25 pages

OF 74

THE URANIUM INDUSTRY IN NEW MEXICO

by

Christopher Rautman

New Mexico Bureau of Mines and Mineral Resources

Socorro, New Mexico

March, 1977

THE URANIUM INDUSTRY IN NEW MEXICO

INTRODUCTION

The uranium industry of New Mexico and of the United States as a whole essentially originated with the birth of the Atomic Age in the mid-1940's. The industry has grown rapidly to the present day, and uranium is expected to become even more important as traditional fuels become progressively more scarce.

New Mexico has produced more uranium than any other state. Although deposits in many parts of the state have produced small quantities of the metal (Figure 1), by far the greatest production -- and all of current production -- has come from a belt of land extending nearly 100 miles northwestward from the Rio Puerco just west of Albuquerque to the vicinity of Gallup. This area on the southern margin of the San Juan basin, known as the Grants Uranium Region, or the Grants Mineral Belt, has produced in excess of 118,600 tons of uranium oxide.

HISTORY OF THE URANIUM INDUSTRY

Uranium minerals have been known in the Colorado Plateau province of Arizona, Colorado, New Mexico and Utah as early as the late 19th century (Chenoweth, 1976). Mining activity was essentially nonexistent prior to 1910, and the deposits were considered merely mineralogical curiosities. Significant deposits of uranium-vanadium ores were discovered in 1918 in the eastern Carrizo Mountains west of Shiprock (Figure 1). However, due to the lack of a market for either uranium or vanadium, no ore was mined at that time. Between 1910 and the early 1920's, uranium

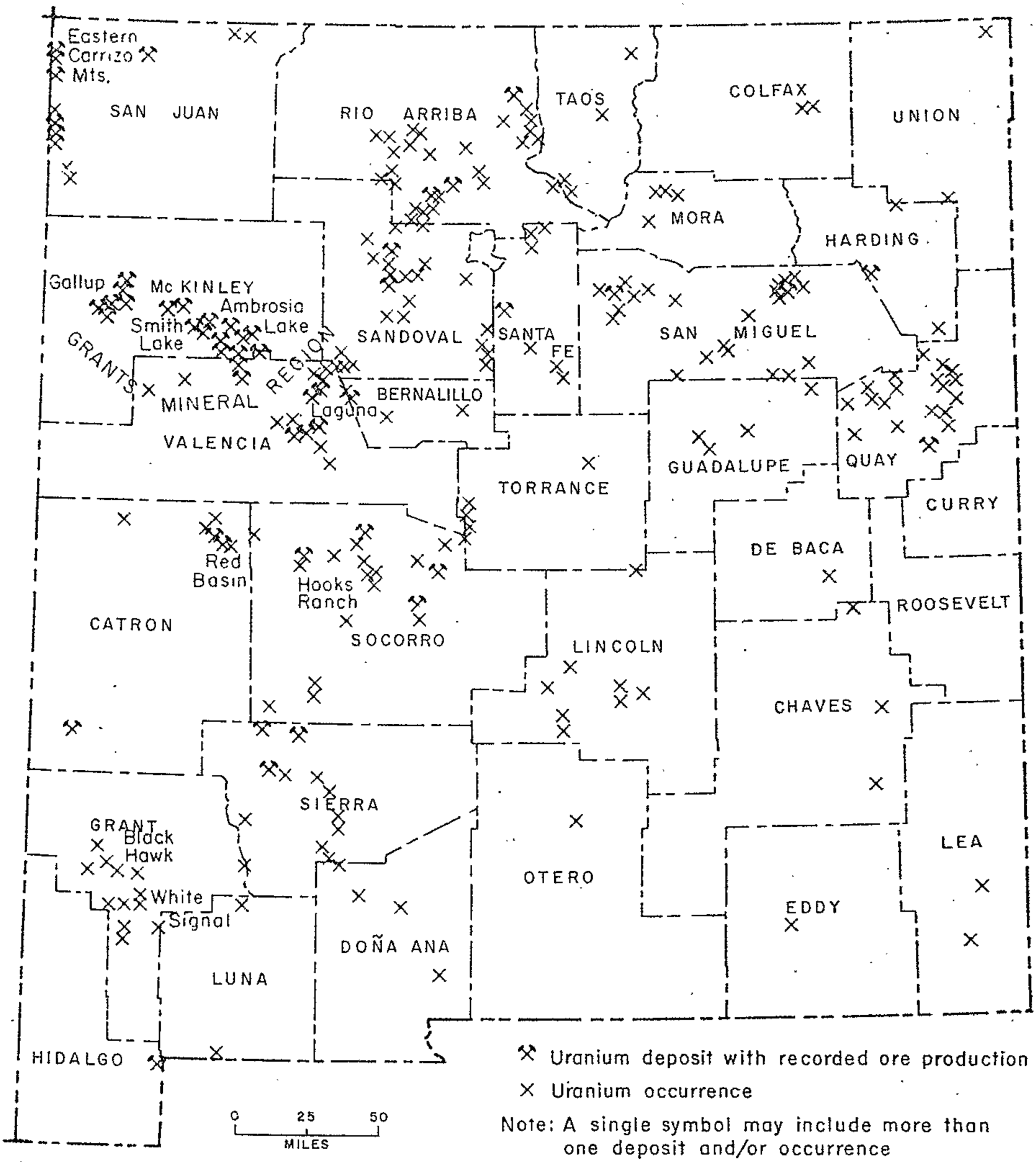

Figure 1. Uranium occurrences in New Mexico. Source: Chenoweth, 1976.

