Working under the assumptions that enough federal coal is already under lease and that many leaseholders have been remiss in developing existing leases, U.S. Department of Interior officials may continue a seven-year-old leasing moratorium for another four or five years. Since the federal government controls more than 70 percent of the coal resource in Wyoming, this moratorium has great significance. Even now, it threatens cancellation or prolonged delays for some proposed mines and possibly even the closing of a few active ones.

The effects are particularly noticeable in portions of southern Wyoming where the federal government controls every other section of land. Companies that have proposed mines in these "checkerboard" lands insist the intervening federal sections are essential for efficient mines and maximum coal recovery. Without federal leases, many of these companies may scrap their plans. The moratorium also has hindered many newcomers from acquiring sufficient reserves in Wyoming to open mines.

While opponents of the federal leasing moratorium admit that some leaseholders are unwilling to develop existing leases at this time, they also point out that many such leases simply do not contain any economically recoverable coal. Opponents also insist that if Washington is indeed serious about expanding development of coal to offset anticipated shortages of other fuels, federal leasing must be resumed. They claim that the U.S. Department of Energy's Western Monitoring System, (a program which identifies productive capacities of 146 million tons per year by 1980 and 260 million tons per year by 1985 for Wyoming mines) doesn't make clear how much of the projected capacity hinges on new, rather than existing, federal leases. Opponents of the moratorium stress that these capacities are not obtainable without resumption of federal coal leasing. Even with the resumption of federal leasing, they say, previous delays already have made proposed start-up dates of many mines unattainable.

Big Horn No. 1 strip mine north of Sheridan, Wyo. Collectively the Monarch and Dietz coal beds are 44 feet thick at this mine. (Wyoming Geological Survey Photo)

The use of giant machines, like this massive shovel, help make the recovery of coal from strip mines economical. (S.T. Mast Photo)

Even officials of the Department of Interior realize that some federal coal leasing is still warranted. There are many small unleased federal coal tracts adjacent to large existing or proposed mines. These small tracts are only minable as part of the larger mining units. If such lands are not leased and mined while the larger mines are active, the future value of those lands will greatly diminish or disappear entirely. Denying the lease of such lands to diligent, compliant companies makes little sense from either an economic or conservation point of view. But the Department of Interior's short-term leasing regulations, which are supposed to permit leasing under these conditions, are in serious jeopardy. Already, one court decision has seriously impaired the original intent of the regulations.

Other federal actions also have had an effect on Wyoming coal development. In particular, there have been delays in the granting of federal mining permits on existing leases. These delays have had a much more immediate effect than the leasing moratorium. Production in 1976 was almost three million tons below expectations. Production in 1977 was off by about 7 million tons. Similarly, estimated annual tonnages must be lowered for at least another two years. Nearly all these shortfalls are easily traced to delayed federal mining permits, which in turn were delayed by the writing of environmental impact statements or by litigation after the statements were completed. In a few cases, similar actions directed at power plants have prevented or delayed construction, thus setting back market demands.

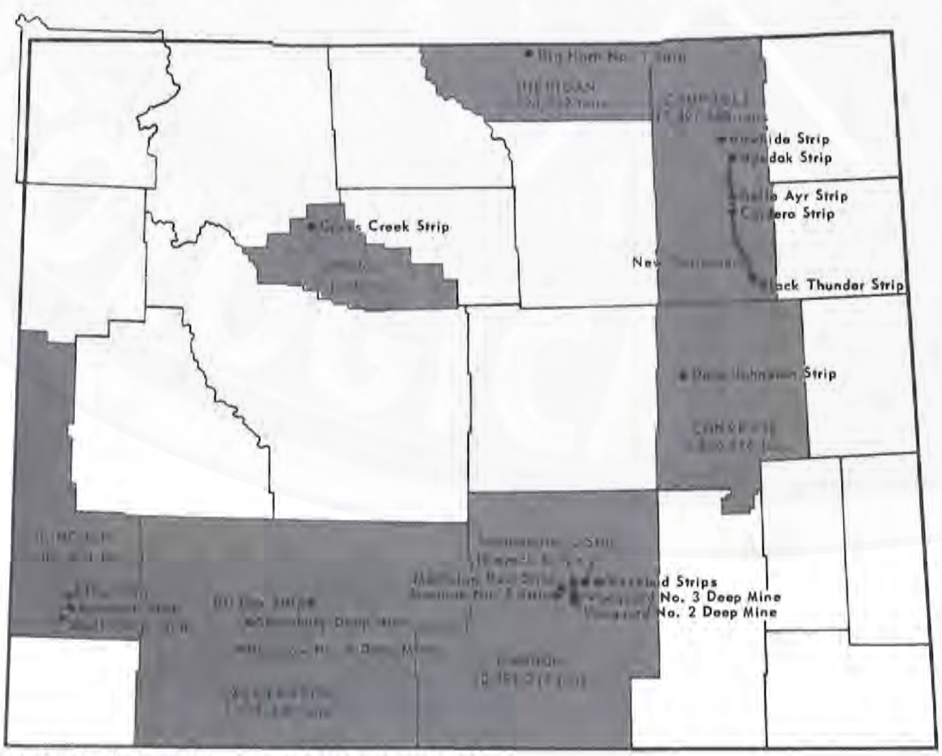
There are still other actions that may have an even more serious impact on Wyoming's coal industry. Coal-producing states in the central and eastern portions of the U.S. are pushing for laws that would destroy the marketability of western coal in their states. One such law would place an import tax on western coal. Another approach would prevent utilities from passing increased transportation costs along to the consumer. Similarly, a bill was introduced in the U.S. Congress that would have forced utilities to burn only locally available coals. Besides these actions, there is a good possibility that the federal government will require all power plants to install sulfur dioxide removal systems, called scrubbers. Especially in Wyoming's more distant markets, scrubbers will eliminate the advantage of using low sulfur western coals.

Despite some rhetoric to the contrary, there is also a growing conviction among many industry, government, and private observers that the Carter Administration wants to promote increased coal production east of the Mississippi River at the expense of western production. Persons who have reached this conclusion point out that the jobless, as well as the votes, are in this area and not in the West. They also note that Wyoming's predicted coal conversion industry has simply disappeared for the time being at least, partially because the federal government is no longer promoting coal gasification plants in the West.

Perhaps the one single observation that lends more support to growing pessimism than any other is a widening disparity between mine capacity and contracted tonnage; that is, tonnage for which there is a signed contract. In 1976, the estimated difference between contracted tonnage and mine capacity was 75 million tons for 1980 and 160 million tons for 1985. By 1977, U.S. Department of Energy figures, which reflected delayed openings and postponed plans of many mines, still showed an estimated difference of 43.6 million tons for 1980 and 116.2 million tons for 1985 (fig. 13). Although some of this disparity might be attributable to overly optimistic company goals, there is still enough difference to suggest that market demand has slackened and that companies cannot find buyers for all their reserves.

Regardless of one's personal view of the slowed pace of coal development, the result is a particularly ironic situation. At the very time the nation is supposedly striving to meet the goal of energy independence, federal actions are helping to keep from development a large portion of the energy needed to meet that goal.

On the other hand, one can point out that 10 years ago the forecast for Wyoming's coal industry was more than bleak: it was grim. By 1972, optimism prevailed and the sky was the limit. Today's somewhat pessimistic forecast is still between those extremes and certainly does not appear dismal. For instance, today's forecasts still show the state outproducing all states west of the Mississippi well into the 21st century. Wyoming, which now accounts for 26 percent of total western production, should produce at least 40 percent of forecast tonnage for 1985. By then, projections show the western



NOTE: The 1977 tonnage from each coal-producing county is shown.

Fig. 12. Active Wyoming coal mines in 1977.

