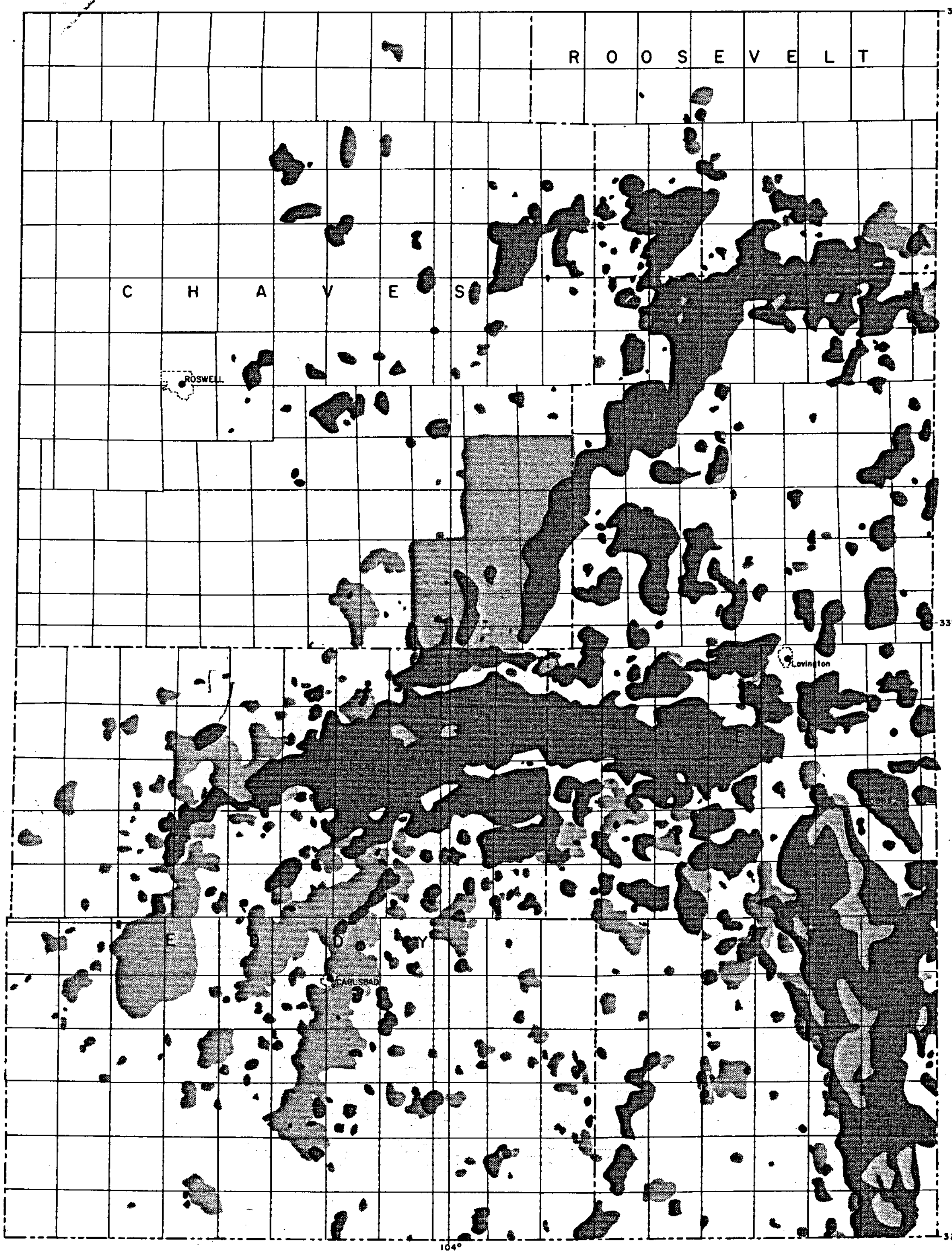
New Mexico's energy resources '81

MASTER

—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



Oil and gas fields in southeast New Mexico

Annual report 1981

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

compiled by
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Santa Fe 1981

New Mexico Energy and Minerals Department
Mining and Minerals Division Staff

COVER—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. Bierberman, New Mexico Bureau of Mines and Mineral Resources).

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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 525 Camino de los Marquez in Santa Fe, New Mexico 87501.

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 sixth reserve and production summary published since the office was established and the fourth report to contain independently derived estimates of oil and gas reserves.

Staff members from the Bureau of Surfacemining and the Bureau of Mine Inspection helped compile information for this report. Robert D. Jebb, of Solo Writing and Editing, Santa Fe, provided a great deal of editorial assistance. I also wish to express my appreciation for advice and assistance received from the New Mexico Oil Conservation Division, the New Mexico Bureau of Mines and Mineral Resources the New Mexico Oil and Gas Accounting Division, the New Mexico Energy Resources and Development Division, the New Mexico Revenue Division, the U.S. Bureau of Mines, the U.S. Department of Energy, the U.S. Bureau of Land Management, the U.S. Geological Survey, the New Mexico State Land Office, the New Mexico Energy Institute at New Mexico State University, and the New Mexico Washington Office, 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
September 3, 1981

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Abstract

Although production of *U_3O_8* declined only slightly in 1980, New Mexico's share of domestic production has declined from 48 percent in 1976 to 35 percent in 1980. Production projections indicate a continued decline in 1981 and lower production until at least 1984. New Mexico has 41 percent of total domestic reserves producible in the $50-per-lb cost category. In keeping with the anticipated steady depletion of reserves, production of *crude oil* in New Mexico was 69.9 million bbls, a 6.3 percent decline in production from 1979. *Condensate* production of 5.4 million bbls in 1980, however, represented an increase of 7 percent from 1979 production. Although *natural gas* production was the lowest since 1970 and declined by 2.6 percent from 1979 production, 1980 was the 15th year that production exceeded 1 trillion cu ft. Despite declines in production, the valuation of oil and gas production has increased significantly with oil sales doubling from the previous year and gas sales increasing by $409 million because of higher prices. Reserves have been estimated to be 959 million bbls of crude oil and 17.667 trillion cu ft of natural gas. Production of 19.5 million short tons of *coal* in 1980 represented a 33 percent increase over 1979 production and an increase of 157 percent since 1970. Coal resources in New Mexico are estimated to be 180.79 billion short tons, and production is projected to increase to 39.61 million tons in 1985 and 67.53 million tons in 1990. The most notable developments in *geothermal* energy have been in technical advances in drilling, testing, and applications, especially in the area of hot dry rock systems. The U.S. Bureau of Land Management has issued 113 geothermal leases that remain active. Recent geothermal exploration activity has been detailed for 21 companies.

New Mexico's role

by E. C. Arnold and J. M. Hill, *Mining and Minerals Division*

New Mexico continues to play an important role in supplying the nation's energy needs and ranks first in the nation in the production and reserves of U_3O_8 (yellowcake), seventh in the production of crude oil, fourth in the production of natural gas, thirteenth in the production of coal, and twelfth in strippable coal reserves. The state is also a primary testing area and has a vast potential for future applications of geothermal energy.

The extensive production associated with the overall sixth place ranking in the production of these primary resources, however, has begun to result in a gradual depletion of reserves in all resources except coal, and new discoveries call for an even more extensive depletion of reserves, particularly of oil, gas, and uranium reserves. Despite declines in production, escalated prices for energy resources has meant more dollars paid for a smaller quantity. The state's 1980 production of all four resources brought a record valuation of $4.27 billion compared to $3.25 billion the year before. This increase in value took place even though 1980 oil production declined by 5.4 percent and 1980 natural gas production declined by 2.61 percent. In two years, the value of New Mexico's coal production has doubled, and oil and gas sales increased by 90 percent. Although 1980 production of coal increased by 33 percent over 1979 production, the value of New Mexico's coal increased by 47 percent.

Table 1 shows production and reserves for New Mexico in 1980 compared to production and reserves in adjacent states and Wyoming. Crude oil and total gas reserve information is not available since the American Petroleum Institute is no longer reporting this information, and state-by-state estimates are not yet available. In comparing crude oil production among adjacent states, only New Mexico and Arizona had a decline in production from 1979 to 1980. The first place lead of Texas broadened in that period with Colorado slipping from 12th to 15th in rank and Utah from 15th to 16th in rank. All adjacent states experienced an increase in natural gas production with the exception of Colorado and New Mexico. The states maintained their national rankings of the previous year except that Texas moved from second to first place in natural gas production and Colorado declined in rank from ninth to tenth and Utah climbed from 19th to 16th in rank. In coal production, New Mexico, Arizona, Colorado, and Utah maintained their rankings of the previous year, but Texas moved from 11th to 10th in rank in 1980 and Oklahoma dropped from 19th to 20th place.

New Mexico has always held an extensive lead over other states in the production and reserves of U_3O_8. In the past two years, however, New Mexico's domestic share of production has been declining significantly, primarily due to a depressed uranium market, the occurrence of resources at greater depth than other states resulting in higher production costs, and the extensive exploitation of reserves in New Mexico over the years compared to production in other states. New Mexico and Wyoming have been the principal producers of U_3O_8 in the past, but 1980 marked the rise of production and exploration in other states, particularly Texas, which along with Wyoming also has deposits occurring at shallower depths than New Mexico. Production in New Mexico may continue to level off or decline in the next four years due to delays in nuclear power plant licensing, lower demand, and oversupply conditions. These delays may be gradually reduced as the present administration's policy of licensing overhaul develops.

TABLE 1—PRODUCTION AND RESERVES OF OIL, GAS, COAL, AND URANIUM FOR NEW MEXICO IN 1980 COMPARED TO ADJACENT STATES AND WYOMING. Dashes indicate that statistics are not available. Oil production figure for Arizona includes production in Missouri, Nevada, and Virginia. Crude oil and gas reserves by national rank are not available. Uranium reserves listed are in the $50 forward-cost category. Figure for U_3O_8 reserves in Utah and Arizona is given as a combined total. U_3O_8 reserves for California, Idaho, Montana, Nevada, North Dakota, South Dakota, Oregon, and Washington totaled 37,000 tons. U_3O_8 production for Texas, Colorado, Utah, Arizona, Florida, Washington, and Louisiana totaled 8,060 tons (data from U.S. Department of Energy, 1981; Keystone, 1981; Energy Information Administration, Demonstrated Reserve Base of Coal in the U.S. on January 1, 1979; DOE News, March 30, and May 13, 1981).

	Crude oil			Total gas			Coal				Uranium			
	Production		Reserves	Production		Reserves	Production		Strippable Reserves		Production		Reserves	
State	Million bbls	U.S. rank	Million bbls	Billion cu ft	U.S. rank	Billion cu ft	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	69.95	7	959	1,132.3	4	17.667	19,481	13	2,400	12	7,750	1	325,000	1
Texas	1,556.16	1	-	7,169.1	1	-	27,000	10	12,700	4	-	-	52,000	3
Oklahoma	134.43	5	-	1,902.1	3	-	5,000	20	400	19	-	-	-	-
Colorado	29.57	15	-	185.8	10	-	19,500	12	3,800	11	-	-	47,000	4
Utah	25.72	16	-	80.8	16	-	16,225	15	300	22	-	-	38,000 (Utah and Arizona)	5
Arizona	00.40	-	-	-		-	11,800	16	300	21	-	-		6
Wyoming	114.28	6	-	349.6	6	-	88,928	4	27,400	2	6,040	2	288,000	2

Slight increases in production from other states, however, may further erode New Mexico's share of national production.

The production and reserve status of oil and gas is expected to decline for all western states in coming years, although natural gas production will not decline as rapidly as crude oil production. New discoveries and recovery from marginal pools along with new methods of tertiary recovery may result in a slower decline, but the nation's supplies of the traditional fossil fuels are destined eventually to be depleted. As reserves are depleted, however, the average price for a barrel of oil and for a thousand cu ft of natural gas will continue to rise, especially in the case of natural gas with deregulation. That impact is being felt even now as the average price for a barrel of oil increased from $14.09 in 1979 to $24.01 in 1980, and the average price for a thousand cu ft of natural gas went from $1.01 in 1978 to $1.39 in 1979 to $1.80 in 1980. With natural gas deregulation, the sales valuation of natural gas should increase dramatically in the future, even with declines in production.

Much of the increase in coal production in 1980 came from Wyoming, primarily because Wyoming has the capability to export coal to 22 states. Transportation problems and the development of coal resources on federal land continue to plague the industry, but other factors, such as lower than expected growth in electric power demand and delays in converting to coal as a fuel for power plants, have also meant that production from western states will not increase as rapidly as once thought. Substantial increases in production have nevertheless taken place with production from New Mexico, Montana, Texas, Colorado, Arizona, Utah, and Oklahoma increasing by 175 percent in the past 5 yrs. In that period, Wyoming production increased by 196 percent while New Mexico production increased by 103 percent. An illustration of the increasing price paid for fossil fuels is that production in New Mexico over the last 10 yrs increased by 157 percent but the sales value of annual coal production increased by 1,123 percent. The U.S. Department of Energy predicts that New Mexico will increase production by almost 200 percent in the next 10 yrs and Texas by 235 percent. Production projections, however, are dependent on future utility needs and the ability to transport the coal to generating plants.

Several organizations are conducting important geothermal research in New Mexico, but development of the state's significant potential remains in an early stage. Foreign countries, such as Japan and Germany, are cooperating in hot dry rock experiments near Los Alamos, where recent advances have greatly increased the possibilities for the use of that type of energy. The expected increase in worldwide geothermal activity may have a beneficial effect on development in New Mexico.

With substantial increases in the price paid for New Mexico's energy resources have come proportionate increases in revenues to the state. Table 2 shows rates for tax receipts collected in 1980 comparing coal, oil, natural gas, and U_3O_8. These rates were based on the 6-month period from July to December 1980. Dividing these receipts by the average prices of $15.06 per ton of steam coal, $25.58 per barrel of oil, $1.86 per thousand

TABLE 2—TAX RECEIPTS FOR ENERGY RESOURCES IN NEW MEXICO, 1980 (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	$ 0.1462	$ --	$ --	$ 0.2341
Severance tax	0.7142	0.8723	0.0976	1.3190
School tax	--	0.5932	0.0428	--
Conservation tax	0.0265	0.0442	0.0032	0.0134
Resource excise tax	0.1020	--	--	0.2096
Ad Valorem (production)	--	0.2699	0.0201	--
Ad Valorem (equipment)	--	0.0534	0.0039	--
Natural gas processors	--	--	0.0069	--
Continued care fee	--	--	--	0.0462
	$ 0.9889	$ 1.8330	$ 0.1745	$ 1.8223

cu ft of gas, and $25.94 per lb of U_3O_8 yields effective tax rates of 6.57 percent for steam coal, 7.16 percent for oil, 9.38 percent for gas, and 7.03 percent for U_3O_8. Compared to the previous year, effective tax rates increased for all resources as shown below.

	Effective tax rates (%)	
Resource	1979	1980
Steam coal	6.40	6.57
Oil	6.25	7.16
Natural gas	7.55	9.38
U_3O_8	5.48	7.03

Severance tax receipts in F.Y. (fiscal year) 1980 in New Mexico from oil, gas, uranium, and coal increased by $22,383,274 or by 23 percent from F.Y. 1979 receipts. Total severance tax receipts collected in 1980 amounted to $118,708,946 compared to $96,325,672 in 1979. Of the severance taxes collected in 1980, oil and gas accounted for $97,790,919, uranium for $13,975,226, and coal for $6,942.801. Although U_3O_8 production was only slightly less in 1980 than in 1979 and oil and gas production declined by an average of 4 percent, severance tax revenues increased by $20.5 million for oil and gas and by only $10,465 for uranium. Coal production in 1980 increased by 33 percent over 1979 and revenues from severance taxes increased by 36 percent. Severance tax receipts for the four resources is expected to be substantially higher in 1981 (State of New Mexico Severance Tax Income Bonds, Series 1981, August 21, 1981).

Uranium

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

Production

Due primarily to a depressed uranium market, U_3O_8 (uranium concentrate) production in New Mexico continued the production pattern of the previous year. A recessionary cycle brought on by excess uranium inventories has adversely affected every phase of the industry in the United States and particularly in New Mexico. Production costs have risen significantly and market prices have fallen from historic highs of more than $40 per lb in 1978 to $23.50 per lb as of August 1981. Uranium, however, is New Mexico's largest mining industry, and New Mexico continues to lead the country in production among the nine uranium-producing states.

During 1980, 5,867,192 tons of uraniferous ore were mined in the state, and 6,623,908 tons, which included stockpiled material, were milled. The ore processed contained 8,079 tons U_3O_8; and, from this amount, 7,407 tons U_3O_8 were recovered, which included amounts from mine-water recovery, heap leach, and in situ methods. According to the New Mexico Bureau of Mine Inspection, uranium concentrate production in New Mexico in 1980 had an FOB (free on board) mine value of $218.5 million. Production during 1980 represented only a slight decline from the 6.9 million tons of ore processed and 7,420 tons U_3O_8 recovered in the previous year. Concentrate production during 1979 and 1980 was still higher than any previous year with the exception of 1978. The noteworthy development has not been in the rise and fall of production but rather that expansion of the industry has not taken place at the rate expected due to uncertainties regarding future demand, uncertainties which began to have impact on production in 1979. Uranium production statistics for 1979 are presented in New Mexico Bureau of Mines and Mineral Resources Circular 181 (Arnold and Hill, 1981).

The most significant trend of New Mexico's production in the past two years has been a dramatic decline in its share of total domestic U_3O_8 production. Combined production from other states has recently eroded New Mexico's traditional share from 48 percent in 1976 to 40 percent in 1979 and 35 percent in 1980. Although New Mexico's production has not markedly declined, production from Wyoming and Texas has increased at a greater rate due to the mining of deposits at shallower depths by both open pit and in situ-leach methods. Table 3 shows comparative production among uranium-producing states. The DOE (U.S. Department of Energy) presents differing statistics on ore processed and concentrate produced in New Mexico because their reporting is based on mill receipts, and the New Mexico EMD (Energy and Minerals Department) reporting is based on individual mine production. Despite a depressed market and oversupply condition, domestic production reached an all-time high of 21,850 tons U_3O_8 during 1980 as existing contracts continued to be fulfilled. New Mexico has led the nation in total production since 1953, except during 1973 when a labor strike significantly slowed production. As New Mexico's reserves are depleted due to extensive production, other states such as Texas and Wyoming, which traditionally have had less production and are now experiencing greater exploration and drilling activity than New Mexico, begin to exploit their reserves at an increased rate. All other states, particularly Texas, Colorado, and Utah, have shown increases in production along with byproduct recovery from Florida phosphates. Fig. 1 compares historical concentrate production among the major uranium-producing states.

Average ore grade, the average percentage of U_3O_8 contained in ore, improved to 0.121 percent in 1980 compared to 0.119 percent in 1979. Fig. 2 shows uranium ore grades had declined from 1976 through 1979 as producers adjusted to record high spot market prices of more than $40 per lb in 1978 and early 1979. The current increase in average ore grade reflects higher

TABLE 3—Domestic uranium ore and concentrate production in 1980 (U.S. Department of Energy, personal communication, June 1981; U.S. Department of Energy, 1981a).

State	Ore processed: Million tons	Ore processed: Contained U_3O_8 (tons)	Tons U_3O_8: Concentrate from ore	Tons U_3O_8: Other	Tons U_3O_8: Total	% of total U.S. U_3O_8 production
New Mexico	6.7	8,300	7,590	160	7,750	35
Wyoming	5.4	6,200	5,870	170	6,040	28
Arizona, Colorado, Florida, Texas, Louisiana, Utah, Washington	4.7	5,430	5,050	3,010	8,060	37
Total	16.8	19,930	18,510	3,340	21,850	100

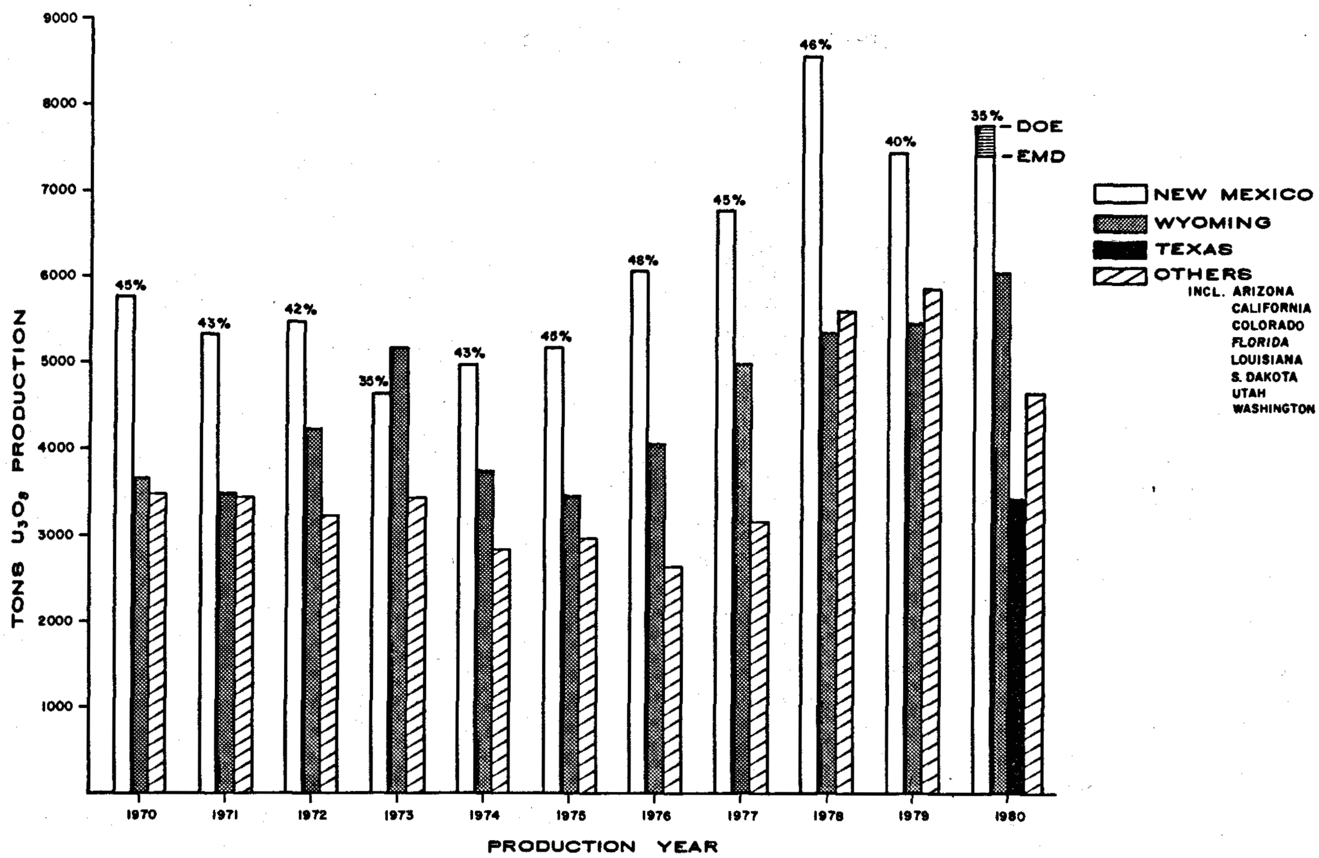

FIGURE 1—URANIUM CONCENTRATE PRODUCTION IN NEW MEXICO AND LEADING STATES, 1970–1980 (U.S. Department of Energy, 1976–1979; U.S. Energy Research and Development Administration, 1975; New Mexico Bureau of Geology, 1981).

production costs which have forced producers to mine higher grade material in order to maintain production of U_3O_8 per ton of ore mined. Average ore grades have undergone similar adjustments in other states. New Mexico has maintained the highest average ore grade sine 1975, but this trend will change as future production shifts to the newer, lower grade deposits currently under development.

Fig. 3 shows the principal areas of uranium mining activity in New Mexico. The Grants Mineral Belt, which trends from northwest to southeast across the southern edge of the San Juan Basin, embraces the most prolific uranium production area in the United States. Among New Mexico's counties, McKinley County has traditionally led other counties in the production of uranium and produced 60 percent or 4,190 tons U_3O_8 in 1980. A newly created county, Cibola County, which came into existence effective July 1981, produced most of the remainder of 1980 production. Cibola County comprises what was formerly western Valencia County with Grants designated as the county seat. Grants in Cibola County and Gallup, the county seat of McKinley County, are the centers of New Mexico's uranium mining and milling employment. Other counties, including Sandoval and San Juan, together accounted for less than 1 percent of 1980 production. Production statistics for New Mexico comparing location, ownership, depth, host rock, and mine methods in tons of U_3O_8 produced are shown in fig. 4.

Mineral ownership within these counties is distributed among Indian, fee (private), federal, and land under

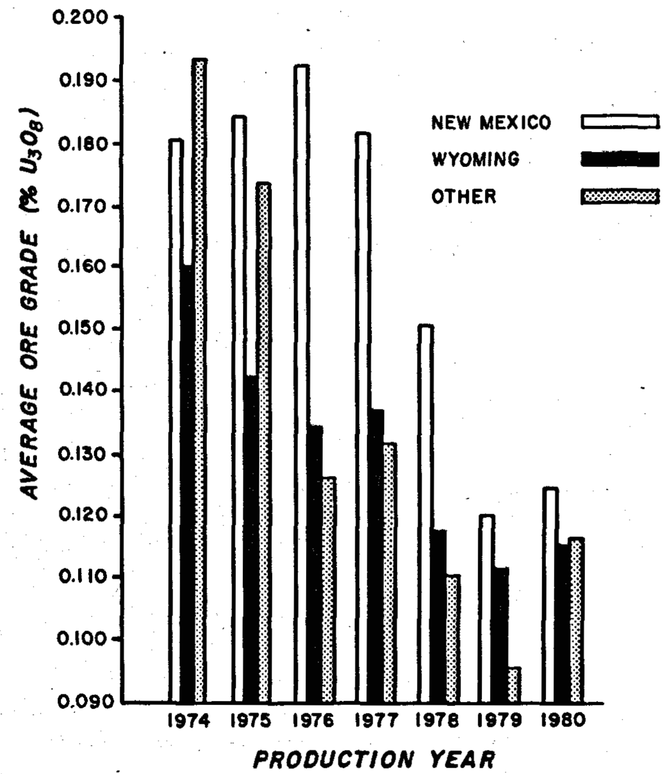

FIGURE 2—AVERAGE URANIUM ORE GRADE IN NEW MEXICO AND LEADING STATES, 1974–1980 (U.S. Department of Energy, 1976–1979; U.S. Energy Research and Development Administration, 1975; New Mexico Bureau of Geology, 1981).

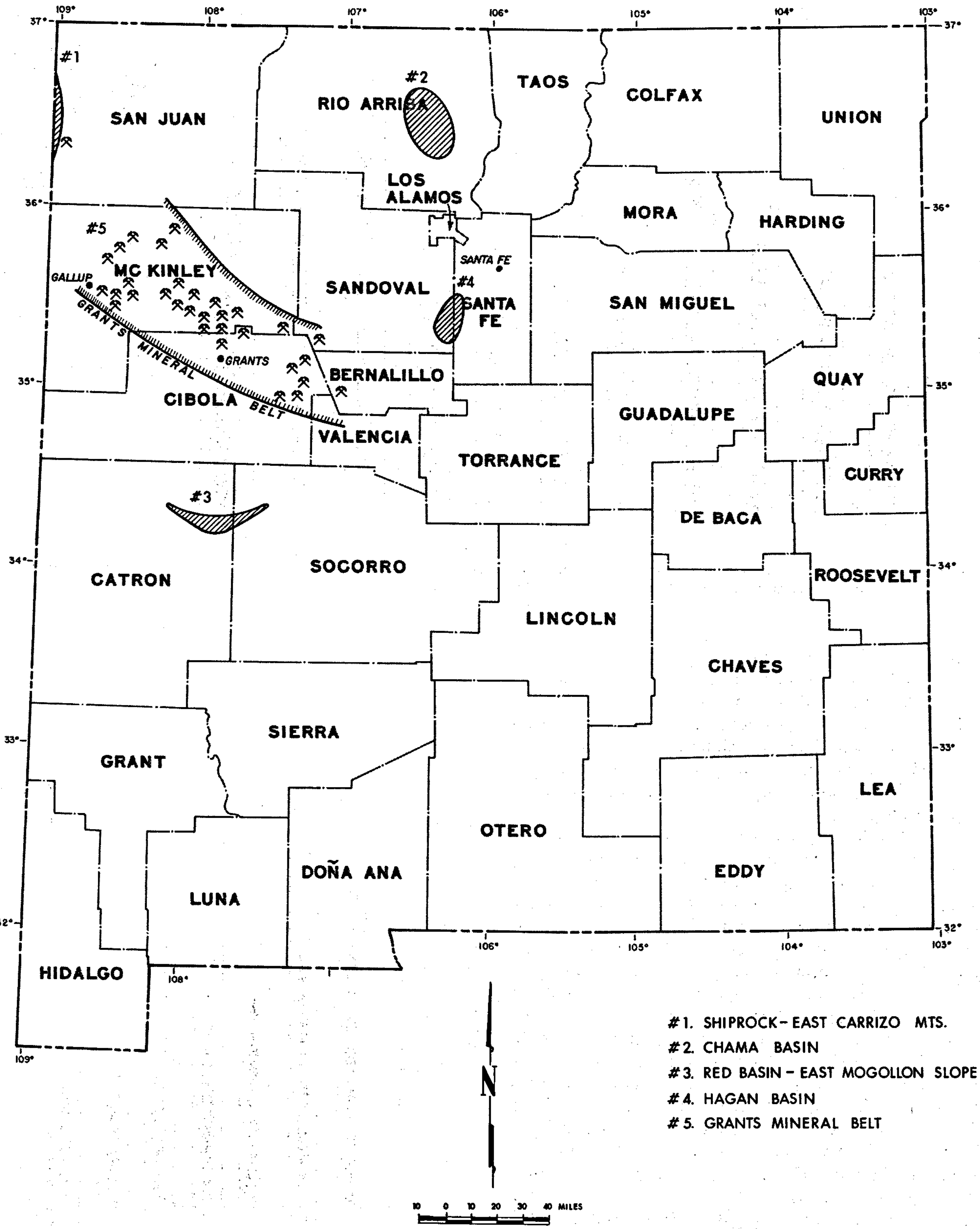

FIGURE 3—Map of uranium mining and exploration areas in New Mexico (New Mexico Bureau of Geology, 1981).

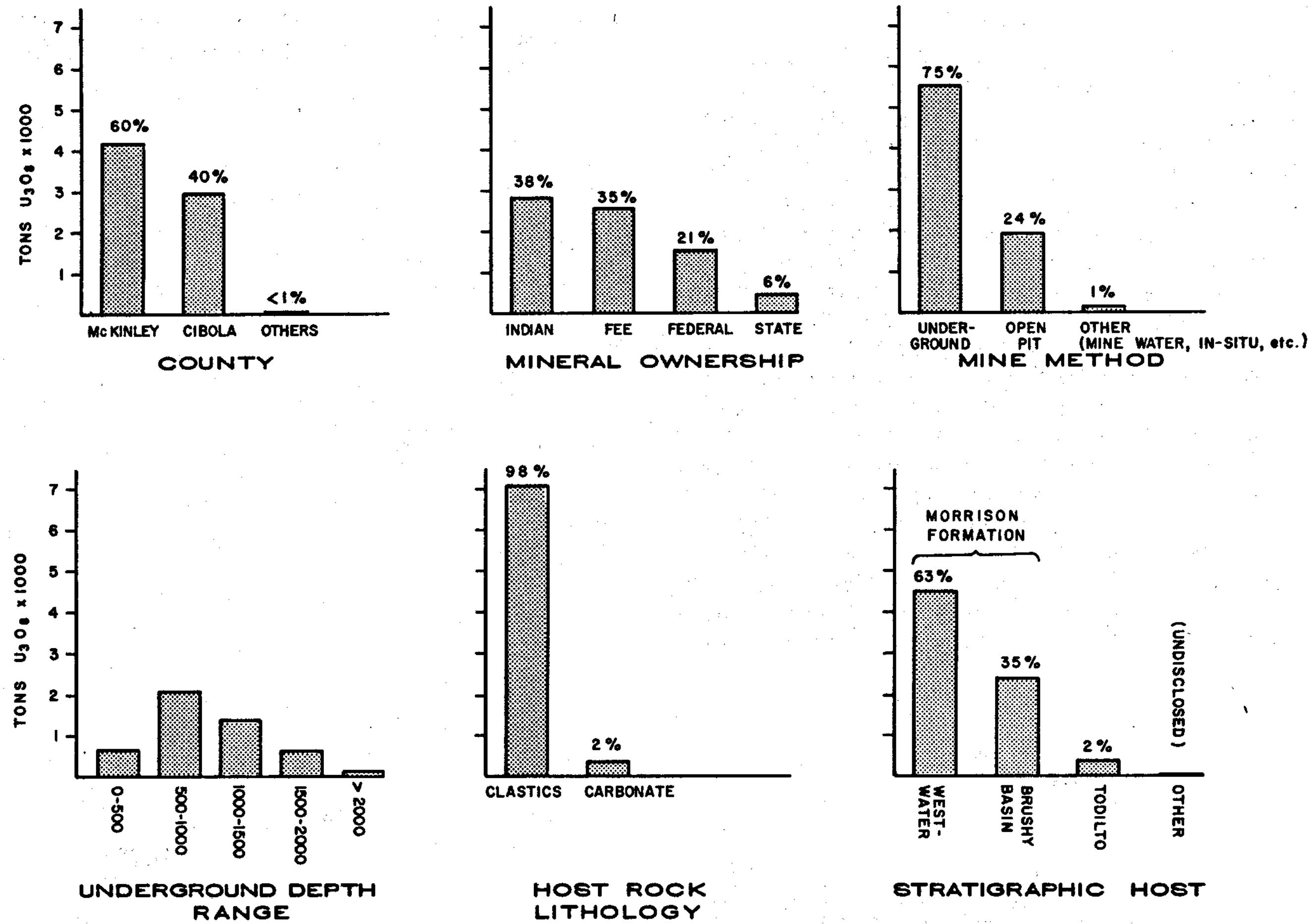

FIGURE 4—U_3O_8 PRODUCTION IN NEW MEXICO IN 1980 COMPARING LOCATION, OWNERSHIP, DEPTH, HOST ROCK, AND MINE METHOD IN TONS U_3O_8 (New Mexico Bureau of Geology, 1981).

state jurisdiction. In 1980, uranium from Indian mineral lands accounted for 38 percent of production, which slightly exceeded that from fee lands with 35 percent and was almost double that from federal land with 21 percent. Two Indian groups are involved, the Lagunas and the Navajos, with Navajo lands including production from both reservation lands and Indian Allotted lands. State mineral lands accounted for about 6 percent of 1980 production.

