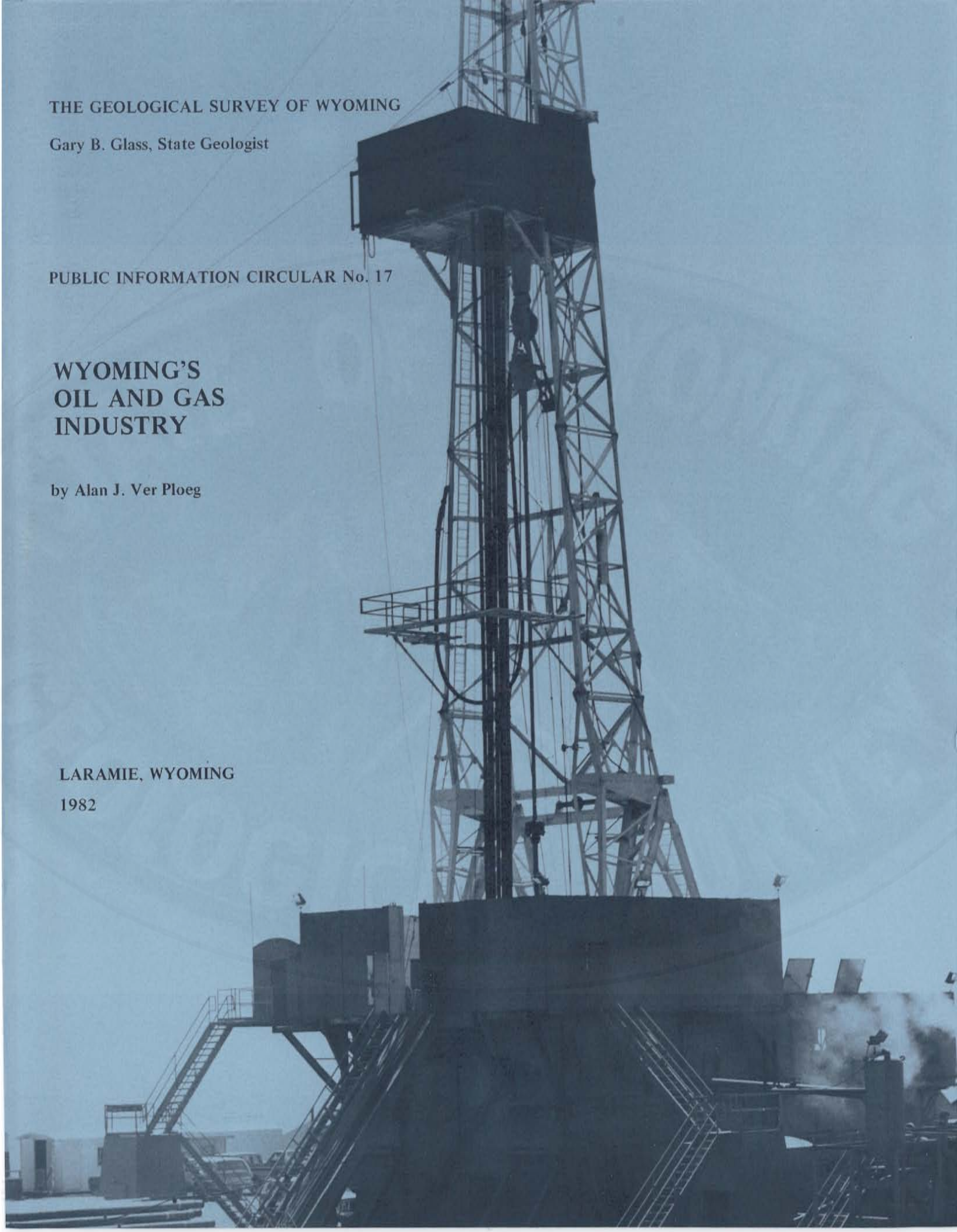
THE GEOLOGICAL SURVEY OF WYOMING

Gary B. Glass, State Geologist

PUBLIC INFORMATION CIRCULAR No. 17

WYOMING'S OIL AND GAS INDUSTRY

by Alan J. Ver Ploeg



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Front cover. Chase #6 rig, under contract by Chevron USA to drill the Chevron USA 1-20E-A East Whitney Canyon well in sec. 20, T.17N., R.119W. The test is scheduled to a depth of approximately 15,800 feet in subthrust Cretaceous rocks. Photograph by Alan J. Ver Ploeg.

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INTRODUCTION AND HISTORICAL BACKGROUND

Wyoming's oil and gas industry is the state's largest mineral industry in terms of value of material produced, income to the state, and employment. According to figures compiled by the Petroleum Association of Wyoming, the oil and gas industry in Wyoming provided 79 percent of the assessed value of all minerals produced in 1980 in the state and employed more than 30,000 people. 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 has 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.

First recorded reference to the occurrence of oil within the state dates back to Captain Bonneville's visit, in 1833, to the "Great Tar Spring" on the Popo Agie River near present-day Lander. 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. Mike Murphy discovered the first oil field, Dallas Dome, in 1884 when he drilled 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 (Figure 1). Development continued in Salt Creek field and transportation of the oil shifted from freight wagons (Figure 2) to pipeline near the turn of the century. Pennsylvania Oil and Gas Company built the first small refinery in Casper in 1895 (Figure 3). During the period 1900-1920, drilling efforts 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 (Plate I).

Although these early discoveries indicated tremendous oil reserves, not only did Wyoming lack close market areas, but rail transportation to the population centers of the East and West was costly. Wyoming could not compete with mid-continent, eastern, and California oil. Crude prices dropped as low as 10¢ per barrel in the 1930's and it wasn't until the 1940's, with the demand brought on by World War II, that development moved back into full swing. Development continued to expand dramatically into the 1970's.

GEOLOGIC SETTING

Occurrence of oil and gas in Wyoming is tied closely to the location of its large sedimentary basins. The most important in terms of oil and gas production are the Powder River Basin, Greater Green River Basin, Bighorn Basin, and Wind River Basin (Plate I). Two smaller basins, the Washakie Basin and Great Divide Basin, have also become important as a result of recent gas discoveries there.

Wyoming's oil and gas normally occur in either structural or stratigraphic traps or in a combination of the two. The majority of Wyoming's stratigraphic traps occur in the stable interior portions of the basins. For example, many of the more recent discoveries in the Powder River Basin are stratigraphic traps.

