Uranium resources in New Mexico--Discussion of the NURE Program

Virginia T. McLemore

New Mexico Geology, v. 3, n. 4 pp. 54-58, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
https://doi.org/10.58799/NMG-v3n4.54

Download from: https://geoinfo.nmt.edu/publications/periodicals/nmg/backissues/home.cfml?volume=3&number=4

New Mexico Geology (NMG) publishes peer-reviewed geoscience papers focusing on New Mexico and the surrounding region. We aslo welcome submissions to the Gallery of Geology, which presents images of geologic interest (landscape images, maps, specimen photos, etc.) accompanied by a short description.

Published quarterly since 1979, NMG transitioned to an online format in 2015, and is currently being issued twice a year. NMG papers are available for download at no charge from our website. You can also subscribe to receive email notifications when new issues are published.

New Mexico Bureau of Geology & Mineral Resources
New Mexico Institute of Mining & Technology
801 Leroy Place
Socorro, NM 87801-4796

https://geoinfo.nmt.edu

This page is intentionally left blank to maintain order of facing pages.

Uranium resources in New Mexico—discussion of the NURE program

by Virginia T. McLemore, Geologist, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM

A function of the Department of Energy's (DOE) National Uranium Resource Evaluation (NURE) program is to estimate the uranium resources of the United States. These estimates are based on geological analogy of an unproductive area or environment with a productive or well defined ore deposit. This procedure involves a very large data base of both known ore deposits and of favorable geologic areas or environments believed to contain ore deposits. The Atomic Energy Commission (AEC), the Energy Resources and Development Administration (ERDA), and now the DOE have been accumulating such a data base for over 30 yrs. In 1974, NURE was given the task of obtaining more data in the form of aerial radiometric and magnetic surveys (ARMS) and hydrogeochemical and stream-sediment reconnaissance (HSSR) surveys for each 1:250,000-scale 1° × 2° topographic quadrangle in the United States. Special studies of uranium deposits not yet exploited in the United States are included as part of the data-gathering process. Finally, each quadrangle was to be fully evaluated and assessed for uranium resources. The assessment and evaluation of the accumulated NURE data for the entire United States is described and summarized in a report by the DOE (1980b), from which most of the information for this summary is taken.

The ARMS and HSSR surveys for all 22 quadrangles in New Mexico are completed, although not all of the reports are yet available from DOE (appendix 1). Only 10 quadrangles in New Mexico are fully assessed and evaluated; three additional quadrangles will be released in 1982. Six of the HSSR reports include concentrations of 42 additional elements.

Uranium resources are defined by the DOE (1980b) as the sum of known uranium reserves and estimated potential uranium resources. Reserves are known quantities of uranium ore, defined by direct measurements of known deposits; potential resources are the quantities of uranium believed to be present in areas of known uranium production or in areas of favorable geologic settings or formations of undiscovered deposits. Potential resources are divided into three classes—probable, possible, and speculative (fig. 1).

Reserves and potential resources are divided into selected maximum forward-cost categories ($30, $50, and $100 per lb of U_3O_8) to cover current economic conditions. Estimated operating and capital costs not yet incurred are used in calculating the forward-cost categories. Cost categories do not represent the price at which the estimated resources would be sold because expenditures prior to reserve calculations (such as land acquisition, exploration, mine and mill development, profit, cost of money, and marketing) are not included in calculating forward costs. Stressing that the forward costs used in calculating cost categories include only those capital and operating costs, in 1980 dollars, which have not yet been incurred is important. In most situations, in today's dollars, forward costs are roughly one-half the actual price (neglecting inflation) needed to sell U_3O_8 at a profit (Cheney, 1981).

The estimation of potential uranium resources involves a complex methodology devised by the DOE (1980b) and Blanchfield (1980) and is only summarized in this report. The United States is divided into 13 resource regions by the DOE on the basis of geologic and physiographic characteristics. Favorable areas are defined in each of the 13 resource regions as promising geologic environments that could contain significant resources of uranium at a minimum grade of 0.01 percent U_3O_8 to a depth of 5,000 ft. Each favorable area is classified as probable, possible, or speculative by the final evaluation team, depending on the location and type of information available for each area. Thus, a promising geologic environment for a particular area possibly was not assessed.

The amounts of uranium that theoretically could be produced from an ore deposit for each cost category ($30, $50, $100 per lb of U_3O_8) are estimated using engineering and cost modeling and probability theory. The endowment is an estimate of the amount of all uranium-bearing material above a cutoff grade of 0.01 percent U_3O_8 postulated to occur in a favorable area to a depth of 5,000 ft and is calculated using the following equation:

$$U_e = A \cdot F \cdot T \cdot G,$$

where U_e is the conditional uranium endowment in tons, A is the projected surface area of the favorable area in sq mi, F is the fraction of A that is underlain by endowment, T is the tons of endowed rock per sq mi within A · F, and G is the average grade of endowment. To account for the uncertainty of the existence of uranium deposits in the favorable area, the conditional endowment (U_e) is multiplied by a probability factor, P_o, which is estimated or derived by the original evaluation team or principal investigator, resulting in unconditional endowment. The endowment and economic potential for each cost category is calculated. Technical reviews of each area or property assessed reasonably guarantees the repeatability of the assessments (Blanchfield, 1980).

New Mexico includes parts of four resource regions and all or part of 22 topographic quadrangles at a scale of 1:250,000 (fig. 2). Most of the reserves and production from New Mexico are from the Colorado Plateau resource region. New Mexico contains approximately 50 percent of the $30 reserves in the United States, amounting to 338,500 tons of U_3O_8 (table 1). The Grants uranium region in the Colorado Plateau contains 22 percent of the total resources (cumulative production, $50 reserves, and potential resources) in the United States, amounting to 890,000 tons of U_3O_8 (DOE, 1980b). Seventy-two favorable areas are found in New Mexico (table 2) and are found in each of the four resource regions (fig. 2). Many of the 72 properties or favorable areas in table 2 overlap in location because of proprietorship or different geologic environments, resulting in only 32 areas shown in fig. 1. Many of the favorable areas coincide with areas of previously known uranium production or uranium occurrences (Chenoweth, 1976).