deposits in the Colorado Plateau and elsewhere produced a small quantity of ore from which radium was extracted. The White Signal district of Grant County (Figure 1) produced a small quantity of uranium ore for pharmaceutical and cosmetic purposes during this time period. During the war years of the 1930's and 1940's, the demand for vanadium as an alloying agent brought a brief flurry of activity to the Colorado Plateau uranium deposits. Approximately 1500 tons of vanadium-bearing ore were produced in the eastern Carrizo Mountains between 1942 and 1944. Although this material was mined principally for vanadium, uranium was later recovered from the mill tailings.

The need for uranium for use in weapons in the mid 1940's led the Atomic Energy Commission (AEC) to establish a uranium ore-buying program in 1948. This program - which set base prices for ores, guaranteed a market, and provided other incentives - was the first major impetus for an industry based on the exploitation of uranium deposits. Within the next few years, most of the major uranium-producing areas of the United States had been delineated. These included the Grants (New Mexico) Mineral Belt, the Uravan (Colorado) Mineral Belt, and the deposits of the Wyoming basins.

In New Mexico, the widely publicized discovery of deposits in the Todilto Limestone near Haystack Butte in Valencia County in 1950 further stimulated exploration. In 1951, a deposit was discovered in Morrison Formation sandstones in the Poison Canyon area. Additional work in this region delineated the Poison Canyon trend deposits. Also in 1951, investigation of an airborne radioactive anomaly in the Laguna area led to the discovery of what would become the Jackpile mine, the largest open pit uranium mine in the United States.

In 1955, a wildcat drilling program on the flanks of Ambrosia Lake dome encountered uranium mineralization in the region which was to become the rich Ambrosia Lake District. Ore bodies in this area are essentially without surface expression. Also discovered during the initial uranium rush of the 1950's were ore bodies in the Church Rock area to the west of Grants.

Discoveries of uranium resulting from the AEC ore-buying program proved to be so large that by the early 1960's, the AEC was faced with a substantial stockpile of uranium above that needed for defense purposes. In 1962, with major development of the nuclear electric power industry predicted as a decade or more away, the AEC announced the beginning of a "stretchout" program whereby delivery of uranium already contracted was to be delayed for periods up to several years and certain additional amounts of uranium purchased. The AEC ceased its procurement program in 1971. After the termination of government purchases, the nuclear power industry has provided almost the only market for uranium. Because development of commercial power reactors has lagged behind earlier projections, a surplus of refined uranium developed, leading to a slump in production which reached its lowest point in 1966.

The 1973 Arab oil embargo and resulting "energy crisis" have stimulated demand for available mineral fuels, reversing the downward trend of domestic uranium production. Significantly higher prices for uranium have led to increased exploration and development activity on a national and international scale.

GEOLOGY

The larger, and historically more productive, uranium deposits in New Mexico have been those which occur in sedimentary rocks and which are essentially parallel (concordant) to the bedding. The most productive deposits of this type have been found in thick fluvial sandstones.

The host rocks of these sandstone-type uranium deposits are typically arkosic, coarse, poorly sorted, and contain locally abundant organic detritus, such as twigs and logs. The uranium mineralization itself appears to be largely controlled by the presence of very finely disseminated organic matter, now thought to be a devolatilized humate similar to some constituents of coal. Lesser production has come from uranium deposits in limestone, and deposits are known to occur in lignite, coal, and carbonaceous shale as well. Individual deposits tend to be limited to certain favorable horizons within the host unit, and clusters of individual deposits are elongated along favorable "trends" or belts. Notwithstanding the stratigraphic and "trend" control of primary of initial mineralization, ground-water movement through the sediment and along faults may redistribute uranium into "stacks" or rolls.

Peneconcordant uranium deposits occur in rocks which range from Paleozoic to Tertiary in age. By far the most important units in terms of quanitity of ore producedare the Upper Jurassic Morrison Formation sandstones, and to a lesser extent the Upper Jurassic Todilto Limestone of the southern San Juan basin (Grants Mineral Belt). (Figure 1). Individual deposits range in size from a few tons to tens of millions of tons of ore.