New Mexico production comes almost entirely from clastic sedimentary rocks (sandstones) of Late Jurassic age. The clastic host rocks account for 98 percent of production and carbonates for 2 percent. Of the 98 percent from sandstone-type ore bodies, 63 percent comes from the Westwater Canyon Sandstone and 35 percent from the Brushy Basin Shale Member of the Morrison Formation. The Todilto Limestone, also of Jurassic age, accounts for approximately 2 percent of the total production. The bulk of all future uranium production in New Mexico will come from the Morrison Formation as the older and smaller Todilto deposits are depleted. Stratigraphic nomenclature of the Grants Mineral Belt is summarized in table 4. Detailed geologic and technologic aspects of the New Mexico uranium industry are presented in Rautman, et al. (1980), and Hatchell and Wentz (1981).

Employment in the uranium industry has declined in 1980 compared to 1979, particularly in exploration and milling. Mine layoffs during 1980 were somewhat balanced by increased employment at several major projects under development, although many of these projects were placed on a holding status by mid-1981. Although employment in mining was relatively the same as in 1979, employment in milling declined and exploration employment declined dramatically. Table 5 shows employment during 1980 in uranium mining and milling. Fig. 5 shows employment trends in mining, milling, and exploration from 1979 to 1980.

TABLE 4—STRATIGRAPHIC NOMENCLATURE WITHIN THE GRANTS MINERAL BELT, NEW MEXICO (New Mexico Bureau of Geology, 1981).

Age	Units	Thickness (feet)
Cretaceous:	Erosion	
	Mesaverde Group	460-2,050
	Mancos Shale	800-1,000
	Dakota Sandstone	10- 150
Jurassic:	Morrison Formation	100- 600
	Brushy Basin Shale Member including "Jackpile Sandstone" of economic usage	20- 350
	Westwater Canyon Sandstone Member	20- 250
	Recapture Shale Member	50- 175
	Cow Springs/Bluff Sandstone	235- 500
	Summerville Formation	20- 270
	Todilto Limestone	2- 80
	Entrada Sandstone	80- 460
Triassic:	Chinle Formation	1,100-2,000

Mining

During 1980, 45 mines reported uranium production in New Mexico compared to 40 mines producing ore as of December 1979. The 15 companies operating these mines are listed in table 6 along with mine location, depth, and host rock. Compared with other states, New Mexico's average mine is a relatively large-scale operation with four mines or 8 percent of the 45 mines accounting for 33 percent of total production in 1980. The four largest mines in New Mexico are operated, in order of volume of production, by Kerr-McGee, Anaconda, United Nuclear-Homestake Partners (now Homestake), and UNC (United Nuclear Corporation).

The larger mines have sufficient reserves to sustain production for several years. High production costs combined with low market prices and an oversupplied market, however, will continue to force the less productive mines out of business. Many of the older mines in New Mexico that have been in production since the 1950's have fulfilled supply commitments of long-term contracts or have not obtained new contracts. These older mines were forced to cease operations rather than

TABLE 5—MINE AND MILL EMPLOYMENT IN NEW MEXICO IN 1980 (U.S. Department of Energy, personal communication, June 1981).

Mining	
Underground	
Miners	1,661
Service and support	1,697
Open pit	
Miners	252
Service and support	230
Technical	416
Other	887
Supervisory	536
Total	5,679
Milling	
Operations	435
Maintenance	333
Technical	98
Other	90
Spervisory	189
Total	1,145

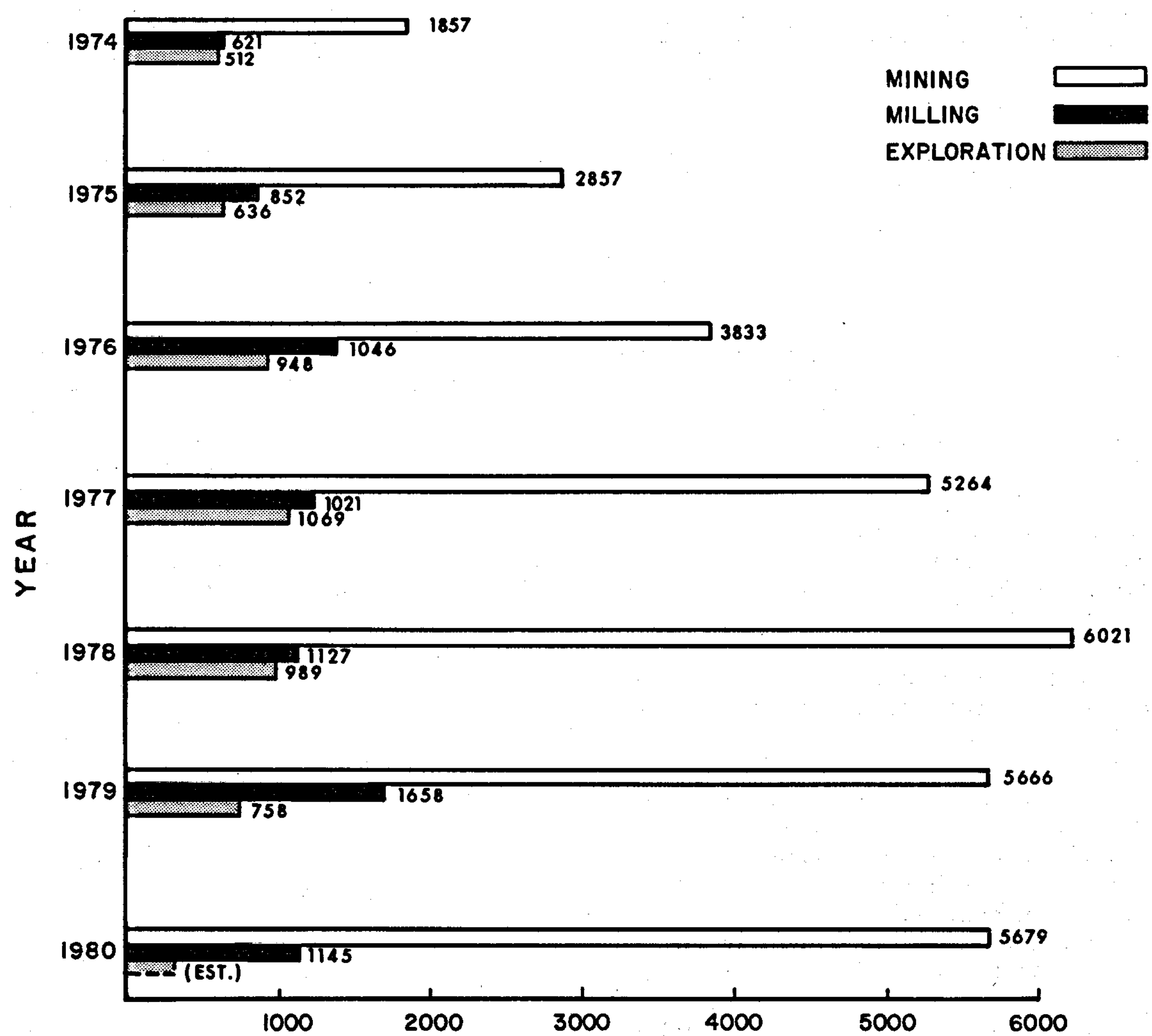

FIGURE 5—EMPLOYMENT TRENDS IN URANIUM MINING, MILLING, AND EXPLORATION IN NEW MEXICO, 1974–1980 (U.S. Department of Energy, 1976, 1977, 1978, 1979, 1980; U.S. Department of Energy, personal communication, June 1981).

TABLE 6—New Mexico uranium mines reporting production in 1980. Single asterisk = production from ore stockpiles only; double asterisk = mine-water recovery plus stockpile and/or ore production; triple asterisk = mine-water recovery only (New Mexico Bureau of Geology, 1981).

Company	Mine	Location: Sec., Twp., Rge.	Location: County	Location: Mining district	Depth (ft)	Host rock
Amiran	Desiderio *	25, 13N, 10W	McKinley	Ambrosia Lake	Open pit	Todilto
Anaconda	Jackpile-Paguate	33&35,11N, 5W	Cibola	Laguna	Open pit	Brushy Basin
	P-10 decline	4-5-8,10N, 5W	Cibola	Laguna	500	Brushy Basin
	PW 2/3 adit	33, 11N, 5W	Cibola	Laguna	150	Brushy Basin
Cobb	Sec. 10 shaft*	10, 14N, 10W	McKinley	Ambrosia Lake	550	Westwater
	Sec. 12 shaft	12, 14N, 10W	McKinley	Ambrosia Lake	666	Westwater
	Sec. 14 shaft	14, 14N, 10W	McKinley	Ambrosia Lake	360	Westwater
	West Ranch shaft	32, 15N, 11W	McKinley	Ambrosia Lake	270	Brushy Basin
Gulf	Mariano Lake**	12, 15N, 14W	McKinley	Smith Lake	470	Brushy Basin
	Mount Taylor	24, 13N, 8W	Cibola	Ambrosia Lake	3,300	Westwater
Kerr-McGee	Church Rock No. 1	35, 17N, 16W	McKinley	Church Rock	1,850	Westwater
	Church Rock No. 1 East	36, 17N, 16W	McKinley	Church Rock	1,650	Westwater
	Sec. 17 shaft**	17, 14N, 9W	McKinley	Ambrosia Lake	1,030	Westwater
	Sec. 19 shaft**	19, 14N, 9W	McKinley	Ambrosia Lake	779	Westwater
	Sec. 22 shaft**	22, 14N, 9W	McKinley	Ambrosia Lake	827	Westwater
	Sec. 24 shaft**	24, 14N, 9W	McKinley	Ambrosia Lake	783	Westwater
	Sec. 30 shaft**	30, 14N, 9W	McKinley	Ambrosia Lake	656	Westwater
	Sec. 30 west ** shaft	30, 14N, 9W	McKinley	Ambrosia Lake	740	Westwater
	Sec. 33 shaft***	33, 14N, 9W	McKinley	Ambrosia Lake	783	Westwater
	Sec. 35 shaft**	35, 14N, 9W	McKinley	Ambrosia Lake	1,336	Westwater
	Sec. 36 shaft**	36, 14N, 9W	McKinley	Ambrosia Lake	1,600	Westwater
Koppen	Sec. 12 shaft	12, 14N, 10W	McKinley	Ambrosia Lake	666	Westwater
	Spencer No. 2 shaft	6 & 8,13N, 9W	McKinley	Ambrosia Lake	260	Westwater
NuFuels	Crownpoint In situ plant	9, 17N, 13W	McKinley	Crownpoint	2,000	Westwater
Ranchers	Hope shaft	19, 13N, 9W	McKinley	Ambrosia Lake	400	Todilto
	Johnny M shaft	7 & 18,13N, 8W	McKinley	Ambrosia Lake	1,340	Westwater
Ray Williams	Enos Johnson decline	Unsurveyed (9 mi. west of Sanostee)	San Juan	Sanostee	Undetermined	Recapture
Reserve	Poison Canyon	19, 13N, 9W	McKinley	Ambrosia Lake	200	Brushy Basin
Sohio-Western	JJ No. 1 shaft**	13, 11N, 5W	Cibola	Laguna	677	Brushy Basin
Todilto	Haystack pit	19, 13N, 9W	McKinley	Ambrosia Lake	Open pit	Todilto
	Haystack pit	13, 13N, 9W	McKinley	Ambrosia Lake	150	Todilto
	Piedra Triste	30, 13N, 9W	McKinley	Ambrosia Lake	200	Todilto
United Nuclear	NE Church Rock**	35, 17N, 16W	McKinley	Church Rock	1,700	Westwater
	Old Church Rock**	17, 16N, 16W	McKinley	Church Rock	850	Westwater
	Ann Lee shaft	28, 14N, 9W	McKinley	Ambrosia Lake	680	Westwater
	Sandstone shaft***	34, 14N, 9W	McKinley	Ambrosia Lake	920	Westwater
	Sec. 27 shaft	27, 14N, 9W	McKinley	Ambrosia Lake	780	Westwater
	St. Anthony pit	19-30,11N,4-5W	Cibola	Laguna	Open pit	Brushy Basin
	St.Anthony shaft	19-30,11N,4-5W	Cibola	Laguna	380	Brushy Basin
Homestake	Sec. 13 shaft	13, 14N, 10W	McKinley	Ambrosia Lake	530	Westwater
	Sec. 15 shaft	15, 14N, 10W	McKinley	Ambrosia Lake	525	Westwater
	Sec. 23 shaft**	23, 14N, 10W	McKinley	Ambrosia Lake	726	Westwater
	Sec. 25 shaft**	25, 14N, 10W	McKinley	Ambrosia Lake	745	Westwater
	Sec. 32 shaft**	32, 14N, 9W	McKinley	Ambrosia Lake	530	Westwater
Western	Ruby 1&2 decline	21&27,15N, 13W	McKinley	Smith Lake	360	Brushy Basin
	Ruby 3&4 decline	25&26,15N, 13W	McKinley	Smith Lake	300	Brushy Basin

rely on a rapidly deteriorating spot market for sales. Even some of the newer mines will be forced to halt production when lower average ore grades fail to justify rising production costs and decreasing demand due to a highly competitive, oversupplied market. During 1980, 19 of the 45 active mines were forced to shut down leaving only 27 in operation. Some mines were aleady closed prior to 1980 but continued to ship ore from stockpiles or to produce from mine waters through IX (ion exchange) circuits. Where feasible, many deposits are being identified for future in situ-leach recovery by the major operators.

Of New Mexico's total uranium production, 75 percent comes from underground mining; 24 percent from open pit production; and approximately 1 percent from mine-water recovery, heap leach, and in situ methods. Of the 45 mines reporting production, 40 were underground mines, four were open pit, and one was an in situ operation. One underground mine, Section 12 shaft, was operated by two different mining firms at separate intervals during the year and, although reported twice, is counted in table 6 as one mine. Several Kerr-McGee and Homestake mines at Ambrosia Lake were producing uranium from mine-water recirculation through IX circuits in addition to ore production. At least two of these mines were producing exclusively from mine-water recovery. Two mining operations in the Ambrosia Lake district, the Desiderio of Amiran and the Section 10 mine of Cobb, produced only from ore stockpiles. The Section 10 mine has been closed since the spring of 1979 due to a fire.

One of the primary factors contributing to New Mexico's declining share of domestic production has been the requirement in recent years of mining at greater depths than other producing states. Geologic endowment, mining economics, and available technology determine the depth to which underground mines are developed, and production costs increase with depth. Of the ore mined in New Mexico during 1980, the ore containing 93 percent of the U_3O_8 produced occurred at depths to about 1,100 ft, and 80 percent of this production was restricted to the 800 to 1,100-ft range (fig. 6). Uranium deposits being exploited in Wyoming and Texas, however, are at considerably shallower depths with most at 500 ft or less. In New Mexico, large tonnages of recovered U_3O_8 came from depths ranging from 500 to 1,000 ft with steadily diminishing tonnages derived as depths increased below 1,000 ft. Total U_3O_8 contained in ores from both underground and open pit mines is compared on an average grade-depth basis in fig. 7. Of the 17 mines operating at the more shallow depths from 0-500 ft, eight or almost one-half ceased production during the year due to dwindling reserves of economically minable, ore grade material.

Milling

Table 7 lists the five uranium mills operating during 1980. Total licensed operating capacity of these mills was 28,360 tons per day, which represents an increase of 4,200 tons per day from the previous year. Actual combined mill operating capacity was 22,160 tons per day, which includes the capacities of the inoperative Bokum mill at Marquez and the licensed but yet to be built Gulf mill at San Mateo. The in situ-leach pilot plant of Mobil at Crownpoint continued as the only such operation in New Mexico producing uranium. Other planned in situ-leach projects have been postponed until market conditions warrant future development. Mills in New Mexico operated at 91 percent capacity during 1980, recovering 92 percent of contained U_3O_8 from ore in mill-feed operations. In addition to recovered U_3O_8 processed from mined ore, at least 40 tons U_3O_8 were recovered in concentrate derived from stockpiled ore shipments during 1980. All of the mills were operating at near capacity with the exception of the Church Rock and L-Bar mills. Uranium mills planned by Conoco at Prewitt, Gulf at

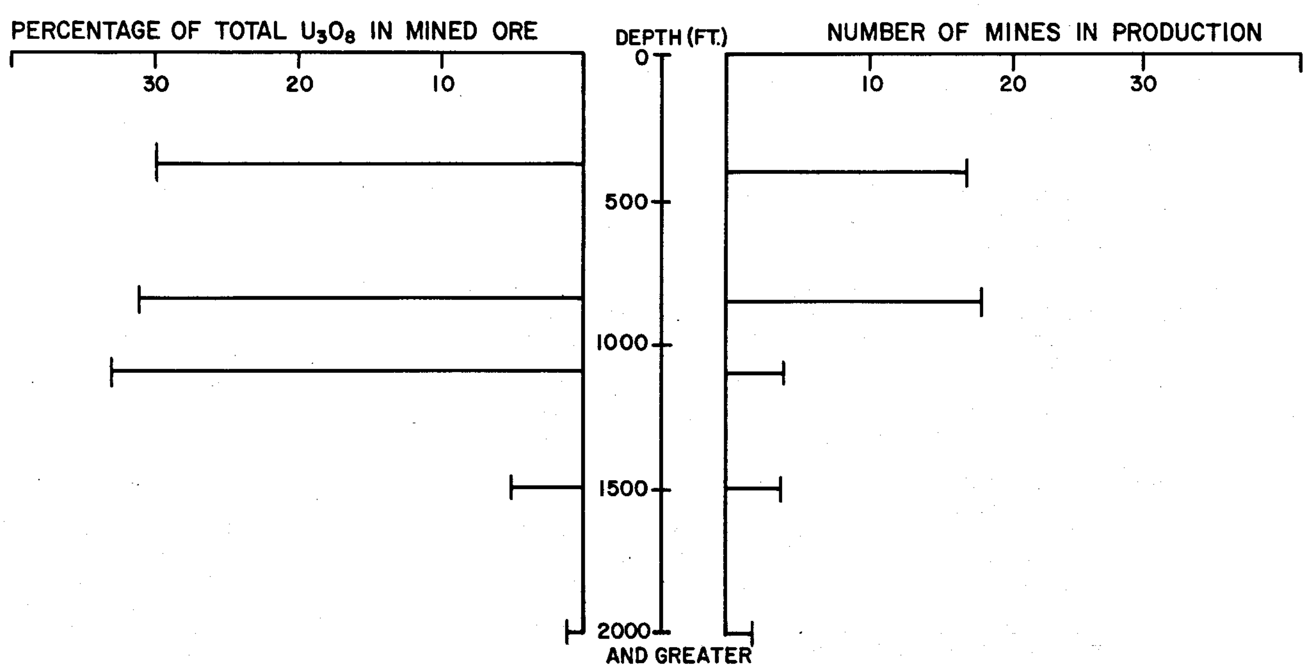

FIGURE 6—U_3O_8 PRODUCTION BY MINE DEPTH AND NUMBER OF MINES IN PRODUCTION IN NEW MEXICO IN 1980 (New Mexico Bureau of Geology, 1981).

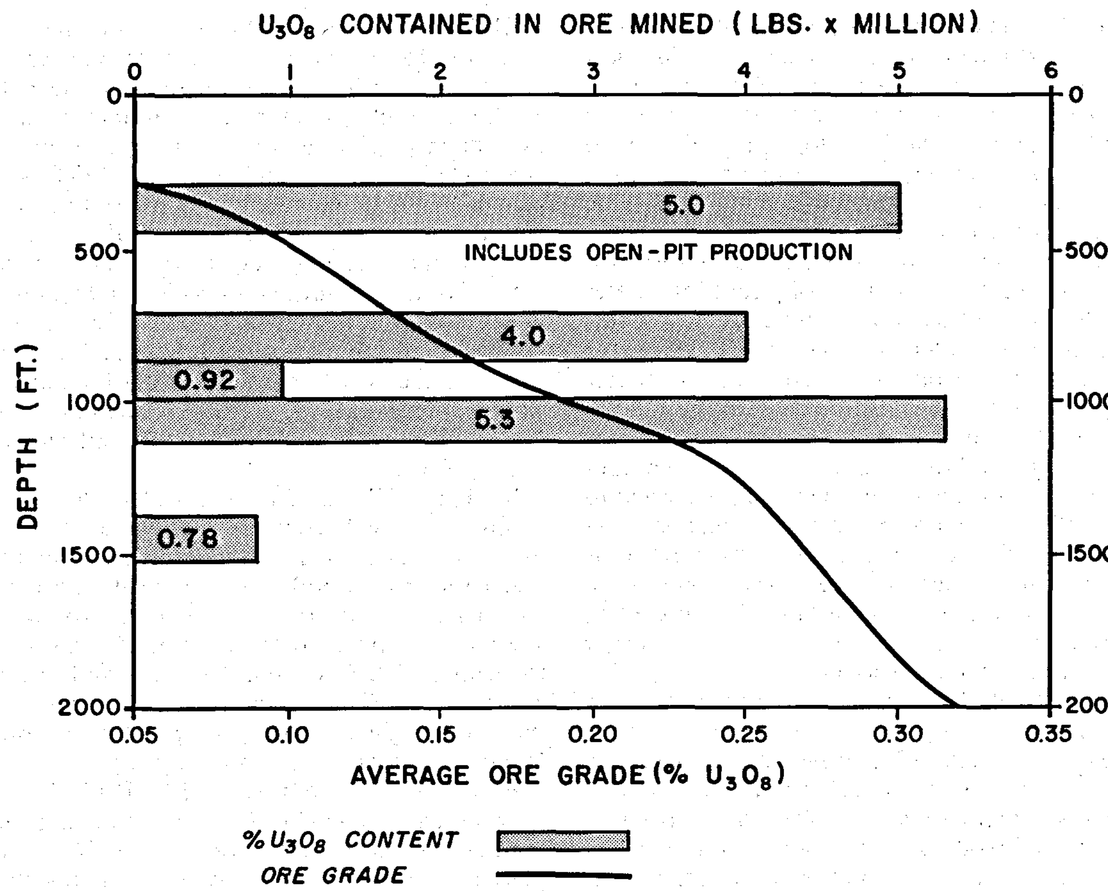

FIGURE 7—U_3O_8 IN ORE MINED FROM UNDERGROUND AND OPEN PIT PRODUCTION BY DEPTH IN NEW MEXICO IN 1980 (New Mexico Bureau of Geology, 1981).

San Mateo, and Phillips at Nose Rock will add approximately 8,000 tons per day of licensed capacity to the state's total if they are all licensed and when they are all operating. Despite adverse market conditions, the companies are proceeding with mill licensing and construction plans to be prepared for future production.

Industry activity

ANACONDA COMPANY—Mine production ended in February 1981 at the mammoth Jackpile-Paguate open pit mine, which had been operated by the Anaconda Company since 1953. The Jackpile-Paguate was the largest open pit uranium mine in the world with more than 1,200 acres of pit area (Reynolds, et al., 1976). Ore production through 1980 including low-grade waste, amounted to more than 20 million tons yielding approximately 100 million lbs of U_3O_8 (New Mexico Mining and Minerals Division records, 1952-80). Although comparative data are not available, it is likely that the Jackpile-Paguate established itself as the world's most productive uranium mine in total tonnage of ore and contained U_3O_8. Anaconda continues to operate its underground mines in the area and is developing a new mine, the H-1 mine, located in secs. 2 and 3, T.10 N., R.5 W. in the Laguna mining district of Cibola County.

BOKUM RESOURCES—Bokum Resources was licensed to begin operation at its partially completed Marquez mill but legal proceedings against the firm by Long Island Lighting Company, financial constraints, and discouraging market conditions have postponed development of the mine-mill complex east of Mount Taylor. The Bokum mill is approximately 90 percent complete, and the Marquez mine shaft is at a depth of 1,835 ft or about 465 ft above the Westwater ore zones. It is uncertain when the Bokum operation will proceed toward completion and begin production.

CONOCO—In a joint venture with Wyoming Mineral Corporation, Conoco began shaft drilling in April 1980 in Section 24 at Crownpoint and completed the

TABLE 7—LICENSED NEW MEXICO URANIUM MILLS, 1980. The Bokum mill at Marquez is licensed but not operable; the Gulf mill at San Mateo is licensed but not yet built. CCD = counter-current decantation (New Mexico Bureau of Geology, 1981).

Company	Location	Type circuit(s)	Licensed capacity (tons/day)
Anaconda	Bluewater	acid, CCD, solvent extraction	6,000
Bokum	Marquez	acid, CCD, solvent extraction	(2,000)
Gulf	San Mateo	acid, CCD, solvent extraction	(4,200)
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
Homestake	Milan	carbonate leach, caustic precipitation	3,500
		Total licensed capacity	28,360
		Operating as of mid-year 1980	22,160

2,200-ft development shaft in September 1980. Conoco indicated that drilling an 18-ft-diameter main shaft rather than using the conventional blast and muck method saved 2 yrs in development. Construction on the mine project, however, was halted in June 1981 due to the depressed uranium market, but development will resume as market conditions improve. As of June 1981, $35 million had been invested in the project. Conoco, meanwhile, is pursuing approval from the New Mexico EID (Environmental Improvement Division) for a water discharge license for its mill planned near Prewitt, and the company has applied to the State Engineer for the appropriation of groundwater from the Bluewater Basin. A projected 1982 production date for the mill has been postponed pending licensing, groundwater appropriation approval, and the resumption of mine development. When in full production, the mine is expected to produce 1,350 tons of ore per day, and planned mill capacity at Prewitt is expected to be 1,000-1,500 tons per day. Although Conoco merged with DuPont in August 1981, the Conoco organization is expected to operate as it has in the past in the field of energy resource exploration and development.

EXXON MINERALS—Exxon cancelled plans for a pilot in situ-leach facility at the L-Bar Ranch deposit near Marquez in March 1981, citing market conditions as the primary factor in its decision. Exxon controls mineral rights to approximately 60,000 acres in the area and will retain mineral rights in order to proceed when uranium prices improve. Ore bodies occur in the Westwater Canyon Sandstone Member of the Morrison Formation at a depth of approximately 925 ft. Plans for the site include the development of 20 production, 12 injection, and 10 monitor wells with five spot configurations. Exxon was also active in exploration in other parts of the state during 1980, including exploration on its exclusive Navajo Tribal leases in western San Juan County and on federal claims and state leases in the Galisteo Basin of central Santa Fe County.

GULF MINERAL RESOURCES—In December 1980, Gulf received a license to operate their proposed mill at San Mateo, but specific clauses in the license remained under litigation until June 1981. In June, the New Mexico Water Quality Control Commission approved a groundwater discharge plan for the proposed Mount Taylor mill but prohibited the disposal of tailings as mine backfill in the Mount Taylor mine until a separate discharge plan for the disposal of tailings as mine backfill has been submitted by Gulf to the EID. Mine development by Gulf, however, has continued at the Mount Taylor mine, and ore produced is being toll milled and stockpiled until the new mill at San Mateo is operational.

HOMESTAKE MINING COMPANY—Homestake and UNC (United Nuclear Corporation) dissolved their joint mining and milling partnership in March 1981. Under the terms of the agreement, Homestake has paid $20 million for yellowcake inventory and has assumed all debts and liabilities of the partnership. Homestake held a 30 percent share of the partnership and UNC 70 percent. UNC will receive a production royalty from certain properties held by the partnership, while Homestake operates the mill and five mines at Ambrosia Lake.

KERR-MCGEE—Kerr-McGee is sinking a production shaft for its new Lee mine located in sec. 17, T.13 N., R.8 W. northeast of Ambrosia Lake near Ranchers Exploration and Development's Johnny M mine. The 14-ft-diameter shaft was 738 ft in depth in July 1981 and is expected to reach a total depth of 1,470 ft when completed. Kerr-McGee operates 11 mines in New Mexico with nine located in the Ambrosia Lake mining district and two in the Church Rock district. The Church Rock No. 1 East mine, which is connected to the Church Rock No. 1 mine, was opened in 1980 and has a 12-ft vertical shaft entry to a total depth of 1,529 ft. Although the Rio Puerco mine was Kerr-McGee's newest mine when it was completed in 1979, the mine located in sec. 18, T.12 N., R.3 W. was closed in late 1979 and remained idle during 1980.

MOBIL OIL CORPORATION—Mobil's in situ facilities in New Mexico are now operated by a wholly-owned subsidiary, NuFuels Corporation, and registered under that name. NuFuels proceeded with plans for a commercial in situ-leach plant at Crownpoint and a second pilot plant at its Monument deposit east of Crownpoint. Applications for wells and groundwater appropriation for the two projects have been filed with the State Engineer. The Crownpoint operation is New Mexico's first large-scale in situ facility.

PHILLIPS URANIUM CORPORATION—Phillips Uranium, a subsidiary of Phillips Petroleum, completed the main 3,295-ft production shaft at Nose Rock and placed the project on standby status in July 1981, until further development can be justified by uranium market conditions. As of July, Phillips had spent $140 million at Nose Rock. Haulage-level pump stations were being cut by early 1980 as part of a primary development phase, which will include drift and stope development. Unlike most New Mexico uranium deposits, the Nose Rock ore bodies are within very large C-shaped ore rolls that must be mined somewhat differently than the tabular and stacked ore bodies so typical of the Grants Mineral Belt (Clark, 1981). Production of this deposit containing over 25 million lbs of U_3O_8 reserves was expected to begin by late 1982 and to reach a maximum production of 2,750 tons per day some time after 1985. Phillips suspended shaft-sinking operations on the adjacent Section 36 ore body in May 1980 to conserve capital expenditures. To consolidate its surface holdings in the area, the firm entered into an agreement in early 1980 with the Navajo Tribe in which 16,000 acres of Phillips' land was traded for 12,480 acres of Navajo (Allotted) land. Under the terms of this agreement, all of the Phillips' land involved will revert to the Navajos on cessation of all uranium mining activity. The exchange was made to alleviate a complicated checkerboard pattern of land-mineral ownership. Although Phillips has applied to the EID for a mill license at Nose Rock and the application has been accepted and is under review, the company has suspended the mill plan until market conditions permit the mine-mill complex to proceed. In June 1980, Phillips submitted a proposal to the EID for an in situ-leach project in sec. 32, T.19 N., R.12 W. on the western end of their Nose Rock project.

RANCHERS EXPLORATION AND DEVELOPMENT—In June 1981, Ranchers Exploration and Development announced that production at the Hope mine in the Ambrosia Lake district would cease since reserves of sufficient grade to meet high production costs had been depleted. The Johnny M mine of Ranchers, however, will remain active. Although Ranchers operates the Johnny M, HNG Oil Company has a 50 percent interest in the mine.

SANTA FE INDUSTRIES—Santa Fe Industries completed an exploration-development drilling project at West Largo in sec. 17, T.15 N., R.10 W. about 5 miles southeast of Borrego Pass. The deposit, originally discovered by Gulf Minerals in 1969 on a Kerr-McGee farm-out lease, is at a depth of 2,200 ft in the Westwater Canyon Sandstone Member with reserves of 7.5 million lbs U_3O_8.

SOHIO-WESTERN—Sohio-Western announced the suspension of milling at its L-Bar (Seboyeta) mill in May 1981 due to a lack of sufficient toll ore required to sustain their 1,660-tons-per-day mill capacity and, a month later, announced the complete cessation of mining at the adjacent JJ No. 1 mine. At that time, 347 employees were laid off at the mine-mill complex, and an additional 113 employees will be terminated after a 3-mo period of concluding operations. Sohio and Kennecott Corporation merged in June 1981, becoming the 16th largest company in the nation in terms of sales.

TODILTO EXPLORATION AND DEVELOPMENT COMPANY—The Haystack mine operated by Todilto terminated all mining operations in late June 1981. The firm's supply contract expired in April, and lack of demand for yellowcake was cited as the prime reason for the shutdown. Haystack mine is a complex of open pit and underground mines in the Todilto Limestone around and beneath Haystack Butte where the original discovery of uranium in the Grants Mineral Belt was made in 1950. Todilto ceased production at the adjacent Piedra Triste mine in October 1980.