TABLE 1—URANIUM RESERVES IN NEW MEXICO AS OF JANUARY 1, 1980 (from DOE, 1980a).

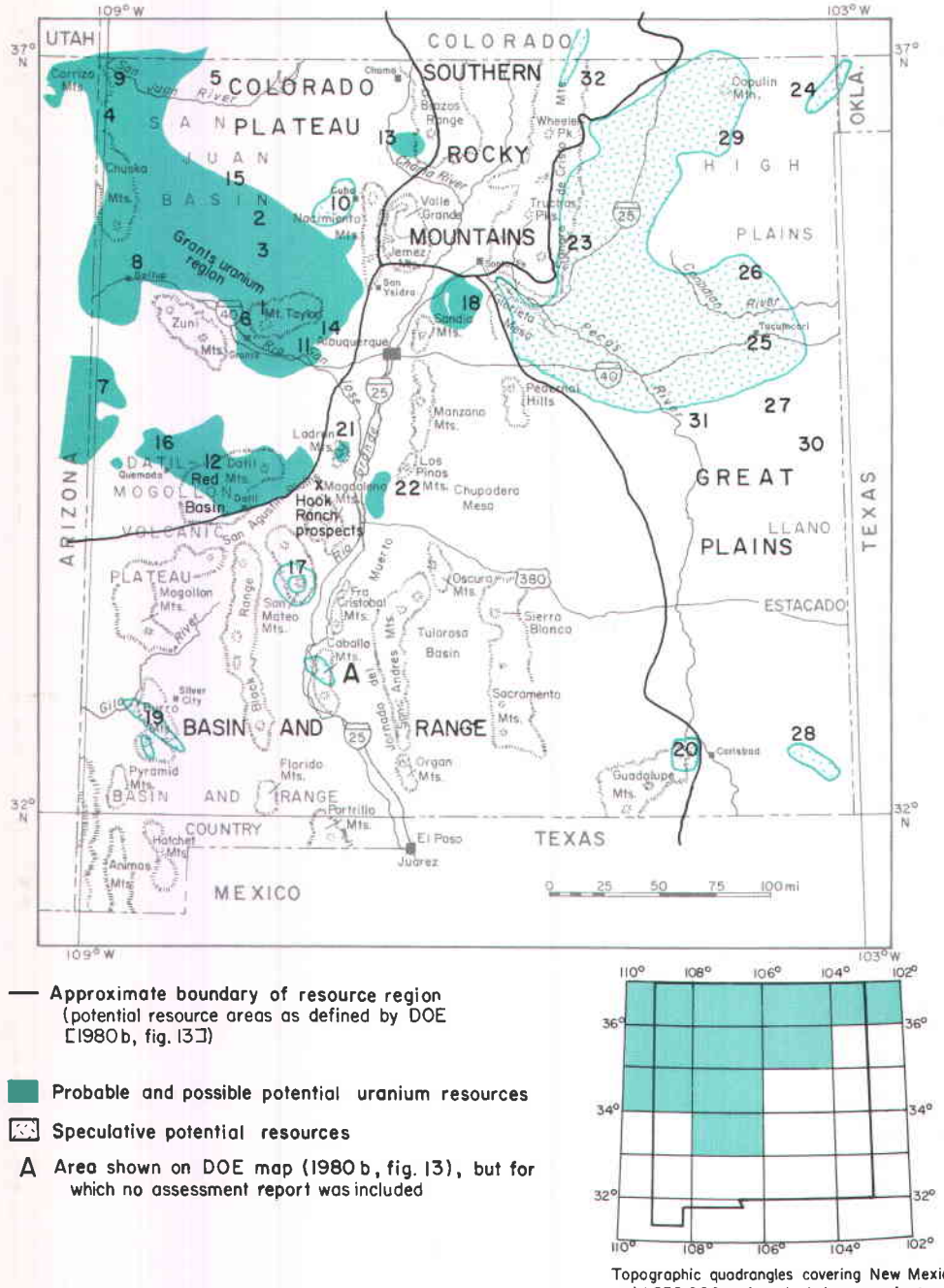
	Tons ore	Percent U_3O_8	Tons U_3O_8	Percent total U.S. reserves	No. of properties
$30/lb	225,700,000	0.13	338,500	52%	140
$50/lb	482,400,000	0.09	448,700	48%	181
$100/lb	670,500,000	0.08	512,300	46%	183

Most of the reserves and potential resources (table 3) are found in the Colorado Plateau region (fig. 2) according to the DOE's assessments. Existing uranium deposits and potential uranium resources occur mainly in Mesozoic host rocks of fluvial sandstones, mudstones, and conglomerates (table 4). Uraniferous limestones (Todilto Limestone) and lignites (Menefee Formation) also are present in this region. According to the DOE's calculations, the most favorable host rocks in the New Mexico portion of the San Juan Basin include the Morrison, the Chinle, and the Baca Formations; all three are potential stratiform sandstone deposits.

The Morrison Formation consists of four members (in ascending order)—the Salt Wash, Recapture, Westwater Canyon, and Brushy Basin Members (fig. 3). The thick sandstones of the Westwater Canyon Member contain large uranium deposits in the Ambrosia Lake and Gallup areas. The green mudstones and claystones with interbedded sandstones (including the Jackpile Bed) of the Brushy Basin Member contain uranium deposits in the Laguna and Smith Lake areas. The Salt Wash Member consists of interbedded mudstones and fluvial sandstones and contains uranium deposits in the Carrizo and Chuska Mountains. Sandstones of the Recapture Member in the Chuska Mountains also have produced uranium ore. The Morrison Formation also contains uranium deposits near San Ysidro.