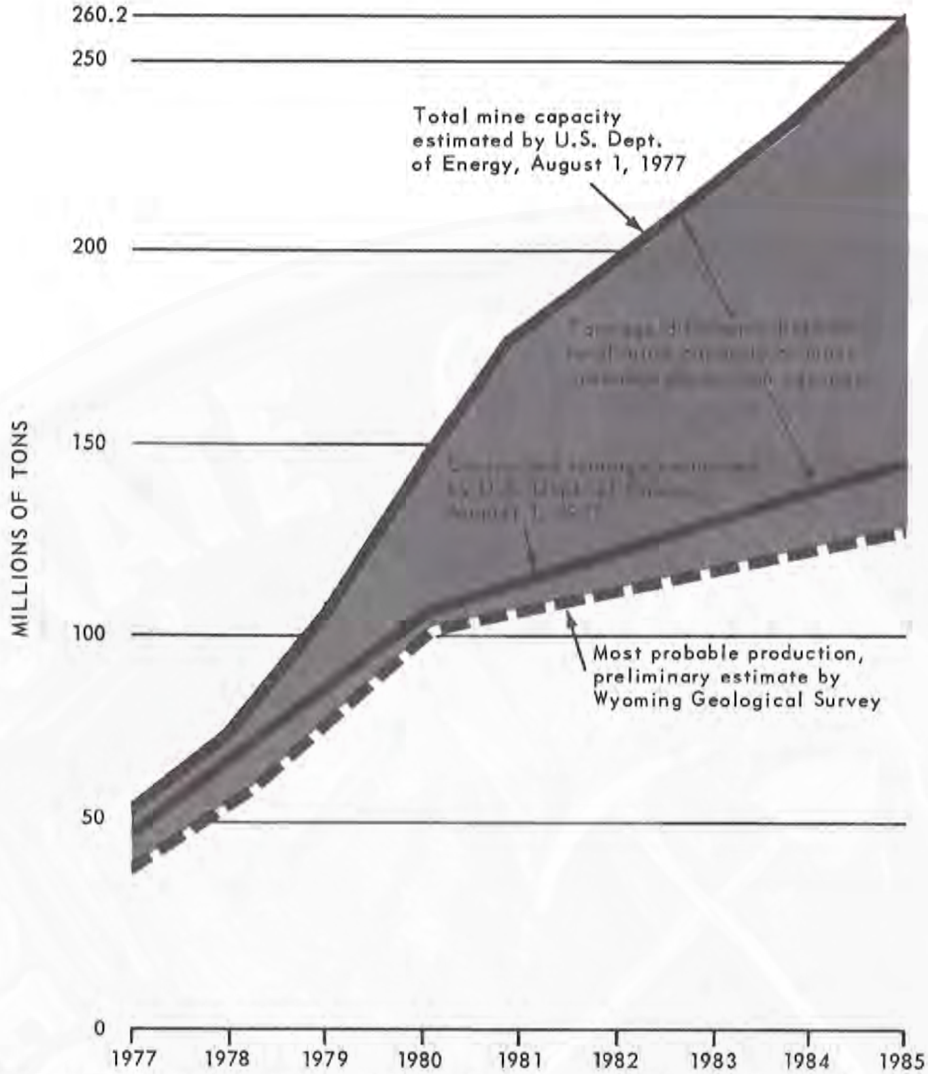


Fig. 13. Forecast mine capacity and estimated annual coal production for Wyoming, 1977-1985.

states mining 377 million tons per year, or 34 percent of the national output, as compared with 20 percent in 1976.

Present and future markets for Wyoming coal also temper today's pessimism. Besides the burgeoning power plant market that continues to consume record amounts of Wyoming coal, industrial markets have gained as well. Granted, the once-imminent coal conversion industry is temporarily shelved, probably into the 1990's. But the state inevitably will play a significant part in that industry simply because of the coal that is located here. Someday, synthetic gases and liquids will be made from Wyoming coal; and perhaps in cleaner, more efficient second or third generation plants.

Looking even further into the future, in situ gasification, researched in Wyoming since 1971, will someday become viable. When that day arrives (and it is admittedly many decades off), underground gasification will convert an even greater percentage of Wyoming's trillion tons of coal into usable energy. One can even imagine coal used as a petrochemical feedstock, since all the many products now made from petroleum also can be made from coal.

Considering all the ways coal could be used, if Wyoming coal development is properly planned and regulated with an eye to the future, the industry should last for many hundreds, perhaps even thousands of years.

Wyoming's economic prospects

W. Dan Hausel

Trona – The Mineral of Many Uses

In 1938, Mountain Fuel Supply Company drilled an oil and gas test well northwest of Green River, Wyoming that resulted in the discovery of trona, a water-bearing, sodium bicarbonate compound with many industrial uses. Since then, geologists have been piecing together a puzzle in order to explain the distribution and geological origin of what later were determined to be the world's largest deposits of natural soda ash.

Geological Setting

Nearly 45 million years ago (fig. 1), trona was precipitated from the waters of Lake Gosiute, an enormous lake which at one time covered over 15,000 square miles in southwestern Wyoming. For millions of years, climatic changes caused the lake to expand and contract in size and eventually to evaporate completely. Since then, the bottom sediments and chemical precipitates have been compacted and lithified to form more than 2,000 feet of rock. Geologists have named these rocks the Green River Formation.

It is now known that the lake sediments were deposited in three distinct episodes, or stages. In the initial stage, Lake Gosiute advanced until it flooded more than 12,500 square miles of surface area. At one time, the lake would have covered the present town sites of Green River and Rock Springs, with its shores extending north to within 10 miles of Big Piney and south into Utah and Colorado. To the west, the shores would have extended to within 10 miles of Kemmerer and to within 20 miles of Evanston; to the east, the shores would have come to within a few miles of Creston Junction.

Climatic changes initiated the Wilkins Peak stage, the episode of significant trona deposition. As precipitation declined, the shores of Lake Gosiute began to withdraw. As the volume of water in the lake diminished, the water became increasingly saline as a result of brine concentrations derived from the leaching of sodium-rich minerals. The localization of trona-rich brines in the southwestern portion of the lake suggests that this area was isolated from the rest of the lake by a feature of low relief and probably received less fresh water from stream runoff.

During the Wilkins Peak stage, there were several periods of evaporation and reflooding. At the lowest evaporitic levels, trona, common salt, and calcareous mudstone were deposited as separate layers. On the other hand, each time that the lake was reflooded with fresh water, oil shale and calcium carbonate were deposited.

At the close of the Wilkins Peak stage, Lake Gosiute expanded to its greatest extent and the period of trona deposition was finally ended.

Reserves and Production

The deposition of trona in Lake Gosiute produced the world's largest reserves of natural soda ash. More than 40 beds of trona underlie a surface area of about 1,300 square miles. Fifty billion tons of minable trona reserves and an additional 30 to 40 billion tons of marginal trona are estimated to be contained in these beds. Some higher estimates by the U.S. Geological Survey suggest that as much as 100 billion tons of trona lie within the Green River Basin.

Wyoming presently produces nearly 95 percent of the nation's supply of natural soda ash. In 1977, 11.3 million tons of trona were removed from Wyoming's underground mines (fig. 14). Although several deposits of natural soda ash are known in the western U.S., only Wyoming and California have active mines.

Mining and Processing

All trona mining is done underground. Panel mining predominates, with some minor room-and-pillar, and longwall mining. Both continuous mining equipment and conventional blasting are used to remove the ore. Through the years, extensive mining at the FMC Corporation mine has produced over 40 million tons of trona. In order to remove the ore, nearly 1,500 miles of drifts and tunnels were constructed beneath 12 square miles of land. This would be essentially equivalent to tunneling three-eighths of the distance to the earth's center!

In the past, soda ash was primarily produced synthetically by the Solvay Process. This process combines sodium chloride (common salt) and calcium carbonate (limestone) to make sodium carbonate (soda ash). With the rising cost of fuel, most plants producing synthetic soda ash could not compete with the natural soda ash plants in Wyoming and California and have closed permanently. Only three Solvay plants are still operating in the U.S., with one scheduled to close in May 1978.

Crude trona as mined contains about 38 percent sodium oxide, 33 percent carbon dioxide, 20 percent water, and 9 percent water-insoluble minerals. To produce usable soda ash from crude trona, the ore must be refined.

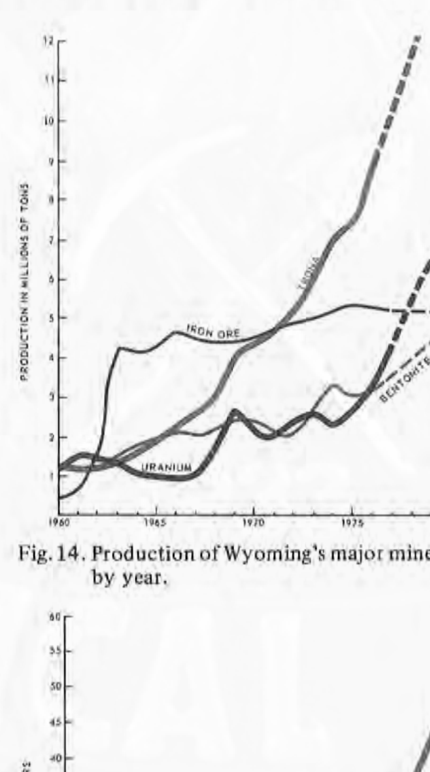


Fig. 14. Production of Wyoming's major minerals by year.

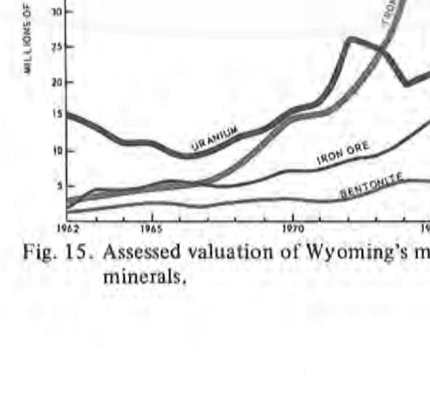


Fig. 15. Assessed valuation of Wyoming's major minerals.

