UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Preliminary map of uranium provinces in the conterminous United States

by

V. P. Byers[1] and W. I. Finch[1]

To accompany Open-File Report 79-576-V

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

1. Denver, Colorado

1984

Preliminary map of the uranium provinces in the conterminous United States

by V. P. Byers and W. I. Finch

INTRODUCTION

The map is part of the atlas of metal and nonmetal provinces in the conterminous United States (Tooker, 1979, 1980a,b) and shows areas called provinces, listed in table 1 that are based mainly on the geographical distribution of known uranium deposits and selected occurrences.

Uranium is a heavy radioactive metal principally used as a fuel in nuclear power generating facilities, which produced 11 percent of electricity in the United States in 1978 (Krymm and Charpentier, 1980). Smaller quantities of uranium are used in the fabrication of nuclear weapons and in the ceramic and chemical industries; depleted uranium, the tails product after 235-enriched uranium is produced, is used in ordnance and shielding applications (Kirk, 1980; U.S. Bureau of Mines, 1981, p. 172-173).

Production of uranium in the U.S. in 1975 (the base year for the atlas survey, Tooker, 1980a) totalled 11,200 metric tons U_3O_8, and in 1980 reached an all-time high of about 18,150 metric tons U_3O_8 (U.S. Dept. Energy, 1980a). The average grade of 1980 production was about 0.11 per cent U_3O_8 compared to 0.16 in 1975.

Total resources of U_3O_8 in the U.S. (including Alaska) is given by the U.S. Department of Energy (DOE) (1980b, table 3) as 4,448,000 metric tons (4,903,000 short tons) at a forward cost of $100 or less per pound ("Forward-cost" is not market price; it refers roughly to the cost of production, excluding expenses previously incurred.) Of this total, 849,000 metic tons are given as reserves at a forward cost of $50 or less per pound U_3O_8. Additional resources, only partly discovered, bring the total $50/lb U_3O_8 resources to about 3,162,000 metric tons. Of this total, an estimate of 109,000 metic tons U_3O_8 is expected as a byproduct from phosphate (southeast U.S.) and copper-leach operations (Utah, Arizona, Montana) during the period 1980-2000. According to DOE, "Currently projected long-term requirements can be met through the year 2019 by production of resources available at $50 per pound of U_3O_8, or less." (U.S. Dept. Energy, 1980b, p. 139).

Uranium is a geochemically persistent element. Uraninite, a common uranium mineral, has been precipitated over a wide range of temperatures and pressures. In the U.S., uranium has precipitated at or near atmospheric temperatures and pressures in clastic host rocks, such as sandstones and conglomerates, that have high transmissivity for ground-water. Other uranium has precipitated at high temperatures and pressures in fracture systems (vein deposits) in less permeable rocks. The primary dull black, gray, and brown uranium ore minerals, pitchblende and uraninite, occur either in extensive bedded deposits in sedimentary rocks or in high-grade veins and pegmatites. Refractory primary uranium-bearing minerals are found in fossil placers of neglible economic importance. Secondary uranium ore minerals, such as carnotite, tyuyamunite, torbernite, meta-torbernite, autunite, meta-autunite, uranophane, and schroeckingerite, occur in weathered and oxidized zones of primary deposits. Vanadates such as carnotite are major secondary minerals in sandstone deposits. Autunite, torbernite, and uranophane are especially widespread uranyl species found in oxidized vein deposits.

Uranium has been concentrated by various processes into numerous kinds of deposits in many different sedimentary, igneous, and metamorphic environments. The resulting uranium deposits are widely variable in form, size, and grade, but the larger and most productive ones fit into fairly distinct classes that might be considered as world-class deposits, because they occur on more than one continent. World-class deposits include quartz-pebble conglomerate, unconformity-related vein, disseminated and/or vein (ultrametamorphic and alkalic pluton), contact, classical vein, sandstone, volcanogenic, and calcrete types of deposits (Nash and others, 1981). Of these, the sandstone-type dominates known U.S. deposits. Certain parts of the country contain volcanogenic and classical vein deposits, and some areas are highly favorable for the volcanogenic-type. However, the U.S. has low favorability for other world-class types. In addition, considerable uranium is recovered in the U.S. as a by-product from slightly uraniferous phosphate and from copper-leach liquors. A very large but not presently viable resource is contained in uraniferous marine black shale.