Reserves	+	**Potential resources**			=	**Uranium resources**
(Defined by direct sampling)		Incompletely defined or undiscovered				
		↑	↑	↑		
		Probable	Possible	Speculative		

FIGURE 1—DEFINITION OF RESOURCE CLASSES.



— Approximate boundary of resource region (potential resource areas as defined by DOE [1980b, fig. 13])

Probable and possible potential uranium resources

Speculative potential resources

A Area shown on DOE map (1980b, fig. 13), but for which no assessment report was included

Topographic quadrangles covering New Mexico at 1:250,000 scale—shaded areas refer to assessed quadrangles.

FIGURE 2—RESOURCE REGIONS AND FAVORABLE AREAS OF URANIUM POTENTIAL RESOURCES IN NEW MEXICO. Numbered areas refer to approximate locations of potential uranium resource areas included in table 2. Each area was located based on Chenoweth's (1976) map, because DOE did not give exact locations for each area. Also note that only 32 numbered areas appear above whereas 72 favorable areas are listed in table 2—a result of different proprietorship or stratigraphic unit.

The fluvial sandstones of the Chinle and Baca Formations are considered by the DOE to contain possible and speculative potential uranium resources. The Chinle Formation is exposed along the southern rim of the Colorado Plateau while the Baca Formation is exposed in the Red Basin area near Datil (fig. 2). The Red Basin uranium deposit was previously assigned to the base of the Baca Formation (Bachman and others, 1957) and is now considered by Chamberlin (1981) to occur in an oxidized and bleached (weathered) zone in the top of the Crevasse Canyon Formation (Cretaceous). Uranium anomalies in a similar oxidized zone are exposed north of Quemado and Magdalena, although no DOE assessment report has been made for these areas. These widespread occurrences are most likely related to a regional unconformity that was buried by the Baca Formation (Chamberlin, 1981).

Other favorable host rocks assessed by the DOE in the Colorado Plateau region include roll-type deposits in the Burro Canyon Formation (Jurassic–Cretaceous) and the Ojo Alamo Sandstone (Tertiary) and sandstone deposits in the Dakota Sandstone (Cretaceous). The Fruitland Formation (Cretaceous) northwest of Farmington has produced uranium ore and the San Jose Formation in Rio Arriba and San Juan Counties contains uranium (Chenoweth, 1977), although the DOE has not included these areas in their assessment.

The Basin and Range resource region (fig. 2) is one of the most geologically diverse areas in the United States. This region is characterized by fault blocks forming mountains and valleys that contain rocks of many types and ages. In New Mexico, probable, possible, and speculative potential uranium resources are present (tables 2 and 3). According to the DOE, potential uranium resources occur as hydrothermal-magmatic and contact-metasomatic veins in the Madera Limestone, Popotosa Formation, Precambrian granitic rocks, and Yeso Formation (table 4). Roll-type sandstone deposits (Galisteo Formation) and uraniferous limestone deposits (Yates Formation) also are postulated as occurring within this resource region (table 4).

A small area in the Caballo Mountains (**A**, fig. 2) is identified by the DOE (1980b, fig. 13) as being a speculative potential resource area, but the DOE does not include an assessment report on the area. The Caballo Mountains area, near Truth or Consequences, contains numerous uranium occurrences in Precambrian rocks and the Abo (Permian), Mesaverde (Upper Cretaceous), and McRae (Upper Cretaceous–Tertiary) Formations (Templain and Dotterrer, 1978). The Thurman and Palm Park Formations (Tertiary) were considered as hosts for speculative potential uranium deposits by the DOE in 1979 (DOE, 1979). Uranium- and thorium-bearing syenites (Staatz and others, 1965) and radioactive fault and shear zones within granitic rocks (Templain and Dotterrer, 1978) occur in the Precambrian terrain. Radioactivity is associated with copper minerals in the red beds of the Abo Formation, similar to many radioactive red-bed deposits throughout the southwestern United States (Gibson, 1952). The unassessed area specifically identified by the DOE coincides with the outcrop of the Mesaverde and McRae Formations in the Cutter sag area (Kelley, 1955). Bushnell (1955, p. 85) mentions reddish sandstones in the uppermost beds of the Mesaverde Group unconformably overlain by the McRae Formation. The uranium occurrences in these formations may be similar to those found in the Red Basin area, Catron and Socorro Counties (Chamberlin, 1981). This area probably will be dropped from future assessments by the DOE (J. A. Olsen, personal communication, 1981).

Speculative potential resources are postulated by the DOE as occurring in the Great Plains and Southern Rocky Mountain (Southern Rockies of NURE) regions of New Mexico (table 3). The Great Plains region is characterized by a thick sequence of Paleozoic sedimentary rocks overlain by continental sediments derived from the Rocky Mountains (Laramide). The Southern Rocky Mountain region in New Mexico includes Laramide uplifts, exposing a Precambrian terrain cut by Tertiary intrusives, and basins of the Rio Grande rift filled with sedimentary and volcanic rocks. Potential uranium resources occur as roll-type or stratiform sandstone deposits in both regions (table 2) and occur in arkosic sand-

TABLE 2—FAVORABLE AREAS FOR POTENTIAL URANIUM RESOURCES IN NEW MEXICO based on DOE (1980b) assessment reports (microfiche DOE, 1980b). 1) Rank number, as given by DOE (1980b, microfiche), is based on the quantity of assessed \$50/lb U_3O_8 resources for all properties in the resource region besides those in New Mexico; 2) member of the Morrison Formation (Late Jurassic); and 3) part of the Mesaverde Group (Cretaceous).

