New Mexico's energy resources '8C

—annual report of Bureau of Geology in the
Mining and Minerals Division of New Mexico
Energy and Minerals Department

Bruce King, Governor of New Mexico

compiled by Emery C. Arnold
and James M Hill

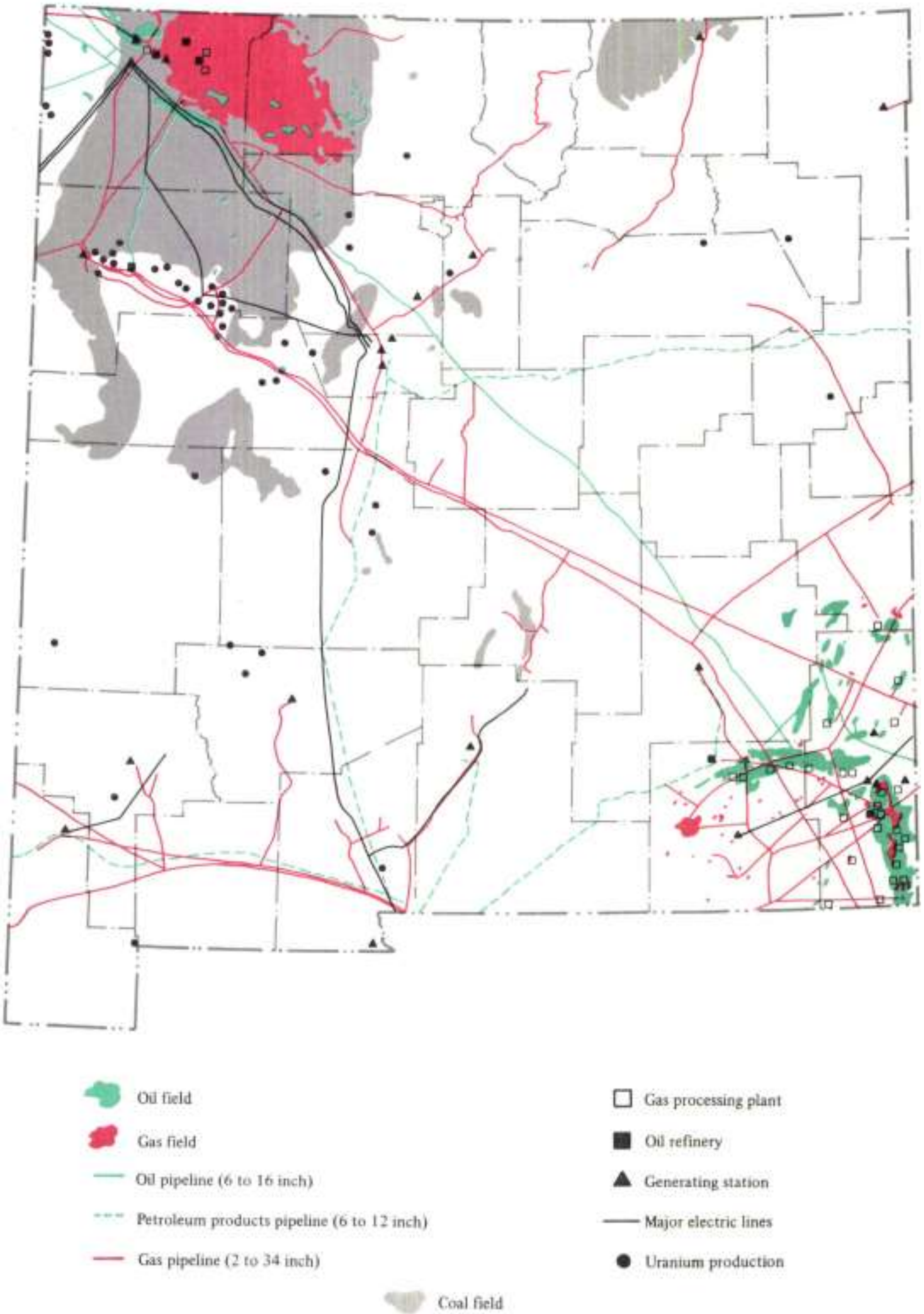
LANL's Hot Dry Rock Geothermal Project at Fenton Hill

New Mexico Bureau of Mines & Mineral Resources

Circular 181

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

1981



FRONTISPIECE—New Mexico's Energy Resources

This map is a small-scale version of Resource Map 2 by the New Mexico Bureau of Mines & Mineral Resources, 1974.

Circular 181

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

New Mexico's energy resources '80

—annual report of Bureau of Geology in the Mining and Minerals Division of New Mexico Energy and Minerals Department

compiled by
Emery C. Arnold, *Director, Mining and Minerals Division,*
and James M. Hill, *Chief, Bureau of Geology*

with contributions by
David A. Donaldson, William 0. Hatchell,
Kay S. Hatton, and Louis B. Martinez

SOCORRO 1981

First Printing, 1981

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63-1-4
Printed by University of New Mexico Printing Plant, April, 1981

Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801 Price $3.00

Preface

I am privileged to present this report to the Secretary of the Energy and Minerals Department for use by the state in formulating energy policy.

The Office of the State Geologist was established by Chapter 289 of the Laws of 1975. The Energy and Minerals Department Act, Chapter 255 of the Laws of 1977, became effective March 31, 1978. Under this act, the Office of the State Geologist became the Bureau of Geology, one of three bureaus in the newly formed Mining and Minerals Division of the Energy and Minerals Department. Permanent quarters are established at 1222 Luisa Street in Santa Fe (Post Office Box 2860, Santa Fe, NM 87501; telephone 505/827-5451). The staff of the Mining and Minerals Division consists of:

Administration
Emery C. Arnold, *Director*
Irene A. Ortiz, *Secretary to Director*

Bureau of Geology
James M. Hill, *Chief*
David A. Donaldson, *Staff Geologist*
William 0. Hatchell, *Staff Geologist*
Kay S. Hatton, *Staff Geologist*
Louis B. Martinez, *Staff Geologist*
Sandra C. Trujillo, *Secretary*

Bureau of Surfacemining
N. Ed Kelley, *Chief*
Larry L. Byrd, *Reclamation Specialist*
Timothy C. Hobbs, *Reclamation Specialist*
Jack F. Reynolds, *Reclamation Specialist*
Frances S. St. Peter, *Secretary*
John H. Spears, *Planner*
Thomas C. Tatkin, *Reclamation Specialist*

Bureau of Mine Inspection
Joe D. Longacre, Sr., *State Inspector of Mines*
Chris J. Aragon, *Deputy Inspector of Mines*
Felix T. Carrasco, *Dep. Insp. of Mines, Electrical*
Lupe 0. Chavez, *Financial Specialist*
Alfredo D. Duran, *Deputy Inspector of Mines*
Manuel Duran, *Deputy Inspector of Mines*
George C. Henckel, *Dust and Mine-Gas Inspector*
Janice L. Jones, *Typist*
Gilbert E. Miera, *Dust and Mine-Gas Inspector*
L. A. Quinones, *Dust and Mine-Gas Inspector*
Earl Roney, *Deputy Inspector of Mines*
William Sabo, *Dust and Mine-Gas Inspector*
Robert A. White, *Deputy Inspector of Mines*
Joanne M. Zamora, *Secretary*

The Bureau of Geology is charged with 1) conducting geological studies aimed at determining reserves of known supplies of energy resources and 2) conducting geological studies of probable potential supplies. The Bureau is also charged with cooperating with the New Mexico Bureau of Mines and Mineral Resources in preparing maps, brochures, and pamphlets on known, probable, and potential sources of energy in New Mexico; cooperating with private, state, and federal agencies in the gathering of geological data concerning energy supplies; and assisting the Secretary of the Energy and Minerals Department in the maintenance of an inventory of all reserves and potential sources of fuel and power in New Mexico.

This report is the fifth reserve and production summary published since the office was established and the third report to contain independently derived estimates of oil and gas reserves.

Personnel from the New Mexico Bureau of Mines and Mineral Resources have contributed time, effort, and material to the preparation of this report, and their cooperation is appreciated. Robert D. Jebb, of Solo Writing and Editing, Santa Fe, provided a great deal of editorial assistance. Staff members from the Bureau of Surfacemining and the Bureau of Mine Inspection helped compile information. I also wish to express my appreciation for advice and assistance received from the New Mexico Oil Conservation Division, the New Mexico Oil and Gas Accounting Division, the New Mexico Revenue Division, the U.S. Bureau of Mines, and the U.S. Department of Energy, as well as from the many industry personnel who contributed information and advice.

Emery C. Arnold
Director
Mining and Minerals Division
Energy and Minerals Department

Santa Fe
October 24, 1980

Contents

Tables

Figures

Abstract

Because of a steady depletion of reserves and the failure to make new discoveries in recent years, production of **crude oil** in New Mexico declined in 1979 with a production of 74.7 million bbls (barrels), which was 3.4 million bbls or 4.6 percent less than 1978 production. Although **condensate** production increased slightly over the previous year, total crude and condensate production continued to decline. **Natural-gas** production increased in 1979 by 3,565,351 thousand cu ft or 4 percent from the previous year, with an increase in production occurring in northwest New Mexico. Drilling continued to increase as the total number of well completions in New Mexico in 1979 was the highest in the past 9 yrs. Primary and secondary **crude oil reserves** were calculated for 50 major pools in southeast New Mexico and for selected oil and gas wells in northwest New Mexico. **Coal** production increased 1.8 million tons in 1979 or 14 percent over 1978 production, and a more extensive expansion will depend partly on factors such as the availability of rail transportation to new areas. The development of synthetic fuel technology may have a substantial impact on longer term coal production. Production of U_30, declined 13 percent from 1978 with 7,420 tons U_30, reported as production in 1979. A depressed uranium market and other economic factors contributed to the decline in production. New Mexico, however, continues to lead the nation in production and uranium reserves. Researchers are continuing to explore **geothermal** energy applications and to characterize geothermal systems in the state, and the U.S. Bureau of Land Management has issued 126 geothermal leases that remain active. Recent geothermal exploration activity has been detailed for 14 companies.

New Mexico's role

by E. C. Arnold and J. M. Hill, *Bureau of Geology*

The importance of New Mexico's role as a leading energy-resource producer is illustrated by the state's 6th-place rank in the nation in an average of state rankings in the production and reserves of oil, gas, coal, and uranium. The extent of New Mexico's energy-resource reserves and potential indicates that the state can be expected to experience accelerated growth in the extraction of these resources as the nation turns to domestic production to offset foreign imports. This trend toward domestic production will be heightened by the attractiveness of strippable western coal, with its low sulfur content, and by emerging new uses for traditional fuels. The federal government is also pressing for the development of new energy technologies, particularly in the area of synthetic fuels, which will create greater demands to develop New Mexico's vast resources.

The production of $U30_8$ (yellowcake) for the nuclear fuel cycle has recently been the area of New Mexico's most significant energy development. New Mexico is not only the leading state in $U30_8$ production and uranium reserves (40 percent of domestic production and 48 percent of reserves producible at $50 per lb) but also is surpassed only by South Africa in nations with reserves at $50 per lb.

In 1979 New Mexico advanced from 14th to 13th in rank among the nation's leading coal producers. The state ranked fourth in the nation in total gas production and reserves, seventh in crude-oil production and reserves, and 11th in strippable coal reserves. The state is also a national leader in geothermal potential and research and continues to receive national attention and funding to pursue the development of geothermal energy.

New Mexico ranks third in energy-resource production among adjacent states, second in gas, and third in strippable-coal reserves and oil reserves. Table 1 shows

TABLE 1—Production and reserves of oil, gas, coal, and uranium for New Mexico in 1979 compared to production in adjacent states. Dashes indicate that statistics are not available. Oil-production figure for Arizona includes production in Missouri, Nevada, and Virginia. U_3O_8 production is unavailable when fewer than three producers are involved within a state (Texas) or when a state's production might reveal an individual producer (data from American Petroleum Institute, 1980; Keystone, 1980; U.S. Bureau of Mines releases; and U.S. Department of Energy, 1980a).

	Crude oil				Total gas				Coal				Uranium			
	Production		Reserves		Production		Reserves		Production		Strippable reserves		Production		Reserves	
State	Million bbls	U.S. rank	Million bbls	U.S. rank	Billion cu ft	U.S. rank	Billion cu ft	U.S. rank	Thousand tons	U.S. rank	Million tons	U.S. rank	Tons U_3O_8	U.S. rank	Tons U_3O_8	U.S. rank
New Mexico	74.65	7	461.48	7	1,113.45	4	13,460.7	4	14,685	13	2,400	11	7,420	1	448,700	1
Texas	980.84	1	7,636.08	2	6,812.80	2	51,610.8	1	22,600	11	3,200	10	—	-	55,800	3
Oklahoma	128.44	5	1,005.33	5	1,659.57	3	11,191.0	6	5,500	19	400	21	—	-	—	-
Colorado	31.65	12	152.06	12	190.86	9	2,043.1	11	18,000	12	3,800	8	—	-	—	-
Utah	26.88	15	144.34	13	46.80	19	677.1	19	12,240	15	300	-	—	-	—	-
Arizona	1.82	-	—	-	—	-	—	-	11,800	16	300	-	—	-	—	-

production and reserves of oil, gas, coal, and uranium for New Mexico compared to that of the five adjacent states in 1979. Texas continues to lead in production and reserves of both oil and gas by a substantial margin over adjacent states.

Total production of crude oil for New Mexico and adjacent states plus Missouri, Nevada, and Virginia was 1,244.28 million bbls in 1979 compared with 1,327.85 million bbls in 1978. Although production of oil declined, production of total gas from New Mexico and four adjacent states increased from 9,489.9 billion cu ft in 1978 to 9,823.48 billion in 1979 primarily because of new discoveries. Every state among the adjacent states, with the exception of Utah, increased production slightly from the previous year; and New Mexico, Oklahoma, and Colorado increased reserves. Despite the continuing overall trend for declining reserves of oil and gas, New Mexico's and Colorado's reserves of gas increased slightly in 1979. Otherwise, reserves for the five adjacent states declined; total reserves of oil decreased from 9,602.50 million bbls in 1978 to 9,399.29 million bbls in 1979 and total reserves of gas decreased from 81,989.45 billion cu ft in 1978 to 78,982.68 billion cu ft in 1979. With Texas continuing as the leading state in coal production among the six states, total coal production increased from 70,800,000 tons in 1978 to 84,825,000 tons in 1979.

New Mexico's share of domestic $U30_8$ production dropped six percentage points in 1979, but the state retained its leadership role in production and reserves. Wyoming, the second leading producer, retained its share of 27 percent of domestic production; other states, particularly Texas, increased their overall share of production by 6 percent. New Mexico, which has averaged 45 percent of domestic production in the years since 1966, had 40 percent of production in 1979; Wyoming retained second place in the share of production with 27 percent in 1979. The balance of production came from Arizona, California, Colorado, Florida, South Dakota, Texas, Utah, and Washington. Factors such as a declining average ore grade, down time at one major mill, and adjustment to a depressed uranium market accounted for the unexpected decrease in New Mexico's production. Drilling activity in New Mexico represented 15.5 percent of total United States drilling compared with 21.1 percent in 1978. New Mexico ranks third behind Wyoming and Utah among the 14 western states with land held for exploration and mining. Colorado is fourth, Arizona is fifth, and Texas is sixth in acreage held. New Mexico has 52 percent of domestic uranium reserves producible at $30 per lb, 48 percent at $50 per lb, and 46 percent at $100 per lb. The state's reserves in the $50-per-lb forward-cost category dropped from 52 percent in 1978. As of January 1, 1980, Wyoming had 34 percent of domestic reserves compared with 31 percent as of January 1, 1979. Although New Mexico's reserves declined while those of Wyoming and Texas increased, New Mexico's reserves are in larger deposits. New Mexico's reserves, however, are produced at higher costs because they are at greater depths.

Taxes collected for energy resources continue to provide a substantial portion of state revenue. Table 2 shows rates for tax receipts in 1979 comparing coal, oil, natural gas, and $U30_8$. These rates were based on the 6-

TABLE 2—TAX RECEIPTS FOR ENERGY RESOURCES IN NEW MEXICO, 1979 (data from New Mexico Taxation and Revenue Department).

Tax	1 ton steam coal	1 bbl of oil	1,000 cu ft natural gas	1 lb U_3O_8
Property tax	$ 0.1961	$ --	$ --	$ 0.1790
Severance tax	0.4350	0.39663	0.04979	0.8942
School tax	--	0.37587	0.03339	--
Conservation tax	0.0217	0.02801	0.00250	0.0109
Ad Valorem (production)	--	0.18339	0.01655	--
Ad Valorem (equipment)	--	0.03417	0.00330	--
Natural-gas processors	--	--	0.00401	--
Resource excise	0.0856	--	--	0.1836
Continued care	--	--	--	0.0920
	$ 0.7384	$ 1.01807	$ 0.10954	$ 1.3597

month period from July to December 1979. Dividing these receipts by the average prices of $11.57 per ton of steam coal, $16.29 per barrel of oil, $1.45 per thousand cu ft of gas, and $24.83 per lb of U308 yields effective tax rates of 6.40 percent for steam coal, 6.25 percent for oil, 7.55 percent for gas, and 5.48 percent for U30,.

Among New Mexico's energy resources, the greatest amount of severance taxes was collected for gas; total severance tax receipts collected in F.Y. (fiscal year) 1979 for oil, gas, coal, and uranium amounted to $96,325,672. Severance taxes for oil in 1979 amounted to $26,907,800 compared to $26,893,330 in 1978. Estimated severance tax receipts for oil are $32,700,000 for 1980; $71,000,000 for 1981; and $105,700,000 for 1982. Severance taxes for gas in 1979 amounted to $50,337,490 compared to $46,971,465 in 1978. Estimated severance tax receipts for gas are $59,000,000 for 1980; $106,200,000 for 1981; and $122,200,000 for 1982. Severance taxes for coal in 1979 amounted to $5,115,621 compared to $4,020,152 in 1978. Estimated severance tax receipts for coal are $6,900,000 for 1980; $10,900,000 for 1981; and $15,000,000 for 1982. Severance taxes for uranium in F.Y. 1979 amounted to $13,964,761 compared to $12,419,601 in F.Y. 1978. Estimated severance taxes for uranium are $13,700,000 for F.Y. 1980; $18,100,000 for F.Y. 1981; and $22,300,000 for F.Y. 1982 (State of New Mexico Severance Tax Bonds, Series 1980-A, May 27, 1980).

Comparisons of tax rates between states is difficult and rarely reflects an accurate and full account of comparative tax rates because of different taxes figured into the rates and because of differing taxation methods. Generally imposed taxes, such as sales or gross receipts taxes, corporate income, and use taxes are usually not considered in such an analysis. An approximate comparison can be made, however, between New Mexico and selected other western states. Comparative coal tax rates are 5.12 percent for New Mexico (6 months-1979), 17.0 percent for Wyoming (1978 values/1979 taxes), 38.2 percent for Montana (1976 values/1977 taxes), and 15.1 percent for North Dakota (6 months-1979), when including resources indemnity and gross production (not included in New Mexico's rate), conservation, resources, severance, and ad valorem taxes. The comparative tax burden on uranium is 5.85 percent for New Mexico (6 months-1979), 3.5 percent for Wyoming (1978 values/1979 taxes), and 4.4 percent for Utah (1978) when including occupation (not included in New Mexico's rate), conservation, continued-care fund, resource, severance, and ad valorem taxes. The comparative tax burden on natural gas is 8.21 percent for New Mexico (6 months-1979), 10.41 percent for Wyoming (1978 values/1979 taxes), 9.17 percent for Oklahoma (6 months-1979), and 9.58 percent for Texas (6 months-1979) when including occupation and gross production (not included in New Mexico's rate), gas conservation, petroleum excise, school, severance, and ad valorem taxes. The comparative tax burden on crude oil is 7.55 percent in New Mexico (6 months-1979), 10.25 percent in Wyoming (1978 values/1979 taxes), 7.18 percent in Oklahoma (6 months-1979), and 6.68 percent in Texas (6 months-1979) when including occupation, petroleum excise, and gross production (not included in New Mexico's rate), conservation, school, severance, and ad valorem taxes (New Mexico Taxation and Revenue Department, 1980).

The tax burden, as defined by the New Mexico Taxation and Revenue Department, is the percentage of direct taxes paid by producers and/or interest owners from total revenues received by them from the first sales of products of natural resources. In those states where the tax rates are a fixed percentage of the gross sales value, the tax/revenue ratio will not change. In those states where a unit tax rate applies independent of the actual sales value of the products, the tax/revenue ratio will fluctuate with any change in sales price or tax rate changes.

Oil and gas

by E. C. Arnold, J. M. Hill, and D. A. Donaldson, *Bureau of Geology*

Oil production

New Mexico's annual crude-oil production continued to decline in 1979 with lower production coming from the southeast. Production has been declining since 1969, when it reached a peak of 123,735,473 bbls (barrels). The decline is due to a decrease in discoveries, especially large discoveries, over the last 10 yrs. The present production decline can be reversed only if major oil discoveries are made. Because of increased drilling and development the rate of depletion in the past 3 yrs, however, has been substantially less than the previous annual rate of decline.

The state's 1979 total crude and condensate production amounted to 79,648,713 bbls, which was 3,716,112 bbls less than that produced in 1978 and represented a 4.7 percent decrease in production. Crude-oil production in 1979 was 74,650,328 bbls, which amounted to a net decrease in production of 4,098,490 bbls from 1978. Crude production increased from the previous year by 114,338 bbls in the northwest but decreased by 4,212,828 bbls in the southeast. Although overall crude production declined in 1979 from the previous year, condensate production increased by 382,378 bbls with production increasing in both the southeast and northwest. Condensate production amounted to 4,998,385 bbls in 1979 compared with 4,616,007 bbls in 1978. The southeast has led in condensate production since 1975, although the northwest led in production by a substantial margin from 1961 through 1974. Table 3 shows the production of oil and natural gas in New Mexico from 1961 through 1979 and also shows a breakdown according to production totals from the northwest and southeast regions of the state. Table 4 shows increases and decreases of oil and gas production in 1979 compared with 1978.

Southeast New Mexico

Combined crude-oil and condensate production in southeast New Mexico for 1979 was 73,454,445 bbls. The southeast's crude-oil production of 70,606,273 bbls represented a decline of 5.63 percent from 1978 production. Condensate production of 2,848,172 bbls, however, indicated an increase of 15.35 percent over 1978 production. As in past years, Lea County ranked first in total oil production with 49,805,509 bbls, and Eddy County ranked second with the production of 20,032,723 bbls. Table 5 shows crude-oil and condensate production for New Mexico in 1979 by county. The combined totals of production from Lea and Eddy Counties added up to 87.5 percent of total crude-oil and condensate production compared with 89.3 percent in 1978. Also in the southeast, Chaves County produced 1,904,543 bbls and Roosevelt County produced 1,711,670 bbls. Chaves and Roosevelt Counties jointly produced 4.6 percent of the state's total oil production, an increase of 1.2 percent over the 1978 share of the state's total. The Empire-Abo Pool in Eddy County, the largest oil-producing pool in New Mexico, produced 12,741,108 bbls in 1979. This amount was 1,626,995 bbls or 11.3 percent less than 1978 production. Empire-Abo Pool production of crude oil reached a peak of 15,296,442 bbls in 1976. Production in 1977 was almost equal to production in 1976 because of the completion of additional development and gas-injection wells during the year. In 1978, however, the drilling of additional development wells declined and had ceased by middle 1979. Production declined to 14.4 million bbls in 1978 and to 12.7 million bbls in 1979. Arco, the primary operator in the Empire-Abo Pool, has estimated that production for 1980 will be approximately 9.0 to 9.5 million bbls. The estimated large production decline is based on the first 9 months of production plus the fact that most of the producing wells show evidence of a breakthrough of injected gas. The gas-injection wells have expanded the gas cap to a point where the producing wells are coning up and the injected gas is bypassing much of the remaining recoverable oil and flowing directly to the producing well. Total crude-oil production in southeast New Mexico other than the Empire-Abo Pool was 57,865,165 bbls, a decrease of 4.28 percent from 1978.

Northwest New Mexico

Oil production in northwest New Mexico comes from four counties in the extreme northwest corner of the state—McKinley, Rio Arriba, San Juan, and Sandoval. Production of crude oil in northwest New Mexico for 1979 was 4,044,055 bbls. Production increased by 114,338 bbls or almost 3 percent from the previous year. A comparison of 1978 and 1979 production by counties is shown below.

	Crude oil (bbls)	
County	1978	1979
Rio Arriba	1,080,779	1,485,318
San Juan	1,323,499	1,126,256
McKinley	1,159,301	1,074,328
Sandoval	366,138	358,153
Total	3,929,717	4,044,055

While 1979 production in Rio Arriba County increased by 404,539 bbls over 1978, production in San Juan County decreased in 1979. As a result of this shift, Rio Arriba County surpassed San Juan County in production and moved into first place in oil production among the four northwest counties. Rio Arriba County ranked fifth in total crude-oil production in the state. Much of the increased production in Rio Arriba County can be attributed to 35 new development wells drilled in the West Lindrith-Dakota/Gallup Pool during 1979. In 1979 production from this pool amounted to 528,251 bbls, an increase of 327,634 bbls over the previous year. Increases in production also came from additional well completions in the Chacon-Dakota Associated Gas Pool in southwest Rio Arriba County and northwest Sandoval County. As of January 1, 1980, northern New Mexico had 2,104 oil wells-1,291 in San Juan County,

TABLE 3—Production of oil and natural gas in New Mexico, 1961 through 1979 (data from New Mexico Oil Conservation Division).

Year and area	*Barrels*				*Thousand cubic feet*		
	Oil	*Condensate*	*Total oil and condensate*	*Water*	*Casinghead gas*	*Dry gas*	*Total gas*
NW	14,210,632	1,525,358	15,735,990	1,862,902	39,954,895	319,541,175	359,496,070
SE	95,596,439	1,220,972	96,817,411	97,512,336	269,373,304	157,725,609	427,098,913
1961, total	109,807,071	2,746,330	112,553,401	99,375,238	309,328,199	477,266,784	786,594,983
NW	9,181,861	1,659,507	10,841,368	3,839,406	35,895,143	304,909,639	340,804,782
SE	97,225,296	1,261,389	98,486,685	113,139,221	275,932,682	170,015,467	445,948,149
1962, total	106,407,157	2,920,896	109,328,053	116,978,627	311,827,825	474,925,106	786,752,931
NW	7,942,818	1,874,934	9,817,752	4,470,887	27,183,166	321,553,533	348,736,699
SE	98,794,993	1,370,312	100,165,305	127,283,521	272,556,376	171,932,132	444,488,508
1963, total	106,737,811	3,245,246	109,983,057	131,754,408	299,739,542	493,485,665	793,225,207
NW	7,443,260	2,550,525	9,993,785	7,131,448	20,991,913	405,718,222	426,710,135
SE	102,508,438	1,361,185	103,869,623	138,760,709	270,538,055	195,430,490	465,968,545
1964, total	109,951,698	3,911,710	113,863,408	145,892,157	291,529,968	601,148,712	892,678,680
NW	8,776,902	2,804,888	11,581,790	10,600,522	18,467,730	441,561,504	460,029,234
SE	105,966,181	1,618,506	107,584,687	150,261,064	276,863,641	208,128,648	484,992,289
1965, total	114,743,083	4,423,394	119,166,477	160,861,586	295,331,371	649,690,152	945,021,523
NW	8,159,673	3,196,280	11,355,953	13,533,781	15,222,739	483,275,803	498,498,542
SE	111,015,456	1,819,342	112,834,798	158,177,814	286,076,861	228,035,560	514,112,421
1966, total	119,175,129	5,015,622	124,190,751	171,711,595	301,299,600	711,311,363	1,012,610,963
NW	7,533,818	3,528,057	11,061,875	16,198,320	13,928,329	523,356,226	537,284,555
SE	113,060,912	1,879,664	114,940,576	167,575,219	281,722,938	236,644,443	518,367,381
1967, total	120,594,730	5,407,721	126,002,451	183,773,539	295,651,267	760,000,669	1,055,651,936
NW	6,732,250	3,673,081	10,405,331	17,020,379	13,140,201	580,374,026	593,514,227
SE	115,700,459	2,505,535	118,205,994	195,073,824	279,612,600	277,239,086	556,851,686
1968, total	122,432,709	6,178,616	128,611,325	212,094,203	292,752,801	857,613,112	1,150,365,913
NW	6,011,237	3,035,489	9,048,726	16,929,938	12,964,592	538,010,671	550,975,263
SE	117,722,236	2,455,899	120,178,135	210,505,804	282,222,689	280,642,531	562,865,220
1969, total	123,735,473	5,491,388	129,226,861	227,435,742	295,187,281	818,653,202	1,113,840,483
NW	5,780,167	2,905,943	8,686,110	18,593,311	11,066,422	513,961,890	525,028,312
SE	117,181,123	2,280,664	119,461,787	226,808,233	292,907,627	305,519,255	598,426,882
1970, total	122,961,290	5,186,607	128,147,897	245,401,544	303,974,049	819,481,145	1,123,455,194
NW	6,012,907	2,801,992	8,814,899	18,860,437	11,573,567	546,546,676	558,120,243
SE	107,708,035	1,887,036	109,595,071	206,386,656	291,253,975	298,056,323	589,310,298
1971, total	113,720,942	4,689,028	118,409,970	225,247,093	302,827,542	844,602,999	1,147,430,541
NW	5,730,714	2,874,298	8,605,012	20,415,149	12,314,515	574,019,873	586,334,388
SE	99,665,888	2,254,324	101,920,212	196,174,211	259,535,532	351,899,738	611,435,270
1972, total	105,396,602	5,128,622	110,525,224	216,589,360	271,850,047	925,919,611	1,197,769,658
NW	5,175,343	2,394,207	7,569,550	20,659,128	12,932,204	537,186,284	550,118,488
SE	91,233,655	2,182,481	93,416,136	199,979,510	250,718,587	398,702,355	649,420,942
1973, total	96,408,998	4,576,688	100,985,686	220,638,638	263,650,791	935,888,639	1,199,539,430
NW	5,599,465	2,401,954	8,001,419	26,544,506	14,612,336	532,780,048	547,392,384
SE	88,483,452	2,210,094	90,693,546	204,598,067	289,089,197	393,191,355	682,280,552
1974, total	94,082,917	4,612,048	98,694,965	231,142,573	303,701,533	925,971,403	1,229,672,936
NW	4,378,951	2,118,324	6,497,275	24,324,927	14,046,453	504,499,980	518,546,433
SE	86,374,571	2,190,689	88,565,260	208,391,779	291,662,510	392,897,887	684,560,397
1975, total	90,753,522	4,309,013	95,062,535	232,716,706	305,708,963	897,397,867	1,203,106,830
NW	3,721,564	2,274,973	5,996,537	26,825,257	10,157,080	517,649,826	527,806,906
SE	83,715,295	2,417,043	86,132,338	212,782,479	269,673,315	403,395,146	673,068,461
1976, total	87,436,859	4,692,016	92,128,875	239,607,736	279,830,395	921,044,972	1,200,875,367
NW	3,716,995	2,209,640	5,926,635	30,505,354	10,248,132	521,800,291	532,048,423
SE	78,899,095	2,396,916	81,296,011	219,653,564	256,711,369	395,558,468	652,269,837
1977, total	82,616,090	4,606,556	87,222,646	250,158,918	266,959,501	917,358,759	1,184,318,260
NW	3,929,717	2,146,946	6,076,663	37,902,386	11,996,782	528,286,348	540,283,130
SE	74,819,101	2,469,061	77,288,162	227,830,311	240,806,743	378,058,461	618,865,204
1978, total	78,748,818	4,616,007	83,364,825	265,732,697	252,803,525	906,344,309	1,159,148,334
NW	4,044,055	2,150,213	6,194,268	42,422,318	14,220,937	549,998,586	564,219,523
SE	70,606,273	2,848,172	73,454,445	234,007,732	231,337,158	367,157,004	598,494,162
1979, total	74,650,328	4,998,385	79,648,713	276,430,050	245,558,095	917,155,590	1,162,713,685

TABLE 4—Comparison of 1978 and 1979 oil and gas production in New Mexico (data from New Mexico Oil Conservation Division).

	Oil production (bbls)			
	1978	1979	Increases	Decreases
Crude oil				
Southeast	74,819,301	70,606,273		4,212,828
Northwest	3,929,717	4,044,055	114,338	
Total	78,748,818	74,650,328		4,098,490
Condensate				
Southeast	2,469,061	2,848,172	379,111	
Northwest	2,146,946	2,150,213	3,267	
Total	4,616,007	4,998,385	382,378	
	Gas production (thousand cu ft)			
	1978	1979	Increases	Decreases
Dry				
Southeast	378,058,461	367,157,004		10,901,457
Northwest	528,286,348	549,998,586	21,712,238	
Total	906,344,809	917,155,590	10,810,781	
Casinghead				
Southeast	240,806,743	231,337,158		9,469,585
Northwest	11,996,782	14,220,937	2,224,155	
Total	252,803,525	245,558,095		7,245,430
Total gas				
Southeast	618,865,204	598,494,162		20,371,042
Northwest	540,283,130	564,219,523	23,936,393	
Total	1,159,148,334	1,162,713,685	3,565,351	

420 in Rio Arriba County, 313 in McKinley County, and 80 in Sandoval County.