The initial concentration of uranium into provinces probably occurred during the formation of the earth's crust. Subsequent geochemical and orogenic processes redistributed and concentrated the uranium into economic deposits of various kinds. To facilitated describing a province and its potential resources one attempts to define a province on the basis of its dominant type of deposit and its geologic environment. Even so, commonly the deposits in a uranium province are of several types and of more than one age. Furthermore certain areas designated as provinces overlap others, especially in the Cordilleran Belt. Although trace amounts of uranium occur nearly everywhere under varied geologic conditions, concentrations large enough to warrant mining are restricted mostly to the western U.S. Principal productive uranium deposits or groups of deposits in the U.S. occur primarily in two types of environments: (1) at the margins and locally along the axial parts of the sedimentary basins, and particularly in those basins containing sediments derived from either granitic terranes or volcanic centers, which may be intracratonic basins (e.g., province 1-Colorado Plateau), intermontane basins (e.g., province 2-Tertiary basins, Wyoming), or gulf-type basins (e.g., province 3-Texas Gulf Coast); and (2) in areas of silicic intrusions in orogenic belts (e.g., province 5-Colorado Front Range, Northern and Southern Rockies). Principal productive deposits in nearby parts of Canada occur at the margins of Precambrian shield areas, such as the Blind River-Elliot Lake and Saskatchewan areas in Canada, and similar deposits that may occur in Michigan, Minnesota, and Wisconsin, where silicic igneous rocks can be as much as five times as radioactive as silicic rocks from the interior parts of the shield areas.

Many of the mineable concentrations of uranium deposits in the U.S. occur at or near persistent but concealed fault-type lineaments that project into the cratonic block, such as the Precambrian shear zone in Colorado, one of at least four NE-trending, alined, linear zones that seem to parallel Precambrian province boundaries; (Osterwald, 1956, Osterwald and Dean, 1961; Tooker, 1979; also see "iron band", Byers, 1978, figures 1a, 1b). The concentrations occur mainly in sedimentary rocks of the continental crust that are underlain by Precambrian rocks.

The nation's chief source and reserve of uranium ore is in epigenetic uranium deposits in continental sandstone that formed in shallow, poorly drained basins either within foreland areas or between fault-block uplifts (Klepper and Wyant, 1956, 1957; Finch, 1965). The deposits in sandstone constitute 95 percent of U.S. production and resources (U.S. DOE, 1980a, 1980b). Most of the remaining 5 percent is in vein-type and related types, including contact and disseminated uranium concentrations.

Production, reserve, and resource data as of January 1, 1976 shown in Table 2 are from the U.S. Energy Research and Development Administration (1976, p. 19), U.S. Bureau of Mines (1976, 1977). and Woodmansee (1975, p. 1178). In

Table 1.--Geologic regions, uranium provinces, and subprovinces.

Geologic region	Province [1]	Subprovince [1]
I. Colorado Plateau	1. Colorado Plateau:	A. Grants mineral belt B. Big Indian or Lisbon Valley mineral belt C. Uravan mineral belt D. Monument Valley and White Canyon mineral belts
II. Cordilleran Belt	2. Tertiary basins, Wyoming and Colorado 4. Northeast Washington 5. Colorado Front Range, Northern and Southern Rockies 6. Black Hills region, South Dakota and Wyoming 7. Basin and Range 10. Phosphoria basin (in Idaho and adjacent states) 15. Pacific Coast, California	
III. Coastal Plains	3. Texas Gulf Coast 9. Phosphate fields of Florida and South Carolina	
IV. Central Plains	8. Dakota lignite fields 11. Permian and Triassic basins (in New Mexico, Texas and Oklahoma) 13. Devonian marine black shale basins	
V. Appalachian Belt	12. Appalachian Highlands Paleozoic and Triassic basins	
VI. Precambrian Shield	14. Precambrian Shield area	

[1] Numbered in approximate order of economic importance.

Table 2.--Distribution of uranium production, reserves and potential resources as of January 1, 1976, by uranium province in the U.S. (Modified after U.S. Energy Research and Development Administration, 1976, table 3).

Index number to geologic region and uranium province (See Table 1)		Area	Production Metric tons U_3O_8	Percent of total production plus reserves ($30/lb U_3O_8)	Estimated value in billion dollars (1975 dollar value at $8.45/lb)	
Region	Province				Production plus reserves ($30/lb)	Potential resources
I	1	Colorado Plateau	179,440	57	8.9	19.7
II	2	Tertiary basins, Wyoming, Colorado	53,700	32	4.9	7.2
III	3	Texas Gulf Coast region	7,530	5.6	0.9	4.3
II	7	Basin and Range	1,270	0.3	0.05	7.5
II	4	Northeast Washington	3,000	2	0.28	1.6
II	6	Black Hills region	3,175	1	0.17	2.0
II	15	Pacific Coast	1/	2/	0.02	1.8
II	5	Colorado Front Range, Northern and Southern Rockies	5,800	1.7	0.26	1.4
IV	11	Central Lowlands, Colorado Kansas	1/	2/	0.02	1.1
III	8	Dakota Lignite	3/	2/	3/	3/
II	5	Southern Rockies New Mexico (vein)	3/	2/	3/	3/
IV	11	Eastern New Mexico, west Texas, and Oklahoma	1.5	2/	0.02	0.3
II	5,10	Northern Rockies and Columbia Plateau (Idaho, Montana, Wyoming)	1,355	0.3	0.02	1.1
V	12	Appalachian Highlands	1/	2/	0.02	1.3
VI	14	Precambrian Shield area (Wisconsin, New York, Michigan)	0	2/	3/	3/
		Totals (rounded)	256,085	100.0	15.56	49.3

1/ Reported as less than 1,000 short tons. Probably on the order of 1 metric ton.