Map no. on fig. 1	Rank no.[2] on microfiche (DOE, 1980b)	Locality	Formation/Host	Deposit class	Favorable environment (Ss—sandstone, Ls—limestone, lig.—lignite)	Potential class (probable, possible, speculative)	Unconditional economic potential: mean tons U_3O_8 \$30/lb	\$50/lb	\$100/lb	assigned average grade \$30/lb	\$50/lb	\$100/lb	Unconditional endowment tons U_3O_8	2° quadrangle
	COLORADO PLATEAU													
1	1	Mount Taylor	Westwater Canyon member[2]	nonchannel-controlled stratiform	Ss	prob.	3,695	7,106	106,174	.33	.20	.12	159,060	Albuquerque
2	2	West Chaco Canyon	Westwater Canyon member[2]	nonchannel-controlled stratiform	Ss	prob.	3,267	6,996	112,787	.35	.20	.12	177,715	Gallup, Albuquerque
2	3	East Chaco Canyon	Westwater Canyon member[2]	nonchannel-controlled stratiform	Ss	prob.	2,077	4,628	77,947	.34	.20	.11	129,050	Albuquerque, Aztec
2	4	West Chaco Canyon	Westwater Canyon member[2]	nonchannel-controlled stratiform	Ss	poss.	2,185	4,588	74,011	.32	.18	.11	117,105	Gallup, Aztec
3	5	Black Jack	Westwater Canyon member[2]	nonchannel-controlled stratiform	Ss	prob.	1,479	3,037	47,215	.29	.17	.10	71,224	Albuquerque, Gallup
4	6	Shiprock	Westwater Canyon member[2]	nonchannel-controlled stratiform	Ss	poss.	1,108	2,853	54,240	.32	.17	.10	102,571	Shiprock
5	7	Central Basin (Aztec)	Westwater Canyon member[2]	nonchannel-controlled stratiform	Ss	poss.	950	2,472	47,581	.33	.18	.10	95,763	Aztec
6	8	Ambrosia Lake	Westwater Canyon member[2]	nonchannel-controlled stratiform	Ss	prob.	1,291	2,400	34,842	.30	.18	.11	50,378	Albuquerque
7	12	East Mogollon Slope	Chinle Formation (Tri.)	channel-controlled stratiform	Ss	poss.	1,083	1,980	26,338	.14	.09	.06	31,793	St. Johns (AZ and NM)
6	13	Ambrosia Lake	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	poss.	910	1,932	31,561	.31	.18	.11	51,187	Albuquerque
1	15	Mount Taylor	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	poss.	790	1,680	27,524	.32	.19	.11	45,278	Albuquerque
8	16	Gallup	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	prob.	854	1,679	25,143	.30	.18	.11	36,964	Gallup
9	17	Central Basin–Shiprock	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	poss.	633	1,636	31,892	.33	.18	.10	64,487	Shiprock
4	19	Shiprock	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	prob.	692	1,471	23,347	.30	.17	.10	35,956	Shiprock
2	24	East Chaco Canyon	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	prob.	532	1,159	19,021	.35	.20	.12	30,575	Albuquerque, Aztec
10	27	Nacimiento	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	poss.	434	995	17,721	.27	.15	.09	32,482	Albuquerque
8	29	Gallup	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	poss.	339	807	14,346	.31	.17	.10	25,134	Gallup
11	30	Laguna	Jackpile sandstone bed[2]	nonchannel-controlled stratiform	Ss	prob.	495	736	9,261	.27	.17	.10	11,948	Albuquerque
12	37	Socorro–Red Basin	Baca Formation (Eoc.)	channel-controlled stratiform	Ss	poss.	344	590	8,077	.31	.19	.12	11,307	Socorro
13	40	Chama Basin	Burro Canyon Formation (Jur.–Cret.)	roll type in basins	Ss	prob.	291	550	8,896	.18	.10	.06	11,650	Aztec
11	41	Laguna	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	prob.	235	513	8,472	.28	.16	.09	13,598	Albuquerque
4	44	Shiprock	Salt Wash member[1]	nonchannel-controlled stratiform	Ss	prob.	313	455	5,607	.25	.16	.10	7,088	Shiprock (AZ and NM)
4	46	Shiprock	Recapture member[1]	nonchannel-controlled stratiform	Ss	poss.	239	427	6,063	.35	.20	.12	9,107	Shiprock
11	49	Laguna	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	poss.	194	404	6,679	.23	.13	.08	10,976	Albuquerque
6	50	Ambrosia Lake	Todilto Limestone (Jur.)	uraniferous limestone	Ls	prob.	162	390	6,251	.25	.15	.10	9,113	Albuquerque
10	53	Nacimiento	Jackpile sandstone bed[1]	nonchannel-controlled stratiform	Ss	poss.	231	350	4,474	.29	.18	.11	6,149	Albuquerque
4	55	Shiprock	Salt Wash member[1]	nonchannel-controlled stratiform	Ss	poss.	125	240	3,520	.36	.20	.11	5,383	Shiprock (NM and AZ)
3	58	Black Jack	Todilto Limestone (Jur.)	uraniferous limestone	Ls	poss.	67	208	3,565	.29	.16	.10	5,322	Gallup
3	61	Black Jack	Todilto Limestone (Jur.)	uraniferous limestone	Ls	prob.	80	175	2,617	.22	.14	.09	3,510	Gallup, Albuquerque
3	62	Black Jack	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	poss.	73	161	2,659	.32	.18	.11	4,249	Gallup, Albuquerque
11	67	Laguna	Jackpile sandstone bed[1]	nonchannel-controlled stratiform	Ss	poss.	76	119	1,564	.30	.19	.12	2,164	Albuquerque
14	73	Central Basin–Albuquerque	Westwater Canyon member[1]	nonchannel-controlled stratiform	Ss	poss.	32	89	1,901	.36	.20	.10	3,838	Albuquerque
15	74	Ojo Alamo	Ojo Alamo sandstone (Ter.)	roll type in basins	Ss	spec.	45	89	1,471	.25	.13	.07	2,859	Aztec, Albuquerque