MINING AND MILLING

Mines in the Grants mineral belts range from open pit surface operations to underground mines with shafts up to 3500 feet deep. Inclined shafts and horizontal adits are used in some of the smaller, shallow ore bodies. While the earlier, shallow mines were located above the ground water table the majority of the currently operating mines have had substantial water problems at some time in their development. Complicating the situation is the fact that the major deposits of the Grants region occur in Morrison sandstones -- a relatively porous and permeable aquifer. Ore bodies are partially dewatered by high-volume surface pumps prior to development. A shaft is sunk to below the ore zone, and haulage drifts are driven underneath the ore body. Holes drilled upward into the ore from these sublevel drifts allow more accurate determination of grade and tonnage, as well as allowing the ore body to dewater further. Driving haulageways in sandstones substantially below the ore zone additionally eliminates ground stability problems which would result if the drift were located in the soft, unstable mudstones which typically immediately underlie the ore. When the ore zone is sufficiently dewatered, raises are driven vertically into the ore body at intervals and connected by development drifts. After the ore body has been segmented into a number of large pillars separated by drifts at 50-100 foot intervals, retreat mining begins. This process involves removing the pillars piecemeal, starting in remote locations and retreating toward the raise or shaft. Broken ore is moved by remotely controlled slushers to raise chutes which load into mine cars on the haulage level below. During retreat, the roof is left largely unsupported, and it caves to a greater or lesser extent; surface subsidence is infrequent. Various types of supports are used to control the rate of caving. Since it is essentially impossible to re-enter an area once retreat mining has begun, longhole drilling is performed from the ends of development drifts to insure that as much ore as can be economically extracted is located and included in the development process.

Milling of the uranium ores involved crushing and grinding the rock preparatory to chemical leaching. The extraction process is chemically complex, but involves converting the uranium (average grade: 0.16 percent) to a soluble form which can be physically separated from the waste tailings. Uranium is then precipitated from solution, processed and dried to form "yellowcake", a product which contains 80-85% U_3O_8 (Matthews, 1963).

PRESENT STATUS OF THE INDUSTRY

Uranium exploration activity has continued since the discovery of the major producing regions in the first half of the 1950's. Nationally, exploratory drilling footage in 1976 was 31% greater than in 1975 (ERDA, 1977). Exploration was most intensive in the Wyoming basins, followed by activity in New Mexico, Texas, Utah and Colorado. Significant recent developments in New Mexico include:

Sinking of the main and auxillary shafts at Gulf Mineral Resources' Mt. Taylor Mines continues. The Mt. Taylor ore body is approximately 3500 feet below the surface. Gulf's Mariano Lake mine should be in production by 1978.

Production from SOHIO-Reserve Oil & Minerals' J.J. No.1 Mine east of Mt. Taylor began in September, 1976. The 1660 ton/day mill is operational as well.

The U.S. Department of Interior agreed to a lease/exploration agreement previously signed by EXXON and the Navajo Tribe.

Anaconda announced plans to expandtheir mill capacity to 6000 tons/day.

Pioneer Nuclear announced the discovery of about 2500 tons of uranium on their Standing Rock porperty.

Kerr-McGee Nuclear Corporation announced plans to start construction on mines in the Rio Puerco area by early 1977, and in the Roco Honda region by late 1977--early 1978.

Kerr-McGee Corporation's Church Rock No. 1 mine is scheduled to begin production in 1977.

Phillips Petroleum is planning a mine on their Nose Rock property north of Crownpoint.

United Nuclear-Homestake is constructing two new mines in the Ambrosia Lake region.

Companies in operation

During 1976, twelve companies operated or were developing 32 major uranium mines in New Mexico; four mills capable of processing 15,160 tons of ore per day were in operation. One mill under construction and planned expansion at an existing mill total 6,000 tons/day. At least ten additional companies have active drilling programs in progress, and several other groups -- including foreign corporations -- are conducting preliminary exploration activities.

Direct mining employment in the Grants region including subcontracted construction totalled in excess of 3500 persons. Indirect employment, those jobs created by the mining industry, but not directly related to the mining process, are estimated at 0.7 jobs for each direct worker. Table 1 summarizes the operations of the industry in 1976.

Table 1. Uranium operations, 1976

	Mines
McKinley County	
Ann Lee	United Nuclear Corp.
Churchrock No. 1	Kerr-McGee Corp.
Haystack	Todilto Exploration & Development Co.
*Hope	Ranchers Exploration & Development Co.
Johnny M	Ranchers Exploration & Development Co.
*Mariano Lake	Gulf Mineral Resources
*Marquez Canyon	Bokum Resources
Northeast Churchrock	United Nuclear Corp.
*Poison Canyon	Reserve Oil & Minerals
Sandstone	United Nuclear Corp.
*Section 11	United Nuclear-Homestake
*Section 13	United Nuclear-Homestake
Section 15	United Nuclear-Homestake
Section 17	Kerr-McGee Nuclear Corp.
Section 19	Kerr-McGee Nuclear Corp.
Section 22	Kerr-McGee Nuclear Corp.
Section 24	Kerr-McGee Nuclear Corp.
Section 25	United Nuclear-Homestake
Sectoin 27 East	United Nuclear Corp.
Section 30	Kerr-McGee Nuclear Corp.
Section 30 West	Kerr McGee Nuclear Corp.
Section 32	United Nuclear-Homestake
Section 33	Kerr-McGee Nuclear
Section 35	Kerr-McGee Nuclear Corp.
Section 36	Kerr-McGee Nuclear Corp.
Western Section 21	Western Nuclear Inc.
Valencia County	
Jackpile-Paguate	The Anaconda Company
J.J. No. 1	SOHIO Petroleum
*Mt. Taylor	Gulf Mineral Resources
P-10	The Anaconda Company
*St. Anthony	United Nuclear Corp.