In the first step of refining, trona is converted to crude soda ash by applying intense heat (200°C) to remove water of crystallization, combustible materials, and carbon dioxide. Next, the crude soda ash residue is taken into solution and filtered to remove insoluble materials. It is then dried. The final product from this process is refined soda ash.

In addition to soda ash, several other chemicals are produced at some mine sites. The Church and Dwight pilot plant produces sodium carbonate monohydrate (water softener) and sodium bicarbonate (a specialty chemical). FMC also produces tripolyphosphate, an ingredient in many detergents.

Uses

The soda ash chemicals are transported by railroad to various regions of the U.S. for use in the manufacture and treatment of many products. About 73 percent of the soda ash market is in states east of the Mississippi River, with primary buyers in the Indiana and Ohio glass-producing area. Of the remaining market, approximately 15 percent is in the Midwest and about 12 percent is in the western U.S. According to the U.S. Bureau of Mines, the majority of soda ash (39 percent - 49 percent) is used in the manufacture of glass. Another 23 percent to 25 percent is used for producing other chemicals, 9 percent is used by the paper and pulp industry, 6 percent is used in soaps and detergents, 3 percent for water softeners, and the rest for a variety of pharmaceutical, photographic, metallurgical and petroleum refining products.

Economic Value to Wyoming

In 1977, a ton of trona was assessed at $7, a 16.7 percent increase in unit value over 1976. Total taxable valuation increased from $44.3 million in 1976 to more than $61.6 million in 1977. Trona now ranks third in terms of total assessed mineral valuation, following petroleum and coal (fig. 15). Dollar value of Wyoming's trona industry was estimated at more than $250 million in 1976, placing the industry second only to petroleum. The dollar value of 1977 production exceeded $340 million.

The trona industry provided the state with more than $7.6 million in property and severance taxes in 1977. During the same period, another $1 million are expected to be paid in royalties and rentals of state lands.

Presently, four companies operate underground trona mines in Sweetwater County in southwestern Wyoming (fig. 16). Allied Chemical Corporation, FMC Corporation, Stauffer Chemical Company, and Texas Gulf Incorporated employ more than 3,000 people at mining and processing facilities. Church and Dwight also operate a processing pilot plant adjacent to the Stauffer Chemical mine.

The Future of Wyoming's Trona Industry

The 1978 price for soda ash recently was established at $55 per ton by Texas Gulf Incorporated. This price can be expected to increase in response to higher mining, refining, and transportation costs. Future demands for trona can be anticipated from year to year and will be met unless employee or railroad transportation strikes, or other unforeseen problems, hinder production.

Market demand for Wyoming trona is expected to increase to at least 15.5 million tons per year by the year 2000. By contrast, the state mined 11.3 million tons in 1977. By the year 2000, a total of about 300 million tons of trona will have been mined, which is less than 1 percent of Wyoming's estimated reserves. It is an understatement to say that the surface of Wyoming's immense trona reserves will barely be scratched at the turn of the century. Consider that if Wyoming's trona deposits were mined at a rate of 15.5 million tons per year, it would take more than 6,000 years to deplete the estimated reserves.

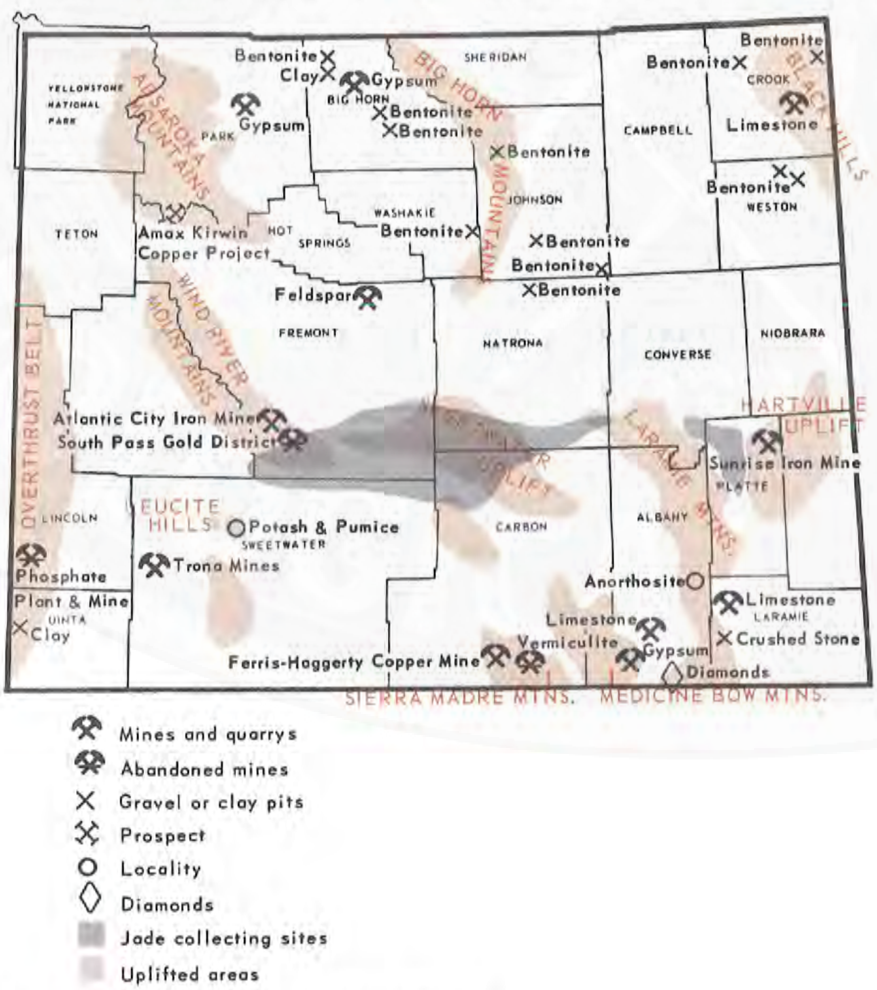


Fig. 16. Major mineral and rock localities of Wyoming.

Uranium – Energy from the Atom

Geological Setting

Although detectable amounts of uranium have been found in rock of practically every geological age in Wyoming, the most important economic uranium deposits found thus far have been in permeable sandstones of Tertiary age (fig. 1). Most geologists agree that the major contributing source of uranium was the ancient Precambrian crystalline rocks which formed the cores of the mountain ranges. Additional radioactive material undoubtedly was supplied by volcanic ash that covered the state during more recent geologic periods. Uranium was leached from these original source rocks and precipitated in sandstones of much younger age.

The major uranium districts of the state are located in areas where the once-dispersed uranium is now concentrated along roll-fronts (fig. 17). In vertical cross-section, a roll-front appears as a C-shaped interface between oxidized and reduced portions of sandstone; uranium mineralization is concentrated along the interface. In map, or plan view, the roll-fronts are characteristically tongue-like features with interiors that face upslope. On the concave side of roll-fronts, the oxidized sandstone is bleached and devoid of radioactivity, suggesting that the roll-fronts migrated downslope to their present positions while removing uranium and concentrating the mineralization at the roll-front interface.

These roll-fronts actually did migrate downslope to their present positions and are still migrating today. They are active geochemical cells produced by oxygenated groundwater and bacteria which remove uranium and other minerals and destroy scattered organic debris. The dissolved minerals are carried in solution and precipitated farther downslope.

Recently, the possibility of economic uranium deposits in rock of Precambrian age in the Sierra Madre and Medicine Bow mountains has stimulated interest throughout the scientific and mining community. These deposits are dispersed through ancient sedimentary rocks that are about 2 billion years old.

Mining and Processing

Uranium ore is recovered by all manner of open-pit, underground, and solution mining methods. Explosives and conventional earthmoving equipment typically are used in open-pit operations, although blasting is sometimes unnecessary. Underground mining operations employ room-and-pillar, open stope, and longwall mining techniques. Ore haulage is accomplished by electric or diesel locomotive, truck, or other rubber-tired equipment.

Upgrading the uranium ore before shipment to the mill is a relatively uncommon procedure, but it is sometimes used to reduce transportation costs. Techniques used for upgrading include grinding, size sorting, and radiometric sorting.

Before milling, the uranium ore is usually blended to get a uniform uranium oxide grade mill feed. The ore is fed into the mill and concentrated by grinding, crushing, and leaching. The milled concentrate is further refined to remove impurities and produce a product acceptable for nuclear reactor use. Since natural uranium contains primarily nonfissionable U_{238} and only about 0.7 percent of the U_{235} isotope, the ore must be enriched to 3.5 percent fissionable U_{235} to be used as nuclear reactor fuel. Enrichment is accomplished by chemically altering the uranium concentrate to uranium fluoride, and finally enriching the fluoride in radioactive U_{235}.