Many of the early discoveries were structural traps, usually occurring on the highly deformed margins of basins. Several of the fields in the Bighorn Basin are excellent examples of this type of occurrence. Because of their obvious surface expression, these features were often the targets of early exploration ventures. Unfortunately, industry has tested nearly all of the obvious structures and only the more subtle, deep-buried structural traps remain as exploration targets. Industry now relies on new high-resolution seis-

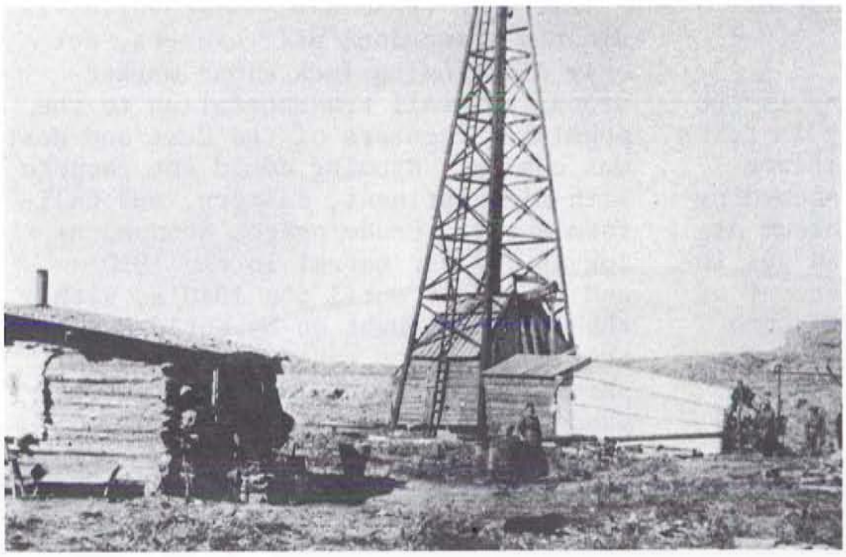
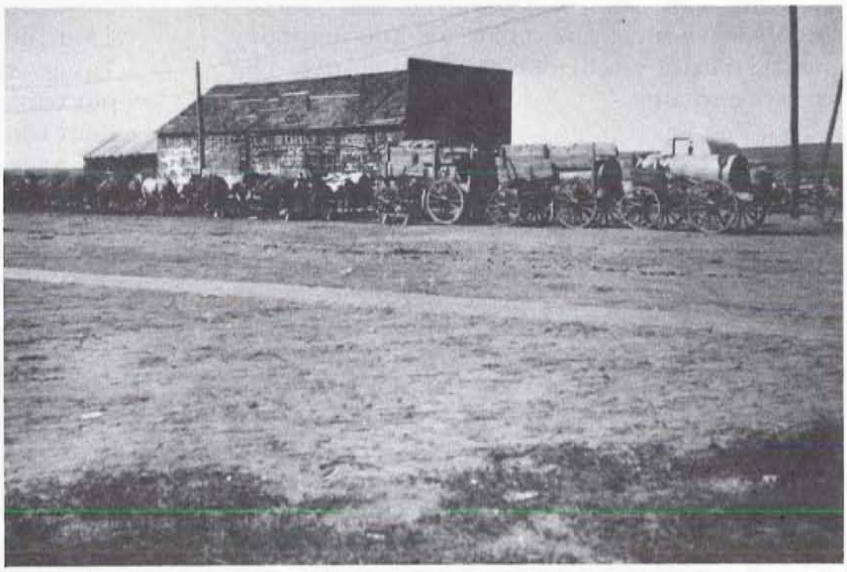


Figure 1. The Shannon Field discovery well, drilled by H.P. Shannon in 1889 and representing the first commercial oil well drilled in Natrona County. Oil flowed at the rate of 10 barrels per day from the Shannon Sandstone at 1,000 feet. Soon after this discovery, Shannon and his associates formed the Pennsylvania Oil and Gas Company. (Photo from University of Wyoming Petroleum History Center).

Figure 2. Oil was transported by wagon from Shannon Field to the refinery in Casper until the completion of a pipeline in 1911. A normal complement of wagons was pulled by 12 to 18 horses. Supplies and equipment were transported to the fields on the return trip. The trip was 60 miles one way and usually took at least two to three days. (Photo from University of Wyoming Petroleum History Center).



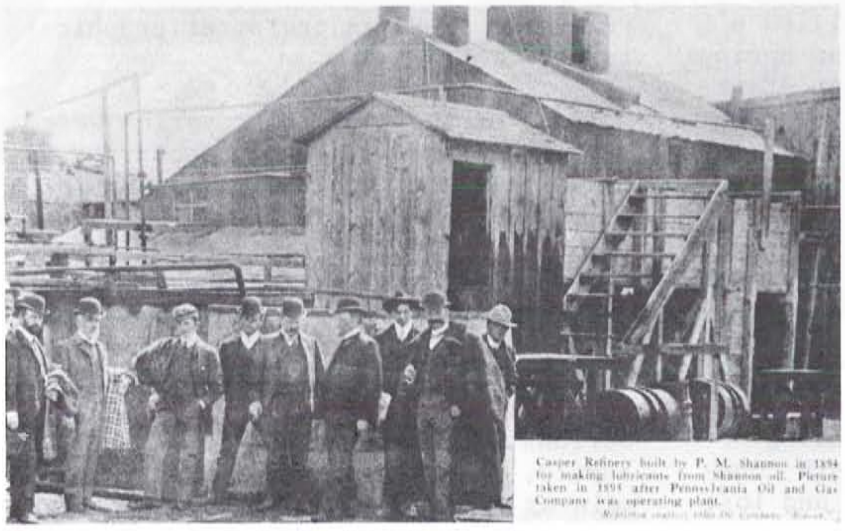


Figure 3. In 1895, Shannon completed construction of the first refinery in Wyoming. The refinery, located at Casper, was quite small by today's standards, having a capacity of 100 barrels per day. Kerosene and lubricants were its first products as there was no real use for gasoline at this time. (Photo from University of Wyoming Petroleum History Center).

Table 1. Ten most important oil-producing formations in Wyoming. Source: Wyoming Oil and Gas Conservation Commission, 1981.

Formation	1980 Oil Production (barrels)	Percent of Total Production
Pennsylvanian Tensleep Sandstone	31,279,800	24.8
Pennsylvanian Minnelusa Formation	14,774,006	11.7
Jurassic Nugget Sandstone	9,276,966	7.3
Mississippian Madison Limestone	7,316,361	5.8
Upper Cretaceous Shannon Sandstone	7,183,322	5.7
Lower Cretaceous Muddy Sandstone	5,864,132	4.6
Permian Phosphoria Formation	5,463,087	4.3
Permian Phosphoria Formation/ Pennsylvanian Tensleep Sandstone	5,375,561	4.3
Permian Embar Formation	4,514,021	3.6
Upper Creatceous Wall Creek Sandstone	4,209,621	3.3
TOTALS	95,256,877 barrels	75.4%

mic techniques, as opposed to surface mapping techniques, to locate deep, subtle structures such as those recently discovered in the Overthrust Belt region. New seismic techniques have proven quite instrumental in Overthrust Belt exploration as well as aiding in the search for stratigraphic traps.