11	75	Laguna	Todilto Limestone (Jur.)	uraniferous limestone	Ls	poss.	34	80	1,229	.23	.14	.09	1,653	Albuquerque
11	76	Laguna	Recapture member[1]	nonchannel-controlled stratiform	Ss	poss.	33	63	940	.31	.17	.10	1,494	Albuquerque
11	77	Laguna	Todilto Limestone (Jur.)	uraniferous limestone	Ls	prob.	40	56	661	.19	.12	.09	700	Socorro
3	78	Black Jack	Recapture member[1]	nonchannel-controlled stratiform	Ss	poss.	20	51	764	.30	.17	.10	1,240	Gallup, Albuquerque
11	80	Laguna	Todilto Limestone (Jur.)	uraniferous limestone	Ls	poss.	22	50	761	.23	.14	.09	1,015	Socorro
6	81	Ambrosia Lake	Recapture member[1]	nonchannel-controlled stratiform	Ss	poss.	26	50	756	.32	.18	.10	1,240	Albuquerque
3	82	Black Jack	Todilto Limestone (Jur.)	uraniferous limestone	Ls	poss.	13	48	880	.32	.17	.11	1,378	Albuquerque
2	85	West Chaco Canyon	Recapture member[1]	nonchannel-controlled stratiform	Ss	poss.	20	38	781	.48	.27	.13	1,502	Gallup, Albuquerque
11	86	Laguna	Todilto Limestone (Jur.)	uraniferous limestone	Ls	prob.	18	36	493	.20	.12	.08	585	Socorro
8	87	Gallup	Dakota Sandstone (Cret.)	general sandstone type	Ss	prob.	18	35	545	.31	.17	.10	875	Gallup
8	88	Gallup	Dakota Sandstone (Cret.)	general sandstone type	Ss	poss.	17	35	587	.36	.20	.10	971	Gallup (NM and AZ)
4	89	Shiprock	Menefee Formation (Cret.)[3]	uraniferous lignite	lig.	prob.		34	1,539	.20	.10	.07	2,062	Albuquerque
4	90	Shiprock	Recapture member[1]	nonchannel-controlled stratiform	Ss	prob.	22	33	422	.27	.17	.10	534	Shiprock
8	93	Gallup	Todilto Limestone (Jur.)	uraniferous limestone	Ls	poss.	5	24	706	.43	.24	.11	1,159	Gallup
1	94	Mount Taylor	Recapture member[1]	nonchannel-controlled stratiform	Ss	poss.	14	23	448	.45	.25	.13	837	Albuquerque
8	96	Gallup	Recapture member[1]	nonchannel-controlled stratiform	Ss	poss.	10	19	305	.33	.19	.11	522	Gallup
4	99	Shiprock	Menefee Formation (Cret.)[3]	uraniferous lignite	lig.	prob.		16	1,539	.21	.11	.07	2,062	Albuquerque
6	101	Ambrosia Lake	Dakota Sandstone (Cret.)	general sandstone type	Ss	poss.	8	14	219	.30	.17	.10	348	Albuquerque
16	104	Quemado	Baca Formation (Eoc.)	channel-controlled stratiform	Ss	spec.	5	13	292	.20	.11	.06	880	St. Johns
6	111	Ambrosia Lake	Todilto Limestone (Jur.)	uraniferous limestone	Ls	poss.	1	8	312	.52	.30	.15	680	Albuquerque
2	117	West Chaco Canyon	Dakota Sandstone (Cret.)	general sandstone type	Ss	poss.	1	2	44	.30	.17	.09	68	Gallup
3	118	Black Jack	Dakota Sandstone (Cret.)	general sandstone type	Ss	poss.		1	27	.30	.17	.10	43	Albuquerque
3	119	Black Jack	Dakota Sandstone (Cret.)	general sandstone type	Ss	poss.			8	.33	.18	.10	13	Gallup
	BASIN AND RANGE													
17	11	San Mateo Mts.	Madera Limestone (Penn.)	magmatic hydrothermal	vein	spec.	370	713	11,136	.46	.27	.15	17,312	Tularosa
18	14	La Bajada–Hagen	Galisteo Formation (Eoc.)	roll type in basins	Ss	prob.	185	399	6,529	.25	.16	.10	9,831	Albuquerque, Santa Fe
19	40	Burro Mts.	Precambrian granitic rocks	contact metasomatic	vein	spec.	29	73	1,094	.14	.08	.05	1,293	Silver City
20	66	San Cristobal	Yates Formation (Perm.)	uraniferous limestone	Ls	spec.	3	10	180	.15	.08	.04	299	Carlsbad
21	76	Ladron Mountains	Popotosa Formation (Ter.)	magmatic hydrothermal	Ss	poss.	2	3	37	.37	.24	.16	47	Socorro
22	86	Chupadera	Yeso Formation (Perm.)	magmatic hydrothermal	vein	poss.			3	.34	.21	.12	4	Socorro
	GREAT PLAINS													
23	1	Santa Fe–Raton	Sangre de Cristo Formation (Penn.–Perm.)	roll type in basins	Ss	spec.	2,787	5,104	76,018	.32	.19	.11	116,352	Santa Fe, Raton
24	22	Dalhart–Morrison	Morrison Formation (Jur.)	channel-controlled stratiform	Ss	spec.	99	164	2,527	.29	.15	.08	4,188	Dalhart (NM and OK)
25	35	San Jon–Tucumcari	Chinle Formation (Tri.)	channel-controlled stratiform	Ss	spec.	25	63	842	.14	.08	.06	920	Tucumcari
26	45	Tucumcari	Sangre de Cristo Formation (Penn.–Perm.)	roll type in basins	Ss	spec.	16	33	584	.40	.22	.11	921	Tucumcari
27	47	San Jon–Clovis	Chinle Formation (Tri.)	channel-controlled stratiform	Ss	spec.	10	27	378	.15	.08	.06	421	Clovis
28	48	Delaware Basin	Chinle Formation (Tri.)	channel-controlled stratiform	Ss	spec.	7	27	474	.18	.11	.07	651	Hobbs
29	57	Dalhart	Sangre de Cristo Formation (Penn.–Perm.)	roll type in basins	Ss	spec.	6	12	223	.40	.22	.11	352	Dalhart
30	60	Clovis	Sangre de Cristo Formation (Penn.–Perm.)	roll type in basins	Ss	spec.	4	10	175	.40	.22	.11	276	Clovis
31	61	Ft. Sumner	Sangre de Cristo Formation (Penn.–Perm.)	roll type in basins	Ss	spec.	4	9	210	.59	.34	.17	433	Ft. Sumner
	SOUTHERN ROCKY MOUNTAINS													
32	20	La Veta	Sangre de Cristo Formation (Penn.–Perm.)	channel-controlled stratiform	Ss	spec.	246	296	3,448	.19	.13	.08	4,663	Raton–Trinidad (CO and NM)