2/ Less than 0.1 percent.

3/ Not separately reported by U.S. Energy Research and Development Administration (1976).

order to be comparable to other maps of the atlas series and U.S. Bureau Mines Bull. 666, the estimated values for production, reserves, and resources in table 2 are in a 1975-dollar value of $8.45 per pound of U_3O_8 (approximately $18,600 per metric ton). The principal uranium mines and mining companies active in 1975 are listed in Table 3.

In compiling the uranium province map, some new districts discovered since 1975 have been added, such as Date Creek basin, Arizona (Otton, 1981a,b), and the McDermitt district, Nevada-Oregon (Sharp, 1956; Rytuba and Glanzman, 1979).

The locations of uranium deposits on the map were compiled from published reports (Butler and Byers, 1969; Butler and others, 1962; Byers, 1978; Eargle and others, 1971; Finch, 1967; Finch and others, 1959, 1978; Hilpert, 1969; Schnabel, 1955; Coney and Reynolds, 1980); unpublished records of uranium resource specialists; and data from the Mineral Resource Data System (MRDS), formerly the Computerized Resource Information Bank (CRIB) of the U.S. Geological Survey. The assistance of R. R. Wahl and C. A. Phillips in providing computerized data is gratefully acknowledged.

Distinguishing Map Features

The map shows the distribution of various types of uranium deposits in the conterminous United States, the outlines of the provinces that contain the most productive deposits, and some of the possibly favorable areas for other world-class deposits as yet poorly developed or not discovered. The shape of the symbol indicates the type of deposit; three groupings of types of deposits are shown on the map. They are: circles for sandstone and related deposits in sedimentary rocks; triangles for classical vein, breccia zone, pipe, contact, and related types; and squares for others, which includes volcanogenic and deposits too poorly described to classify. The character of the symbol indicates the relative size of a deposit or group of closely spaced deposits; those that have more than 10,000 metric tons of contained U_3O_8 are shown by a large solid symbol, 1,000 to 10,000 by a small solid symbol, those 1 to 1,000 by a small half-darkened symbol, and those less than 1 metric ton or any size at a cutoff-grade between 0.01 and 0.049 percent U_3O_8 by an open symbol. A large star overprint indicates that the deposit was being actively in mined in 1975 (table 3).

The boundaries of uranium provinces and sub-provinces are drawn only where they are reasonably distinct; many are indicated only by a number in the center of the general area of the known occurrences and their favorable rocks and geologic setting. Those boundaries delineated on the map by lines are at best inferred and follow physiographic provinces, basinal outlines, and distribution of potential host rocks. Boundaries of some major geologic regions and the zones of accreted oceanic and island-arc crust bordering the old continental crust are shown in order to conform to other maps of the atlas series even though they may not in every case relate to the distribution of uranium deposits.

URANIUM PROVINCES

For purposes of this report following the guidelines in Tooker (1979, 1980a,b), 14 uranium provinces are shown in the 6 major geologic regions of the conterminous United States, table 1. The most important province, the Colorado Plateau, is divided into 4 subprovinces. The uranium provinces are indicated on the map and keyed to tables 1 and 2. Almost 95 percent of the total production plus reserves of uranium in 1975, the base year for the Atlas survey (Tooker, 1980a), occurs in the first three uranium provinces described below.

The Colorado Plateau, map province no. 1 (Fischer, 1968, 1970, 1974; Fischer and Hilpert, 1952; Webber, 1947), is the major source of uranium in the U.S. and within the Plateau the San Juan Basin is the dominant district. In essence the Colorado Plateau has been an uranium province since Late Precambrian time because Precambrian igneous rocks beneath and around the Colorado Plateau probably contained anomalously high amounts of uranium as suggested by the anomalously radioactive zircons from these rocks with contents of 2 to 20 times the normal content (Silver, 1976). The Morrison Formation of Late Jurassic age is the principal uranium-bearing formation and consists of a coalesced sequence of large, low-gradient, alluvial fans derived from source areas to the south and southwest (Craig and others, 1955). The stratiform or peneconcordant uranium deposits were formed by ground waters that moved along the sandstone host beds. The ore minerals were precipitated in pockets having strong reducing capacity (Hostetler and Garrels, 1962). Estimated production plus reserves for the Colorado Plateau were almost 475,200 metric tons U_3O_8 ($30/lb or less) as of January 1, 1976 (U.S. ERDA, 1976, p. 19) or 57 percent of the U.S. total. The Colorado Plateau contains four principal generally linear uranium-productive subprovinces whose trends are shown on the map: (A) the Grants mineral belt in the San Juan Basin, New Mexico; (B) the Big Indian or Lisbon Valley mineral belt, Utah; (C) the Uravan mineral belt, Colorado; and (D) the Monument Valley and White Canyon mineral belts, Utah and Arizona. Other productive districts include the Henry Mountains and San Rafael? in central Utah, Shiprock in northeast Arizona, and Cameron in Coconino County, Arizona. All of these contain only sandstone-type deposits but a single important vein-type, the Orphan Lode, occurs in the Grand Canyon of Arizona.