UNITED NUCLEAR CORPORATION—After a breached tailings dam at the UNC Church Rock mill created a spill on July 16, 1979, both milling and mining operations at the Church Rock facility were disrupted for the balance of that year and through 1980 with intermittent production. UNC has been working with the EID to contain seepage at the Church Rock facility's mill tailings pond. By May 1980, it appeared that underground radioactive contaminated seepage could be controlled by surface pumping through a series of intercept wells drilled at strategic points downdip from the ponds. As of May 26, 15 monitoring wells and 10 recovery wells had been drilled in the area of seepage. Reclamation has been proceeding to recover contaminated effluent from the aquifer and to neutralize tailings liquor acidity. UNC is committed to a relocation of the tailings site within 5 yrs. Production at the Old Church Rock mine, formerly operated by Phillips Petroleum, was begun by UNC in 1980 after the mine was reentered by a 10-ft-diameter, 850-ft-deep concrete lined shaft. The Old Church Rock mine is located in sec. 17, T.16 N., R.16 W., approximately 31 mi southwest of UNC's Northeast Church Rock mine. Mineralization occurs in three zones, which are, in ascending order of occurrence, the Westwater, the Brushy Basin, and the Dakota Sandstone.

WESTERN NUCLEAR—Western Nuclear, the uranium mining subsidiary of Phelps-Dodge, began production from its Ruby No. 3 mine in November 1980 and has proceeded with mine development at the connecting Ruby No. 4 mine. Since reserves have been depleted at the Ruby No. 1 mine, primary production comes from the Ruby No. 2 mine. All Ruby mines are on the same production level with Brushy Basin (Poison Canyon) ore bodies. Western Nuclear is in a joint venture with New Mexico and Arizona Land Company on Western Nuclear's New Mexico properties. Western Nuclear controls a 45 percent interest in the Ruby ore bodies and another 15 percent interest pending reimbursement of costs it carries on behalf of another partner, Reserve Oil and Minerals. Mineral rights to the Ruby mining properties are actually owned by New Mexico and Arizona Land Company which has a 40 percent interest in the operation. Western Nuclear estimates that ore reserves on their New Mexico properties contain 918,000 lbs U_3O_8. Sales contracts are in effect for delivery of up to 1.6 million lbs U_3O_8 in each of the years 1981-83 and for 6.0 million lbs U_3O_8 over the period 1984-95. Contracts will be supplied from both New Mexico and Wyoming properties.

Exploration and development

Drilling activity in New Mexico has declined significantly since September 1979 due in part to a depressed uranium market and extensive exploration in the past compared to other states. A total of 4,445,719 ft was drilled in 5,550 exploration and development holes in New Mexico in 1980, compared to 6,277,240 ft in 1979 and 9,922,380 ft in 1978. The principal change in drilling activity in 1980 came from a decline in development drilling. Development drilling footage during 1980 was 1,390,777 ft from 2,230 holes compared to 3,287,417 ft from 4,100 holes in 1979. Exploration drilling activity, however, remained comparable to the previous year with 3,054,942 ft drilled from 3,320 holes compared to 2,989,823 ft drilled from 3,199 holes drilled in 1979.

Although New Mexico leads the nation in production of uranium, in most reserve and resource categories, and has deeper deposits, it is third in total exploration and development drilling footage. This position has been the result of extensive exploration drilling in Texas, which was almost double that of New Mexico and also that of Wyoming in 1980. Wyoming, however, has a substantial lead over other states in development drill footage. Utah and other states, primarily Colorado, Arizona, Nevada, and South Dakota, have also increased drilling activity in recent years. Comparisons among states of exploration and development drill footage are shown in table 8 and fig. 8. Despite New Mexico's significant downturn in drilling footage in the past two years, the 1980 total reflects 15.9 percent of total United States drilling compared to 15.5 percent in 1979. Total domestic drilling declined from 40.8 million ft in 1979 to 27.9 million ft in 1980. The seasonal variations of drilling activity in New Mexico are shown in fig. 9, which indicates monthly drilling rig counts from 1977 through 1980 and the first 8 mos of 1981.

McKinley County, which also accounts for the bulk of New Mexico production, reports the greatest share of footage drilled for both exploration and development with 2.5 million ft in exploration drill footage and 1.3 million ft in development drill footage. McKinley

TABLE 8—Comparative surface drilling in New Mexico and other states in 1980 (data from U.S. Department of Energy, personal communication, June 1981; U.S. Department of Energy, GJO-100, 1981).

State	Exploration footage	Development footage
Texas	5,950,574	816,587
New Mexico	3,054,942	1,390,777
Wyoming	2,933,980	3,871,016
Utah	2,879,788	855,113
Others	5,130,513	971,444
Total U.S.	19,949,797	7,904,937

County encompasses the deeper portions of the Grants Mineral Belt within the San Juan Basin where exploration and development have traditionally been focused. The older, yet prolific, production centers around Church Rock, Smith Lake, and Ambrosia Lake also lie within McKinley County. Newly formed Cibola County constitutes a significant portion of drill footage among other counties, although activity there has slackened. Portions of the Ambrosia Lake and Laguna mining districts lie within Cibola County's boundaries, but exploration and development drilling around the known deposits there has not been extensive in recent years. A limited amount of exploration and development drilling occurred in Sandoval, San Juan, and Catron Counties. Deposits in Tertiary sandstone have been discovered and delineated in Catron and Sandoval Counties, and exploration in the Morrison Formation of Jurassic age has continued in western San Juan County. Fig. 5 shows employment levels in uranium exploration and the industry as a whole between 1974 and 1980. Employment in exploration has declined considerably since 1977 in relation to mining and milling employment.

Production forecast

Uranium production in New Mexico will decline sharply during 1981 and should not exceed current levels again until 1984 or later. Fig. 10 shows U_3O_8 production projections by both the New Mexico Bureau of Geology and the U.S. Department of Energy from 1981–90. Factors that will ultimately determine New Mexico production levels during these years include: Market price, supply, and demand; foreign and domestic competition; regulatory constraints; mining and extractive techology; and production development lead times. Several new mines are ready to proceed with development and production but are awaiting an improved uranium market and regulatory approval of certain phases of their planned mining and milling operations. Some of these mines either presently lack supply contracts or lack firm commitments to such contracts. Many existing supply contracts involving New Mexico producers will have been fulfilled by 1986 or soon after, and the ability of these producers to bid successfully for new and unfulfilled demand will be critical. Innovative mining technology and new extractive techniques must be developed to cope with excessive mine depths and decreasing grades of new deposits, particularly in the San Juan Basin but also in areas outside the San Juan Basin. The mineral and land ownership pat-

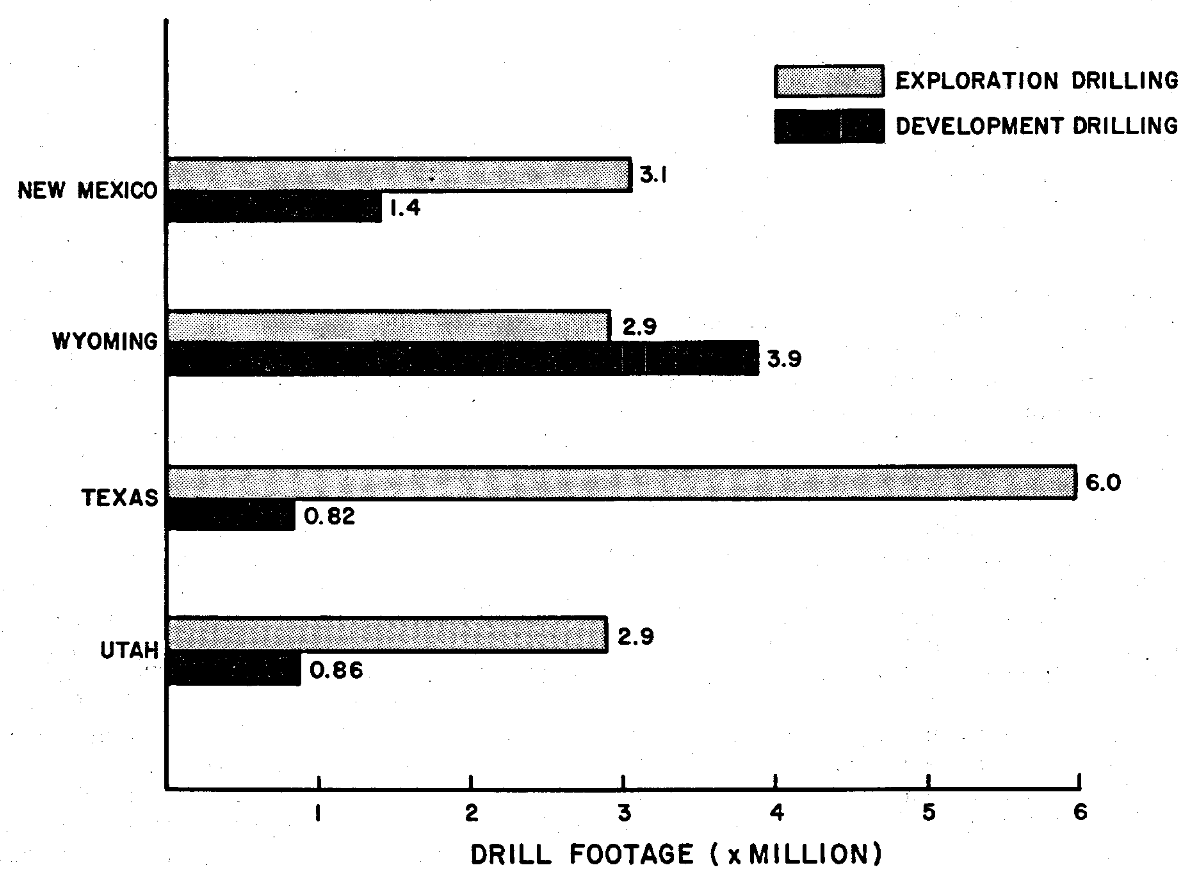

FIGURE 8—Exploration and development drill footage in New Mexico and other states, 1980 (U.S. Department of Energy, personal communication, June 1981).

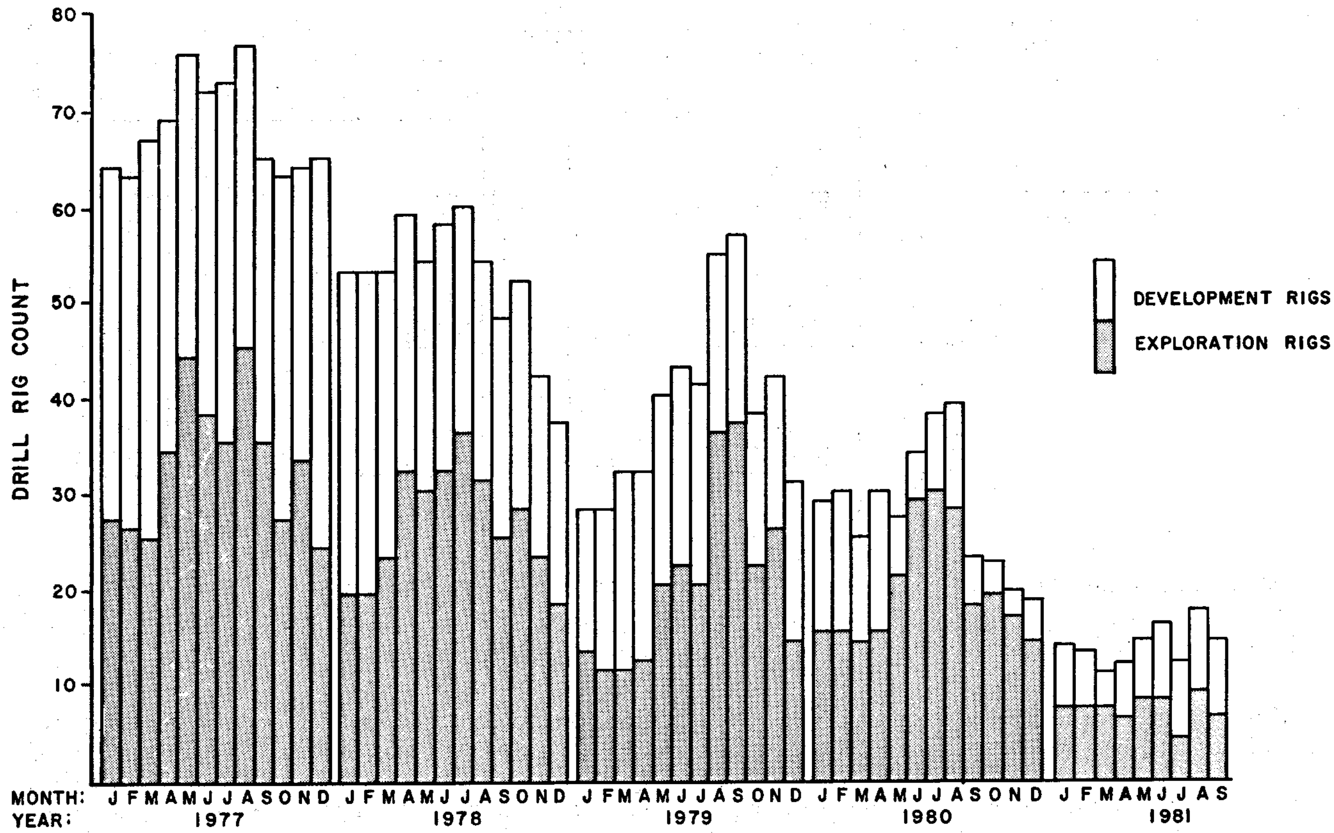

FIGURE 9—URANIUM DRILLING ACTIVITY IN NEW MEXICO, January 1977–September 1981 (New Mexico Bureau of Geology, 1981; New Mexico Uranium Newsletter, 1976–1981).

terns are more complicated in New Mexico than in other states and, along with regulatory and depth factors, result in longer lead times of from 8–10 yrs required to bring newer discoveries into production, ultimately with higher production costs. New Mexico producers will be forced to turn to less labor intensive and more economically favorable extraction techniques. One major firm is experimenting with one such technique, in situ solution mining, in the Crownpoint area. Other firms that control newly delineated deposits at the Church Rock, Nose Rock, L-Bar Ranch, and Marquez areas are also considering the technique. In situ leaching is a new mining process that uses chemical solutions to dissolve uranium in an underground ore body. The uranium is then pumped to the surface for recovery. Compared to conventional mining, in situ leaching permits increased recovery of uranium from lower grade ore. Only a fraction of the water pumped for underground mining is required, and the need for surface tailing waste is eliminated. The process is less labor intensive, and surface disruptions by mining activities are drastically reduced.

Reserves and resources

Uranium reserves in New Mexico have been declining since January 1979 due to depletion through production, declining average ore grades, and higher production costs. Fig. 11 shows New Mexico reserves as of January 1, 1981 in various cost categories. In the \$50-per-lb forward-cost category, New Mexico holds 325,000 tons U_3O_8 at an average grade of 0.11 percent U_3O_8 as of January 1, 1981, compared to 449,000 tons U_3O_8 at an average grade of 0.09 percent as of January

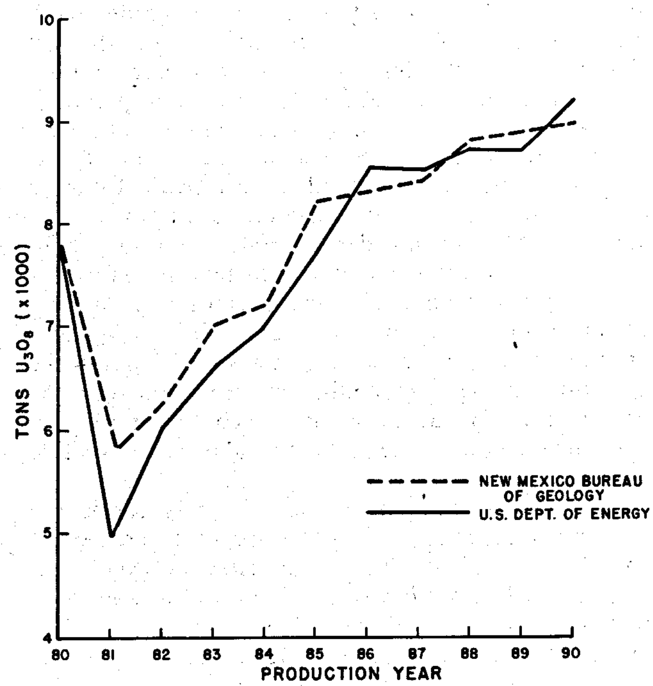

FIGURE 10—U_3O_8 PRODUCTION PROJECTIONS FOR NEW MEXICO, 1981–1990 (U.S. Department of Energy, personal communication, June 1981; New Mexico Bureau of Geology, 1981).

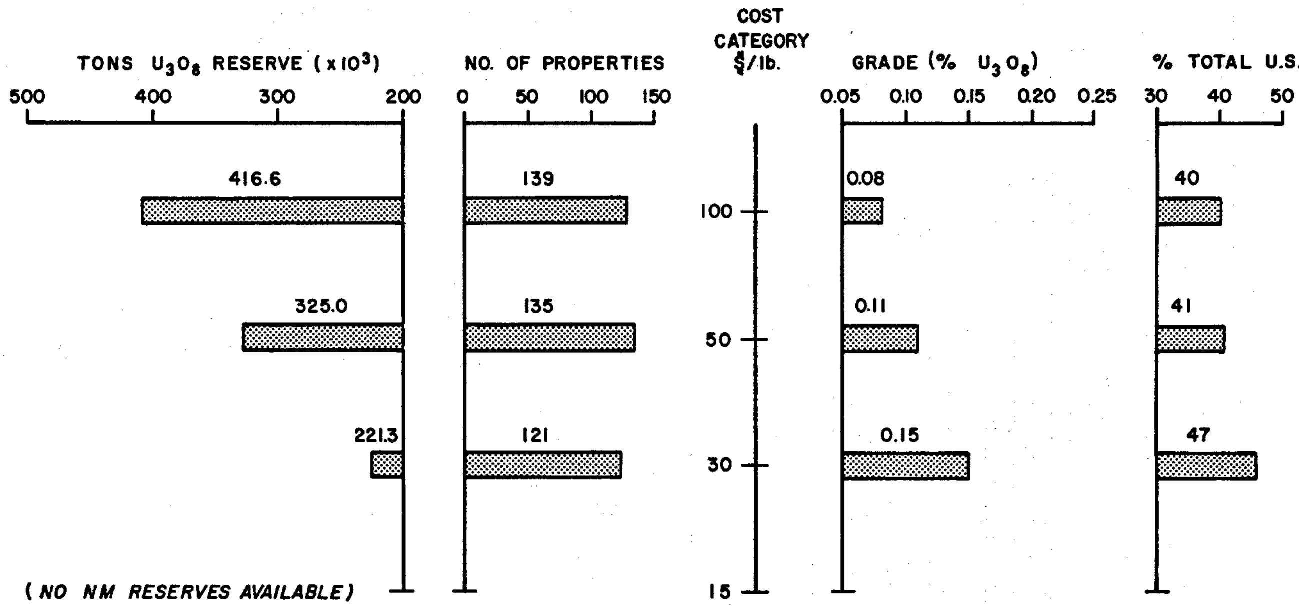

FIGURE 11—NEW MEXICO U_3O_8 RESERVES BY COST CATEGORY, NUMBER OF PROPERTIES, ORE GRADE, AND PERCENT OF TOTAL DOMESTIC RESERVES AS OF JANUARY 1, 1981 (U.S. Department of Energy, 1978, 1979b, 1980a, 1981b).

1, 1980. Reserves are considered to be estimated quantities of in-place, uranium-bearing material occurring in known deposits that are producible at or less than specified costs using current mining technology. Uranium reserves are classified according to categories based on the minimum cost required to extract a pound of U_3O_8 contained in the ore. Forward costs, therefore, include operating and capital costs in present dollars that will be incurred in production. Costs of acquisition, exploration, mine development, and mill construction are not included in forward costs. Lower grade reserves will be produced at a relatively greater cost than higher grade reserves. Reserve estimates therefore fluctuate since quantities available are determined by ore grade, depth of deposit, the geology of the occurrence, and the cost of production at the time of estimating reserves. Recent high production costs have excluded certain quantities of uranium-bearing material from reserve estimates because the material is too low in grade to justify existing production costs and still yield a profit. Reserves within each cost category, however, are always being mined and blended in order to produce optimum millfeed. Each higher cost reserve category therefore includes tonnages from the lower cost categories. At present, most mines are being forced to mine ever greater tonnages of higher grade reserves while avoiding the high costs entailed in exploiting low-grade tonnages. As the low-grade tonnages are abandoned during mine retreat, they may never again be available as recoverable reserves.

New Mexico uranium reserves currently considered economic to produce are in the $50-per-lb cost category. Fig. 12 shows $50-per-lb uranium reserves in New Mexico compared with other states along with average contract and spot market prices from January 1, 1978, through January 1, 1981. New Mexico currently has 41 percent of total domestic reserves producible in the $50-per-lb cost category, compared to 48 percent as of January 1, 1980. New Mexico's position has declined, particularly in comparison to Wyoming. High production costs, declining ore grades, and low demand which has driven down market prices have affected all uranium-producing states but have had a more detrimental effect in New Mexico due to several factors peculiar to the industry in New Mexico. These factors include: Relatively high depth-grade ratios of New Mexico deposits, depletion in old and maturing mining districts, little exploration effort beyond the San Juan Basin, and sustained high production from New Mexico deposits compared to the rate of new discoveries and additions to reserves.

New Mexico has 47 percent of domestic reserves in the $30-per-lb U_3O_8 cost category as of January 1, 1981, compared to 52 percent as of January 1, 1980. The domestic share of reserves in the $100-per-lb U_3O_8 cost category has also declined substantially with New Mexico holding 40 percent compared to 46 percent the previous year. The number of properties where reserves occur in New Mexico has declined for all three cost categories. Although figures for the location of reserves by county are not available, McKinley and Cibola Counties are known to possess the bulk of New Mexico reserves. Higher cost reserves are clustered in deposits in the Crownpoint-Nose Rock area of McKinley County and the Mount Taylor and Marquez areas of Cibola County. Lower cost reserves occur around older, developed deposits in the Church Rock, Smith Lake, and Ambrosia Lake mining districts in McKinley County, as well as in the Ambrosia Lake and San Mateo areas in Cibola County. Table 9 shows reserves in New Mexico by mineral ownership within cost categories. Reserves on privately owned (fee) mineral lands account for more than 50 percent of reserves in all three cost categories, federal ownership approximately 22 percent, Indian ownership less than 20 percent, and state mineral lands only 2 percent.

Inventories of New Mexico uranium for 1979 and 1980 are compared in table 10. Inventoried uranium, which is derived from company drill data, is a compilation of tonnages of U_3O_8 estimated to occur within

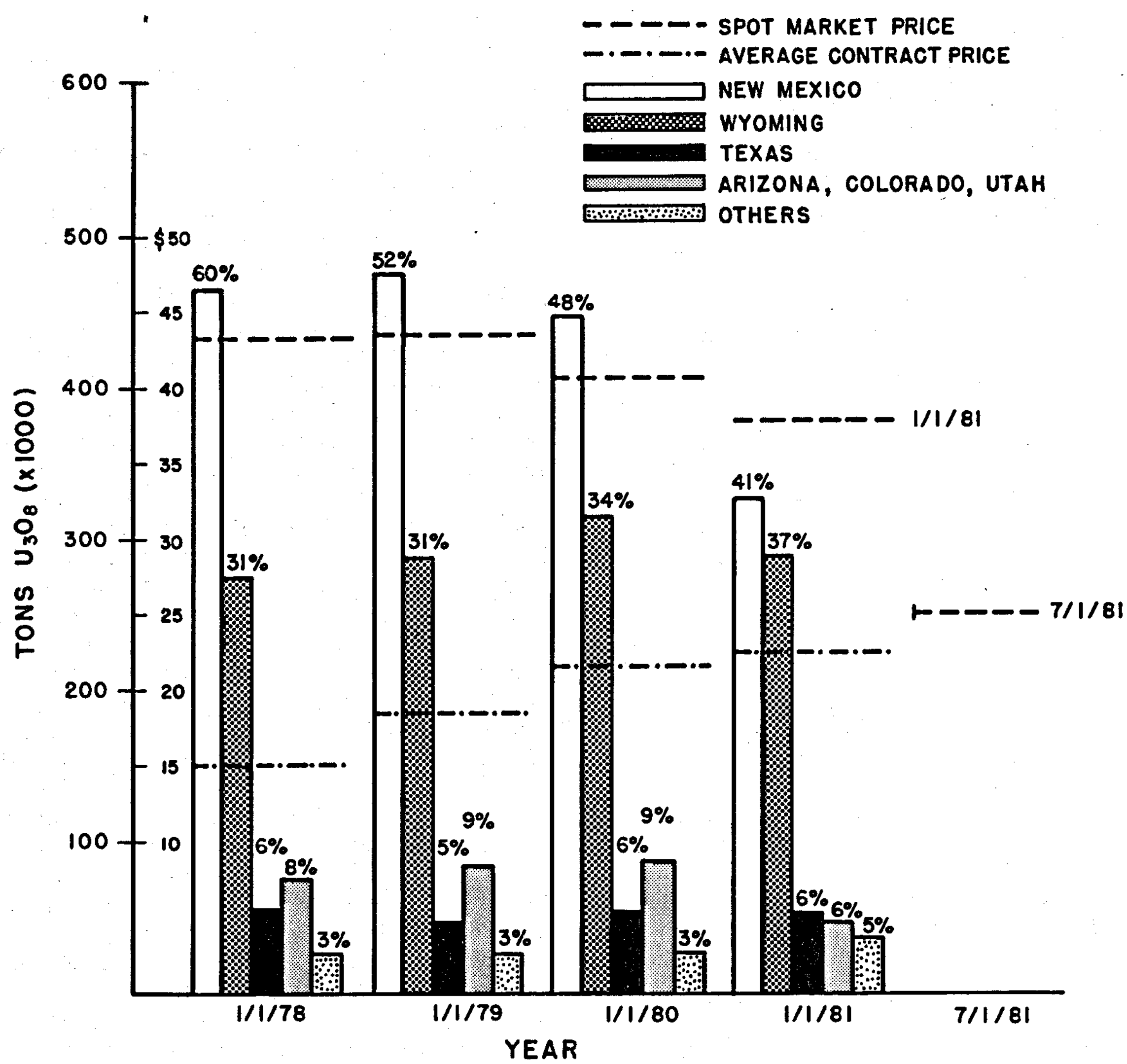

FIGURE 12—U_3O_8 RESERVES IN NEW MEXICO AND OTHER STATES IN THE $50 PER LB COST CATEGORY, JANUARY 1, 1978 TO JANUARY 1, 1981 (U.S. Department of Energy, 1981c).

minimum ore grade limits and minable thicknesses. Inventories are not the same as reserves since the economics of production are not taken into consideration. When differentiated as preproduction and postproduction, inventories are a good measure of the distribution of uranium available within precise grade tonnage categories. Preproduction inventories include in-place grade tonnages prior to January of each year. Postproduction inventories reflect distributions after production.

Table 11 shows potential uranium resources in New Mexico according to cost category, physiographic province, and resource reliability as of January 1, 1981 with a map of provinces in the state shown in fig. 13. Resources are less finite than reserves and are defined as potential quantities of U_3O_8 contained within inferred deposits that are assigned limits of reliability within forward-cost categories. Potential resources are divided into three classes of reliability: Probable, possible, and speculative. Probable resources are extensions of known deposits. Possible resources are those estimated to occur within geologic environments similar to those hosting known and productive deposits. Speculative resources are those estimated to occur in unexplored geologic settings not previously productive. Potential resources can be categorized in a manner similar to reserves with each cost category including quantities from lower cost categories; and resources may be converted to reserves as exploration, economics, and technology permit. Potential uranium resource estimates declined substantially in 1980 as more resources have been converted to reserves. In the $50-per-lb forward-cost category, probable resources as of January 1, 1981 were 332,900 tons U_3O_8, compared to 549,500 tons U_3O_8 as of January 1, 1980; possible resources in this category dropped from

TABLE 9—NEW MEXICO URANIUM RESERVES BY MINERAL OWNERSHIP AND FORWARD-COST CATEGORY AS OF JANUARY 1, 1981. Private ownership includes patented and homestead with no mineral rights reserved, land grants, and railroad lands; federal ownership includes unpatented, homestead with mineral rights reserved, and Atomic Energy Commission withdrawn lands (data from U.S. Department of Energy, personal communication, August 1981).

	Reserves (tons U_3O_8)		
Mineral Ownership	$30/lb.	$50/lb.	$100/lb.
Fee (Private)	135,100	193,400	234,200
Federal	48,000	70,800	96,700
State	4,800	6,700	8,900
Indian	33,400	53,900	76,800
Total	221,300	324,800	416,600

TABLE 10—COMPARISON OF 1979 AND 1980 PREPRODUCTION AND POSTPRODUCTION IN NEW MEXICO URANIUM INVENTORY. Uranium inventories are not the same as reserves, since the economics of exploitation and mineability are not considered. 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 at year's end (U.S. Department of Energy, 1978, 1979b, 1980a, 1981b).

PREPRODUCTION

Minimum Grade (% U_3O_8)	Cumulative Tons of Ore (millions) 1979	1980	Avg. Grade % of Cumulative Tons 1979	1980	Cumulative Tons U_3O_8 (thousands) 1979	1980
0.01	1317	1308	0.06	0.06	792	783
0.02	979	968	.08	.08	744	735
0.03	715	704	.10	.10	683	674
0.04	546	536	.12	.12	626	618
0.05	432	424	.13	.13	577	569
0.06	352	345	.15	.15	534	527
0.07	293	287	.17	.17	497	491
0.08	247	242	.19	.19	464	458
0.09	212	207	.21	.21	435	430
0.10	183	180	.22	.23	408	404
0.11	160	157	.24	.24	384	381
0.12	140	138	.26	.26	362	359
0.13	124	132	.27	.28	341	338
0.14	111	104	.29	.30	323	321
0.15	99	98	.31	.31	306	305
0.16	89	88	.33	.33	291	290
0.17	80	80	.34	.35	276	276
0.18	73	72	.36	.36	263	263
0.19	67	66	.38	.38	252	253
0.20	61	61	.40	.40	241	242

POSTPRODUCTION

Minimum Grade (% U_3O_8)	Cumulative Tons of Ore (millions) 1979	1980	Avg. Grade % of Cumulative Tons 1979	1980	Cumulative Tons U_3O_8 (thousands) 1979	1980
0.01	1124	875	0.06	0.06	648	524
0.02	906	648	.08	.08	600	492
0.03	642	471	.10	.10	539	451
0.04	473	359	.12	.12	482	413
0.05	360	284	.13	.13	433	381
0.06	280	231	.15	.15	390	353
0.07	220	192	.17	.17	353	328
0.08	175	162	.19	.19	320	306
0.09	150	139	.21	.21	300	287
0.10	130	120	.22	.23	281	270
0.11	113	105	.24	.24	265	255
0.12	99	92	.26	.26	250	240
0.13	88	82	.27	.28	235	227
0.14	78	73	.29	.30	222	245
0.15	70	65	.31	.31	211	204
0.16	63	59	.33	.33	201	194
0.17	57	53	.34	.35	191	185
0.18	51	48	.36	.36	182	176
0.19	47	44	.38	.38	174	169
0.20	43	41	.40	.40	166	162

440,000 tons U_3O_8 in 1980 to 248,810 tons U_3O_8 in 1981. Speculative resources, however, increased from an estimated 200 tons U_3O_8 in 1980 to 1,030 tons U_3O_8 as of January 1, 1981.

As shown in table 11, the Colorado Plateau contains the bulk of estimated probable and possible resources. The Great Plains and Basin and Range provinces, however, contain more speculative resources. Uranium resources are distributed primarily among three of New Mexico's four physiographic provinces. The most important region of potential uranium resources is the San Juan Basin in the Colorado Plateau province where Jurassic sandstones within the Morrison Formation and limestones within the Todilto Limestone are the principal hosts. Some additional potential exists in sandstones of Late Cretaceous, Early Tertiary, and other Jurassic units (table 4). The high estimates for resource reliability in the Colorado Plateau province reflect the degree of exploration activity and geologic knowledge of the San Juan Basin. San Juan, McKinley, and Cibola Counties lie within the Colorado Plateau province as do parts of Rio Arriba, Sandoval, Socorro, and Catron Counties. Although the Great Plains province of eastern New Mexico has many geologic and stratigraphic similarities to the Colorado Plateau, which is a region that has been most favorable for the occurrence of large deposits of uranium, the Great Plains province has received only limited attention. Minor occurrences in the Chinle Formation of Late Triassic age have resulted in the recording of past production of a few hundred tons of ore. Structural basins around Raton, Las Vegas, and Tucumcari are potential settings for additional resources in the Great Plains province. Potential resources also occur in the Basin and Range province of New Mexico to the south and southwest of Albuquerque, but extremely variable geology and insufficiently understood uranium environments in igneous rocks tend to lower the reliability of potential resources. Early Tertiary sandstones of intermontane basins in the northern part of the province between Albuquerque and Santa Fe, however, are somewhat favorable environments due to a limited occurrence of low-grade deposits. The principal counties of the Basin and Range province are Torrance, Bernalillo, and Socorro Counties in the northern part of the province and Hidalgo, Luna, Doña Ana, Otero, Sierra, and Grant Counties in the southern part. Potential uranium resources are thought to occur

TABLE 11—U_3O_8 RESOURCES BY PROVINCE, RELIABILITY, AND COST CATEGORY IN NEW MEXICO. See figure 13 for map of provinces. Resource figures are as of January 1, 1981 (data from U.S. Department of Energy, personal communication, June 1981).