Uses

Uranium is used primarily in nuclear reactors and in national defense programs. Commercial uses of uranium, other than for the generation of electricity, are somewhat limited. Depleted uranium, according to the U.S. Bureau of Mines, is used in X-ray and gamma ray shielding and in counterweights for aircraft. Small amounts of uranium are used as colorants for glass, ceramics, and steel. Uranium also is used on a small scale in X-ray tubes and ultraviolet lamps, and in the resistors of incandescent lamps.

Uranium is a strategic mineral, vital to national defense. Military applications include nuclear weapons and propulsion systems. For nuclear weapon use, the uranium must be enriched to greater than 90 percent fissionable U_{235}. This requires the construction of special nuclear processing plants. Depleted uranium is used in the manufacture of special ammunition.

The Uranium Industry

Several new uranium projects are in various planning or development stages in Wyoming. Besides as many as 14 new mines scheduled for the Powder River Basin, one mine is proposed for the Red Desert area and one for the Crooks Gap area in Sweetwater and Carbon counties.

Exploration and development drilling continues in all of Wyoming's uranium districts. The most active areas, in descending order, are the Powder River Basin,

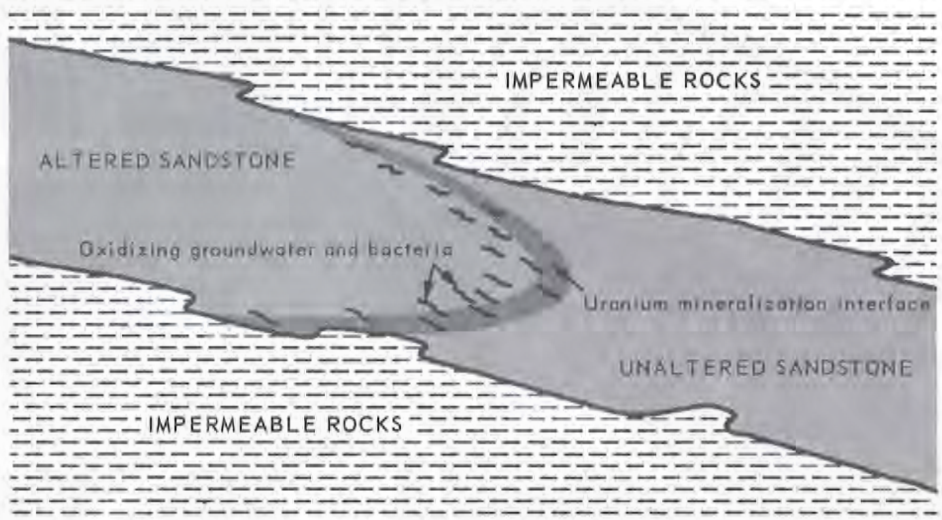


Fig. 17. Diagrammatic cross-section of a uranium roll-front. The oxidizing groundwater and bacteria migrate downslope concentrating uranium mineralization at the oxidizing-reducing interface.

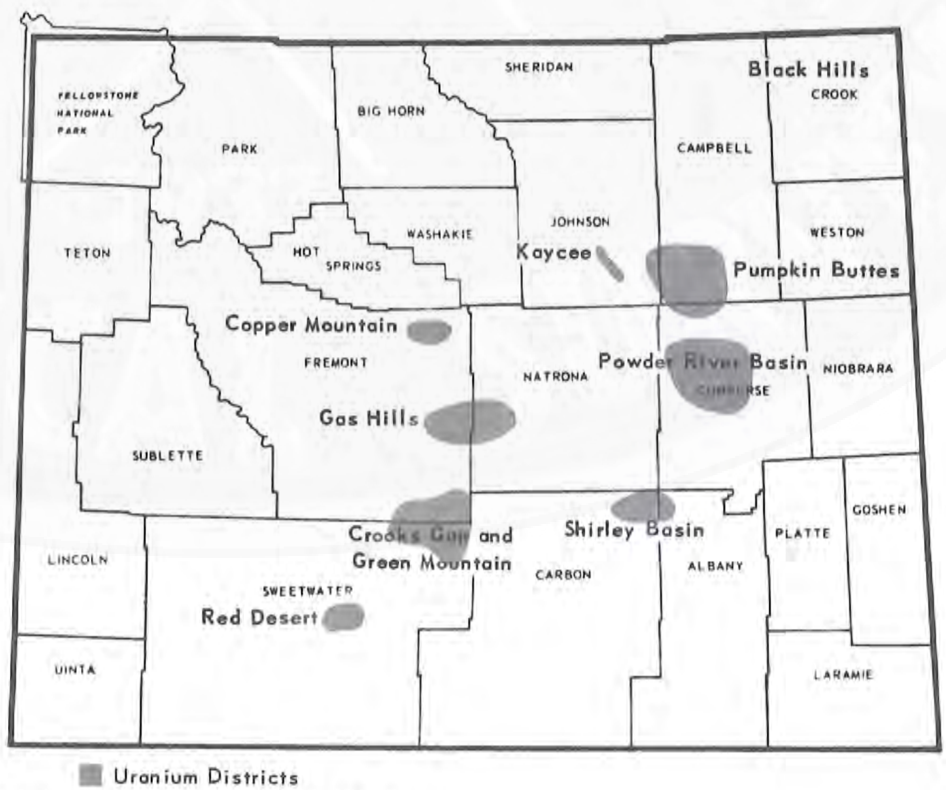


Fig. 18. Wyoming's major uranium districts.

The Rim Pit Mine in the Gas Hills District of Fremont County yielded about $3.2 million worth of uranium ore before it was closed by Western Nuclear Corporation. (U.S. Geological Survey Photo)

Gas Hills, Crooks Gap-Green Mountain, Red Desert, and Black Hills districts (fig. 18).

The uranium industry is expanding in Wyoming. At present there are more than 3,000 people directly employed by the industry, and this number is expected to triple before the year 2000, provided uranium production increases as expected.

The long-term future of the uranium industry is somewhat uncertain. The U.S. presently mines enough uranium to meet domestic demands, but new reserves are becoming more difficult to find. The cost of exploration is at an all-time high and will continue to rise as exploration is extended into more inaccessible areas and to greater depths.

Reserves and Production

In the U.S., Wyoming ranks second only to New Mexico in uranium production and reserves. Wyoming's production in 1977 totaled more than 4.5 million tons of ore (fig. 14). In 1976, the Energy Research and Development Administration estimated that the U.S. has 640,000 tons, 430,000 tons, and 270,000 tons of uranium oxide (U_3O_8) that is recoverable at a cost of $30, $15, and $10 per pound, respectively. Wyoming's reserves of U_3O_8 are estimated at 233,100 tons recoverable at $30 or less per pound, 158,000 tons recoverable at $15 or less per pound, and 73,000 tons recoverable at $10 or less per pound, or about 35 percent of the nation's total reserves. About 98 percent of these reserves are contained in sandstone roll-front deposits of the type previously described.

Severance and property taxes paid by the uranium industry amounted to more than $4.9 million in 1977. Rentals and royalties paid the state for uranium lands totaled $1,020,479 in 1976 and are expected to be about the same for 1977.

In the late 1960's and early 1970's, uranium oxide (yellow cake) sold for $4 to $8 per pound. In 1978, the average price will be about $17 to $20 per pound, or a 300 percent increase in about 10 years. The rapid rise in price was in direct response to the market demand for uranium by public utilities and power companies. With the increased market demand that is expected during the next decade, yellow cake prices may well rise to over $50 per pound.

The increase in price for uranium oxide will allow companies to mine lower grade uranium ore and thereby increase our national reserves. Estimates by several federal agencies and research groups suggest that significant depletion of domestic uranium reserves will not occur before the year 2000, which should allow sufficient time to develop safe and reliable breeder reactors.

The present controversial position of the Carter Administration against development of the breeder reactor until possibly the 1990's initiated an assessment of the nation's uranium reserves by a special committee of the National Academy of Sciences. The committee concluded that demand for uranium in the U.S. will likely exceed domestic supply before the year 2000, and possibly as early as 1985.

In any event, increased exploration and drilling is necessary just to keep pace with present long-term uranium contracts. As the known reserves are depleted, lower grade deposits that are not feasible to mine now will become minable as market prices rise. New deposits undoubtedly will be discovered as a result of increased exploration, adding to domestic reserves and allowing the U.S. to remain self-sufficient for a longer period of time.