The reservoir rock in Wyoming is Tertiary to Precambrian in age (a recent Amoco well in Lost Soldier field was completed in fractured Precambrian crystalline rock). In general, fields in more stable interior basin areas are characterized by stratigraphic traps and produce from Tertiary and Cretaceous reservoirs. Conversely, those in more highly deformed margins of the basins are characterized by structural traps and produce from older rocks (Jurassic, Permian, Pennsylvanian, Mississippian, etc.). Bighorn Basin fields, for example, fall in the latter category, while the Powder River and Greater Green River Basin fields fall predominately in the former. Wind River Basin fields are included in both categories. Based on 1980 production, the most important formations in terms of oil production are the Tensleep, Minnelusa, Nugget, and Madison (Table 1). The most significant gas-producing formations include the Frontier, Nugget, Mesaverde, and Lewis (Table 2). Over 75 percent of total oil production comes from the top ten oil-producing formations and over 70 percent of total gas production comes from the top ten gas producers. In all, at least 141 different formations or combinations of formations produce oil and/or gas in Wyoming according to Wyoming Oil and Gas Conservation Commission statistics for 1980.

DRILLING AND PRODUCTION

Drilling activity in Wyoming fluctuated greatly during the period 1970-80 (Table 3). Rotary rig activity (Figure 4) in Wyoming reached a 14-year high in 1974 (107) and continued at

Table 2. Ten most important gas-producing formations in Wyoming. Source: Wyoming Oil and Gas Conservation Commission, 1981.

Formation	1980 Gas Production (MCF)	Percent of Total Production
Upper Cretaceous Frontier Formation	66,438,811	14.7
Jurassic Nugget Sandstone	52,176,125	11.6
Upper Cretaceous Mesaverde Formation	49,298,306	10.9
Upper Cretaceous Lewis Shale	28,841,572	6.4
Lower Cretaceous Muddy Sandstone	28,434,511	6.3
Upper Cretaceous Almond Formation	23,787,249	5.3
Lower Cretaceous Dakota Sandstone	20,402,903	4.5
Mississippian Madison Limestone	17,235,918	3.8
Pennsylvanian Weber Sandstone	16,637,366	3.7
Tertiary Fort Union Formation	14,181,397	3.1
TOTALS	317,434,162 MCF	70.3%

Table 3. 1970-1981 Wyoming drilling summary. Source: Data for 1970-1980 from American Association of Petroleum Geologists. Data for 1981 from Petroleum Association of Wyoming.

Year	Exploration Wells	Percent Success	Development Wells	Percent Success	Total Wells	Total Footage Drilled (millions)	Average Depth	Average Active Rotary Rigs
1970	586	12.5	830	72.2	1,416	9.7	6,831	71
1971	345	12.5	548	73.9	893	5.7	6,339	45
1972	452	13.7	513	65.5	965	6.5	6,722	61
1973	369	13.6	516	75.9	885	5.8	7,553	70
1974	457	13.1	519	74.4	976	6.8	6,942	107
1975	462	19.9	798	75.0	1,260	8.9	7,114	107
1976	338	18.0	637	63.4	975	7.0	7,144	86
1977	468	21.7	827	78.9	1,295	9.5	7,332	120
1978	477	18.7	905	86.6	1,382	9.7	7,000	137
1979	379	23.5	956	76.9	1,334	9.1	6,787	147
1980	412	24.7	995	75.5	1,407	10.8	7,667	155
1981	590	20.2	1,134	75.8	1,724	12.4	7,174	190

that rate into 1975 when a five-year high of 1,260 wells were drilled. After dropping off in 1976, activity began its most recent climb to its present peak. This trend has continued into 1981, as 1,724 wells were drilled and active rigs averaged 190 (Table 3).

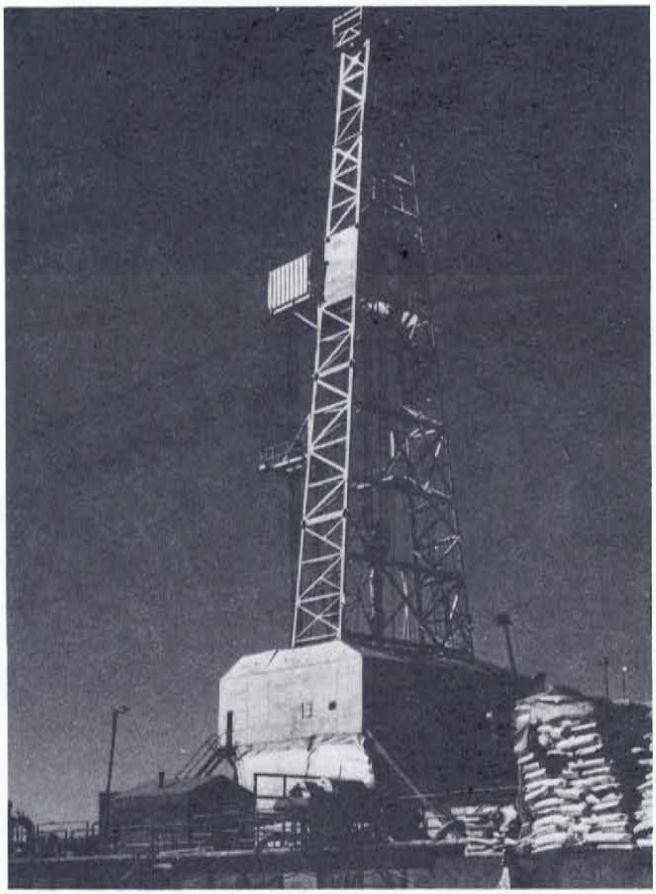


Figure 4. Parker Drilling Rig #112 contracted by Colorado Interstate Gas Company to drill the 1-6-36-86 Bullfrog Unit well in western Natrona County. This well was drilled to a depth of 20,850 feet in Waltman Field and completed in October 1979 in the Muddy, Dakota, Morrison, and Sundance, producing at the rate of 1,764,000 cubic feet of gas per day. (Photograph by compiler.)