Mills

McKinley County	Cpy (t/d)
*United Nuclear Corp., Church Rock	3000
Kerr-McGee Nuclear Corp., Ambrosia Lake	7000
Valencia County	
Anaconda Company, Bluewater	3000
* planned expansion	3000
SOHIO Petroleum Company, near Laguna	1660
United Nuclear-Homestake Partners, Grants	3500
*Gulf Mineral Resources, San Mateo	?

Groups with Drilling Programs (4th quarter, 1976)

(Companies other than the above)

Atlantic Richfield (ARCO)
Continental Oil Co. (CONOCO)
Exxon
Frontier Mining Co.
Homestake Mining Co.
Hydro-Nuclear Corp.
Mobil Oil Corp.
Phillips Petroleum Co.
Pioneer Nuclear
Teton Drilling (related to United Nuclear Corp.)
Union Carbide

*--under development, 1-1-77

Production and Value

Domestic production of uranium from 1948 through 1976 has exceeded 295,900 tons of U_3O_8. New Mexico has produced more than 118,600 tons or about 40% of the national production; 99.8% of the state's production has been from the Grants Mineral Belt. New Mexico's production of yellowcake has led the nation each year since the early 1950's except 1973, when Wyoming's production was about 1% greater. With discovery and development of the Ambrosia Lake district in the Grant's region, New Mexico's production of uranium reached a high of 7750 tons in 1960. Since, production has averaged closer to 5500 tons/year. (Fig. 2).

Discussion of the market value of uranium is complicated by the fact that until 1968, essentially all uranium was purchased by the government at prices established by the AEC, and by the contract nature of uranium sales. Data on the private sale of uranium between 1968 and 1971 are essentially lacking. Following the cessation of the AEC uranium procurement program in 1971, all sales have been to private purchasers. The trend of per-pound uranium prices is shown in Fig. 3. The market value of all uranium produced in New Mexico in 1976 is estimated at 195 million dollars, and the average price was approximately $16 per lb. (USBM,1977a).

The price at which uranium concentrates will be sold in the future is likewise a difficult subject. Despite highly publicized "spot sales" at prices in excess of $40 per pound, most yellowcake is sold under long-term contracts at considerably lower prices. <u>Each year through 1985, over 50% of domestic uranium will be delivered at a price less than $20.00 per pound</u>. In fact, even in 1985, only 10% of

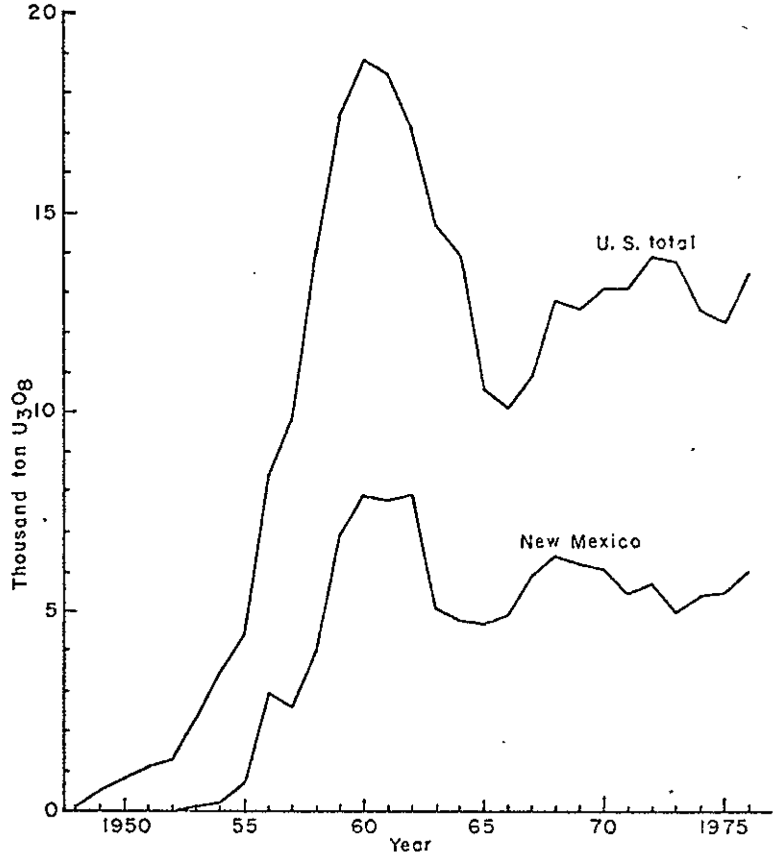

Figure 2. Historical trend of domestic uranium production. Source: Kerr-McGee Nuclear Corp., 1975; Chenoweth, 1976; ERDA, 1976; USBM, 1977a.