Iron — The Workhorse of Modern Civilization

Geological Setting

Iron is one of the most abundant elements contained in the earth's crust, and one of the most important commodities used by modern civilization. An unlimited amount of iron is known to exist in low-grade deposits in Wyoming: there are the taconites (iron silicates) in the Wind River and Owl Creek mountains; the banded-iron deposits in the Sweetwater Uplift; the titanium-bearing iron deposits in the Laramie Mountains; the titaniferous black sandstones, which occur along the peripheries of Wyoming's basins; and the red iron oxides of the Chugwater Formation found throughout central and extreme western Wyoming. Although most of these deposits probably will never be mined for their iron content, geologists know their locations and understand that they could be mined if necessary.

Today, two active mines produce iron ore in Wyoming (fig. 16). U.S. Steel Corporation's Atlantic City Mine is an open-pit mine in Precambrian rocks located in the southern Wind River Mountains of Fremont County. The mine is located about 8,300 feet elevation where the annual snowfall averages 134 inches. The iron ore is an iron silicate rock known as taconite. Taconite ore occurs in alternating bands of magnetite (iron oxide) and quartz (silica) and averages 30 percent to 32 percent iron and about 50 percent silica.

In the southeastern part of the state, Colorado Fuel and Iron Corporation operates the Sunrise Mine, an underground mine at the southern end of the Hartville Uplift in Platte County. The ore at the Sunrise Mine in hematite, an iron oxide. Although the iron ore was initially extracted from an open-pit in 1901, it was converted to an underground operation by the 1930's because of changing mining conditions. The igneous rocks of the area also contain other valuable minerals. In fact, the Sunrise Mine was originally a copper mine in the 1880's.

Reserves and Production

Wyoming ranks fifth in the nation in iron production, producing about 2.5 percent of the total iron ore mined in the U.S. Minnesota, Michigan, California, and Utah lead Wyoming in production, followed by Missouri, Pennsylvania, New York, Texas, and Wisconsin.

The 1977, production of iron ore in Wyoming amounted to about 5.2 million tons (fig. 14). Of this total, approximately 4.9 million tons were taconite ore and about 330,000 tons were hematite ore.

In 1977, the unit valuation increased 13 percent to $2.95 for a ton of taconite ore mined at Atlantic City and increased 5.5 percent to $4.75 for a ton of hematite ore mined at the Sunrise Mine. The total assessed valuation of Wyoming iron ore was $16.6 million (fig. 15).

Estimated iron reserves indicate that Wyoming can retain its position in U.S. production for at least the next 15 years. The reserves of taconite at the Atlantic City Mine are estimated at 60 to 90 million tons of proved reserves. In addition, there are indicated reserves as high as 250 million tons. Hematite iron ore reserves at the Sunrise Mine are estimated at 23 million tons. Based solely on present production levels and identified reserves, the Atlantic City Mine can remain operational for at least 15 to 20 years, while the Sunrise Mine could operate for 30 years or more. However, mining costs and market price ultimately will determine the longevity of the mines.

The Iron Industry

U.S. Steel employs nearly 500 people at the Atlantic City Mine, most of whom reside in Lander. U.S. Steel also owns and operates its own railroad from the mine to Winton Junction, located 76 miles to the southwest. From Winton Junction, ore cars are handled by the Union Pacific Railroad, which transports them 355 miles to the Geneva Steel Works near Provo, Utah.

The Sunrise Mine and processing facilities employ more than 200 people and contribute to the economy of the town of Guernsey. The iron ore is mined, crushed, and concentrated at the site, then shipped 330 miles south to the blast furnaces of Colorado Fuel and Iron Corporation at Pueblo, Colorado. About 50 percent of CF&I's iron requirements are supplied by the Sunrise Mine.

Mining and Processing

The Atlantic City Mine is an open-pit operation. The ore is mined along benches spaced every 38 feet, with an overall pit slope of 45°. At its maximum limit, the pit is expected to be about 1,400 feet deep. Electric shovels remove the ore and waste which are dumped into 75-ton diesel-powered dump trucks. Trucks transport the ore from the pit to a primary crusher in preparation for beneficiation.

Before it is suitable for use in blast furnaces, taconite ore must be upgraded. After the ore is crushed in a primary crusher, it passes through a series of finer crushing and sizing operations, and eventually through magnetic separators. In the final stage, the ore is crushed to a fine powder, combined with bentonite (clay), and heated to produce small hardened pellets about one-half inch in diameter. The taconite from Atlantic City averages 30 percent iron before beneficiation and about 62 percent afterward. The pellet concentrates are transported to the blast furnaces at the Geneva Steel Works near Provo, Utah.

The Sunrise Mine is one of only six underground iron mines still operating in the U.S. In the 1930's, the mine was converted from an open-pit mining operation to an underground mine that uses a block caving system. In this system, large blocks of ore are undercut and blasted. The fractured ore falls into a lower haulage level, where the ore is hoisted to the surface in 10-ton capacity buckets.

Ore from the Sunrise Mine is processed by gravity methods through a 600,000 ton-per-year beneficiation plant. The ore is passed through a series of screens and dehydraters to obtain the desired upgrading.

Uses

The U.S. Bureau of Mines estimates that 98 percent of the iron ore produced in the U.S. is used in blast furnaces, 1.6 percent is used in steel-making furnaces, and 0.4 percent is used in the production of various other products. Some of the other products include cement, paint, concrete aggregate, ferroalloys, and additives in animal feed.

The Future of Wyoming's Iron Industry

It is hoped that Wyoming's iron production can remain stable for at least the next 10 to 15 years. The processing capabilities at the Atlantic City and Sunrise mines are essentially operating at full capacity and no additions to the milling facilities are anticipated. There are, however, other factors on the international scene that may have a bearing on the local iron market.

The U.S. iron industry at present is economically depressed. Union contracts, transportation costs, taxes, royalties, government price controls, increased competition from government subsidized foreign industries, increasing costs of materials, reclamation and pollution control equipment, and the high costs of fuel are just a few economic factors that have made a serious impact on the iron industry.

The recent decision by the iron industry to terminate over 24,000 employees nationwide is an example of the depressed iron economy. Included in this layoff were 700 CF&I employees at Pueblo, Colorado and 165 employees at the Geneva Steel Works near Provo, Utah.

Increased import duties or other controls over foreign iron may become necessary. Presently, the U.S. is competing with foreign countries that in effect subsidize their iron industries and allow them to operate with more modern equipment, minimal governmental restrictions, and fewer environmental safeguards. The economic outlook for domestic iron will remain somewhat depressed until the U.S. can compete on a more reasonable basis with the foreign market.

Bentonite — A Very Special Clay

Geological Setting

During the geologic past (Cretaceous period), Wyoming was covered by shallow seas that flooded and receded across the state many times. To the west, the Pacific Ocean Basin was overridden by the North American Continent which caused tremendous geological disturbances that drastically changed the surface of western America. Volcanic explosions spewed great volumes of cinder and ash into the atmosphere, some of which were carried over Wyoming by prevailing westerly winds. Much of the ash settled into the shallow seas and reacted with salt water, producing an altered clay we call bentonite. Similar disturbances during the Tertiary period resulted in the deposition of more ash as a result of volcanic activity in northwestern Wyoming and to the west of Wyoming. The ash was altered to clay in freshwater lakes or later altered by groundwater (fig. 1).

Bentonite is a name applied to a special type of monomineralic rock that has undergone extensive alteration to clay. Two principle types of bentonite are recognized; the sodium-rich and the calcium-rich varieties. The sodium-rich variety, commonly termed "Wyoming" bentonite, occurs predominately in Wyo-

The production of iron ore from the Sunrise Mine in Platte County began in the late 1880's and led to the establishment of the town of Sunrise in 1902. The vein of iron ore—one of the purest iron deposits in the nation—extends over 35 miles from Guernsey north to Sunrise. (Wyoming Travel Commission Photo)

Bentonite deposits being mined in the Clay Spur District of Crook and Weston counties. Wyoming leads the nation in bentonite production with about 65 percent of the total output. (Wyoming Geological Survey Photo)

ming and extends into adjacent mining districts in other states. "Southern" bentonite is a calcium-rich variety located primarily in the southern U.S.

Sodium-rich bentonites are important because of their unique ability to adsorb water, increasing their volume as much as 30 percent. The calcium-rich variety, on the other hand, shows little to no volume increase when wetted. Both varieties exhibit high viscosity, plasticity, and gelling and bonding strength when wet. Variations in the sodium-calcium ratio profoundly affect the physical properties of the clay.

Reserves and Production

Wyoming produces about 65 percent of the nation's bentonite and has ranked first ever since mining for the clay began in Wyoming 90 years ago. Bentonite production in the state reached a record high of 3.4 million tons in 1974 (fig. 14). In 1975, production declined by more than 600,000 tons, partly as the result of a decrease in demand by the petroleum and iron-mining industries. In 1976, production increased once again to more than 3.1 million tons, and 1977 production is expected to be even higher.