Condensate production from the northwest in 1979 was 2,150,213 bbls. This amount represents an increase of 3,267 bbls over the previous year. As shown below, San Juan County produced 73.2 percent of the condensate produced in the northwest, and Rio Arriba County produced 26.8 percent. Condensate production from Sandoval County was less than 1 percent of total production, and no condensate production was reported from McKinley County.

County	Condensate (bbls) 1979	Percent of total state production
San Juan	1,574,610	73.2
Rio Arriba	575,481	26.8
Sandoval	122	less than 1
McKinley	—	—
Total	2,150,213	100.0

Gas production

Natural-gas production in New Mexico for 1979 was 1,162,713,685 thousand cu ft, making 1979 the 14th consecutive year that gas production has exceeded 1 trillion cu ft. Gas production in 1979 exceeded 1978 production by 3,565,351 thousand cu ft. Of the total 1979 gas production, 917,155,590 thousand cu ft were dry gas and 245,558,095 thousand cu ft were casinghead gas. Both casinghead- and dry-gas production declined in the southeast region of the state; but, as in 1978, production increased in the northwest. Production increases in northwest New Mexico resulted from greater deliverability of the fields because of infill drilling and the development of marginal gas zones. Table 4 shows a comparison of 1979 and 1978 gas production.

TABLE 5—New Mexico crude-oil and condensate production for 1979 ranked by county (data from New Mexico Oil Conservation Division).

Rank	County	Location	Bbls	Percent of total State Production
1	Lea	SE	49,805,509	62.4
2	Eddy	SE	20,032,723	25.1
3	San Juan	NW	2,700,866	3.4
4	Rio Arriba	NW	2,060,799	2.6
5	Chaves	SE	1,904,543	2.4
6	Roosevelt	SE	1,711,670	2.2
7	McKinley	NW	1,074,328	1.4
8	Sandoval	NW	358,275	.5
			79,648,713	100.0

Southeast New Mexico

Although natural-gas production in southeast New Mexico in 1979 declined by over 3 percent from the previous year, the decline would have been more if not for the continuing number of successful Pennsylvanian gas-well completions during 1978 and 1979 in the Delaware Basin of Lea County. Natural-gas production in southeast New Mexico for 1979 was 598,494,162 thousand cu ft compared with 618,865,204 thousand cu ft in 1978. Of the total gas production, dry gas accounted for 367,157,004 thousand cu ft or a 2.9 percent decline from the previous year and casinghead gas for 231,337,158 thousand cu ft of a 3.9 percent decline from 1978. The 1979 production decline for casinghead gas and particularly for dry gas would have been much greater if the number of successful Pennsylvanian gas-well completions in the Delaware Basin had not continued into 1979. The highly productive Morrow gas wells completed along the eastern edge of the Delaware Basin in Lea County are of particular interest. Extensive drilling activity in this area has continued into the first 6 months of 1980. The completion of many infill wells in 1979 also slowed the rate of decline of gas production.

Northwest New Mexico

In 1979 natural-gas production for northwest New Mexico was 564,219,523 thousand cu ft, an increase of 23,936,393 thousand cu ft over production in 1978. Dry-gas production was 549,998,586 thousand cu ft, an increase of 21,712,238 thousand cu ft over 1978 production; and casinghead-gas production was 14,220,937 thousand cu ft, an increase of 2,224,155 thousand cu ft over 1978 (table 6).

Total gas production in northwest New Mexico has increased each year since 1974, with 1979 total gas production a 6-yr record high and the third highest annual production in the history of the San Juan Basin gas industry. Only 1968, with 593,514,227 thousand cu ft, and 1972, with 586,334,388 thousand cu ft, showed larger annual production. Most of this increase in production was due to greater deliverability from established pools. This increased capability has been accomplished by additional infill drilling in the Basin-Dakota and Blanco-Mesaverde gas pools and by development drilling in marginal zones within or near established pools. Of all the wells drilled in the northwest in 1979, 706 (78 percent) were gas development wells.

TABLE 6—PRODUCTION OF NATURAL GAS IN NORTHWEST NEW MEXICO IN 1979 (data from New Mexico Oil Conservation Division).

	Production (thousand cu ft)		
County	Dry gas	Casinghead	Total
San Juan	378,635,582	3,124,271	387,759,853
Rio Arriba	170,261,937	9,581,176	179,843,113
Sandoval	1,064,613	1,406,429	2,471,042
McKinley	26,050	109,061	135,111
Mora	10,404	-	10,404
Total	549,998,586	14,220,937	570,219,523

Natural-gas liquid production

Thirty-five liquid-extraction plants were operating in New Mexico in 1979. Twenty-nine of these plants were in southeast New Mexico and six were in the northwest. Total plant intake for the 35 plants was 998,737,181 thousand cu ft, which was 28,806,818 thousand cu ft more than in 1978. Of the total intake, 531,066,606 thousand cu ft went to southeast plants and 467,670,575 thousand cu ft went to northwest plants. Liquid production in 1979 was 29.8 million bbls, a decrease of 1.6 million bbls from 1978 liquid production. The New Mexico Oil and Gas Engineering Committee reported New Mexico extraction plant production for 1979 as shown below.

	Southeast (29 plants)	Northwest (6 plants)	Total (35 plants)
Bbls gasoline	12,156,864	2,477,814	14,634,678
Bbls butane	3,322,439	3,234,097	6,556,536
Bbls propane	4,366,250	4,240,662	8,606,912

Drilling and development

The total number of well completions in New Mexico in 1979 surpassed the 8-yr record high set in 1978. In 1979, 1,899 wells were completed in New Mexico's four districts compared to 1,828 wells completed in 1978. This total includes oil, gas, service, plugged-and-abandoned, and temporarily abandoned wells (table 7). Well completions in 1979 exceeded 1978 district totals in every category except the classifications of plugged-andabandoned wells and temporarily abandoned wells. There were 571 oil-well completions in 1979 compared to 548 in 1978, 995 gas-well completions compared to 958 in 1978, 53 service-well completions compared to 49 in 1978, 264 plugged-and-abandoned wells compared to 278 in 1978, and 16 temporarily abandoned wells compared to 20 in 1978.

Southeast New Mexico

Drilling and development in southeast New Mexico remained active in 1979, continuing a trend of the past 3 yrs. According to the NMOCD (New Mexico Oil Conservation Division), 473 oil-well completions, 286 gas-well completions, and 250 dry holes were recorded during the year. Table 7 shows well completions by district in New Mexico during 1979. The average total depth of new oil wells completed in 1979 was 5,053 ft; of new gas wells, 9,427 ft; and of dry holes, 6,374 ft. The NMOCD (1979) noted that over 50 percent of the new gas wells were completed below 10,000 ft. Total footage drilled in southeast New Mexico during 1979 was 5,392,823 ft compared to 4,998,056 ft in 1978.

TABLE 7—OIL, GAS, SERVICE, AND TEMPORARILY ABANDONED WELLS COMPLETED IN NEW MEXICO IN 1979; districts 1 and 2 are southeast New Mexico; district 3 is northwest New Mexico; and district 4 is Mora County (data from New Mexico Oil Conservation Division).

	Districts 1 and 2	District 3	District 4	Total State
Oil well completions				
New oil well completions	390	94	0	484
Oil wells drilled deeper	5	0	0	5
Oil wells plugged back	48	2	0	50
Oil wells reentry	15	1	0	16
Additional zone	15	1	0	16
Subtotal	473	98	0	571
Gas well completions				
New gas well completions	234	682	0	916
Gas wells drilled deeper	2	3	0	5
Gas wells plugged back	31	7	0	38
Gas wells reentry	6	1	0	7
Additional zone	13	16	0	29
Subtotal	286	709	0	995
Service well completions				
New service well completions	35	1	2	38
Service wells plugged back	0	0	0	0
Service wells reentry	2	0	0	2
Additional zone	13	0	0	13
Subtotal	50	1	2	53
Plugged & abandoned wells				
New P & A wells	143	72	23	238
P & A wells reentry	23	1	2	26
Subtotal	166	73	25	264
Temporarily abandoned wells				
New temporarily abandoned wells	13	1	0	14
Temporarily abandoned wells reentry	2	0	0	2
Subtotal	15	1	0	16
Total	990	882	27	1,899

Northwest New Mexico

The number of oil-well and gas-well completions in northwest New Mexico increased significantly in 1979 from the previous year. Table 7 shows 98 oil- and 709 gas-well completions in 1979—an increase of 23 oil-well and 28 gas-well completions over 1978.

Table 8 shows oil-well completions by pool and stratigraphic unit. The greatest number of oil-well completions occurred in the West Lindrith-Dakota/Gallup Pool with 34 completions or 33 percent of total oil completions. The pool is in southwest Rio Arriba County, much of it on the Jicarilla Apache Indian Reservation. There were 27 completions in the three Dakota Sandstone pools, consisting of 23 completions in the Chacon Pool, three completions in the Salt Creek Pool, and one completion in the Rattlesnake Pool. These 27 completions accounted for 26 percent of total oil-well completions. There were 38 completions in the Gallup Sandstone pools or 37 percent of all oil-well completions, with the greatest number (10) of these completions in the Verde Pool. The Bisti, Otero, South Hospah, and an undesignated pool in the Gallup Sandstone unit each had five completions, and there were four completions in the Cha Cha-Gallup Pool. The three completions in the Mesaverde Group and one completion in the Pennsylvanian System give a total of 103 oil-well completions.

TABLE 8—OIL-WELL COMPLETIONS DURING 1979 IN NORTHWEST NEW MEXICO BY POOL AND STRATIGRAPHIC UNIT (data from New Mexico Oil Conservation Division).

Name of pool	Total oil-well completions	Percent of total completions
Gallup Sandstone		
Bisti	5	
Cha Cha	4	
Escrito	1	
La Plata	1	
Nageezi	1	
Otero	5	
South Hospah (lower Gallup)	5	
Verde	10	
Undesignated	5	
Wildcat	1	
Formation total	38	37
Dakota-Gallup		
Lindrith, West (Dakota-Gallup)	34	33
Dakota Sandstone		
Chacon	23	
Rattlesnake	1	
Salt Creek	3	
Formation total	27	26
Mesaverde Group		
Franciscan Lake	1	
Star	1	
Wildcat	1	
Formation total	3	3
Pennsylvanian System		
Wildcat Pennsylvanian	1	1
Grand total	103	100

The discrepancy in the total number of oil- and gas-well completions in the different tables (tables 7, 8, and 9) is due to wells completed in late 1978 and not reported to the NMOCD until 1979.

The largest number of 1979 gas-well completions in the San Juan Basin occurred in the Mesaverde Group, in which 272 completions were in the Blanco-Mesaverde gas pool and two were wildcat completions (table 9). There were 182 completions in the Pictured Cliffs gas pools; the largest number of completions was 73 in the Blanco-Pictured Cliffs Pool and the second largest number was 36 in the South Blanco-Pictured Cliffs Pool. There were 139 completions in the Dakota Sandstone unit, of which 134 were completions in the Basin-Dakota Gas Pool. There were 36 completions in the Chacra unit, 11 completions in the Farmington unit, 19 in the Fruitland unit, 53 in the Fruitland/Pictured Cliffs unit, eight in the Gallup Sandstone unit, and one in the Pennsylvanian.

The NMOCD authorized the establishment of two gas pools and two oil pools in the San Juan Basin as of November 1, 1979. As shown below, three of the pools are in San Juan County and one is in McKinley County.

County and pool	Location
San Juan County	
Big Gap Pennsylvanian	T. 27 N., R. 19 W.
Bisti Farmington	T. 25 N., R. 12 W.
Farmer Fruitland	T. 30 N., R. 11 W.
McKinley County	
Star Mesaverde	T. 19 N., R. 6 W.

Sandoval County had the greatest number of wildcat wells drilled in northwest New Mexico-18 wells, 12 dry holes and six gas wells. In San Juan County 16 wildcat

TABLE 9—GAS-WELL COMPLETIONS DURING 1979 IN NORTHWEST NEW MEXICO BY POOL AND STRATIGRAPHIC UNIT (data from New Mexico Oil Conservation Division).

Name of Pool	Total gas-well completions	Percent of total completions (%)
Chacra		
Bloomfield	3	
Harris Mesa	4	
Largo	5	
Otero	8	
Rusty	7	
Undesignated	4	
Wildcat	5	
Formation total	36	5.0
Dakota		
Barker Creek	1	
Basin	134	
Straight Canyon	1	
Ute Dome	3	
Formation total	139	19.2
Farmington		
Aztec	1	
Bisti	1	
Bloomfield	1	
Kutz	2	
Undesignated	3	
Wildcat	3	
Formation total	11	1.5
Fruitland		
Aztec	4	
Blanco	3	
Kutz	1	
North Los Pinos	1	
South Gallegos	3	
Undesignated	6	
Wildcat	1	
Formation total	19	2.6
Fruitland-Pictured Cliffs		
Harper Hill	5	
South Los Pinos	10	
WAW	38	
Formation total	53	7.3
Gallup		
Campo	1	
Devils Fork	1	
Otero	3	
Undesignated	1	
Verde	1	
Wild Horse	1	
Formation total	8	1.1
Mesaverde		
Blanco	272	
Wildcat	2	
Formation total	274	37.9
Pennsylvanian		
Barker Creek Paradox	1	
Formation total	1	.14
Pictured Cliffs		
Albino	1	
Aztec	22	
Ballard	8	
Blanco	73	
Chozo Mesa	1	
East Blanco	1	
Fulcher Kutz	3	
Gavilan	1	
Gobernador	6	
South Blanco	36	
South Gallegos	1	
Tapacito	5	
Undesignated	4	
West Kutz	17	
Wildcat	3	
Formation total	182	25.2
Grand total	723	99.94

wells were drilled; five were discovered-gas wells, one was a discovered-oil well, and 10 were dry holes. There were six gas discoveries in Rio Arriba County and no oil-discovery wells or dry holes. McKinley County reported two oil discoveries and five dry holes. Table 10 shows a breakdown of wildcat and development completions by county.

Oil and gas industry in New Mexico

Geologic setting

New Mexico has three major oil and gas provinces: the San Juan, Permian, and Delaware Basins (figs. 1 and 2). The Permian and Delaware Basins of southeast New Mexico and west Texas have long been among the major oil- and gas-producing provinces in the nation, and over 90 percent of the state's oil production has come from these two basins. Most of the oil and gas that has been produced in the San Juan Basin has come from reservoirs in the Pennsylvanian and Cretaceous Systems, the majority from the Cretaceous System.

The first major oil discovery in the state was made in 1922 in the Hogback Oil Pool in San Juan County. During the previous year gas was discovered at Ute dome in the same county. The oil found in the Hogback Pool is in a structural dome in the Dakota Sandstone. The producing depth is 633-795 ft. After the discovery of the Hogback Pool, additional exploration drilling led to the discovery of the Rattlesnake Pool in 1924. The Rattlesnake Pool in the Dakota Sandstone is also a small structure with low relief. The producing depth of this pool is 680-990 ft. The Gallup sands of the Cretaceous System have been the site of the major oil production in the San Juan Basin. This production has come from sandbar-type stratigraphic traps and from fractured zones in the Mancos Shale.

The Horseshoe-Gallup Pool in San Juan County was discovered in 1956 and is the largest oil pool in northwest New Mexico as of 1979 with cumulative production of more than 36 million bbls. Crude-oil production is derived from two fossilized offshore sandbars of Gallup age, an upper and lower sand unit. These sand units, enclosed in impervious mudstones and shales, were deposited near the shore of a Late Cretaceous sea. After the sandbars were deposited, they were buried with clays and muds that were washed into the Mancos sea to form a stratigraphic trap. The longitudinal axis of the two reservoirs trends northwesterly, which is the general trend of most of the Gallup pools in northwest New Mexico. The cigar-shaped lower sandbar is approximately 14 mi long and 1 1/2 mi wide, and the upper sandbar is approximately 10 mi long and 4 mi wide near the middle of the structure. The producing mechanism is solution-gas drive.

Some of the recent oil discoveries in the San Juan Basin have been in the Entrada Sandstone (Jurassic). The Entrada pools are located in the southwest portion of the San Juan Basin in San Juan, McKinley, and Sandoval Counties. The pools are found along a northwest trend line approximately 40 mi long. The oil in the pools has been trapped within small structural highs or noses at the top of the formation. All of the pools have similar reservoir characteristics with good porosity averaging approximately 23 percent and good permeability of approximately 300 millidarcies. Production is from an active water drive.

The first major discovery in southeast New Mexico was the Artesia Pool in Eddy County in 1924. The reservoir rock of the Artesia Pool is composed of San Andres oolitic dolomite and the Grayburg sands of the Guadalupian Series (Permian). The reservoir is a stratigraphic trap that has a gas-solution type drive. Most of the early production in the southeast came from reservoirs in Permian strata. These reservoirs were relatively shallow and allowed prolific production. Oil was later discovered in deep structures in Pennsylvanian, Mississippian, Devonian, Ordovician, and Silurian strata. Devonian beds, in particular, have been prolific oil producers.

Ninety-eight percent of the gas production in the San Juan Basin comes from Upper Cretaceous rocks at depths from 1,000 to 8,500 ft. There has been some significant Pennsylvanian production, particularly from Barker Creek dome, but that source is now nearing depletion and contributes little to the total. The major sources of gas in the San Juan Basin are two huge stratigraphic reservoirs: the Blanco-Mesaverde and the Basin Dakota gas pools. Gas produced from the Blanco-Mesaverde Pool is derived from the Mesaverde Group, which consists of three formations: the Cliff House Sandstone, Menefee Formation, and Point Lookout Sandstone. The net pay within the pool varies from 80 to 200 ft. The major portion of dry gas produced comes from the Cliff House and Point Lookout Sandstones, although gas is found in sand lenses and coal seams in the Menefee Formation. Porosities of the Mesaverde sandstones range from 4 to 14 percent and average approximately 9 percent. Average permeability of the Cliff House is 0.9 millidarcy, and the Point Lookout averages 2 millidarcies (Arnold, 1974). Natural fracturing influences well productivity. Mesaverde reservoir characteristics in the eastern side of the pool are generally inferior to those of the western side. The Blanco-Mesaverde reservoir contains 3,181 wells and is approximately 70 mi long and 40 mi wide.

TABLE 10—OIL, GAS, AND DRY WILDCAT AND DEVELOPMENT COMPLETIONS DURING 1979 IN NORTHWEST NEW MEXICO BY COUNTY. Some wells were completed in late 1978 but were not reported to the New Mexico Oil Conservation Division until 1979 (data from New Mexico Oil Conservation Division).

County		Gas	Oil	Dry
Sandoval	Development	12	15	2
	Wildcat	6	0	12
San Juan	Development	440	25	31
	Wildcat	5	1	10
Rio Arriba	Development	254	53	6
	Wildcat	6	0	0
McKinley	Development	0	7	12
	Wildcat	0	2	5
Total	Development	706	100	51
	Wildcat	17	3	27
		TOTAL WELLS	904	

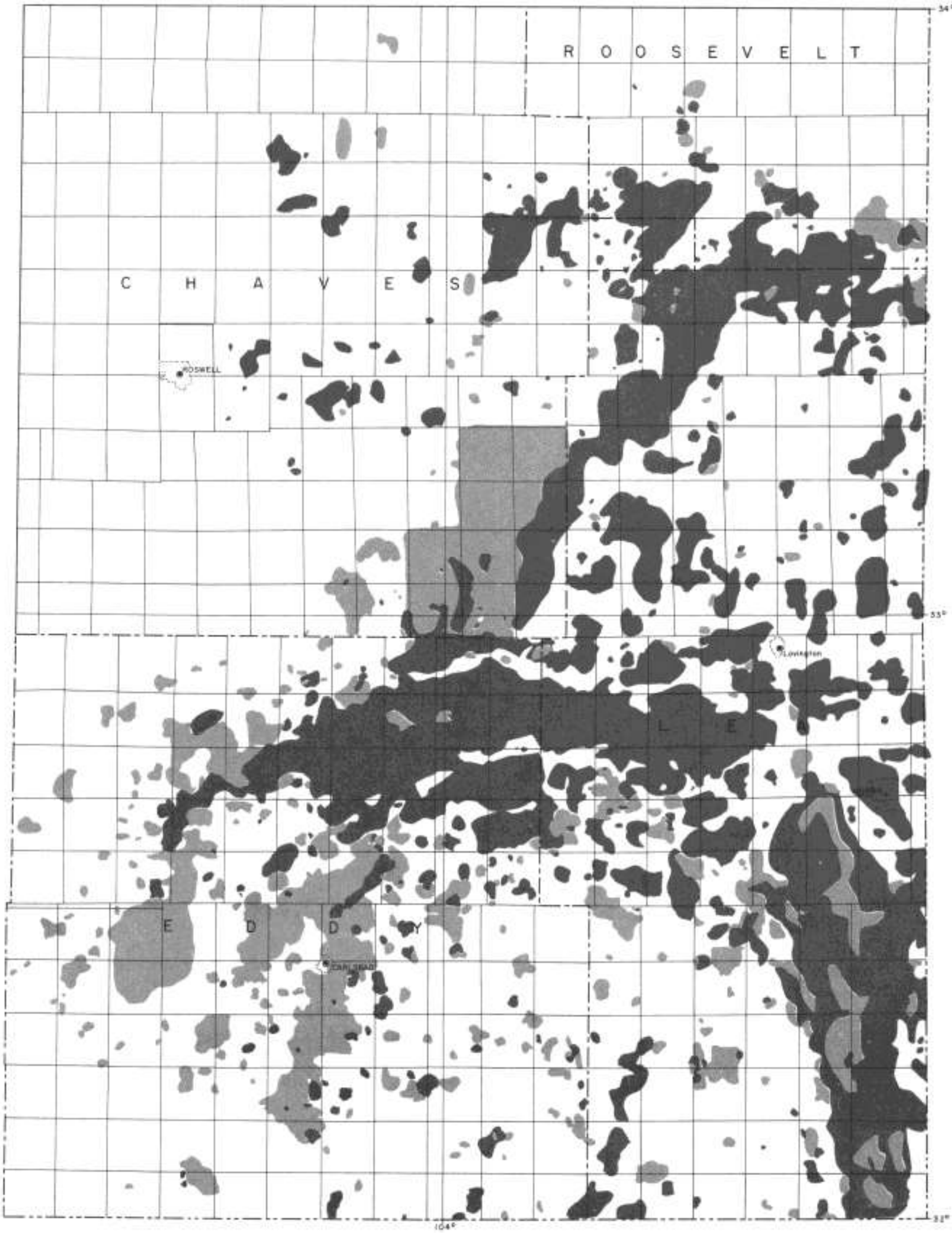


FIGURE 1—OIL- AND GAS-PRODUCING AREAS IN SOUTHEAST NEW MEXICO; darker areas represent oil fields; lighter areas represent gas fields (data from R.R. Chavez and R.A. Bieberman, New Mexico Bureau of Mines and Mineral Resources).

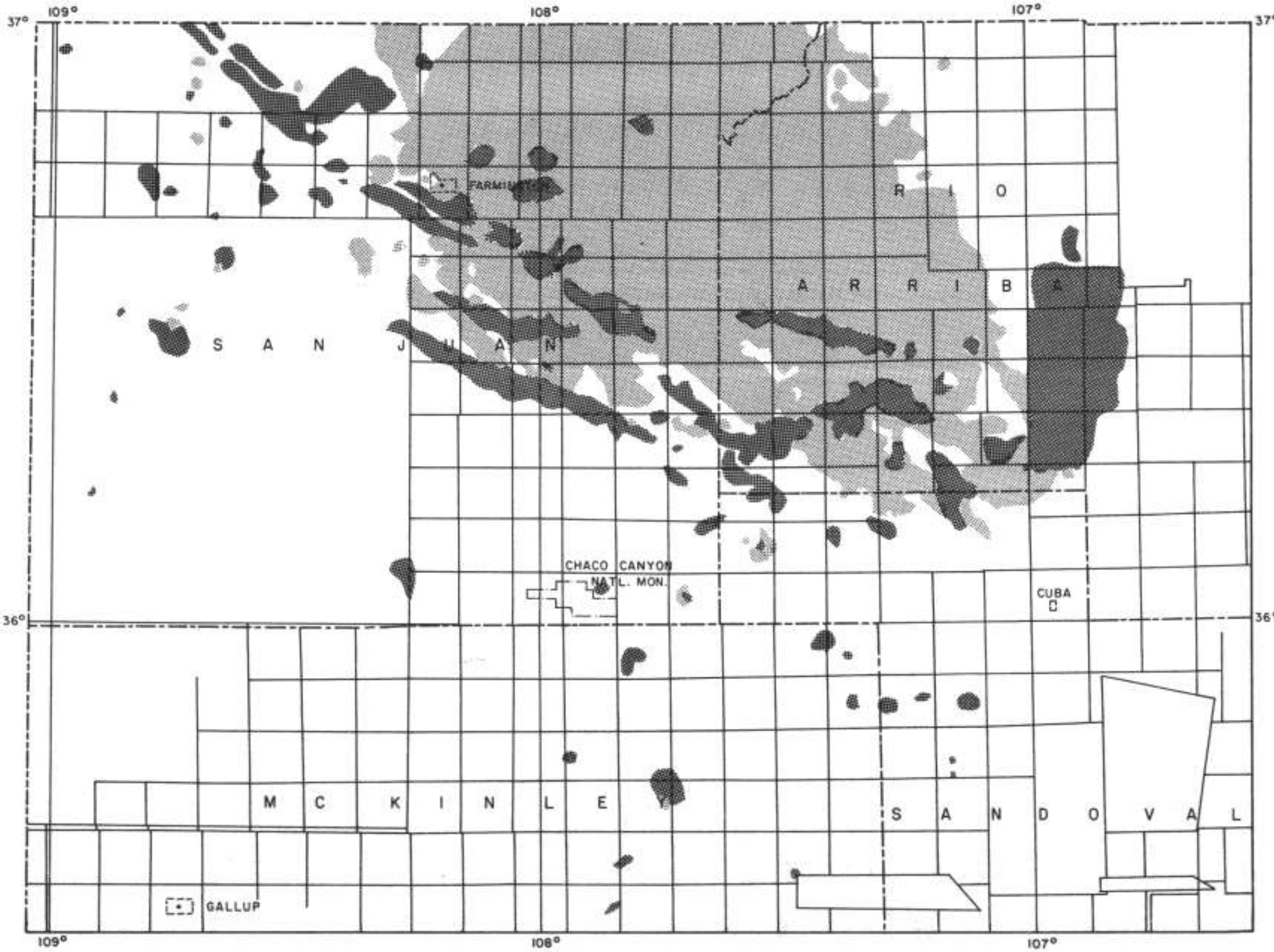


FIGURE 2—OIL- AND GAS-PRODUCING AREAS IN NORTHWEST NEW MEXICO; darker areas represent oil fields; lighter areas represent gas fields (data from R.R. Chavez and R.A. Bieberman, New Mexico Bureau of Mines and Mineral Resources).

The Basin-Dakota Gas Pool produces from a similar stratigraphic reservoir that occupies much of the same geographic area as the Blanco-Mesaverde Pool. The Dakota Pool extends from 10 to 18 mi southwest of the Blanco-Mesaverde Pool and 10 mi southeast of the southeastern extremity of the pool. Productive sands in the Dakota Pool, however, are less continuous. Dakota reservoir quality is also inferior to that of the Mesaverde and average-per-acre reserves are smaller. Porosities in Dakota pay sands range from 7 to 11 percent and permeabilities average 0.15 millidarcy (Deischl, 1973). Fracturing, both natural and induced, is necessary in order to attain commercial flow rates. Areas in the Dakota Pool where production has been high are Angel Peak, Huerfano, Gallegos Canyon, South Blanco, and Otero. On the average, Dakota gas wells produce more liquids than Mesaverde gas wells. The Basin-Dakota Pool contains 2,575 producing wells.

The third major gas-producing zone in northwest New Mexico occurs in the Pictured Cliffs Sandstone, which—like the Dakota Formation and the Mesaverde Group—is of Cretaceous Age. There are 25 Pictured Cliffs pools. The Pictured Cliffs reservoirs occupy much of the same geographic area as the Blanco-Mesaverde and Dakota Pools. In all of the Pictured Cliffs pools the gas has accumulated in elongated, northwest-southeast-trending beach or nearshore sandstone bodies that are separated somewhat imperfectly by shale and siltstone trending in the same direction. The sandstone units terminate abruptly to the southwest but wedge out gradually to the northeast in several of the pools. Net-pay thickness varies from 10 to 50 ft and averages about 30 ft. Permeabilities vary widely but generally decrease as the sandstone units thin.

Cretaceous gas production in the San Juan Basin has come (in descending order) from the Farmington Sandstone, Fruitland Formation, Chacra Sandstone, Mesaverde Formation, Gallup Formation, and Dakota Formation.

Major reserves of dry gas in the southeast have been discovered in Pennsylvanian formations. The Morrow Formation (Lower Pennsylvanian) has been the primary target in recent years. Many of these discoveries have been made in Eddy County.

Oil and gas sales

Oil and gas sales for New Mexico in 1979 continued to reflect a tfend of higher prices paid for diminishing supplies. Table 11 shows oil and gas sales for New Mexico in 1979. According to the New Mexico Oil and Gas Accounting Division (1979), total oil sales in 1979 amounted to $1,114,525,614 for 79,058,793 bbls at an average price of $14.09 per bbl. The average price was $10.02 per bbl in 1978 and $9.21 in 1977. As a result of a lower price, total sales in 1978 amounted to a lower value of $837,826,081 for a larger quantity of 83,597,408 bbls. The largest volume of sales came from state land with 47 percent of total oil sales compared with 46 percent in 1978. The greatest sales volume came from Lea County with total sales amounting to $662,510,369 for 49,630,352 bbls at an average price of $13.34.

Total gas sales in 1979 amounted to $1,591,114,510 for 1,139,926,636 thousand cu ft at an average price of

TABLE 11—OIL AND GAS SALES IN NEW MEXICO, 1979 (New Mexico Oil and Gas Accounting Division, 1979).

Oil sales				Percent of sales volume				
County	Volume (bbls)	Value (dollars)	Price	State land	Federal land	Private land	Indian land	Percent of total
Chaves	1,906,295	37,331,379	19.58	40	34	26		02
Eddy	20,026,019	297,027,759	14.83	53	44	03		25
Lea	49,630,352	662,510,369	13.34	52	22	26		63
McKinley	1,059,714	15,755,961	14.86	05	58	18	19	01
Roosevelt	1,715,218	30,105,755	17.55	15	49	36		02
Rio Arriba	1,911,308	29,014,463	15.18	03	56	01	40	02
Sandoval	236,183	4,129,293	17.48		53		47	
San Juan	2,573,704	38,650,635	15.01	04	67	04	26	03
Total oil sales	79,058,793	1,114,525,614	14.09	47	32	19	02	100
Gas sales								
County	1,000 cu.ft.							
Chaves	9,148,145	12,119,241	1.32	49	44	07		01
Eddy	229,919,473	345,606,916	1.50	24	57	20		20
Lea	345,270,166	361,034,767	1.04	40	23	37		30
McKinley	59,555	69,363	1.16		27	73		
Roosevelt	3,645,744	4,598,845	1.26	12	59	29		
Rio Arriba	166,884,951	272,540,303	1.63	06	74		19	15
Sandoval	2,060,461	5,203,610	2.52		09		91	
San Juan	381,837,140	589,708,098	1.54	09	85	03	03	33
Harding	1,094,756	224,209	.20	03		97		
Mora	6,245	9,158	1.46			100		01
Total gas sales	1,139,926,636	1,591,114,510	1.39	21	58	17	04	100
Total sales		$2,705,640,124						

$1.39 per thousand cu ft. The average price was $1.01 per thousand cu ft in 1978 with sales of $1,154,502,027 for 1,137,853,045 thousand cu ft. The largest volume of gas sales came from federal land with 58 percent of total sales compared with the same percentage in 1978. The greatest volume came from San Juan County with 381,837,140 thousand cu ft for sales amounting to $589,708,098 at an average price of $1.54.

According to the New Mexico Employment Security Department (personal communication, 1980), 10,800 persons were employed in oil and gas extraction in New Mexico in 1979 compared with 10,050 employed in 1978—an increase of 750 employees.