The breakdown of development wells versus exploratory wells averaged only 50-55 percent in favor of development during the period from 1966 to 1974. However, in 1975 and 1976, with recently enacted and impending tax legislation unfavorable to exploratory efforts, the percentage of exploratory wells dropped from nearly 50 percent to 35 percent, and by 1980 dropped to 29 percent. This trend should begin to reverse with price incentives for tight gas sand production and increased capital for exploration as a result of oil price decontrol in 1981.

The majority of the exploratory and developmental drilling during the last ten years occurred in the Powder River Basin and it appears that trend will continue for several years. Statistics for 1980 show 55 percent of all exploratory wells were drilled in the Powder River Basin. The Greater Green River Basin claimed 21 percent of all exploratory wells drilled in 1980 (Table 4).

Compared with some of the big oil and gas producing states, Wyoming seems to play a relatively insignificant role in domestic production. According to statistics for 1980, Wyoming ranks sixth in crude oil production, following (in descending order) Texas, Alaska, Louisiana, California, and Oklahoma, and sixth following Texas, Louisiana, Oklahoma, New Mexico, and Kansas in natural gas production (based on API statistics for 1980). However, with the exception of gas reserves and production, Wyoming dominates oil and gas statistics in the Rocky Mountain area (Table 5).

Early crude oil production in Wyoming (Figure 5) peaked in 1923 after discovery and development of some of the 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 was stable from 1961 to 1968. Discovery and development of large stratigraphic traps in the Powder River Basin led to a 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 returned to the level of the early and mid-1960's due to rapid depletion of some of the large old fields like Salt Creek in Natrona County. Production in 1980 is estimated at 126,361,962 barrels, nearly a 4.5 percent decline from 1979. A

Table 4. Completion summary for Wyoming, 1980.

	Oil	Gas	Dry	Total	Percentage Success
Exploratory wells					
Powder River Basin	35	4	188	227	17.2
Green River Basin	3	38	44	85	48.2
Bighorn Basin	3	2	23	28	17.9
Overthrust Belt	7	3	17	27	37.0
Wind River Basin	1	3	15	19	21.1
Denver Basin	0	0	13	13	0
Laramie-Hanna Basin	1	2	11	14	21.4
TOTAL	50	52	311	413	24.7

	Successful	Dry	Total	Percentage Success
Development wells	751	244	995	75.5

similar decline is expected in 1981, although new production from recent Overthrust Belt discoveries could counteract this anticipated decline.

When examining crude oil production on a county basis, in descending order, Park, Campbell, Sweetwater, Hot Springs, and Natrona Counties emerge as leaders in the state (Table 6). Large, old structural traps like 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, relatively recent stratigraphic discoveries (Hilight and Raven Creek fields, and most recently Hartzog Draw field) are largely responsible for Campbell County's production. Wyoming's reliance on the large, old fields for its oil production is evidenced by the fact that over 43 percent of the state's total production comes from the 10 largest fields, which average 51 years in age, according to statistics compiled for 1980 by the Petroleum Association of Wyoming. It is obvious that any sudden

Figure 5. Annual oil production in Wyoming 1912-1980 (from Wyoming Oil and Gas Conservation Commission).

decline in production from one of these large fields will greatly affect that particular county's production. Natrona County experienced this recently with the abrupt drop in production from Salt Creek field.

Gas production in Wyoming 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 (Figure 6). With declining production from some of the

Table 5. Wyoming's role in domestic production. Sources: Beck (1981) and American Petroleum Institute (1980).

Indicator	Percentage of *Rocky Mountain Total	Percentage of U.S. Total
Crude Oil Production	44.0	4.0
Crude Oil Reserves	64.4	3.0
Marketed Natural Gas Production	20.6	1.8
Natural Gas Reserves	21.4	2.4
Total Wells Drilled	23.5	2.1
Footage Drilled	30.1	3.6
Average Rig Count	34.8	5.3
Petroleum Refinery Capacity	29.8	1.1

*Includes Colorado, Montana, New Mexico, Utah, and Wyoming

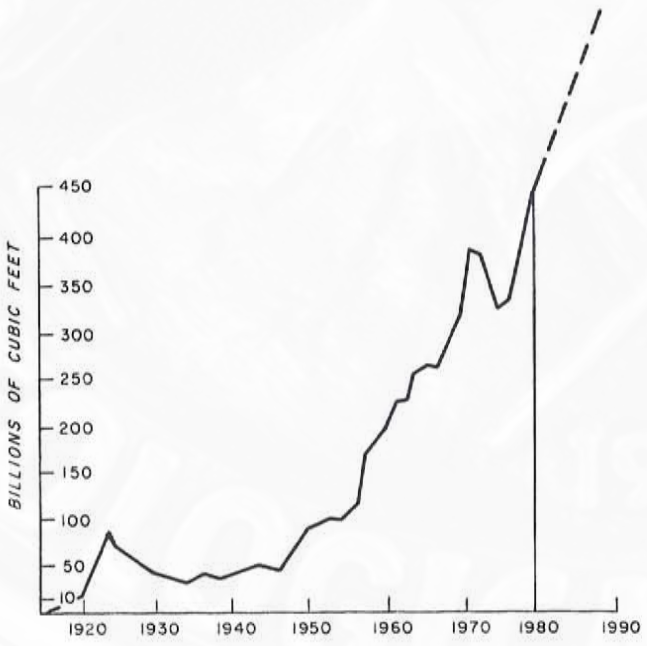


Figure 6. Annual gas production in Wyoming 1917-1980 (from Wyoming Oil and Gas Conservation Commission).

large older gas fields, overall production started a decline in 1973. New discoveries during 1974 and 1975 in the Green River and Wind River Basins initiated the upturn in 1976. Additional discoveries in these two basins along with vast new discoveries in the Overthrust Belt account for the dramatic increase of the last four years leading to an all time high gas production of 450,553,045 MCF in 1980.

Gas production totals on a county basis show that the leaders, in decending order, are Sweetwater, Fremont, Sublette, Uinta, and Campbell Counties (Table 6). In general, gas production in Park and Sublette Counties comes from large, old fields (structural traps) like Elk Basin and Oregon Basin in Park County and Hogsback and Tip Top in Sublette County. Campbell, Sweetwater, and Fremont Counties owe much of their gas production to Tertiary and Cretaceous stratigraphic or structural 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 nearly 50 percent of the total coming from the 10 largest gas fields, which average 16 years in age (Petroleum Association of Wyoming, 1980).

Table 6. 1980 Production of oil and gas by county. Source: Oil and Gas Conservation Commission, 1981.