The total amount of bentonite in Wyoming's major basins is not known, but it certainly measures in the hundreds of millions, and possibly billions, of tons. Unfortunately, only a small amount of the clay of acceptable quality is close enough to the surface so that it can be mined economically. The deposits presently mined are exposed at the surface in narrow belts around the perimeters of the basins. Available data suggest that known minable bentonite reserves in Wyoming total at least 90 million tons.

The Bentonite Industry

There are at least 10 bentonite processing plants intermittently operating in Wyoming. Besides employing and paying the salaries of nearly 600 residents, the bentonite industry pays taxes, royalties, and rental fees to the state. In 1976, the taxable value of the clay was assessed at more than $6.5 million. The 1977 unit value averaged $2.06 per ton, or a 6.7 percent increase over the previous year. More than $32,000 was paid to the state in lease rental and royalty payments in 1976. The total dollar value of bentonite production over the last four years has averaged $50 million per year.

Mining and Processing

Bentonite occurs extensively in Upper Cretaceous and Lower Tertiary rocks of Wyoming. However, the important bentonite mining districts are located in Upper Cretaceous deposits in the northern half of the state. More than three-fourths of the state's bentonite is mined in Big Horn and Crook counties (fig. 16).

Conventional open-pit and strip mining methods are used by the bentonite industry. Before a bentonite bed is mined, extensive auger-drilling is conducted to determine the quality and thickness of the bed. If the bed is determined to be minable, the overburden is stripped away by bulldozers. The exposed bentonite is plowed or loosened before removal with ordinary earth moving equipment. As a general economic rule, the thickness of the overburden should not exceed six times the thickness of the bentonite bed. Usually only yellow to yellow-green clays are mined because of their higher quality. Underlying blue or blue-gray poor quality, nonswelling bentonite has no significant value and mining usually stops when the top of the blue clay is reached. Although it is uncommon, some operators do mine the blue clay and then leave it exposed in the air to dry for several years, thereby increasing its quality.

After it is mined, bentonite is stockpiled at the mill site in piles of different quality. The lower and higher quality piles are blended to produce piles of average quality before milling. Milling consists of slicing or crushing the crude ore into a fine powder. The pulverized bentonite is dried to lower the moisture content by from 5 percent to 30 percent. Finally, it is bagged or loaded directly onto railroad cars.

Uses

Wyoming's sodium-rich, swelling bentonites are used by a variety of industries. Approximately 32 percent is used in pelletizing taconite iron ore, 21 percent is used by the petroleum industry for drilling muds, 18 percent is exported to foreign markets, and 17 percent is used in foundry sands. Manufacturers of animal food products use about 5 percent, and 3 percent is used in waterproofing and sealing compounds. The remainder is used in a variety of other products, from bricks to pesticides.

The Future of Wyoming's Bentonite Industry

The price of bentonite has been essentially fixed at $14 to $16 a short ton for the past few years, and no large price increases are expected in the near future.

Because most of Wyoming's production is either used to make drilling muds or to process taconite iron ore, the amount of bentonite mined in Wyoming tends to fluctuate in direct response to the level of activity in both the petroleum and iron ore industries.

The present reserves of bentonite are sufficient to supply domestic needs into the next century. After the turn of the century, in order to keep up with demand, new reserves will be required. Although technological breakthroughs designed to increase the quality of blue bentonites will contribute some reserves, most of the new reserves will come from deeply buried bentonite deposits in Wyoming's basins. Presently, these bentonites are simply too expensive to mine. However, dwindling supplies and higher prices can make them more attractive to future mining.

Wyoming's Other Minerals

The Feldspar Industry

Wyoming has a very small feldspar mining industry in northern Fremont County that produces about 0.3 percent of the nation's total production.

The mine and mill located north of Shoshoni have a 100-ton-per-day capacity, and produced nearly 5,000 tons in 1977. Future expansion of the mining operations is possible since the company owns several claims and prospecting pits on adjoining lands.

Feldspar, a complex sodium-potassium aluminum silicate mineral, has many uses in modern society. In the past, the feldspar mined in Fremont County was used in the manufacture of soap, detergents, abrasives, false teeth, and glass; however, present production is shipped to Kansas City to be used entirely for the manufacture of detergents.

The Phosphate Industry

Thick sequences of phosphate-rich sediments were deposited in the marine seas that covered western Wyoming and southeastern Idaho during the Permian period (fig. 1). Today, the most important phosphate deposits in Wyoming are identified as part of the Phosphoria Formation. Unfortunately, practically all the phosphate deposits have been withdrawn from mineral entry by the federal government; hence, they are not presently available for exploration or development.

Another possible phosphate resource of the future occurs in low-grade, uranium-bearing phosphates associated with near-surface deposits in the Green River Basin, Sweetwater County. No reserve estimates are available; however, these deposits could become attractive for uranium and phosphate production as reserves are depleted sometime in the distant future.

Stauffer Chemical Company presently operates the only phosphate plant in the state, and until recently, operated the only mine. The mine at Leefe in Lincoln County showed sharp declines in production in 1976 and 1977 because of dwindling phosphate reserves. On January 1, 1978, the company announced that it was terminating mining operations entirely, but elected to leave the plant open to process phosphate trucked from Idaho.

The Gypsum Industry

The state's gypsum production comes from mines located in Park, Big Horn, and Albany counties. In 1976 these areas produced about 450,000 tons, which was used in the manufacture of wallboard. The 1977 production is expected to have remained at about the same level. Gypsum is a soft, white, hydrated calcium sulfate mineral.

Construction Materials

The major construction materials mined in Wyoming include limestone, sand and gravel, and crushed stone and rock for cement. In 1977, more than 1.1 million tons of limestone were produced, directly employing 100 people. Nearly 1.4 million tons of sand and gravel were extracted, employing 170 people. Nearly 1.5 million tons of crushed rock were mined by more than 50 people. Monolith Portland Midwest Company employed over 90 people at their rock quarry and cement manufacturing plant at Laramie, producing nearly 350,000 tons of rock for the manufacture of cement.

Jade

Nephrite, known as Wyoming jade, has been found at numerous locations throughout the Sweetwater Arch. Collecting sites extend from southeastern Sublette County to as far east as Glendo and Wheatland in Platte County (fig. 16).

Originally, the jade formed in vein deposits in ancient Precambrian igneous and metamorphic rocks. There are still a few small quarries in central Wyoming that recover jade of this type. Jade also is found in pebbles and boulders that are the eroded remnants of veins that have been redistributed by streams. Although the jade industry of Wyoming is small, it is well known throughout the world and serves as a source of employment for hundreds of people.

Vermiculite

Vermiculite is a lightweight flaky (micaceous) mineral, small quantities of which have been produced in Wyoming from time to time. The deposits are small and mined through simple quarrying operations. Although market demand for vermiculite is very good, the deposits in Wyoming are too small to be developed economically under present market conditions. Vermiculite is used primarily in the manufacture of insulation and lightweight construction material.

Nonswelling Clays

Besides bentonite, Wyoming has deposits of common clay that are mined on a small scale in Big Horn and Uinta counties for the manufacture of brick and other products. About 45,000 tons are mined per year; however, 1977 production declined by more than 30,000 tons because of a mine closure in Uinta County.

Potential Industries in Wyoming

In the future, many new industries will be tapped in Wyoming. These potential industries are either waiting to be discovered or have already been discovered and await changes in market demand or technological advances. Who would have thought, prior to 1975, that diamonds would be discovered in Wyoming? Yet here lies a potential diamond industry that awaits the verdict of the future.

Some industries will be pondered for decades, while others will develop more rapidly, as technology or economics dictates minability. For example, potential iron extraction from low-grade taconite deposits in Atlantic City was considered for more than half of a century before advances in technology made it a reality. Changes in the market demand for uranium attracted people by the thousands to Wyoming in a few short years.

Only the naive would suggest that all Wyoming's valuable mineral resources have been discovered or developed. Potential industries only await favorable conditions before springing to fulfillment.

Diamonds

In 1975, several tiny microdiamonds were discovered near the Wyoming-Colorado state line south of Tie Siding in Albany County (fig. 16). This is only the second known occurrence of diamonds found in place (that is, in the kimberlite host rock in which they were formed) in the U.S. The other deposit is located in Murfreesboro, Arkansas.

The microdiamonds occur in rocks that originated deep within the earth under conditions of extremely high temperature and pressure and extruded upward along fractures sometime during the Devonian period (fig. 1). Subsequent erosion of the igneous rock body has now exposed the diamond-bearing material at the surface. Similar rocks outcrop about 45 miles to the north near Iron Mountain, but no diamonds have been recovered as yet from this area.

The diamonds found in the State-Line District are very small, the largest being just over 2 mm (fig. 19). Abundant mineral inclusions give them a dark appearance and poor quality. M.E. McCallum, professor of geology at Colorado State University, has extracted a significant number of the tiny diamonds in the Laramie Mountains in Colorado and Wyoming.