stones and siltstones of the Sangre de Cristo, Morrison, and Chinle Formations (table 4).

Table 3 shows the potential uranium resources by potential class and table 4 by the host rock. Most of the probable potential resources in New Mexico are found in the Colorado Plateau, although some probable potential resources occur in the Basin and Range region. Only speculative potential resources are found in the Great Plains and Southern Rocky Mountain regions. Most of the potential uranium resources in New Mexico are found in sandstone deposits in the Colorado Plateau, although limestone, lignite, hydrothermal-magmatic, and contact-metasomatic deposits do occur.

While the majority of the United States' potential resources are in Phanerozoic sandstones, some of the world's largest uranium deposits are found in Precambrian host rocks (both granitic and metamorphic). However, most of the NURE project emphasized Phanerozoic sandstone and volcanic deposits. In New Mexico, many isolated exposures of Precambrian rocks were classified as "unevaluated." Detailed geologic mapping and detailed ARMS and HSSR surveys are needed to fully evaluate the Precambrian rocks in New Mexico.

Other problems are apparent with the DOE study. The assessment of 1° × 2° quadrangles involves a large amount of territory to be evaluated in a relatively short period of time and some uranium deposits may have been inadequately evaluated or completely overlooked. Local problems such as rugged topography, lack of access roads, and uncooperative landowners hampered field investigations. Not all of the geology in some quadrangles has been mapped or if mapping has been completed, the geology and structure of the area still may be poorly understood. Subsurface data in many quadrangles is incomplete. At times the ARMS and HSSR surveys were not completed in time for the final evaluation (for example, the Gallup and St. Johns quadrangles). Some of the HSSR data does not indicate from which aquifers or formations well-water samples were taken.

Since the assessments are based on geologic analogy of promising environments with known deposits, an understanding of the promising environments and the known deposits must be achieved. Genetic models and favorability criteria, based on known uranium deposits, have been subjectively employed to indicate favorable environments for uranium deposits. Abrupt truncations of favorable areas at quadrangle boundaries (DOE, 1980b, fig. 13) illustrate the subjectivity involved in delineating favorable areas. Thus, an area may fit the model or favorability criteria, yet the probability of a uranium deposit occuring within this favorable environment may be low. Such may be the case for the Sangre de Cristo Formation in the Great Plains region of New Mexico. Reid and others (1980) consider the Sangre de Cristo Formation to be a favorable environment for roll-type uranium deposits. However, no broad areas of reduced rock have yet been delineated in this formation. Other areas in New Mexico contain favorable geologic environments for uranium deposits but because models are lacking or the probability of uranium deposits occurring is low or cannot be measured, these areas are not included in DOE assessments. One area, the Costilla Peak massif in the Raton quadrangle (Reid and others, 1980), was shifted from a favorable to an unfavorable area classification because geologic data was insufficient to compare with available models.

Since the DOE's original purpose of the NURE program was to provide an estimate of the uranium resources in the United States, many of the calculations and assessments may not represent actual economic conditions. The DOE's assessments include all favorable environments to a depth of 5,000 ft. The DOE assessment reports include ore distribution at various depths; many of New Mexico's favorable uranium resources (listed in table 2) are at depths greater than 2,500 ft.

The DOE assessment reports also indicate the endowment for various probabilities of uranium exceeding a certain amount. This distribution is often several orders of magnitude; however, only the mean endowment is given in table 2. The distribution function for economic potential also is given in the reports and varies from zero to several orders of magnitude—only the mean is given in table 2.

Another problem of the DOE assessments is that the uranium deposits are classified, in ☞

TABLE 3—POTENTIAL URANIUM RESOURCES BY POTENTIAL CLASS (from table 2).

Potential class	Mean tons of U_3O_8 \$30/lb	\$50/lb	\$100/lb	No. of properties assessed
Colorado Plateau				
probable	15,561	31,505	492,779	20
possible	10,045	22,037	372,483	34
speculative	50	102	1,763	2
total	25,656	53,644	867,025	56
Basin and Range				
probable	185	399	6,529	1
possible	2	3	40	2
speculative	402	796	12,410	3
total	589	1,198	18,979	6
Great Plains				
probable				
possible				
speculative	2,958	5,449	81,431	9
total	2,958	5,449	81,431	9
Southern Rocky Mountains				
probable				
possible				
speculative	246	296	3,448	1
total	246	296	3,448	1
Total New Mexico	29,449	60,587	970,883	72
probable	15,746	31,904	499,308	21
possible	10,047	22,040	372,523	36
speculative	3,656	6,643	99,052	15

TABLE 4—POTENTIAL URANIUM RESOURCES IN NEW MEXICO BY HOST ROCK (from table 2).