County	Number of Fields	Number of Wells	Oil Production -BBLS-	Gas Production -MCF-
Albany	6	35	164,571	18
Big Horn	23	452	6,038,738	4,355,871
Campbell	169	1,508	23,591,348	25,188,075
Carbon	43	348	1,719,005	39,428,733
Converse	43	995	7,642,650	19,156,171
Crook	47	372	2,983,478	307,704
Fremont	50	767	7,210,475	68,379,301
Goshen	2	5	2,180	—
Hot Springs	25	844	10,207,475	149,992
Johnson	25	506	3,513,285	2,149,313
Laramie	10	51	236,326	36,237
Lincoln	19	220	264,787	18,824,416
Natrona	45	2,078	9,389,214	11,607,813
Niobrara	25	262	1,451,427	1,202,702
Park	43	1,188	27,099,350	14,816,525
Platte	—	—	—	—
Sheridan	5	37	150,890	12,273
Sublette	23	656	1,990,670	50,034,086
Sweetwater	95	767	11,220,335	144,264,423
Teton	—	—	—	—
Unita	14	93	6,757,155	43,690,951
Washakie	20	245	2,448,300	5,241,251
Weston	33	1,219	2,280,303	1,707,190
TOTAL	765	12,648	126,361,962	450,553,045

Out of nearly 400 companies operating in Wyoming, the top twenty account for 80 percent of the oil production and 65 percent of the gas production (Table 7). Although the major oil companies play a very important role in Wyoming's production, the figures in Table 7 illustrate the importance of the smaller independent companies. In terms of recent important discoveries, the smaller independents are playing an ever increasing role. Hartzog Draw, where the most active operators are Woods Petroleum, Davis Oil, and Diamond Shamrock, is a prime example.

Much less than half of the oil within a field is ever recovered by normal production techniques, and, as a result, efforts are eventually geared toward very expensive enhanced recovery techniques. One of the first "secondary recovery" methods, 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. "Tertiary recovery" techniques include 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

Table 7. Wyoming's 1980 oil and gas production by company.

Company Name	Percentage of Wyoming's Total Oil Production	Percentage of Wyoming's Total Gas Production
Amoco Production	24.2	17.7
Marathon Oil Co.	17.0	2.8
Conoco Oil	5.2	.9
Champlin Petroleum Co.	3.7	9.5
Atlantic Richfield Co.	3.1	1.1
Davis Oil Co.	3.1	4.6
Inexco Oil Co.	1.9	1.1
Mobil Oil Co.	1.8	4.0
Chevron Oil Co.	3.2	6.0
Texaco, Inc.	1.7	8.6
Gulf Oil Corp.	1.7	.1
Woods Petroleum	1.6	.8
Terra Resources	1.6	.9
Husky Oil	1.8	.4
Cities Service Co,	2.2	1.1
Fenix and Scisson	1.2	.5
Petro Lewis	2.0	.2
Union Oil of California	1.2	1.9
Shell	1.0	1.9
Diamond Shamrock Corp.	.8	1.1
TOTAL	80.0%	65.2%

*Note: Mountain Field Supply, Monsanto Company, and Belco Petroleum account for 16.8 percent of gas production in Wyoming although they are not in the top twenty oil producers listed above.

Source: Oil and Gas Conservation Commission, 1981.

recovery methods, however, are the more common as industry strives to prolong production from the large oil fields. According to 1980 statistics compiled by the Oil and Gas Conservation Commission, industry is involved with 200 water injection projects, 8 gas injection projects, 3 hydrothermal or steam injection projects, 2 air injection projects, and 15 tertiary projects in various fields within Wyoming.

INCOME TO THE STATE OF WYOMING

Although oil 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 OPEC price increases and decreasing domestic supplies (Figure 7). The assessed valuation of oil produced in Wyoming should increase considerably with the price decontrol initiated in January 1981. Prior to this price decontrol, there was a two-tier pricing system based on "new" oil and "old" oil. Simply stated, "old" oil is oil from wells drilled prior to 1973 and "new" oil is oil from wells drilled after 1973. Due to the enactment of the Energy Policy and Conservation Act of 1975, the price of oil moved from less than $3.00 per barrel prior to 1973 to over $12.00 for "new" oil in 1976 as the ceiling for

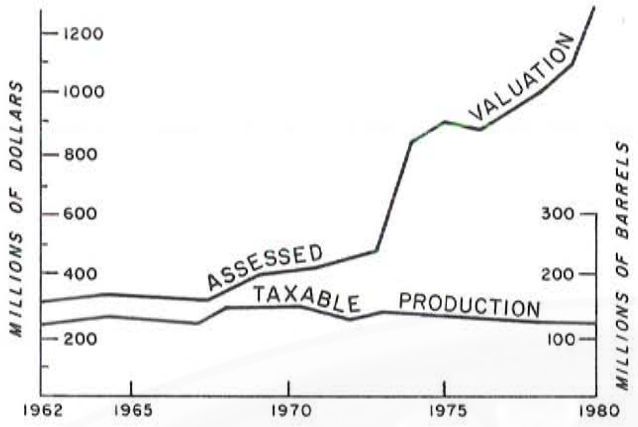


Figure 7. Annual taxable production and assessed valuation of Wyoming's oil production 1962-1980 (from Wyoming Department of Economic Planning and Development). Note: Assessed valuation is based on the previous year's taxable production.

"new" oil was lifted (1978 Wyoming Mineral Yearbook). Obviously, counties with a high percentage of newly discovered oil fields, Campbell County for examples, have had a higher assessed valuation on the same amount of production. However, this situation should change with the decontrol of prices.

Essentially the same situation applies to natural gas in Wyoming. Recent price increases have caused a dramatic rise in assessed valuation, 129 percent for the period from 1971 to 1976 (Figure 8). During the same period, overall production declined 12 percent. New regulations set by the Federal Power Commission in July 1976 provided that (1) gas discovered after December 31, 1974 may be sold at up to $1.42 per thousand cubic feet (MCF); (2) gas 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 29.5¢ per MCF. However, when current contracts expire, the price may be raised to as high as 52¢ per MCF (1978 Wyoming Mineral Yearbook). Here, again, a county's relative percentage of new versus old gas production has greatly affected its assessed valuation.

As mentioned previously, production the last four years has increased dramatically and should continue to do so, spurred by price incentives for designated tight gas sand production. This, along with lifting of price ceilings and eventual decontrol, should push assessed valuation up very dramatically.

EXPLORATION AND RESERVES

Exploration efforts during the past seven years have been concentrated in the Powder River Basin, and the second most active area, the Greater Green River Basin. Most drilling during this time has been to locate new stratigraphic traps in these two basins, based on indications from seismic profiles.