Fig. 19. One of the first diamonds discovered in Wyoming (scale is in millimeters).

Besides the diamonds found in place near the state line, there have been a few other reported occurrences of diamonds in placer deposits in stream beds. Continued exploration of the Precambrian terrain of Wyoming may lead to the discovery of the source or sources of these crystals.

The possibility of a diamond industry in the state is remote. Wyoming would have to compete with the diamond industries in South Africa, Brazil, and the Soviet Union. Since these countries produce several million carats per year with low labor costs, a diamond deposit would have to be extensive, high-grade, and produce occasional crystals of good gem quality in order to compete in the world market.

Copper

Copper mineralization occurs sporadically throughout every mountain range in Wyoming. Most of the mineralization occurs in Precambrian rocks. Notable exceptions include copper mineralization in Paleozoic rocks of the northern Laramie Mountains and the Hartville Uplift, and in Tertiary rocks of the Absaroka Mountains (fig. 1).

Most of Wyoming's copper was produced before World War I and only negligible amounts have been mined since. Total production thus far probably amounts to less than 15,000 tons.

Copper prices generally are increasing from year to year but are not keeping pace with the rate of inflation. At the end of 1977, copper prices increased to 63 cents per pound, which is still well below the 70 cents per pound most companies need to conduct a profitable venture. In part, the depressed condition of the copper market is due to the stockpiling of large amounts of copper on a worldwide scale during the 1950's and 1960's.

An attempt is being made through several acts recently introduced in the U.S. Congress to stimulate the domestic copper market. The most recent, the "Copper Environmental Act of 1977," would impose a duty on imported copper. Most imported copper comes from countries without environmental restrictions, which allows them to produce refined copper at a lower cost.

The possibility of a substantial copper industry in Wyoming does not seem likely for some time. Even though recent announcements concerning the reopening of the famous Ferris-Haggerty Copper Mine in Carbon County, and a copper discovery and mine proposal by AMAX Incorporated in the Absaroka Mountains in Park County, have made a copper industry for Wyoming seem brighter, it is doubtful that much production will result for several decades.

Gold

Gold was first discovered and mined in stream gravels on the southeastern end of the Wind River Mountains in 1842. Subsequent prospecting resulted in the discovery of lode deposits about 1867. There are no records to indicate how much gold was recovered, but the total dollar value has been estimated at less than $6 million.

With the average price of gold expected to increase to over $165 per ounce this year, new mining can be expected in the future. At least one application for a mining permit has already been submitted for a placer operation in Teton County, and others are expected to follow.

Gold has been found in all the mountain ranges of Wyoming. In the past, the significant mines were located in the Wind River Mountains, the Medicine Bow Mountains, and in the Sierra Madre Mountains (fig. 16). Practically all of these operations were very shallow and none of them have been explored below 400 feet. As an example, in the South Pass District in the Wind River Mountains, all the major mines closed before reaching 400 feet in depth, even though they were reported to still be mining in gold-bearing rock.

Potash and Pumice

Potash, or potassium, is a valuable mineral material used primarily as a fertilizer. Wyoming has several known deposits of potassium-bearing rocks; however, commercial extraction is not feasible under present market conditions. Wyomingite, a potassium-rich volcanic rock occurring in the Leucite Hills of Sweetwater County, has been studied extensively for possible extraction. The potash content varies from 9.81 percent to 11.91 percent. It is estimated that 400 million tons of potassium and alumina are contained in these deposits.

Western Aggregates Company of Rock Springs has plans to develop pumice from the same area for use in statuary, landscaping, building stone, lightweight portland cement aggregate, and in other miscellaneous products.

Zeolites

Zeolites are sodium and/or calcium aluminum hydrated silicate minerals that occur in bedded clay deposits and in vesicles in porous igneous rocks. Although Wyoming has not yet produced zeolites on a commercial scale, research is underway that may lead to an important industry in the near future. The most significant deposits are known from surface exposures in Fremont County.

Zeolites are primarily used in water softeners and are used to manufacture catalysts and moisture absorbants. It is projected that they will be used on a large scale for the extraction of radioactive products from nuclear reactor wastes.

Anorthosite

The Laramie Mountains northeast of Laramie contain a massive body of igneous rock called anorthosite. Anorthosite is an aluminum-rich rock formed by the cooling of magma below the earth's surface. Like bauxite, anorthosite contains enough aluminum to be economically attractive.

The aluminum occurs in plagioclase feldspar, a calcium-sodium alumina silicate. Typical chemical analyses of the anorthosite body average 25 percent to 30 percent aluminum and 12 percent to 18 percent calcium plus sodium. At a few localities, ferromagnesium (iron-magnesium-rich) and magnetite-ilmenite (iron-rich and iron titanium-rich) minerals average more than 50 percent of the rock.

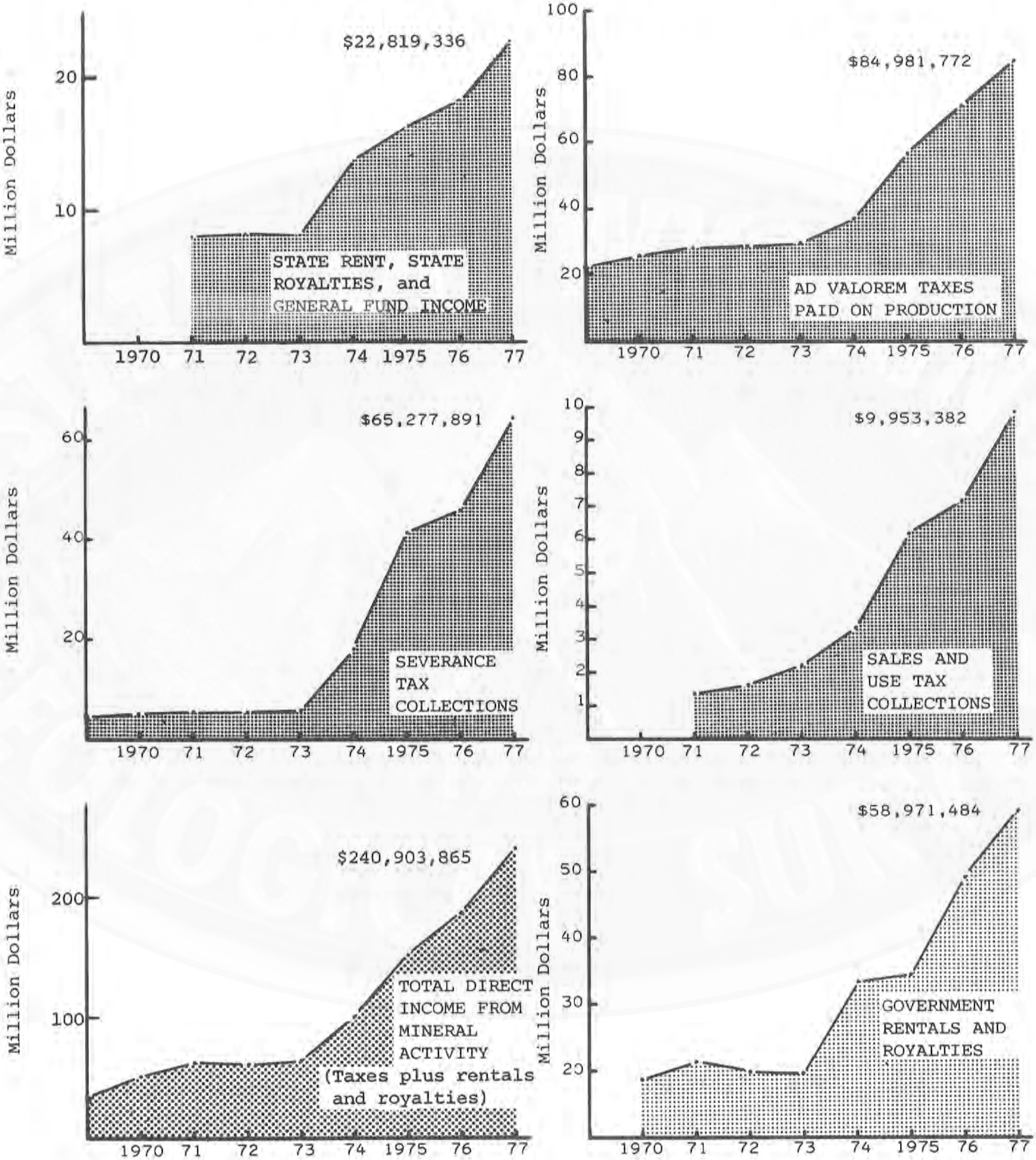
Depending on market demands, this deposit could be developed for its aluminum, calcium, sodium, and possibly iron sometime in the future.