Formation/host	Age	Deposit class	Mean tons of U_3O_8 \$30/lb	\$50/lb	\$100/lb	No. of properties
COLORADO PLATEAU						
Westwater Canyon Sandstone Member[1]	Juassic	stratiform	21,770	46,606	765,063	20
Chinle Formation	Triassic	stratiform	1,083	1,980	26,338	1
Jackpile Bed[1]	Jurassic	stratiform	802	1,205	15,299	3
Baca Formation	Eocene	stratiform	349	603	8,369	2
Burro Canyon Formation	Jurassic–Cretaceous	roll-type	291	550	8,896	1
Salt Wash Member[1]	Jurassic	stratiform	438	695	9,127	2
Recapture Member[1]	Jurassic	stratiform	392	704	10,479	8
Todilto Limestone	Jurassic	limestone	442	1,075	17,475	10
Ojo Alamo Sandstone	Tertiary	roll-type	45	89	1,471	1
Dakota Sandstone	Cretaceous	sandstone	44	87	1,430	6
Menefee Formation[2]	Cretaceous	lignite		50	3,078	2
BASIN AND RANGE						
Madera Limestone	Pennsylvanian	hydrothermal-magmatic	370	713	11,136	1
Galisteo Formation	Eocene	roll-type	185	399	6,529	1
Precambrian Granite	Precambrian	contact-metasomatic	29	73	1,094	1
Yates Formation	Permian	limestone	3	10	180	1
Popotosa Formation	Tertiary	hydrothermal-magmatic	2	3	37	1
Yeso Formation	Permian	hydrothermal-magmatic			3	1
GREAT PLAINS						
Sangre de Cristo Formation	Pennsylvanian–Permian	roll-type	2,817	5,168	77,210	5
Morrison Formation	Jurassic	stratiform	99	164	2,527	1
Chinle Formation	Triassic	stratiform	42	117	1,694	3
SOUTHERN ROCKY MOUNTAINS						
Sangre de Cristo Formation	Pennsylvanian–Permian	stratiform	246	296	3,448	1

[1]Morrison Formation
[2]Mesaverde Group

TABLE 5—DISTRIBUTION OF URANIUM RESOURCES IN NEW MEXICO AND THE UNITED STATES according to DOE. Reserve calculations are from DOE, 1980a; probable, possible, and speculative calculations for New Mexico are from table 2 (this report) and for total United States are from DOE, 1980b.

	Mean thousand tons U_3O_8											
	Reserves			Resources								
				Probable			Possible			Speculative		
	\$30	\$50	\$100	\$30	\$50	\$100	\$30	\$50	\$100	\$30	\$50	\$100
New Mexico	339	449	512	16	32	499	10	22	373	4	66	99
Total United States	645	936	1,122	885	1,426	2,080	346	641	1,005	311	482	696
New Mexico as percent of total	52	48	46	1.8	2.2	24	2.9	3.4	37	1.3	14	14

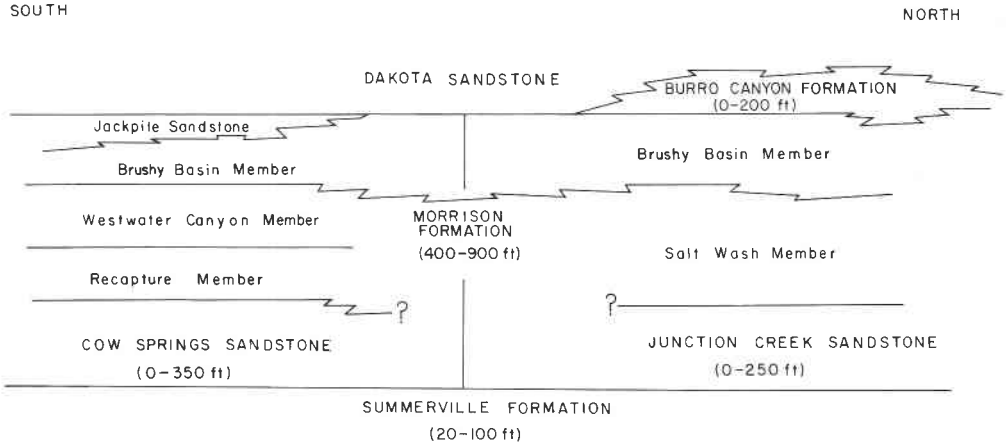


FIGURE 3—Stratigraphic nomenclature of Upper Jurassic–Lower Cretaceous rocks in the San Juan Basin (Molenaar, 1977). Thicknesses are shown in ft measurement.

part, according to their genesis or origin (DOE, 1980b, appendix B). This type of classification requires a prior knowledge of the genesis or origin of the uranium deposit, which in many cases is not always clear or is sometimes based on an investigator's interpretation or speculation. In many areas of uranium deposits, remobilization of uranium by meteoric waters, which tends to conceal the origin of the initial mineralization, has occurred.

In spite of shortcomings, the DOE assessments and evaluations provide a gross estimate of the uranium resources in areas of previously known uranium occurrences in New Mexico (table 5). DOE estimates confirm that the San Juan Basin remains one of the most favorable areas for uranium exploration in New Mexico, even though other smaller deposits do occur in the state. This study (DOE, 1980b) and the individual quadrangle evaluation reports (appendix 1) indicate areas that need further evaluation and exploration. Finally, the DOE has accumulated a large amount of new data (including HSSR and ARMS studies) that still needs to be evaluated with incorporation of available geologic data.

Acknowledgments—R. M. Chamberlin and F. E. Kottlowski are acknowledged for their discussion and criticism of this manuscript.