	$/lb U_3O_8 Cost Categories	Physiographic Province: Southern Basin & Range	SE Basin & Range	Colorado Plateau	New Mexico Rocky Mtns.	Great Plains
Probable	30	-	1,860	166,340	-	-
	50	-	4,000	332,900	-	-
	100	-	6,530	514,190	-	-
Possible	30	-	30	111,540	-	-
	50	-	30	248,810	-	-
	100	-	40	426,410	-	-
Speculative	30	290	3,740	510	-	29,210
	50	740	7,240	1,030	-	53,880
	100	1,100	11,320	1,760	-	80,420

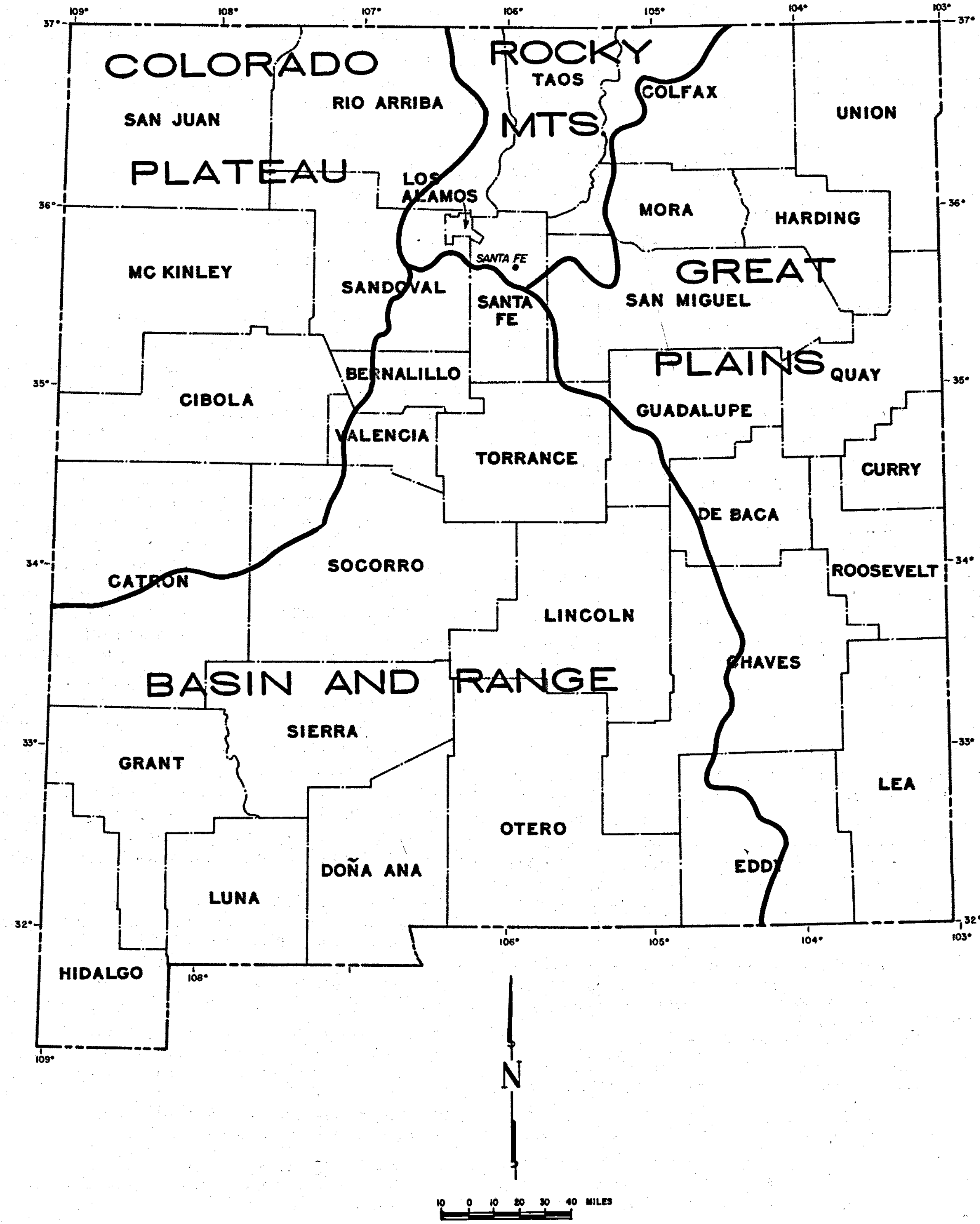

FIGURE 13—MAP OF PHYSIOGRAPHIC PROVINCES IN NEW MEXICO (New Mexico Bureau of Geology, 1981).

in the New Mexico Rocky Mountains, as they do further north in Colorado, but there has been insufficient exploration and research to estimate quantities of resources. Poor access; restrictive mineral ownership patterns among land grants, wilderness areas, and national forests; and the complex geology of the area are factors partly responsible for the failure to delineate potential uranium resources in this province. The Rocky Mountains province in New Mexico encompasses Taos, Los Alamos, and parts of Santa Fe, Sandoval, Rio Arriba, Colfax, San Miguel, and Mora Counties.

Table 12 shows potential uranium resources in New Mexico according to mineral ownership in the \$30-per-lb, \$50-per-lb, and \$100-per-lb cost categories as of January 1, 1981. The greatest share of resources is found on private (fee) lands with 147,000 tons U_3O_8 or 44 percent of the \$50-per-lb cost category. Resources on Indian lands comprise 25 percent of estimated tonnage in the \$50-per-lb category with 21 percent on federal lands, 6 percent withdrawn, and 4 percent on state lands.

Drilling and production costs

The U.S. Department of Energy estimates drilling costs overall averaged \$4.46 per ft drilled during 1980. Exploration drilling costs averaged \$4.84 per ft nationally and development drilling costs \$3.60 per ft. Exploration and development drilling costs vary greatly according to drill depths, type of drilling, and rock type. Drilling costs have escalated both nationally and in New Mexico, although costs generally run higher in New Mexico than in other states due to greater depths of deposits and technical and geologic aspects unique to New Mexico. The New Mexico Bureau of Geology estimated that New Mexico drill costs averaged \$4.02 per ft during 1979 (New Mexico Energy and Minerals Department, 1981).

Production costs have risen also in response to inflationary pressures and the demands of higher cost environmental, safety, and production standards. In New Mexico, 75 percent of all production is underground, and 80 percent of that production occurs at depths between 800-1,000 ft. As a result, production costs are higher in New Mexico than in Wyoming where most production is from open pit mines less than 300 ft in depth. Production in Texas is also less costly than in New Mexico since production comes primarily from in situ leaching, a high technology chemical method that does not require the techniques, equipment, or personnel of rock mining. Production costs per pound of U_3O_8 recovered from ore in New Mexico for 1979 and 1980 have been calculated by the New Mexico Mining Association (Jacobsen, 1980) and can be compared to average contract and spot market sales prices as follows:

End of year average	1979	1980
Cost per lb U_3O_8 (New Mexico)	\$29.83	\$35.50
Sales price (New Mexico)	24.27	25.41
Contract price per lb U_3O_8 (United States)	20.15	28.16
Spot market price per lb U_3O_8 (United States)	40.75	28.00

Taxation and revenues

Uranium production is a significant source of severance and excise tax revenues for the State of New Mexico. Even though the uranium mining industry is experiencing a recessionary cycle, revenues to New Mexico in 1980 exceeded \$20 million, compared to \$16 million in 1979. Table 13 shows detailed severance and resource excise tax collections in New Mexico between 1974 and 1980. Uranium severance taxes are imposed for the privilege of severing an irreplaceable natural energy resource. New Mexico uranium severance tax proceeds are allocated to a severance tax bonding fund with the tax revenues pledged to pay the principal and interest on the bonds. Severance tax bonds are issued for the purpose of financing road construction and other capital improvements to energy impacted areas. Revenues not commited to outstanding bonds are deposited in a severance tax permanent fund. The point of severance or taxable event in New Mexico is considered to be the sale of U_3O_8 as concentrate. A resource excise tax is imposed on the severing and processing of uranium in New Mexico at the rate of 25 percent of taxable value. Revenues are deposited in the Oil and Gas Accounting Commission Conservation Tax Fund. The State of New Mexico's General Fund receives 7 percent of each month's

TABLE 12—DISTRIBUTION OF POTENTIAL URANIUM RESOURCES IN NEW MEXICO BY MINERAL OWNERSHIP AND FORWARD-COST CATEGORY AS OF JANUARY 1, 1981 (data from U.S. Department of Energy, personal communication, June 1981).

	\$/lb U_3O_8 Cost Categories	Mineral Ownership Category: State	Indian	Fee	Federal	Withdrawn & Others
Probable	30	6,940	41,770	74,060	35,880	9,540
	50	14,190	85,150	146,950	70,620	19,990
	100	22,070	134,710	225,550	107,050	31,710
Possible	30	3,710	99,140	53,780	21,590	3,300
	50	8,130	69,720	114,340	48,900	7,750
	100	13,750	126,090	189,300	85,660	13,650
Speculative	30	330	440	29,150	3,270	560
	50	630	870	54,040	6,310	1,020
	100	980	1,430	80,970	9,700	1,520

TABLE 13—URANIUM SEVERANCE AND EXCISE TAX COLLECTIONS IN NEW MEXICO, 1974–1980 (New Mexico Taxation and Revenue Department, personal communication, May 1981).

Calendar Year	Quantity (Lbs.U_3O_8)	Price	Gross Value	Deductions	Taxable Value	Tax Due
1980	14,482,995	25.62	371,017,915	- 0 -	371,017,915	17,215,585
1979	15,306,368	24.21	370,502,077	- 0 -	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
			RESOURCE EXCISE TAX			
1980	15,341,089	25.20	386,558,451	8,266,465	378,291,986	2,841,245
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

TABLE 14—GRADUATED URANIUM SEVERANCE TAX SCHEDULE (New Mexico Statutes Annotated, 1978b).

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

previous collections. The Oil and Gas Reclamation Fund is credited with all unencumbered balances monthly at the rate of 1/100 of 1 percent, and the remainder is appropriated by the New Mexico Energy and Minerals Department (New Mexico Taxation and Revenue Department, 1979). The severance tax rate schedule is shown in table 14. Through an act of the 35th Legislature, a bill was passed in 1981 to reduce temporarily the taxable value of severed uranium from 100 percent to 60 percent of the sales price per pound of U_3O_8. After June 30, 1984, the full sales price per pound

TABLE 15—SEVERANCE TAX RATES FOR NEW MEXICO AND OTHER STATES (Blackstone, 1980).

State	Tax amount ($)	$/lb U_3O_8	% of producers gross income	Rank
New Mexico	$1,717,500	$1.99	5.7	1
Wyoming	515,625	0.69	1.7	2
Utah	209,500	0.28	0.7	3
Colorado	112,500	0.15	0.4	4

of U_3O_8 will be taxed according to the tax rate schedule shown in table 14.

Table 15 shows a comparison of New Mexico's uranium severance tax rates with other states. New Mexico ranks first among the four states shown in the amount taxed per pound of U_3O_8 and first in the percentage of gross income derived from such taxation among the uranium-producing states (Blackstone, 1980). The tax rates for New Mexico and three adjacent states is as follows:

State	Tax rate
New Mexico	$1.99 per lb U_3O_8 valued at $40 per lb plus 0.75 percent of gross value
Wyoming	5.5 percent of gross value only
Utah	1 percent of gross value over $50,000
Colorado	2.25 percent of gross income over $11 million, up to 50 percent credit for property taxes

Oil and gas

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

Oil production

Although New Mexico's annual condensate production has been increasing over the past 4 yrs, crude oil production has been declining by an average of approximately 4 million bbls (barrels) a year since 1976. The period of greatest decline in total oil and condensate production, however, came in the years 1970 through 1973 when crude oil production was declining by an average of almost 9 million bbls a year. Oil production in New Mexico has been steadily declining since the peak year of 1969, and forecasts call for increasing rates of decline in the years ahead since production from the state's largest oil-producing pool has substantially declined and no new large oil discoveries have been made. Production within the state would have continued at the same rate of decline after 1973 had it not been for increased drilling and development in recent years, increased production from smaller pools, and the completion of marginal wells. Despite declining oil production, New Mexico is ranked seventh in the nation in the production of crude oil. New Mexico has produced 2,154,890,686 bbls of crude oil and 94,915,247 bbls of condensate in the past 21 yrs.

New Mexico's total crude and condensate production in 1980 amounted to 75,323,665 bbls compared to 79,648,713 bbls in 1979. The decline in production of 4,325,048 bbls in 1980 represented a decrease of 5.4 percent from 1979. By comparison, total production in 1979 represented a decline of 3,716,112 bbls or a 4.7 percent decrease from 1978. Table 16 shows the production of oil and natural gas in New Mexico from 1962 through 1980 with a breakdown of production from the northwest and southeast regions of the state. Fig. 14 portrays an historical graph of crude oil and condensate production in New Mexico over a 20-yr period showing the production trends for the northwest and southeast regions.

New Mexico's crude oil production in 1980 was 69,948,636 bbls, which was 4,701,692 bbls or 6.3 percent less than production in 1979. Production in 1980 decreased from both the northwest and southeast regions. Condensate production, however, increased by 376,644 bbls in 1980, an increase of 7 percent from 1979 production with increases coming from both regions. Condensate production was 5,375,029 bbls in 1980 compared with 4,998,385 bbls in 1979, 4,616,007 bbls in 1978, and 4,606,556 bbls in 1977. Table 17 compares 1979 and 1980 crude oil and condensate production in New Mexico showing increases and decreases in production from the northwest and southeast. Crude and condensate production for the first quarter of 1981 amounted to 23,885,089 bbls compared to 25,843,327 bbls for the first quarter of 1980, representing a decrease of 7.6 percent.

New Mexico's annual crude oil and condensate production followed an upward trend from 1960 until production peaked in 1969. Production in 1960 was 107,365,148 bbls with 86 percent coming from the four southeastern counties. The remaining 14 percent of 1960 production came from the four northwestern counties. Production in 1969 reached a high of 129,226,861 bbls with 93 percent of production coming from the southeast region and only 7 percent from the northwest. During this period, production increased annually in the southeast and, except for 1964 and 1965, decreased in the northwest. Since 1970, however, production has been declining dramatically in the southeast and somewhat less in the northwest. New Mexico's crude and condensate production in 1980 was 42 percent less than the peak production year of 1969.

Over 90 percent of New Mexico's oil production comes from the Permian and Delaware Basins of southeast New Mexico. The remainder of the state's oil production comes from the San Juan Basin in northwest New Mexico. According to the New Mexico Employment Security Department, 13,400 persons were employed in the oil and gas extraction industry in New Mexico in 1980 compared with 10,800 employed in 1979, which was an increase of 2,600 employees.

Southeast New Mexico

Southeast New Mexico accounted for 91.1 percent of the state's total crude oil and condensate production in 1980 with the production of 69,212,232 bbls. Crude oil production from the four counties in this region, Lea, Eddy, Chaves, and Roosevelt Counties, amounted to 66,083,909 bbls in 1980 and represented a decline of 6.4 percent from 1979 production. Condensate production, however, was 3,128,323 bbls in 1980, representing an increase of 8.95 percent from 1979 production. Table 18 shows combined crude oil and condensate production by county in 1980. Lea and Eddy Counties in the southeast account for most of the production in New Mexico and together produced 87 percent of total state production compared to 87.5 percent in 1979. Production from Lea County with 65.8 percent of state production was 49,535,060 bbls compared with 49,805,509 bbls and 62.4 percent of production in 1979. Lea County's share of state production increased despite a decline in production of 270,449 bbls because of a substantial decline in production in Eddy County. Production in Eddy County in 1980 was 15,996,147 bbls or 21.2 percent of state production compared to 20,032,723 bbls or 25.1 percent of production in 1979. The decline of 4,036,576 bbls in Eddy County in 1980 was primarily due to lower production from New Mexico's largest oil-producing pool, the Empire Abo Pool, where production in 1980 declined by 3,741,365 bbls. Declining production from the Empire Abo Pool was also a significant share of the decline in 1980 production of 4,522,364 bbls from the southeast region as a whole. Production from the Empire Abo Pool reached a peak in 1976 with 15.3 million bbls produced and then declined to a production of 14.4 million bbls in 1978, 12.7 million bbls in 1979, and 9.0 million bbls in 1980.

TABLE 16—PRODUCTION OF OIL AND NATURAL GAS IN NEW MEXICO, 1962 THROUGH 1980 (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
NW	3,864,727	2,246,706	6,111,433	44,915,908	16,758,542	549,605,036	566,363,578
SE	66,083,909	3,128,323	69,212,232	237,812,516	213,455,871	352,496,795	565,952,666
1980, total	69,948,636	5,375,029	75,323,665	282,728,424	230,214,413	902,101,831	1,132,316,244

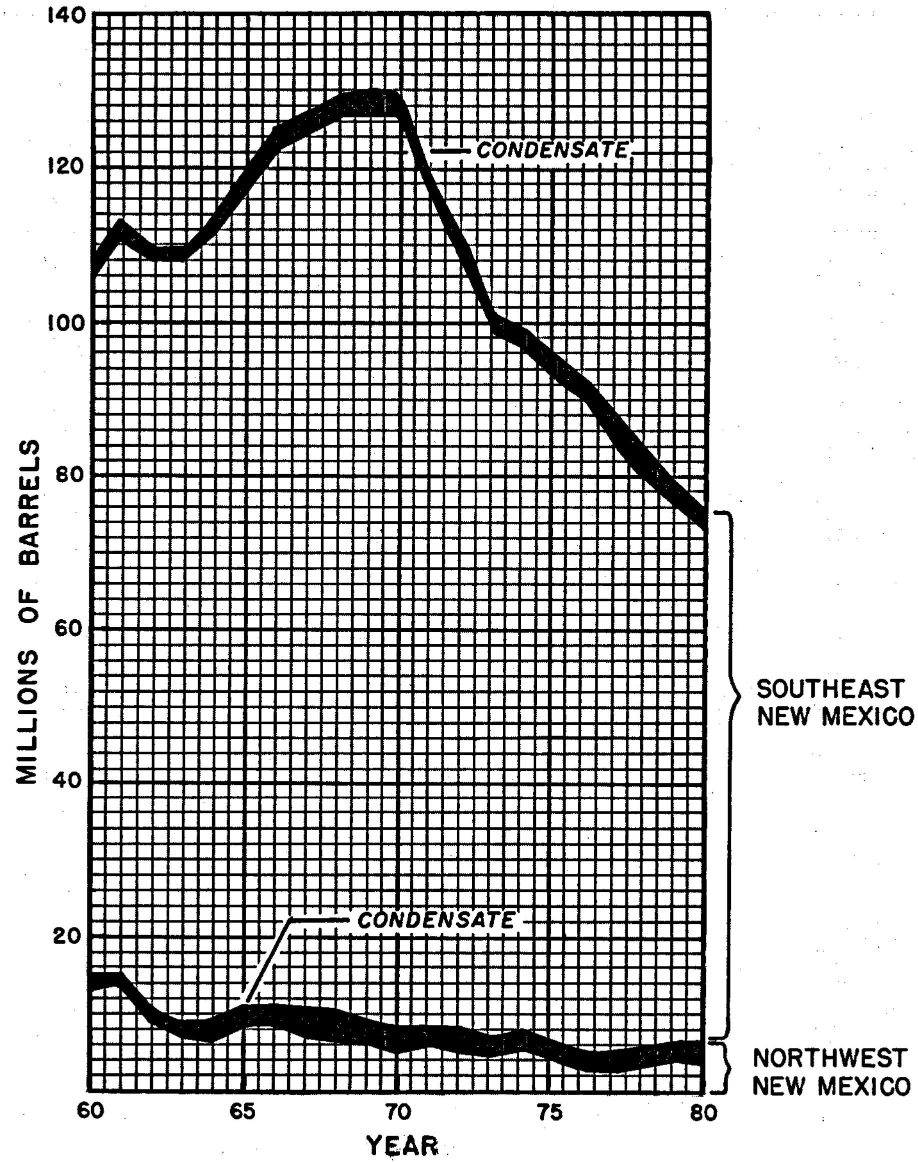

FIGURE 14—PRODUCTION OF CRUDE OIL AND CONDENSATE IN SOUTHEAST AND NORTHWEST NEW MEXICO, 1960 THROUGH 1980 (data from New Mexico Oil Conservation Division).

TABLE 17—COMPARISON OF 1979 AND 1980 OIL PRODUCTION IN NEW MEXICO (data from New Mexico Oil Conservation Division).

	Oil production (bbls)			
	1979	1980	Increase	Decrease
Crude oil				
Southeast	70,606,273	66,083,909		4,522,364
Northwest	4,044,055	3,864,727		179,328
Total	74,650,328	69,948,636		4,701,692
Condensate				
Southeast	2,848,172	3,128,323	280,151	
Northwest	2,150,213	2,246,706	96,493	
Total	4,998,385	5,375,029	376,644	

TABLE 18—NEW MEXICO CRUDE OIL AND CONDENSATE PRODUCTION FOR 1980 RANKED BY COUNTY (data from New Mexico Oil Conservation Division).

Rank	County	Location	Bbls	Percent of total state production
1	Lea	SE	49,535,060	65.8
2	Eddy	SE	15,996,147	21.2
3	San Juan	NW	2,740,038	3.6
4	Chaves	SE	2,158,238	2.9
5	Rio Arriba	NW	2,090,343	2.8
6	Roosevelt	SE	1,522,787	2.0
7	McKinley	NW	912,053	1.2
8	Sandoval	NW	368,999	0.5
Total state crude oil and condensate production			75,323,665	100.0

Although production from New Mexico's largest pool declined significantly in 1980, crude oil production from other sources in southeast New Mexico declined by only 780,999 bbls from 1979. Crude oil production in 1980 in southeast New Mexico excluding production from the Empire Abo Pool was 57,084,166 bbls compared to 57,865,165 bbls in 1979. This less significant decline has been due to the most extensive drilling activity in New Mexico's history; higher completion rates; and more oil produced from infill wells, oil and gas extensions, and new discoveries in older pools during 1980. Production levels in several pools are increasing due to a favorable response from water or gas injection wells that have been drilled in the last few years. The southeast's Chaves County, which had ranked fifth in the state in total oil production in 1979, increased production in 1980 and became the fourth ranking county in production, exchanging positions with the northwest's Rio Arriba County. Production from Roosevelt County, however, declined slightly from the previous year.

Total southeast oil production in the first quarter of 1981 amounted to 17,983,322 bbls, representing a decline of 7.86 percent compared to the first quarter of 1980. Crude oil production was 16,608,771 bbls, declining 8.35 percent from the first quarter of 1980, and condensate production was 1,374,551 bbls, declining 1.34 percent. As of January 1, 1980, there were 19,422 oil wells in southeast New Mexico, which included 3,180 input wells and 2,260 temporarily abandoned and shut-in wells. As of January 1, 1981, there were 19,854 oil wells in southeast New Mexico or an increase of 432 wells from the previous year, which included 3,208 input wells and 2,629 temporarily abandoned and shut-in wells.

Northwest New Mexico

Northwest New Mexico's San Juan Basin is primarily a gas rather than an oil province. The northwest region comprising Rio Arriba, San Juan, McKinley, and Sandoval Counties contributed only 8.1 percent of total crude oil and condensate production in 1980. The region produced only 5.5 percent of the state's crude oil but almost 42 percent of condensate production. Although production of crude oil in northwest New Mexico increased by almost 3 percent from 3,929,717 bbls in 1978 to 4,044,055 bbls in 1979, production decreased to 3,864,727 bbls in 1980 or 179,328 bbls less than 1979 and 64,990 bbls less than 1978. A comparison of 1978, 1979, and 1980 production of crude oil in the four northwestern counties is shown below.

	Crude oil (bbls)		
County	1978	1979	1980
Rio Arriba	1,080,779	1,485,318	1,485,344
San Juan	1,323,499	1,126,256	1,098,331
McKinley	1,159,301	1,074,328	912,053
Sandoval	366,138	358,153	368,999
Total	3,929,717	4,044,055	3,864,727

The northwest county with the greatest decrease in crude oil production in 1980 was McKinley County, which produced 162,275 bbls less than in 1979. San Juan County also had a decrease in production, producing 27,925 bbls less than the previous year. Rio Arriba County's crude oil production, however, was only 1,974 bbls less than 1979, and Sandoval County produced 10,846 bbls more in 1980 than in 1979.

Condensate production from the northwest amounted to 2,246,706 bbls in 1980. Although only Rio Arriba and San Juan Counties reported condensate production in 1980, production increased by 96,493 bbls compared to the previous year's production. Condensate production for 1979 and 1980 in the northwest is shown below.

	Condensate production (bbls)	
County	1979	1980
San Juan	1,574,610	1,641,707
Rio Arriba	575,481	604,999
Sandoval	122	—
McKinley	—	—
Total	2,150,213	2,246,706

Crude oil production for the first quarter of 1981 in the northwest was 1,278,443 bbls, reflecting an increase of 2.55 percent compared to the first quarter of 1980. Condensate production for the first quarter of 1981 was 867,996 bbls. By the end of 1980, there were 2,239 oil wells in northwest New Mexico of which 619 were temporarily abandoned or shut-in wells. This total compared with 2,104 oil wells in the northwest at the end of 1979 which included 363 injection wells and 426 temporarily abandoned or shut-in wells. The number of wells increased in 1980 by 135 oil wells from 1979.

Gas production

Although total natural gas production in New Mexico declined from the previous year, 1980 was the 15th consecutive year that production has exceeded 1 trillion cu ft. Total 1980 gas production of 1,132,316,244 thousand cu ft, however, was the lowest since 1970 when production was 1,123,455,194 thousand cu ft. Production in New Mexico from 1966 through 1980 amounted to 17,272,815,774 thousand cu ft for an average of 1.15 trillion cu ft a year. Total gas production in 1980 declined from 1979 production by 30,397,441 thousand cu ft, representing a decline of 2.61 percent. Although total gas production increased in northwest New Mexico, production declined significantly in southeast New Mexico due to an 8 percent decline in dry gas production in Eddy County and an 8.8 percent decline in casinghead gas production in Lea County. Both casinghead and dry gas production declined in New Mexico in 1980 with casinghead gas production of 230,214,413 thousand cu ft in 1980 compared to 245,558,095 thousand cu ft in 1979, and dry gas production of 902,101,831 thousand cu ft in 1980 compared to 917,155,590 thousand cu ft in 1979. Table 19 shows a comparison of 1980 and 1979 gas production with increases and decreases in production. Fig. 15 compares natural gas production from 1960 through 1980 in southeast New Mexico, which includes Chaves, Eddy, Lea, and Roosevelt Counties, and northwest New Mexico, which includes McKinley, Rio Arriba, San Juan, and Sandoval Counties.

TABLE 19—COMPARISON OF 1979 AND 1980 GAS PRODUCTION IN NEW MEXICO (data from New Mexico Oil Conservation Division).

	Gas production (thousand cu ft)			
	1979	1980	Increases	Decreases
Dry				
Southeast	367,157,004	352,496,795		14,660,209
Northwest	549,998,586	549,605,036		393,550
Total	917,155,590	902,101,831		15,053,759
Casinghead				
Southeast	231,337,158	213,455,871		17,881,287
Northwest	14,220,937	16,758,542	2,537,605	
Total	245,558,095	230,214,413		15,343,682
Total gas				
Southeast	598,494,162	565,952,666		32,541,496
Northwest	564,219,523	566,363,578	2,144,055	
Total	1,162,713,685	1,132,316,244		30,397,441

Southeast New Mexico

Natural gas production in southeast New Mexico in 1980 was 565,952,666 thousand cu ft compared to 598,494,162 thousand cu ft in 1979, representing a decline of 5.44 percent. Of the total 1980 gas production in the southeast, dry gas production was 352,496,795 thousand cu ft or a 3.99 percent decline from 1979, and casinghead gas production was 213,455,871 thousand cu ft or a 7.73 percent decline. Casinghead gas production has been declining steadily since 1975 when production was 291,662,510 thousand cu ft. Dry gas production has declined since 1976 when production reached a peak of 403,395,146 thousand cu ft. An additional 12,800,172 thousand cu ft of casinghead gas was produced in 1980 but was reinjected and used in pressure maintenance projects.

Formations within the Pennsylvanian System, particularly the Morrow Formation, continued to be the favorite targets of companies drilling for natural gas in New Mexico. The most significant production increases

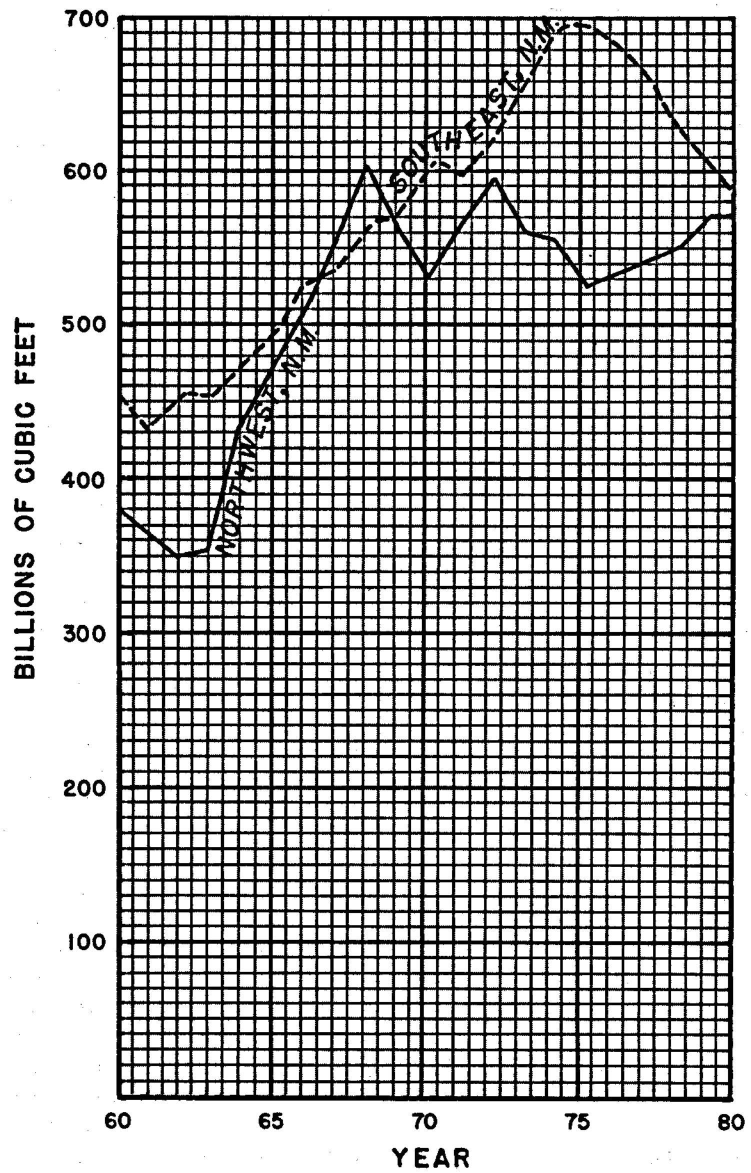

FIGURE 15—PRODUCTION OF NATURAL GAS IN SOUTHEAST AND NORTHWEST NEW MEXICO, 1960 THROUGH 1980 (data from New Mexico Oil Conservation Division).

in 1980 compared to the previous year came from 30 gas pools, and 22 of these were producing from Pennsylvanian formations. The 30 gas pools having the largest production declines, however, included 23 pools also producing from Pennsylvanian formation. Total gas production from southeast New Mexico for the first quarter of 1981 amounted to 138,988,183 thousand cu ft, a decline of 4.7 percent from the first quarter of 1980. Dry gas production was 89,411,899 thousand cu ft and casinghead gas production was 49,576,284 thousand cu ft of the total gas production. In the first quarter of 1981, dry gas production declined by 2.24 percent in southeast New Mexico and casinghead gas production declined by 8.85 percent compared to the first quarter of 1980. Fig. 16 shows the production of dry gas and casinghead gas in southeast New Mexico from 1960 through 1980.

Northwest New Mexico

In 1980, natural gas production for northwest New Mexico was 566,363,578 thousand cu ft, an increase of 2,144,055 thousand cu ft over production in 1979. Although dry gas production declined by 393,550 thousand cu ft from the previous year, casinghead gas production increased by 2,537,605 thousand cu ft, the most substantial increase from one year to the next in over 20 years. Casinghead gas production of 16,758,452 thousand cu ft was also the greatest amount produced since 1965 when production was 18,467,730 thousand cu ft. Production, however, has declined considerably since the 39,954,895 thousand cu ft produced in 1961. Although 1980 dry gas production of 549,605,036 thousand cu ft represented a decline from the previous year, it was still greater than any previous year with the exceptions of 1968 and 1972.