Reserves

Southeast New Mexico

The Bureau of Geology has calculated primary and secondary crude-oil reserves for 50 major pools in southeast New Mexico to be 746.95 million bbls as of January 1, 1979. Primary reserves are considered to be the amount of oil (in barrels) that can be recovered using conventional oil-field techniques. A well is drilled, and, if found to be commercial, it will be completed naturally or a pump will be installed to extract the oil. Secondary reserves, produced by the application of enhanced-recovery techniques, are those reserves that remain after conventional methods no longer produce commercial quantities of oil. Using primary-recovery methods, as much as one-half the oil in the reservoir may be recovered. Secondary-recovery methods, such as water or gas injection into a reservoir to obtain additional oil by movement of reservoir oil to a producing well, allows much more oil to be produced. Some oil still remains, however, and if it can be removed, it is classed as tertiary oil.

The annual report of the New Mexico Oil and Gas Engineering Committee (1979) indicated that the 50 pools produced 54.9 million bbls of oil in 1979, a decline of nearly 8 percent from 1978. Crude-oil production in southeast New Mexico for 1979 was 70.6 million bbls; nearly 78 percent was production from the 50 pools. Because production from these pools is approximately 78 percent of southeast New Mexico's production, a logical assumption is that the 50 pools may also contain approximately 78 percent of southeast New Mexico's crude-oil reserves. If this is so, the remaining reserves of the 50 pools are postulated to be 957.6 million bbls as of January 1, 1979. By subtracting production in the southeast for 1979 of 70.6 million bbls, remaining reserves as of January 1, 1980, would be 887 million bbls.

Fig. 3 shows the API (American Petroleum Institute) estimates of oil and gas reserves in New Mexico as of December 31, 1979. The 1980 production figures estimated by API were adjusted in fig. 2 to show actual production reported by the NMOCD, which yielded a

Crude Oil (thousands of barrels)	
Northwest	15,097
Southeast	446,386
New Mexico	461,483

Gas liquids (thousands of barrels)	
Northwest	294,351
Southeast	148,415
New Mexico	442,766

Total Oil (thousands of barrels)	
Northwest	309,448
Southeast	594,801
New Mexico	904,249

Total Gas (millions of cubic feet)	
Northwest	9,837,186
Southeast	3,553,944
New Mexico	13,391,130

Dry Gas (millions of cubic feet)	
Northwest	9,784,681
Southeast	1,339,733
New Mexico	11,124,414

Casinghead gas (millions of cubic feet)	
Northwest	52,505
Southeast	2,214,211
New Mexico	2,266,716

FIGURE 3—NEW MEXICO'S OIL AND GAS RESERVES AS OF DECEMBER 31, 1979 (figures reflect an adjustment in official American Petroleum Institute data. API's estimated 1979 production figures are replaced by New Mexico Oil Conservation Division's 1979 production figures).

slight difference in reserve figures. When a comparison is made between API gas reserves as of December 31, 1976, to reserves as of December 31, 1979, the effect of expanded drilling and completion activity on reserves is apparent. Total gas reserves increased from 11.9 trillion cu ft as of December 31, 1976, to 13.4 trillion cu ft as of December 31, 1979. In this 3-yr period, 4.5 trillion cu ft of gas were discovered and added to reserves. Production of over 1 trillion cu ft in each of the 3 yrs led to a net increase in reserves of 1.5 trillion cu ft. Total oil reserves were 904 million bbls as of December 31, 1979, a decrease of 26 million bbls from December 31, 1976. However, the increased drilling and development over the past 3 yrs has slowed the annual rate of decline considerably.

Northwest New Mexico

Reserves were calculated by the Bureau of Geology for selected new oil and gas wells completed in northwest New Mexico during 1976 and 1977. This work, done under contract, used the following procedures. The recoverable reserves were determined for each well by analyzing the suite of electrical logs recorded after the well was drilled. By analyzing the various well logs, the following properties and formation characteristics can be interpreted: porosity, water saturation, net pay, well-head shut-in pressure, gas gravity, and formation volume factors. After the well data and pressure values were tabulated, the bottom-hole shut-in pressure was calculated from the well-head shut-in pressure given for each well. The area in acres assigned to a well is that area a well can efficiently drain of oil and gas. The area for an oil well is 40 contiguous acres, and the area of a gas well is generally 160 contiguous acres. Calculation of the volumetric oil and gas reserves for each well was in accordance with the pool rules of the NMOCD for the particular pool from which the well was producing. A simple volumetric calculation was made for oil and gas reserves on a well-by-well basis. The formulas used to calculate the gas reserves on an individual-well basis were the standard oil-industry formulas for volumetric estimates of gas-in-place in subsurface reservoirs. No condensate reserves were estimated for gas wells and no associated gas reserves were estimated for oil wells.

Table 12 shows reserves calculated for 67 selected gas wells and two selected oil wells completed in 1976. Total gas reserves added through the drilling of the 67 gas wells were 178,625 million cu ft, with 144,854 million cu ft of this amount in the Blanco-Mesaverde Gas Pool and 27,819 million cu ft of gas added to the Basin-Dakota Gas Pool reserve base. Reserves were calculated for two Entrada oil wells drilled in 1976. The combined recoverable reserves amounted to 87,595 bbls.

Table 13 shows reserves that were determined for 513 gas wells drilled in 1977. The total recoverable reserves amounted to 1,047,244 million cu ft. As in 1976, the Blanco-Mesaverde had the greatest number of gas completions in 1977 with 246 completions and a recoverable reserve of 888,868 million cu ft. Many of the completions were infill wells. Reserves were calculated for 27 of the total number of oil wells completed in northwest New Mexico during 1977. These 27 wells had a combined recoverable reserve of 4,834,367 bbls. The oil pool with the greatest number of completions was the Chacon Dakota Pool with 14 completions.

The Bureau of Geology has used the volumetric method and the pressure-production-decline-curve method to calculate reserves of the gas wells in northwest New Mexico. The reserve calculation method has been dependent on readily available information. To determine reserves using the volumetric method, the

TABLE 12—NEW GAS AND OIL RESERVES IN NORTHWEST NEW MEXICO ADDED FROM 1976 COMPLETIONS. The totals of gas and oil pools do not include all wells drilled in 1976 in northwest New Mexico (data from New Mexico Bureau of Geology).

Pool	Gas Pools number of wells	(MMCF) Recoverable Reserves
Blanco Mesaverde	34	144,854
Otero Chacra	2	551
Largo Chacra	1	131
Aztec Fruitland	1	392
South Blanco Pictured Cliffs	5	1,275
Nipp Pictured Cliffs	5	228
Undesignated Pictured Cliffs	1	34
Tapacito Pictured Cliffs	2	1,752
Waw Pictured Cliffs	1	75
Fulcher Kutz Pictured Cliffs	1	84
Aztec Pictured Cliffs	1	143
Blanco Pictured Cliffs	2	1,099
Gobernador Pictured Cliffs	1	188
Basin Dakota	10	27,819
Total	67	178,625
	Oil Pools	(bbls.)
S.W. Media Entrada	1	68,553
Wildcat Entrada	1	19,042
Total	2	87,595

TABLE 13—NEW GAS AND OIL RESERVES IN NORTHWEST NEW MEXICO ADDED FROM 1977 COMPLETIONS. The totals of gas and oil pools do not include all wells drilled in 1977 in northwest New Mexico (data from New Mexico Bureau of Geology).

Pool	(Gas Pools) number of wells	MMCF Recoverable Reserves
Blanco Mesaverde	246	888,868
Gonzales Mesaverde	1	542
Bloomfield Farmington	1	244
Wildcat Farmington	1	72
Otero Chacra	19	5,265
Largo Chacra	2	477
Aztec Fruitland	2	406
Undesignated Fruitland	3	1,083
North Los Pinos Fruitland	1	1,580
Wildcat Fruitland	1	79
South Gallegos Fruitland	6	693
Kutz Fruitland	1	39
Ballard Pictured Cliffs	15	2,869
South Blanco Pictured Cliffs	50	16,405
Nipp Pictured Cliffs	20	1,737
Undesignated Pictured Cliffs	6	1,680
Tapacito Pictured Cliffs	13	7,747
Waw Pictured Cliffs	5	379
Fulcher Kutz Pictured Cliffs	2	406
West Kutz Pictured Cliffs	12	1,797
Choza Mesa Pictured Cliffs	7	10,732
Wildcat Pictured Cliffs	1	25
Aztec Pictured Cliffs	3	899
Blanco Pictured Cliffs	48	17,650
Wildcat Pictured Cliffs	2	1,566
Potwin Pictured Cliffs	1	248
Gobernador Pictured Cliffs	3	1,922
Ballard Pictured Cliffs	3	663
Basin Dakota	34	80,116
Straight Canyon Dakota	1	209
Otero Chacra	1	154
Rusty Chacra	2	692
Total	513	1,047,244
Pool	(Oil Pools)	Bbls
Paper Wash Entrada	5	153,210
Snake Eyes Entrada	2	30,468
Wildcat Entrada	1	20,566
Wildcat Gallup	1	52,879
Gallegos Gallup	1	29,605
Bisti Lower Gallup	1	25,187
Marcelina Dakota	2	378,476
Chacon Dakota	14	4,143,976
Total	27	4,834,367

data were extrapolated from electrical logs, which are available within a few days after a well is completed. The historical data needed to calculate reserves using the pressure-production-decline method are not available until several years after a well is completed.

The volumetric method used to determine new gas-well reserves for the San Juan Basin may give higher recoverable reserve figures per well than the pressure-production-decline-curve method. A review of reserve estimates and methods appears in Arnold (1978). Comparing new-well reserves (determined by the volumetric-reserve method) with the reserves of adjacent older wells (determined by pressure-production-decline method) indicates the new wells had consistently higher total recoverable reserve figures than the older wells. In the gas pools in northwest New Mexico, the pressure-production-decline method may be more reliable than the volumetric method. The Bureau of Geology uses the pressure-production-decline method when it is possible to do so. After the new wells shown in tables 12 and 13 have established a production record and a history of pressure decline, some of their reserve figures may be adjusted downward.

Coal

by L. B. Martinez, *Bureau of Geology*

Production

Coal use

National coal production remains in a stage of transition. Although coal production in the West has increased substantially in recent years, the resource is on the verge of fulfilling an even greater role as a growing replacement for diminishing oil and gas supplies. The nature of this role, however, will depend on the cost of development, market availability and diversity, and the attractiveness of the resource in comparison with other fuels. Markets for coal on a national level will expand as mining technology improves, as new technologies for using the resource are developed, and as the cost of pollution control is lowered. Another key factor in the growth of coal development hinges on the resolution of transportation problems, including access to sites and the capacity of transportation. If the projected tenfold increase for gas prices and the predicted tripling of the price of oil take place in the next 10 yrs, coal production and use will become even more cost competitive with oil and gas (Office of Technology Assessment, 1979).

Although recent federal regulations have resulted in rising costs to mine and burn coal, New Mexico's coal production has increased significantly over past years. Coal production is likely to expand more dramatically in the future, even without a relaxation of regulations or the development of new technologies, providing that new areas of production will have adequate transportation facilities available. However, without additional transportation capacity or slurry pipelines, New Mexico production will level off at approximately 20 million short tons annually.

Statewide production

New Mexico producers extracted 14,635,188 short tons of coal in 1979, which represented an increase of 1,847,256 short tons or 14 percent over the 1978 production of 12,787,932 short tons. This production increase enabled the state to advance from the rank of 14th in nationwide production in 1978 to 13th in 1979 (Keystone, 1980). New Mexico ranked fifth in 1979 among the 14 coal-producing states west of the Mississippi. Table 14 shows annual coal production from 1958 through 1979 in New Mexico. Table 15 shows the ranking of the 20 leading coal-producing states in the nation in production of coal and lignite in 1979.

The reported value of coal sales for 1979 was $176,399,153 for 14,050,968 short tons. The difference between the quantity of coal produced and the quantity of coal sold in 1979 was due to amounts of coal stockpiled that is not sold at the time it is mined. Sales for 1979, therefore, represented an increase of 43 percent over 1978 sales of $123,440,601. Sales in 1978 had increased 40.5 percent over 1977. The increase in value can be attributed to increased production, increased value per ton of coal, and inflation. Table 16 gives the sales value of coal production in New Mexico from 1970 through 1979.

Sales and price trends are difficult to establish for New Mexico. Until recent years, most coal produced was committed to long-term contracts and not much of the coal was available for the spot market. Mine expansion, however, has allowed some operators to enter the spot market. Average prices over the past 5 yrs have

TABLE 14—Annual coal production in short tons, 1958 through 1979 (data from New Mexico Bureau of Mine Inspection).

1958	85,212	1969	5,130,653
1959	113,046	1970	7,643,319
1960	235,068	1971	8,175,059
1961	279,021	1972	8,248,745
1962	592,869	1973	9,350,156
1963	2,260,303	1974	9,658,700
1964	3,354,917	1975	9,559,920
1965	3,519,265	1976	9,980,322
1966	2,933,757	1977	11,895,411
1967	3,596,488	1978	12,787,932
1968	3,582,793	1979	14,635,000

TABLE 15—Coal and lignite production for New Mexico and leading coal-producing states in 1979. New Mexico Bureau of Mine Inspection estimates coal production for New Mexico to be 14,685 million short tons; Keystone estimates coal production for New Mexico to be 12,900 million short tons (data from Keystone 1980; New Mexico Bureau of Mine Inspection, 1980).

Rank	State	Estimated thousand short tons mined
1	Kentucky	142,450
2	West Virginia	111,600
3	Pennsylvania	92,500
4	Wyoming	75,000
5	Illinois	58,500
6	Ohio	42,900
7	Virginia	35,000
8	Montana	32,870
9	Indiana	27,850
10	Alabama	24,300
11	Texas	22,600
12	Colorado	18,000
13	NEW MEXICO	14,635
14	North Dakota	14,600
15	Utah	12,240
16	Arizona	11,800
17	Tennessee	6,435
18	Missouri	5,820
19	Oklahoma	5,500
20	Washington	5,000

TABLE 16—SALES VALUE OF COAL PRODUCTION IN NEW MEXICO FROM 1970 THROUGH 1979 (data from New Mexico Bureau of Mine Inspection).

Year	Valuation ($)	Year	Valuation ($)
1970	21,266,732	1975	61,030,169
1971	25,455,175	1976	68,175,429
1972	29,055,820	1977	87,841,748
1973	30,763,429	1978	123,440,601
1974	41,732,019	1979	176,399,153

demonstrated a steady, upward trend; but the increases from year to year have been relatively small compared to price increases for other fossil fuels. Average New Mexico coal prices for 1975 through 1979 are shown below.

Year	Price per ton
1975	$ 6.38 (estimated)
1976	$ 7.21
1977	$ 7.39
1978	$ 9.65
1979	$12.55

Prices in 1979 ranged from $5.87 per short ton to $31.29 per short ton according to figures reported to the Bureau of Mine Inspection. The average price per short ton was $12.55 in 1979 compared to $9.65 for 1978.

Production by mine

In the past 4 yrs, Carbon Coal Company, Kaiser Steel Corporation, and, most recently, Consolidation Coal Company have opened large strip mines (capacities greater than 500,000 tons per year) in the state. New production from these mines has boosted New Mexico's production significantly. Production from the Carbon Coal Company Mentmore mine and the Kaiser Steel West Ridge strip mine totaled 1,151,424 short tons in 1979. The newly opened Burnham mine operated by Consolidation Coal Company is expected to produce 250,000 short tons in 1980, but the mine capacity is approximately 6 million short tons per year.

Three mines in New Mexico ranked among the top 20 coal-producing mines in the United States. The largest mine in New Mexico was the Navajo mine operated by Utah International, producing 5,203,000 short tons; followed by Western Coal Company's San Juan mine, producing 4,000,534 short tons; and Pittsburg and Midway's McKinley mine, producing 3,365,916 short tons. Nationwide, these three mines rank eighth, 14th, and 16th, respectively. Other strip operations were the Amcoal mine operated by Amcord, producing 94,296 short tons and the Arroyo No. 1 mine operated by Trans Continental Coal and Export Company, producing 4,466 short tons. The Arroyo No. 1 mine is the only mine producing coal on state trust land.

Among underground mines, Kaiser Steel Corporation's York Canyon mine produced 766,459 short tons of metallurgical grade (coking) coal. Due to the nationwide softness of the metallurgical coal market, there has been no expansion of mines producing metallurgical coal. Because of the higher market price per short ton for coking coal, however, metallurgical coal remains an important part of the coal industry in New Mexico. Steam-coal production as a percentage of total coal production in the state has steadily increased in comparison to coking-coal output, as shown below.

Year	Steam coal (percent)	Coking coal (percent)
1976	91	9
1977	90	10
1978	92	8
1979	95	5

There were eight surface-mining operations and one underground-mining operation in 1979. These totals compare with five strip mines and one underground mine operating in the state in 1977. Table 17 shows comparisons of coal production for 1977, 1978, and 1979.

Employment

Coal companies operating in New Mexico in 1979 employed 1,527 persons, an increase of 143 employees or 10 percent over employment of 1,384 in 1978. Employment in 1978 had increased by 28 percent over 1977. The most significant change in 1979 was at the McKinley mine, which employed 325 persons—an increase of 126 percent from the 1978 total of 144. The three active mines in McKinley County—Amcoal No. 1, Mentmore, and McKinley mines—each showed an increase in employment. Employment figures are expected to increase in 1980 because of the openings of Consolidation Coal Company's Con Paso mine and Sunbelt Mining Company's De-Na-Zin mine.

Resources and geology of the Raton Basin

The Raton coal field in the northeast corner of the state contains sizable amounts of coal resources, con-

TABLE 17—NEW MEXICO COAL PRODUCTION IN TONS FOR 1977, 1978, AND 1979; s = strip mine, u = underground mine (data from Keystone, 1977, 1978, and 1979).

County	1977	1978	Percent Change	1979	Percent Change
Colfax					
West York (s)	95,641	134,100	+ 40	577,517	+330
York Canyon (u)	1,005,123	803,056	- 20	766,459	- 5
Total	1,100,764	937,156	- 15	1,343,976	+ 38
McKinley					
Amcoal #1 (s)	160,000	100,000	- 38	94,296	- 6
McKinley (s)	1,369,200	2,992,958	+ 11	3,365,916	+ 13
Mentmore	-	40,000	new mine	628,250	+1470
Total	1,529,200	3,132,958	+105	4,088,462	+ 30
Sandoval					
Arroyo #1 (s)	-	-	-	4,466	new mine
Total	-	-	-	4,466	new mine
San Juan					
Navajo (s)	7,420,066	6,100,000	- 18	5,203,000	- 17
San Juan (s)	1,843,076	2,613,038	+ 42	4,000,534	+ 53
San Juan test (u)	2,305	0	-100	0	
Total	9,265,447	8,713,038	- 6	9,203,534	+ 6
Grand total	11,895,411	12,783,152	+ 7	14,635,972	+ 13

siderable potential for the expansion of existing operations, as well as the potential for future development of both surface and underground mines. Historical production information from the New Mexico State Mine Inspector indicates that approximately 37 million short tons of coal have been extracted from the portion of the Raton Basin in New Mexico in the period 1880-1979. Kaiser Steel, currently the only operator in the Raton field, produced 1,294,883 short tons in 1979 with 766,459 tons of this production coming from an underground mine and 528,424 tons from a surface mine. The total value of the coal was estimated to be $41,900,000. Coal produced from Kaiser's underground mine is a coking coal that is shipped by rail to Fontana, California, to be blended with other metallurgical coals used to make steel. Coal from the surface mine, also of metallurgical grade but of lesser quality, is sold to the Salt River Authority in Arizona for use in electric-power generation. The aggregation of this large tract of private coal ownership has been possible because the acreage was formerly part of the Beaubien and Miranda Spanish Land Grant issued in the 1840's and transferred through many owners until the 1950's when Kaiser Steel purchased a large portion of the coal rights. Kaiser Steel controls over 500,000 acres of coal rights in the Raton Basin and is actively exploring its entire lease. Kaiser has also filed an application for exploration permits for two additional areas. This coal acreage, however, is only a fragment of the original land grant. Thus far, one permit to Kaiser in the Potato Canyon area has been approved, and preliminary drilling information has indicated the presence of enough coal to support another underground mine. Steps for developing a final mine plan have been undertaken by Kaiser. Kaiser's application for a second exploration permit has not yet been approved.

The USGS (U.S. Geological Survey) estimates reserves for the area to be 700 million short tons for the northern portion and 1.5 billion short tons for the southern portion of the field (Pillmore, 1969; Wanek, 1963). This information brought up to date earlier USGS studies by Read and others (1950), who estimated total reserves to be 4.7 billion short tons with a minimum thickness of 14 inches when including inferred reserves. The U.S. Bureau of Mines, however, calculates the total reserve base to be 1.3 billion short tons. By comparison, company data estimate recoverable reserves to be 700 million short tons for the Kaiser Steel properties on the New Mexico side of the Raton Basin. The difference in reserve estimates is partly due to differing classification methods used in calculating reserves.

There are significant similarities in the geology of the San Juan and Raton Basins. The stratigraphic histories of the Upper Cretaceous (Pierre Shale, Trinidad Sandstone, and Vermejo Formation) and Tertiary (Raton Formation) coal-bearing rocks are of major importance to the presence of commercial coal deposits in the Raton Basin. The sequence of marine transgression and regression so evident in the coal-bearing section of the San Juan Basin is also evidenced in the Raton Basin. The Raton Basin area was inundated by the Late Cretaceous sea that extended over much of the Western Interior of the United States. As in the San Juan Basin, coals in the Raton Basin were deposited during retreats and transgressions of seas across the area. As shorelines migrated across the basin during this cycle, extensive shoreward swamp environments were created that also migrated adjacent to the shoreline. During relatively stable periods, thick deposits of organic material accumulated, and this organic material was transformed into coal under certain geologic conditions. The Pierre Shale, Trinidad Sandstone, and Vermejo Formation were deposited in such a regressive coastal complex. The Trinidad Sandstone deposited in a beach, nearshore environment records the final retreat of the Western Interior seaway. It overlies and sometimes intertongues with the Pierre Shale. The boundary between the two deposits is transitional, and no sharp contact has been observed. The Vermejo Formation sediments were deposited in coastal swamps and lagoonal and floodplain environments adjacent to the beach sediments of the Trinidad. Leighton (1980) states that coal deposits of the Vermejo Formation were deposited in this back-barrier swamp environment and are generally thin and lenticular. Leighton interprets this deposition to be the result of smooth, continuous regression of the seaway across the basin. Where the organic material was formed and protected directly behind the beach ridge in the Trinidad Sandstone, the coals should be thicker and more extensive as in the San Juan Basin, making this stratigraphic relation between the beach-nearshore sediments and the back-barrier swamp deposits a favorable target for exploration.

The Raton Formation (Tertiary) unconformably overlies the Vermejo Formation (Cretaceous), and the Raton Formation deposition across the Tertiary-Cretaceous boundary is continuous. The Raton Formation is recognized as a terrestrial floodplain sequence and is the thickest of the coal-bearing units, reaching a thickness of 2,000 ft. Pillmore (1968) divides the Raton Formation into three zones: a basal zone, a lower zone of sandstone and mudstone, and an upper, coal-bearing zone of sandstone, siltstone, and mudstone with beds of coal. Coal is found in the lower zone but is generally thin and impure. The coal in the coal-bearing zone occurs in minable thickness locally. This coal-bearing zone varies in thickness from 0 to 1,000 ft in the central part of the basin. Fig. 4 shows the Raton field and other coal fields in New Mexico.

Production projections

Coal production in the United States historically has been destined for use by public utilities with 70 percent of domestic coal being produced for that market (Schmidt, 1979). New markets will be developing, however, for the production of synthetic fuels as technological advances allow coal to be used (through conversion techniques) for purposes other than electrical generation. Forecasts for the rate and intensity of coal extraction, therefore, are difficult to make and are dependent on lease restrictions, transportation obstacles, and the climate in the country for the development of synthetic fuels. The marketability of low-sulfur coal in the western United States, nevertheless, is enhanced by the present concern over environmental pollutants from coal generation.

The Bureau of Geology recognized the importance of

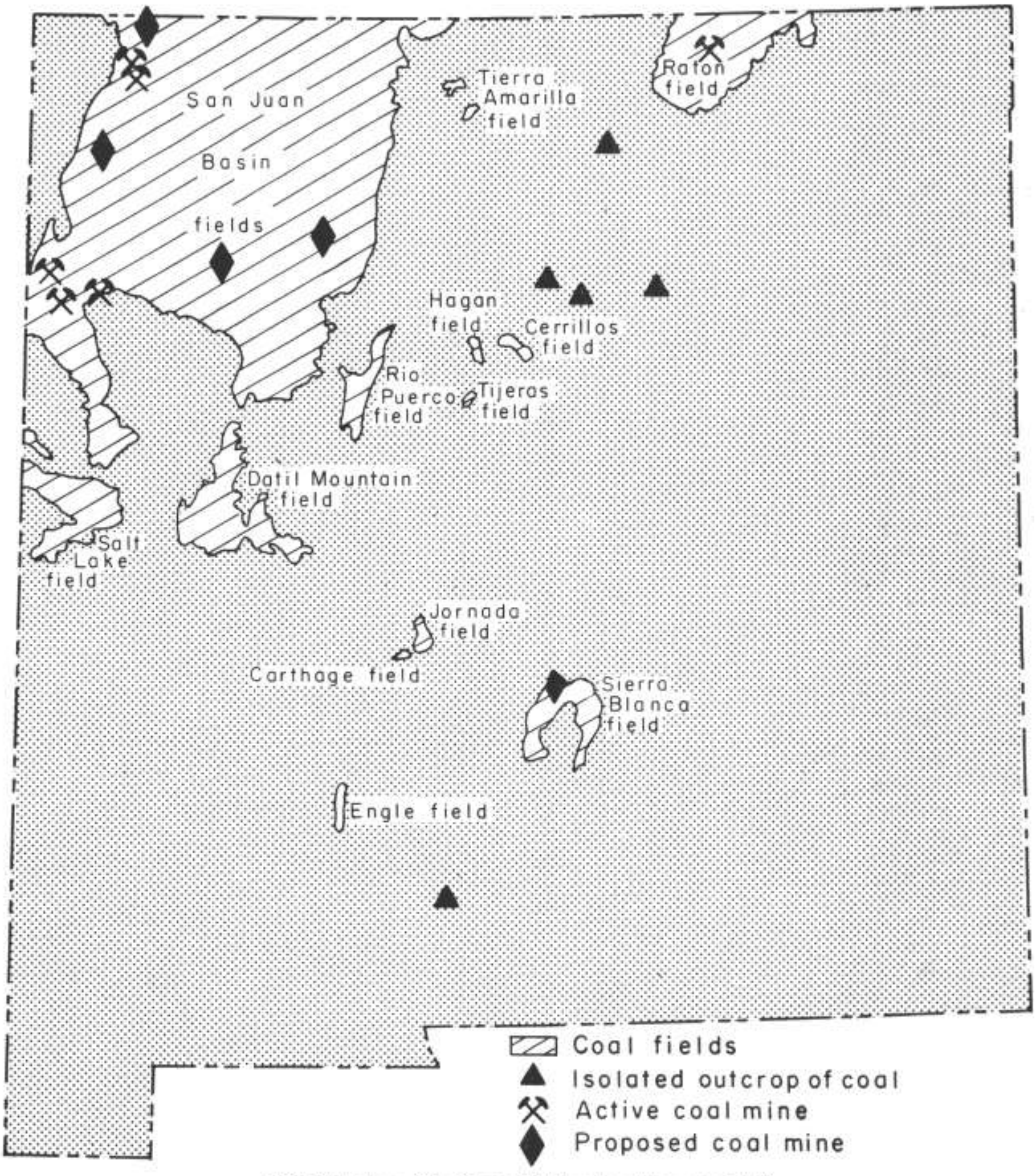


FIGURE 4—COAL IN NEW MEXICO (Kottlowski and Thompson, 1980).

analyzing coal reserves from the standpoint of quality, production, and final use. The Bureau followed a framework set up by the Office of Technology Assessment and worked with the New Mexico Bureau of Mines and Mineral Resources and coal-industry personnel to quantify production projections. This framework consisted of assessing the present and potential value of federal, state, Indian, and private leases by identifying technical criteria to describe representative mining operations, general mining conditions, and typical coal characteristics for both surface- and underground-mining conditions.

The major mine-model criteria for a New Mexico mine examined for the years 1980-1990 included the following key characteristics: coal rank, quality, thickness parameters, minimum leasehold and recoverable reserve requirements, mining technologies, mine capacities (production levels), and likely markets. The mine models used in conjunction with an operator survey conducted by the Bureau of Geology can provide general measures of production levels that might be anticipated from an undeveloped lease, potential markets and end-uses of the leased coal, and labor and transportation requirements associated with a mine's develop-

TABLE 18—New Mexico projected coal production, 1980 through 1990 (data from New Mexico Bureau of Geology).

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Active Mines											
Amcoal	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000
Arroyo #1	100,000	200,000	200,000	200,000	200,000	200,000	200,000	- 0 -	- 0 -	- 0 -	- 0 -
McKinley	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
Mentmore	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000
Navajo	6,750,000	6,750,000	6,750,000	6,750,000	6,750,000	6,750,000	6,750,000	6,750,000	6,750,000	6,750,000	6,750,000
San Juan	4,900,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,700,000	1,700,000	1,700,000	1,700,000	1,700,000
West Ridge	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
York Canyon	800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000
Total	18,930,000	15,930,000	15,930,000	15,930,000	15,930,000	15,930,000	15,830,000	15,630,000	15,630,000	15,630,000	15,630,000
New Mines											
Tres Hermanos	18,000	closed									
Con Paso	250,000	250,000	500,000	1,000,000	6,400,000	6,400,000	6,400,000	6,400,000	6,400,000	12,800,000	12,800,000
Total	19,198,000	16,180,000	16,430,000	16,930,000	22,330,000	22,330,000	22,230,000	22,030,000	22,030,000	28,430,000	28,430,000
Future Mines											
Black Diamond	- 0 -	500,000	500,000	500,000	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -
Black Lake	- 0 -	- 0 -	- 0 -	uncertain	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -
La Ventana	- 0 -	- 0 -	- 0 -	100,000	293,000	482,000	569,000	816,000	1,070,000	1,284,000	1,284,000
De-Na-Zin	- 0 -	490,000	490,000	343,000	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -
Star Lake	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	3,000,000	3,000,000	4,000,000	6,000,000	6,000,000	6,000,000
Lee Ranch	- 0 -	- 0 -	- 0 -	1,000,000	1,000,000	1,000,000	1,000,000	3,000,000	3,000,000	3,000,000	3,000,000
Old Abe	- 0 -	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000
Gallo Wash	- 0 -	- 0 -	- 0 -								
So. Hospah	- 0 -	- 0 -	- 0 -	1,000,000	1,000,000	1,000,000	3,400,000	3,400,000	3,400,000	3,400,000	3,400,000
Bisti	120,000	250,000	250,000	250,000	250,000	1,200,000	2,400,000	2,400,000	2,500,000	2,500,000	2,500,000
La Plata											
Arch											
San Juan Undrg.	- 0 -	2,600,000	367,000	1,200,000	2,200,000	2,200,000	N.A.	N.A.	N.A.	N.A.	N.A.
Cottonwood Cyn.											
Potatoe Cyn.											
Cerrillos Mine	40,000	47,500	47,500	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -	- 0 -
Total	19,518,000	20,137,500	18,154,500	21,393,000	27,143,000	31,282,000	32,669,000	35,716,000	38,070,000	44,684,000	44,684,000

ment (Office of Technology Assessment, 1979). Projected production for 1980 through 1989 is shown in table 18 and fig. 6.

Coal transportation

Any projected production of coal must be qualified by the assumption that adequate transportation will be made available to deliver the coal to markets. Approximately 65 percent of the coal produced in the United States is now being transported by rail, and 85 percent of this rail-transported coal is in a captive situation. In this captive situation the railroad is the only economical means of service. Therefore, since there is essentially no competing service, coal producers are dependent on governmental protection against exorbitant prices to transport coal to market. Fig. 5 shows coal rail-transportation lines serving New Mexico along with the proposed Star Lake Railroad line. Because slurry lines may need several years' lead time before completion and will need Congressional legislation passed to permit rights-of-way, any further increase in coal production in New Mexico is likely to have to be transported by rail. If transportation is available, this increase could be as much as 35 million tons a year.

Coal producers in New Mexico have already lost a 3-yr time advantage in the market over Colorado, Wyoming, and Utah because of federal leasing delays and problems in obtaining rights-of-way across Indian-allotment land. Federal coal-lease sales are now being held in other states, and the BLM (U.S. Bureau of Land Management) has stated that no public domain land will be leased in New Mexico until 1984—a 3-yr difference. Another financial constraint to development has been created by the Interstate Commerce Commission (ICC): railroads will be allowed to charge a rate up to a level that equates the price of coal per unit of electricity with the delivered price of other fossil fuels. The cost advantage of using coal will then be realized by the railroads, and the state's coal producers will lose the selling price advantage inherent in the lower cost strippable coal to the coal transporters. Under these conditions, consumers may not derive an advantage from using coal instead of other fuels, and coal will lose its cost advantage over oil.