References

Bachman, G. O., Baltz, E. H., and Griggs, R. L., 1957, Reconnaissance of geology and uranium occurrences of the upper Alamosa Creek valley, Catron County, New Mexico: U.S. Geological Survey, Open-file Rept. TEI-521

Blanchfield, D. M., 1980, Methodology for uranium resource estimates and reliability: Grand Junction, Colorado, Uranium Industry Seminar, U.S. Department of Energy, October 1980

Bushnell, H. P., 1955, Mesozoic stratigraphy of south-central New Mexico: New Mexico Geological Society, Guidebook 6th field conference, p. 81-87

Chamberlin, R. M., 1981, Unconformity-related uranium deposits in Late Cretaceous sandstones in the Datil Mountains area, west-central New Mexico (abstract): Albuquerque, New Mexico, American Association of Petroleum Geologists, Rocky Mountain Section, April 1981

Cheney, E. S., 1981, The hunt for giant uranium deposits: American Scientist, v. 69, no. 1, p. 37-48

Chenoweth, W. L., 1976, Uranium resources of New Mexico, *in* Tectonics and mineral resources of southwestern North America: New Mexico Geological Society, Spec. Pub. No. 6, p. 138-143

———, 1977, Uranium in the San Juan Basin—an overview: New Mexico Geological Society, Guidebook 28th field conference, p. 257-262

Gibson, R., 1952, Reconnaissance of some red bed copper deposits in the southwestern United States: U.S. Atomic Energy Commission, Open-file Rept. RMO-890, 78 p.

Kelley, V. C., 1955, Geologic map of the Sierra County region, New Mexico: New Mexico Geological Society, Guidebook 6th field conference, 2 sheets, scale 1 inch = 1.85 mi

Molenaar, C. M., 1977, San Juan Basin time stratigraphic nomenclature chart: New Mexico Geological Society, Guidebook 28th field conference, p. xii

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

Staatz, M. H., Adams, J. W., and Conklin, N. M., 1965, Thorium-bearing microcline-rich rocks in the southern Caballo Mountains, Sierra County, New Mexico: U.S. Geological Survey, Prof. Paper 525-D, p. D48-D51

Templain, C. J., and Dotterrer, F. E., 1978, Preliminary study of the uranium favorability of the Jornada del Muerto Basin and adjacent areas, south-central New Mexico: U.S. Department of Energy, Open-file Rept. GJBX-80 (78), 22 p.

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

———, 1980a, Statistical data of the uranium industry: Open-file Rept. GJO-100(80), 94 p.

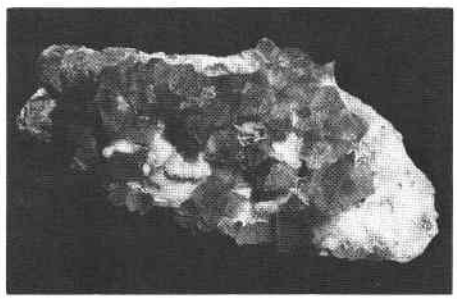
———, 1980b, An assessment report on uranium in the United States of America: Open-file Rept. GJO-111(80), 150 p. □

Appendix 1

Available NURE quadrangle reports (DOE open-file reports); these reports are available at the NMBMMR in Socorro, NM, and the U.S. DOE in Grand Junction, CO. Preliminary reports for public inspection are denoted by an asterisk*.

Quadrangle	HSSR	ARMS	Folio
Albuquerque	GJBX-145(79), 21(77)	GJBX-116(79)	PGJ-016(80)*
Aztec	GJBX-129(78)	GJBX-65(80)	PGJ-012(80)*
Brownfield	GJBX-103(78), 60(76)	GJBX-33(76)	—
Carlsbad	—	—	—
Clifton	GJBX-69(78)	GJBX-69(78), GJBX-23(79)	(1982)
Clovis	—	—	—
Dalhart	GJBX-207(80)	GJBX-46(80)	PGJ-081(81)*
Douglas	GJBX-69(78), GJBX-244(81)	GJBX-69(78), GJBX-23(79)	(1982)
El Paso	—	—	—
Ft. Sumner	GJBX-21(77)	—	—
Gallup	GJBX-186(80)	GJBX-116(79)	PGJ-013(80)*
Hobbs	GJBX-103(78)	GJBX-228(80)	—
Las Cruces	—	—	—
Raton	GJBX-138(78)	GJBX-9(80)	GJQ-005(80)
Roswell	—	—	—
Santa Fe	GJBX-197(80), 21(77)	GJBX-9(80)	PGJ-021(80)*
Shiprock	GJBX-143(80)	GJBX-116(79)	PGJ-024(80)*
Silver City	GJBX-69(78)	GJBX-69(78), GJBX-23(79)	(1982)
Socorro	GJBX-12(81), 21(77)	GJBX-163(79)	PGJ-068(81)*
St. Johns	GJBX-191(80), 69(78), 23(81)	GJBX-126(79)	PGJ-011(80)*
Tucumcari	—	—	—
Tularosa	GJBX-104(78)	GJBX-67(79)	PGJ-004(80)*

New Mexico's minerals



Fluorite, CaF_2. Cooke's Peak mining district, Luna County, New Mexico

Crystal system: isometric Hardness: 4

Specific gravity: 3.18 Cleavage: {111} perfect

Color: varies greatly; most commonly purple, blue, green, and yellow. Fluorite also occurs as colorless, pink, white, rose, and brown. Specimen pictured is green with purple at the intersection of the crystal faces.

Specimen pictured: 25 × 7 cm

Fluorite is a common mineral found throughout New Mexico. It is commonly associated in hydrothermal deposits with barite, galena, quartz, gypsum, sphalerite, calcite, and dolomite. Fluorite also is found in pegmatites associated with feldspar, quartz, and garnet. The name comes from the Latin "fluere," to flow, because fluorite melts more easily than other minerals that may otherwise be confused with it. The specimen pictured has octahedral crystals up to 1 inch (2.5 mm) on a side. The specimen was collected in 1980 by Dick Jones of Dick Jones Mineral Company from a new find of fine fluorite specimens.

Photo by K. S. Rider