Fig. 17 shows the distribution of dry gas production by gas pools in northwest New Mexico in 1980. A significant proportion of northwest production comes from two of the 97 gas pools in the San Juan Basin, with 53 percent of 1980 production coming from the Blanco Mesaverde Gas Pool, 25 percent from the Basin Dakota Gas Pool, and 22 percent from the remaining 95 gas

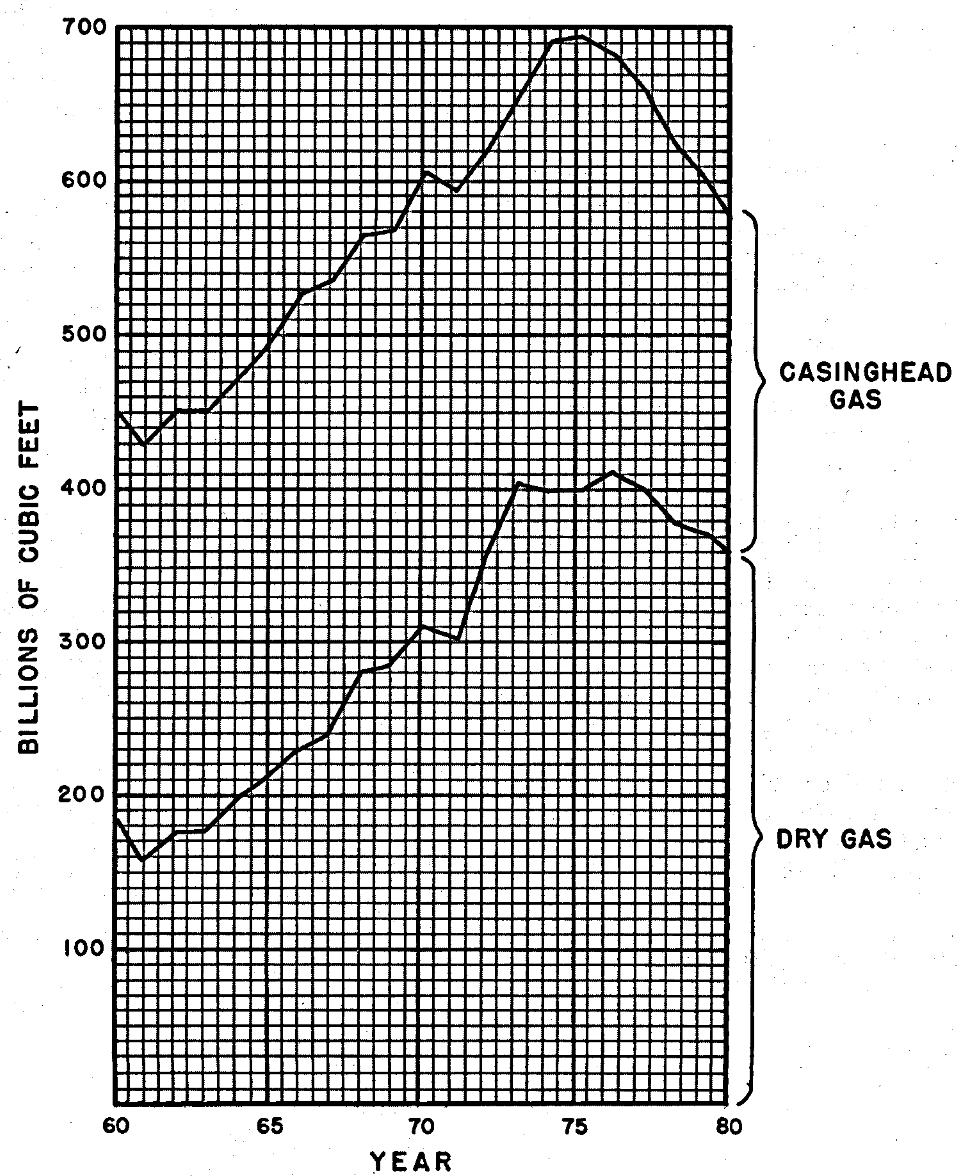

FIGURE 16—PRODUCTION OF NATURAL GAS IN SOUTHEAST NEW MEXICO, 1960 THROUGH 1980 (data from New Mexico Oil Conservation Division).

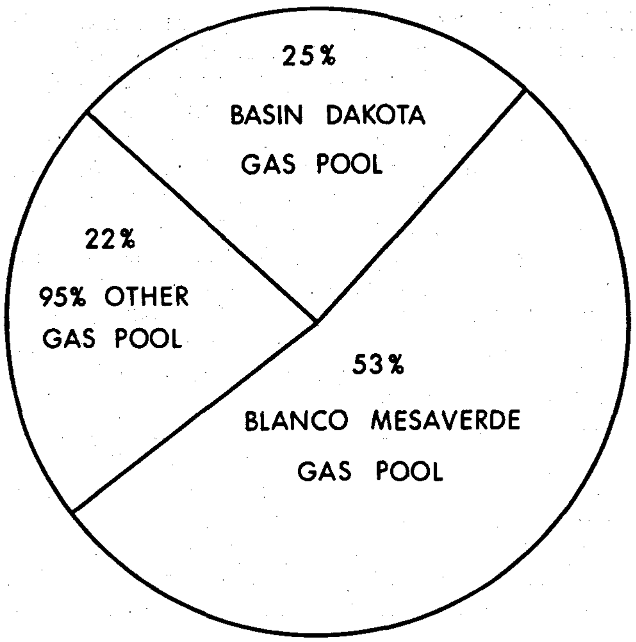

FIGURE 17—DISTRIBUTION OF DRY GAS PRODUCTION IN NORTHWEST NEW MEXICO BY POOL, 1980 (data from New Mexico Oil Conservation Division).

pools. Over 67 percent of the 1980 natural gas production in northwest New Mexico came from San Juan County, with another 32 percent produced in Rio Arriba County. Rio Arriba County led the four northwest counties in casinghead gas production with 75 percent of total production. Table 20 shows 1980 production of natural gas from the four northwest counties.

The production of natural gas in northwest New Mexico from 1960 through 1980 is shown in fig. 18. Casinghead gas production has contributed a small share of total natural gas production in northwest New Mexico with a cumulative production of 368.9 billion cu ft for the 20-yr period, which represented only 4 percent of the total gas produced during those years. Dry gas production for the same 20-yr period was 10.1 trillion cu ft. In the period from 1960-62, total annual production declined from 373.4 billion cu ft in 1960 to 340.8 billion cu ft in 1962, but from 1963 to the peak production year of 1968, annual production increased at a steep rate until reaching production of 593.5 billion cu ft in 1968. Annual production has fluctuated between 518 and 586 billion cu ft since 1967. There have been increases in production each year since 1974, however, and 1980 total gas production in northwest New Mexico was the third highest annual production in the history of the San Juan Basin gas industry. In 1979, there were 11,025 gas wells in northwest New Mexico, which included 247 temporarily abandoned or shut-in wells. By the end of 1980, there were 11,769 gas wells or an increase of 744 wells in northwest New Mexico, which included 367 temporarily abandoned or shut-in wells.

TABLE 20—PRODUCTION OF NATURAL GAS IN NORTHWEST NEW MEXICO IN 1980 (data from New Mexico Oil Conservation Division).

	Production (thousand cu ft)		
County	Dry gas	Casinghead	Total
San Juan	378,032,010	2,827,823	380,859,833
Rio Arriba	170,667,843	12,525,179	183,193,022
Sandoval	875,009	1,353,879	2,228,888
McKinley	30,174	51,661	81,835
Total	549,605,036	16,758,542	566,363,578

Natural gas liquid production

In 1980, 34 liquid extraction plants, or one less than 1979, were operating in New Mexico. Of the 34 plants operating, 28 were in southeast New Mexico and six were in the northwest. Total plant intake for the 34 plants was 969,047,250 thousand cu ft, which was 29,689,931 thousand cu ft less than intake in 1979. Of the total intake, 500,505,994 thousand cu ft went to southeast plants and 468,541,256 thousand cu ft went to northwest plants. Liquid production in 1980 was 29,161,211 bbls, representing a decrease of 636,915 bbls from 1979 liquid production. The New Mexico Oil and Gas Engineering Committee reported New Mexico extraction plant production for 1980 as shown below.

	Southeast (28 plants)	Northwest (6 plants)	Total (34 plants)
Bbls gasoline	11,977,859	2,300,272	14,278,131
Bbls butane	3,339,687	3,135,106	6,474,793
Bbls propane	4,146,804	4,261,483	8,408,287

Drilling and development

There were 2,281 well completions in New Mexico during 1980, which represented a 20 percent increase over the 1,899 wells completed in 1979. By comparison, well completions in 1979 increased by 23 percent over 1978. The total number of well completions, which include oil wells, gas wells, service wells, plugged and abandoned wells, and temporarily abandoned wells, has been increasing steadily over the past 10 yrs. Table 21

TABLE 21—OIL, GAS, SERVICE, AND TEMPORARILY ABANDONED WELLS COMPLETED IN NEW MEXICO IN 1980; districts 1 and 2 are southeast New Mexico; district 3 is northwest New Mexico; and other counties are San Miguel, Union, Colfax, Curry, De Baca, Harding, Hidalgo, Otero, and Quay (data from New Mexico Oil Conservation Division).

	Districts 1&2	District 3	Other Counties	Total State
Oil Well Completions				
New oil well completions	554	138		692
Oil wells drilled deeper	4	1		5
Oil wells plugged back	44	1		45
Oil wells reentry	20	2		22
Additional zone	24	0		24
Subtotal	-646-	-142-		-788-
Gas Well Completions				
New gas well completions	299	831		1130
Gas wells drilled deeper	0	12		12
Gas wells plugged back	29	8		37
Gas wells reentry	4	3		7
Additional zone	18	15		33
Subtotal	-350-	-869-		-1219-
Service Well Completions				
New completions	31	7	2	40
Wells plugged back	0	0		
Wells reentry	2	2		4
Subtotal	-33-	-9-	-2-	-44-
Plugged & Abandoned Wells				
New P&A wells	143	29	13	185
P&A wells reentry	25	1		26
Subtotal	-168-	-30-	-13-	-211-
Temporarily Abandoned Wells				
New temporarily abandoned	17	1		18
Temporarily abandoned reentry	1	0		1
Subtotal	-18-	-1-		-19-
TOTAL	1215	1051	15	2281

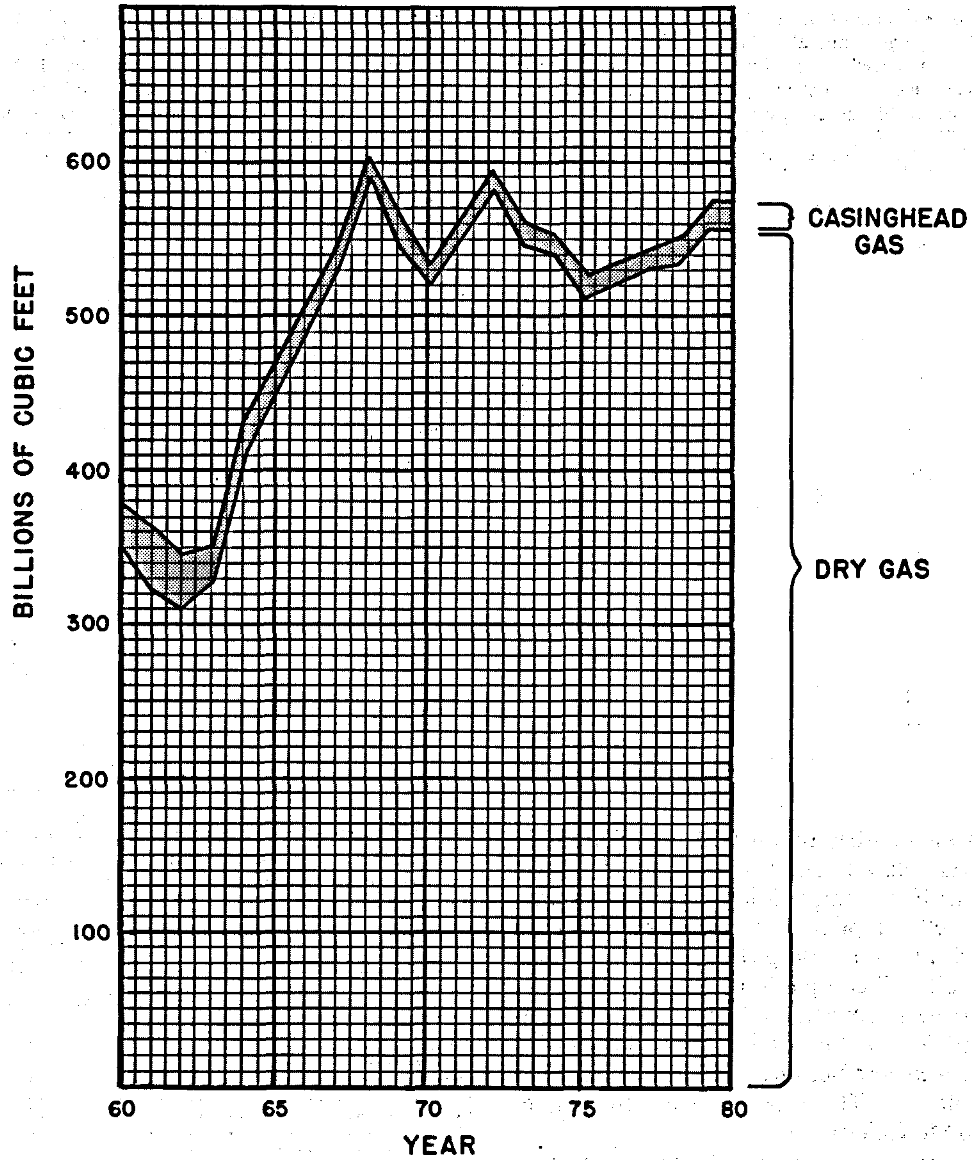

FIGURE 18—CASINGHEAD AND DRY GAS PRODUCTION IN NORTHWEST NEW MEXICO, 1960 THROUGH 1980 (data from New Mexico Oil Conservation Division).

shows well completions by district in New Mexico in 1980. There were 788 oil well completions in 1980 compared to 571 in 1979, 1,219 gas well completions compared to 995 in 1979, and 211 dry holes compared to 250 in 1979. The 1,219 gas well completions make 1980 the third consecutive record-breaking year for gas well completions. The total oil, gas, and dry hole completions of 2,218 represents the largest number of completions ever attained, exceeding the record of 2,205 completions in 1957. Total footage drilled in New Mexico during 1980 was 11,278,025 ft, compared to 9,198,144 ft drilled in 1979 and 8,448,802 ft drilled in 1978.

Southeast New Mexico

Continuing the trend of the past four years, drilling and development in southeast New Mexico was active in 1980 and into 1981. In the first quarter of 1981, more intents to drill had been filed with the New Mexico OCD (Oil Conservation Division) than in the first quarter of 1980. According to the OCD, 646 oil well completions, 350 gas well completions, and 168 dry holes were recorded in southeast New Mexico during 1980. The average total depth of new wells completed in 1980 in the southeast districts was 4,901 ft for oil wells, 8,987 ft for gas wells, and 6,250 ft for dry holes. The number of oil and gas well completions in the first quarter of 1981 remained at about the same level as the 1980 average quarterly completion rates, but the number of dry hole completions increased slightly. There were 162 oil well completions, 83 gas well completions, and 52 dry holes reported for the first quarter of 1981. Table 22 shows well completions for southeastern New Mexico's districts 1 and 2. Total footage drilled in southeast New Mexico in 1980 was 6,527,018 ft, compared to 5,392,823 ft drilled in 1979. Footage drilled in the first quarter of 1981 was 1,777,495 ft.

Northwest New Mexico

The number of oil well and gas well completions in northwest New Mexico increased by 12 percent over the previous year. Table 23 shows well completions for the San Juan Basin in 1980, which included 142 oil well completions and 869 gas well completions compared to 98 oil well completions and 709 gas well completions in

TABLE 22—Oil and gas wells completed in southeast New Mexico in 1980. P&A = plugged and abandoned; T-A = temporarily abandoned; New = new well completions; DD = drilled deeper; PB = plugged back; RE = re-entry; and AZ = additional zone (data from New Mexico Oil Conservation Division).

Well Completions for Southeast New Mexico -1980- (District 1 & 2)

County	oil	gas	injection	others	P&A	T-A
Chaves						
New	109	47			35	3
PB	0	2				
RE	3	0			9	
AZ	0	2				
Total	112	51			44	3
Eddy						
New	159	142		1	52	3
DD	2	0			0	0
PB	8	13			0	0
RE	6	1			5	0
AZ	2	9			0	0
Total	177	165		1	57	3
Lea						
New	266	110	25	5	48	10
DD	2	0	0	0	0	
PB	36	14	0	0	0	
RE	11	3	1	1	10	1
AZ	22	7		0	0	
Total	337	134	26	6	58	11
Roosevelt						
New	20				8	1
RE	0				1	0
Total	20				9	1
Southeast Totals						
New	554	299	25	6	143	17
DD	4	0				
PB	44	29				
RE	20	4	1	1	25	1
AZ	24	18				
Total	646	350	26	7	168	18

TABLE 23—Oil and gas wells completed in northwest New Mexico in 1980. P&A = plugged and abandoned; T-A = temporarily abandoned; New = new well completions; DD = drilled deeper; PB = plugged back; Re = re-entry; and AZ = additional zone (data from New Mexico Oil Conservation Division).

Well Completions for San Juan Basin - 1980 - (District 3)

County	oil	gas	injection	others	P&A	T-A
McKinley						
New	33	0	6		10	0
RE	0	0	0		0	0
Total	33	0	6		10	0
Rio Arriba						
New	71	216			1	
DD	1	11			0	
PB	1	4			0	
AZ	0	12			0	
Total	73	243			1	
Sandoval						
New	17	17	1	1	6	0
Total	17	17	1	1	6	0
San Juan						
New	17	598	0		12	1
DD	0	1	0		0	0
PB	0	4	0		0	0
RE	2	3	2	0	1	0
AZ	0	3	0		0	0
Total	19	609	2	0	13	1
(District 3)						
New	138	831	7	1	29	1
DD	1	12	0	0	0	0
PB	1	8	0	0	0	0
RE	2	3	2	0	1	0
AZ	0	15	0	0	0	0
Total	142	869	9	1	30	1

New- new well completions
DD- drilled deeper
PB- plugged back
RE- re-entry
AZ- additional zone

1979. The greatest number of oil well completions in 1980 in northwest New Mexico was recorded in Rio Arriba County with 73 completions. McKinley County reported 33 oil well completions followed by San Juan County with 19 oil well completions and Sandoval County with 17 oil well completions. San Juan County led the four northwest counties with 609 gas well completions or 70 percent of the total. Rio Arriba County reported 243 gas well completions and Sandoval County 17 gas well completions. There were no gas well completions reported in McKinley County.

There were no new pools established by the New Mexico OCD in 1980 in northwest New Mexico. Table 24 shows oil well completions by pool and stratigraphic unit. The greatest number of oil well completions in a pool occurred in the West Lindrith–Dakota Gallup Pool and the Chacon Dakota Pool, with each reporting 32 completions for a combined total of 46 percent of the oil well completions in the San Juan Basin. The West Lindrith–Dakota Gallup Pool located in Rio Arriba County was discovered in 1959, but the New Mexico OCD did not authorize the establishment of the pool until March 1972. Increased activity in low permeable oil wells has resulted from an enhanced economic situation due to the recent increases in the price of crude oil. The 1980 production for the West Lindrith–Dakota Gallup Pool was 580,238 bbls, and the accumulative production to date for the pool has been 2,627,853 bbls. As of January 1, 1981, there were 127 wells in the pool. The Chacon Dakota (associated) Pool discovered in 1974 is located on the southeastern flank of the San Juan Basin, occurring in both Rio Arriba and Sandoval Counties. As of January 1, 1981, there were 71 wells in Rio Arriba County within this pool and 39 wells in Sandoval County. The accumulated oil production from the Chacon Dakota Pool as of January 1, 1981

TABLE 24—Oil well completions in northwest New Mexico in 1980 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	
Devils Fork	1	
Escrito	4	
Lybrook	10	
Miguel Creek	14	
Nageezi	3	
Otero	3	
Verde	1	
Wildcat	8	
Formation total	53	38
Dakota-Gallup		
Ojito	1	
South Lindrith	2	
West Lindrith	32	
Formation total	35	25
Dakota Sandstone		
Chacon	32	
Marcelina	1	
Salt Creek Dakota	1	
Wildcat	1	
Formation total	35	25
Mesaverde Sandstone		
Chacon Wash	3	
Franciscan Lake	1	
Red Mountain	2	
Star	2	
Formation total	8	6
Hospah Sandstone		
Hospah Lower Sand	2	
South Hospah Lower Sand	5	
Formation total	7	5
Entrada Sandstone		
Wildcat	2	1
Grand total	140	100

was 1,703,837 bbls. The formation with the greatest number of completions was the Gallup Sandstone with 53 well completions, which accounted for 38 percent of total oil well completions in northwest New Mexico. There were 35 oil well completions in the Dakota Gallup pools and 35 completions in the Dakota Sandstone pools, 8 completions in the Mesaverde Group, and 5 completions in the Hospah Sandstone pools. There were also two wildcat completions in the Entrada Sandstone.

The greatest number of 1980 gas well completions in the San Juan Basin took place in the Dakota Sandstone, with all 373 completions occurring in the Basin Dakota Pool. Table 25 shows gas well completions during 1980 in northwest New Mexico by pool and stratigraphic unit. There were 221 completions in the Mesaverde Group with 218 of these completions occurring in the Blanco Mesaverde Pool. The Pictured Cliffs gas pools had 144 completions, with the largest number coming from the Blanco Pictured Cliffs Pool with 40 completions and the second largest number coming from the South Blanco Pictured Cliffs Pool with 26 completions. There were 54 completions in the Chacra unit; 5 in the Farmington unit; 17 in the Fruitland unit; 42 in the Fruitland Pictured Cliffs unit; 7 in the Gallup unit; 2 in the Organ Rock unit; and one each in the Mississippi, Greenhorn, and Naciemento units.

Oil and gas sales

The widening margin in recent years between the price paid for a barrel of crude oil and available supplies became even more pronounced in 1980 as the average price paid for a barrel of crude oil almost doubled from that of the previous year while production declined. According to the New Mexico Oil and Gas Accounting Division, total oil sales in 1980 amounted to $1,799,007,174 for 74,907,598 bbls of crude oil at an average price of $24.01 bbl. The average price for a barrel of crude oil in 1979, by comparison, was $9.92 per bbl less or $14.09 per bbl for 79,058,793 bbls valued at $1,114,525,614. Table 26 shows oil and gas sales for New Mexico in 1980. The average price for a barrel of crude oil in 1977 was $9.21, and the average price in 1975 was $4 to $5. Although crude oil production in 1975 was 94.6 million bbls or 19.7 million bbls more than that produced in 1980, the value of 1975 produc-

TABLE 25—Gas well comparisons in northwest New Mexico in 1980 by pool and stratigraphic unit (data from New Mexico Oil Conservation Division).

Name of pool	Total gas-well completions
Chacra	
Bloomfield	5
Harris Mesa	1
Largo	5
Otero	16
Rusty	10
Undesignated	3
Wildcat	14
Formation total	54
Dakota	
Basin	373
Formation total	373
Farmington	
Aztec	1
Bisti	1
Bloomfield	1
South Gallegos	1
Wildcat	1
Formation total	5
Fruitland	
Aztec	4
Blanco	1
Flora Vista	1
Mt. Nebo	1
South Gallegos	3
Undesignated	4
Wildcat	3
Formation total	17
Fruitland-Pictured Cliffs	
WAW	35
Harper Hill	2
South Los Pinos	5
Formation total	42
Gallup	
BS Mesa	2
Flora Vista	1
Largo	1
Otero	1
Wildcat	2
Formation total	7
Mesaverde	
Blanco	218
Undesignated	1
Wildcat	2
Formation total	221
Pictured Cliffs	
Aztec	5
Ballard	15
Blanco	40
Choza Mesa	5
East Blanco	1
Fulcher Kutz	10
Gavilan	2
Gobernador	1
Potwin	1
South Blanco	26
Tapacito	10
West Kutz	20
Undesignated	1
Wildcat	7
Formation total	144
Mississippian	
Beautiful Mountain	1
Formation total	1
Greenhorn	
Wildcat	1
Formation total	1
Naciemento	
Wildcat	1
Formation total	1
Organ Rock	
Wildcat	2
Formation total	2
Grand total	868

TABLE 26—OIL AND GAS SALES IN NEW MEXICO, 1980 (New Mexico Oil and Gas Accounting Division, 1980).

Oil sales				Percent of sales volume				
County	Volume (bbls)	Value (dollars)	Price	State land	Federal land	Private land	Indian land	Percent of total
Chaves	2,145,365	70,646,740	32.92	.33	.31	.36		.03
Eddy	16,043,948	390,682,965	24.35	.51	.46	.04		.21
Lea	49,626,157	1,149,244,554	23.15	.53	.22	.25		.66
McKinley	811,402	23,020,572	28.37	.08	.48	.28	.15	.01
Roosevelt	1,518,784	44,733,124	29.45	.16	.43	.41		.02
Rio Arriba	1,957,273	50,974,951	26.04	.03	.53	.01	.43	.03
Sandoval	251,383	8,073,362	32.11		.39		.61	
San Juan	2,553,286	61,630,906	24.13	.06	.65	.05	.23	.03
Total oil sales	74,907,598	1,799,007,174	24.01	.48	.31	.20	.02	1.00
Gas sales								
County	1,000 cu.ft.							
Chaves	10,662,411	20,301,254	1.09	.44	.46	.10		.01
Eddy	212,477,413	414,421,186	1.95	.27	.57	.16		.19
Lea	330,329,848	499,477,474	1.51	.41	.24	.35		.30
McKinley	9,283	7,703	.82		.54	.46		
Roosevelt	4,000,448	6,250,357	1.56	.10	.62	.28		
Rio Arriba	170,505,560	342,733,324	2.01	.06	.74		.20	.15
Sandoval	1,815,863	5,583,464	3.07		.13		.87	
San Juan	377,149,462	711,212,911	1.88	.09	.85	.03	.03	.34
Harding	775,689	199,273	.25	.02		.98		
Total gas sales	1,107,725,977	2,000,186,946	1.80	.22	.59	.15	.04	1.00
Total sales		$3,799,194,120						

tion was $770.6 million or $1,028.4 million less than the value of 1980 production. Production from state land accounted for 48 percent of crude oil sales volume in 1980, and 66 percent of the total volume came from sales in Lea County.

Total gas sales in 1980 amounted to $2,000,186,946 for 1,107,725,977 thousand cu ft at an average price of $1.80 per thousand cu ft. The 1980 average price was $0.41 more than the $1.39 average price in 1979. Although gas production in 1979 was 1,139,926,636 thousand cu ft or 32,200,659 thousand cu ft more than 1980 production, the value of 1979 production was $1,591,114,510 or $409,072,436 less than the value of 1980 production. In 1975, natural gas production was 1.2 trillion cu ft or about the same as 1980 production, yet the value of the 1975 gas production was $452.4 million compared to over $2.0 billion for 1980 gas production. Over one-half of the gas sales volume in New Mexico in 1980 came from federal land with 21 percent from state land. The greatest volume came from San Juan County with 377,149,462 thousand cu ft of production for sales amounting to $711,212,911 at an average price of $1.88 per thousand cu ft.

Projection of gas production

In 1975, the New Mexico Bureau of Geology (Office of the State Geologist) made its first oil and gas production projections. Since then, the Bureau has updated the projections periodically, and this will be the third revision. Two projections, a higher and lower projection, were constructed for natural gas production in New Mexico through the year 2000. The last higher and lower projections of natural gas production prepared in 1978 have been revised and updated. Tables 27 and 28 show these updated projections in addition to actual 1978–80 production. Actual gas production in 1979 and 1980 was close to the 1978 projection for those years. Southeast dry gas production declined slightly less than 3 percent in 1979 and 4 percent in 1980 instead of the predicted decline of 4 percent in 1979 and 5 percent in 1980. Dry gas production in 1981 is projected to be 4 percent less than 1980 on the higher projection and 5 percent less than 1980 production on the lower projection for southeast New Mexico. Dry gas production may decline more in 1981 in southeast New Mexico than what is shown on the lower projection (table 28) since many of the Morrow gas wells that were completed 5–10 yrs ago are beginning to decline at an increasing rate, and there were large production declines in 1980 from several of the most productive gas pools.

There were 350 gas completions in 1980, 64 more than in 1979, yet dry gas production declined by 4 percent. One development that may help to slow the dry gas production decline in the next several years is the Abo tight sand production that has been established in northwest-

TABLE 27—HIGHER PROJECTION FOR NATURAL GAS PRODUCTION IN NEW MEXICO, 1981–2000; figures are in billions of cu ft (data from New Mexico Bureau of Geology).

	Higher						
Year	SENM dry gas	% change	NWNM dry gas	% change	Statewide csghd. gas	% change	Total gas
1978	378.1	-4.4	528.3	+1	252.8	-5	1,159.2
1979	367.2	-2.9	550.0	+4.1	245.6	-2.85	1,162.8
1980	352.5	-4.0	549.6	- .07	230.2	-6.3	1,132.3
1981	338.4	-4	544.1	-1	216.4	-6	1,098.9
1982	321.5	-5	538.7	-1	201.3	-7	1,061.5
1983	305.4	-5	527.9	-2	187.2	-7	1,020.5
1984	290.1	-5	517.3	-2	172.2	-8	979.6
1985	272.7	-6	501.8	-3	158.4	-8	932.9
1986	256.3	-6	486.7	-3	144.1	-9	887.1
1987	240.9	-6	472.1	-3	131.1	-9	844.1
1988	226.4	-6	457.9	-3	119.3	-9	803.6
1989	212.8	-6	444.2	-3	107.4	-10	764.4
1990	197.9	-7	430.9	-3	96.7	-10	725.5
1991	184.0	-7	418.0	-3	87.0	-10	689.0
1992	171.1	-7	405.5	-3	78.3	-10	654.9
1993	159.1	-7	393.3	-3	70.5	-10	622.9
1994	148.0	-7	381.5	-3	63.5	-10	593.0
1995	137.6	-7	370.1	-3	57.2	-10	564.9
1996	126.6	-8	355.3	-4	51.5	-10	533.4
1997	116.5	-8	341.1	-4	46.4	-10	504.0
1998	107.2	-8	327.5	-4	41.8	-10	476.5
1999	98.6	-8	314.4	-4	37.6	-10	450.6
2000	90.7	-8	301.8	-4	33.8	-10	426.3
TOTAL	4,001.8		8,530.1		2,101.7		14,633.60

ern Chaves County. The Federal Energy Regulatory Commission has approved a tight gas sand designation covering over 1.5 million acres in northwestern Chaves County and part of southern DeBaca County. Tight gas sand producers can sign wellhead sales contracts at a considerably higher price than what is allowed under Section 107 of the Natural Gas Policy Act. Several hundred wells could be drilled within the next few years since completed gas wells are spread over a broad area. Because most of the completed wells have low deliverabilities, a large number of wells would have to be completed and connected to have much impact on natural gas production in southeast New Mexico.

Dry gas production in 1980 in the San Juan Basin declined by 0.7 percent from the previous year, and additional declines in production are expected in the future. Based on the higher projection (table 27), an annual decline in production of 1 percent has been projected for 1981 and 1982, a 2 percent annual decline for 1983 and 1984, a 3 percent annual decline for 1985–95, and a 4 percent annual decline for 1996–2000. Based on the lower projection for northwest New Mexico dry gas production (table 28), a 2 percent annual decline has been projected for 1982 and 1983, a 4 percent annual decline for 1984 and 1985, a 5 percent annual decline for 1986–95, and a 6 percent decline for 1996–2000. Dry gas production has shown an annual increase from 1975–79 with a slight decline in 1980. The increase in production can be attributed to infill drilling in the Blanco Mesaverde and Basin Dakota Gas pools and the drilling in marginal zones brought about by more favorable gas pricing. The Blanco Mesaverde infill drilling program was started in early 1976, and the Basin Dakota infill drilling program was approved in 1979. Infill drilling activity, however, has declined in the Blanco Mesaverde Gas Pool since most if not all of the prime areas have been drilled, and a 2 percent decline in production is expected in the next few years. Production from infill drilling in the Basin Dakota Gas Pool should cushion the decline but not reverse it.

TABLE 28—Lower projection for natural gas production in New Mexico, 1981–2000; figures are in billions of cu ft (data from New Mexico Bureau of Geology).