FIGURE 5—Coal rail transportation lines and proposed Star Lake Railroad line (rail lines of New Mexico adapted from Southern Pacific Cotton Belt map).

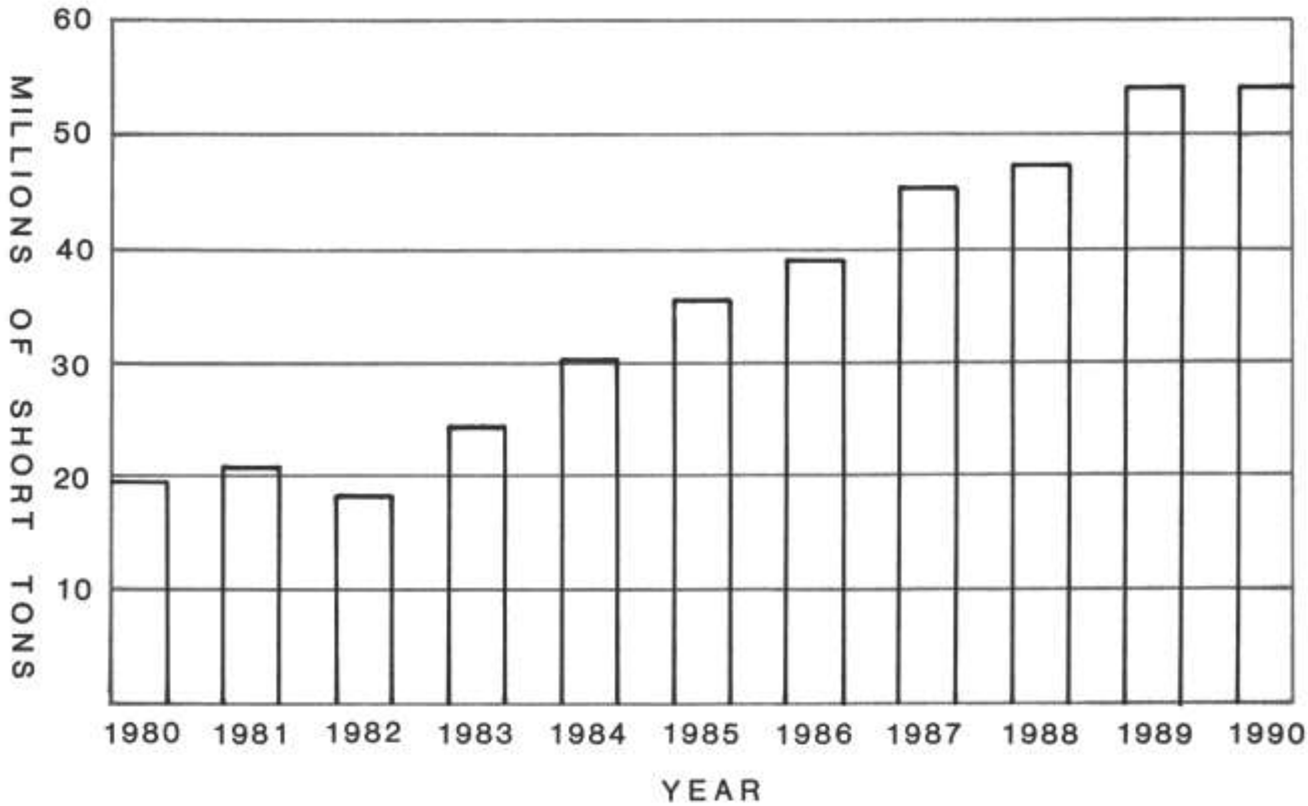


FIGURE 6—NEW MEXICO PROJECTED COAL PRODUCTION (data from New Mexico Bureau of Geology).

In the early 1960's, mines were developed in New Mexico to supply coal to mine-mouth generating plants. Other mines were located near existing rail systems and were satisfactorily serviced by these rail systems. Recently, however, the SLR (Star Lake Railroad Company), a subsidiary of the Atchison, Topeka and the Santa Fe Railroad, submitted a proposal to the Interstate Commerce Commission to construct a new line for a distance of 82 mi in McKinley and San Juan Counties. The SLR line would enable mining and shipping of presently inaccessible Fruitland Formation coal in the Star Lake-Bisti coal fields. This line would tie into existing, nationwide, east-west rail systems. Without this line, several potential coal mines will not be developed. The rail project would cross land with several different surface landowners: federal, Indian allotment, state, and private. Rights-of-way have been granted by the state, BLM, and private surface landowners. Right-of-way problems between the railroad and the Navajo Indians, however, have delayed this project; and the Navajo have refused passage of the spur line with negotiations continuing. The U.S. Secretary of the Interior has authority as trustee (under an 1899 law) to approve right-of-way across allotments but has refused to grant approval.

The BLM estimates that an average traffic rate of 13.3 unit trains per day carrying 16.5 million short tons of coal annually may use the SLR line by 1987 (U.S. Bureau of Land Management, 1978). The spur line to the Star Lake-Bisti area would have a significant effect on proposed mines and is essential for any major expansion in San Juan Basin coal production.

Future coal development

In addition to the nine active mines operating in New Mexico in 1979, five mines were granted permits by the New Mexico Mining and Minerals Division but were not yet engaged in mining activities as of June 20, 1980. Active mines are listed below.

Company	Mine	Location
Kaiser Steel Corp.	York Canyon	west of Raton
Western Coal Co.	San Juan	Fruitland
Pittsburg and Midway Coal Co.	McKinley	Window Rock
Utah International, Inc.	Navajo	Fruitland
Amcoal, Inc.	Amcoal	Ft. Wingate
Carbon Coal Co.	Mentmore	Mentmore
Consolidation Coal Co.	Con Paso-Burnham	Burnham
Cactus Industries, Inc.	Tres Hermanos	east of San Antonio
Trans Continental Coal and Export Co.	Arroyo No. 1	San Luis
Sun Belt Mining Co., Inc.	De-Na-Zin	Bisti

Production has stopped and reclamation continues at the Tres Hermanos mine operated by Cactus Industries. A permit was issued for an amendment to Kaiser's York Canyon mine June 13, 1979; to Western Coal's San Juan mine January 10, 1980; and to Pittsburg and Midway's McKinley mine February 15, 1979. The five companies granted permits for mines not yet operating are Alamito Coal Company's Gallo Wash mine in Pueblo Pintado with a starting date of 1982; Chaco Energy's

South Hospah mine in Hospah with no starting date set; Sunbelt Mining Company's De-Na-Zin mine in the Bisti area by the end of November 1980; Western Coal Company's Bisti mine in Bisti with no starting date set; and Western Coal's La Plata mine in La Plata with a starting date of 1981.

As of June 20, 1980, four applications for permits were in process: Black Diamond Coal Company's Black Diamond mine with an Environmental Impact Hearing October 29, 1980; Chaco Energy's Star Lake mine; Ideal Basic Industries' La Ventana mine with a permit hearing June 11, 1980; and Western Coal Company's San Juan underground mine project with an Environmental Impact Hearing March 28, 1980. As of June 1980, nine more applications for permits were anticipated, including one for Amcoal, Incorporated, in an area adjacent to its present mine that will require a permit amendment. Federal lease approval is expected. Other anticipated applications include Arch Minerals north of Chaco Canyon, which was in the planning stage for reclamation research; Carbon Coal Company south of Gallup; Cerrillos Coal Mining Company near Madrid; Great American Coal Company, Old Abe mine near White Oaks with a permit application expected in 1981; Kaiser Steel Corporation, Cottonwood Canyon, east of its York Canyon mine with an application expected in July 1981; Kaiser Steel Corporation, Potato Canyon expected June 1981; Santa Fe Mining, Incorporated, Lee Ranch, south of Star Lake, awaiting a decision on the Star Lake Railroad right-of-way; and Western Associated, Black Lake mine, expected in 1981.

Four permits were issued as of June 1980 for exploration: Albert J. Firchau, Arroyo No. 1, February 21, 1979, with exploration now completed; Mathis and Mathis Mining and Exploration Company, September 13, 1979, with exploration now completed; Kaiser Steel Corporation, Potato Canyon underground mine, October 30, 1979; and Great American Coal Company, Old Abe mine near White Oaks, November 30, 1979.

La Ventana mine

The start-up date of the La Ventana coal mine is being delayed by the OSM (U.S. Office of Surface Mining), which requires that an Environmental Impact Statement be completed first. Because the coal is federally owned, mining approval must come from both the OSM and the New Mexico Mining and Minerals Division. Although the OSM contends an Environmental Impact Statement is necessary, the State of New Mexico believes that socioeconomic as well as earth-science environmental considerations were sufficiently addressed in the many Environmental Impact Statements completed for the San Juan Basin coal region. In addition, the mine plan submitted addresses site-specific effects of mining. The permit area, as approved by the New Mexico Mining and Minerals Division, is of mixed private, state, and federal ownership; and the coal leased is for two state leases and five federal leases. An estimated 42 million tons of recoverable coal would be mined from these seven leases.

Star Lake mine

Chaco Energy Corporation, a wholly owned subsidiary of Texas Utilities Company, plans to operate a coal surface mine located 50 mi southwest of the village of Cuba, New Mexico. The permit area, totaling 18,220 acres, is divided among the following surface owners: Navajo tribe, Indian allotment, Indian homestead trust patent, State of New Mexico, federal government, Tanner, Incorporated (private), and Chaco Energy Company (private). The coal in this area is owned by the federal government, State of New Mexico, or Hospah Coal Company and is either leased, subleased, or assigned to Chaco Energy Company. The anticipated start-up date for the Star Lake mine is January 1984 with production projected to be 3 million short tons for each of the first two years of operation; 4 million tons for the third year; 6 million for the fourth year; 8 million for the fifth year; and 8 million for the sixth, seventh, and eighth years of production. The first three years of operation will be a scraper operation and, in the fourth year of operation, a 60 cu-yd dragline will be used. Recovery of the coal is expected to be approximately 90 percent, and coal seams that are greater than 3 ft in thickness will be mined to a depth of overburden of 150 ft. The estimated cumulative production on this lease is 265,000,000 short tons of coal, and the coal will be sold on the spot market or under contract.

De-Na-Zin mine

Sunbelt Mining Company, Incorporated, a wholly owned subsidiary of Public Service Company of New Mexico, will operate a surface mine in the Bisti area of San Juan County with an estimated cumulative mine production of 1.3 million tons. The proposed mine is located entirely on state-owned land acquired by an assignment from Eastern Associated Properties Corporation in March 1979. The assignment was for the northern half of sec. 16, T. 23 N., R. 13 W., totaling 320 acres. Using the current market value, the state may expect to receive $2.4 million from royalties, severance, resource-excise, and conservation taxes during its 3-yr mine life. The De-Na-Zin mine plan was approved by the State of New Mexico and start-up date has been set for November 1980. The first year of production is estimated to be 490,000 short tons, the second year 490,000 short tons, and the third year 324,000 short tons.

Black Diamond mine

The Black Diamond Coal Company, a Texas corporation, has filed a mine plan in the State of New Mexico to begin a 500,000-ton-per-year surface mine. The Black Diamond mine is located aproximately 15 mi north of Farmington. The coal and surface are leased from the Cardin-Neff Trust, and the permit area consists of approximately 160 acres of sec. 28, T. 23 N., R. 13 W. Production in the first year is estimated to be 460,000 short tons, in the second year 540,000 tons, in the third year 54,000 tons, and in the fourth year 80,000 tons.

Lee Ranch project

Santa Fe Mining Company, a wholly owned subsidiary of Santa Fe Industries, is in the developmental engineering stages of preparing a mine plan for its Lee Ranch properties, which are under private and state coal ownership. This project is expected to be the first of several proposed mines on Santa Fe Mining Company properties. The tentative date set for the mine plan's submittal is January 1981. Some of the coal is being internally committed but much is uncommitted. The proposed mine will have a capacity of 3 million tons annually, but development of this mine hinges on the proposed Star Lake Railroad.

Potato Canyon

Kaiser Steel Corporation, operators of the existing York Canyon and West Ridge strip mines, received permission to open an exploratory mine at Potato Canyon. The mine is approximately 10 mi west of Raton just off NM-555. The mine will be opened to study coal quality and to test mining conditions for future mine development. Any of Kaiser's existing customers could provide a market for the coal. During exploration, the company is expected to employ 10 persons.

Arch Minerals

Arch Minerals (under the name Ark Land Company) holds two Preference Right Lease Applications containing coal reserves of over 200 million short tons. The company is optimistically hoping to have its coal committed by 1988.

Freeman United

Freeman United has completed a close-space drilling program and calculated reserves for its New Mexico properties. These reserves now remain uncommitted; more environmental work and economic studies will have to be carried out before further development of the property can take place. Final federal leasing policy will also affect development of the lease. The lease contract calls for a $0.15-per-ton royalty, and the decision to mine will be influenced by whether the lease has to be renegotiated at increased royalty rates.

Amcoal

In order to continue existing operations, Amcoal will again seek to obtain under emergency leasing criteria a federal lease of 320 acres with an estimated 1.436 million tons of reserves. Amcoal now operates a mine near Gallup in McKinley County that produces approximately 120,000 tons per year; however, the present lease reserves are expected to be depleted this year. This lease sale covers the same acreage that was applied for and then postponed by the Secretary of the Interior in 1979. The BIA (U.S. Bureau of Indian Affairs) holds 160 acres of this half section of surface ownership in trust for the Navajo Tribe. The underlying coal, however, is reserved by the federal government and administered by the BLM and known as a split estate. The BIA contended that the acreage could not be leased until its approval was also granted. This conflict was resolved at the departmental level, and the lease is expected to occur as scheduled with no further contest from the BIA.

Reserves

Reserve estimates for the San Juan Basin listed by Beaumont and others (1978) and Tabet and Frost (1979) have not changed except that these figures must be revised downward because of the cumulative effect of production in the Fruitland, Navajo, and Gallup fields. A total of 112 million tons has been extracted since 1962. Field investigations conducted by the New Mexico Bureau of Mines and Mineral Resources in the Zuni-Fence Lake and Salt Lake coal areas may officially revise the figures for these areas upward.

Strippable reserves for the San Juan Basin are shown in table 19. Strippable reserves within 150 ft are 3,735 million tons and in the 150-to-250-ft category are 2,769 million tons, totaling 6.5 billion tons for both the

TABLE 19—Original strippable coal reserves in New Mexico in millions of tons. Combined category includes both measured and inferred overburden (Beaumont and others, 1978; Tabet and Frost, 1979).

	Overburden less than 150 ft			Overburden 150 ft to 250 ft			
Coal field or area	Measured (column 1)	Combined	Inferred (column 2)	Measured (column 3)	Combined	Inferred (column 4)	Total
Mesaverde Group							
Gallup		270.0			88.0		358.0
Newcomb			78.5			6.3	84.8
Chaco Canyon			31.0				31.0
Chacra Mesa		34.7					34.7
San Mateo		82.3	21.2				103.5
Standing Rock			63.5			75.0	138.5
Zuni			6.2				6.2
Crownpoint			15.0				15.0
South Mount Taylor			1.4				1.4
East Mount Taylor							
Rio Puerco							
La Ventana			15.0				15.0
Mesaverde total		618.8			169.3		788.1
Fruitland Formation							
Fruitland	93.0		16.5	65.0			174.5
Navajo		1,934.5			1,352.8		3,287.3
Bisti			617.0			912.0	1,529.0
Star Lake			455.0			270.0	725.0
Fruitland total		3,116.0			2,599.8		5,715.8
Total		3,734.8			2,769.1		6,503.9

Mesaverde and Fruitland Formations. Coal extracted from the Navajo mine in the Navajo coal field and the San Juan mine in the Fruitland field has been 15 million short tons and 82 million short tons respectively. Subtracting this total from the original estimate brings the total estimate for the Navajo field in the less than 150-ft overburden category to 1,852 million short tons, which represents an insignificant change; however, the 78 million short tons have been produced in the Fruitland field. At the current rate of production, this field's strippable reserves will be depleted by 2000.

In the deep-coal resource category, Shomaker and Whyte (1977) listed Fruitland Formation coal resources as follows:

Overburden (ft)		Coal resource (millions of short tons)
0- 500		14,638.3
500-1,000		13,868.2
1,000-2,000		27,937.2
2,000-3,000		58,808.2
3,000-4,000		82,824.1
4,000+		3,060.8
	Total	201,136.8

Coal-leasing management

Federal coal leasing

An EIA (Energy Information Administration) report (1980) states that coal on federal land will become the dominant source of coal for the nation by 1995. The federal government directly controls 60 percent of the coal west of the Mississippi and—because of checkerboard patterns (federal coal land interspersed with fee, state, and Indian-allotted land)—has additional de facto control over an estimated 15-25 percent of state and private land. Owing to the federal Surface Mining Control and Reclamation Act of 1977, the federal government may also exert some control over coal on privately owned land. This circumstance is a drastic change from 1970, when less than 2 percent of United States coal production came from federal land.

The importance of coal on federal land in New Mexico may also drastically change at an even greater rate than projected by EIA because of administration policy aimed at accelerating coal development in order to reduce oil imports. Table 20 shows Fruitland Formation coal ownership and reserve statistics, and table 21 shows the current status of each type of coal-ownership category in New Mexico. This change of control will depend

TABLE 20—Fruitland Formation coal ownership and reserve statistics to a depth of 150 ft as of September 1977 (data from New Mexico Bureau of Geology).

	Coal Reserves (millions short tons)	Percent of reserves in each ownership category
Indian	1,934	62
Federal	796	25.6
Fee	280	9.0
State	106	3.4
Total	3,116	100

TABLE 21—Coal production in New Mexico by ownership category for 1979 (data from New Mexico Bureau of Mine Inspection).

	Short tons	Percent of production in each category
Indian	6,815,288[1]	42.49
Federal	4,606,036	28.72
Fee	4,611,636	28.76
State	4,466	0.03
Total	16,037,426	100.00

on the outcome of the BLM's approval or cancellation of the PRLA's (Preference Right Lease Applications). Under this program, permittees may make an application for a preference-right lease to the U.S. Department of Interior after finding commercial quantities of coal on land before the term of the prospecting permit has expired. The applicant is entitled to a preference-right lease only if the existence of commercial quantities of coal can be demonstrated. The lease is granted for all or part of the land with a preference to the applicant to develop the coal over other subsequent lease applications. The BLM action may have the most significant impact on the New Mexico coal industry since the opening of the large mine-mouth generation stations in the 1960's because of the existence of significant amounts of exploitable shallow coal reserves within PRLA's.

This program has been abolished; outstanding applications will be processed using these criteria, and all other future new leases will be issued only through a competitive bid process.

Preference Right Lease Applications

In New Mexico, five companies now control 75,508 acres under Preference Right Lease Application; this acreage accounts for 2.892 billion short tons of in-place reserves:

Company	McKinley County (acres)	San Juan County (acres)
Ark Land		21,848.51
Eastern Associated Properties, Inc.		35,937.78
Freeman United	2,811.00	
Kin Ark		2,880.00
Thermal	4,654.00	
Total	7,465.00	60,666.29

Strip reserves on this land are estimated to be 831.4 million short tons. This strip-reserve figure represents three times the amount of reserves now under federal lease in New Mexico (table 22). Only 93.09 million short tons of federal, non-Indian coal is within the boundaries of mining plans that have been approved by the U.S. Office of Surface Mining. If the BLM's tentative June 1984 date for the final processing of the PRLA's is met, the leaseholders on record have indicated coal production might occur by 1985. The PRLA's held by Ark Land, a holding company for Arch Minerals, will be processed by August 1982, for the Secretary of the In-

TABLE 22—Coal reserves in New Mexico under federal lease (data from Beaumont and others, 1978).

Preference Right Lease Applications	Acreage	RESERVES Millions of Short Tons In-Place	Strip	Underground
Thermal Energy Co.	12,031.92 (7)	91.82	82.64	- 0 -
Ark Land	21,848.51 (7)	259.62	233.66	- 0 -
Eastern Assoc.	35,937.78 (10)	2,376.53	452.15	625.57
Freeman United	2,811.00 (1)	69.94	62.95	- 0 -
Kin Ark Corp.	2,880.00 (1)	91.76	- 0 -	25.69
Total	75,509.21	2,889.67	831.40	651.26
Federal Leases				
Total	40,745.00	403.43	268.08	56.92
O.S.M. Approved mine plan	14,931.91	113.18	93.09	- 0 -
Lease Exchange Western Coal	- 0 -	- 0 -	21.11	- 0 -

terior has stated that it would be in the public interest to process these leases first. Production scenarios obtained from the leaseholders on record is shown in table 23. A doubling of current 1979 production from these leases alone is not unlikely by 1988.

All of the five companies with PRLA's will be operating surface mines. Their plans, however, indicate that at least one surface mine will progress into a deep-mine operation. This decision to mine the deeper coal will be based on the large quantity of reserves beyond stripping limits that become accessible after mining operations move away from the outcrop. Underground, in-place reserves under PRLA's are estimated to be 648 million short tons. The production from these mines is earmarked for utility consumption. Table 22 shows in-place, strip, and underground reserves by leaseholder. These large coal-lease blocks also have excellent suitability for some form of synfuel development.

The reserve figures shown in table 22 are those generated by the company and then provided to the BLM for its evaluation. The term "reserve" as used in table 22 is not used in the strictest sense of the USGS definition (U.S. Bureau of Mines and U.S. Geological Survey, 1976). The usage differs because a standard reserve classification system had not been in effect at the time of the classification of reserves for PRLA's. Whether USGS will use standards set forth in Bulletin 1451-B to establish the initial showing of commercial quantities of coal or if the companys' methods to calculate reserves meet USGS standards is not known.

State coal leasing

The State Land Office has leased 68,974 acres of state trust land (table 24). By comparison, only 40,745 acres of federal land has been leased (table 22). There are 28 leaseholders of state trust land on record. These leases are generally not greater than two contiguous sections (1,280 acres) and are often bounded by land that is controlled by the federal government in the public domain. State leases for major mining operations will be severely restricted by the lack of reserves unless there is intertract leasing or a consolidation of many other leases. Leaseholders may also use many scattered leases to acquire sufficient reserves that could equal production of a large mine, but this approach may be more costly. Coal is leased in eight counties, and the combined acreage leased in McKinley and San Juan Counties accounts for approximately 80 percent of total state land leased. Acreage leased on state land by county is shown below.

County	Acreage
Bernalillo	2,401
Catron	640
Colfax	1,320
Lincoln	3,600
McKinley	29,652
Rio Arriba	400
Sandoval	6,269
San Juan	24,492
Total	68,774

Gulf Oil, Salt River project, Santa Fe Mining, Western Coal, and Utah International are the major lessees of state trust land. Table 24 shows state trust land leaseholders and acreage held by county as of May 28, 1980. The only producing lease is in Sandoval County and is being operated by Transcontinental Coal and Export Company for A. J. Firchau. Another lease close to Bisti and involving only state trust land is the Western Coal De-Na-Zin mine.

TABLE 23—Projected annual coal production for Preference-Right Lease Applications, 1983 through 1990 (data from New Mexico Bureau of Geology).

PRLA's (Leaseholder)	1983	1984	1985	1986	1987	1988	1989	1990
Ark Land	3,000,000	3,000,000	3,000,000	3,000,000	6,000,000	6,000,000	6,000,000	6,000,000
Eastern Assoc.	- 0 -	- 0 -	uncertain					
Freeman United	- 0 -	- 0 -	2,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000
Kin Ark	- 0 -	- 0 -	uncertain					
Thermal	- 0 -	- 0 -	500,000	500,000	500,000	500,000	500,000	500,000
Total	3,000,000	3,000,000	5,500,000	6,500,000	9,500,000	9,500,000	9,500,000	9,500,000
Projected total from table 18	21,393,000	27,143,000	31,282,000	32,669,000	35,916,000	38,070,000	44,684,000	44,684,000
PRLA's added to projected total from table 18	24,393,000	30,143,000	36,782,000	36,782,000	45,416,000	47,570,000	54,184,000	54,184,000

TABLE 24—COAL LEASES ON STATE TRUST LAND IN NEW MEXICO BY COUNTY AS OF MAY 28, 1980 (data from New Mexico State Land Office).

	ACREAGE							
Lease Holder on Record	Bernalillo	Catron	Colfax	Lincoln	McKinley	Rio Arriba	Sandoval	San Juan
Amax					2560		320	640
Arizona Elec.Power Coop.					3680			
Ark Land								641
Chace Oil					487			
Chaco Energy					2105		640	1962
Chaco & Thermal Energy								440
Cherokee & Pittsburg Co.					1280			640
Chevron					80			
Eastern Assoc.Prop.Corp.								2801
Albert J. Firchau							640	
Gallo Wash Coal								640
Gulf Oil					8441		640	2080
Hamilton Brothers					640			
Hospah Coal Co.					2237			
Hutchings, A.W.			40					
I.B.I. Coal Company							1836	
Independence Energy								439
Kin Ark Corp.								640
Meadowlark Farms				720				
Newmont Expl. Ltd.				2880				
Peabody Coal Co.					647			480
Rigs, Elliot								240
Salt River Project					1211		2193	6398
Santa Fe Mining	2401	640	1280		1938			
Sunbelt Mining Co.								1560
Thermal Energy								1680
Utah International					4546			
Western Coal								4771
Western Nuclear						400		
Total	2401	640	1320	3600	29,852	400	6,269	26,052

County totals = 70,534 acres

Coal Management Program

The federal Coal Management Program, a new program to lease federal coal based on state participation, is being implemented by the BLM. The program's design involves the setting of regional coal production goals and leasing targets; the delineation of tracts of federal coal lands; and the ranking, selection, and scheduling of these tracts. To implement the program, the concept of a Regional Coal Team was formulated; the team consists of the state director of the BLM for each state involved, the governor of each state with the chairman appointed, and a representative appointed by the Secretary of the Interior. This team is to be the vehicle through which the state interacts with and implements federal coal-leasing policies. New Mexico will be represented on two regional coal teams—the San Juan River and the Denver Basin-Raton Mesa. The San Juan River team was established in October 1980, with the first lease sale to occur in 1983. In addition to an urgent concern to develop coal resources, the Regional Coal Team must also deal with meeting other recognized national objectives and problems created by rapid energy development. The team must make decisions that will prevent the possibility of future court litigation such as that which has delayed leasing for nearly a decade. The team must also develop a plan for a balanced program to insure that all interests concerned are represented.

Large-scale use of coal to meet increasing electrical and industrial demand and to make synthetic fuel products will require expansion of existing mines and the development of new coal deposits. This expansion will require the leasing of federal coal acreage. The Regional Coal Team, in examining the need of increased leasing, will also be faced with a number of earth-science considerations, such as reclamation requirements, geologic constraints, and environmental concerns.

New technologies

Synthetic fuels

New technologies may play a major role in shifting supplies of energy from oil and gas to coal. These technologies are receiving direction through a federally subsidized synthetic-fuel program. The Energy Security Act of 1980 has created the Synthetic-Fuel Corporation intended to accelerate synthetic-fuel production by providing funding in the form of loan guarantees, joint ventures, cooperative agreements, or grants. In 1979,

$200 million had been allocated to 110 projects, and 11 of these projects were for coal conversion. If the federal 1987 synthetic-fuel-production goal of 500,000 bbls of equivalent crude oil is met from only domestic coal, the required coal tonnage would be approximately 110 million tons.

Coal as raw material

Many processes are known for converting coal into fuels usable for purposes other than electrical generation. Several processes are aimed at converting coal to crude oil (liquefaction), and the processes that have been the focus of research include SRC (Solvent Refined Coal), H-Coal, and Exxon Donor Solvent methods. Each method is a variation of similar processes to produce a synthetic crude oil.

Other promising processes are those initially designed to convert coal into a gas (gasification). Refining is easier when coal is converted into a gas rather than into a synthetic crude oil. The cleaned gas is then taken through a series of intermediate steps before conversion into a liquid. The South African government has produced "gasoal" (the conversion of coal to gasoline) in quantities large enough for that country to become energy self-sufficient through the use of its own coal reserves. Both liquefaction and gasification produce a combustible product.

Two processes used primarily in Europe for making synthetic gas are the Lurgi process, a fixed-bed, pressurized gasifier; and the Koppers-Totzek process, a fully entrained, atmospheric gasifier now being studied in the proposed New Mexico projects. Neither process is an ideal design for gasifying coal because neither process can produce cheaply a gas equivalent in quality to most natural gas. A producer gas is the product of both processes, which use a hot bed of coal blasted and reacted with a mixture of air and/or oxygen. Nitrogen derived from the air and left over in the final mixture of gas substantially dilutes the heating value of a single-stage and continuous producer gas. The Koppers-Totzek process has an advantage over the Lurgi process because the Lurgi process requires the coal to be crushed to certain dimensions, and the Koppers-Totzek process will function with any size of coal.

Coal mining for power generation and coal mining to make synthetic fuels are very similar processes; some of the major geologic constraints associated with synthetic fuels include inadequate coal bodies in existing leases, thin or discontinuous coal beds, excessive depth of coal, the complex structure of coal-bearing rocks, aquifer disruption, underground mining hazards, post-mining hazards, and coal quality. The USGS estimates that a standard-sized synthetic fuel plant would require 20,000 to 40,000 tons of coal per day (depending on the type of coal) to produce the equivalent of 50,000 bbls of oil or 250 million cubic ft of gas per day. This tonnage requirement, if projected through the life span of 30 yrs of a synthetic-fuel plant, would mean 360 to 720 million tons of reserves would be required to feed the plant. These large reserves are unavailable in existing leases. Even if coal reserves are sufficient, however, they cannot be mined by large-scale mechanized methods because coal seams are too thin. Much of the coal in New Mexico is beyond the range of current mining methods. To mine areas of severe faulting or folding will require detailed geologic investigations or nonconventional mining techniques to avoid high costs and delayed production schedules. To avoid such adverse conditions might severely limit the decision to develop an area. In New Mexico, at least one of the major coal seams is located in an aquifer; and mining, if not properly planned, could disrupt water supplies and degrade water quality. Another constraint may be a serious hazard from poor physical characteristics of roof and floor rocks where the occurrence of the coal is exceptionally thick. One primary post-mining consideration will be mine subsidence. In the San Juan Basin coal region, this problem may not be serious; however, subsidence may pose a serious problem in the more mountainous terrain of the Denver Basin-Raton Mesa region. Knowledge of the physical properties of the coal is needed to assure proper selection to meet end uses (synthetic fuel, electrical generation, or industrial).

The great size of a commercial plant and the large mine necessary to supply the plant creates environmental and health problems that must be considered and dealt with prior to construction. Mining and the conversion of coal are complicated processes, and the advantages and disadvantages will be weighed before any final decisions are made. The product from a synthetic-fuels plant could be consumed in a local market—unlike electrical-power generation, which in many cases must be transported great distances to power plants before consumption.

New Mexico contains several billion tons of uncommitted coal that could serve to supply several synthetic-fuel plants. Large capital investments are necessary for the start-up of plants converting coal to synthetic fuels. The requirement of as much as 12 million tons of coal per year would increase the demand for coal in New Mexico by almost 80 percent. Thermal Energy has a plan to produce methanol; Texas Eastern and Utah International in a partnership agreement were granted $3 million by the U.S. Department of Energy to develop a coal-to-methanol and high-Btu gas feasibility study. This project may initially use 3 million tons and at full production reach 12 million tons of coal per year from the Utah International lease on the Navajo Reservation. Such a projected use illustrates that coal requirements to support a synthetic-fuel plant may be significant. A coal lease or leases large enough to supply the demand for synthetic-fuel development might require recoverable reserves of several hundred million tons.

State revenue

In 1979 the state collected $8,133,134 from the severance, resource-exise, and conservation taxes and $351,867 from rental bonus bids and royalties on state trust lands. The state also receives a portion of the royalties collected by the federal government on public lands (table 25).

Total state revenue was $8,485,001 in 1979, up from $6,995,406 in 1978. This figure does not include the royalties from the federal government. The state does not receive royalties from coal extracted from Indian lands. Table 26 shows severance-tax and resourceexcise-tax collections on coal for New Mexico from 1973 through 1979.

TABLE 25—REVENUE FROM TAXES AND ROYALTIES FROM COAL FOR NEW MEXICO, 1978 AND 1979. Royalties from state lands include bonus payment and rental payment; no state leases are in production, but royalties are accruing as stipulated by state-lease regulations. Years are fiscal years; 1978 is July 1, 1977–June 30, 1978, and 1979 is October 1, 1978–September 30, 1979. Due to a change in fiscal years in 1978, there is a gap of 3 months in 1978. Only a portion of federal royalties is returned to the state (data from New Mexico Taxation and Revenue Department and U.S. Geological Survey).