The Grants mineral belt, map province no. 1A (Kelley, 1963; Kelley and others, 1968; Granger, 1963, 1968; Granger and others, 1961; Granger and Warren, 1969; Hilpert, 1969; Hilpert and Moench, 1960; Moench and Schlee, 1967; Brookins, 1976; Chenoweth, 1977; Chapman, Wood and Griswold, Inc., 1977; Kelly, 1977; Rautman, 1980; Leventhal, 1980b; Scarborough, 1981; Adams and Saucier, 1981), contains the largest known concentration of uranium ore in the United States and accounted for more than 42 percent of the total U.S. production plus reserves as of January 1, 1976 (Byers, 1978). The mines active in 1975 are listed in table 3. Adams and Saucier (1981) pointed out that projection of known ore trends provide the greatest potential for major new discoveries in the Grants mineral belt, and that future exploration will be deeper and more expensive. The deposits are peneconcordant, range in size from small to very large, and lie from at the surface outcrop to about 1-2 kilometers below the surface. They are mostly in relatively thick sandstone masses in the Morrison Formation of Late Jurassic age along and near the south margin of the boundary of the Jurassic basin of deposition. They occur in stream-laid sandstone lenses interbedded with lacustrine and overbank mudstone.

The Big Indian or Lisbon Valley mineral belt, map subprovince no. 1B (Butler and Fischer, 1978; Fischer, 1974; Wood, 1968), contains uranium deposits in the Moss Back Member of the Chinle Formation of Late Triassic age. Production and reserves as of January 1, 1976 in the belt comprised about 9.5 percent of the U.S. total. The mines active in 1975 are listed in table 3. Fischer (1974) pointed out that ground water seeping downward along the crest of the ancestral Lisbon Valley anticline could have leached uranium from the volcanic mudstones in the upper part of the Chinle Formation and carried it downdip into the Moss Back Member of the Chinle to a favorable reducing environment, probably somewhere below the paleo-water table.

The Uravan mineral belt, map subprovince no. 1C (Fischer and Hilpert, 1952; Shawe, 1962; Shawe and others, 1968; Motica, 1968; Fischer, 1974; Butler and Fischer, 1978; Granger and Warren, 1981), contains more than 1,000 mines ranging in size from a few metric tons of U_3O_8 in isolated locations to clusters totalling as much as 0.75 million tons of uranium and vanadium ore. Production plus reserves as of January 1, 1976 for the Uravan mineral belt comprised about 7 percent of the U.S. total. The uranium-vanadium deposits are in the Salt Wash Member of the Morrison Formation. The

Table 3.--Principal uranium mines and mining companies active in 1975 (Mining Magazine, 1976, Table B; files)

Uranium province and map number (See Table 1)	Mine or area	Company	Location
Colorado Plateau, Grants mineral belt, 1A	Ambrosia Lake deposits (includes Sec. 23 mine, T. 14 N., R. 10W.; Sec. 25 mine, T. 14 N., R. 10 W.; Sec. 17 mine, T. 14 N., R. 9 W.)	United Nuclear Corp., Inc.	Ambrosia district, McKinley County, New Mexico
"	Church Rock I	Kerr-McGee Corp.	"
"	Johnny M	Ranchers Exploration and Development Corp.	"
"	Jackpile and Paguate	Anaconda Co.	Laguna district, Valencia County, New Mexico
"	Sec. 1, T. 13 N., R. 9 W.	Kerr-McGee Corp.	Ambrosia district, McKinley County, New Mexico
"	Sec. 19, T. 14 N., R. 9 W.	"	"
"	Sec. 30, T. 14 N., R. 9 W.	"	"
"	Sec. 24, T. 14 N., R. 9 W.	"	"
Colorado Plateau, Big Indian (or Lisbon Valley) mineral belt, 1B	Humeca	Rio Algom Mines, Ltd.	Lisbon Valley district, San Juan Co., Utah
Colorado Front Range, 5	Schwartzwalder	Cotter Corp.	Front Range, Jefferson Co., Colorado
Tertiary basins, Wyoming, 2	Bill Smith	Kerr-McGee Corp.	Powder River Basin, Converse Co., Wyoming
"	F Group	Utah International, Inc.	Shirley Basin, Carbon Co., Wyoming
"	Highland	Exxon Nuclear Co.	Powder River Basin, Converse Co., Wyoming
"	Lucky Mc	Utah International, Inc.	Powder River Basin, Converse Co., Wyoming
"	Pay Aljob	Union Carbide Corp.	East Gas Hills district, Natrona Co., Wyoming
Texas Gulf Coast, 3	Felder	Mobile Oil Co.	Live Oak Co., Texas
"	Butler-Weddington	Conoco & Pioneer Nuclear	Karnes, Co., Texas

Salt Wash was deposited as a broad alluvial fan by a distributary stream system (Craig and others, 1955; Thamm and others, 1980) and consists of interbedded fluvial sandstone and flood-plain type mudstone units.