Year	SENM dry gas	% change	NWNM dry gas	% change	Lower Statewide csghd. gas	% change	Total gas
1978	378.1	-4.4	528.3	+1	252.8	-5	1,159.2
1979	367.2	-2.9	550.0	+4.1	245.6	-2.85	1,162.8
1980	352.5	-4.0	549.6	- .07	230.2	-6.3	1,132.3
1981	334.9	-5	544.1	-1	216.4	-6	1,095.4
1982	318.2	-6	533.2	-2	201.3	-7	1,052.7
1983	299.1	-6	522.5	-2	187.2	-7	1,008.8
1984	281.2	-6	501.6	-4	172.2	-8	955.0
1985	261.5	-7	481.5	-4	158.4	-8	901.4
1986	243.2	-7	457.4	-5	142.6	-10	843.2
1987	226.2	-7	434.5	-5	128.3	-10	789.0
1988	210.4	-7	412.8	-5	115.5	-10	738.7
1989	193.6	-8	392.2	-5	104.0	-10	689.8
1990	178.1	-8	372.6	-5	93.6	-10	644.3
1991	163.9	-8	354.0	-5	84.2	-10	602.1
1992	150.8	-8	336.3	-5	75.8	-10	562.9
1993	137.2	-9	319.5	-5	68.2	-10	524.9
1994	124.9	-9	303.5	-5	61.4	-10	489.8
1995	113.7	-9	288.3	-5	55.3	-10	457.3
1996	102.3	-10	271.0	-6	48.7	-12	422.0
1997	92.1	-10	254.7	-6	42.9	-12	389.7
1998	82.9	-10	239.4	-6	37.8	-12	360.1
1999	74.6	-10	225.0	-6	33.3	-12	332.9
2000	67.1	-10	211.5	-6	29.3	-12	307.9
TOTAL	3,655.9		7,455.6		2,056.4		13,167.9

Projection of crude oil production

Table 29 shows projections for crude oil production in New Mexico for the period from 1981 to 2000. Since over 90 percent of New Mexico's production and reserves is in the southeast region of the state, no attempt was made to give separate production projections according to region. Three projections were developed allowing for a 5 percent decline in production, a 7.5 percent decline, and a 10 percent decline. Based on a recent study, the New Mexico Bureau of Geology considers the projection of a 7.5 percent decline in production to be the most likely development. The choice of the 7.5 percent decline projection is based on the current decline rate of 8.35 percent for the first quarter of 1981 and 7.08 percent decline for the first 6 months of 1981. On the basis of the 7.5 percent decline projection, production of crude oil in New Mexico is expected to decline from 69,948,636 bbls in 1980 to 64,702,488 bbls in 1981 and 59,849,802 bbls in 1982. Projecting this rate of decline, production is expected to decline to 32 million bbls in 1990 and to as low as 14.7 million bbls by 2000.

Reserves

The New Mexico Bureau of Geology has calculated primary and secondary crude oil reserves and natural

TABLE 29—New Mexico projected production of crude oil, 1981 through 2000; 1980 production was 69,948,636 bbls (data from New Mexico Bureau of Geology).

	Bbls of crude oil		
Year	5% decline	7.5% decline	10% decline
1981	66,451,204	64,702,488	62,953,772
1982	63,128,644	59,849,802	56,658,395
1983	59,972,212	55,361,067	50,992,555
1984	56,973,601	51,208,987	45,893,300
1985	54,124,921	47,368,313	41,303,970
1986	51,418,675	43,815,689	37,173,573
1987	48,847,741	40,529,512	33,456,216
1988	46,405,354	37,489,799	30,110,594
1989	44,085,086	34,678,064	27,099,535
1990	41,880,832	32,077,209	24,389,581
1991	39,786,790	29,671,419	21,950,623
1992	37,797,451	27,446,062	19,755,561
1993	35,907,578	25,387,608	17,780,004
1994	34,112,199	23,483,537	16,002,004
1995	32,406,590	21,722,272	14,401,804
1996	30,786,260	20,093,101	12,961,623
1997	29,246,947	18,586,119	11,665,461
1998	27,784,600	17,192,160	10,498,915
1999	26,395,370	15,902,748	9,449,023
2000	25,075,601	14,710,042	8,504,121
1981 - 1990	533,288,270	467,080,930	410,031,491
1991 - 2000	319,299,386	214,195,068	142,969,139
Total	852,587,656	681,275,998	553,000,630

gas reserves for New Mexico as of January 1, 1981. Reserve estimates are shown below.

	Reserves as of January 1, 1981
Crude oil	959 million bbls
Natural gas	17.667 trillion cu ft

The Bureau of Geology has determined a preliminary estimate of primary and secondary crude oil reserves for 50 major pools in southeast New Mexico to be about 700 million bbls as of January 1, 1981. Estimates of reserves were obtained for the most part by using pool production decline curves, and volumetric studies were conducted in some of the pools. When a production decline curve could not be established for a pool, other standard engineering procedures were used to estimate reserves. By combining the reserve and production data for the 50 pools with API (American Petroleum Institute) data, which included an average of new reserves added from revisions, extensions, and other discoveries, the statewide primary and secondary crude oil reserves were estimated to be 959 million bbls.

The natural gas reserve estimate for New Mexico of 17.667 trillion cu ft is based on calculations of additions to reserves through new well completions using the volumetric method and the pressure-production decline-curve method. A simple volumetric calculation was made for gas reserves on a selected well-by-well basis of new wells completed in 1975, 1976, 1977, and 1978. The formulas used to calculate gas reserves on an individual well basis were the standard oil industry formulas for volumetric estimates of gas in place in subsurface reservoirs. In some of the larger and older gas pools, the pressure-production decline-curve method was used to calculate reserves. The reserves of the Blanco Mesaverde and Basin Dakota Gas Pools were calculated using this method. About 12 percent or 2.276 trillion cu ft of New Mexico's natural gas reserves is casinghead gas, and 87 percent or 15.4 trillion cu ft is dry gas.

The Bureau of Geology has calculated oil and gas reserves for selected new oil and gas wells completed during 1978 in southeast and northwest New Mexico. These reserve estimates were obtained by using standard oil industry formulas for volumetric estimates of oil or gas in place in subsurface reservoirs. Values for porosity, water saturation, and net effective pay were obtained from electrical logs recorded soon after the wells were drilled. Shut-in pressures and gas gravities were observed after the gas wells were completed. Drainage areas were based on standard allocated acreage in conjunction with well potentials. Spacing of wells is designated by the New Mexico Oil Conservation Division according to established pool rules. Well spacing is generally 40 acres for an oil well and 160 acres for a gas well.

Table 30 shows reserves calculated for 308 selected oil wells and 195 gas wells completed in 1978 in southeast New Mexico. The Yates, Seven Rivers, and Queen Formations combined had the largest number of oil well completions with 118 completions. Estimated ultimate recovery from these wells was calculated to be 2,812,090 bbls. The Abo Formation with 37 oil well completions was calculated to have 5,493,587 bbls of estimated ultimate recovery. The Atoka and Morrow Formations accounted for the largest number of gas well completions with 105, which were calculated to have an estimated ultimate recovery of 226,327,000 thousand cu ft. Estimated ultimate recovery (table 30) should be more accurate than in the past since a majority of the wells had at least some production history, and the volumetric reserve calculations were modified by analysis of past production history where available.

Reserves were calculated by the Bureau of Geology for over 600 gas wells completed in 1978 in 39 gas pools in northwest New Mexico. According to the reserve study, the drilling in 1978 added 270,191,108 thousand cu ft of recoverable reserves. Table 31 shows new gas reserves in northwest New Mexico added from completions in 1978. Of the reserves added, 51 percent are in the Pictured Cliffs Formation.

TABLE 30—New oil and gas reserves in southeast New Mexico added from 1978 completions. The totals of oil and gas pools do not include all wells drilled in 1978 in southeast New Mexico (data from New Mexico Bureau of Geology).

Formation	Number of oil wells	Estimated Bbls. Ultimate Recovery
Capitan	3	28,371
Yates/7 Rivers/Queen	118	2,812,090
Grayburg/San Andres	73	2,113,265
Delaware	12	293,431
Yeso	3	200,536
Paddock	2	23,647
Blinebry	10	296,082
Tubb	8	343,433
Drinkard	15	682,701
Abo	37	5,493,587
Bone Springs	3	151,090
Wolfcamp	5	412,569
Pennsylvanian	4	285,947
Cisco	2	182,438
Strawn	1	5,178
Mississippian	1	80,299
Devonian	3	218,761
Fusselman	2	83,452
Montoya	1	1,240
Granite Wash	5	287,580
Total	308	13,995,697

Formation	Number of gas wells	MMCF
Yates/7Rivers/Queen	36	20,463
Grayburg/San Andres	6	1,607
Glorieta	1	5,281
Tubb	1	1,332
Drinkard	2	1,331
Abo	2	1,258
Bone Springs	1	141
Wolfcamp	9	5,736
Pennsylvanian	10	10,093
Cisco	3	1,806
Canyon	2	374
Strawn	13	7,940
Atoka/Morrow	105	226,327
Mississippian	1	4,523
Devonian	1	2,515
Ellenburger	2	6,262
Total	195	296,989

TABLE 31—New gas reserves in northwest New Mexico added from 1978 completions by formation (data from New Mexico Bureau of Geology).

Formation	(MCF) recoverable reserves
Farmington	490,379
Paradox	2,376,503
Gallup	812,997
Fruitland	15,833,208
Chacra	7,230,746
Dakota	65,043,131
Pictured Cliffs	138,931,797
Mesaverde	39,472,347
Total	270,191,108

Coal

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

Production

Although the climate for extensive development of western coal remains uncertain, New Mexico and other western states have experienced a significant growth in coal production in 1980. New Mexico maintained its rank of 13th leading coal-producing state in the nation and has increased production by 157 percent in the last 10 yrs. Production in New Mexico increased from 7.6 million short tons in 1970 to 19.5 million short tons in 1980. The primary reason for increased production in the state has been new coal-fired generation station capabilities in New Mexico and Arizona. Expectations for accelerated growth in production, however, may be delayed by factors such as lower electric growth rates than previously predicted, higher transportation costs, a lessening of the advantage of western low sulfur coal over eastern coal because all coal-fired generation stations are now required under the Clean Air Act amendments to have pollution control equipment installed regardless of sulfur content, and slower than anticipated conversion to coal by utilities and industrial gas users. Indecisiveness about coal use may cause problems for possible future demand for coal since lead times for mine development are now in the vicinity of 8 yrs. In order to meet anticipated demand for coal, new energy supply initiatives will be required in western states, along with more leasing and development on federal coal lands.

Statewide production

The production of coal in New Mexico in 1980 increased by 33.1 percent over 1979 production as New Mexico producers extracted 19,480,820 short tons of coal in 1980 compared to 14,635,188 short tons of coal produced in 1979. Production for 1980 was calculated from information reported to the New Mexico Bureau of Geology and the Keystone Coal Industry Manual. The increase in 1980 production was substantial compared to increases from one year to the next in the past decade. Production in 1979 represented a 15 percent increase over production in 1978, and 1978 production had increased by only 7.5 percent over 1977. Table 32 shows annual coal production in New Mexico from 1959 through 1980 based on production figures from the New Mexico Bureau of Mine Inspection. According to the Bureau of Mine Inspection, the value of New Mexico's 1980 production was $260,037,421, which represented a 47 percent increase over the value of $176,399,153 for 1979 production. The value of production in 1979 represented a 43 percent increase over 1978 production, and sales in 1978 had increased by 40.5 percent over 1977. The sales value of coal production in 1970 was $21,266,732, and production for that year was 7,643,319 short tons. While production increased by 157 percent from 1970 to 1980, sales value of annual coal production increased by 1,123 percent.

The 1980 average price per short ton of coal was approximately $13.65, according to the New Mexico Taxation and Revenue Department, with prices ranging from $6.48 per ton to $33.58 per ton. The 1979 average price per short ton was $12.55, with prices ranging from $5.87 to $31.29 per short ton. Average New Mexico coal prices reported to the New Mexico Bureau of Mine Inspection for 1976 through 1980 are shown below.

Year	Price per ton
1976	$ 7.21
1977	7.39
1978	9.65
1979	12.55
1980	13.65

Although average prices have increased steadily over the past 5 yrs, increases from year to year have been considerably smaller than price increases for other fossil fuels.

The amount of reported production of coal in New Mexico is dependent on the source of the information. The 1980 production of 19,480,820 short tons is based on information from Keystone combined with mine production reported to the New Mexico Bureau of Geology. Data from mines that was not reported to Keystone was voluntarily provided by operators to the Bureau of Geology. The New Mexico Bureau of Mine Inspection reported 19,286,665 short tons for coal production in New Mexico in 1980, and Keystone reported 16,500,000 short tons, and the U.S. Bureau of Mines reported 18,307,036 short tons. Keystone, which obtains production figures from operators, mining offices, and the DOE, obtains production on a voluntary basis in New Mexico and does not always report all the mines active in the state. In 1980, Keystone did not report production from four of the 11 active mines in New Mexico. The DOE publishes its information through the U.S. Energy Information Administration, which obtains information on a form that does not always distinguish between

TABLE 32—Annual coal production in short tons, 1959 through 1980 (data from New Mexico Bureau of Mine Inspection).

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	9,668,700
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
1969	5,130,653	1980	19,286,665

the disposition of the coal-tons of coal mined and tons sold. Coal produced but stockpiled during the year is therefore not reported. The DOE also only published information on a statewide basis rather than reporting mine-by-mine production. The U.S. Bureau of Mines recently initiated an accounting system to monitor coal sales for the purpose of collecting revenues generated from the AML (Abandoned Mine Lands) program. As the system is refined, it should provide an accurate figure for the tons of coal sold by individual mines, but the system will still not account for any stockpiling of coal by the operator. The New Mexico Bureau of Mine Inspection, however, collects individual mine production information, the volume of coal that has been sold, and the amount of coal that has been stockpiled but also reports on a statewide basis.

For the past 2 yrs, 95 percent of New Mexico's total coal production has been steam coal production and 5 percent has been coking coal production. Most of New Mexico's coal production comes from the San Juan Basin with McKinley and San Juan Counties as the principal coal-producing counties. Production by county is shown below.

County	Short tons	Percent of state production
San Juan	12,323,829	63
McKinley	5,636,041	29
Colfax	1,505,202	8

Over 95 percent of New Mexico coal is used strictly for its energy content in electric power generation or for individual boilers. Much of New Mexico's coal that can be recovered by strip mining is of sub-bituminous to bituminous rank. Techniques for strip mining vary greatly from simple earth moving truck and shovel operations to steam shovel and small and large dragline operations. Underground mining operations in New Mexico utilize two different techniques to recover coal, a longwall system and a continuous miner system.

Production by mine

There were nine surface mining operations, one underground mining operation, and one underground exploration mine in New Mexico in 1980, compared with eight surface mining operations and one underground mine active in 1979. Table 33 shows New Mexico coal production from mines from 1978, 1979, and 1980. Production from some of the mines was not reported by the Keystone Coal Industry Manual, but production was reported to the Bureau of Geology and is shown in table 33 in conjunction with data from Keystone. The 11 active mines and locations are listed below.

Company	Mine	Location
Amcoal, Inc.	Amcoal	Ft. Wingate
Carbon Coal Co.	Mentmore	Mentmore
Consolidation Coal Co.	Con Paso–Burnham	Burnham
Kaiser Steel Corp.	York Canyon	west of Raton
	West York Canyon	west of Raton
	Potato Canyon (exploration)	west of Raton
Pittsburg and Midway Coal Co.	McKinley	Gallup
San Juan Coal Co.	San Juan	Waterflow
Sunbelt Mining Co., Inc.	De-Na-Zin	Bisti area
Transcontinental Coal Co.	Arroyo No. 1	San Luis
Utah International, Inc.	Navajo	Fruitland

The Navajo mine operated by Utah International has declined in rank from the fourth largest mine in the United States in 1978 to the eighth largest in 1979 and ninth largest in 1980 (Keystone, 1981). The Navajo mine, however, continued to be New Mexico's leading producer with 7,733,000 short tons of production in 1980, representing an increase in production from 5,203,000 short tons produced in 1979 and 6,100,000 short tons reported in 1978. The McKinley strip mine operated by Pittsburg and Midway Coal and Mining Company produced 4,568,154 short tons of coal in 1980, compared to 3,365,916 short tons in 1979, replacing the San Juan mine as New Mexico's second largest mine but declining in rank from the 16th to the 17th largest mine in the United States. The third mine in New Mexico to rank in the 20 largest coal-producing mines in the country is the San Juan mine operated by the San Juan Coal Company, a subsidiary of Utah International and formerly operated by Western Coal Company. The San Juan mine produced 4,538,000 short tons of coal in 1980, compared to 4,000,534 short tons in 1979, resulting in a decline from second to third largest mine in New Mexico and from the 14th to the 18th largest mine in the nation. Production from these three mines accounted for an increase in production from 1979 to 1980 of 4,269,704 short tons. Since total production of coal in

TABLE 33—New Mexico coal production in tons for 1978, 1979, 1980; s = strip mine, u = underground mine, S = state coal ownership, F = federal coal ownership, P = private or fee coal ownership, I = Indian reservation (data from Keystone, 1978, 1979, and 1980; New Mexico Bureau of Geology).

County/mine	1978	1979	Percent change	1980	Percent change
Colfax					
Potato (u,p)	--	--	--	5,202	--
West York (S,P)	134,100	577,517	+331	600,000	+ 4
York Canyon (u,P)	803,056	766,459	- 5	900,000	+17
Total	937,156	1,343,976	+ 43	1,505,202	+12
McKinley					
Amcoal (s,P)	100,000	94,296	- 6	93,907	- 0.4
McKinley (s,I,F,P)	2,992,958	3,365,916	+ 12	4,568,154	+36
Mentmore (s,P)	40,000	628,250	+1,471	973,980	+55
Total	3,132,958	4,088,462	+ 31	5,636,041	+38
Sandoval					
Arroyo No.1 (s,S)	--	4,466	--	15,748	+253
Total	--	4,466	--	15,748	+253
San Juan					
Navajo (s,I)	6,100,000	5,203,000	- 15	7,733,000	+ 49
San Juan (s,F)	2,613,038	4,000,534	+ 53	4,538,000	+ 13
Burnham (s,I)	--	--	--	39,652	--
De-Na-Zin (s,S)	--	--	--	13,177	--
Total	8,713,038	9,203,534	+ 6	12,323,829	+ 34
Socorro					
Tres Hermanos (s,P)	--	--	--	closed	--
Grand Total	12,783,152	14,640,438	+ 15	19,480,820	+ 33

New Mexico increased by 4,485,632 short tons, production increases from the state's three largest mines represented 95 percent of the state's increase in production. Other coal producers in New Mexico included Kaiser Steel's York Canyon mine with 900,000 short tons of production, West York Canyon mine with 600,000 short tons, and the Potato Canyon mine with 5,202 short tons. Carbon Coal Company's Mentmore mine produced 973,980 short tons, Amcoal's Amcoal No. 1 93,907 short tons, and Transcontinental Coal's Arroyo No. 1 15,748 short tons. The Tres Hermanos mine operated by Cactus Industries reported no production, and Amcoal, Inc., has ceased operations after exhausting reserves in their current lease. Amcoal was unable to obtain adjacent federal coal needed to continue operations at the Amcoal mine, and reclamation of disturbed areas at the mine is in the final stages. Cactus Industries ceased operations after determining that reserve estimates for the area had been miscalculated and overestimated and that recoverable reserves did not warrant further mining.

Western coal production

Coal production from the western states of Wyoming, Montana, New Mexico, Texas, Colorado, Arizona, Utah, and Oklahoma has increased from a combined production of 80 million short tons in 1975 to approximately 220 million short tons in 1980, representing an increase of 175 percent (Keystone, 1980). Table 34 shows coal and lignite production for New Mexico and leading coal-producing states in 1980. Fig. 19 shows coal production in eight western states from 1976 through 1980. Wyoming has led the major western coal-producing states in production with 30 million short tons in 1975, increasing to 89 million short tons in 1980. This increase in production has been the result of readily accessible strip reserves deposited in large amounts in that state. Wyoming now exports coal to 22 states, two of which are east of the Mississippi River and traditionally supplied by eastern coal producers (U.S. Office of Technology Assessment, 1980). New Mexico, by comparison, exports steam coal to Arizona, some coking coal to California, and steam coal to Texas, Missouri, and Colorado. Demand from Wyoming coal is expected to continue to increase, and production goals for 1955 have been projected to be 220 million short tons (U.S. Department of Energy, Production goals/targets for years 1985–1990–1995, 1980).

Montana ranks second among western states with 33 million short tons of coal production reported in 1980. Montana's production, however, has not increased at the same rate as other western states, and a severance tax of approximately 30 percent in that state has been cited by industry as the main reason for low annual growth in production. Two other factors contributing to lower growth rates in Montana have been limited rail service and the ban of coal sales for export to foreign countries other than Canada and Mexico from State Trust Lands. The main attraction of Montana coal continues to be the 75 billion tons of recoverable reserves estimated for that state by the Montana Coal Council. Coal production projections by the DOE for the Powder River Basin, which lies within Montana and Wyoming, are shown below with a low, medium, and high production projection category.

	Millions of tons		
Year	Low	Medium	High
1985	128.7	158.6	222.6
1990	186.0	275.0	438.0
1995	226.1	382.5	705.2

The coal industry in Colorado, Texas, and Arizona has also experienced a dramatic increase in coal production for the period from 1975 through 1980. In a projected production for the 15-yr period from 1980 through 1995 using medium projections, Arizona is the only western state that the DOE shows having steadily decreasing production to a 40 percent decline in production by 1995. Colorado production over that period is expected to increase by 86 percent and Texas production by 20 percent. By comparison, the DOE expects New Mexico production to increase by 195 percent in the period 1980–95. Production projections for Colorado, Arizona, Texas, and New Mexico for 1985, 1990, and 1995 in the medium production goal category are shown on the next page.

TABLE 34—Coal and lignite production for New Mexico and leading coal-producing states in 1980. New Mexico Bureau of Mine Inspection estimates coal production for New Mexico to be 18,863 thousand short tons; Keystone estimates coal production for New Mexico to be 16,000 thousand short tons (data from Keystone, 1981; New Mexico Bureau of Mine Inspection, 1981).

Rank	State	Estimated thousand short tons mined
1	Kentucky	156,300
2	West Virginia	118,000
3	Pennsylvania	89,417
4	Wyoming	88,928
5	Illinois	62,930
6	Virginia	49,000
7	Ohio	37,100
8	Montana	32,920
9	Indiana	29,851
10	Texas	27,000
11	Alabama	26,000
12	Colorado	19,500
13	NEW MEXICO	18,868
14	North Dakota	17,231
15	Utah	16,225
16	Arizona	11,800
17	Tennessee	11,539
18	Missouri	5,415
19	Washington	5,144
20	Oklahoma	5,000

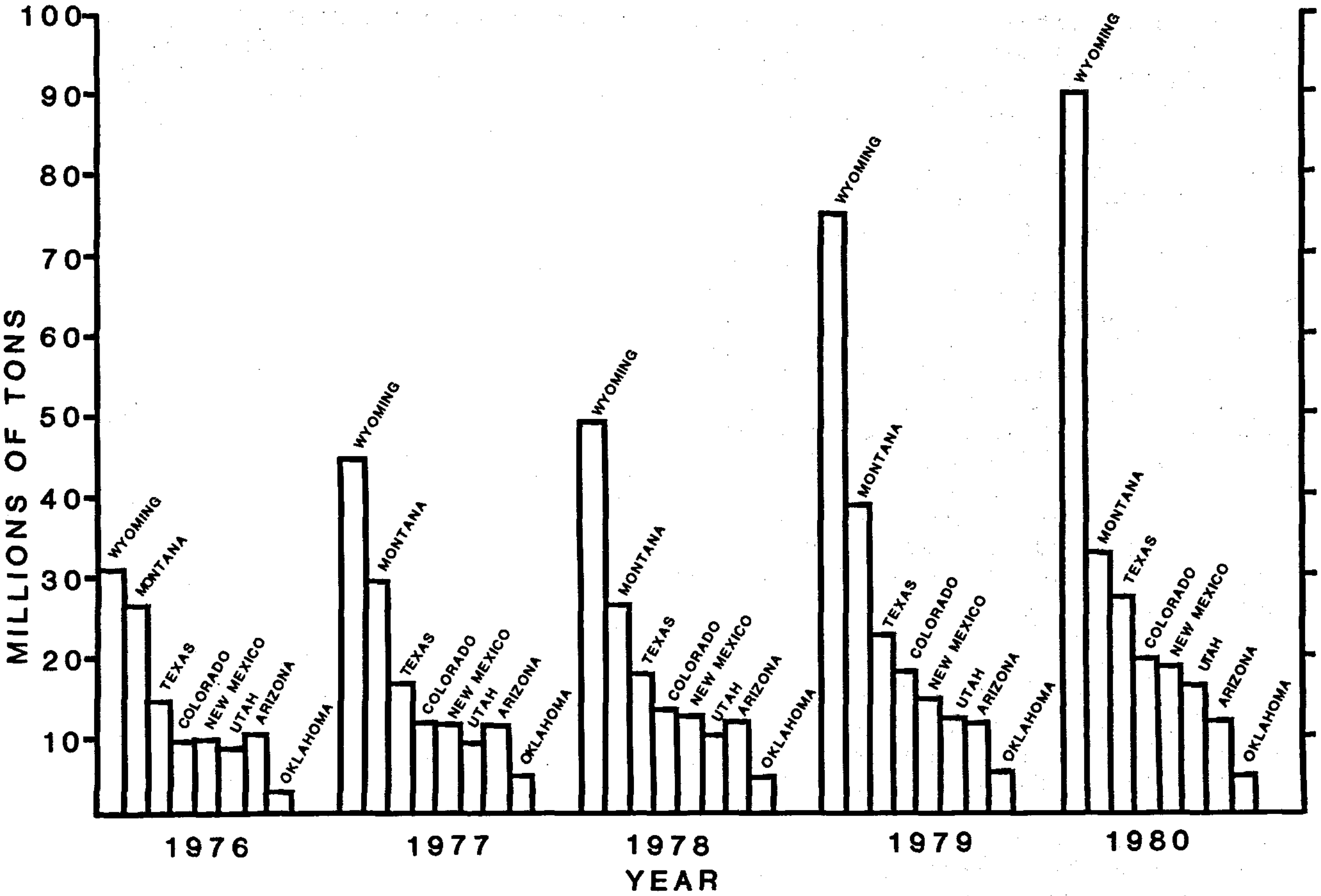

FIGURE 19—Coal production in New Mexico and leading western coal-producing states in millions of short tons, 1976 through 1980 (data from Keystone, 1981; New Mexico Bureau of Geology).

	Millions of tons		
State	1985	1990	1995
Colorado	36.3	41.6	43.1
Arizona	7.0	7.9	2.2
Texas	32.4	90.5	140.7
New Mexico	34.2	56.6	57.6

Employment

According to the New Mexico Bureau of Mine Inspection (1980), coal companies operating in New Mexico in 1980 employed 1,964 persons, an increase of 437 employees or 29 percent over employment of 1,527 in 1979. Employment in 1979 had increased by only 10 percent over 1978. Of the total employed in 1980, 1,670 were employed in surface mining operations, and 294, all in Colfax County, were employed in underground operations. San Juan County led coal mining employment with 878 employees, followed by McKinley County with 556, Colfax County with 527, and Sandoval County with 3 employees at the Arroyo No. 1 mine. The mine with the most employees was the Navajo mine with 550 employees, followed by the McKinley mine with 351 employees.

Future coal development

Fig. 20 shows coal fields, active coal mines, and proposed coal mines in New Mexico. In addition to the 11 active coal mines operating in New Mexico, six mines were granted permits by the New Mexico Mining and Minerals Division as of July 20, 1981 but were not yet engaged in mining activities. The six mines granted permits are listed below.

Company	Mine	Location
Alamito Coal Co.	Gallo Wash	Pueblo Pintado
Black Diamond Coal Co.	Black Diamond	La Plata
Chaco Energy	South Hospah	McKinley County
Cactus Industries, Inc.	Tres Hermanos	east of San Antonio
Western Coal Co.	Bisti	Bisti
Western Coal Co.	La Plata	La Plata

Alamito Coal Company has announced a starting date of 1982 for its Gallo Wash mine and Western Coal Company a starting date of 1981 for its La Plata mine. Black Diamond Coal Company has not set a date for starting mining activity at its Black Diamond mine nor has Western Coal Company for its Bisti mine. Chaco Energy is awaiting the development of the Star Lake Railroad to begin activity at its South Hospah mine, and production has stopped at the Tres Hermanos mine of Cactus Industries with the backfilling and grading phase of reclamation completed.

Three applications to the New Mexico Mining and Minerals Division for mine permits are in process. These are for the Chaco Energy Company's Star Lake mine near Torreon, La Ventana mine of Ideal Basic Industries near Cuba, and the Lee Ranch mine of Santa Fe Coal Corporation located southeast of Star Lake. A permit for the Lee Ranch mine is anticipated in the fall of 1981.

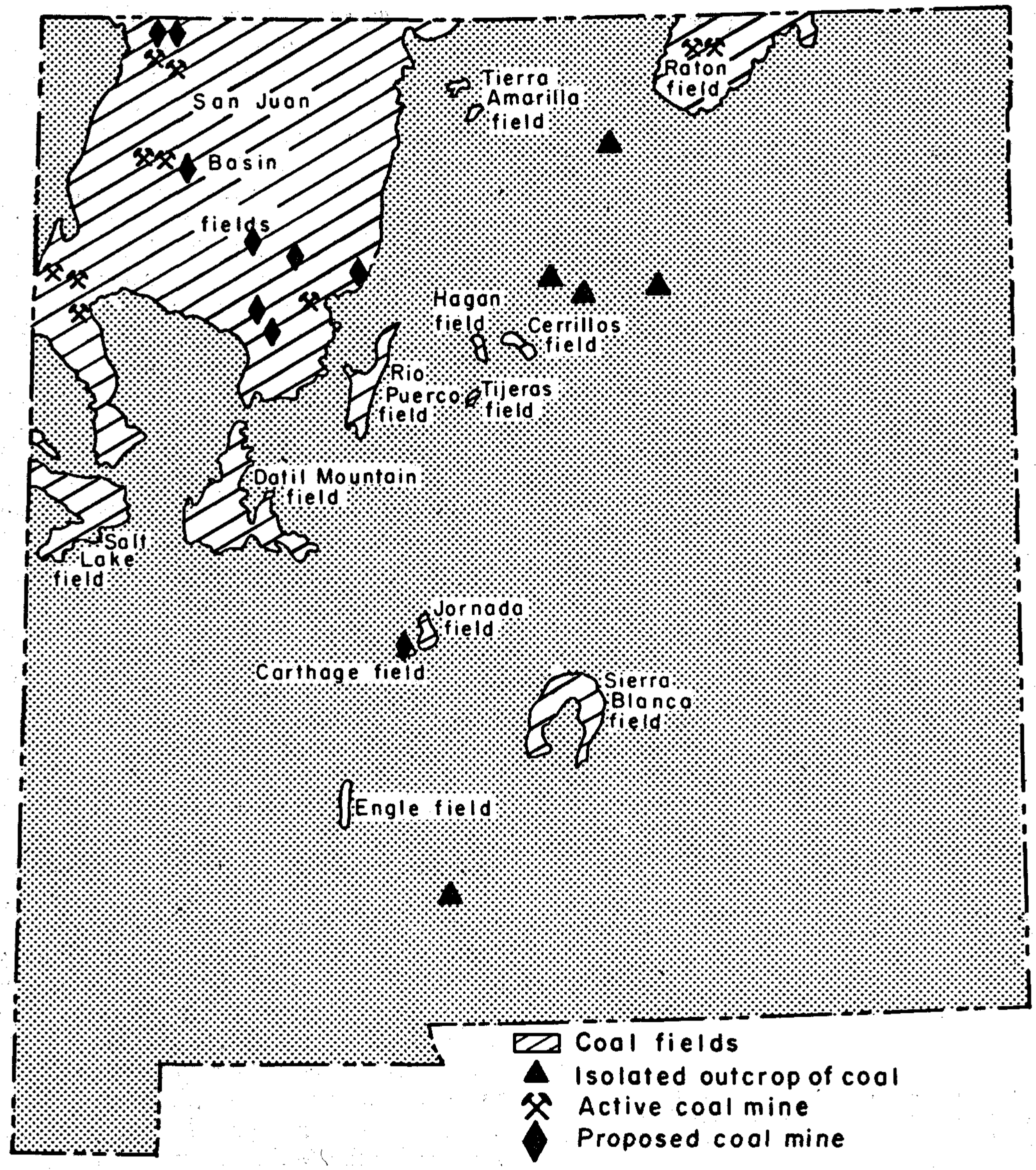

FIGURE 20—COAL IN NEW MEXICO (Kottlowski and Thompson, 1980; revised 1981 by the New Mexico Bureau of Geology).

Nine more applications for mine permits are anticipated including an application for the Cerillos mine near Madrid of Horizon Mining Company, the Old Abe mine near White Oaks of the Great American Coal Company, the Carbon II mine south of Gallup of Carbon Coal Company, and the Black Lake mine near Chaco Canyon to be operated by Western Associated Coal Corporation. Permit submittals for the Carbon II and Black Lake mines are expected in 1981. Amcoal, Inc., may develop a mine near Crownpoint with a proposed permit submittal expected some time in 1981. Arch Minerals is in the planning stages for reclamation research for a mine to be located north of Chaco Canyon, and a permit application is expected in July 1981 for Kaiser Steel Corporation's proposed Cottonwood Canyon mine east of their York Canyon mine in Raton. A permit application is also expected from Kaiser Steel for its proposed Upper York Canyon and Ancho mines near Raton by June 1981. The Sunbelt Mining Company, Inc., has proposed submitting an application for a mine permit in September 1981 for its Bisti mine on state land.