State revenue	1979	1978
Severance tax	$ 6,165,748	$ 4,791,920
Resource excise tax	1,535,483	991,413
Conservation tax	431,903	288,638
Royalties-State Trust Land	351,866.96	455,887
Total	$ 8,485,000.96	$ 6,527,858

Royalties-U.S. Government

	1979 Tons	1979 Royalties ($)	1979 Value ($)	1978 Tons	1978 Royalties ($)
Indian	6,815,288.39	$1,052,819.52	$52,170,339.66	6,279,840	$1,088,476
Federal	4,606,036.12	$1,036,368.33	$63,579,611.62	4,361,690	$ 958,880
Total	11,421,324.51	$2,089,187.85	$115,749,951.28	10,641,530	$2,047,356

TABLE 26—SEVERANCE AND RESOURCE EXCISE TAX COLLECTIONS ON COAL FOR NEW MEXICO, 1973 THROUGH 1979. Years are fiscal years, July 1 through June 30 (data from New Mexico Taxation and Revenue Department).

Calendar Year	Quantity (Tons)	Price	Gross Value	Deductions	Taxable Value	Tax Due
SEVERANCE TAX						
1979	15,075,881	12.95	195,191,985	-	195,191,985	6,165,748
1978	12,528,452	10.25	128,403,200	-	128,403,200	4,791,920
1977	11,368,939	8.67	98,598,923	-	-	2,337,148
1976	9,980,322	6.76	67,497,989	11,747,307	55,750,682	278,753
1975	8,731,136	6.97	40,848,016	866	52,185,866	260,929
1974	9,482,805	4.42	41,871,482	8,262,210	33,609,272	105,593
1973	9,148,594	3.53	32,319,629	5,432,518	26,887,111	33,609
RESOURCE EXCISE TAX						
1979	16,350,019	12.66	206,997,280	2,556,119	204,441,161	1,535,483
1978	12,064,255	11.02	132,910,202	1,871,861	131,038,341	991,413
1977	11,015,785	8.99	99,072,365	1,692,402	97,379,964	730,445
1976	9,690,933	7.21	69,883,586	1,363,310	68,520,276	513,902
1975	8,748,338	6.97	61,016,223	1,334,924	59,681,299	447,610
1974	9,371,465	4.39	41,441,440	1,484,352	39,657,088	297,428
1973	9,116,852	3.56	32,498,976	1,378,551	31,120,425	233,403

Uranium

by W. 0. Hatchell, *Bureau of Geology*

Production

Although the amount of uraniferous ore weighed and sampled by mills and buying stations in New Mexico continued to increase in 1979, uranium-concentrate ($U30_8$) production declined compared with 1978, and New Mexico's share of total domestic $U30_8$ production dropped six percentage points to 40 percent. A record 6,906,547 tons of ore were weighed and sampled in 1979, which represented an increase of 644,547 tons or a 10-percent increase over the previous year. Table 27 provides comparative production data for the past 6 yrs.

The ore processed in 1979 contained 8,186 tons of U30, of which 7,420 tons were actually reported as production. The difference between the amount of U30, contained in the weighed ore and the amount reported as production is due to quantities of $U30_8$ that have been lost in the milling process as well as the amount that has been stockpiled for later blending and milling and thus is not reported as production. Production of $U30_8$ in 1979 represented a decline of 1,140 tons or 13 percent from 1978. Concentrate production in the period 1966-1979 is shown in table 28 and on fig. 7. Table 27 lists the amount of $U30_8$ contained in the ore, and table 28 lists the actual production of U_30,. Fig. 7 compares cumulative $U30_8$ production in ore by state between 1963 and 1979.

Despite a decline from 1978, New Mexico's 1979 uranium concentrate production was, nevertheless, greater than that of any previous year except 1978. The noteworthy change in production patterns from past years has been a significant decline in the percentage of total United States production. New Mexico's share of domestic production dropped from 46 percent in 1978 to 40 percent in 1979. This decline has resulted from a greater share of production from other states, particularly Texas, which have experienced an increase of 6 percent of domestic production. Wyoming's share of total production has remained about the same at 27 percent. New Mexico, however, has retained its first-place ranking among uranium-producing states and only during 1973 when a prolonged labor strike adversely affected mining and milling has the state failed to lead in U_30_8 production. Between 1966 and 1979, New Mexico has averaged 45 percent of United States production. Following New Mexico and Wyoming, the balance of production in 1979 came from Arizona, California, Colorado, Florida, South Dakota, Texas, Utah, and Washington. Fig. 7 compares New Mexico's uranium-concentrate production with that of Wyoming and with total domestic production between 1963 and 1979.

The decrease in concentrate production can be attributed to a combination of factors that include a decline in average ore grade, down time at one major mill, and adjustment to a depressed uranium market. Since 1977, the average ore grade as a weight percentage of contained $U30_8$ has steadily declined in New Mexico. The average ore grade reported by the DOE (U.S. Department of Energy) as weighed and sampled at mills and buying stations in New Mexico during 1979 was 0.119 percent $U30_8$. This percentage represents a substantial decline from 0.150 percent U_30, reported during 1978 and 0.181 percent $U30_8$ reported during 1977. A large part of the decline in average ore grade from 1978 to 1979 can be attributed to a dilution effect from the milling of large stockpiles of low-grade ore from Anacon-

TABLE 27—URANIUM ORE WEIGHED AND SAMPLED BY MILLS AND BUYING STATIONS IN NEW MEXICO, 1974–1979. According to W.L. Chenoweth (personal communication, August 1980), U.S. Department of Energy's Grand Junction Office (1980a) erroneously reported 1979 ore weighed and sampled as 6,880,000 tons (U.S. Energy Research and Development Administration, 1975, 1976, 1977; U.S. Department of Energy, 1978, 1979c).

Year	Ore(tons)	U_3O_8 (tons)	Ore grade %	% of total U.S. U_3O_8 production
1974	2,997,000	5,400	0.180	43
1975	2,985,000	5,500	0.184	45
1976	3,401,000	6,500	0.191	46
1977	4,209,000	7,600	0.181	46
1978	6,262,000	9,400	0.151	47
1979	6,906,547	8,186	0.119	40

TABLE 28—URANIUM-CONCENTRATE PRODUCTION AS RECOVERED FROM ORE WEIGHED AND SAMPLED IN NEW MEXICO, 1966–1979; concentrate production for 1973 was adversely affected because of a prolonged labor strike at Kerr-McGee that year (U.S. Department of Energy, 1980a).

Year	U_3O_8 (tons)	% of total U.S. production
1966	5076	48
1967	5933	53
1968	6192	50
1969	5993	51
1970	5771	45
1971	5305	43
1972	5464	42
(1973)	(4634)	(35)
1974	4951	43
1975	5191	45
1976	6059	48
1977	6780	45
1978	8560	46
1979	7420	40
Average (excluding 1973)		45

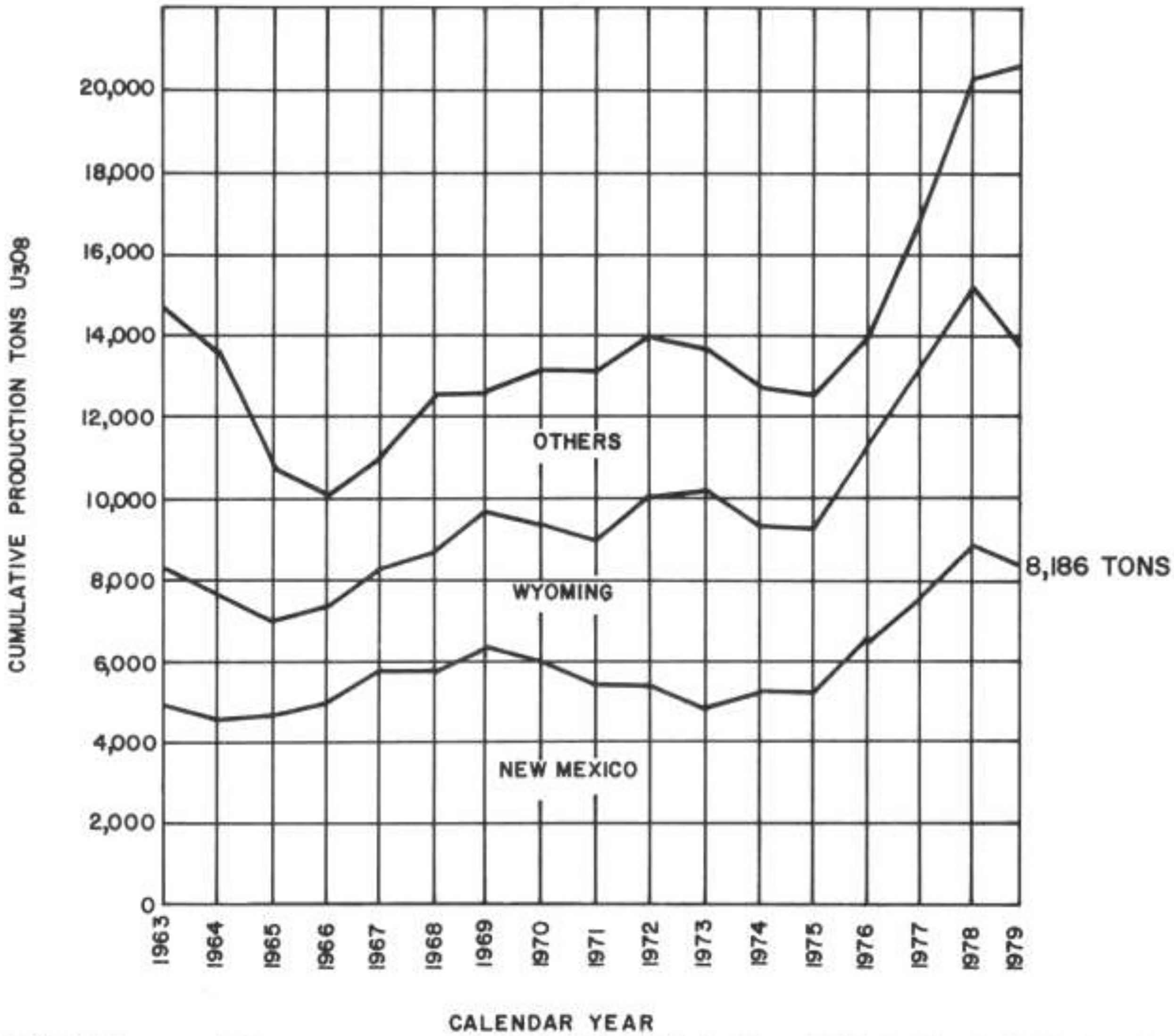


FIGURE 7—CUMULATIVE U_3O_8 PRODUCTION BY STATE, 1963-1979. "Others" includes Arizona, California, Colorado, Florida, Texas, Utah, and Washington (U.S. Department of Energy, 1980a; W.L. Chenoweth, personal communication, August 1980).

da's Jackpile-Paguate mine at Laguna. Other factors that have lowered the average ore grade include the mining of lower grade ores as a response to relatively high market and contract prices of the recent past and, ultimately, the overall lower grades of newer deposits being mined and developed today compared to those of the past. Ore-grade percentages for the past 6 yrs are presented in table 27.

The most significant factor affecting production in 1979 resulted from a breached tailings dam at the United Nuclear Corporation Church Rock mill on July 16. The breach created a spill that resulted in the facility's being out of operation for at least 100 work days. Both milling and mining operations at the Church Rock facility were seriously disrupted for the balance of 1979 and into 1980. Mine closings and layoffs during 1980 are expected to create further production declines over the near future until significant new production comes on stream in 1982. According to industry, the depressed domestic uranium market, acting in conjunction with higher production costs and severance taxes, foreign competition, and uncertainties regarding future demand, has adversely affected both production and development.

In terms of potential energy, using conventional LWR (light-water reactors), the state's 1979 production can be expected to yield approximately 3.4 quadrillion Btu (British thermal units) or the equivalent of 996 GWe (gigawatts electric) of electrical energy prior to transmission. The United States currently has about 61 GWe of nuclear-generating capacity in operation out of a total of 170 GWe in reactors that are ordered, under construction, or licensed to operate.

With the exception of some minor production from the Todilto Limestone and the Recapture Shale Member of the Morrison Formation, most of the 1979 New Mexico production came from the Westwater Canyon Sandstone and the Brushy Basin Shale Members of the Morrison Formation, where fluviatile, feldspathic sandstones are hosts for major uranium deposits. The deposits discovered to date occur as tabular, stacked, and roll-type ore bodies where coffinite is the principal ore mineral. Molybdenum and vanadium are elements commonly associated with the uranium ores and are recovered as byproducts of uranium milling. Fig. 8 shows a cross section of typical ore deposits in the Grants uranium region. All production was from the Grants uranium region of the southern San Juan Basin, except

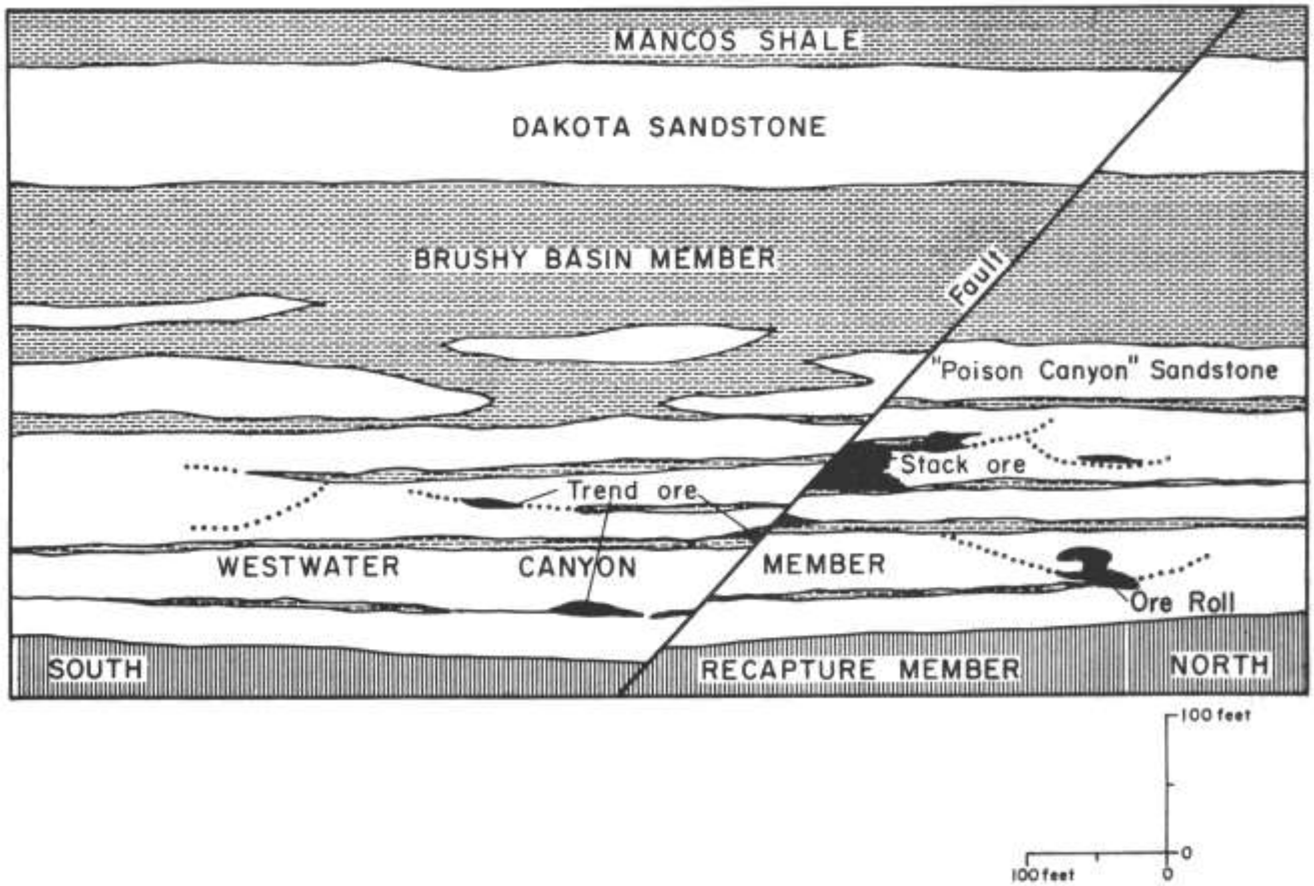


FIGURE 8—IDEALIZED CROSS SECTION THROUGH TREND, STACK, AND ROLL-TYPE ORE DEPOSITS, GRANTS MINERAL BELT, NEW MEXICO (modified from Chenoweth, 1979a).

for the one Recapture deposit at Sanostee in the Chuska mining district. From west to east, the Church Rock, Smith Lake, Ambrosia Lake, and Laguna mining districts compose the Grants uranium region. Fig. 9 shows the Grants uranium region, established mining districts, and areas of new discoveries in northwest New Mexico.

Uranium mining is the largest mining industry in the state in terms of the number of employees, payroll, and product value. Of 18,641 mining personnel employed in New Mexico during 1979, approximately 40 percent were in the uranium industry. Layoffs through the middle of 1980, however, have affected approximately 18 percent of the uranium industry's work force. More than 1,000 employees, primarily miners and support personnel, were idle by middle 1980 as a result of mine closings. Table 29 shows employees in uranium mines and mills by county. More detailed data on employment may be found in the Annual Report of New Mexico Bureau of Mine Inspection (1980).

Mining

As of December 1979, 40 mines were producing ore in New Mexico. Gulf Mineral Resources' Mt. Taylor mine is included as an active mine although all ore mined is being stockpiled until mill facilties are complete. Seven active mines were out of operation by July 1980, reducing the total number of producing mines to 33. Of the 33 producing mines, all except five were operating on full shifts. At least three mines were producing uranium through mine-water recirculation only, and several active mines were undergoing mine-water recirculation through ion-exchange units. Table 30 lists all uranium mines in production as of July 31, 1980.

In January 1980, Kerr-McGee announced that it was suspending operations at the new Rio Puerco mine in Sandoval County and cited the soft uranium market and unfavorable production economics as the reasons for suspension (The Mining Record, January 30, 1980). Other mining projects that were terminated or curtailed during the first half of 1980 include:

Company	Project
Reserve Oil and Minerals	Poison Canyon mine
M and M Mining	Doris extension
Koppen Mining and Construction	Spencer shaft
United Nuclear	Saint Anthony mine
Kerr-McGee	Section 17 mine
Kerr-McGee	Section 24 mine
Todilto Exploration and Development	Piedra Triste mine

Ore-production capacity, calculated by the New Mexico Bureau of Geology, has declined by 7 percent during the first half of 1980 as a result of mine closings.

Total employment in uranium mining as reported to the DOE in middle 1979 was 5,666 in New Mexico compared to 6,021 in 1978. Of this total, 1,843 were underground miners with an additional 1,836 service and support personnel; 338 were open-pit miners with an additional 237 service and support personnel; 496 were technical personnel; 555 were supervisory personnel; and 361 were classified in other job categories.

TABLE 29—NUMBER OF EMPLOYEES IN NEW MEXICO URANIUM MINES AND MILLS BY COUNTY, 1969–1980 (data from New Mexico Bureau of Mine Inspection, sixty-seventh annual report, 1980).

Year	McKinley	San Juan	Sandoval	Valencia	Total	% change from previous year
1969	1783	2	-	519	2304	
1970	1863	2	-	727	2592	+13
1971	1459	2	-	778	2239	-14
1972	1133	-	-	791	1924	-16
1973	1012	4	-	855	1871	- 3
1974	1698	-	-	990	2688	+44
1975	2192	-	-	1204	3396	+26
1976	2953	4	-	1652	4609	+36
1977	3886	5	44	1958	5893	+28
1978	4101	5	55	2273	6434	+ 9
1979	4574	6	55	2689	7324	+11
1980(est.)	3660	6	-	6015	6112	-18

TABLE 30—NEW MEXICO URANIUM MINES IN PRODUCTION AS OF JULY 1, 1980. Kerr-McGee Sec. 22 and Sec. 33 mines and United Nuclear-Homestake Sec. 32 mine are mine-water recirculation only. Kerr-McGee Sec. 17 and Sec. 24 mines closed after July 1, 1980. The Piedra Triste mine operated by Todilto closed after October 1, 1980. Mining operations in Anaconda's Jackpile-Paguate mine to end by December 1980 (data from New Mexico Bureau of Geology).

Company	Mine	Location Sec., Twp., Rge.	Depth (ft)
Anaconda	Jackpile-Paguate	33-35, 11N., 5W.	<100 to ~350
Anaconda	P-10	4-5&8, 10N., 5W.	450
Cobb	Section 12	12, 14N., 10W.	694
Cobb	Section 14	14, 14N., 10W.	360
Cobb	Westranch	32, 15N., 11W.	320
Gulf	Mariano Lake	12, 15N., 14W.	519
Gulf	Mount Taylor	24, 13N., 8W.	3,300
Kerr-McGee	Church Rock No. 1	35, 17N., 16W.	1,851
Kerr-McGee	Section 17	17, 14N., 9W.	1,094
Kerr-McGee	Section 19	19, 14N., 9W.	779
Kerr-McGee	Section 22	22, 14N., 10W.	827
Kerr-McGee	Section 24	24, 14N., 9W.	837
Kerr-McGee	Section 30	30, 14N., 9W.	750
Kerr-McGee	Section 30W	30W, 14N., 9W.	810
Kerr-McGee	Section 33	33, 14N., 9W.	848
Kerr-McGee	Section 35	35, 14N., 9W.	1,398
Kerr-McGee	Section 36	36, 14N., 9W.	1,473
Ranchers	Hope	19, 13N., 10W.	400
Ranchers	Johnny M	7&8, 13N., 8W.	1,380
Sohio - Reserve	JJ No. 1	13, 11N., 5W.	672
Todilto	Haystack	19, 13N., 10W.	157
Todilto	Piedra Triste	30, 13N., 9W.	190
United Nuclear	Ann Lee	28, 14N., 9W.	720
United Nuclear	N.E. Church Rock	35, 17N., 16W.	1,800
United Nuclear	Old Church Rock	17, 16N., 16W.	840
United Nuclear	Saint Anthony	19&30, 11N., 4W.	150-200
United Nuclear	Sandstone	34, 14N., 9W.	940
United Nuclear	Section 27	27, 14N., 9W.	850
UN-Homestake	Section 13	13, 14N., 10W.	618
UN-Homestake	Section 15	15, 14N., 10W.	623
UN-Homestake	Section 23	23, 14N., 10W.	850
UN-Homestake	Section 25	25, 14N., 10W.	811
UN-Homestake	Section 32/29	19&32, 14N., 9W.	595
Western Nuclear-Reserve	Ruby No. 1 & 2	21&27, 15N., 13W.	360
Ray Williams	Enos Johnson	9 mi. W. of Sanostee	450

Milling

Five mills were operating in New Mexico during 1979. A list of licensed uranium mills as of July 1, 1980, is presented in table 31. Although the United Nuclear Corporation Church Rock mill was down for at least 100 work days during the year, the other four mills were running at near capacity throughout the year. The DOE reported that New Mexico mill recovery from ore during 1979 averaged 91 percent (W. L. Chenoweth, personal communication, August 1980). The Bokum mill at Marquez was essentially completed by the end of 1979 but was not operating because of licensing difficulties. State licensing applications were under review for Gulf and Phillips, and mill plans for Conoco were as yet incomplete. The in-situ-leach pilot plant of Mobil at Crownpoint was operating on an experimental basis. Planned mills are listed in table 32 and in-situ-leach projects operating or planned as of July 1, 1980, are listed in table 33.

TABLE 31—LICENSED NEW MEXICO URANIUM MILLS AS OF JULY 1, 1980; excludes ion-exchange facilities. The Bokum Marquez mill is licensed but not operable; CCD—counter-current decantation (data modified from New Mexico Bureau of Geology, 1979).

Company	Location	Type circuit(s)	Licensed capacity (tons/day)
Anaconda	Bluewater	acid, CCD, solvent extraction	6,000
Bokum	Marquez	acid, CCD, solvent extraction	22,000
Kerr-McGee	Ambrosia Lake	acid, CCD, solvent extraction	7,000
Sohio-Reserve	Seboyeta	acid, CCD, solvent extraction	1,660
United Nuclear	Church Rock	acid, CCD, solvent extraction	4,000
United Nuclear-Homestake Partners	Milan	carbonate leach, caustic precipitation	3,500
	Total licensed capacity		24,160
	Operating as of mid-year 1980		22,160

Exploration and development

Drilling

A total of 6,277,240 ft was drilled in 153 exploration and development projects in New Mexico in 1979 compared to 9,922,380 ft drilled during 1978. This activity in New Mexico represents 15.5 percent of total United States drilling, as compared with 21.1 percent in 1978, 22.2 percent in 1977, 32.4 percent in 1976, and 21.9 percent in 1975.

The 1979 New Mexico total includes 3,199 exploration holes for a total of 2,989,823 ft drilled and 4,100 development holes for a total of 3,287,417 ft drilled. As in 1978, McKinley County claimed the bulk of all exploration and development drilling, although Valencia and San Juan Counties continued to show extensive drilling activity. The drilling in San Juan County reflects to some degree the effort that has been expended on deep drilling near Chaco Canyon as well as drilling on the Navajo Reservation. The drilling that took place in

TABLE 32—NEW MEXICO CONVENTIONAL URANIUM MILLS PLANNED AS OF JULY 1, 1980 (data from individual company sources, New Mexico Bureau of Geology).

Company	Location	Planned capacity (tons/day)	Status
Conoco	Prewitt Vicinity	1,000 - 1,500	Feasibility studies in progress
Gulf	San Mateo	4,200	License application approved
Phillips	Nose Rock	2,750	License application filed

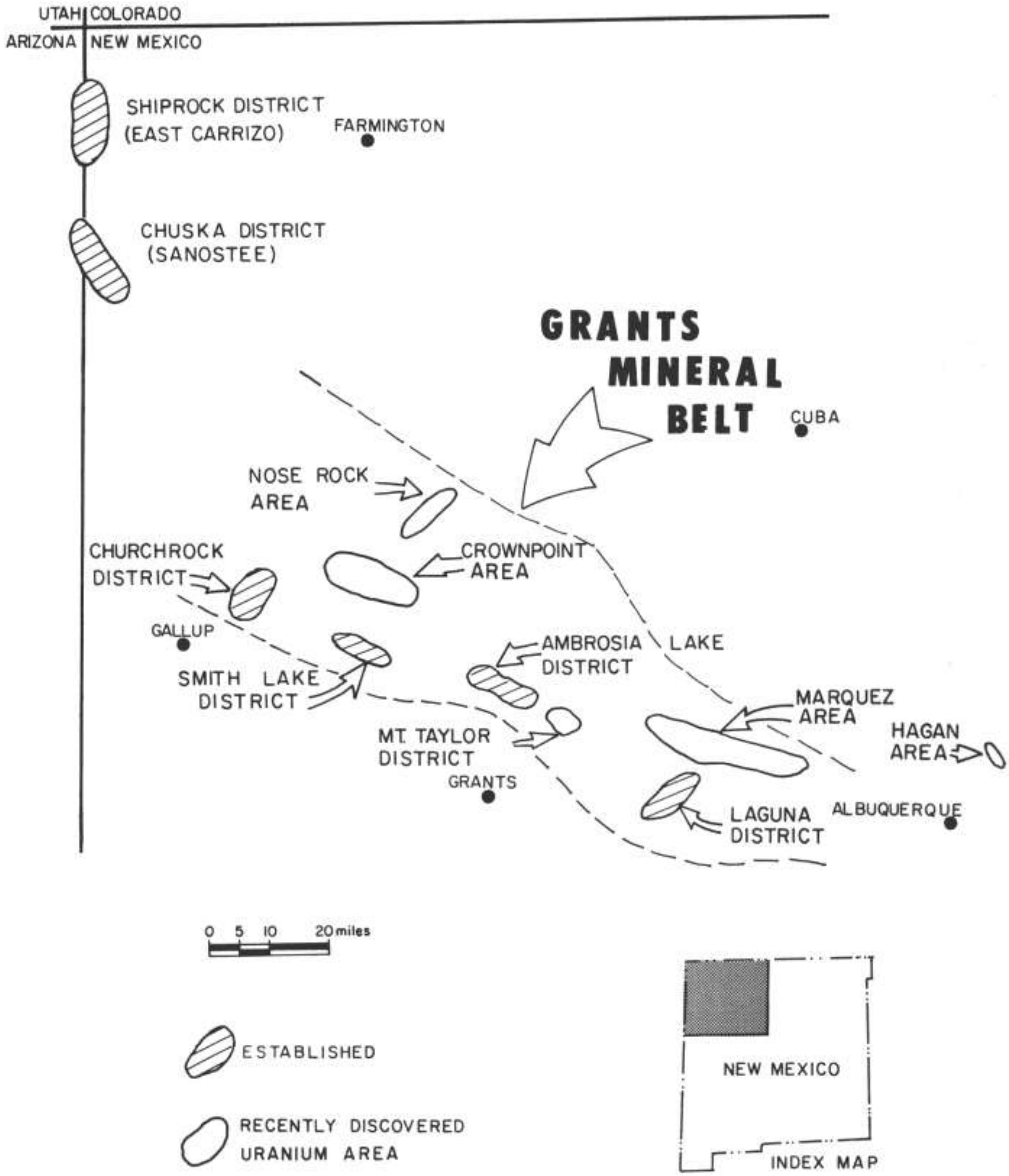


FIGURE 9—Grants mineral belt mining districts and areas of new discoveries in northwest New Mexico (New Mexico Bureau of Geology).

TABLE 33—New Mexico uranium in situ projects operating or planned as of July 1, 1980. The Mobil Crownpoint pilot plant is scheduled to become a commercial operation by 1982. UNC-Teton plans to proceed with a pilot-plant operation by late 1980 as a result of its push-pull test (data from New Mexico Bureau of Geology).

Company	Location	Planned No. of wells	Depth (ft)	Status
Exxon	Sec.21,T.21N.,R.4W.	42	925	Tests planned for 1981
Mobil	Sec.9,T.17N.,R.13W. (Crownpoint)	25	2,000	Operating pilot plant
Mobil	Sec.28,T.17N.,R.12W. (Monument)	5	2,000	Start-up in 11/80
Phillips	Sec.32,T.19N.,R.12W.	5	3,200-3,400	Planned
UNC-Teton	Sec.13,T.16N.,R.17W.	1 (push-pull)	700-1,500	Test completed 6/80

Catron County was principally undertaken to explore the Baca Formation (Tertiary). Table 34 shows surface drilling by county and fig. 10 compares exploration and development drill footage between 1975 and 1979 in New Mexico.

Exploration

The San Juan Basin continued to be the prime area of exploration activity; newer and deeper mineralized trends within the Westwater Canyon Sandstone Member of the Morrison Formation were discovered and drilled basinward, thus extending the Grants uranium region northward. Mineralized intercepts at depths in excess of 4,500 ft have been reported near Chaco Canyon (Bendix Field Engineering Corporation, 1980a). New exploration concepts continue to be revealed, including the announcement by Phillips Uranium Corporation of a large roll-type deposit at its Nose Rock project northeast of Crownpoint. The Phillips discovery of roll-type deposits in the Westwater Canyon Member is the first publicized recognition of this particular type of deposit in the San Juan Basin of New Mexico, where roll-front morphology and geochemistry were employed as primary exploration and development guides to a 24-million-lb (U308) orebody. A thorough discussion of the Nose Rock roll-type deposit is presented in Clark (1980).

In addition to the Phillips Nose Rock ore trend, three distinct and somewhat parallel mineralized trends have been discovered in the Crownpoint vicinity through intense exploration drilling since the early 1970's. To date,

TABLE 34—Surface drilling for uranium in New Mexico by county in 1979. "Others" includes Chaves, Grant, Hidalgo, Rio Arriba, Sierra, Socorro, and undisclosed counties; development data for Catron and Sandoval counties are lumped (W.L. Chenoweth, U.S. Department of Energy, personal communication, August 1980).