The Monument Valley and White Canyon mineral belts, map no. 1D (Thaden and others, 1964; Young, 1964; Finch, 1959; Malan, 1968: Witkind and Thaden, 1963), have significant ore deposits in the carbonaceous sandstone and conglomerate of the basal Shinarump Member of the Chinle Formation of Late Triassic age. In Monument Valley, the Shinarump sediments fill deep channels formed by streams that flowed from the south and southeast. The economic deposits are all of the vanadium-uranium type ($V_2O_5 > U_3O_8$). In the White Canyon mineral belt, the Shinarump sediments fill shallow channels formed by streams that flowed from the northeast, and the significant deposits are all of the copper-uranium type ($Cu > U_3O_8$). Production plus reserves as of January 1, 1976 in the two belts totalled about 1 percent of the U.S. total.

The Orphan Lode mine (in map province no. 1), Grand Canyon National Park, Arizona, is an important vein-type deposit that occurs in a collapse breccia pipe within highly fractured and brecciated zones of Paleozoic sedimentary rocks (Finch, 1967, figs. 11, 12; Bowles, 1977; Rich and others, 1977).

In Tertiary basins, Wyoming and northern Colorado, map province no. 2, the major uranium deposits are in structural intermontane and/or erosional basins. The principal districts are the Shirley Basin in south central Wyoming, the Powder River Basin in northwest Wyoming, the Gas Hills area on the south flank of Wind River Basin in central Wyoming, and the Crooks Gap area on the north flank of the Great Divide Basin (Anderson, 1969; Armstrong, 1970; Bailey, 1969; Davis, 1969; Melin, 1969; Sharp and others, 1964; Harshman, 1972; Harshman and Adams, 1980; Seeland, 1978). The principal host rocks are medium- to coarse-grained sandstone and coarse-grained conglomeratic arkose. These rocks were derived in large part from granitic cores of uplifts and the older sedimentary rocks that flank the cores (Harshman, 1968a, 1968b, 1972). Stuckless (1979) suggests that the region of Central Wyoming has been an uranium province since early Precambrian time. The deposits contain from a few hundred to a few hundred thousand metric tons of ore, ranging in grade from 0.1 percent to 1.0 percent U_3O_8. More than 95 percent of the known reserves are in formations of Early Eocene age. Production plus known reserves as of January 1, 1976 in deposits in Tertiary sediments in the Wyoming basins, including the Maybell deposits in the Sand Wash Basin in northwestern Colorado, accounted for about 32 percent of the U.S. total, of which the Shirley Basin constitutes more than half. The mines active in 1975 are listed in table 3.

In the Texas Gulf Coast, map province no. 3, deposits in Karnes, Live Oak, Atascosa, Starr, Duval, McMullen, and Gonzales Counties in south Texas have most of the production and reserves of uranium (Eargle and others, 1971; 1975; Dickinson, 1976a, b, c; Galloway and others, 1979a,b; Galloway and Kaiser, 1979; Adams and Smith, 1981). The uranium deposits occur in several Eocene to Pliocene formations. Uranium occurs chiefly in the shoreline, beach, and fluvial facies of the mainly upper Eocene Jackson Group and subordinately in highly tuffaceous fluvial beds of the Catahoula Formation of Late Oligocene age. In all cases uranium occurs within regressive units that unconformably overlie transgressive sequences (Adams and Smith, 1981). Both oxidized and unoxidized deposits are present, but the oxidized deposits are now mostly mined out. The oxidized ore occurred near the surface. The unoxidized ore occurs to depths of 600 m and more. The unoxidized ore deposits, located downdip and southeast of the area of oxidized deposits, occur at and directly above the water table and are larger deposits of generally lower grade ore that is more nearly in equilibrium than is the oxidized ore (Bunker and MacKallor, 1973). Much of the unoxidized ore in the Karnes County area is in C-shaped ore rolls similar to those in Wyoming (Harshman and Adams, 1980; Fischer, 1974). The uranium in the deposits is thought to have been leached from the volcanic ash in the host beds and in beds associated with them by ground water that moved downdip along permeable facies to a reducing environment where the ore minerals precipitated. H_2S that rose along faults from gas fields is thought to be the active reducing agent (Eargle and others, 1971; Eargle and Weeks, 1968; Klohn and Pickens, 1970, 1974; Goldhaber and others, 1978, 1979a, b; Goldhaber and Reynolds, 1977, 1979). The uranium mined ranges from 0.05 percent to 0.5 percent in the Oakville Sandstone. Recovery by in-situ leaching to depths of 170 m had extracted 113 metric tons of U_3O_8 from sandstone by January 1, 1975 (Crawford, 1975; White, 1975). Of the U.S. total production and reserves, as of January 1, 1976, the Texas coastal region accounted for 5.6 percent (table 2). Mines active in 1975 are listed in table 3.