As of July 20, 1981, 20 approvals for exploration have been granted by the New Mexico Mining and Minerals Division (table 35).

Production projections

The key question in respect to future New Mexico coal production is when and to what extent coal will be used to meet the nation's energy demand that has been met by oil and gas in the past, particularly in the area of electricity generation. There is still uncertainty in the nation as to how much of future electric utility needs will be met by nuclear power plants and how much of that need will be met by coal-fired plants. Recent forecasts for electricity growth over the next decade have been significantly lower than estimates made in 1975 and 1976. Table 36 shows a comparison of forecasts for the annual growth rate of electric generation from a variety of sources. As the year of the study approaches 1980, the projected growth rate declines. The latest study concluded jointly by the U.S. Economic Regulatory Administration and the U.S. Energy Information Administration in December 1980 shows a projected growth rate

TABLE 35—APPROVALS ISSUED TO MINING COMPANIES FOR EXPLORATION IN NEW MEXICO AS OF JULY 20, 1981 (data from New Mexico Mining and Minerals Division).

APPROVALS ISSUED TO DATE FOR EXPLORATION

Permit Number	Name of Company	Mine Name	Exploration Approval Date
# 1	Albert J. Firchau	Arroyo No.1-near San Luis	2/21/79
# 2	Mathis & Mathis Mining & Exploration Company	Mathis Lime	9/13/79
# 3	Kaiser Steel Corp.	Potato Canyon-near Raton	10/30/79
# 3A	Santa Fe Mining Inc.	Lee Ranch #1-near Star Lake	10/26/79
# 3B	Santa Fe Mining Inc.	Lee Ranch #2-Divide Area	4/24/81
# 4	Great American Coal Co.	Old Abe - near White Oaks	11/30/79
# 4A	Amcoal, Inc.	Amcoal - near Ft. Wingate	2/19/80
# 5	Garland Coal & Mining Co.	Dawson Ranch - Dawson	9/ 3/80
# 6	Carbon Coal Co.	Carbon II, Mentmore	8/ 8/80
# 7	Horizon Mining Co. (Cerrillos Coal Mining Co.)	Cerrillos - near Madrid	11/26/80
# 7 Amend No.1	Horizon Mining Co.	Cerrillos - near Madrid	1/14/81
# 7 Amend No.2	Horizon Mining Co.	Cerrillos - near Madrid	3/ 2/81
# 8	Orville Million	no name - near White Oaks	3/24/81
# 9	Kaiser Steel Corp.	Areas I-V - near Raton	3/24/81
#10	Pittsburg & Midway Coal Mining Co.	McKinley, Gallup	3/24/81
#11	Santa Fe Mining Inc.	no name - near Datil	3/24/81
#12	Pittsburg & Midway Coal Mining Co.	North McKinley, Gallup	6/16/81
#13	Santa Fe Mining Inc.	no name-near Fence Lake	5/21/81
#14	Sunbelt Mining Co., Inc.	no name-near Bisti	5/21/81
#15	Page Mills Intercapital Corp.	Arroyo La Azabache near Torreon	5/26/81
#16	Utah International Inc.	La Plata - near La Plata	6/ 2/81
#17	Gulf Resources, Inc.	no name-near Gallup	6/18/81
#18	Kaiser Steel Corp.	Upper York Mine, near Raton	7/81
#20	Salt River Project	Negezzi Project-near Negezzi	7/ 8/81

TABLE 36—HISTORICAL FORECASTS OF ANNUAL PROJECTED GROWTH RATE OF TOTAL ELECTRIC GENERATION (data from New Mexico Mining and Minerals Division).

Source and year of study	Projected growth rate (%)	Time period
U.S. Energy Outlook - 1971	7.2	1971-1985
Department of the Interior - 1972	6.1	1971-2000
Oak Ridge National Laboratory - 1973	4.4	1974-1985
Lawrence Livermore Laboratory - 1974	5.6	1974-1985
Technical Advisory Committee - 1974	6.0	1974-1985
Oak Ridge National Laboratory - 1975	5.1	1974-1985
Westinghouse - 1975	5.0	1974-1985
Electrical World - 1975	5.8	1975-1985
Exxon Co. - 1977	4.8	1977-1990
Energy Information Administration Annual Report to Congress - 1978	4.7	1977-1985
National Electric Reliability Council - July 1980	4.0	1979-1985
Department of Energy - August 1980	3.0	1978-1985
ICF, Inc. - November 1980	3.5	1979-1985
Economic Regulatory Administration and Energy Information Administration - December 1980	2.5	1979-1985
Actual rate of increase for the first 47 weeks of 1980 over corresponding period of 1979	1.4	

for the period from 1979 through 1985 of only 2.5 percent. The decline in forecasts for electrical generation growth has had the effect of lessening the demand for coal, and utilities have postponed the construction of new coal-fired plants.

The Fuel Use Act (Powerplant and Industrial Fuel Use Act of 1978) has been expected to effect the future demand for New Mexico coal because of requirements forcing additional electricity demand to switch to the coal alternative from oil or gas-fired plants. This act prohibits the use of natural gas or oil as a primary energy source in any new electric power plant, limits the use of natural gas as a primary energy source in existing electric power plants in any calendar year before 1990 in a greater proportion than the average yearly proportion of natural gas used during 1974 through 1976, and requires the use of natural gas in such facilities to cease by 1990 unless specific exemptions can be obtained. The Fuel Use Act which mandates these changes, however, may be rewritten or abolished by legislation under the new administration in favor of market forces decisions being allowed to select the fuel to be used. If existing legislation is repealed, coal will have to be less costly than oil and gas, and there will have to be financing available for plant conversions in order for coal to capture future fuel demand. From studies on mining costs undertaken by the Energy Management Information System of the New Mexico Energy and Minerals Department, an estimate of the markets that an operator can economically enter can be made by examining the cost of development of new mines on a comparable basis, assuming similar geologic, engineering, and reclamation conditions. The ability to predict new markets for New Mexico mine operators, however, is obscured by limited data made available on mining costs in New Mexico.

The level of out-of-state demand will have a significant effect on New Mexico's future coal production. Much of Arizona's new coal-fired generation station capacity has been supplied from New Mexico mines, specifically the McKinley and Mentmore mines, near the New Mexico–Arizona border. The Burnham mine opened with the intent of supplying coal to generation stations in Arizona. Table 37 shows coal-fired electrical generating plant capacity in Arizona, New Mexico, and Texas from 1975 through 1981 and beyond and major coal suppliers. Generating capacity in Arizona increased from 1,615 megawatts in 1975 to 4,250 megawatts in 1981. Generating capacity in New Mexico increased from 2,507 megawatts in 1975 to 3,352 megawatts in 1981, but Texas increased their capacity by only 545 megawatts from 3,050 to 3,595 megawatts. Limited new generation is planned for Arizona, and current supply is expected to continue to come from New Mexico mines. The only new generating plants in New Mexico and Arizona are the Escalante Station in Prewitt of Plains Electric with a future estimated annual requirement of 700,000 tons of coal and the New Mexico generation station in Bisti with a projected annual requirement of 7 million tons of coal. Development of the N.M. plant, however, has been delayed by environmental impact studies, land exchanges, slower electric demand growth rates, and the lack of a mine to supply coal.

A potential for a future market for New Mexico's coal exists in the Texas utilities system but that market is

TABLE 37—CAPACITIES OF COAL-FIRED ELECTRICAL GENERATING PLANTS IN ARIZONA, NEW MEXICO, AND TEXAS AND MAJOR COAL SUPPLIERS FROM 1975 THROUGH 1981. Estimates given for future planned capacity with probable major coal suppliers (data from Moody's Public Utility Manual, 1981).

ARIZONA	1975	1976	1977	1978	1979	1980	1981	Future	Major Coal Supplier
		MEGAWATTS							
Mine/Location									
Navajo/Page Units 1-2-3	1500	2250	2250	2250	2250	2250	2250		Black Mesa
Springerville	-	-	-	-	-	-	-	700	Lee Ranch Mine
Cholla/Holbrook Units 1-2	115	115	115	350	350	350	350	350	McKinley Mine
Cholla/Holbrook Units 3-4	-	-	-	-	-	250	600		McKinley Mine
Coronado/ St. Johns Units 1-2-3	-	-	-	-	350	700	700	350	McKinley Mine York Canyon Salt River Project
Cochise/Benson Units 1-2	-	-	-	-	350	350	350		Mentmore Mine
Total							4250	1400	
NEW MEXICO									
Four Corners/Fruitlnd Units 1-2-3	572	572	572	572	572	572	572		Navajo Mine
Four Corners/Fruitlnd Units 4-5	1590	1590	1590	1590	1590	1590	1590		Navajo Mine
San Juan/Fruitland	345	345	690	690	1190	1190	1190		San Juan Mine/De-Na-Zin /Burnham
Escalante/Prewitt								700	Wyoming(?), Lee Ranch(?)
New Mexico GS/Bisti								2150	Bisti Mine
Total							3352	2850	
TEXAS									
Montecello	1900	1900	1900	1900	1900	1900	1900		
Martin Lake (Unit 4)	-	-	2250	2250	2250	2250		750	
Big Brown	1150	1150	1150	1150	1150	1150	1150		
Sandow	-	-	-	-	-	-	545		
Twin Oak	-	-	-	-	-	-	-	562	
Units 1-2	-	-	-	-	-	-	-	563	
Forrest Grove	-	-	-	-	-	-	-		
Roy S. Nelson (Unit 6) Under Construction	-	-	-	-	-	-	-	750	Wyoming Texas Lignite
Total							3595	2625	

currently not a favorable one. Several Texas mine-mouth generating stations fueled by lignite are on hold due to a lack of demand. Texas Utilities (Texas Power and Light Company, Dallas Power and Light, and Texas Electric Service), however, are using coal extensively in their systems at three different stations and more are under construction. Texas Utilities will not commit themselves to New Mexico coal unless the fuel reserve is proven and there is reliable transportation to the Texas power grid. Other utilities in Texas, however, purchase coal from the market as it is needed. Lignite is being used extensively by Texas Power and Light, a Texas Utilities subsidiary, at three stations.

Gulf State Utilities Company, which services areas in Texas and southeastern Louisiana, began a program to switch to fuels other than gas in 1972 when gas curtailments became increasingly severe. The company now has a 20-yr supply of low sulfur Wyoming coal from delivery by unit trains and is also examining coal slurry pipelines and has acquired lignite leases for future production needs. The competition between Texas lignite, Wyoming coal, and New Mexico coal for future markets will become more significant to New Mexico production in coming years. Historically, Texas lignite has had an advantage in average price, although New Mexico coal is cheaper to mine on a mine-mouth cost per million Btu. A comparison of the average price of New Mexico coal and Texas lignite from 1975 to 1979 is shown below.

	Average price per ton	
Year	Texas lignite	New Mexico coal
1975	$3.12	$ 6.38
1976	3.75	7.21
1977	5.21	7.39
1978	6.28	9.65
1979	8.15	12.55

The New Mexico Bureau of Geology has made coal production projections for New Mexico for the period from 1981 through 1990. Table 38 shows these projections by county and mine. Noting that some of the projected production is dependent on the construction of railroad lines and the review of Preference Right Lease applications, the projected production for New Mexico is 39.43 million tons in 1985 and 67.35 million tons in 1990. These projections are slightly higher than projections given by the DOE for New Mexico, which are shown below.

	Million tons	
Projection category	1985	1990
Low	32.0	43.4
Medium	34.2	56.6
High	40.1	61.0

TABLE 38—NEW MEXICO PROJECTED COAL PRODUCTION BY COUNTY AND MINE IN MILLIONS OF TONS, 1980 THROUGH 1990; RR = mine opening is contingent on construction of the Star Lake Railroad, PRLA = mine plan development contingent on a lease being issued by the BLM following review of Preference Right Lease Application. Reported production for 1980 is shown in parentheses. Production from Consolidation Coal Company's Burnham mine is dependent on construction of a north-south railroad line for expansion (data from New Mexico Energy and Minerals Department, March 1981).

NEW MEXICO'S PROJECTED COAL PRODUCTION CAPACITY (MILLIONS OF TONS PER YEAR) BY COUNTY

OPERATOR-MINE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Colfax County										
Kaiser Steel-York Canyon	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Kaiser Steel-West York Strip	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Cottonwood Canyon	Exploration									
Potato Canyon	Exploration									
County Total	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
McKinley County										
Amcoal-Amcoal #1	Closed	-	-	-	-	-	-	-	-	-
Carbon Coal-Mentmore	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
(RR)Chaco Energy-So. Hospah	-	-	1.0	2.0	3.0	3.4	3.4	3.4	3.4	3.4
(RR)Chaco Energy-Star Lake	-	-	-	-	3.0	3.0	4.0	6.0	6.0	6.0
(PRLA)Freeman United	-	-	-	-	2.0	3.0	3.0	3.0	3.0	3.0
Pittsburg & Midway-McKinley	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
(RR)Santa Fe Coal-Lee Ranch	-	-	1.0	1.0	1.0	3.0	3.0	3.0	3.0	3.0
County Total	5.7	5.7	7.7	8.7	14.7	16.1	19.1	21.1	21.1	21.1
San Juan County										
(RR)Alamito-Gallo Wash	-	-	-	1.33	1.33	2.0	2.68	3.3	4.0	4.6
(RR,PRLA)Arch Minerals #1	-	-	-	-	1.0	2.0	3.0	3.0	3.0	3.0
(RR,PRLA)Arch Minerals #2	-	-	-	-	-	1.0	2.0	3.0	3.0	3.0
Black Diamond-Black Diamond	0.5	0.5	0.5	Closed	-	-	-	-	-	-
Consolidation-Burnham	0.25	0.5	1.00	6.4	6.4	6.4	6.4	6.4	12.8	12.8
(RR)San Juan-Bisti	-	-	-	-	0.25	0.25	0.25	1.2	2.5	2.5
San Juan-La Plata	-	-	-	1.25	1.25	1.25	1.25	1.25	1.25	1.25
San Juan-San Juan	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Sunbelt - De-Na-Zin	0.49	0.49	0.34	Closed	-	-	-	-	-	-
Utah Intl.-Navajo	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75
(RR,PRLA)Western Associated-Black Lake	-	-	1.0	1.0	1.0	5.0	5.0	5.0	5.0	5.0
County Total	12.29	12.54	13.98	21.03	22.28	28.95	31.63	34.2	42.6	43.2
Sandoval County										
A.J. Firchau-Arroyo #1	0.2	0.2	0.2	0.2	0.2	0.2	-	-	-	-
Ideal Basic Ind. Coal-La Ventana	-	-	0.1	0.29	0.48	0.57	0.82	1.07	1.28	1.28
County Total	0.2	0.2	0.3	0.49	0.68	0.77	0.82	1.07	1.28	1.28
Other Counties										
Cactus-Tres Hermanos	Closed	-	-	-	-	-	-	-	-	-
Great American Coal-Old Abe	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Horizon-Cerrillos	-	0.047	0.047	0.047	-	-	-	-	-	-
STATEWIDE TOTAL	19.96	20.25	23.71	32.04	39.43	47.59	53.32	58.14	66.75	67.35

"RR" indicates mine opening is contingent upon construction of the Star Lake Railroad, or other railroad construction
"PRLA", Preference Right Lease Application, indicates mine development is contingent upon lease issuance by BLM

In the projections developed by the New Mexico Bureau of Geology, San Juan and McKinley Counties would account for the greatest growth. Fig. 21 shows New Mexico's projected coal production capacity by county from 1980 through 1990.

Surface mining reclamation

In late 1977, the U.S. Congress passed the Surface Mining Control and Reclamation Act, thereby creating a federal role in coal mining regulation and enforcement. New Mexico, however, had already passed legislation in 1972 to protect the environment and to mitigate the environmental damages associated with coal strip mining. In an effort to adopt a wide range of national standards to address problems that spanned across state borders, Congress took action to enable the federal government to work with states in a cooperative fashion to reach a common goal. In this effort, Congress established uniform national standards for mining and reclamation control, and an Office of Surface Mining Reclamation and Enforcement within the U.S. Department of the Interior to promulgate regulations and enforce standards. Congress also gave exclusive jurisdiction to the states for regulation and enforcement on non-federal lands, provided a process for a cooperative jurisdictional arrangement on federal lands within a state's borders, and provided for public participation in the process. Congress also established a self-supporting abandoned mine-land fund to restore lands affected by past mining operations. This fund was to be developed with a fee of 35 cents per ton of production from surface mining operations and 15 cents per ton from underground operations. As of December 1980, this fund had accrued over $5 million for the State of New Mexico and $14 million for the Navajo Tribe in New Mexico and Arizona to restore abandoned mine lands.

The OSM (U.S. Office of Surface Mining Reclamation and Enforcement) was given the responsibility of reviewing state-submitted programs for surface mining reclamation to determine if these programs were consistent with federal regulations and the 1977 Act. The OSM was also give the responsibility of administering the states' grant-in-aid programs, programs designed to aid states in preparing grants for monies to pay for the regulation of mining on state and federal lands. The review procedure for a state required the establishment

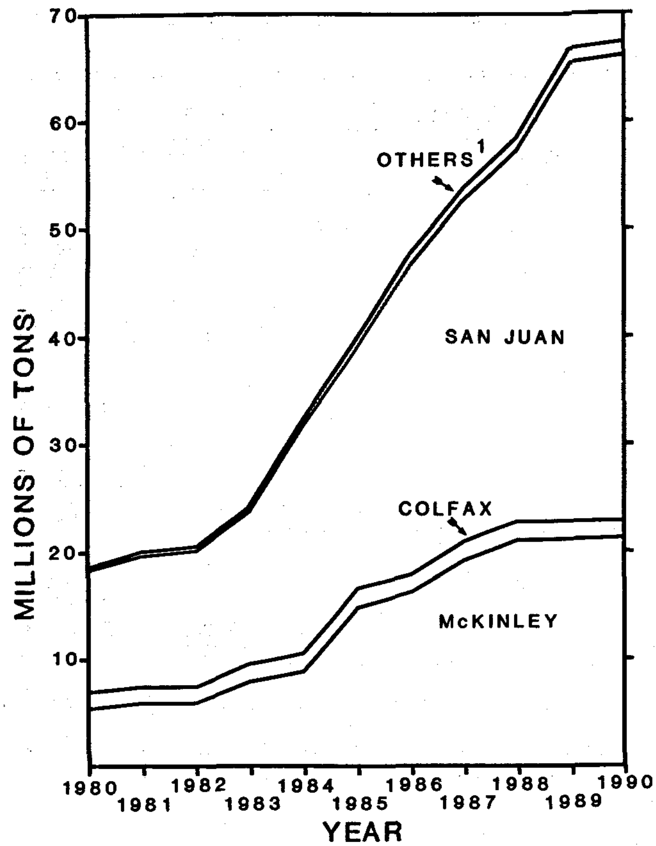

FIGURE 21—NEW MEXICO PROJECTED COAL PRODUCTION BY COUNTY, 1980 THROUGH 1990. Other counties include Lincoln, Sandoval, and Santa Fe Counties (data from New Mexico Bureau of Geology).

first of an Interim Regulatory Program and then of a Permanent Regulatory Program. In New Mexico, the Energy and Minerals Department, the Attorney General's Office, and the coal industry developed the legislation necessary to parallel the federal act, and the New Mexico Surfacemining Act was enacted in July 1979. The New Mexico Mining and Minerals Division has been given the principal responsibility for administering the Act, and a Coal Surface Mining Commission composed of members of seven state agencies was established to adopt all regulations and to serve as an appeals body for decisions made by the Mining and Minerals Division.

On December 31, 1980, the New Mexico Mining and Minerals Division received a conditional approval from the Secretary of the Interior for New Mexico's Permanent Regulatory Program which would carry out the environmental protection provisions of the Surface Mining Control and Reclamation Act. With the approval of a Permanent Regulatory Program, the state rather than the federal government will become the primary regulator of activities subject to the Surface Mining Control and Reclamation Act. Coal surface mining operators will be required to obtain a permit prior to actual operations, and operators are required by law to reclaim and return the mined land to a productive capacity that is equal to or better than conditions prior to mining activities.

Reserves

Table 39 shows estimated remaining statewide coal resources for New Mexico to be 180,791 million short tons of total strippable and deep resources. A breakdown of strippable coal reserves in New Mexico by overburden category in the San Juan Basin is shown in table 40. Revisions of these estimates have not been made since 1979. The Fence Lake area and the Salt Lake Field are the only areas where resource data is currently being accumulated through a coal research program of the New Mexico Bureau of Mines and Mineral Resources. Campbell, Frost, and Roybal are expected to publish the findings of this study in an open file report by late 1981. Field mapping by Anderson and Cather in other areas may lead to future refinement of estimated coal reserves.

TABLE 39—ESTIMATED REMAINING STRIPPABLE AND DEEP COAL RESOURCES OF NEW MEXICO IN MILLIONS OF SHORT TONS. Strippable resources estimated are within 250 ft or less of overburden. Where strippable resource estimates are unknown, estimates are given for combined strippable and deep resources (data from Keystone, 1981).

Resource area	Strippable resources	Strippable and deep resources combined	Deep resources
San Juan Basin			
Fruitland Formation	5,716		154,177
Menefee Formation	788		12,000
Raton Basin		4,709	
Cerrillos field			59
Hagan field		17	
Tijeras area			2
Datil Mountain area		1,320	
Salt Lake area		320	
Carthage field			
Jornado del Muerto area		39	
Sierra Blanca field		1,644	
Engle area		unknown	
Total strippable and deep resources		180,791	

The New Mexico demonstrated reserve base of coal as of January 1, 1980, according to the DOE, by rank and potential method of mining is shown below.

Rank	Million short tons Underground	Surface	Total
Anthracite	2.30	—	2.30
Bituminous	1,254.57	588.00	1,842.57
Sub-bituminous	889.00	1,807.61	2,696.61
Total	2,145.87	2,395.61	4,541.48

The surface mining method in this DOE estimate of reserves includes resources to a depth of 250 ft. These figures are not in complete agreement with state estimates. To resolve this problem it will be necessary to work with and compare the DOE and Energy Information Administration data on a more specific basis. The New Mexico Bureau of Mines and Mineral Resources is planning to provide specific data on a field by field basis to compare data with the figures furnished by the DOE.

Revenue

In 1980, the State of New Mexico collected $13,693,833 from severance, resource-excise, and conservation taxes on coal production and $419,860 from rental bonus bids and royalties on state trust lands. New Mexico also received a portion of the royalties collected by the federal government on public lands. Table 41

TABLE 40—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).

Coal field or area	Overburden less than 150 ft			Overburden 150 ft to 250 ft			Total
	Measured (column 1)	Combined	Inferred (column 2)	Measured (column 3)	Combined	Inferred (column 4)	
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

TABLE 41—REVENUE FROM TAXES AND ROYALTIES FROM COAL FOR NEW MEXICO, 1979 AND 1980; shown in calendar years and fiscal years. Revenues from conservation taxes, rental payments, and state land royalties are not available for calendar years. Royalties from Indian land is shown in parentheses; *the state does not receive royalties from coal extracted from Indian reservation land* (data from U.S. Office of Surface Mining; New Mexico Taxation and Revenue Department; U.S. Geological Survey; New Mexico State Land Office).

State revenue	Calendar year		Fiscal year	
	1980	1979	1980	1979
Abandoned Mine Land Fee	2,188,403	1,928,506	--	--
Severance tax	9,926,412	6,165,748	--	--
Resource excise tax	1,982,206	1,535,483	--	--
Conservation tax	--	--	431,904	288,638
Rental payment	--	--	67,993	68,859
Royalties-state lands	--	--	351,867	387,028
	14,097,021	9,629,737	851,764	744,525

Royalties - U.S. Government	1980 calendar year		1979 calendar year	
	Tons	Royalties ($)	Tons	Royalties ($)
Indian	(10,189,991)	(2,017,739)	(8,847,201)	(1,772,609)
Public domain	6,316,551	1,316,261	5,403,421	1,215,770

shows the revenues collected from taxes and royalties for 1979 and 1980.

Revenues to the state from taxes and royalties including royalties from federally owned, public domain lands increased from $11,229,641 in 1979 to $17,618,357 in 1980 or a 57 percent increase when adding revenues for both calendar and fiscal years. The state does not receive royalties from coal extracted from Indian lands. New Mexico has received $5,289,090 for the calendar quarters from December 1977 through March 31, 1980 from Abandoned Mine Land fees of which New Mexico's share is 50 percent or $2,644,545. This amount will be used for an inventory of New Mexico's abandoned mines and to correct adverse effects from mining activities where mining might pose a significant danger to the public well-being. The fees will first go to reclamation and when reclamation is completed a few years from now, the fees will then to go areas impacted by energy development for such purposes as roads, sewer systems, and research with the fees allocated by the New Mexico Mining and Minerals Division.

Geothermal energy

by K. S. Hatton, *Bureau of Geology*

Geothermal potential

Although geothermal alternatives to ease the nation's dependence on imported energy resources remain in an early stage of development, inroads have been made in exploration and testing that could make New Mexico a leader in future applications. Currently, economic, technical, and institutional obstacles prevent the state's geothermal resources from being extensively utilized, but there have been significant recent advances in such areas as drilling techniques, the seismic detection and extraction of energy from magma bodies, and the development of more advanced hot dry rock energy extraction systems. Technical successes by LANL (Los Alamos National Laboratory) in hot dry rock systems at the Fenton Hill site west of the Valles Caldera in 1980 and 1981 have made this type of geothermal resource more attractive not only to domestic companies, but also to countries in Europe and the Far East. There are vast amounts of accessible hot dry rock energy under the continental United States. It has been estimated that if just one-tenth of 1 percent of this accessible resource base could be put to use, enough energy would be available to supply the nation's present needs for 200 yrs (Pettitt, 1981).

Barriers to geothermal development are beginning to be overcome, and the geothermal potential draws more interest as costs for traditional fuels escalate. Legislation is pending in Congress that would make more acreage available to individual developers, expedite existing bidding and leasing systems, and bring more uniformity to exploration and leasing requirements. Federal tax credits encouraging geothermal and other alternative energy utilization were also implemented in 1981. New Mexico remains a leader among states with active private and governmental exploration and development activities. Companies active in New Mexico have taken a mixed approach to geothermal energy development with some awaiting an improved economic climate and others moving ahead with exploration and drilling activity.

New Mexico's geothermal potential exists primarily in association with Quaternary faulting, such as along the Rio Grande rift, or in association with Quaternary volcanic activity. 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.

The USGS (U.S. Geological Survey) designates areas having sufficient geothermal potential to warrant spending money for development as KGRA's (Known Geothermal Resource Areas). Fig. 22 shows the eight KGRA's designated in New Mexico, which 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 Doña Ana County, and Kilbourne Hole in Doña Ana County.

The New Mexico State Land Office also defines areas in which geothermal energy may be capable of being produced in commercial quantities, and these areas are called KGRF's (Known Geothermal Resource Fields). The 12 KGRF's in New Mexico 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, Bernalillo, and Cibola Counties; KGRF No. 5 in McKinley and Cibola 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. 22).

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 compiled the statewide geothermal evaluation work into composite geothermal maps 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. Some of the technical information categories

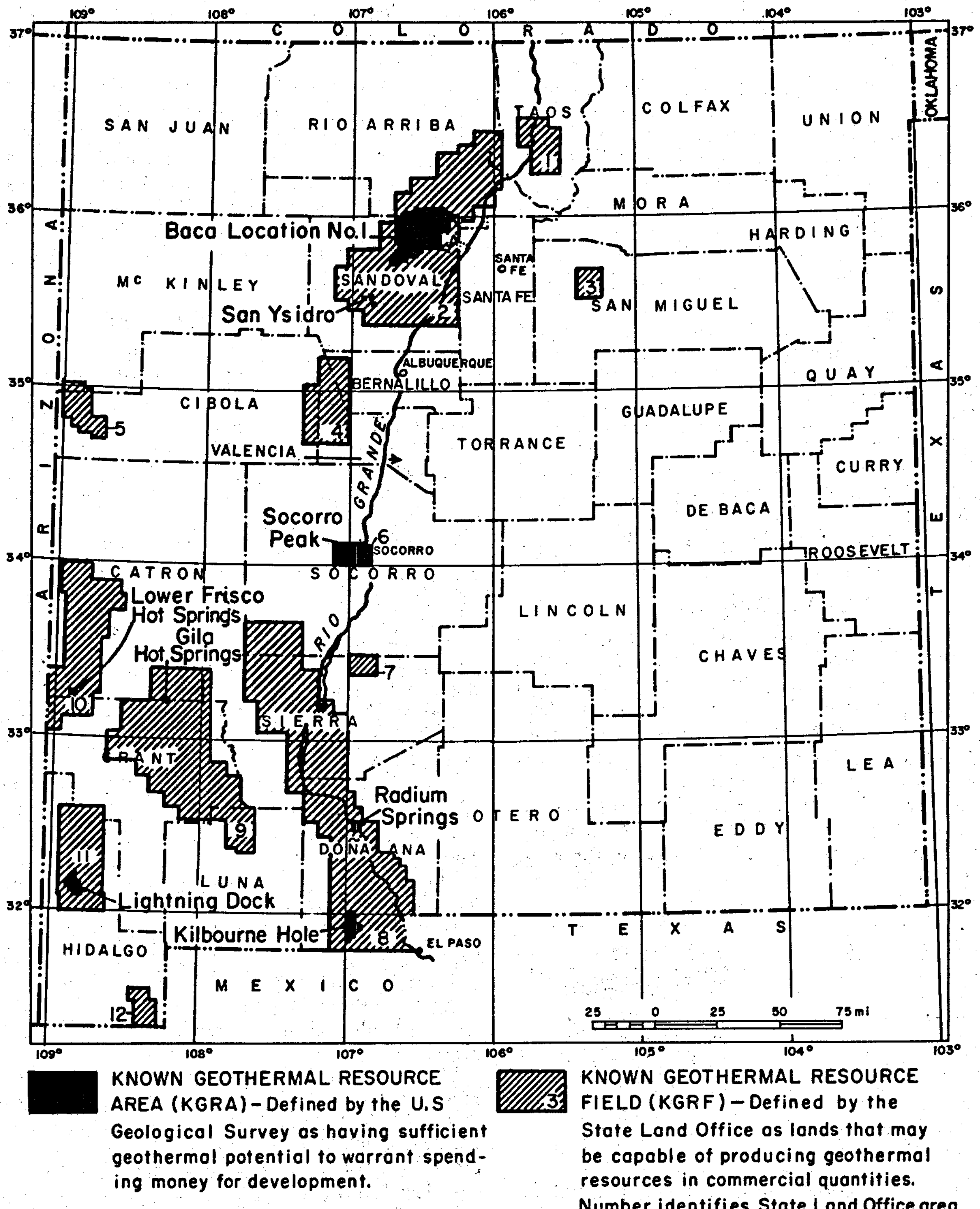

FIGURE 22—Known geothermal resource areas and known geothermal resource fields in New Mexico (from New Mexico Bureau of Mines and Mineral Resources Resource Map 1, Hydrothermal anomalies in New Mexico).

planned for this map are: Geologic faults, volcanic centers and flows, volcanic age data, heat flow, springs and wells, and base data similar to that shown on the first map. Insets and overlays are being considered that would show hydrology of deep sedimentary basins, salinity, isotope data, gravity, and lineaments (J. Ikelman, personal communication, July 1981).

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, crop drying, waste-water treatment, ethanol production, fish farming, and industrial applications. Geothermal ethanol production and the use of geothermal energy for process heat are especially economical and technically viable applications. Geothermal ethanol production has grown rapidly during 1980 and into 1981, and four geothermal ethanol plants are now in service producing 5 million gals of ethanol per year. This application of geothermal energy saves an equivalent of nearly 52,000 bbls of oil annually. If all of the ethanol facilities currently under consideration become operational, 53 new plants will be producing 281 million gals of ethanol by 1984, with the total capacity of all plants amounting to 286 million gals per year. This capacity would save the equivalent of 2,813,000 bbls of oil per year. A geothermal ethanol plant is proposed for the Silver City area in New Mexico, and a feasibility study is being made for an ethanol plant to be located in Doña Ana County (U.S. Department of Energy, 1981).

Leasing activity

As of July 1981, the BLM (U.S. Bureau of Land Management) had issued 113 geothermal leases, which are currently active, covering 198,906 acres of national resource land in New Mexico. Seventy-five of these leases, comprising 138,613 acres, were issued after noncompetitive bidding; 38 leases, comprising 60,293 acres, were issued after competitive bidding.

There were 27 federal geothermal lease applications filed between July 1980 and June 1981 that are pending, and these applications cover 52,188 acres in the areas shown below.

Area	Company
Elephant Butte Reservoir	Southland Royalty Co.
Hillsboro–Truth or Consequences	Amax Exploration, Inc., and MCR Geothermal Corp.
Radium Springs	Southland Royalty Co.
Las Cruces	Southland Royalty Co.
Mesquite–Berino–Anthony	Southland Royalty Co.
Lordsburg and Upper Animas Valley	Reading & Bates Petroleum Co.
Tres Hermanas Mountains northwest of Columbus	O'Brien Resources Corp.

The BLM's next geothermal lease sale is planned for August 26, 1981. The leases are located in the Baca Location No. 1, San Ysidro, Socorro Peak, and Lightning Dock KGRA's. There are 21 leasing units of land being offered totaling 31,016 acres.