The discovery of Pineview field in Utah (1975) and Yellow Creek field (1976) in Wyoming initiated accelerated

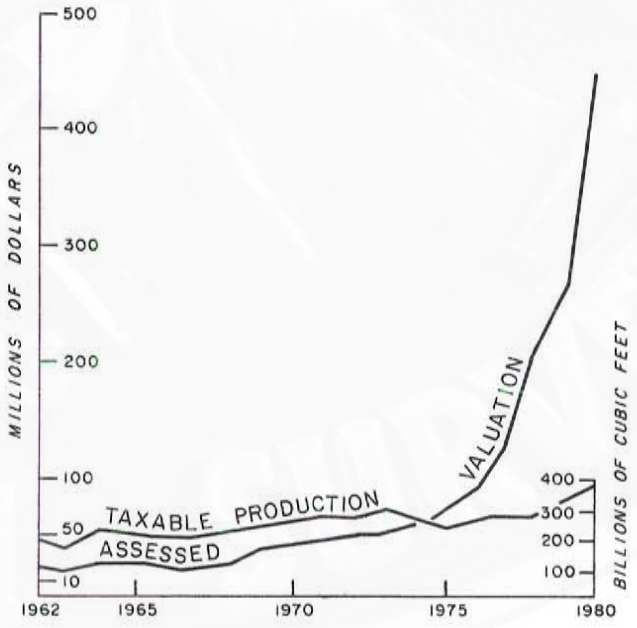


Figure 8. Annual taxable production and assessed valuation of Wyoming's gas production 1962-1980 (from Wyoming Department of Economic Planning and Development). Note: Assessed valuation is based on previous year's taxable production.

exploratory work in the Overthrust Belt. New seismic techniques, including multiple sensing of a single subsurface point, digital data recording, and computer processing made much more accurate determination of subsurface geologic structures possible. Thanks to these new improved high resolution seismic techniques, these highly complicated, deep structural traps were recognized and successfully drilled. Industry now recognizes seismic surveying as the primary form of pre-drilling exploration, and seismic crews remain very active 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. At the end of 1980, forty-six rigs were active in the area.

Recent gas discoveries in the Washakie and Great Divide Basins have spurred exploration drilling and seismic surveying in that region. Deep drilling in the interior of the Wind River Basin has encountered vast new gas reserves and is prompting industry to consider the untested interior portion of the Bighorn Basin.

Reserve totals, as might be expected, depend heavily on exploration success. Many variables are involved in estimating discovered and undiscovered oil and gas reserves and, as a result, values arrived at are quite subjective and vary considerably with the parameters and definitions used. This is especially true of estimates of undiscovered reserves. For example, in 1971 the U.S. Geological Survey's estimate of undiscovered reserves in the U.S. was 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 more concrete numbers. 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 1969-80 are shown in Table 8.

As might be expected, the trends in the oil and gas reserve estimates in Table 8 and 9 correlate quite closely with those noted for production during the same time period. For example, the increase in oil reserves from 1970 to 1971 resulted largely from the discoveries in the Powder River Basin during that period. The increase in gas reserves from 1973 to 1974 corresponds with 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 could slow the trend as shown by the increase from 1979 to 1980. Gas reserves should continue to increase significantly as a result of continuing exploration success in the Overthrust Belt and in Sweetwater and Fremont Counties. For example, discovered reserve estimates for the Whitney Canyon - Carter Creek complex in the Overthrust Belt total 5.3 trillion cubic feet of gas, a number that will more than double the state's total reserves.

REFINING AND TRANSPORTATION

The 13 refineries currently operating within the state (Table 9) are capable of processing crude oil at the rate of 209,290 barrels per day, more than half of Wyoming's 1980 daily production of crude oil and lease condensate, 348,000 barrels. Recent figures indicate that major refineries in the state are operating at between 80 and 90 percent capacity. Wyoming's refineries obtain 95 to 100 percent of their crude oil from within the state. Although no precise data are kept regarding refinery yields in Wyoming, indications are that they are quite close to the average for the Northern Rocky Mountain area shown in Table 10.

Products are normally extracted from crude oil through a complex process of heating, catalyst action, molecular alteration, distillation, or several other

Table 8. Estimated discovered oil and gas reserves in Wyoming, 1969-1980. Source: Petroleum Association of Wyoming, 1980, from data supplied by the American Petroleum Institute.

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
1-1-78	815,578	3,962,850
1-1-79	804,567	4,315,775
1-1-80	808,765	4,685,491

Note: Reserve numbers are now kept by the Department of Energy, using different accounting techniques. They show oil reserves of 841 million barrels and 928 million barrels for 12-31-79 and 12-31-80 and gas reserves of 7.5 trillion cubic feet and 9.1 trillion cubic feet for 12-31-79 and 12-31-80.

Table 9. Refineries in Wyoming. Source: Cantrell (1981).

Location	Operating Company	Rated Capacity (barrels per calendar day)
Casper	Amoco Oil Co.	48,000
*Casper	Texaco, Inc.	21,000
Casper	Little America Refining	24,500
Cheyenne	Husky Oil Co.	28,800
Cody	Husky Oil Co.	11,500
Cowley	Sage Creek Refining Co.	1,000
LaBarge	Mountaineer Refining	500
LaBarge	Southwestern Refining	800
LaBarge	Silver Eagle Oil, Inc.	2,000
Lusk	C&H Refinery, Inc.	190
Newcastle	Wyoming Refining Co.	12,500
Osage	Glacier Park Co.	9,500
Sinclair	Sinclair Oil Corp.	49,000
	TOTAL	209,290

*Indications are that the Texaco refinery in Casper will close in early 1982.

Table 10. Northern Rocky Mountain area refinery yields for August 1981. *(Area includes Wyoming, Utah, Montana, and Colorado) Source: D.O.E. Monthly Petroleum Statement, August, 1981.*

Product	(Total U.S.)	(Northern Rockies)
Gasoline	45.5	49.2
Distillate fuel oil	20.1	27.4
Residual fuel oil	9.3	3.2
Jet fuels	7.7	7.2
Asphalt	3.3	6.0
Still gas for fuel	4.4	4.3
Coke	3.0	2.3
Others	6.7	.4
TOTAL	100.0	100.0

techniques, any combination of which may be used by a refinery. Techniques of vacuum distillation, catalytic cracking, catalytic hydro-treating, and catalytic reforming predominate in Wyoming refineries.