County	Exploration		Development	
	No. of holes	Footage	No. of holes	Footage
Catron	708	326,556	[66]	[37,400]
Sandoval	96	39,713	[66]	[37,400]
McKinley	1,748	1,975,484	3,834	3,058,467
San Juan	155	230,674	0	0
Valencia	219	220,150	200	191,550
Others	273	197,246	0	0
Totals	3,199	2,989,823	4,100	3,287,417

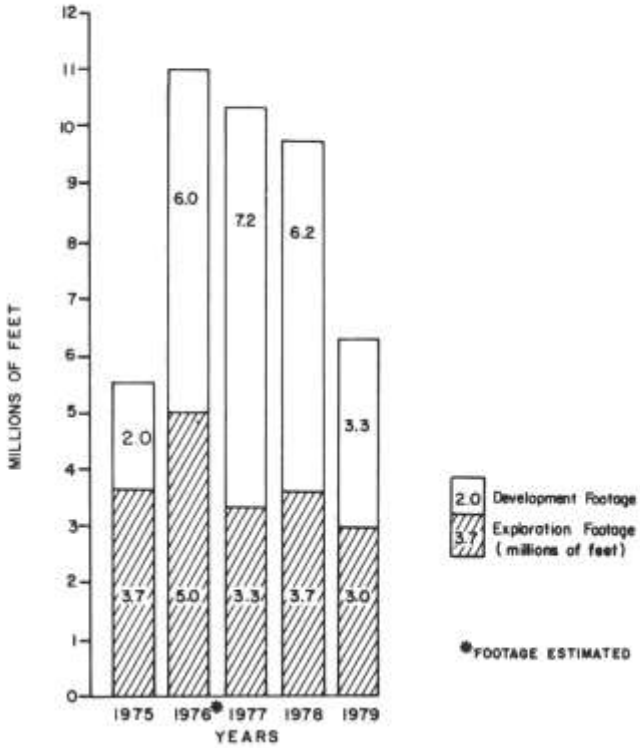


FIGURE 10—Uranium drilling footage in New Mexico, 1975–1979 (compiled by New Mexico Bureau of Geology using data from U.S. Department of Energy).

some 75 million lbs of $U3O_8$ reserves have been blocked out within these three trends, which are as yet vaguely defined and open-ended to the east and west. Other areas within the San Juan Basin being explored include the eastern and western extremities of the Grants uranium region at Bernabe-Montaño and at Church Rock; the western San Juan Basin near Sanostee; and the eastern San Juan Basin or Chama embayment near Canjilon. The Westwater Canyon, Salt Wash, and Recapture Members of the Morrison Formation are the exploration targets near Sanostee, and the Burro Canyon Formation is the target in the Chama embayment. To the south, there has been limited success in defining mineralization on the Mogollon slope in the Datil-Quemado area, where the exploration target is the unconformity between the Mesaverde Group (Cretaceous) and the overlying Baca Formation (Eocene).

During early 1980 Phillips Uranium submitted a proposal to the Carson National Forest to drill between 12 and 19 exploration holes in Rio Arriba County near Tres Piedras, but that project has been cancelled after 6 months of environmental and regulatory delays.

Plans for exploration drilling in the Galisteo Basin south of Santa Fe have been announced by Exxon. The Galisteo Formation (Tertiary) has been selected as the target because this stratigraphic unit is also known to be the host of a deposit in the nearby Hagan Basin that is currently being developed by Union Carbide. Lone Star Mining and Development Company has filed plans for additional exploration at the inactive La Bajada mine site located 4 mi west of La Cienega in Santa Fe County.

As a result of the U.S. Department of Energy's NURE (National Uranium Resource Evaluation) program, a radioactive anomaly was discovered on the southwest flank of Costilla Peak in the Culebra Range of northern New Mexico in Taos County. The anomaly occurs in an area underlain by Precambrian granite and pegmatite dikes, both of which may be a likely source. Although the anomaly is still under investigation, stream sediment, rock, and water samples are being collected along the principal drainage, Costilla Creek. Some sediment samples are reported to range up to 7,688 ppm (parts per million) U_30,, rock samples to 461 ppm U_3O_8, and water samples from 59 to 380 parts per billion. The Costilla Peak anomaly is discussed in more detail by Reid and others (1980).

During 1979 approximately 4,650 net acres of land were held for uranium exploration and mining in New Mexico, an 8 percent increase over 1978. This acreage was distributed among state, federal, Indian, and private (fee) lands as follows (Bendix Field Engineering Corporation, 1980b):

Ownership	Acreage
Federal (claim)	2,407,000
Fee (private)	1,390,000
State	468,000
Indian	386,000
Federal (acquired)	1,000
Total	4,652,000

Among the 14 western states where lands are held for uranium exploration and mining, New Mexico ranks third in total acreage held. Wyoming ranks first, Utah second, and Colorado fourth. The distribution of lands by the six leading states follows:

State	Acreage
Wyoming	**12,416,000**
Utah	7,038,000
New Mexico	4,652,000
Colorado	3,901,000
Arizona	1,662,000
Texas	1,539,000
Other eight states	3,953,000

Cumulative annual acreage held by county in New Mexico for uranium exploration and development during 1979 is shown in table 35. Land transactions in acres by county, including lease terminations and claim abandonments, are also shown.

More than 40 nuclear-energy-resource companies were active in New Mexico during 1979. Most of these companies were engaged in one or more phases of land acquisition, exploration, development drilling, mining, and milling. The companies are listed below.

Anaconda (Arco)
Anschutz
Bokum Resources
Cobb Nuclear
Conoco
Energy Fuels Nuclear
Energy Reserves Group
Exxon
Frontier Mining
Getty
Gulf Minerals
Homestake Mining
Houston International Minerals
Keradamex
Kerr-McGee
Koppen Mining
Lone Star Mining and Development
Mining Unlimited
Mobil
New Cinch Mines
Noranda Exploration
Nuclear Assurance
Occidental
Pathfinder
Phillips Uranium
Pioneer Nuclear
Ranchers Exploration and Development
REE-CO Energy, Inc.
Rocky Mountain Energy
Resource Assoc. of Alaska
Reserve Oil and Minerals
Robert Sayre
Santa Fe Mining (Santa Fe Railway)
Sohio
St. Joe Minerals
Teton Exploration Drilling
Thermal Energy
Union Carbide
United Nuclear
United Nuclear-Homestake Partners
Urania
Uranium King
Wesco
Western Nuclear (Phelps Dodge)
Wyoming Mineral

TABLE 35—NEW MEXICO LAND HELD FOR URANIUM EXPLORATION AND DEVELOPMENT, SECOND HALF 1979. Parentheses indicate lease terminations and claim abandonments; see Arnold and Hill (1980) for breakdown of transactions from January 1 to June 30, 1979 (U.S. Department of Energy, Grand Junction Office, 1980).

	Acres Held by County and Land Category					
	State	Claim	Federally Acquired	Indian	Fee	Total
CUMULATIVE TOTAL to January 1, 1979	431,461	2,098,515	608	386,215	1,362,390	4,279,189
Total January 1 to June 30, 1979 (See previous report)	(30,284)	305,140	-0-	-0-	26,940	301,796
Land Transactions July 1 to December 31, 1979						
Bernalillo	(4,596)					(4,596)
Catron	26,055					26,055
Doña Ana	2,206					2,206
Grant	5,357					5,357
Guadalupe	2,879					2,879
Hidalgo	11,737					11,737
Lincoln	(1,440)					(1,440)
Luna	7,762					7,762
McKinley	(2,113)	2,440				327
Otero	1,370					1,370
Rio Arriba	(2,077)					(2,077)
Sandoval	1,044	1,100				2,144
San Juan	(1,283					(1,283)
Santa Fe	(341)					(341)
Sierra	5,170					5,170
Socorro	14,551					14,551
Valencia	796					796
Total July 1 to December 31, 1979	67,077	3,540	-0-	-0-	-0-	70,617
Total for Calendar Year	36,793	308,680	-0-	-0-	26,940	372,413
CUMULATIVE TOTAL to January 1,1980	468,254	2,407,195	608	386,215	1,389,330	4,651,602

Mine development

In addition to the 33 mines in operation as of July 1980, several mining projects were in various stages of development or planning. Table 36 lists New Mexico uranium mines currently under development.

By early 1980 Gulf's Mt. Taylor production-mine shaft at San Mateo had been completed to the 3,300-ft sump level, and drifts to more than 200 ft beyond the shaft had produced up to 100,000 lbs of $U30_8$ from the Westwater Canyon orebodies. All production to date has been stockpiled except for a minor amount that was shipped for metallurgical and milling tests. The ore mineralogy is principally coffinite and averages approximately 0.30 percent U30, with a uranium/molybdenum ratio of 15:1. Gulf considers 6 ft at 0.10 percent to be its grade-thickness cutoff. Production will be from ore pods within both the upper and lower Westwater Canyon, which host the complex of deposits estimated to contain in excess of 100 million lbs of U30,. The life of the mine is expected to be 20 yrs; the production-shipping target date is 1982. Nominal production capacity of the mine in full production is expected to be 4,500 tons per day. Gulf is still awaiting final licensing for a 5-million-lb-per-year milling operation to be located at San Mateo. The Mt. Taylor deposit is regarded as the largest and deepest uranium deposit known in the United States.

Phillips Uranium Corporation continued to sink its 18-ft-diameter production shaft at the Nose Rock No. 1 mine northeast of Crownpoint. Work on the Nose Rock No. 2 mine shaft was suspended in May 1980; the company cited economic reasons—delays in mill licensing and a slumping uranium market. By September 1980, the No. 1 shaft had reached a depth of 2,600 ft toward a target depth of 3,200 ft. The Nose Rock deposit is unique to the San Juan Basin of New Mexico because the ore occurs in large roll-type deposits. All mineralization is within the upper and middle Westwater Canyon Sandstone and is distributed along four horizons that compose about 150 ft of total thickness. When in full production, the 24-million-lb deposit connected by mine shafts No. 1 and 2 should average 2,950 tons per day.

The Crownpoint development mine shaft begun by the Wyoming Mineral-Conoco Corporation in mid-April 1980 had reached a depth of over 1,000 ft by mid-June 1980 and reached the 2,200-ft production level by September. In order to minimize shaft-sinking time, the shaft was drilled to total depth; the conventional blast-and-muck method was not used. Now that the development shaft has been completed, the 3-ft-diameter pilot hole for the main production shaft located 100 ft away will be connected to it by drifting. As the production shaft is drilled and blasted down through the pilot hole, muck and water will be hauled through the drift and pumped out of the adjoining development shaft. The company estimates that two full production years can be saved if the operation continues as planned. The Crownpoint deposit could be in production as early as 1982. Total recoverable reserves contain at least 10 million lbs of U_30_8 and occur in four Westwater Canyon Sandstone horizons. Mill plans are as yet incomplete because the firm is in the process of evaluating potential sites.

Dewatering problems and procedural delays in mill licensing continued to hamper development at the Bokum Resources Corporation Marquez mine through 1979. By February 1980, however, the firm's below-surface tailings disposal plan had been approved and a license was issued. At least two minable uranium deposits occur at the Marquez property. The deepest deposit is located at approximately 2,100 ft and has recoverable reserves of 10.7 million lbs of U30,. This deeper deposit is intercepted by the 2,100-ft-deep Marquez No. 1 shaft. The Marquez No. 2 orebody, located at a depth of 1,600 ft, has reserves of some 751,000 lbs of U30, and will be developed as market conditions and sales commitments allow.

Kerr-McGee plans to develop a new mine (to be called the Lee mine) in the Roca Honda area of Ambrosia Lake. The production-shaft site is located in sec. 17, T. 13 N., R. 8 W. The collar for the 14-ft-diameter concrete-lined shaft has been completed, and other site work is progressing. A second production shaft was completed at Church Rock; and mine feasibility and planning studies are continuing at Marquez, where the company is involved in a joint venture with the TVA (Tennessee Valley Authority).

By May 1980, Western Nuclear was retreat mining the Ruby No. 2 deposit, opened by a 300-ft drift from the Ruby No. 1 mine. The Ruby No. 3 and Ruby No. 4 incline was completed in June 1980, and drift work should

TABLE 36—New Mexico uranium mines under development as of July 1980 (data from New Mexico Bureau of Geology).

Company	Mine	Location	Target Depth (Feet)	Status
Anschutz	Blackjack No.2	Sec.18,T.15N,R.13W.	~240	Develop.Drlg.
Bokum	Marquez	Sec.25,T.13N,R. 5W.	2100	Sinking shaft
Cobb	Section 10	Sec.10,T.14N,R.10W.	Unknown	Unknown
WMC-Conoco	Crownpoint	Sec.24,T.17N,R.13W.	2000	Sinking shaft
Energy Fuels	Evelyn	Sec. 9,T.14N,R.11W.	Unknown	Develop.Drlg.
Kerr-McGee	Lee (Roca Honda)	Sec.17,T.13N,R. 8W.	1675	Preparing shaft site
Kerr-McGee-TVA	Marquez	Sec.23,T.13N,R. 5W.	2200	Mine planning phase
Mobil	Crownpoint (in situ project)	Sec. 9,T.17N,R.13W.	2000	Pilot operation
Mobil	Monument (in situ project)	Sec.28,T.17N,R.12W.	~2000	Test Drilling
Phillips	Nose Rock No.1	Sec.31,T.19N,R.11W.	3200	Sinking shaft
REE-CO Energy	REE-CO No.1	Sec. 8,T.14N,R.11W.	Unknown	Unknown
Union Carbide	Diamond Tail	Sec.16,T.13N,R. 6E.	10-400	Develop.Drilling in process
Western Nuclear-Reserve	Ruby No. 3 & 4	Secs.25&26,T.15N,R.13W	~300	No.3 decline now completed

intersect the two orebodies by October 1980. The Ruby No. 3 will produce approximately 800 tons per day when in full production. The Ruby orebodies are in the Poison Canyon tongue (uppermost Westwater). Western Nuclear anticipates that the Ruby deposits will be depleted within 5 yrs; meanwhile, exploration is continuing on its Section 16 orebody near Lee Ranch in the Ambrosia Lake district.

Another development during 1979 includes the apparently successful Mobil in situ leach project in sec. 9, T. 17 N., R. 13 W. near Crownpoint. Although actual results have been withheld, a concentrated uranium slurry appears to have been produced by the pilot plant. The firm plans to apply to the state's EID (Environmental Improvement Division) for a permit to build a commercial-size, leach-solution facility planned for operation by 1982 with an ultimate capacity of about 2,000 tons per day. Mobil's Monument in-situ project in sec. 28, T. 17 N., R. 12 W. is progressing with chemical testing to commence in November 1980. Monument is located approximately 2 mi east of Crownpoint, where the mineralized Westwater host rock will be tested at depths of approximately 2,000 ft.

Preliminary push-pull testing for a pilot in-situ operation was successfully completed by Teton in June 1980 at sec. 13, T. 16 N., R. 17 W. Teton plans to apply for a license to operate a pilot plant in the general vicinity of this testing in the late fall of 1980 and to proceed with additional development drilling and core testing. Potential production horizons in the area lie at depths of 700 to 1,500 ft. Other in-situ leach projects that are planned and have been announced are listed in table 33.

During 1979, approximately 758 exploration personnel were employed in New Mexico compared to more than 1,000 during the previous year. Exploration employment statistics for the state by job category are shown below (W. L. Chenoweth, personal communication, August 1980).

Job category	Number of employees
Geology and engineering	172
Drilling services	345
Logging services	78
Aerial services	3
Others (landmen, surveyors, drafting personnel)	160
Total	758

NURE program

The purpose of the NURE (National Uranium and Resource Evaluation) program of the DOE is to acquire and compile geologic and other information to assess the magnitude and distribution of uranium resources and to determine areas of favorability for the occurrence of uranium in the United States. Contracts are awarded by DOE to various firms and institutions throughout the United States that have demonstrated or proven their ability to conduct these studies in a professional manner. New Mexico-based institutions presently involved in NURE contract work include LANL (Los Alamos National Laboratory) of the University of California, Sandia National Laboratories, New Mexico Bureau of Mines and Mineral Resources, and the University of New Mexico.

The NURE program strategy involves three successive work phases, including data collection, data evaluation, and—ultimately—resource assessment of each map quadrangle. Aerial radiometric surveys, hydrogeochemical and stream-sediment surveys, topical surveys, world class resource investigations, subsurface geologic investigations, technology application, and resource-estimation methodology are among those NURE activities being funded in the United States. ARMS (airborne radiometric and magnetic surveys) of 22 quadrangles that compose New Mexico and portions of those quadrangles that are shared with surrounding states were completed for the NURE program. The 1 °-by-2 ° quadrangles of the NTMS (National Topographic Map Series) at a scale of 1:250,000 were the basic work unit. In addition, HSSR (hydrogeochemical stream sediment reconnaissance) and land-status maps at this scale are being prepared for public release. Other data-gathering approaches used by the NURE program include geologic, geochemical, and geophysical methods in a more direct way, such as in the East Chaco Canyon drilling project.

The East Chaco Canyon drilling project of NURE consisted of 15 boreholes drilled in the Chaco Canyon area of the San Juan Basin for the purpose of obtaining subsurface data on possible basinward extensions of the mineralized Morrison Formation in the CrownpointNose Rock areas. Of 15 holes drilled, four intercepted uranium mineralization at depths ranging from 3,975 to 4,670 ft. The mineralization was reported to be within both the Westwater Canyon and the Brushy Basin Members of the Morrison Formation. A total of 70,421 ft was drilled; and, of this total, 4,938 ft was cored. Lithologic and geophysical logs were taken of each drill hole, and a comprehensive study of the cores was made by the University of New Mexico Geology Department. Those conducting the drilling project concluded that environments favorable for the occurrence of uranium exist for considerable distances basinward from known Grants uranium region deposits. Data from the Chaco drilling project is presented in Bendix Field Engineering Corporation (1980a).

AML study

As part of a national inventory of abandoned coal mines, the Surface Mining and Reclamation Act of 1977 authorized the State of New Mexico to inventory and assemble data on all abandoned or inactive mine lands within the state. Although the act calls for primary emphasis to be directed on coal mines, uranium-mine data were collected during the course of the inventory. All data collected will be used by the State of New Mexico in the development of AML (Abandoned Mine Lands) reclamation projects.

The EMD (New Mexico Energy and Minerals Department) has been designated the state agency to receive federal AML funds. The New Mexico Bureau of Mines and Mineral Resources has been contracted by the EMD to inventory and assess lands for AML reclamation under Phase I of a national inventory as well as under the state's cooperative planning agreement with the federal government. Other agencies, both state and federal, will become involved in subsequent phases of the AML project; meanwhile, the inventory of uranium sites that qualify under the terms of AML has been completed and will be released by EMD as part of a series of open-file reports in 1981. Thus far, over 200 uranium mine sites have been located in New Mexico and include both prospects and properties with past production.

Exploration forecast

Data on planned exploration activities by United States' industry at both the foreign and domestic levels have been surveyed by DOE. Land acquisitions, drilling footage, and exploration costs are among those parameters reported by 164 responding companies (U.S. Department of Energy, 1980b). The survey indicates that the level of planned exploration activity will decrease nationally in most categories except for costs. Land acquisition costs averaged about $10.58 per acre nationally during 1979 compared to $4.81 in 1978 and $4.70 in 1977. A $10,311,233 bonus bid on 640 acres of state trust land by Western Nuclear at Ambrosia Lake accounted for the significant average-cost increase. Because a considerable proportion of the acreage reported has increased in mineral value as a result of exploration drilling, land acquisition costs are expected to continue to increase rapidly.

Surface drilling is expected to decrease slightly in 1980 compared to 1979 and to decline further during 1981. According to the industry survey, total surface drilling in the United States between 1979 and 1981 should drop by approximately 14 percent. In New Mexico, surface drilling has declined by 18 percent since 1976 (fig. 10), when exploration and development drilling of newly discovered San Juan Basin ore deposits reached maximum intensity. The current decline is expected to continue over the next few years as exploration incentive is further eroded in New Mexico and other uranium-producing states by adverse market pricing, regulatory uncertainties, and—ultimately—the lack of a coherent national energy policy toward nuclear power. Exploration drilling costs include site and road preparation, geological and other technical support, drilling, sampling, and drill-hole logging and cementing. During 1979, the average cost was $3.97 per foot of hole drilled, which is a 12 percent increase over 1978. In New Mexico, with deposits at greater depth, surface drilling costs in 1979 averaged $4.03 per ft. Although total budgeted exploration expenditures by industry are expected to fall through 1981, costs will continue to rise.

Planned exploration activities in frontier (non-established) areas and in nonsandstone deposits are expected to consume approximately 51 percent of industry's exploration budget by 1981. In 1979, such expenditures amounted to 48 percent. Although the emphasis in New Mexico is still on the San Juan Basin, potential resources are also estimated to occur in frontier sandstone and nonsandstone geologic environments outside of the San Juan Basin.

Reserves

New Mexico still holds a dominant position among all uranium-producing states in each of the forward-cost reserve categories. Forward cost is defined as operating and capital costs, in present dollars, that will be incurred to produce uranium from deposits of known average grade and economic interest. The cost categories are used to cover those reserves at grades and depths of current economic interest. Because no known reserves at $15 per lb or less can be mined given present economic conditions, the $15 forward-cost category was deleted in 1979. In order to produce these lower grade reserves at rising costs per pound, more tons of ore from substantially increasing numbers of properties will have to be produced.

New Mexico has 52 percent of domestic uranium reserves producible at $30 per lb, 48 percent of uranium reserves producible at $50 per lb, and 46 percent of uranium reserves at $100 per lb. In the $30-per-lb range, 15 fewer properties are included for calendar year 1980 than for 1979, resulting in a net decrease. This change indicates that, after production, additional reserves are being defined only in extensions of known orebodies rather than in newly discovered orebodies. Table 37 shows reserve data for New Mexico in the various forward-cost categories from January 1978 through January 1980. Compared to calendar year 1978, when New Mexico held 52 percent of uranium reserves in the $50-per-lb forward-cost category, the state now has 48 percent of all the United States uranium reserves in the $50-per-lb category. Although six new deposits have been added to $50-per-lb reserves, lower average grade and recent production depletion may account for the net decrease. Table 38 shows that New Mexico's reserves have declined while those of Wyoming and Texas have increased. New Mexico's reserves are in larger deposits, but must be produced at higher costs because they are at greater depths than those in Wyoming and Texas. Compared to the leading nations of the world in terms of reasonably assured uranium reserves at $50 per lb, New Mexico trails only South Africa. A comparison of international uranium reserves producible at $50 per lb is as follows:

Area	Tons of U_3O_8
South Africa	508,000
New Mexico	484,000
Sweden	390,000
Australia	390,000
Canada	305,000
Niger	210,000

Table 39 shows preproduction and postproduction inventories of U_3O_8 in New Mexico and indicates the grade ranges within which most of the state's reserves are included. Inventories are compiled by the DOE us-

TABLE 37—New Mexico uranium reserves by cost categories, 1978–1980; $15/lb forward-cost category dropped in 1979; $100/lb forward-cost category added in 1979 (U.S. Department of Energy, 1978, 1979a, c, 1980a).

Forward-cost category	Year	Tons ore	Percent U_3O_8	Tons U_3O_8	Percent of total U.S. reserves	Number of properties
$15/lb	1978	111,300,000	0.20	222,000	60	106
	1979	85,700,000	0.22	190,900	66	89
	1980	Not included				
$30/lb	1978	318,000,000	0.12	367,700	53	174
	1979	309,700,000	0.12	375,000	54	155
	1980	255,700,000	0.13	338,000	52	140
$50/lb	1978	547,100,000	0.09	465,000	52	177
	1979	539,000,000	0.09	473,900	52	175
	1980	482,400,000	0.09	448,700	48	181
$100/lb	1978	Not included				
	1979	Not included				
	1980	670,500,000	0.08	512,300	46	183

TABLE 38—Distribution of domestic uranium reserves in the \$50/lb forward-cost category, January 1, 1979–January 1, 1980. "Others" includes Alaska, Arizona, California, Colorado, Idaho, Montana, North Dakota, Oregon, South Dakota, Utah, and Washington (U.S. Department of Energy, 1979c, 1980a).

Date	State	Tons ore	% U_3O_8	Tons U_3O_8	Percent total US (tons U_3O_8)	No. Properties
1/1/79	New Mexico	539,000,000	0.09	473,900	52	175
	Wyoming	504,100,000	0.06	287,300	31	276
	Texas	97,100,000	0.05	49,600	5	136
	Others	159,800,000	0.07	109,200	12	1225
1/1/80	New Mexico	482,400,000	0.09	448,700	48	181
	Wyoming	510,900,000	0.06	314,700	34	283
	Texas	104,400,000	0.05	55,800	6	135
	Others	173,300,000	0.06	116,800	12	1150

ing company drilling data from individual properties. The preproduction inventories are cumulative tonnage-grade distributions of U_3O_8 prior to production; postproduction inventories represent in-place distributions of U_3O_8 after subtracting all production before January 1, 1980. Since all material that meets minimal mining thickness and is equal to or exceeds 0.01 percent U_3O_8 is inventoried, all postproduction inventories cannot be considered to be economically recoverable reserves; however, some 70 percent of New Mexico's current postproduction inventory may be considered recoverable at costs of \$50 per lb or less. The balance of postproduction inventory at grades equal to or below 0.05 percent U_3O_8 must be produced at substantially higher costs.

TABLE 39—Preproduction and postproduction in New Mexico uranium inventory, January 1, 1980. Preproduction inventories of U_3O_8 are cumulative tonnage-grade distributions of individual properties prior to production. Postproduction inventories reflect in-place distributions of U_3O_8 after subtracting all production prior to January 1, 1980 (U.S. Department of Energy, 1980a).

Minimum Grade (% U_3O_8)	Cumulative Tons of Ore (Millions)	Avg. Grade (% U_3O_8) of Cumulative Tons	Cumulative Tons U_3O_8 (Thousands
PREPRODUCTION			
0.01	1,317	0.06	792
0.02	979	0.08	744
0.03	715	0.10	683
0.04	546	0.12	626
0.05	432	0.13	577
0.06	352	0.15	534
0.07	293	0.17	497
0.08	247	0.19	464
0.09	212	0.21	435
0.10	183	0.22	408
0.11	160	0.24	384
0.12	140	0.26	362
0.13	124	0.27	341
0.14	111	0.29	323
0.15	99	0.31	306
0.16	89	0.33	291
0.17	80	0.34	276
0.18	73	0.36	263
0.19	67	0.38	252
0.20	61	0.40	241
POSTPRODUCTION			
0.01	1,124	0.06	648
0.02	906	0.08	600
0.03	642	0.10	539
0.04	473	0.12	482
0.05	360	0.13	433
0.06	280	0.15	390
0.07	220	0.17	353
0.08	175	0.19	320
0.09	150	0.21	300
0.10	130	0.22	281
0.11	113	0.24	265
0.12	99	0.26	250
0.13	88	0.27	235
0.14	78	0.29	222
0.15	70	0.31	211
0.16	63	0.33	201
0.17	57	0.34	191
0.18	51	0.36	182
0.19	47	0.38	174
0.20	43	0.40	166

Potential uranium resources in New Mexico occur in all of the state's four physiographic provinces, including the Colorado Plateau, Basin and Range, Great Plains, and Southern Rocky Mountains. Host rocks range in age from Precambrian to Quaternary. Potential resources are divided into three classes of reliability: probable, possible, and speculative. Probable resources are those estimated to occur in known productive uranium areas. Possible resources are those estimated to occur in discovered or partly defined deposits in formations or geologic settings productive elsewhere within the same geologic province or subprovince. Speculative resources are those estimated to occur in previously unproductive geologic settings, provinces, or subprovinces. Table 40 shows New Mexico's uranium resources estimated by DOE to be producible at \$50 per lb of contained U_3O_8 as of January 1, 1980.

The San Juan Basin of the Colorado Plateau province accounts for approximately 99 percent of the probable and possible uranium resources in the \$50-per-lb U_3O_8 category but for only about 2.5 percent of resources in the speculative category. This difference is an indication of the degree of exploration drilling in the plateau area compared to other geologic environments within the state. The second greatest potential for probable and possible deposits seems to be in the northern portion of

TABLE 40—New Mexico \$50/lb U_3O_8 resources by region, January 1, 1980; \$15/lb category dropped in 1979; \$100/lb category added in 1979 (U.S. Department of Energy, 1980a).

Physiographic province	Resources (tons U_3O_8) Probable	Possible	Speculative
Colorado Plateau	549,500	440,000	200
Basin and Range	500	1,000	300
Southern Rocky Mountains	-	-	500
Great Plains	-	-	7,000
Totals	550,000	441,000	8,000

New Mexico's Basin and Range province, which embraces the Estancia and Hagan Basins between Albuquerque and Santa Fe, where a deposit in the Galisteo Formation has been delineated within the past few years by Union Carbide. On the other hand, an area of speculative potential deposits seems to be the Great Plains province, where little is yet known from drilling and geological studies about the occurrence of uranium at numerous localities, some of which have recorded minor past production. The extent of surface exploration drilling in counties outside the Grants uranium region gives some indication of the degree of exploration effort being expended in these frontier areas (table 34), which is less than 10 percent of the total for the state. The bulk of the uranium exploration effort is therefore still concentrated in the San Juan Basin area.

Geologic formations that seem to be most favorable in New Mexico for potential uranium resources, in addition to those of the prolific Morrison Formation of Jurassic age, are shown in table 41.

Probable potential resources are converted to reserves as new deposits are discovered and reserves delineated. In the same manner, as the reliability of the data improves, possible or speculative resources may be converted to probable and possible resources. For example, as a result of a 15-hole uranium-drilling program by DOE in the East Chaco Canyon area of the San Juan Basin in 1977-1978, resources in the $50-per-lb category were increased by 60,000 tons of U_3O_8 in the combined probable and possible reliability classes. As economics allow, most reserves are ultimately committed to production and enter the nuclear-consumption cycle. Table 42 shows the percentages of potential resources that have been converted to reserves and production in the United States and in the Grants uranium region since 1968. New Mexico's uranium resource areas are shown in fig. 11.

TABLE 41—URANIUM RESOURCE AREAS IN NEW MEXICO (data from New Mexico Bureau of Geology).

Formation or host rock	Geological age	Tectonic element	Physiographic province
Calcrete/Basin-fill	Quaternary	Lordsburg, Animas Valley area	Basin and Range
Tesuque Formation	Oligocene	Espanola Basin, Rio Grande rift	Basin and Range Southern Rocky Mountains
Popotosa Formation	Oligocene	Ladron Uplift	Basin and Range
Galisteo Formation	Eocene	Estancia, Galisteo, and Hagan Basins	Basin and Range
Baca Formation	Eocene	East Mogollon Slope, Acoma Sag	Colorado Plateau
Ojo Alamo Sandstone	Tertiary-Cretaceous	East San Juan Basin	Colorado Plateau
Dakota Sandstone	Cretaceous	Southern San Juan Basin	Colorado Plateau
Burro Canyon Formation	Cretaceous	Chama Basin	Colorado Plateau
Todilto Limestone	Jurassic	Acoma Sag, Defiance Uplift	Colorado Plateau
Chinle Formation	Triassic	Tucumcari Basin, Sierra Grande Uplift	Great Plains
		Gallina Uplift	Colorado Plateau
		Nacimiento Uplift	Southern Rocky Mountains
Sangre de Cristo Formation	Permo-Pennsylvanian	Las Vegas Basin	Great Plains
		Sangre de Cristo Uplift	Southern Rocky Mountains
Granitic rocks	Precambrian	Burro Uplift, Pedernal Uplift	Basin and Range
		Brazos, Sangre de Cristo Uplifts	Southern Rocky Mountains

Supply and demand

Both domestic and WOCA (world outside of communist areas) demand will affect the market for New Mexico uranium. Several factors must be considered in projecting demand, including the growth potential of nuclear-generating capacity, actual and projected contract sales commitments, the United States' enrichment capacity, and the production capacity of the state's mines and mills. Future supply will be determined by the rate and cost of the discovery of additional potential resources as well as by the lead times and investment capital required to develop reserves and to construct new mines and processing facilities. Although the mechanics of supply and demand will ultimately determine the market for uranium, highly controversial, complex, and largely unresolved issues involving our national energy policy, permitting, regulation, environmental issues, and public acceptance will play important roles.

Previous short-term demand projections for nuclear energy seem to have been overly optimistic in terms of projected growth. Between 1973 and 1979, the energy/GNP (Gross National Product) ratio has actually de-

TABLE 42—DISTRIBUTION OF URANIUM RESOURCES IN THE UNITED STATES AND THE GRANTS MINERAL BELT (GMB). The cost categories selected for reserves and potential resources were $30 per lb of U_3O_8 in 1968 and 1972 and $50 per lb in 1976 and 1980. Total resources include cumulative production, reserves, and potential resources (U.S. Department of Energy, 1980c).