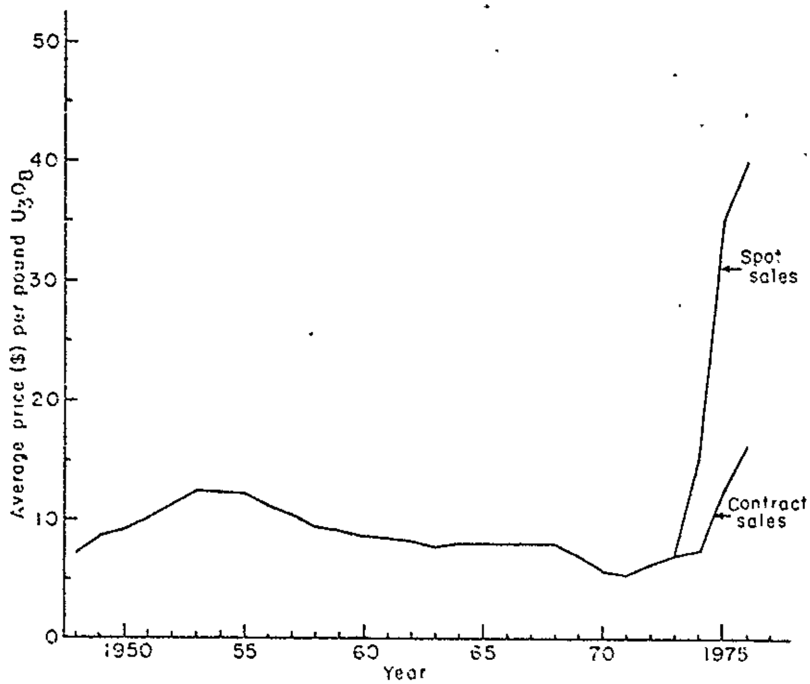

Figure 3. Historical trend of domestic uranium prices. Source: see Fig.2; also Gordon, 1973, 1974, 1975, 1976.

the anticipated yellowcake deliveries will bring a price greater than $30 per pound (Hanrahan and others, 1976). ERDA data on the price of yellowcake contracted through 1985 are shown in Figure 4, giving the percentage of uranium to be delivered each year in $5 price increments. Contract sales will undoubtedly continue in the future, but unlike in past years, the newer contracts will probably contain price adjustments for general inflation. Contracts involving seller and purchaser as partners in the mining venture may also become more common.

The relationship of sale price and mining cost is commonly misunderstood; misunderstanding of this relationship in times of rapid price increases can erroneously lead to the conclusion that producers are making unreasonable profits. Because the uranium in the host rock is irregularly distributed, the quantity of uranium recovered per ton of material varies. Since the cost of mining (per ton) is largely independent of the grade of material mined, higher prices received for yellowcake mean that the operation can process material containing fewer pounds of uranium per ton and still meet expenses. The effect of mining the lower grade material, which would otherwise be uneconomical and therefore left as waste, is to increase both the mine life and the total amount of uranium recovered and sold.

Reserves and Resources

The uranium reserves of New Mexico as now known consist almost exclusively of sandstone ores in the nearly flat-lying sediments of the Morrison Formation. Known ore reserves for the state of New Mexico are summarized in Table 2 (source: ERDA, 1976).