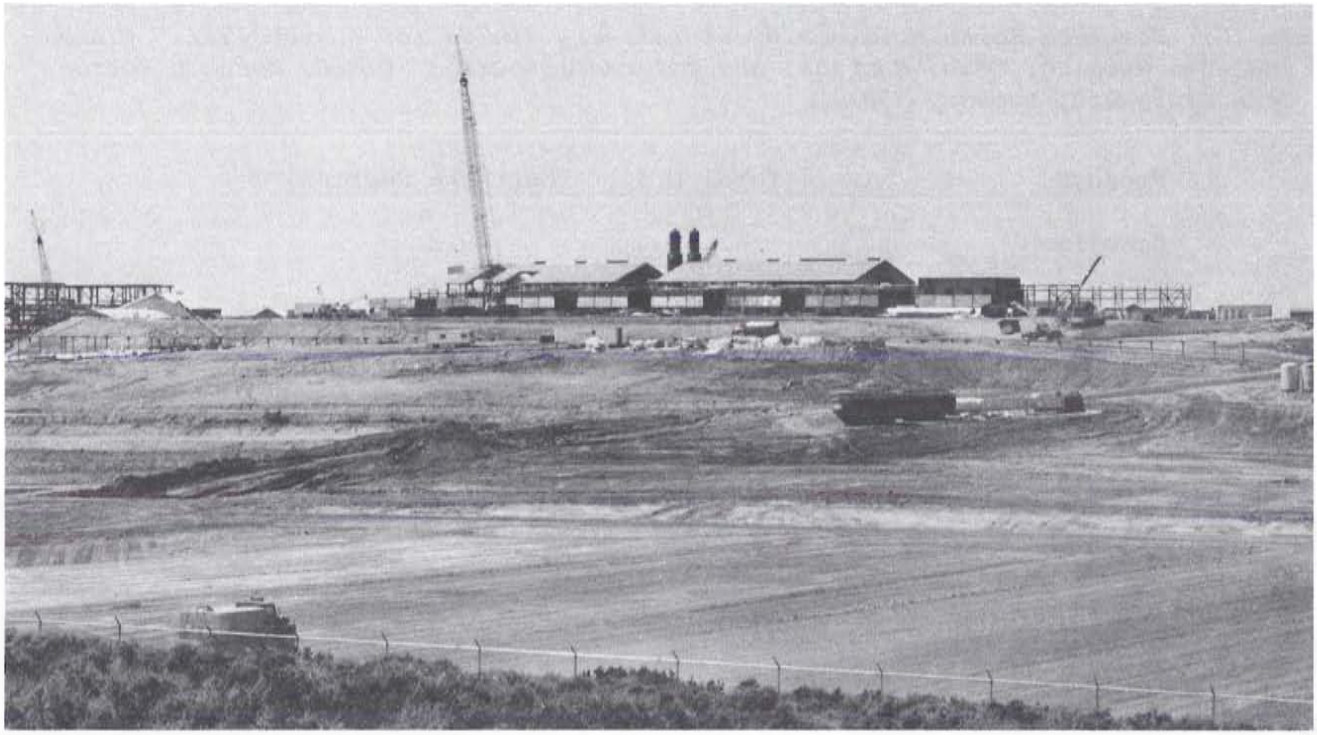
If crude oil production declines sharply within the state, refineries will have to cut back. However, refining companies in Wyoming are hopeful that new discoveries in the state and especially the Overthrust Belt will maintain their supply of crude oil.

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. On January 1, 1981 forty-three natural gas processing plants were operating in Wyoming. In 1980 these plants produced 442,271,023 gallons of liquid petroleum fuels from 299,467,740 MCF of processed natural gas. In conjunction with the recent Whitney Canyon - Carter Creek Overthrust Belt discoveries, Amoco and Chevron commenced work on 250- and 150-million-cubic-feet-per-day hydrogen sulfide removal plants, two of the largest in the state (Figures 9A,B).

The trend in production of liquid petroleum fuels essentially parallels that of natural gas production in the state over the last ten years. Table 11 shows a breakdown of LP yields in the Northern Rocky Mountain area for December 1980 (Department of Energy, 1980-81).

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° Fahrenheit. This process condenses most of the liquid out of the gas. To maintain their operations, gas plant operators are heavily dependent on new discoveries of large reserves like those recently found in the Overthrust Belt, Green River Basin, and Wind River Basin.

Nearly all of Wyoming's produced crude oil is transported by pipeline. Simply stated, gathering lines from each well link with larger trunk line systems that move the oil to refineries. In newly discovered oil fields, tank trucks transport the oil until gathering and trunk lines are constructed. Product lines carry more than half of the refined products and the remainder is



A

B

Figure 9. (A) Construction activity at the Amoco Whitney Canyon sour gas treatment plant. The plant will have a processing capacity of over 250 million cubic feet of gas per day. Photograph by A.J. Ver Ploeg, June 1981. (B) Work camp constructed by Amoco to house the construction force necessary for completion of the Whitney Canyon plant. Photograph by A.J. Ver Ploeg, June 1981.

Table 11. Breakdown of December 1980 natural gas plant yields in Wyoming. Source: Department of Energy (1980-81).

Type of Natural Gas Liquid	Percent of December, 1980, Production
LPG (includes butane, propane, ethane, etc.)	69%
Natural gasoline and isopentane	29
Plant condensates	2
TOTAL	100%

transported by truck or railroad tank car.

Natural gas is transported to processing plants in much the same manner as crude oil, i.e., gathering lines converging 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.

In pipeline transportation of petroleum, four-inch-diameter pipe is normally used for gathering lines, eight-inch for trunk lines and oil product lines, and 16- to 20-inch or more for gas transmission lines. With the recent rise in steel prices, along with greatly increased labor costs, the price of installing a pipeline has risen dramatically and in most cases has more than doubled over the last ten years.

There are 30 pipeline companies operating 10,051 miles of pipeline in Wyoming. Amoco Pipeline Company operates the most extensive crude oil and product pipeline system (1,456.42 miles) in Wyoming. The largest gas pipeline system (1,409.4 miles) is operated by Colorado Interstate Gas Company (Petroleum Association of Wyoming, 1980).

Of the 125 million barrels of crude produced in Wyoming in 1980, less than 50 percent went to in-state refineries. The remainder was moved by pipeline to refineries in other states in the Rocky Mountain area and the Midwest. Table 12 shows the distribution of crude oil exported from Wyoming in 1975 and 1980.

Crude oil from Wyoming is important to Colorado, Montana, and Utah. For example, in 1980 Montana refineries received 69 percent of their total crude oil from Wyoming, Colorado received 45 percent, and Utah received 24 percent. These percentages have remained fairly constant over the last 5 years.