In the northwest part of the Cordilleran Belt, in northeast Washington, important uranium deposits occur in Stevens and Spokane Counties, map province no. 4, which accounted for 2 percent of the U.S. total production plus reserves as of January 1, 1976 (table 2). The largest and most productive deposit is at the Midnite-(Boyd) mine, Stevens County. Production during 14 years of operation was about 3,600 metric tons U_3O_8 from oxidized and reduced ores averaging 0.23 percent U_3O_8 (Nash and Lehrman, 1975). High content of iron and sulfur, contained chiefly in FeS_2, appear to be an important feature of favorable host rocks (Nash and Lehrman, 1975). At the Midnite mine uranium occurs in discordant tabular bodies 50 m or less thick, as much as 210 m wide, and as much as 380 m long, in metamorphosed steeply dipping Precambrian pelitic and calcareous rocks. These metasediments form a roof pendant in a Cretaceous to Eocene porphyritic quartz monzonite pluton named the Loon Lake Batholith. The ore bodies, which are best developed in the sheared carbonaceous and pyritic phyllite and argillite, occur as stockworks and irregular masses parallel with contacts with granite. The thickest ore zones invariably coincide with depressions in the metasediments-granite contact, and the margins of the ore zones generally terminate against steep granite contacts.

At the Peters lease (in map province no. 4), also known as the Northwest Uranium mine or Sherwood mine, Stevens County, Wash., uranium is disseminated in a low-grade orebody in gently dipping Oligocene conglomerate beds (Weisenborn and Moen, 1974). The conglomerate is poorly sorted and very poorly cemented, and, except for the large boulders that must be broken to be moved, the rock can be mined in open pit without blasting. The ore consists of uraninite intimately associated with carbonaceous material near the base of the conglomerate that makes up the basal unit of the Eocene Sanpoil Volcanics (formerly known as Gerome Andesite) in the mine area. The Sherwood open-pit mine was estimated to contain 5,440 metric tons U_3O_8 in 1966 (Engineering and Mining Journal, 1975, v. 176, no. 9, p. 206).

In the Mount Spokane area (in map province no. 4), Spokane County, Wash., the uranium deposits are entirely within the Cretaceous to Eocene Loon Lake Batholith, which consists of two-mica quartz monzonite intruded into gneissic rocks (Weis and others, 1958; Weissenborn and Moen, 1974; Weissenborn and Weis, 1976). Alaskite with a network of narrow pegmatite dikes, which are differentiates of the quartz monzonite, extends in an irregular north-south trending belt along the west flank of Mount Spokane. The pegmatites make up 25 percent of more of the rock. Uranium in the form of autunite or meta-autunite, which is accompanied only by clay as a gangue mineral, fills crevices, joints, shear zones, and other open spaces in the alaskite and pegmatite (Leo, 1960; Ross, 1963). At leaat 30 occurrences of uranium are known, all of which are either within or adjacent to the alaskite-pegmatite rock. Total recorded production from the Mount Spokane area amounts to 40 metric tons of U_3O_8 (A. E. Weissenborn, oral communication others, 1958; Weissenborn and Moen, 1974; Weissenborn and Weis, 1976). Nine properties contributed to this production, but the great bulk of it came from the Daybreak mine on the Dahl lease.

North and east of the Colorado Plateau within the Cordilleran Belt lies the large, narrow, poorly defined province of the Colorado Front Range and Northern and Southern Rockies, map province no. 5. This province is defined for the most part by vein-type deposits in Precambrian rocks and partly overlaps area of sedimentary deposits in the Phosphoria basin (province no. 9) in the north and an extension of the Tertiary basin province of Wyoming (province no. 2) into Colorado and northern New Mexico in the south. Production plus reserces as of January 1, 1976 for province 5 totalled about 1.7 percent of the U.S. total (table 2).

In the Front Range of Colorado a number of vein-type deposits occur in Precambrian host rocks at the eastern edge of the Colorado mineral belt (Rich and others, 1977; Walker and others, 1963). In this area there are three classes of uranium veins: those with minor sulfides, which are economically the most important; those with moderate to abundant sulfides; and thoses with moderate to abundant fluorite. At the Schwartzwalder mine (Young and Lahr, 1975), active in 1975 (table 3) and the largest in the area, the veins contain pitchblende and coffinite with minor amounts of iron, lead, zinc and copper sulfides. The deposit is in Precambrian metamorphic rocks in a complexly branched southeastward extension of the Rogers breccia reef fault near the edge of the Front Range (Sheridan and others, 1967; Sims and Sheridan 1964). The main faults and fault breccias and subsidiary, less steeply dipping faults are mineralized where they cut brittle, competent lime-silicate rock and garnetiferous quartz-biotite gneiss.