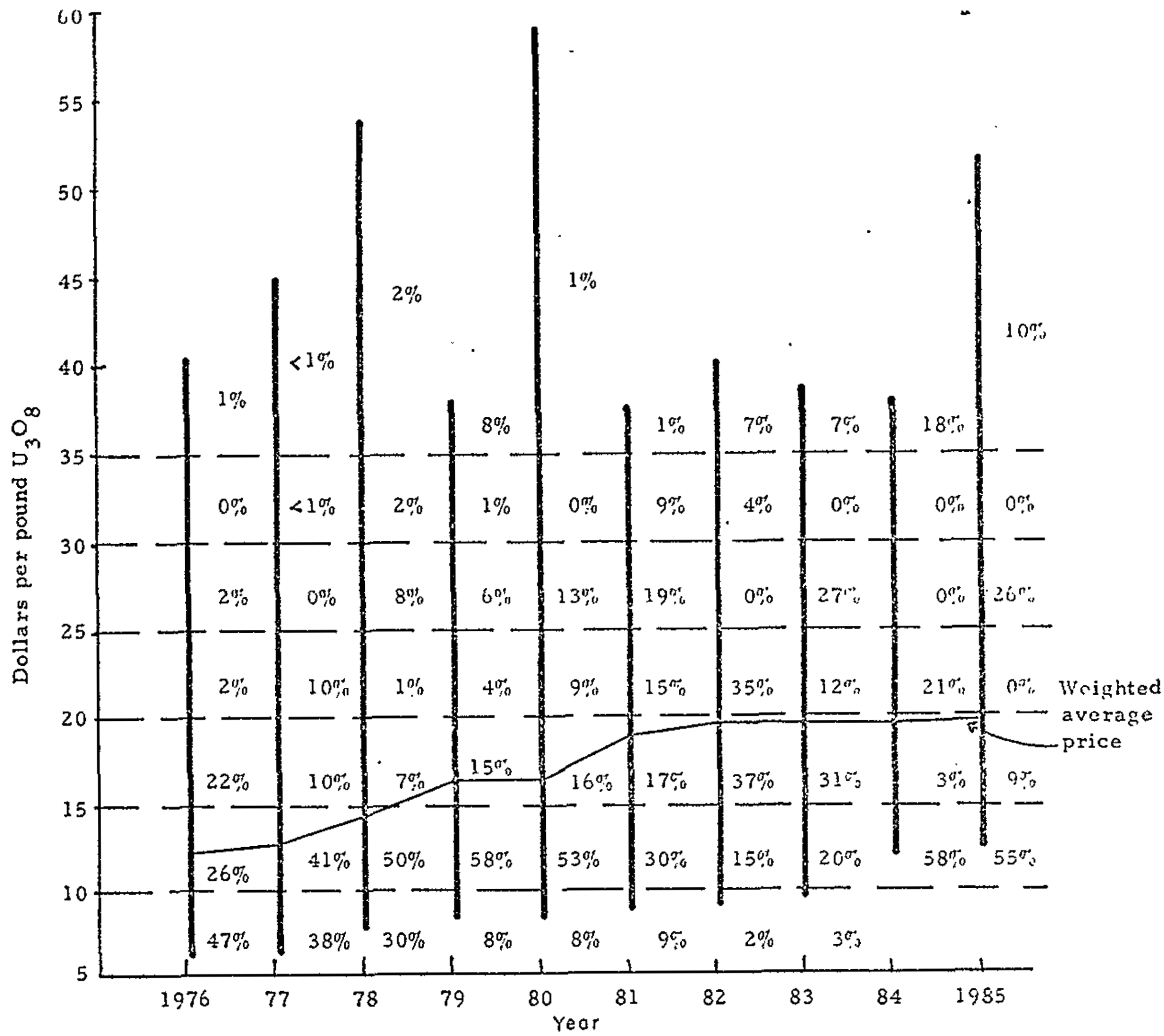

Figure 4. Range of reported uramium prices as of July 1, 1976. Source: Hanrahan and others, 1976.

Table 2. Uranium Reserves of New Mexico

Cost Category	Tons ore	% U_3O_8	Tons U_3O_8	% U.S. Total	No. of deposits
$10	57,100,000	0.26	151,000	56	73
$15	115,900,000	0.18	206,200	48	106
$30	302,000,000	0.10	302,700	47	173

The use of "cost categories" in reporting reserve information requires some explanation to avoid serious misinterpretation. Estimated operating costs and capital costs not yet incurred are used in calculating reserves. Profit and monies spent prior to the time of reserve estimation are not included (expenditures such as land acquisition, exploration, mine and mill development for example). Cost categories therefore cannot and do not represent the price at which the estimated reserves would be sold. Each category includes all lower cost categories.

Deposits not yet discovered, but inferred to exist on the basis of geologic information are referred to as potential resources. Resources are further classified in decreasing order of confidence into: (1) probable - postulated deposits in unexplored extensions of known deposits; (2) possible - postulated deposits in known uranium areas; and (3) speculative - postulated deposits in other areas geologically favorable to uranium. Relevant ERDA data on uranium resources are given in Table 3 (tons U_3O_8).

Table 3. Domestic Uranium Resources

New Mexico

Cost Category	Reserves	Probable	Possible	Speculative
$10	151,00	160,000	240,000	44,000
$15	206,200	210,000	325,000	55,000
$30	302,700	293,000	448,00	76,000

U. S. Total

Cost Category	Reserves	Probable	Possible	Speculative
$10	270,000	440,000	420,000	145,000
$15	430,000	655,000	675,000	290,000
$30	640,000	1,060,000	1,270,000	590,000

Future Production

Projections of future uranium production in New Mexico are, by definition, somewhat speculative, and may be altered drastically by changing conditions. However, some predictions are possible, based on past experience and present trends.

Since the early days of the uranium industry in the state, New Mexico has generally produced about 40 to 45 percent of the nation's total uranium. Assuming that this trend is to continue, and using ERDA cumulative uranium requirements based on projections of moderate growth of demand, it is possible to calculate a trend for uranium production in New Mexico. Figure 5 shows the cumulative domestic requirements from 1975 to 2000 A.D. The figure also shows 40 and 45 percent of this total, or that proportion historically produced by the state. Also shown are the reserves plus resources estimates for cost categories of $10, $15, and $30 per pound U_3O_8 (from Table 3).