Other Factors Affecting Mineral Development

Several bills are before a congressional subcommittee concerning the repeal or updating of the Mining Law of 1872, which affects claim-staking of "hardrock" minerals (copper, iron, gold, uranium, etc.). A competitive leasing plan supported by the Carter Administration (H.R. 9292) would attach several environmental restrictions and add many costs to exploration, development, and production. The proposed bill would require advanced permission from the Department of Interior to explore – and lengthy, costly bureaucratic delays involving permits and licenses which, in most cases, would be granted only *after* competitive leasing. The enactment of a competitive leasing system also would call for payments of annual rentals, minimum royalties, and periodic lease-term renegotiations at the discretion of the Interior Department. Opponents of the bill claim that small mining operations would be forced out of business, and that the effect on the mineral industry would be devastating.

According to the opposition, the major thrust of the competitive "hardrock" leasing law would be to protect the environment to a maximum, and at the same time, restrict exploration for hardrock minerals and add costly expenditures to an already ailing mining industry. They claim that such a bill would add to the long list of nearly unsurmountable problems now confronting the hardrock mining industries, greatly restrict efforts at new exploration, and price the U.S. out of the world mineral market. The result, they argue, would be an even greater balance-of-payments deficit because of the need for imports. The extent of federal intervention concerning these proposed changes will have a very real and lasting effect on the future economy of Wyoming.

DIRECT INCOME TO WYOMING BY TOTAL TAX OR REVENUE CATEGORY



APPENDIX TABLE 1. MINERAL INCOME TO THE STATE OF WYOMING AND ASSESSED VALUATION BY MINERAL CATEGORY AND TAX TYPE – 1969-1977

Assessed Valuation on Production

Assessed Valuation is on the previous year's production –e.g. 1977 Assessed Valuation is on 1976 Production.

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Oil	342,095,561	393,521,962	408,316,110	410,960,436	386,433,220	484,677,222	833,099,266	894,047,178	871,638,686
Oil Stripper									54,635,836
Gas	32,568,891	35,896,344	38,876,833	42,917,421	45,799,719	56,303,866	65,041,856	88,861,898	132,925,715
Coal	5,158,890	6,604,717	12,823,567	15,230,522	20,220,230	36,525,380	70,658,473	124,656,316	182,641,777
Uranium	11,973,833	12,887,471	17,793,920	18,584,904	26,734,686	24,469,735	19,519,275	20,829,685	41,830,148
Trona	7,206,779	10,792,192	14,830,637	14,616,185	17,127,262	22,793,340	33,537,931	44,278,752	61,604,249
Others	8,435,480	10,435,621	128,127,781	13,341,962	15,654,176	18,231,793	23,009,044	26,252,467	29,872,572
Totals	407,439,434	470,138,307	505,453,848	515,651,430	511,969,293	643,001,336	1,044,865,845	1,198,926,296	1,375,149,102

Ad Valorem Tax

Taxes are paid on previous year's production – e.g. 1977 taxes were paid on 1976 production.

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Oil	18,630,403	21,250,757	22,497,626	22,745,100	21,647,269	27,428,035	44,062,703	52,011,268	53,242,493
Oil Stripper									(3,337,395)
Gas	1,818,047	2,026,025	2,231,793	2,479,267	2,735,809	3,361,474	3,791,780	5,416,016	8,363,221
Coal	278,203	347,724	781,847	933,916	1,125,772	2,018,242	3,991,473	7,321,256	11,216,632
Uranium	745,436	800,216	1,113,915	1,139,758	1,594,162	1,441,087	1,181,988	1,268,260	2,661,655
Trona	439,181	627,674	925,135	913,663	1,186,837	1,580,954	2,390,070	3,089,771	4,239,604
Others	496,108	615,480	772,514	832,974	975,059	1,122,396	1,363,208	1,648,239	1,919,772
Totals	22,407,378	25,667,876	28,272,830	29,044,678	29,264,908	36,952,188	56,781,222	70,754,810	84,981,772

Severance Tax

Severance tax is paid on previous year's production.

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Oil	3,436,531	3,934,661	4,087,588	4,129,909	3,865,316	14,427,959	32,689,133	34,781,276	35,958,264
Gas	323,794	357,047	388,585	412,267	457,930	1,504,043	2,604,405	3,554,476	5,317,029
Coal	51,592	63,778	128,199	159,272	202,202	1,095,230	2,826,339	4,986,253	17,716,252
Uranium	119,739	128,838	178,136	186,020	267,347	244,697	390,395	416,594	2,300,658
Trona	72,068	107,922	148,306	146,162	171,273	683,800	1,341,517	1,771,150	3,388,234
Others	84,355	104,362	117,948	137,782	157,241	182,852	463,772	527,052	597,454
Totals	4,088,079	4,696,607	5,048,761	5,171,412	5,121,308	18,138,581	40,315,561	46,034,800	65,277,891

Sales and Use Tax (Fiscal Year)

		1971	1972	1973	1974	1975	1976	1977
Oil and	Sales	866,859	857,224	1,115,123	1,724,261	3,224,274	4,082,391	4,837,746
Natural Gas	Use	75,794	102,405	147,793	228,076	428,594	380,383	494,689
Coal	Sales	6,162	8,060	8,830	14,006	84,439	78,312	238,357
	Use	47,955	181,463	216,691	135,461	680,171	661,775	1,441,992
Metal Mining	Sales	8,522	8,837	10,961	9,763	83,042	149,608	187,762
	Use	142,472	107,287	89,826	94,839	358,945	670,004	868,173
Other Mining	Sales	98,180	86,481	115,294	270,561	405,655	429,123	459,592
	Use	187,333	312,709	462,320	865,722	895,296	727,911	1,425,173
Totals	Sales	979,722	960,602	1,250,209	2,018,592	3,797,410	4,739,434	5,723,459
	Use	453,554	703,865	916,630	1,324,098	2,363,006	2,440,024	4,229,927
	Both	1,433,276	1,664,467	2,166,838	3,342,689	6,160,416	7,179,457	9,953,382

U.S. Government Royalty (Mineral Royalty Returns to State)*

1970	1971	1972	1973	1974	1975	1976	1977
18,624,702	21,085,849	19,855,029	19,412,665	33,392,197	34,450,233	49,433,822	58,971,484

**Prior to 7/1/76 the State received 37 ½% of the Federal Mineral Royalties, and after 7/1/76 the State received 50%*

Prepared by: John T. Goodier, The Department of Economic Planning and Development, Mineral Development Division. December 1977.
Sources: Department of Revenue and Taxation and the State Treasurer.

APPENDIX TABLE 2. MINERAL INCOME TO THE STATE OF WYOMING – 1971-1977

in dollars per calendar year

Source	1971	1972	1973	1974	1975	1976	1977
Ad Valorem	28,272,830	29,044,678	29,264,908	36,952,188	56,781,222	70,754,810	84,981,772
Severance	5,048,761	5,171,411	5,121,307	18,138,581	40,315,561	46,034,800	65,277,891
Sales and Use	1,433,276	1,664,466	2,166,838	3,342,689	6,160,415	7,179,457	9,953,382
U.S. Rent and Royalty Returns*	21,085,848	19,855,028	19,412,664	33,392,196	34,450,233	49,433,821	58,971,484
State Rent	2,533,127	2,548,206	2,690,933	3,030,133	3,648,785	3,372,336	3,532,586
State Royalties	5,157,428	5,008,511	4,613,961	9,429,243	10,413,284	12,160,309	15,254,011
General Fund Income (Filing fees, etc.)	345,808	828,585	893,839	1,294,785	2,143,956	2,828,502	4,032,739
TOTAL	63,877,078	64,120,885	64,164,450	105,579,815	153,913,456	191,764,035	240,903,865

**Prior to 7/1/76 the State Received 37.5% of the Federal Mineral Royalties; after 7/1/76 the State Received 50%*

Prepared by: The Geological Survey of Wyoming
Sources: The Department of Economic Planning and Development, Department of Revenue and Taxation, the State Land Commission and the State Treasurer.

APPENDIX TABLE 3. DISTRIBUTION OF U.S. GOVERNMENT ROYALTY RETURNS TO THE STATE OF WYOMING, BY W.C.S. SEC. 1-9-577-1

Foundation Program	Highway Commission	University of Wyoming	Counties for Roads	Highway Commission for Counties	Incorporated Cities & Towns	Government Royalty Impact Assistance Act	School District Capitol Construction	State Highway
37.5%	26.25%	6.75%	2.25%	2.25%	7.5%	7.5%	4%	6%

Prepared by: John T. Goodier, The Department of Economic Planning and Development, Mineral Development Division. December 1977.
Sources: Department of Revenue and Taxation, and the State Treasurer.

STATE OF WYOMING

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GEOLOGICAL SURVEY

STATE OF WYOMING

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