Vein-type deposits are found at the Marshall Pass locality (in map province no. 5), in the southern part of the Sawatch Range in the Southern Rockies of Colorado, along the foot-wall of a reverse fault in brecciated, steeply dipping strata of Paleozoic age. A major deposit in the area is at the Pitch mine which contains a reserve of 3,245,000 Kg U_3O_8 (7,140,000 lbs) in ore with an average grade of 0.17 percent U_3O_8 (Nash, 1981), and there is a potential for considerable more in the same major structure as well as even more in other structures (J. T. Nash, oral communications, 1983).

The Cochetopa district (in map province no. 5) includes the Los Ochos mine and others, Saguache County, Colorado. The Los Ochos deposit consists of secondary uranium minerals, pitchblende, and marcasite in fractured and silicified sandstone and mudstone of the Jurassic Morrison Formation or the Middle Jurassic Junction Creek Sandstone and adjacent underlying schist and gneiss of Precambrian age where the rocks have been broken by an east-trending fault (Derzay, 1956; Olson, 1976a, 1976b; Wright and Everhart, 1960). Although the crystalline rocks are mineralized, most of the workable part of the deposit, which is now largely mined out, was in sedimentary rocks (Butler, 1964).

Mesozoic sedimentary rocks on the flanks of the Black Hills region, S. Dakota and Wyoming, map province no. 6, contain productive peneconcordant uranium deposits and reserves that together with the North and South Dakota uraniferous lignite deposits (discussed below) represent less than 3 percent of the U.S. total production and reserves as of January 1, 1976. The deposits are in gently dipping rocks of the Lakota and Fall River Formations of the Lower Cretaceous Inyan Kara Group on the southwest flank and around the northern nose of the Black Hills Uplift, a broad domal uplift of Laramide age (Gott and others, 1974). The Dakota and Fall River Formations are composed predominately of mudstone and lenticular sandstone, in part conglomeratic. Coalified plant fossils are common in the sandstone. The environment of sedimentation was mainly fluvial and lacustrine, and partly marginal marine. Overlying sediments of Tertiary age, since largely removed by erosion, contained abundant volcanic ash. The ore bodies in the Inyan Kara are chiefly irregularly tabular or pod-shaped masses, and some are crescent-shaped rolls (Hart, 1968; Renfro, 1969; Harshman and Adams, 1980).

The Basin and Range, map province no. 7, is a geographic province dominated by fault-block mountains separated by broad alluvium-filled basins. It was a geosyncline during most of Paleozoic and Mesozoic eras and great thicknesses of sedimentary rocks accumulated. During the Late Cretaceous and early Tertiary time, folding and thrusting of the Laramide orogeny deformed the sediments in a southward-trending zone that extends from Canada to Mexico. High-angle normal faulting during the mid- to late-Tertiary extension determined the present topography of long graben valleys partially filled with alluvial debris from the intervening mountains. The uranium deposits occuring in this uranium province include sedimentary, vein, and other types. Total production plus reserves for the Basin and Range province was estimated as 0.3 percent of total U.S. (U.S. ERDA, 1975, 1976) (see table 2).

In the Marysvale district of central Utah, at the eastern edge of the Basin and Range province where it adjoins the Colorado Plateau, (Kerr and others, 1957; Kerr, 1968; Cunningham and Steven, 1978; Cunningham and others, 1980) uranium occurs in veins where Tertiary volcanics have been intruded by subvolcanic acidic plutons.

Contact-type deposits near Austin, Lander County, Nevada in the Reese River district occur in intensely fractured zones peripheral to the contact of a Jurassic quartz monzonite intrusive and Precambrian or Cambrian quartzite or argillite (Sharp and Hetland, 1954; Thurlow, 1956; Chenoweth and Malan, 1969).

In the northern part of Basin and Range province, uranium occurs in veins in rhyolite breccia in the Kings River and McDermitt area, Humboldt County, Nevada and adjoining Oregon; in Lassen and Kern Counties, California; and in Esmeralda, Lincoln, and Washoe Counties, Nevada (Sharp, 1956; Staatz and Carr, 1964; Yates, 1952; Duncan, 1953). At McDermitt the uranium deposits occur along the ring fracture of a nonresurgent caldera (Rytuba and Glanzman, 1979). The Moonlight mine is an uranium vein deposit along the ring fracture (or basin-range faults) on the west side of the caldera complex. The Aurora deposit, on the other hand, occurs with abundant pyrite and leucoxene in altered mafic flows beneath moat-filled sediments south of the northern rim of the McDermitt complex (Roper and Wallace, 1980). The deposit was formed during intense alteration by hydrothermal fluids moving upward along pre-existing fractures (J. K. Otton, 1983, oral communication) and thus is not a vein deposit but a replacement-type orebody. The Aurora deposit has reserves of 7,700 metric tons U_3O_8 contained in rock that averages 0.05 percent U_3O_8.