According to these estimates, by the year 2000, New Mexico will need to produce between 574,000 and 646,000 tons of yellowcake (cumulative). Present reserves in cost categories up to and including $30 per pound are inadequate to meet even half of this projected demand. Only delineation of reserves from resources presently classed as "probable" at $30 per lb. will allow New Mexico to continue the role the state currently plays in the uranium industry. For lower cost categories, reserves must be delineated from resources now classed as "possible" and "speculative"

Intensive exploration efforts by industry are needed to convert potential resources into known reserves. The question then arises as to

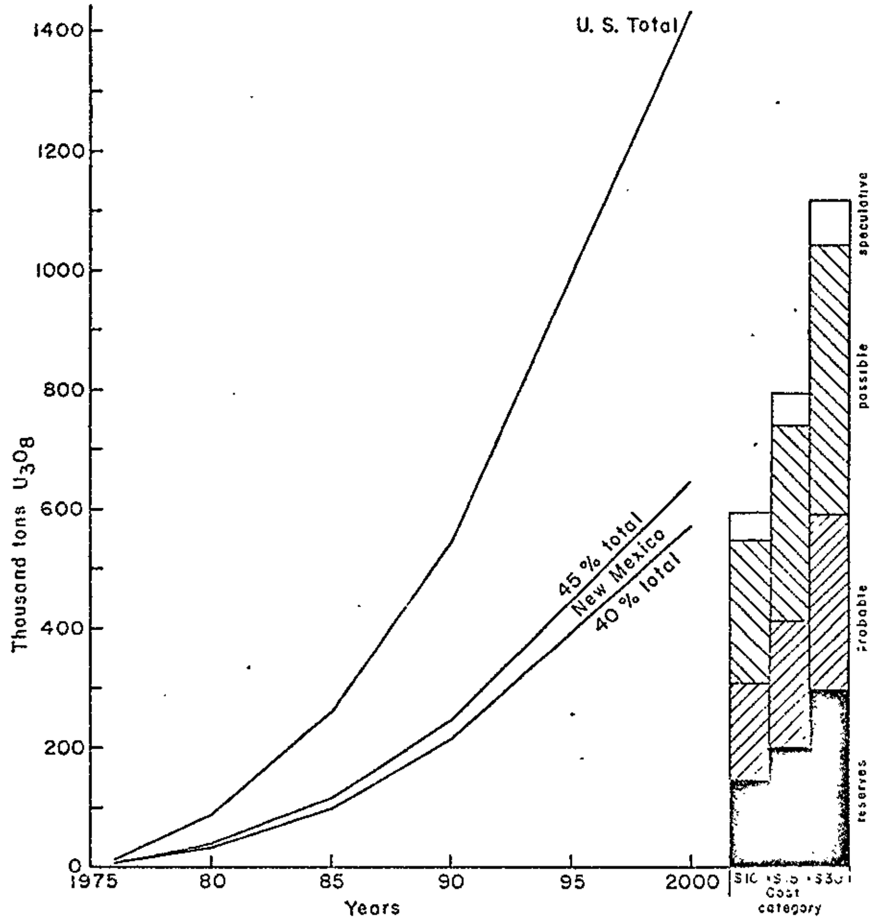

Figure 5. Cumulative domestic uranium requirements, 1975--2000, relative to New Mexico reserves plus resources; see text for explanation. Demand estimate from Hanrahan and others, 1976 (mid case, limited uranium recycle, no plutonium recycle, 0.30% enrichment tails).

whether or not such exploration efforts are being made in the state. Land holdings and drilling footage are two indicators of the intensity of exploration. Figure 6 summarizes the relative standing of New Mexico in terms of surface drilling —— the basic mode of exploration. From 1970 to 1975, drilling in New Mexico has remained essentially constant in terms of percent of national effort. However, drilling in Wyoming basins increased dramatically from 1971 to 1973 and remains at a high level. If surface drilling is taken as indicative of near-term future exploration, New Mexico's position appears roughly unchanged during the 6 years from 1970 to 1975. The abrupt increase in footage in 1976 reflects, in part, the increase in hole depth as exploration efforts move farther north into the San Juan Basin. Unfortunately, statistics on the number of holes drilled in New Mexico are unavailable at this time.

Land holdings, summarized in Figure 7, may be more indicative in terms of long term trends. Because of the very long lead times necessary to develop mineral deposits (ten or more years from land acquisition to first production), land holdings may be indicative both of additional exploration work needed to delineate deposits, and of future production from those deposits. The consistent downward trend of New Mexico's relative land position suggests, perhaps, that in the mid to late 1980's, industry's exploration efforts may be concentrated elsewhere. The problem then arises that without intensive exploration, potential resources in this state will not be converted to reserves quickly enough to meet the demands of increased production. In the face of increasing production from present reserves, decreased exploration means exhaustion of those reserves by 1990-1995 (see Fig. 5).