	Tons U_3O_8 X 10^3									
	Cumulative production & reserves		Potential resources		Total resources		% potential resources in total resources		% of 1968 potential resources converted to reserves & production	
Year	US	GMB	US	GMB	US	GMB	US	GMB	US	GMB
1968	500	200	940	130	1,440	330	65	39	--	--
1972	650	265	1,650	680	2,300	945	72	72	16	50
1976	900	415	2,970	605	3,870	1,020	77	59	43	165
1980	1,480	600	2,550	290	4,030	890	63	32	104	320

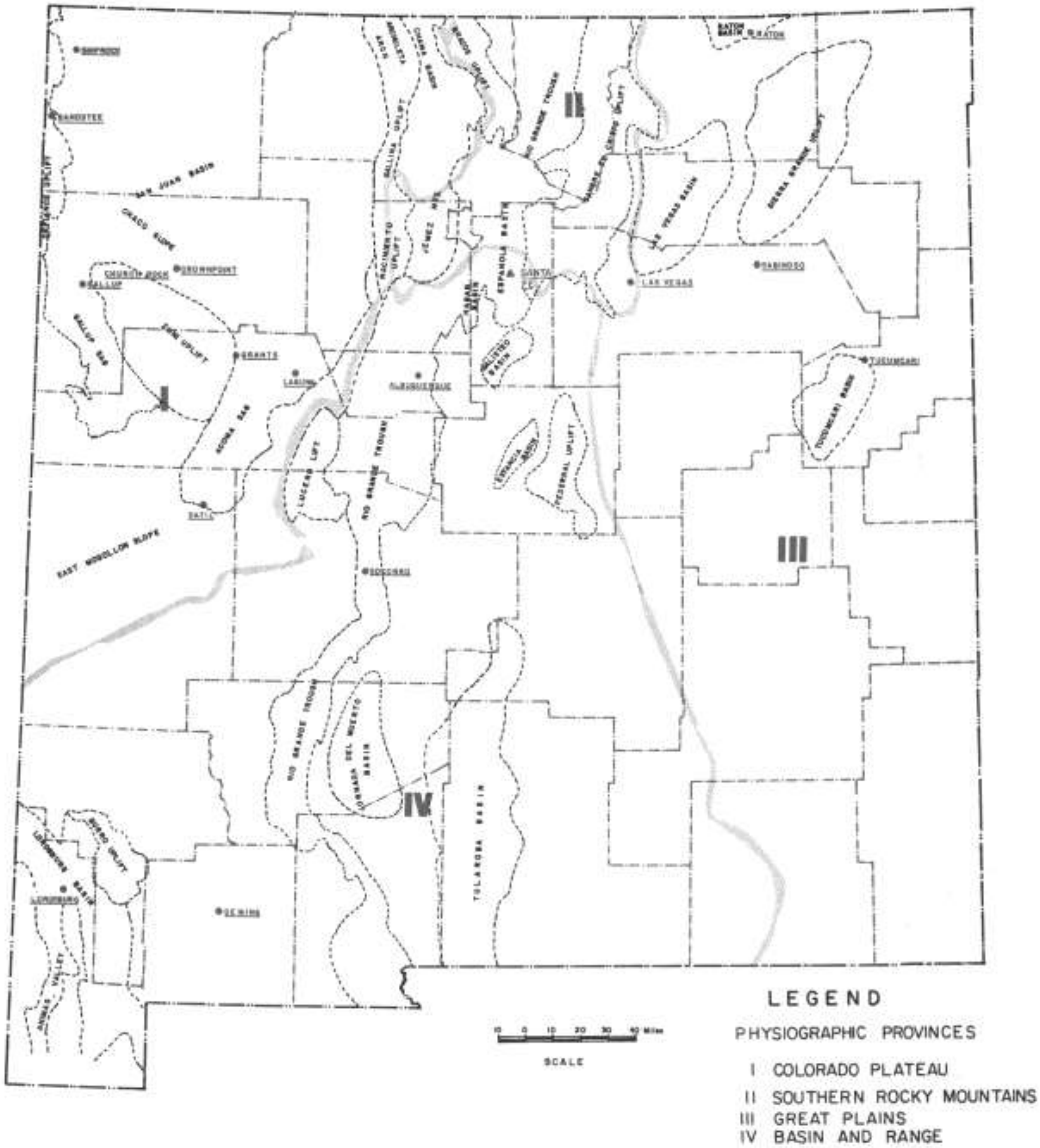


FIGURE 11—URANIUM RESOURCE AREAS IN NEW MEXICO SHOWING TECTONIC ELEMENTS WITHIN PHYSIOGRAPHIC PROVINCES THAT ARE FAVORABLE TO OCCURRENCE OF URANIUM IN NEW MEXICO.

dined rather than increased; this decline can be attributed, at least in part, to inflationary energy costs. Although total nuclear-power capacity has been gradually increasing, the projected number of reactors has decreased since 1975 because cancellations have exceeded new orders. The anticipated supply of domestic uranium through 1985, therefore, seems to be more than adequate to fulfill probable demand. Similarly, the annual rate of increase in total domestic electrical generation capacity has averaged 4.8 percent during the last decade. Present projections call for an annual increase of 3.2 percent in 1980 and only 2.8 percent in 1981 (B. L. Perkins, personal communication, July 1980).

In addition, since actual domestic production of uranium has been in excess of consumption, the liquidation of large inventories by the utilities has been one of several factors contributing to a depressed market situation. Utilities in the United States have been under severe financial constraints, including high interest rates and inflationary fuel costs, a situation that has resulted in lagging construction of all types of electrical generating stations including nuclear facilities. In the case of nuclear power, short-term growth potential has been further depressed by largely unresolved problems involving waste disposal, plant licensing, safety standards, and regulations. The long-term projected demand based on planned nuclear capacity, however, would seem to indicate a substantial future market for uranium. Because many of the state's producers will have fulfilled current utility supply contracts by 1986 and less than half of the uranium required for delivery after 1985 has been purchased, additional uncommitted markets will be available to state producers (Combs and Krusiewski, 1980).

New Mexico's traditional share of United States' production has been used to forecast the state's uranium production requirements. Table 43 shows the proportion of total domestic uranium demand that is expected to be met from production in New Mexico between 1980 and 2000 as projected by the DOE. Although New Mexico's production since 1966 averaged 45 percent of total domestic production, 1979 production dropped to only 40 percent. In order to meet domestic demand as forecast by the DOE, New Mexico producers will have to double current production of U30, by the year 1991. On the other hand, if the higher NUEXCO (Nuclear Exchange Corporation) consumption projections are to be met, New Mexico will have to double $U30_8$ production as soon as 1983. Considering the long project lead times involved, it is uncertain whether New Mexico producers can achieve either of these goals. Table 44 shows NUEXCO's projected domestic and WOCA consumption through 1990. New Mexico's share of projected consumption is shown for comparison.

Demand for New Mexico's uranium will also be affected by sales commitments of domestic origin to the foreign market. These delivery commitments, in fact, have grown over previous years. Table 45 shows United States and foreign sales commitments for uranium through 1985, along with New Mexico's projected share of those commitments. Although foreign sales commitments for New Mexico's uranium are at an all-time high, price competition from foreign producers may have an adverse effect in the future. Both Canada and Australia possess substantial proven reserves in large, high-grade deposits that can be produced at low costs competitive with or lower than New Mexico's reserves. In addition, foreign import quotas are gradually being lifted by the United States; therefore, stiff foreign competition for uncommitted projected production is considered likely.

TABLE 44—NUEXCO PROJECTIONS FOR U_3O_8 CONSUMPTION BY THE UNITED STATES AND WOCA NATIONS, 1979–1990; compiled and computed on an individual reactor basis and based on specific core characteristics, 0.2 percent tails assay, no recycling, 24-month lead time for first cores, and 18-month lead time for each reload (data from Nuclear Fuel, 1980).

	Tons U_3O_8 x 10^3				
Year	U.S.	New Mexico (45%)	WOCA	New Mexico (16%)	N.M. total (U.S. & WOCA)
1979	14.2	6.4	22.0	3.5	9.9
1980	14.3	6.4	20.5	3.3	9.7
1981	18.7	8.4	25.4	4.0	12.4
1982	19.9	9.0	28.3	4.5	13.5
1983	22.2	10.0	29.6	4.8	14.8
1984	22.1	9.9	31.5	5.0	14.9
1985	23.2	10.4	32.8	5.3	15.7
1986	23.8	10.7	30.8	4.9	15.6
1987	24.1	10.8	31.0	5.0	15.8
1988	24.8	11.2	31.5	5.0	16.2
1989	25.7	11.6	31.5	5.0	16.6
1990	25.2	11.3	31.6	5.0	16.3

Although the decline in production in New Mexico during 1979 was partly due to the loss of milling capacity at the United Nuclear Church Rock mill, milling capacity is expected to increase for the state during the next few years as gauged by pending mill-license applications and mines under development. More critical to New Mexico production during the near term should be the effect of lower grade ores, the economics of deeper deposits, and excessive lead times required to bring new discoveries into production. As a result of these factors and in combination with current production losses incurred through mine closings, it is doubtful that the state will attain or exceed the recent historical levels of production until early 1982. At that time, several important mines currently under development are expected to go into production.

Pricing and revenues

Market pricing and production costs

The NUEXCO exchange value for uranium in the United States has dropped from a high of $43.25-per-lb $U30_8$ in December 1978 to a low of $28.50 per lb by October 1980. NUEXCO's price is the immediate delivery price that the nuclear commodity exchange estimates could be concluded as of the reporting date. On the

TABLE 43—PRODUCTION FORECAST FOR NEW MEXICO U_3O_8 IN TONS OF CONCENTRATE REQUIRED TO FULFILL DOMESTIC DEMAND, 1980 THROUGH 2000 (W.L. Chenoweth, U.S. Department of Energy, personal communication, August 1980).

Year	Tons U_3O_8 in concentrate x 10^3	Year	Tons U_3O_8 in concentrate x 10^3
1980	8	1991	15
1981	9	1992	15
1982	10	1993	16
1983	11	1994	17
1984	11	1995	18
1985	12	1996	18
1986	12	1997	19
1987	13	1998	20
1988	13	1999	20
1989	14	2000	20
1990	14		

TABLE 45—FUTURE COMMERCIAL SALES COMMITMENTS OF U_3O_8 IN THE UNITED STATES AND FOREIGN COUNTRIES, 1980–1985 (New Mexico figures calculated by New Mexico Bureau of Geology using U.S. Department of Energy data, 1980c).

	Tons U_3O_8				
Year of delivery	Domestic sales commitments	Foreign sales commitments	Domestic share New Mexico (45%)	Foreign share New Mexico (16%)	Cumulative New Mexico
1980	20,700	1,600	9,315	256	9,571
1981	19,400	800	8,730	128	18,429
1982	19,100	500	8,595	80	27,104
1983	17,900	500	8,055	80	35,239
1984	14,500	400	6,525	64	41,828
1985	13,000	400	5,850	64	47,742

TABLE 46—ESTIMATED URANIUM RECOVERY COST RANGES FOR NEW MEXICO; cost estimates calculated by applying the U.S. Bureau of Labor Statistics Industrial Commodities Index as a cost escalation factor using 1977 dollars. These figures are only estimates and are not actual costs; specific data for New Mexico are available only in the area of underground mining costs. Calculations exclude miscellaneous and other royalty costs (New Mexico Bureau of Geology using modified 1977 U.S. Department of Energy cost data and New Mexico Taxation and Revenue Department tax data).

Acquisition and exploration costs $/lb U_3O_8	Ore haulage costs $/ton of ore	Severance taxes $/lb U_3O_8	Excise taxes $/lb U_3O_8	Total average taxes $/lb U_3O_8
1.74-9.78	0.67-3.62	1.09-3.24	0.15-0.38	1.24-3.62

	$/ton of ore		
	Capital	Operating	Total
Underground mining costs	5.36-25.46	37.52-60.30	42.88-85.76
Open-pit mining costs	8.38-18.76	6.70-18.76	21.44-28.14
Conventional milling costs	1.34-5.36	6.70-14.74	8.04-20.10

other hand, the average price per pound of U_3O_8 currently being delivered under contract is $25.40. As the current, low-priced contracts expire, they will be replaced by contracts negotiated at higher prices, and the uncommitted supply for future planned reactor capacity will be filled under a more favorable pricing situation. Table 46 shows current projected production costs for New Mexico using 1977 dollars and applying the U.S. Bureau of Labor Statistics Industrial Commodities Index.

TABLE 47—GRADUATED URANIUM SEVERANCE-TAX SCHEDULE AS PASSED BY THE NEW MEXICO STATE LEGISLATURE IN HOUSE BILL 204 IN 1979 (data from New Mexico Taxation and Revenue Department).

If Taxable Value Per Pound of U_3O_8 is:

Over	But Not Over	The Tax Per Pound Shall Be:
$ 0	$ 5.00	2.0%
$ 5.00	$ 7.50	$ .10 + 4.0% of excess taxable value over $ 5.00
$ 7.50	$10.00	$ .20 + 6.0% of excess taxable value over $ 7.50
$10.00	$15.00	$ .35 + 7.0% of excess taxable value over $10.00
$15.00	$20.00	$ .70 + 8.0% of excess taxable value over $15.00
$20.00	$25.00	$ 1.10 + 9.0% of excess taxable value over $20.00
$25.00	$30.00	$ 1.55 +10.0% of excess taxable value over $25.00
$30.00	$40.00	$ 2.05 +11.0% of excess taxable value over $30.00
$40.00 and over		$ 3.15 +12.5% of excess taxable value over $40.00

Taxation and revenue

In 1979 the New Mexico Legislature passed an amended uranium severance-taxation bill, House Bill 204, which became effective on July 1, 1980. The bill created a new, graduated tax scale for uranium as shown in table 47. A temporary tax credit for uranium producers is provided by the bill. The amount of the credit is 50 percent of the tax due on the first 100,000 lbs produced during the first year, the first 75,000 lbs produced during the second year, and the first 50,000 lbs produced during the third year. Detailed severance and resource excise tax collections between 1973 and 1979 are summarized in table 48. Gross-value taxes on uranium sales and production during calendar year 1979 amounted to more than $16,000,000 in revenues for the state, an apparent decline from 1978.

TABLE 48—URANIUM SEVERANCE- AND EXCISE-TAX COLLECTIONS IN NEW MEXICO, 1973–1979. Years are calendar years, based on month of production activity. Deductions are total federal or state royalties payable (data from New Mexico Taxation and Revenue Department).

Calendar Year	Quantity (Lbs. U_3O_8)	Price	Gross Value	Deductions	Taxable Value	Tax Due
1979	15,306,368	24.21	370,502,077	-	370,502,077	13,354,032
1978	16,518,959	25.69	424,369,460	565	424,368,895	17,960,856
1977	12,317,108	14.89	183,377,081	146,817,283	36,559,798	4,414,590
1976	12,434,876	5.09	63,322,529	37,348,812	25,973,717	259,737
1975	10,852,685	3.68	39,962,377	21,806,794	18,155,583	181,556
1974	10,797,712	3.35	36,123,740	19,944,868	16,178,872	162,179
1973	9,922,639	3.10	30,728,244	17,534,721	13,193,523	131,935
			RESOURCE EXCISE TAX			
1979	15,881,014	24.32	386,259,346	5,724,872	380,534,474	2,857,763
1978	16,649,335	25.28	420,933,093	1,865,169	418,967,924	3,143,628
1977	13,827,394	25.00	345,675,642	2,513,677	343,161,965	2,573,715
1976	13,043,391	12.54	163,627,799	5,898,892	157,728,907	1,182,967
1975	9,671,941	7.98	775,835	1,935,526	75,200,309	564,002
1974	10,392,288	6.83	70,971,418	1,931,719	69,039,699	517,798
1973	9,897,508	6.33	62,946,413	2,200,037	60,746,376	455,598

Geothermal energy

by Kay S. Hatton, *Bureau of Geology*

Geothermal potential

Occurrences

Most of New Mexico's geothermal areas are associated with one of two geologic occurrences: 1) Quaternary faulting along deep sedimentary basins, especially along the Rio Grande rift, with hot water traveling along the faults to the surface, and 2) Quaternary volcanic activity (Swanberg, 1979).

New Mexico is the site of eight KGRA's (Known Geothermal Resource Areas) and 12 KGRF's (Known Geothermal Resource Fields). A KGRA is an area defined by the USGS (U.S. Geological Survey) as having sufficient geothermal potential to warrant spending money for development. A KGRF is an area defined by the New Mexico State Land Office in which geothermal energy may be capable of being produced in commercial quantities.

The eight KGRA's are Baca Location No. 1 in Sandoval County, San Ysidro in Sandoval County, Socorro Peak in Socorro County, Lower Frisco Hot Springs in Catron County, Gila Hot Springs in Grant County, Lightning Dock in Hidalgo County, Radium Springs in Dab. Ana County, and Kilbourne Hole in Doña Ana County (fig. 12).

The 12 KGRF's are KGRF No. 1, an area in Taos County encompassing Mamby's (American) Hot Spring and Ponce de Leon Hot Spring; KGRF No. 2, an area that spans parts of Taos, Rio Arriba, Los Alamos, and Sandoval Counties and encompasses Ojo Caliente, the Baca Location No. 1 KGRA (Valles caldera), San Ysidro KGRA, and many thermal springs and wells; KGRF No. 3, an area in San Miguel County containing Montezuma Hot Springs; KGRF No. 4 in Valencia and Bernalillo Counties; KGRF No. 5 in McKinley and Valencia Counties; KGRF No. 6, an area in Socorro County that encompasses the Socorro Peak KGRA; KGRF No. 7 in Sierra County, containing two abandoned hot wells; KGRF No. 8, an area covering parts of Socorro, Sierra, and Doña Ana Counties that contains the Radium Springs and the Kilbourne Hole KGRA's, San Diego Mountain, the Las Cruces thermal area, the Truth or Consequences thermal area, the Mesquite-Berino thermal area, and many thermal springs and wells; KGRF No. 9, an area in Sierra, Catron, Grant, and Luna Counties containing Gila Hot Springs KGRA, the Cliff-Gila Riverside thermal area, and many thermal springs; KGRF No. 10 in Catron and Grant Counties containing the Lower Frisco Hot Springs KGRA and other thermal springs; KGRF No. 11 in Hidalgo County containing Lightning Dock KGRA (the Animas Hot Spot); and KGRF No. 12 in Hidalgo County containing an abandoned hot well (fig. 12).

Researchers have designated other areas in the state that also have geothermal potential. An evaluation of the hydrologic characteristics of New Mexico's low-temperature geothermal sites was initiated in August 1978 under the auspices of the DOE (U.S. Department of Energy) State Cooperative Low Temperature Geothermal Resource Assessment Program.

The researchers in this DOE-sponsored program have compiled the statewide geothermal evaluation work into composite geothermal maps to be published in conjunction with the National Oceanic and Atmospheric Administration. The first map, intended for the general public, is available free of charge from the New Mexico Energy Institute at New Mexico State University. The second map, containing detailed technical information, will be available at a later date.

Geothermal systems

In addition to the dramatic displays of heat from the earth flowing to the surface as volcanoes, hot springs, and geysers, the geothermal resource has a broad base with immense and diversified reservoirs of stored heat. Although the potential resource is vast, technical, economic, and institutional barriers must be overcome before geothermal resources can be developed to become a significant sector of the nation's energy base; more progress toward this end is being made every year. Current efforts to make use of this resource depend on many factors and among the most crucial conditions are temperatures and depths of deposits. These factors, in turn, have an impact on drilling feasibility and other technical limitations that also affect economic decisions to proceed with development.

Geothermal systems may be classified into three systems: 1) hydrothermal-convection systems, which include vapor-dominated and hot-water systems; 2) conduction-dominated areas, including geopressured deposits; and 3) igneous-related systems, including hotdry-rock deposits and magma systems. Hot-dry-rock systems may also occur in conduction-dominated areas. In hydrothermal-convection systems, heat moves toward the surface through the convective circulation of water in which heated fluids rise and denser, cooler fluids move downward. Geopressured deposits are those in which the fluid in the reservoirs is at unusually high pressures because it is bearing part of the weight of overlying rock. The waters are trapped by insulating beds and thus absorb heat rising from the earth's interior. These waters are often saturated with methane. The presence of this natural-gas fuel greatly increases the economics of producing geopressured waters. Hot-dry-rock systems, however, lack circulating fluids and consist of rocks with temperatures that increase the closer they are to magma chambers. As a result, the resource is more accessible where the earth's crust is thin or has been disrupted by recent volcanic activity or large-scale faulting of other types with high heat flows. Energy is extracted by inducing fractures in the hot rock and circulating water through the large surface area produced. Magma systems are large bodies of hot molten rock that have moved toward the surface from great depths. These systems, because of high pressures and temperatures and an extremely corrosive environment,

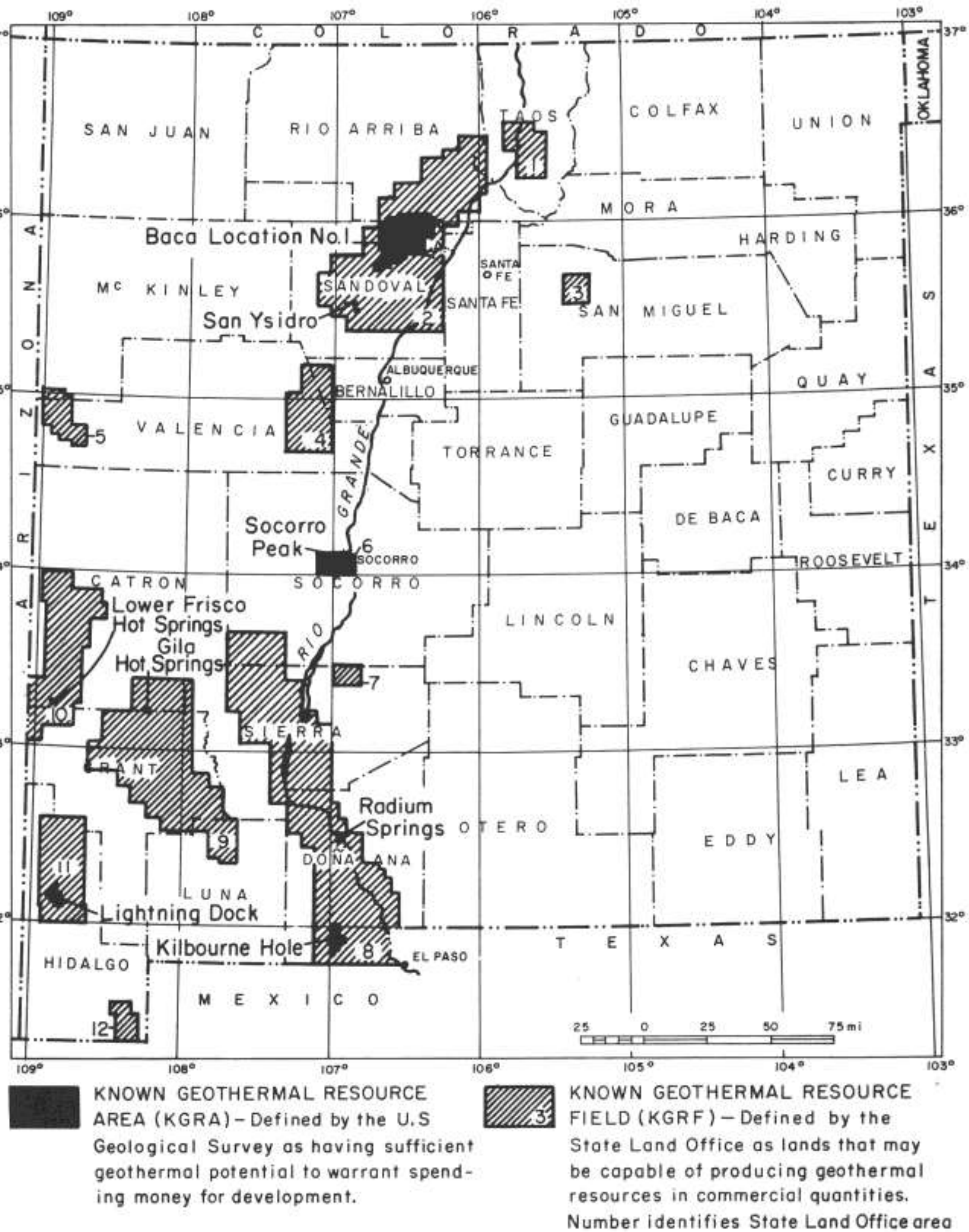


FIGURE 12—KNOWN GEOTHERMAL RESOURCE AREAS AND KNOWN GEOTHERMAL RESOURCE FIELDS IN NEW MEXICO (from New Mexico Bureau of Mines and Mineral Resources Resource Map 1, Hydrothermal anomalies in New Mexico).

present many problems to drilling and energy extraction. Research is progressing in ways to overcome these obstacles. In general, heat in geothermal systems is generated by the decay of radioactive isotopes, by compression and friction at faults and crustal plate junctures, and in some cases from exothermic chemical reactions.

Another method of classifying geothermal systems is by temperatures. High-temperature reservoirs include magma chambers with temperatures ranging from 700° C to 1,600° C (1,292° F to 2,912° F); the more extensive hot-dry-rock areas with temperatures above 290° C (554° F); and vapor-dominated and water-dominated reservoirs, which are two forms of hydrothermal convection systems with a variety of high temperatures. Water-dominated reservoirs are also found in the other temperature ranges. Medium-temperature reservoirs include geopressured systems with temperatures ranging from 90° C (194° F) to over 200° C (392° F). Lower temperature systems are generally more suitable to space heating and agricultural purposes, and the higher temperature systems to the production of electricity.

The Rio Grande rift, which passes through the center of the state from Mexico to the Colorado border, is thought to be one of the places where large plates in the earth's crust are being pulled apart. This movement has resulted in geologically recent volcanic activity along the western edge of the rift and also includes areas where the magma did not reach the surface but rose to within an estimated 3-6 mi of the surface (such as in the Socorro area). Principal geothermal areas also exist in the southwest portions of the state.

Geothermal energy is being used in the United States and other countries as a source of electricity and in direct heat applications to heat homes, public buildings, and greenhouses. It is also used for commercial food processing, agricultural purposes, fish farming, and industrial applications. Extensive research and development activities are underway in New Mexico and around the country to determine the commercial feasibility of a variety of geothermal applications.

Leasing activity

As of July 1980, the BLM (U.S. Bureau of Land Management) had issued 126 geothermal leases, which are currently active, covering 220,640 acres of national-resource land in New Mexico. Eighty of these leases, comprising 145,214 acres, were issued after noncompetitive bidding; 46 leases, comprising 75,426 acres, were issued after competitive bidding. Included in these totals are 15 active competitive geothermal leases covering 25,625 acres of National Forest lands in New Mexico. All 15 leases are in the Santa Fe National Forest in the Baca Location No. 1 KGRA vicinity. BLM's next geothermal lease sale is planned for late 1980.

As of July 30, 1980, the New Mexico State Land Office had issued 54 geothermal leases, which are currently active, covering 21,829 acres. All state geothermal leases are issued on a competitive basis.

In 1967 the U.S. Department of the Interior had withdrawn 1,345,670 acres of federal land from all subsurface use because of the value or potential value of the land for geothermal development. Of this amount, 140,180 acres of federal land were set aside in New Mexico. Public Law 91-581 enacted in December 1970 provided statutory authority for the Secretary of the Interior to issue leases for the development of geothermal resources on public land (Berman, 1975). Under this law, each lease was limited to 2,560 acres, and total acreage that any lessee may hold within any one state was set at 20,480 acres (see discussion of recent legislation below).

Recent exploration

From July 1979 through June 1980, the NMOCD (New Mexico Oil Conservation Division) approved 37 temperature-gradient wells and six geothermal production and injection wells. Chevron Resources Company; Amax Exploration, Inc.; Hunt Energy Corporation; Occidental Geothermal, Inc.; D. A. Campbell; and Union Geothermal Company of New Mexico are drilling these wells on state and private land in New Mexico. Drilling is concentrated in and around the Lightning Dock KGRA (Chevron and Amax), north of the Radium Springs KGRA near San Diego Mountain (Hunt), the Kilbourne Hole area (Hunt), the Faywood Hot Springs area (Occidental), the Gila Hot Springs KGRA (D. A. Campbell), and the Baca Location No. 1 (Union) (W. J. Stone, personal communication, October 1980).

From January 1, 1979, through August 8, 1980, the USGS issued permits for 54 shallow temperature-gradient holes (500-ft maximum), 29 deep temperature-gradient holes (3,000-ft maximum), and one deep exploration well to be drilled on federal land in New Mexico. The following is a summary of USGS permits for geothermal activity in the state.

In the Valles caldera area, Amax Exploration, Inc., drilled 19 shallow temperature-gradient holes in 1979. These permits were issued by the USGS on February 14, 1979.

In the Socorro area, Thermal Power Company proposed to drill five deep temperature-gradient holes. The permit was issued on July 18, 1980.

In the Radium Springs area, Chevron Resources Company completed the following in 1979: a self-potential survey (permit issued May 30, 1979); a gravity survey (permit issued June 28, 1979); and a dipole-dipole resistivity survey (permit issued July 9, 1979). Chevron recently completed another dipole-dipole resistivity survey (permit issued December 12, 1979). Also in the Radium Springs area, Hunt Energy Corporation (Lamar Hunt, lessee) proposed a deep exploration well and was issued a permit in mid-July 1980.

In the Kilbourne Hole area, Hunt Energy Corporation drilled 35 shallow temperature-gradient holes and two deep temperature-gradient holes in 1980 (permits issued February and March 1980).

In the Lordsburg area, Chevron received a permit to drill four deep temperature-gradient holes in 1979.

In the Lightning Dock area, Chevron drilled one deep temperature-gradient hole in 1979 (permit issued December 13, 1979). Amax proposes to drill up to 17 deep temperature-gradient holes in the Lightning Dock area (permit issued March 6, 1980).

Companies are under no obligation to drill as many holes or to drill as deeply as permits allow.

The following information on recent exploration activity has been submitted to the Bureau of Geology at the Bureau's request.

CHEVRON RESOURCES COMPANY—Chevron is concentrating on three main areas in New Mexico: Radium Hot Springs, the Socorro area, and the LordsburgAnimas Valley region. Other areas in the state are also being evaluated for possible new prospects. The following information outlines the company's New Mexico exploration activities up to July 14, 1980:

1) Radium Springs: 18 shallow temperature-gradient holes; one intermediate temperature-gradient hole (1,640-ft total depth); a gravity survey, 12 stations; a magnetotelluric survey, 12 stations; a seismic survey, 5 line-miles; a dipole-dipole resistivity survey, 4 line-miles; a survey of mercury in the soil; and a self-potential survey.

2) Socorro area: 10 shallow temperature-gradient holes; a magnetotelluric survey, 23 stations; a dipole-dipole resistivity survey, 52 line-miles; a gravity survey; and an aeromagnetic survey.

3) Lordsburg-Animas Valley area: three shallow temperature-gradient holes; one 830-ft temperature-gradient hole; one 1,000-ft temperature-gradient hole; and a dipole-dipole resistivity survey, about 11 line-miles.

AMAX EXPLORATION, INC.—Amax is pursuing a general reconnaissance program in New Mexico, especially along the Rio Grande rift. This program includes the study of temperature-gradient information from existing wells and water analyses from wells and springs. During the fall of 1980, the company plans to drill three or four deep temperature-gradient holes in the Animas area (1,000-2,000 ft deep). The data will be used for the targeting of a deep exploration well in 1981. Plans for Amax's holdings in the Baca area will be formulated as the proposed Union-PNM (Public Service Company of New Mexico)-DOE electrical-generation plant develops.

ANADARKO PRODUCTION COMPANY—Anadarko has dropped all of its geothermal leases in New Mexico; all were federal leases and all were in the Kilbourne Hole area.

THERMAL POWER COMPANY—Thermal Power is planning to drill up to eight deep temperature-gradient holes on 13,000 acres of federal leases the company bought last year in the Socorro Peak KGRA. The temperature-gradient holes will be drilled to a maximum depth of 2,000 ft and will be available for re-entry for approximately 1 yr.

GULF OIL CORPORATION—Gulf drilled shallow temperature-gradient holes in the Socorro area in 1979. The company has dropped most of its geothermal acreage in New Mexico and is concentrating on its Socorro holdings. Gulf and Thermal Power may work out a joint project in this area.

TEXACO, INC.—Texaco has no plans at present for geothermal work in New Mexico, but the company is continuing to hold its leases in the state.

SUNOCO ENERGY DEVELOPMENT COMPANY—Sunoco holds leases on 59,524 acres of private land and 7,198 acres of federal land within the state. The company's future development plans call for at least one 10,000-ft exploration well to be drilled in 1981 in the San Diego Grant north of Jemez Springs. Sunoco has invested about $3 million in statewide heat-flow studies.

EARTH POWER CORPORATION—Earth Power's leases are all located in the Lightning Dock area. Several leases have been partially farmed out to Amax.

OCCIDENTAL GEOTHERMAL, INC.—Occidental holds an interest in approximately 19,000 gross acres of undeveloped prospective geothermal lands in New Mexico. The company presently does not have any development activities in the state. Information on present or anticipated levels of exploration activity in New Mexico has not been released.

CALVERT DRILLING COMPANY—Calvert plans no exploration or drilling activities in New Mexico for 1980.