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 in New Mexico were set aside. 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).

As of June 29, 1981, the New Mexico State Land Office had issued 53 geothermal leases, which are currently active, covering 21,184 acres. All state geothermal leases are issued on a competitive basis. These leases are held by the following companies: Chevron USA, Aminoil USA, Amax Exploration, J. W. Covello, Gulf Oil Corporation, and Atlantic Richfield Company. The leases are in Doña Ana, Grant, Hidalgo, and Socorro Counties.

Recent exploration

From January 1, 1980, through July 10, 1981, the New Mexico OCD (Oil Conservation Division) approved 47 intentions to drill on state and private lands in New Mexico. Twenty-four of the proposed wells are on state land and 23 are on private land. Thirty-five are heat flow (gradient) wells, eight are production wells, and four are temperature observation wells. The following is a summary of OCD approvals.

In the Radium Springs area, H. N. Bailey and Associates proposed to drill one 500-ft low temperature production well, five 500-ft heat flow wells, and one 500-ft temperature observation well.

In the Baca Location No. 1, Union Geothermal Company proposed to drill four production wells to depths from 6,000–10,000 ft.

NMSU (New Mexico State University) proposed to drill three 300-ft heat flow wells southwest of Faywood Hot Springs.

In the Las Cruces area, NMSU proposed to drill one 505-ft production well, one 1,000-ft production well, two 100-ft observation wells, and one 860-ft observation well.

The City of Truth or Consequences proposed to drill one 500-ft production well.

Hunt Energy Corp. proposed to drill three 2,000-ft heat flow wells in the San Diego Mountain area and six 2,000-ft heat flow wells in the Kilbourne Hole area.

Amax Exploration, Inc., proposed to drill 18 heat flow wells to a depth of 2,000 ft in the Lightning Dock area.

From August 9, 1980, through July 14, 1981, the USGS issued permits for 56 shallow temperature-gradient holes (500-ft maximum), six deep temperature-gradient holes (2,000-ft maximum), and two deep exploration wells to be drilled on federal land in New Mexico. The following is a summary of USGS permitted projects for geothermal activity in the state which have been completed.

In the Valles Caldera area, GRI (Geothermal Resources International) drilled 16 shallow temperature-gradient holes and two deep temperature-gradient holes as operators for Aminoil USA, Inc.

In the Socorro Peak area, Thermal Power Company drilled three shallow temperature-gradient holes.

In the Radium Springs area, Hunt Energy Corporation (Lamar Hunt, lessee) drilled two deep exploration wells. The wells are presently classified as suspended drilling wells and are being studied and evaluated.

In the Lightning Dock area, Amax Exploration has completed a magnetotelluric survey.

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

AMAX EXPLORATION, INC.—Geochemical and thermal gradient evaluations have been concluded on holdings in the Jemez area and no work is planned in 1981. Amax will watch with interest the progress of Union Oil Co. on the Baca Location. In the Lightning Dock area, final temperature logs have been completed for the four intermediate-depth gradient holes drilled last year. A downward continuation of the heat flow was made based on all of the company's previous thermal gradient holes, and a magnetotelluric survey was recently carried out over the thermal anomaly and will be interpreted in the near future. The geophysical data acquired is being assessed and reinterpreted, and Amax is re-evaluating its geochemical data in light of the recent thesis by M. J. Logsdon on the aqueous geochemistry of the area. Amax is planning some follow-up work in certain areas of interest elsewhere in New Mexico that were indicated by the company's 1980 reconnaissance program.

AMINOIL USA, INC.—Aminoil and GRI (Geothermal Resources International) Exploration and Development Company have an agreement whereby GRI conducts Aminoil's exploration program. The final well gradient program is now being completed on the leases in the Valles Caldera area. Seventeen 500-ft thermal gradient holes and three 2,000-ft thermal gradient holes have been drilled on the west flank of the caldera, and the companies plan to file an application for drilling a deep test well within the next year. The geological and geophysical program for leases in the Radium Springs area is scheduled to start in the spring of 1982. The same is planned for the leases in the Animas and Faywood-Mimbres areas. Aminoil has dropped some of its leases on federal land in the Socorro area.

ALAN J. ANTWEIL—Antweil has interests in three areas in the state, Animas, Rincon, and Ojo Caliente-La Madera, and has working arrangements with active geothermal companies. Leases in the Ojo Caliente-La Madera area are on federal land and are pending approval from the BLM.

ATLANTIC RICHFIELD CO.—ARCO is dropping all geothermal leases in New Mexico. Most of these were in the Socorro area.

H. N. BAILEY AND ASSOCIATES—During the first half of 1981, Bailey drilled production, gradient, and observation wells on 450 acres of private land in the Radium Springs area. Results, such as the production of 164° F water at about 100 gals per minute at depths less than 27 ft, have been encouraging. Drawdown tests are planned on wells which are scattered over the thermal anomaly. While the geothermal potential is being evaluated, possible uses of the hydrothermal resource are being considered, such as greenhouses, crop drying, and industrial process heat applications. A possible energy park is also under consideration.

CHAFFEE GEOTHERMAL, LTD.—The State of New Mexico and Chaffee have a cooperative agreement whereby the State contributes $100,000 in research and development funds to drill 40 to 50 shallow temperature-gradient holes to a depth of 300 ft. Chaffee is drilling these holes on the East Mesa area, which stretches from the east side of Las Cruces to the Texas border, and expects to be finished by the late summer of 1981. In the fall of 1981, after picking the most promising site indicated by the shallow tests, Chaffee will drill three or four 2,000 to 4,000-ft test wells in search of 200-300° F fluids. If successful, Chaffee may go into a joint venture with several partners to produce geothermal fluids usable for industrial processing in the Las Cruces area.

CHEVRON RESOURCES COMPANY—Chevron has been evaluating data during 1981 from extensive drilling and geophysical work done on its leases in the Radium Springs, Socorro, and Lordsburg-Animas Valley areas.

EARTH POWER CORPORATION—Earth Power has a joint venture agreement with Amax in the Lightning Dock area and is planning to drill a deep exploration test well in 1981 with Amax.

FLUID ENERGY CORPORATION—Fluid Energy is not planning any geothermal activity in the state during fiscal year 1981-82.

GULF OIL CORPORATION—Gulf plans no exploration in New Mexico at this time.

HUNT ENERGY CORPORTION—Hunt plans to drill a third deep exploration well in the Radium Springs area.

MCR GEOTHERMAL CORPORATION—MCR plans to continue evaluating its leases in the Truth or Consequences and Magdalena areas.

O'BRIEN RESOURCES—O'Brien has four prospects in New Mexico: Two in Luna County (one northeast of Deming and one in the Tres Hermanas Mountains), and two in Socorro County (one east and one south of Augustine). The company has over 40,000 acres of leases and pending leases on private and federal lands in New Mexico. This acreage also includes state lands which the company has nominated for leasing. The company is now doing preliminary evaluations on its prospects to determine their geothermal potential.

OCCIDENTAL GEOTHERMAL, INC.—Occidental has concluded its exploratory work in the Faywood area and has made an assignment of its interest in the area to Aminoil USA, Inc. Occidental is planning to do some preliminary geophysics studies and temperature-gradient drilling in 1981 in an area of interest north of Albuquerque. The program is small and will probably not exceed $50,000 in fiscal year 1981.

PHILLIPS PETROLEUM COMPANY—Phillips continues its interest in geothermal development in New Mexico and has hired an additional geologist to make further studies in the state.

READING AND BATES PETROLEUM COMPANY—Reading and Bates has applied for leases to 14,581 acres of federal land in the Lordsburg and Upper Animas Valley areas. After approval for the leases is received, an exploration program will begin.

SOUTHLAND ROYALTY COMPANY—Southland has not conducted any new activities in its current New

Mexico prospects. Between February 1979 and May 1981, it applied for leases on 61,031 acres of federal land in the areas near Elephant Butte Reservoir, Radium Springs, Las Cruces, and Mesquite–Berino–Anthony.

SUNOCO ENERGY DEVELOPMENT COMPANY—Sunoco is negotiating with several other companies to drill a joint well 3 mi northeast of Jemez Springs. The well has been permitted to a depth of 9,000 ft and will be called the No. 4 A. E. Thomas, et al. Spudding is planned for the fall of 1981.

SUPRON—Supron has done chemistry, fault, and shallow ground-water studies on its holdings southwest of Socorro. The company is considering magnetotelluric and deep resistivity surveys but no temperature holes or deep drilling for the present.

TEXACO, INC.—Texaco has relinquished its two leases formerly held in the Radium Springs KGRA.

THERMAL POWER COMPANY—Thermal Power has been drilling deep temperature-gradient holes on its 13,000 acres of federal leases in the Socorro Peak KGRA. Additional geophysical work is planned for this area.

Research and development

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 achieved goals and yielded technical successes in 1980 and 1981. In May 1980, LANL produced electrical energy from hot dry rock for the first time in history, when 60 kilowatts electric were 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). Essentially no thermal drawdown was detected during testing of the improved system (G. H. Heiken, personal communication, August 1980). A circulation experiment of nearly 400 days duration, which ended in December 1980, was performed on this Phase 1 system.

For Phase 2 of the hot dry rock project, LANL drilled two deeper holes into hotter rock and, in the spring of 1982, will make a series of vertical fractures along the boreholes, which are oriented at a 35° angle from the vertical near the bottom of the holes. The first and deeper borehole, EE2, has been cased with a 9 ⅝-in. casing to a wellbore depth of 11,600 ft (R. A. Pettitt, personal communication, July 1981). This borehole is 15,294 ft in length and is 14,500 ft below ground surface. Bottomhole temperature was 337° C (639° F), which was hotter than expected (G. H. Heiken, personal communication, August 1980). The second borehole, EE3, has been completed at a depth of 13,048 ft below ground surface. It lies above and parallel to the first borehole. As in the original concept demonstrated in Phase 1, water will be injected into the first borehole, circulated through the series of fractures, and withdrawn through the second borehole. The new system is expected to be capable of producing 10–20 megawatts of electrical power for 20 yrs using three to five vertical fractures. After experiments have been performed for 4–5 yrs, LANL may turn this system over to Plains Electric Generation and Transmission Coöperative to be used for electrical generation.

Approximately 24 potential hot dry rock sites are under consideration in the United States. LANL's hot dry rock Site 2 will be chosen and 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. Potential sites LANL has examined fall into three categories according to the nature of their thermal anomalies: 1) Quaternary magma-hydrothermal (volcanic or igneous) systems such as The Geyers–Clear Lake region in California, 2) regional thermal anomalies of tectonic origin such as the Basin and Range province of the Southwest, and 3) pre-Quaternary plutonic and metamorphic complexes such as the Conway Granite in New Hampshire. At the current level of technology, the optimal hot dry rock system would have a temperature of 200–300° C (392–572° F) at depths of 2–4 km (1.2–2.5 mi). The site that now appears to be the most preferred for Site 2 is Roosevelt Hot Springs, Utah. This site has high temperatures over a broad area, and the approximate depth to impermeable granite and gneiss is known. This site would also require the least development of new technology to achieve success (Goff, et al., 1981).

The immense potential for hot dry rock systems and the success of the Fenton Hill Project have interested several domestic and foreign energy suppliers. Some domestic companies are considering the possibility of working at other hot dry rock sites and combining their knowledge with LANL's 6-yr experience with hot dry rock systems. There is also enthusiasm for hot dry rock systems among several European and Far Eastern governments. England has initiated a hot dry rock development program to complement LANL's project, and information and personnel have been exchanged. Two Italian engineers have worked at Los Alamos for 6 months. Three engineers sent by the West German government have worked at Fenton Hill in the past year, and West Germany will contribute up to $2.5 million per year for the next 5 yrs to the hot dry rock development costs. The government of Japan has signed an agreement similar to West Germany's regarding the contribution of personnel and money to the hot dry rock effort in the United States (Pettitt, 1981).

Union Geothermal Company of New Mexico has begun an exploratory drilling program to increase productivity at the Baca Geothermal Demonstration Project. During the 6-month drilling program, Union and PNM

(Public Service Company of New Mexico) will evaluate the geothermal reservoir potential and its ability to provide competitively priced electricity. The start-up date for the power plant has been changed from 1982 to 1983 as a result of the delay. A decision from the New Mexico Public Service Commission on whether PNM can build the power plant is being withheld until all new resource and cost data is available. Power produced from the proposed 50-megawatt plant could supply the electrical needs of a city the size of Santa Fe with a population of approximately 50,000. PNM will also evaluate fuel-diversity benefits, the desirability of smaller base-loaded units, and the potential for geothermal energy in the state from this project. The DOE (U.S. Department of Energy) is a participant in the project, supplying approximately 50 percent of the funds to the two companies and also supplying data on the project to financial institutions as well as other electric utilities (M. Zimmerman, personal communication, July 1981).

The DOE's initial reservoir stimulation experiments at Baca and at two other geothermal sites in the western United States have been highly successful. The results have allowed the reservoir stimulation program to be extended to the stimulation of hotter wells and the evaluation of additional fracturing techniques. A casing packer, using newly developed elastomeric seals, performed well at 232° C (450° F) during the Baca experiment. Other recent DOE accomplishments include the development of a new high temperature drilling mud and high temperature cements. The mud is now used commercially for geothermal drilling in California's Imperial Valley, and the cements used for well completion applications will be field tested at the Cerro Prieto geothermal field in Mexico. Advances were also made in high temperature well-logging tool components, a 1 megawatt electric transportable wellhead generator system, corrosion-minimizing water treatment techniques, and the development of an exploration strategy for hydrothermal resources in the Rocky Mountain Basin and Range Province (U.S. Department of Energy, 1981).

At New Mexico Institute of Mining and Technology, new discoveries are being made in the seismic detection of magma bodies in the earth's crust near Socorro. The magma occurs as a large, deep body and as several postulated shallow bodies. As it is now mapped, the large body is a thin, flat sill at depths of 19–20 km (11.8–12.4 mi) beneath the central part of the Rio Grande rift near Socorro, and occupies an area of approximately 1,700 sq km. The shallow pockets may occur at depths of 4–10 km (2.5–6 mi). One such shallow body at a depth of 4 km (2.5 mi) has been detected southwest of Socorro at the intersection of the Capitan and Morenci Lineaments. In this area, magma is apparently moving upward from the mid-crustal magma body because the crust has been greatly disrupted by local tectonic and volcanic processes. Sanford and Schlue concluded that only a relatively small amount of magma occurs at these shallower depths in the crust and is probably in a complex network of dikes and sills (A. R. Sanford, personal communication, August 1981; Ward, 1981). This method of exploration for magma bodies may prove effective for predicting the occurrence of hydrothermal systems in areas where their existence might otherwise go undetected, owing, for example, to the flow of ground-water masking the heat flow. If the presence of shallow magma pockets is confirmed by further studies, the overlying crust may prove to be a favorable area for exploratory geothermal drilling (A. R. Sanford, personal communication, September 1979).

At NMSU (New Mexico State University), Phase 1 of the geothermal campus heating project has been completed. State funds contributed to this phase amounted to a total of $125,000. For Phase 2, DOE will contribute $336,000 and the State $829,000. An observation well, NMSU-OW-1, was completed in November 1980 and is 282 ft east of NMSU-PG-1, NMSU's first geothermal production well. A 48-hr flow test was conducted on the observation well, which verified the parameters established in the July 1980 test performed on NMSU-PG-1, except that the new tests showed even higher transmissivity values. Based on that test, the decision was made to site the second production well at least 1,000 ft away to avoid interference. After reviewing gradient well data and topographical considerations, the second major production well, NMSU-PG-3 was sited 1,200 ft due north of NMSU-PG-1. The well was completed to a depth of 860 ft in January 1981, and the screen was set between 750 ft and total depth. A 48-hr flow test was conducted in which NMSU-PG-3 demonstrated a 250 gpm (gallons per minute) flow at 63° C (146° F). Both wells were pumped at a combined flow rate of 400 gpm. Subsequently, in June 1981, another 48-hr flow test was conducted after the permanent pump was set in NMSU-PG-3. During this latter test, NMSU-PG-3 was pumped at 300 gpm, and the combined flow test for 24 hrs produced a 570 gpm combined flow rate with NMSU-PG-1. During these tests, constant temperatures (141–142° F in NMSU-PG-1, and 146° F in NMSU-PG-3) were maintained in both wells.

Construction has started on the campus portion of the heating project. As of August 6, 1981, 10,000 ft of insulated pipeline was in place. Pump houses and the gas separator equipment complex have been constructed, and all major equipment has been ordered. The New Mexico Oil Conservation Division has granted approval to use the NMSU golf course well as a disposal well. In this phase of the project, heating water will be connected to 11 campus buildings, for an estimated gross fuel savings of $330,000 per yr. The estimated payback period for this phase of the project is 4–6 yrs at 1980 natural gas prices (R. Cunniff, personal communication, August 1981).

At Sandia National Laboratories, recent tests have shown that corrosion of drill pipe in geothermal wells may be reduced by 90 percent by the addition of nitrogen to drilling fluid. By using a nitrogen-water mist instead of a chemically treated air-water mist, pipe could last up to 600 days instead of the normal 60 days for deep geothermal drilling. Costs can be reduced further by producing nitrogen at the well site, and this technology is now under study at Sandia. On-site production of nitrogen could decrease the expenses of premature pipe degradation and current corrosion control methods, which now cost about $4,000 per day in a full-scale drilling operation in northern New Mexico, to about $2,000 per day. This work is part of the DOE's Geothermal Drilling and Well Completion Technology

Development Program managed by Sandia. Other advances under this program include the development of high temperature microelectronics for geothermal well-logging tools and the diffusion bonding of diamond compact cutters onto drill bits, which prolongs bit life and increases drilling speed (Sandia Science News, Vol. 16, No. 3, June 1981).

Sandia recently completed a series of field experiments as part of its Magma Energy Research Project, which deals with the investigation of the scientific and economic feasibility of extracting energy from magma (subsurface molten rock) bodies. These experiments measured a seismic velocity of 3.3 km per second through molten in situ basalt, drilled and cored through 30 m (nearly 100 ft) of molten basalt, extracted energy from the solid margin just above a molten zone using a closed heat exchanger at a steady rate of 17 kilowatts per sq m of heat exchanger area, and extracted energy from molten basalt using an open heat exchanger at a rate of 980 kilowatts per sq m of heat exchanger area (transient) and 93 kilowatts per sq m (steady). Research on this project is continuing (J. Colp, personal communication, August 1981).

Recent legislation

The New Mexico State Legislature approved House Bill 2 in 1981, which included an appropriation of $829,000 for the construction and installation of a geothermal energy system that would provide hot water service to buildings and the outdoor instructional swimming pool on the New Mexico State University campus. In other geothermal-related action, a joint memorial requested the New Mexico Energy and Minerals Department and the New Mexico Public Service Commission to report to the Legislature on the progress and changes in the Baca Location No. 1 geothermal plant demonstration project. The reports are to include information on project participants, projected plant capacity, demand forecasts, and any changes in the scope of the project that would affect New Mexico consumers and state control of the project.

Two bills have been introduced in the 97th Congress, H.R. 4067 and S. 1516, which would amend the Geothermal Steam Act of 1970 to expedite exploration and development of geothermal resources. These bills would

1) authorize the Secretary of the Interior to issue geothermal leases in any lands administered by another federal agency or department with the consent of the agency or department head;

2) revise the definition of KGRA (Known Geothermal Resource Area) to mean an area where the Secretary of the Interior determines the prospects for extraction of geothermal resources for the primary purpose of generating electricity in commercial quantities warrant substantial expenditures for that purpose;

3) require that lands within any KGRA which are offered for lease and which receive no bids be declassified and leased to the first qualified applicant;

4) increase the acreage limitation for federal geothermal leases from 24,480 acres to 51,200 acres and authorize the Secretary of the Interior to increase this limitation up to 155,200 acres at any time after 15 yrs from the effective date of the Geothermal Steam Act of 1970 (currently this limitation may be increased to 51,200 acres);

5) exempt from the determination of holdings leases which contain wells capable of commercial production and leases operated under approved operating, drilling, or development contracts;

6) permit readjustment of geothermal lease terms and conditions at 20-yr intervals beginning 20 yrs after the date production commences (currently such readjustment is permitted at 10-yr intervals beginning 10 yrs after geothermal steam is produced);

7) set forth procedures for judicial review of a decision by the Secretary of the Interior;

8) authorize the issuance of free-use permits for the non-commercial application of geothermal resources in lands administered by the Secretary of the Interior and free-use permits for surface use and use of geothermal resources for the continued operation of any geothermal energy research and development facility, pilot plant, or demonstration facility in which the federal interest is transferred; and

9) permit the head of each federal agency to develop for the benefit of the agency the geothermal energy resources within the lands under its jurisdiction provided such use is in the public interest and will not deter any commercial development that might be more beneficial.

Another bill, S.669, would amend existing geothermal leasing and permitting laws. This bill is similar in some sections to the above two bills and would

1) provide for an expedited bidding and leasing system for lands within any KGRA;

2) require the development of uniform standards for the consideration and approval of permits for exploration and testing of geothermal resources on lands subject to wilderness study and lands within the National Forest System, and direct the Secretary of the Interior to include stipulations in any permit granted to assure that exploration and testing activities do not permanently impair the wilderness values of such lands;

3) set time limits for the review and approval of lease applications and exploratory permit applications pursuant to a lease;

4) permit the Secretary of the Interior to defer royalty payments for non-electric geothermal developments for municipal, cooperative, or other political subdivision lessees where legal limitations on front-end financing would prohibit or significantly deter development;

5) require that a maximum of 10 percent of the tracts leased in any one year be offered to public bodies, including rural electric cooperatives, to produce energy for their own use or for sale to their members or customers; and

6) direct the Secretary of the Interior to promulgate regulations to ensure the prompt reoffering of all relinquished, abandoned, and expired geothermal leaseholds.

A bill before the House, H.R.771, would create a commission to grant exclusive franchises for exploration and the commercial development of geothermal energy and for the right to market any such energy in its natural state.

Regulatory activity

The FERC (Federal Energy Regulatory Commission) has issued final regulations applicable to geothermal small power production facilities under the PURPA (Public Utility Regulatory Policies Act). PURPA provides for the exemption of qualifying small power producing facilities from certain federal and state regulations and requires utilities to buy excess power generated by small power producers. The ESA (Energy Security Act), enacted in June 1980, extends regulatory exemptions to utility owned as well as non-utility owned facilities and increases the size limit for qualifying geothermal facilities from 30 to 80 megawatts electric. The final regulations issued by FERC on March 23, 1981 increase the eligible plant size to 80 megawatts electric in accordance with the ESA but do not extend non-utility benefits to utility owned, qualifying geothermal facilities. A decision on this extension has been deferred because of objections raised by the public utility commissions of California, New Mexico, and Hawaii. A decision will be made after public hearings are held to address the issue. The status of these exemptions has been clouded by a decision of a federal district court in Mississippi ruling PURPA's rate provisions unconstitutional. FERC has appealed to the Supreme Court. The regulatory exemption might also make these plants eligible for the 15 percent business investment tax credit for energy property, which is not applicable to public utility property as defined by IRS (Internal Revenue Service) regulations (Federal Register, March 30, 1981).

On January 23, 1981, the IRS published final regulations implementing tax credit provisions of the Energy Tax Act of 1978. Under the regulations, tax credits are extended to owners and renters investing in certain energy conservation measures or alternative energy sources for residential properties and to businesses investing in certain types of energy property. In order for geothermal resource-related expenditures to qualify for the credits, geothermal fluids must have wellhead temperatures exceeding 50° C (122° F).

The credit for residential geothermal systems is 40 percent of the system cost to a maximum credit of $4,000. The eligible costs include labor as well as equipment. Heating and cooling systems that supplement or back up geothermal systems are excluded and all heat pump equipment is excluded. Parts of systems that are not exclusively geothermal are also ineligible for the credit. The business investment credit is 15 percent of the cost of equipment used to produce, distribute, or use energy derived from a geothermal deposit, and exploration and development equipment does not qualify. The existence of backup equipment to protect against a failure in the geothermal system will not disqualify the system; otherwise, equipment that uses both geothermal energy and energy derived from other sources is not eligible. Equipment through the turbine-generator stage of geothermal electric power plants is eligible for the credit (Federal Register, January 23, 1981).

Geothermal projects

The New Mexico State Legislature passed the Energy Research and Development Act in 1974. By July 31, 1981, $2,162,454 in state funding had been invested in geothermal research projects in the state. As of July 22, 1980, this money had attracted an additional $4,326,210 in funding from government, individual, and corporate sources.

Geothermal projects in progress as of July 31, 1981, and funded from the Energy Research and Development Fund by the Energy and Minerals Department through the New Mexico Energy Institute at NMSU were

Project number and title	Authorized funding	Investigator
2-67-2135—Evaluation of the geothermal resource in the Albuquerque area	$ 76,874	Jiracek UNM
2-67-2238—New Mexico cooperative low temperature resource assessment program (Phase 2)	$ 43,248	Icerman NMEI-NMSU
2-67-2537—Conduct a geothermal test well drilling program for the Village of Jemez Springs	$ 47,223	Armenta non-profit
2-68-2102—Assessment of the geothermal potential of southwestern New Mexico (Phase 2)	$ 26,810	Elston UNM
2-68-2204—Electrical exploration and geothermal gradient studies near Columbus, New Mexico	$ 75,000	Swanberg and Young NMSU
2-68-2208—Jemez Springs geothermal heating demonstration	$ 9,000	La France NMSU
2-68-2305—Assessment of geothermal reservoirs by analysis of gases in thermal water	$ 16,498	Norman NMIMT
2-69-2202—Doña Ana County geophysical/ geothermal evaluation	$100,000	Icerman NMSU
2-69-2208—Regional geothermal exploration in north central New Mexico	$100,000	Icerman NMSU
2-69-2209—Monitoring environmental and related performance parameters for a Rankine-cycle turbine electric generator utilizing geothermal energy at Gila Hot Springs, New Mexico	$ 12,500	Starkey NMSU

State funds totaling $142,783 were allocated to five projects now active under the geothermal demonstration 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 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

Project number and title	Authorized funding	Investigator
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
67-71—Geothermal well for space-heating of University Center, New Mexico State University	$10,000	Huff NMSU

One project that has been under negotiation is for the Sandyland Nursery for the geothermal heating of an expanded greenhouse in the Las Cruces area. State funding of $100,00 would be authorized on approval, and the principal investigator would be F. Cobb. If the geothermal reservoir is shown to exist, there is a potential for offsetting 88 million cu ft of natural gas per year that is now being consumed by the nursery.

During the 1981 session, the New Mexico State Legislature authorized an appropriation of $829,000 to construct and bring on line the NMSU campus heating project (see Recent Legislation). R. Cunniff is the principal investigator.

Current DOE-funded state projects are

Project Title	Funding	Project director
Regional geothermal commercialization program	$1,037,015	J. Marlin
New Mexico cooperative low temperature resource assessment program	$ 236,931	L. Icerman
State geothermal commercialization planning for New Mexico	$ 102,000	G. Scudella
NMSU campus heating project	$ 336,000	R. Cunniff

The DOE's AET (Appropriate Energy Technology) Small Grants Program awarded $32,500 in August 1980 to D. A. Campbell of Gila Hot Springs for a proposal to develop rural geothermal energy technologies through the expansion of the Gila Hot Springs geothermal resource. The project included the installation of a Rankine-cycle generator at the hot springs. Campbell is now using 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 drives an induction generator. It is hoped that this project will 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.

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., and others, compilers, 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.

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

Blackstone, Sandra L., 1980, Mineral severance taxes in western states: legal, and policy considerations; Colorado School of Mines Quarterly, vol. 75, no. 3, July 1980, 39 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

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

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 develolpment: U.S. Department of Energy, DOE/EIA-0201-8, 125 p.

Fassett, J. E., 1978, Oil and gas fields of the Four Corners area: Four Corners Geological Society, v. 1 & v. 2

Goff, F., A. Laughlin, J. Aldrich, M. Ander, B. Arney, E. Decker, J. Gardner, G. Heiken, A. Kron, C. LaDelfe, R. Pettitt, and S. Shannon, 1981, Hot dry rock geothermal prospects, 1981: Los Alamos National Laboratory, LA-UR-81-1807, 4 p.

Hatchell, W. O., and Wentz, Chris, compilers, 1981, Uranium resources and technology—a review of the New Mexico uranium industry 1980: New Mexico Energy & Minerals Dept., Santa Fe, New Mexico, 256 p.

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

Jacobsen, Lynn C., 1980, New Mexico uranium severance taxes: prepared for the New Mexico Operators Committee of the New Mexico Mining Assoc., October, 1980, 7 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

———, 1981, The 50 biggest bituminous and lignite mines in 1979: New York, McGraw-Hill, p.

———, 1981, Estimated 1980 coal production by states bituminous and lignite: New York, McGraw-Hill, p. 1419

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, 1970–1981, Fifty-seventh—Sixty-eight annual reports (1969–1980): 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

———, 1981, Coal Surface Mining Permitting Activities, New Mexico Bureau of Surface Mining, July 20, 1981

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, 1980, Annual report: Hobbs, New Mexico Oil and Gas Engineering Committee, v. I and II

New Mexico Oil Conservation Division, 1980, Quarterly activity reports: Santa Fe, New Mexico Oil Conservation Division

New Mexico Oil and Gas Accounting Division, 1980, Interdepartment statistical reports: Santa Fe, Taxation and Revenue Department

New Mexico State Planning Division, 1979, State railroad plan: Santa Fe

New Mexico Taxation and Revenue Department, 1979, Index to the revenue sources of New Mexico, Sixth edition; compiled by State Government Research, Inc., Santa Fe, New Mexico, April 1979, 288 p.

New Mexico State Taxation and Revenue Department, 1981, Levels of taxation on energy minerals extracted in New Mexico: Santa Fe, unpublished report

New Mexico Statutes Annotated, 1978a, Mines, Chapter 69, Section 69-26-2, NMSA 1978

———, 1978b, Uranium severance tax rate schedule: Sec. 7-26-7, NMSA, 1978

New Mexico Uranium Newsletter, 1977–1981, Tabulation of Active Drilling Rigs in New Mexico, Jan. 1977–Sept. 1981: Evelyn N. Saucier, editor, Sedi-met, Inc., Publisher, Cedar Crest

Nunz, G. J., 1979, The Hot Dry Rock Geothermal Energy Development Program—an overview: Los Alamos Scientific Laboratory, LASL 79-79, 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 Surface Mining reclamation and enforcement, Regulations pertaining to the permanent program: OSM 30 CFR(PL 9587): U.S. Department of Interior

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

Office of Technology Assessment, 1981, An Assessment of the development potential and production prospects of federal coal leases: 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.

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

Pettitt, Roland A., 1981, Development of man-made geothermal reservoirs: Los Alamos National Laboratory, LA-UR-81-852, submitted to "Energy in the man-built environment—the next decade," a conference set for August 3–5, 1981, in Vail, Colorado, sponsored by the American Society of Civil Engineers, 8 p.

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.

Reynolds, Jack F., Cwik, Michael J., and Kelley, N. Ed., 1976, *Reclamation at Anaconda's open-pit uranium mine:* presented at the 1st annual land reclamation assoc., Univ. of Guelph, Ontario, Canada, Nov. 23, 1976, 28 p.

Rinehart, E. J., and A. R. Sanford, 1981, Upper crustal structure of the Rio Grande rift near Socorro, New Mexico, from inversion of microearthquake S-wave reflections *in* Bulletin of the Seismological Society of America, Vol. 71, No. 2, p. 437–450, April 1981

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, Log evaluations of selected 1978 oil and gas wells drilled in Southeast New Mexico: Midland, Texas, Petroleum consultants report, New Mexico Energy and Minerals Department, Professional Services Contract 69-25

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 Report 102, 134 p.

U.S. Bureau of Land Management, 1979, Draft environment 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 3400

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.

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

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

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

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

———, 1980, Uranium exploration expenditures in 1980 and plans for 1981–82: U.S. Department of Energy, GJO-103(81), 18 p.

———, 1981, An assessment report on uranium in the United States of America: U.S. Department of Energy, GJO-111(80), 150 p.

———, 1981a, Statistical data of the uranium industry, January 1, 1981: U.S. Department of Energy, GJO-100(81), 91 p.

U.S. Dept. of Energy, 1981b, DOE reports 1980 U.S. uranium production and drilling activity *in* DOE News, March 30, 1981, p. 1–3

———, 1981c DOE reports latest estimates of U.S. uranium reserves *in* DOE News, May 13, 1981, p. 1–3

———, 1981d, Geothermal Progress Monitor 5, progress report, June 1981: U.S. Department of Energy, Assistant Secretary for Conservation and Renewable Energy, Division of Geothermal Energy, Washington, D.C., DOE/CE-0009/5, 93 p.

U.S. DOE/EIA, 1979, Coal Production-energy data report: U.S. Department of Energy, DOE/EIA 0118(79), 108 p.

———, 1981, Demonstrated reserve base of coal in the United States on Jan. 1, 1979, 121 p. Office of Coal and Electric Power Statistics, Washington, D.C.

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, SAND 80-0703, 222 p.

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

Ward, R. M., J. W. Schlue, and A. R. Sanford, 1981, Three-dimensional velocity anomalies in the upper crust near Socorro, New Mexico *in* Geophysical Research Letters, Vol. 8, No. 6, p. 553–556, June 1981