For the last five years, less and less of the state's gas production has been consumed in-state. For example, in 1972, 38 percent of the state's total production was consumed within the state. By 1979, according to the Department of Energy, only 23 percent was consumed in Wyoming. This trend is alarming to some Wyoming residents as more and more of the new discovered gas is going out-of-state. In-state shortages of gas are already evident in some communities. The interstate distribution of natural gas from Wyoming differs somewhat from that of oil in that it goes primarily to immediately surrounding states. In descending order, these states are Colorado, Utah, Nebraska, and Montana. As with crude

Table 12. Distribution of total crude oil exported from Wyoming. Source: Miller et al. (1978) and Department of Energy (1980-81).

State	Annual percentage 1975	Annual percentage 1980
Illinois	17.3%	8.1%
Indiana	10.1	16.2
Kansas	19.7	12.4
Michigan	8.1	9.3
Missouri-Nebraska	1.1	2.8
Ohio (west)	4.2	2.7
Colorado	8.7	7.6
Montana	20.3	25.2
Utah	7.1	14.8
TOTAL	96.6%	99.1%

oil, gas from Wyoming represents a relatively large portion of the gas received by these states. This pattern has remained essentially the same during the past 5-10 years.

OIL SHALE

Simply stated, "oil shale," or marlstone as it is more accurately termed in Wyoming, is a fine-grained rock containing not oil but an organic substance called kerogen which, when heated to 900°F, is distilled into a type of crude oil that provides all the fuels obtained from crude petroleum (McAuslan, 1971).

Essentially all the potentially economic oil shale in the United States is contained within three basins, the Piceance Creek Basin in Colorado, the Uinta Basin in Utah, and the Green River Basin in Wyoming. Deposits in this three-state area contain an estimated 8 trillion barrels of shale oil, a quantity greater than the sum of the world's entire oil reserve. Obviously, these shale oil resources will become more important as our petroleum reserves dwindle. Unfortunately, many problems involving technology, economics, and the environment remain to be solved. The oil shale industry in Colorado is experimenting with various mining techniques, including "in situ" or in-place techniques, which can recover the shale oil without removing the rock from the ground. The Laramie Energy Technology Center at Laramie, Wyoming, (U.S. Department of Energy) is currently conducting "in situ" oil shale research.

Wyoming's oil shale occurs in the Green River Formation of Tertiary Eocene age. The richest deposits are situated in the central and eastern Green River Basin (Plate I). Studies completed by the U.S. Bureau of Mines (Culbertson, Smith, and Trudell, 1980) indicated potential yields of up to 30 gallons 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. The deposits have not been fully evaluated, but rough estimates are as high as 430 billion barrels of shale oil resources (in rock with 10 gallons of oil or better per ton) in the Green River Basin.

Unfortunately, development of Wyoming's oil shale is apparently some distance down the road. Industry interest and efforts are now centered in Colorado

where yields are as high as 25 to 65 gallons per ton, more than double the quality of Wyoming's oil shale. In 1974, the State of Wyoming offered 1,280 acres of the state's best oil shale lands for lease and received no bids from industry. However, as petroleum reserves are depleted, economics and improved technology may rekindle interest in Wyoming's oil shale deposits.

FORECAST

Wyoming's role as the Rocky Mountain area's leader in petroleum production should continue well into the future. Oil production will probably continue its decline of the past four years, as production in the large oil fields in the Bighorn and Powder River Basins, which have traditionally carried Wyoming's production, continues to decrease. However, the rate of this overall decline is dependent on additional successes in the Overthrust Belt.

As a result of new successes in the Wind River and Green River basins and, most importantly, the Overthrust Belt, the outlook for natural gas production is excellent. Production should continue to phenomenal rates of increase exhibited for the past four years as fields such as Whitney Canyon - Carter Creek in the Overthrust Belt come on production with their enormous reserves.

Exploration will continue in the Powder River Basin, primarily for new stratigraphic traps. Deep drilling will be stepped up in the Wind River Basin in order to better define the extent of recently discovered large gas reserves. This deep drilling trend should carry over into the interior portion of the Bighorn Basin, which is relatively untested except for a recent deep gas success. Recent discoveries in the Green River, Washakie, and Great Divide Basins should stimulate increased exploration for gas there. The area now receiving the most exploratory interest, the Overthrust Belt, should continue to headline activity in the Rocky Mountain area as industry steps up its search for subtle deep structural traps. A recent Frontier gas discovery on the west flank of the Casper Arch should spur a relatively new type of exploration in Wyoming to test the nearly unexplored sedimentary sections beneath mountain-front thrusts: drilling though Precambrian crystalline rocks to reach the underlying sedimentary rocks. Good seismic data will be the key to success in these ventures (Gries, 1981).

Much improved high-resolution seismic techniques will continue as the most successful method of search for extremely subtle stratigraphic and deep structural traps. New remote satellite sensing techniques may also become important exploration tools.

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 stratigraphic and deep, subtle structural traps in the untested interior portions of basins. The upward trend in drilling noted in 1977 should continue as more and more wells are drilled as a result of Federal price decontrol and tight gas sand production incentives. Movement into the interior portions of basins will necessitate the drilling of much deeper wells with a concurrent increase in drilling costs. Obviously, labor and materials costs will increase, causing additional increases in drilling, production, and refining costs.

Out-of-state distribution of crude oil and gas should follow the same trends noted for recent years: percentages of outflow will probably increase. Because nearly all the new gas discoveries are earmarked for interstate transport, the problem of shortages within the state will not be mitigated by these new discoveries. Refinery expansion should level off, keeping pace with production.

In general, reserve totals for the state will follow the same trends expected for production. Experiments to

fracture tight gas sands in the Pinedale Unit in the northern part of the Green River Basin, if successful, could add quite significantly to the state's gas reserves. Also, the vast reserves represented by the state's oil shale could bolster production in the future as new technology and a more favorable economic climate develop.

It is obvious that exploration for new reserves is sensitive to government legislation and new regulations which affect costs. Projected trends could vary drastically in either a positive or negative sense, depending on steps taken by government. For example, Federal withdrawal of certain areas from mineral entry has been an exploration problem, particularly in the Overthrust Belt, and may remain one in the future. Withdrawals, in effect, close portions of this important area to exploratory drilling. Additional regulations affecting drilling procedures and exploration techniques could add to drilling costs and even lead to drilling cut-backs. Conversely, legislation decontrolling oil and gas prices should stimulate exploration drilling. It is quite evident that many variables affect the industry's future, not the least of which is the Federal government.

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