FLUID ENERGY CORPORATION—Fluid Energy will be doing exploratory work on its leases in the Truth or Consequences area during late 1980 and early 1981. The geophysical investigations planned include Curie-point determinations and gravity surveys. In the Las Cruces area, Fluid Energy is considering a DOE user-coupled reservoir confirmation program in conjunction with other companies.

SOUTHLAND ROYALTY COMPANY—Southland Royalty's current geothermal activity in the state consists almost entirely of compiling information that the company has been gathering from its acreage in the Radium Springs area. Future activities are dependent on these findings.

PHILLIPS PETROLEUM COMPANY—Phillips is continuing to evaluate its leases in New Mexico. The Company's commitment to geothermal energy will hinge on encouragement from future commercial discoveries and developments in New Mexico.

AMINOIL USA, INC.—Aminoil USA, Inc., and GRI (Geothermal Resources International) recently entered into an agreement whereby GRI will conduct Aminoil's exploration program. Approximately 80 percent of Aminoil's New Mexico geothermal interest is in the Valles caldera area. The company also has an interest in the Socorro, Animas, and Faywood-Mimbres areas and in various smaller prospects along the Rio Grande rift. Temperature-gradient and seismic studies are being concentrated in an approximately 30-sq-mi area west and southwest of the Valles caldera and in a roughly 20-sqmi area west of Socorro.

Recent legislation

In the 1980 session, the New Mexico State Legislature approved the House Appropriations and Finance Committee Substitute for House Bills 70, 157, and 246. This major, geothermal-related legislative action appropriates $600,000 from the Oil Conservation Fund for expenditure by the EMD (Energy and Minerals Department) in the 69th and 70th fiscal years. The money is to be used by the EMD to fund geothermal drilling and demonstration projects. Expenditure of any portion of this appropriation is contingent upon the EMD's or its agent's obtaining matching funds from federal or private sources. Any unexpended or unencumbered balance at the end of the seventieth fiscal year will revert to the Oil Conservation Fund.

The Federal Geothermal Energy Act of 1980 (Title VI of Public Law 96-294: The Energy Security Act) establishes a new loan program to assist the geothermal industry in exploration for and confirmation of the economic viability of geothermal reservoirs. Loans are to be paid back at a rate of not more than 20 percent of annual gross revenue from the sale of either electrical energy or direct energy from geothermal resources in the confirmed reservoir. The Secretary of the U.S. Department of Energy may cancel the unpaid balance on any loan if the geothermal reservoir is determined to be technically or economically unacceptable for commercial development. The loan may cover up to 90 percent of the project costs for a project to be used primarily for space heating or cooling or for process heat. An amount up to $3 million per project is available from this program. If revenues are inadequate to repay in full the principal and accrued interest within 20 yrs after production begins, any remaining unpaid amounts will be forgiven. No new loans will be made in this program after September 30, 1986.

A total of $85 million has been authorized by Congress under this act to be appropriated for the Geothermal Resources Development Fund for the purpose of federal loans for geothermal reservoir confirmation. This amount includes $5 million for fiscal year 1981 and $20 million for each of the 4 yrs from fiscal years 1982 through 1985.

A feasibility study loan program (Subtitle C of Title VI of the Energy Security Act) also exists for up to 90 percent of the costs of feasibility studies and regulatory applications and up to 75 percent of costs of programs for the construction of a proposed nonelectric geothermal system that is shown to be feasible. The loans for studies may be cancelled if the development of the proposed system is not technically or economically feasible. In addition to these programs, the Secretary of the U.S. Department of Energy has been directed by Congress (Subtitle B of Title VI of the Energy Security Act) to conduct a detailed study of the need for and feasibility of establishing a reservoir insurance and reinsurance program.

Several amendments to the Public Utility Regulatory Policies Act of 1978 and the Geothermal Energy Research, Development, and Demonstration Act of 1974 were made by Congress (Subtitle D of Title VI of the Energy Security Act) to lessen regulatory burdens on small geothermal power plants and to expedite the processing of loan guarantees. The Federal Government is also required to consider the option of using geothermal energy in any new federal building, facility, or installation located in a geothermal resource area.

An important bill now under consideration is Senate Bill 1388. Among the provisions of this bill are

1) an increase from 20,480 acres to 51,200 acres in the per-state limitation on geothermal leaseholds held by a single company or individual,

2) an adjustment of the primary lease term from 10 to 20 yrs,

3) the expediting of government leasing and permit decision-making, and

4) the establishment of a special lease-offering procedure for public power and rural electric cooperatives.

Research and development

In October 1979, NMSU (New Mexico State University) completed its first geothermal production well (NMSU-PG-1). This well marked the confirmation of an important geothermal aquifer yielding 61°C (141°F) water. The well is located in sec. 27, T. 23 S., R. 2 E. and is approximately 1 mi east of 1-25 on university property in Las Cruces. The total depth of the well is 860 ft, and the aquifer is tapped between 700 ft and 860 ft. A pump test was conducted for 10 days in July 1980, and the well was pumped 24 hrs per day at a rate of 200 gpm (gallons per minute) and later at 225 gpm. During the pumping, the well reached equilibrium in terms of drawdown and the temperature remained at 61° C (141° F). When the well was allowed to recover, the water returned to within 1 ft of the original level in 4 hrs. Transmissivity was calculated at between 5,000 to 10,000 gallons per day per square foot. When the observation well is drilled, a more precise figure can be obtained for transmissivity. Further exploration wells and a new production well (NMSU-PG-2) are planned for late 1980 (L. Chaturvedi, personal communication, August 1980). The New Mexico Energy and Minerals Department provided $125,000 for the first phase of this project. R. Cunniff, L. Chaturvedi, and C. Keyes, Jr., NMSU, are the principal investigators.

The U.S. Department of Energy will provide $371,000 for the second phase of the project during fiscal years 1980 and 1981. NMSU is considering contributing between $1 million and $2 million. Up to 25 buildings on the NMSU campus will be converted to use the geothermal resource for hot-water supply at a potential fuel-cost savings of at least $500,000 per year (R. Cunniff, personal communication, August 1980).

During the past year, the City of Las Cruces found geothermal waters while drilling three wells in an effort to expand the city's water supply. These wells are 4, 6.5, and 8 mi north of the NMSU geothermal well and are located on the east mesa of the Mesilla Valley. Temperatures encountered ranged from 57° C (135° F) to 69° C (156° F) at approximately 780 ft below ground surface. These hot wells have been given to NMSU for testing and research purpoks. The wells add to the knowledge of the extent of the Las Cruces geothermal anomaly and add weight to current thought that a geothermal prospect may exist from Radium Springs to El Paso (L. Chaturvedi, personal communication, August 1980).

A major geothermal study by eight principal investigators from UNM (University of New Mexico) and NMSU has been completed and the final report is being prepared. The report is on the geological, geochemical, and geophysical characteristics of potential geothermal areas in the Rio Grande rift and Basin and Range province of New Mexico with presentations of both regional and site-specific information. Site-specific studies include the Animas Valley, Las Cruces area (Radium Springs and Las Alturas Estates), Truth or Consequences region, the Albuquerque Basin, the San Ysidro area, and the Abiquiu-Ojo Caliente region. The regional geologic and geophysical studies focused on the Rio Grande rift and southwest New Mexico, and regional geochemical water studies were conducted for the entire state. Funding for the study was provided by the USGS and the State of New Mexico's Energy Research and Development Program. Some of the findings of this report are listed below.

1) At least seven and possibly as many as 20 discrete

areas may have subsurface temperatures in excess of 150° C (302° F), which is sufficiently high for economic development of electricity.

2) Almost every major geothermal anomaly in the southwest corner of New Mexico occurs at the intersection of a Basin and Range fault zone and a mid-Tertiary cauldron complex, such as Lightning Dock, Mimbres Hot Springs, Faywood Hot Springs, Lower Frisco Hot Springs, and Gila Hot Springs. If these relationships are more than a coincidence, areas south of the Lightning Dock KGRA hold favorable prospects for future discoveries of geothermal hot water or steam. Several cauldrons in southwestern New Mexico are larger than the Muir cauldron, which is associated with Lightning Dock. Geologically recent seismicity and volcanism are prevalent near the junction of New Mexico, Arizona, and Sonora, Mexico.

3) Nearly all ground waters in southern New Mexico have temperatures in excess of 20° C (68° F), the minimum temperature designated by DOE for low-temperature utilization. Industries having the ability to use such waters should find a nearly inexhaustible geothermal resource in southern New Mexico.

4) Regarding the Ojo Caliente region: Cold meteoric ground water in the basin-fill sediments tends to mask the presence of a deep geothermal system because of dilution; therefore, thermal gradients measured in shallow holes will not be indicative of those at greater depths.

The shallowest drilling depths to hot rock might be expected in uplifted blocks in which the overlying basin-fill sediments have been removed. The area of hot springs between Ojo Caliente and La Madera may be the most favorable area to drill according to this model. Furthermore, in the recently uplifted Brazos area, the elevated isotherms of the uplift may not have had time to equilibrate with the regional geothermal gradient, thereby contributing additional heat to the rising water (Callender and others, 1980).

M. Parker, G. Jiracek, and others at UNM and NMSU have continued their study of the geothermal potential of the Albuquerque area with funding from the New Mexico Energy and Minerals Department and the USGS. This program included temperature logging of municipal water wells, gravity and magnetic investigations, electrical resistivity measurements, shallow (about 83 ft) borehole drilling and temperature logging, and water-chemistry analysis. Three areas of geothermal interest in or near Albuquerque were reported: the Llano de Atrisco thermal anomaly, the West Mesa well field, and the Walker well field (M. D. Parker, personal communication, September 1980).

The Hot Dry Rock Geothermal Energy Project undertaken by LANL (Los Alamos National Laboratory) at the Fenton Hill site west of the Valles caldera has continued to yield technical successes. In May 1980, LANL produced electrical energy from hot dry rock for the first time in history, when 60 kilowatts electric was produced using a special turbine generator in which Freon (R 114) was used to drive the turbines. In this Phase 1 system, water was injected into hot, fractured granitic rock beneath the earth's surface, withdrawn through a second well, and circulated through a heat exchanger, all in a closed loop, in order to determine how much heat can be extracted from this system. As a side experiment to test this method of generating electricity, a second loop was added in which Freon heated by the water vaporizes, spins the turbine, and then circulates past cooling fans and returns to repeat the process. An improved hot-dry-rock reservoir was used in this phase. Using the original pair of wellbores, a second reservoir was created by fracturing a deeper interval of granitic rock at a depth of 9,620 ft. The heat-transfer area of the new fracture system is approximately 10 times that of the old system. Rock temperature at the bottom of the deeper interval is 197 ° C (387 ° F). During testing of the improved system, essentially no thermal drawdown was detected (G. H. Heiken, personal communication, August 1980).

For Phase 2 of the hot-dry-rock project, LANL has drilled the first of two deeper holes into hotter rock and will make a series of fractures along the borehole, which is oriented at a 35-degree angle from the vertical near the bottom of the hole. The second borehole will be completed by the end of 1980 (R. A. Pettitt, personal communication, August 1980). The new borehole is 15,294 ft long and is 14,500 ft below ground surface. Bottom-hole temperature was 337° C (639° F), which was hotter than expected (G. H. Heiken, personal communication, August 1980). The new system is expected to be capable of producing 20-50 megawatts of thermal power for at least 10 yrs (Nunz, 1980). After experiments have been performed for 4-5 yrs, LANL will turn this system over to Plains Electric Generation and Transmission Cooperative to be used for electrical generation.

A number of new hot-dry-rock sites are under consideration. Site 2 will be used to show that the reservoir techniques developed at Fenton Hill may be used in a geologically dissimilar area. LANL will install a heat loop in the new area as inexpensively and at as shallow a depth as is economically possible.

Sandia National Laboratories is continuing its development program aimed at reducing well costs through improvements in geothermal drilling and completion technology. Cost reduction goals, based on analyses of existing well costs, are to develop the technology required to reduce well costs by 25 percent by 1983 and by 50 percent by 1987. The program has six parts: 1) geothermal drilling hardware, 2) drilling fluids, 3) completion technology, 4) lost-circulation control methods, 5) advanced drilling systems, and 6) supporting technology. Technology development is conducted primarily through contracts with private industries and universities, and some projects are conducted internally by Sandia. Sandia manages this development program for DOE (Varnado, 1980).

Sandia is also continuing its Magma Energy Research Project, which deals with the investigation of the scientific feasibility of extracting energy from magma (subsurface molten rock) bodies. The four tasks of the project are: 1) resource location and definition, 2) source tapping, 3) magma characterization and materials compatibility, and 4) energy extraction. Magmatic thermal energy is being considered for the generation of steam and for the generation of synthesis gas (carbon monoxide, hydrogen, and methane) from the reaction of water and biomass. The iron in basalts may also enhance fuel production by the reduction of water to hydrogen (Colp and Traeger, 1980).

At NMIMT (New Mexico Institute of Mining and Technology), work is progressing on the seismic detection of magma bodies in the crust of the Rio Grande rift near Socorro. Results of the work of NMIMT researchers on this project have been placed in open-file reports in the Department of Geoscience.

Union Geothermal Company of New Mexico and PNM (Public Service Company of New Mexico) have completed preliminary site preparation for the 50-megawatt electrical-generating facility in the Valles caldera. The demonstration plant is partially funded by DOE. Construction starts on the plant are pending hearings. Electricity produced from a plant of this size could supply the electrical needs of a city the size of Santa Fe (population approximately 50,000). PNM is interested in determining how costs of geothermally produced electricity compare with other generating alternatives, such as coal. Other factors being evaluated by PNM include fuel diversity, the desirability of smaller base-loaded units, and the potential for geothermal energy in the state. PNM hopes, with the success of the proposed geothermal power plant, to partially offset its use of gas and oil-fired plants (M. H. Zimmerman, personal communication, September 1980).

Geothermal projects

The New Mexico State Legislature passed the Energy Research and Development Act in 1974. Since then, $1,780,816 has been invested in geothermal research projects in the state. This money has attracted an additional $4,326,210 in federal funds from the DOE, USGS, and the National Science Foundation. As a result, New Mexico is a leader among states with active private and governmental geothermal exploration and development (New Mexico Energy Institute, 1980).

Geothermal projects in progress as of July 22, 1980 and funded from the Energy Research and Development Fund by the Energy and Minerals Department were

Project number and title	**Authorized funding**	**Investigator**
76-264—Evaluation of geothermal potential of the Basin and Range province of New Mexico	$103,235	Callender UNM
77-2203—Active and passive seismic studies of geothermal resources in New Mexico and investigations of earthquake hazards to geothermal development	$ 50,000	Morgan NMSU
77-2211—United States DOE and New Mexico cooperative program low-temperature geothermal resource assessment	$ 15,000	Daw NMEI-NMSU
77-2218—Las Alturas geothermal reservoir confirmation study	$ 20,000	Chaturvedi NMSU
77-2314—Development and application of a computer model for simulating a geothermal system in New Mexico (Phase I)	$ 31,600	Gelhar and Stephens NMIMT
78-2135—Evaluation of the geothermal resource in the Albuquerque area	$ 76,874	Jiracek UNM
78-2238—New Mexico cooperative low temperature resource assessment program (Phase 2)	$ 30,000	Icerman NMEI-NMSU
78-2321—Deep subsurface temperature studies in the basins of New Mexico and neighboring geologic areas	$ 35,500	Reiter NMBMMR NMIMT
78-2537—Conduct a geothermal test well drilling program for the Village of Jemez Springs	$ 39,223	Armenta non-profit
68R-2102—Assessment of the geothermal potential of southwestern New Mexico (Phase 2)	$ 26,810	Elston UNM
68R-2203—Comprehensive planning for the development of geothermal energy in Las Cruces and DOña Ana County (Phase 2)	$ 10,000	Starkey NMSU
68R-2204—Electrical exploration of geothermal gradient studies near Columbus, New Mexico	$ 75,000	Swanberg and Young NMSU
68R-2206—Utilization of geothermal energy for agribusiness development in southwestern New Mexico	$ 17,625	Lansford NMSU
68R-2207—New Mexico State University project for geothermal application and natural gas conservation	$125,000	Cunniff NMSU
68R-2208—Jemez Springs geothermal heating demonstration	$ 9,000	LaFrance NMSU
68R-2305—Assessment of geothermal reservoirs by analysis of gases in thermal water	$ 16,498	Norman NMIMT

State funds totaling $199,020 were allocated to six projects under the geothermal space-heating program of the New Mexico Energy and Minerals Department. Demonstration project funds are contingent on several conditions, including a requirement that matching money be obtained from federal or private sources. Awards were based on recommendations of the New Mexico Energy Research and Development Review Committee. The projects, all in progress, have obtained the necessary matching funds. The projects are

Project number and title	**Authorized funding**	**Investigator**
67-51—Geothermal heating of Carrie Tingley Hospital, Truth or Consequences (preheating of boiler water)	$46,186	BDM Corp. Albuquerque
67-52—Geothermal heating of Senior Citizens Center, Truth or Consequences (space-heating system)	$24,726	Mancini and Chaturvedi NMSU
67-53—Geothermal heating of solar-assisted greenhouse, Taos County (Ponce de Leon Hot Spring at Ranchos de Taos)	$40,663	Solar America, Inc.
67-54—Geothermal heating of greenhouse, Silver City area (development by handicapped to raise native plants for revegetation of mine tailings, Faywood Hot Springs)	$21,208	Southwestern Service to Handicapped Children and Adults, Inc. and NMSU

67-70—Geothermal resource evaluation and well drilling for industrial use, Las Cruces	$56,237	L'Eggs Products, Inc. and Energetics
67-71—Geothermal well for space-heating of University Center, New Mexico State University	$10,000	Huff NMSU

The Bureau of Geology has initiated two of New Mexico's geothermal projects: the geothermal evaluation of the Columbus area and the geothermal heating of Carrie Tingley Hospital. All the geophysical studies and temperature-gradient holes have been completed on the Columbus project and data are now being analyzed. Preliminary findings indicate that the thermal gradient in the area is sufficient for direct heat utilization. The bottom-hole temperature in the 301-m (988-ft) hole was 35 ° C (95 ° F) (C. A. Swanberg, personal communication, October 1980). The geothermal-heating project at the Carrie Tingley Hospital is essentially complete. If present plans for the moving of the hospital to Albuquerque are carried out, there are plans to use the geothermally heated facilities in another manner to benefit the City of Truth or Consequences and the state.

During the past year, Shell Oil Company drilled the Shell Isleta No. 2, a 21,266-ft oil and gas test well south of Albuquerque near the Isleta Pueblo in the Albuquerque-Belen basin. EMD was asked to initiate a geothermal and hydrologic testing program on this well after Shell had completed testing. Permission was not obtained from the Tribal Council to perform the testing because the well was located near sacred sites; however, Shell had added a maximum recording thermometer and a spare to each logging run and temperature data were made available. The maximum temperature recorded in the well was 223° C (434° F) at total depth. This reading was taken 40 hrs after circulation ended. The geothermal gradient at this location was found to be normal—that is, not at economic temperatures. No information on the formations encountered or their depths was released by Shell.

DOE's Appropriate Energy Technology Small Grants Program awarded $32,500 in August 1980 to D. A. Campbell of Gila Hot Springs in a proposal to develop rural geothermal energy technologies through the expansion of the Gila Hot Springs geothermal resource. The project will include the installation of a Rankine-cycle generator at the hot springs and will use this low-temperature geothermal source to generate electricity. This type of generator uses a heat exchanger that extracts heat from the hot spring water and heats Freon, which then expands and turns a turbine. The turbine will drive an induction generator that will be tied to the local power line. If this project demonstrates that electricity can be produced on a cost-effective basis, it may encourage the use of similar thermal areas in New Mexico and other states. This technology could also be applied to any area possessing a similar combination of hot and cold water from other sources. Other hot water sources include municipal power plants, smaller business-sized power plants, hot wells, industrial hot-water discharge, and large refrigeration units.

Current projects at the New Mexico Energy Institute at NMSU which are funded by DOE are

Project title	**Funding**	**Project director**
Regional geothermal commercialization program	$600,000	J. Marlin
New Mexico cooperative low-temperature resource assessment program	$285,000	L. Icerman
State geothermal commercialization planning for New Mexico	$ 70,000	R. Cunniff
Campus well project	$336,000	R. Cunniff
Environmental overview for the development of geothermal resources	$ 50,000	A. Starkey

Selected references

American Petroleum Institute, American Gas Association, and Canadian Petroleum Association, 1980, Reserves of crude oil, natural gas liquids, and natural gas in the United States and Canada as of December 31, 1979: American Petroleum Institute, v. 34, p. 22-23, 109

Arnold, E. C., 1974, Oil and gas development and production, eastern San Juan Basin: New Mexico Geological Society, Guidebook 25th field conference, p. 323-328

, compiler, 1978: New Mexico's energy resources '77-Office of the State Geologist: New Mexico Bureau of Mines and Mineral Resources, Circ. 167, 48 p.

Arnold, E. C., and Hill, J. M., compilers, 1980, New Mexico's energy resources '79-annual report of Bureau of Geology: New Mexico Bureau of Mines and Mineral Resources, Circ. 172, 55 p.

Beaumont, E. C., Shomaker, J. W., and Speer, W. R., 1978, Coal resources of the San Juan Basin, New Mexico: New Mexico Energy and Minerals Department, Professional Services Contract 65-1

Bendix Field Engineering Corporation, 1980a, Geologic report on East Chaco Canyon Drilling Project, McKinley and San Juan Counties, New Mexico: U.S. Department of Energy, GJBX-98(80), 53 p.

, 1980b, Survey of lands held for uranium exploration, development, and production in fourteen western states in the six-month period ending December 31, 1979: U.S. Department of Energy, GJBX-82(80), 20 p.

Berman, E. R., 1975, Geothermal energy, *in* Energy technology review no. 4: Park Ridge, New Jersey, Noyes Data Corporation, 336 p.

Brown, H. H., 1979, Log evaluation of new oil and gas wells drilled in northwest New Mexico: Farmington, New Mexico, consulting petroleum geologist's report, New Mexico Energy and Minerals Department, Professional Services Contract 68-27

Callender, J. F., and others, 1980, Evaluation of geothermal potential of the Basin and Range province of New Mexico: University of New Mexico, Geology Department, unpublished manuscript, 153 p.

Chaturvedi, L. N., 1980, New Mexico State University geothermal production well-technical completion report: New Mexico State University, Engineering Experiment Station, 48 p.

Chenoweth, W. L., 1978, Uranium in the San Juan Basin-an overview: New Mexico Geological Society, Guidebook 28th field conference, p. 257-262

, 1979a, Grants uranium region-prepared for field trip symposium on Grants uranium region, May 13, 1979: U.S. Department of Energy, Grand Junction Office, Resource Division, 18 p.

, 1979b, Uranium in the Santa Fe area, New Mexico: New Mexico Geological Society, Guidebook 30th field conference, p. 261-264

Clark, D. S., 1980, Uranium ore rolls in Westwater Canyon Sandstone, San Juan Basin, *in* Geology and mineral technology of the Grants uranium region 1979, C. A. Rautman, compiler: New Mexico Bureau of Mines and Mineral Resources, Mem. 38, p. 195-201

Colp, J. L., and Traeger, R. K., 1980, Magma Energy Research Project State-of-the-Project report-October 1, 1978: Sandia Laboratories, SAND78-2288, 159 p.

Combs, G. F., Jr., and Krusiewski, V. S., 1980, Survey of U.S. uranium marketing activity: U.S. Department of Energy, DOE/RA-0053, 21 p.

Deischl, D. G., 1973, The characteristics, history, and development of the Basin Dakota gas field, San Juan Basin, New Mexico, *in* Cretaceous and Tertiary rocks of the southern Colorado Plateau: Four Corners Geological Society, Mem., p. 168-173

Energy Information Administration, 1980, Use of federal lands for energy development: U.S. Department of Energy, DOE/EIA-0201-8, 125 p.

Fassett, J. E., Arnold, E. C., Hill, J. M., Hatton, K. S., Martinez, L. B., and Donaldson, D. A., 1978, Oil and gas fields of the Four Corners area: Four Corners Geological Society, v. 1, p. 46-61

Hetland, Donald, 1979, Potential uranium resources, *in* 1979 Uranium industry seminar: U.S. Department of Energy, GJO-108, p. 9-10

Hilpert, L. S., 1969, Uranium resources of northwestern New Mexico: U.S. Geological Survey, Prof. Paper 603, 166 p.

Kelley, V. C., compiler, 1963, Geology and technology of the Grants uranium region: New Mexico Bureau of Mines and Mineral Resources, Mem. 15, 227 p.

Keystone Coal Industry Manual, 1977, New Mexico: New York, McGraw-Hill, p. 633-641

_____ , 1978, New Mexico: New York, McGraw-Hill, p. 520-528

______ 1979, New Mexico: New York, McGraw-Hill, p. 520-528

, 1980, The 50 biggest bituminous and lignite mines in 1979: New York, McGraw-Hill, p. 1364

Kottlowski, F. E., and Thompson, Sam, III, 1980, Estimate of energy resources of New Mexico, 1979: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1978-1979, fig. 1

Leighton, V. L., 1980, Depositional environments and petrography of the Trinidad Sandstone and related formations, Raton area, New Mexico: M.S. thesis, Colorado State University

New Mexico Bureau of Mine Inspection, 1979, Sixty-sixth annual report (1978): Albuquerque, New Mexico Energy and Minerals Department, 65 p.

, 1980, Sixty-seventh annual report (1979): Albuquerque, New Mexico Energy and Minerals Department, 65 p.

New Mexico State Inspector of Mines, 1970-1978, Fifty-seventh-Sixty-fifth annual reports (1969-1977): Albuquerque, New Mexico State Inspector of Mines

New Mexico Bureau of Surface Mining, 1980, Update of New Mexico coal mines: New Mexico Bureau of Surface Mining, memorandum New Mexico Employment Security Dept. (1980), cited p. 34

New Mexico Energy Institute at New Mexico State University, 1980, A report to the Legislature Interim Committee on alternative energy sources: New Mexico Energy Institute at New Mexico State University, 30 p.

New Mexico Engineering Committee, 1979, Annual report: Hobbs, New Mexico Oil and Gas Engineering Committee, v. I and II

New Mexico Oil Conservation Division, 1979, Quarterly activity reports: Santa Fe, New Mexico Oil Conservation Division

New Mexico Oil and Gas Accounting Division, 1979, Interdepartment statistical reports: Santa Fe, Taxation and Revenue Department New Mexico State Planning Division, 1979, State railroad plan: Santa Fe

New Mexico State Taxation and Revenue Department, 1980, Levels of taxation on energy minerals extracted in New Mexico: Santa Fe, unpublished report, 52 p.

Nuclear Fuel, 1980, NUEXCO's assessment of apparent future uranium consumption: Nuclear Fuel, April 14, 1980, p. 11

Nunz, G. J., 1979, The Hot Dry Rock Geothermal Energy Development Program-an overview: Los Alamos Scientific Laboratory, LASL79-79, 21 p.

Office of Coal Leasing, Planning, and Coordination, 1979, Federal Coal Management Program-a narrative description: U.S. Department of the Interior

Office of Technology Assessment, 1979, The direct use of coal: Congress of the United States

Organization for Economic Cooperation and Development Nuclear Energy Agency and International Atomic Energy Agency, 1979, Uranium resources, production, and demand: Paris, Organization for Economic Cooperation and Development, 195 p.

Perkins, B. L., 1979, An overview of the New Mexico uranium industry: New Mexico Energy and Minerals Department, Professional Contract 67-7, 147 p.

Perry, Harry, 1974, The gasification of coal: Scientific American, v. 230, no. 3

Pillmore, C. L., 1969, Geology and coal deposits of the Raton coal field, Colfax County, New Mexico: The Mountain Geologist, v. 61, no. 3, p. 125-142

Rautman, C. A., compiler, 1980, Geology and technology of the Grants uranium region, 1979: New Mexico Bureau of Mines and Mineral Resources, Mem. 38, 400 p.

Read, C. B., Duffner, R. T., Ward, G. H., and Zapp, A. D., 1950, Coal resources of New Mexico: U.S. Geological Survey, Circ. 89, 24 p.

Reid, B. E., Griswold, G. B., Jacobsen, L. C., and Lessard, R. H., 1980, Uranium resource evaluation, Raton quadrangle, New Mexico and Colorado: U.S. Department of Energy, GJQ-005(80), 83 p.

Rickert, D. A., Ulman, W. J., and Hampton, E. R., editors, 1979, Synthetic fuels development: U.S. Geological Survey, 45 p.

Saucier, Evelyn N., 1979-1980, New Mexico uranium newsletter: Cedar Crest, New Mexico, January 1979-July 1980

Schmidt, R. A., 1979, Coal in America-an encyclopedia of reserves, production, and use: New York, McGraw-Hill, 458 p.

Shomaker, J. W., Beaumont, E. C., and Kottlowski, F. E., 1971, Strippable low-sulfur coal resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources, Mem. 25, 189 p.

Shomaker, J. W., and Whyte, M. R., 1977, Geologic appraisal of deep coals, San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circ. 155, 31 p.

Sipes, Williamson and Associates, Inc., 1979, Oil reserves evaluation for 40 major oil pools in New Mexico: Midland, Texas, Sipes, Williamson and Associates, Inc., consulting engineers' report, New Mexico Energy and Minerals Department, Professional Services Contract 68-8

Summers, W. K., 1979, Hydrothermal anomalies in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Resource Map 1, scale 1:1,000,000

Swanberg, C. A., 1979, Chemistry of thermal and non-thermal groundwaters in the Rio Grande rift and adjacent tectonic provinces, *in* Rio Grande rift-Tectonics and magmatism, R. E. Riecker, ed.: American Geophysical Union, p. 279-288

Tabet, D. E., and Frost, S. J., 1979, Environmental characteristics of Menefee coals in the Torreon Wash area, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Rept. 102, 134 p.

The Mining Record, 1980, Kerr-McGee suspends operations of uranium mines: Denver, January 3, 1980, p. 1

U.S. Bureau of Land Management, 1978, Draft Environmental Statement, Star Lake-Bisti region coal: U.S. Bureau of Land Management, 3 volumes

, 1979, Regulations pertaining to coal management federally owned coal: U.S. Bureau of Land Management, 43 CFR 34000

U.S. Bureau of Mines and U.S. Geological Survey, 1976, Coal resource classification system of the U.S. Bureau of Mines and U.S. Geological Survey: U.S. Geological Survey, Bull. 1450-B, 7 p.

U.S. Department of Energy, 1978, Statistical data of the uranium industry, January 1, 1978: U.S. Department of Energy, GJO-100(78), 107 p.

, 1979a, DOE reports results of uranium price survey: U.S. Department of Energy, DOE News, November 30, 1979, p. 2

, 1979b, National uranium resource evaluation, interim report, June 1979: U.S. Department of Energy, GJO-111(79), 137 p.

, 1979c, Statistical data of the uranium industry, January 1, 1979: U.S. Department of Energy, GJO-100(79), 123 p.

, 1979d, Uranium industry seminar-proceedings: U.S. Department of Energy, GJO-108(79)

, 1980a, Statistical data of the uranium industry, January 1, 1980: U.S. Department of Energy, GJO-100(80), 94 p.

, 1980b, Uranium exploration expenditures in 1979 and plans for 1980-81: U.S. Department of Energy, GJO-103(80), 12 p.

, 1980c, An assessment report on uranium in the United States of America: U.S. Department of Energy, GJO-111(80), 150 p.

U.S. Energy Research and Development Administration, 1975, Statistical data of the uranium industry: U.S. Energy Research and Development Administration, GJO-100(75), 85 p.

, 1976, Statistical data of the uranium industry: U.S. Energy Research and Development Administration, GJO-100(76), 87 p.

__________ , 1977, Statistical data of the uranium industry: U.S. Energy Research and Development Administration, GJO-100(77), 107 p.

U.S. Geological Survey, 1975, The interior of the Earth: U.S. Geological Survey, INF-73-16(R.1), pamphlet

Varnado, S. G., editor, 1980, Geothermal Drilling and Completion Technology Development Program quarterly progress report, January-March, 1980: Sandia Laboratories, SAND80-0703, 222 p.

Verhoogen, J., and others, 1970, The Earth-an introduction to physical geology: New York, Holt, Rinehart, and Winston, Inc., 748 p.

Wanek, A. A., 1963, Geology and fuel resources of the southwestern part of the Raton coal field, Colfax County, New Mexico: U.S. Geological Survey, Coal Inv. Map C-45, scale 1:45,000 [1964]

Typefaces:	Text in 10-pt. English Times, leaded one point References in 8-pt. English Times, leaded one point Display heads in 24-pt. English Times
Presswork:	Miehle Single Color Offset Harris Single Color Offset
Binding.•	Saddlestitched
Paper:	*Cover* on 65-lb. White Carnival Hopsack Text on 60-lb. White Offset
Ink:	Cover—PMS 181 Text—Black
Press Run:	1,200