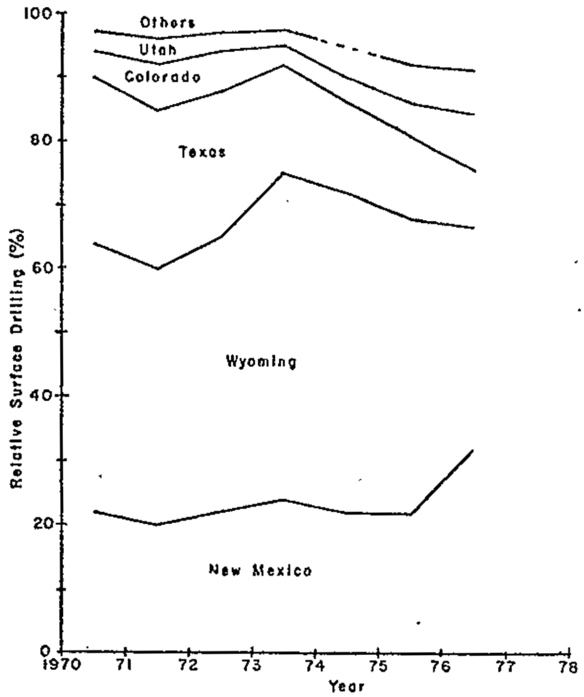

Figure 6. Trend of surface drilling footage since 1970. Source: Kerr-McGee Nuclear Corp., 1975, ERDA, 1976, 1977b. Data for Utah, 1974 not available (dashed line).

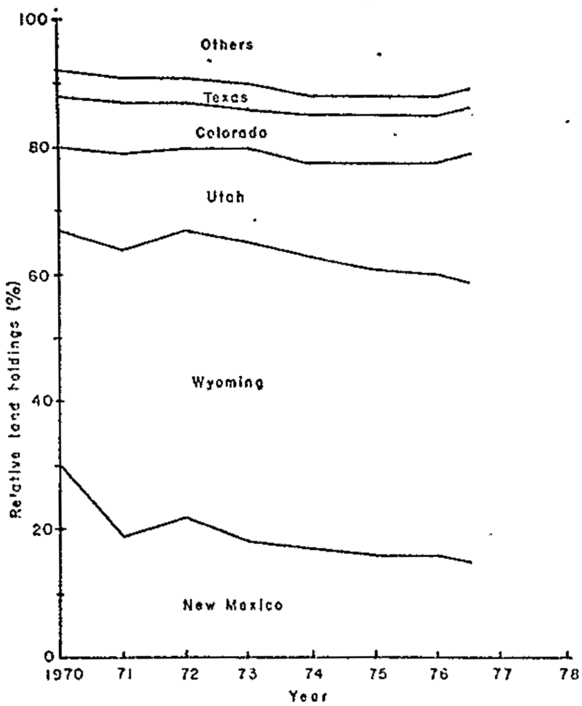

Figure 7. Trend of land holdings for uranium exploration and development since 1970. Source: Kerr-McGee Nuclear Corp., 1975; ERDA, 1976, 1977a.

In addition to the long term trends (since 1970) discussed earlier, changes in the political/tax/economic climate could drastically alter the more "normal" course of events. Such changes, like the severance tax increases proposed in the 1977 state legislature, could accelerate the trend toward exploration elsewhere.

SELECTED BIBLIOGRAPHY

Chenoweth, W. L., 1976, Uranium resources of New Mexico: New Mexico Geol. Soc., Sp. Publ. 6, p. 138-143.

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

ERDA, 1977a, Survey of lands held for uranium exploration, development and production in fourteen western states in the six month period ending June 30, 1976: U. S. Energy Research and Development Administration Rept. GJBX-2(77),20 p.

ERDA, 1977b, ERDA announces figures for 1976 uranium exploration and development drilling by industry: Grand Junction Office, U. S. Energy Research and Development Administration News Release 77-15.

Gay, I. M., 1963, Uranium mining in the Grants district: in New Mexico Bur. Mines & Min. Res. Mem. 15, Geology and technology of the Grants uranium region, p. 244-246.

Gordon, E., 1973, Uranium — plant expansion should start now to meet projected demand in 1975: Engineering/Mining Journal, v. 174, p. 125-129.

-----, 1974, Uranium -- new development is targeted at future nuclear generating market: Engineering/Mining Journal, v. 175, p. 156-160.

-----, 1975, Uranium -- prices firm up in '74, new foreign policies affect investment: Engineering/Mining Journal, v. 176, p. 213-217.

-----, 1976, Uranium -- new projects anticipate coming demand: Engineering/Mining Journal, v. 177, p. 190-2-6.

Hanrahan, E. J., Williamson, R. H., and Brown, R. W., 1976, United State uranium requirements: text of oral paper presented at ERDA 1976 Uranium industry seminar, Grand Junction, CO., Oct., 1976.

Hetland, D. L., 1976, Discussion of the preliminary NURE report and potential resources: text of oral paper presented at ERDA 1976 Uranium industry seminar, Grand Junction, CO., Oct., 1976.

Hilpert, 1965, Uranium: in New Mexico Bur. Mines & Min. Res. Bull 87, Mineral and water resources of New Mexico, p. 209-226.

Kelley, V. C., ed., 1963, Geology and technology of the Grants uranium region: New Mexico Bur. Mines & Min. Res. Mem. 15, 277 p.