Uranium occurs in Tertiary lake sediments and water-laid tuffs at widely separated areas in Nevada and California of the Basin and Range province (Davis and Hetland, 1956). Intensive search for large low-grade deposits in these Tertiary lake beds and associated rocks, such as in the Date Creek basin, Arizona (Otton, 1981a, b), is needed, but many deposits may prove uneconomic to mine. Otton (1981c, oral communication, 1983) has identified resources of 580,000 metric tons U_3O_8 in rock with an average grade of 0.023 percent for the Date Creek basin deposits and about 1.2 million metric tons of potential resources in the unexplored parts of Date Creek basin and two additional western Arizona Tertiary basins. At Lakeview, Oregon, deposits occur in the contact zone between a rhyolite intrusive of late Tertiary age and pyroclastic and lacustrine sediments of Miocene age (Cohenour, 1960; Walker and others, 1963).

Uraniferous lignites and sandstones, which occur in the Fort Union Formation of Paleocene age in the Cave Hills-Slim Buttes and other parts of the western Williston Basin in North and South Dakota, in Dakota lignite fields, map province no. 8 (Denson and Gill, 1956; Vine, 1962; Gott and Pipiringos, 1964), are characterized by a relatively low concentration of uranium and by a relatively large areal extent. At the Flat Top Butte and other claims in Harding County, South Dakota, uranium associated with lignite occurs in Fort Union host rocks that range in thickness from 15 centimeters to more than 0.6 meters and are characterized by high volcanic ash content and quite high permeabilities (Denson and Gill, 1965).

Phosphorite layers in the Bone Valley Formation of Pliocene age in the land-pebble phosphate field in Florida, part of the Phosphate fields, Florida and South Carolina, map province no. 9, range in thickness from 1.8 to 2.1 meters over about 800 square kilometers and average 0.012-0.024 percent U_3O_8 and 20-30 percent P_2O_5 (Altschuler and others, 1956, 1964; Cathcart, 1963). Uranium in marine phosphorite deposits was probably deposited from sea water during sedimentation, or in some places, possibly later from downward percolating ground water. The Bone Valley Formation has bedded pebbly and clayey phosphatic sands in which alteration to aluminum phosphate has occurred. Most of the formation was deposited in a flat platform area that was gradually inundated by marine water. The region had an irregular shore line, scattered islands, a gently sloping bottom, and distinct connections with the ocean that influenced the nature of sedimentation and alteration. The Engineering and Mining Journal, 1976 (v. 177, no. 5, p. 79-89) reported that both U_3O_8 and fluorine were being recovered from some wet-process phosphoric acid plants and sold as by-products of phosphate production.

Uranium occurs in marine phosphorite beds on the lower Coastal Plain of South Carolina (in map province no. 9), mainly in the mineral carbonate-fluorapatite. The uranium content of phosphorite ranges from 0.025 to 0.063 percent equivalent U_3O_8 (Southern Interstate Nuclear Board, 1969).

Marine phosphatic rocks with anomalous uranium concentration occur in the Phosphoria Formation and its stratigraphic correlatives of Permian age in an area of about 350 square kilometers in Idaho, Montana, Utah, and Wyoming (McKelvey and Carswell, 1956). The limit of the part of the Phosphoria Formation with the highest uranium concentration (0.012 percent U_3O_8) is outlined as Phosphoria basin, map province no. 10 in eastern Idaho and adjacent parts of Montana, Wyoming, and Utah (McKelvey, 1967; McKelvey and Carswell, 1956). These phosphate beds are more than 1 meter thick and average more than 31 percent P_2O_5 (McKelvey and Carswell, 1956, 1967). The Phosphoria consists of a sequence of phosphatic carbonaceous shale and mudstone, phosphorite, chert, carbonate rock, and sandstone. Deposition of these rocks occurred in marine geosynclines and on platforms. Thin platform facies lie to the east, and a thick geosynclinal facies occurs on the west. The richest phosphate beds occur in two phosphatic shale members of the formation in the tightly folded and faulted geosynclinal facies. The Phosphoria deposits are not presently economic to mine for uranium except as a by-product of wet-process phosphoric acid production.

Subeconomic resources of U.S. phosphate deposits that contain at least 0.012 percent U_3O_8 are estimated to be 1,000,000 metric tons U_3O_8, of which 800,000 are in the Phosphoria and its equivalents in the western U.S., and 200,000 are in pebble phosphate field of Florida (in map province no. 9) (Sheldon, 1964; Davidson and Atkin, 1953).

The Permian and Triassic Basins of eastern New Mexico, West Texas, and the Oklahoma Panhandle and the Quachita Mountain area along the Oklahoma-Texas border in the Central Plains, map province no. 11, contain uranium deposits in continental sandstones of Triassic and Permian ages, Permian and Triassic basins (Russell, 1958; Finch, 1972, 1975). A few of the deposits, mainly in Triassic rocks, have been mined and yielded a total of about 800 tons of ore averaging about 0.20 percent U_3O_8. This province is only moderately favorable for small deposits similar to those mined.

In the Appalachian Highlands, map province no. 12, continental sandstone sediments accumulated during Paleozoic and Triassic times in the shallow, poorly drained foreland and deep post-orogenic basins of New Jersey, New York, Pennsylvania, Virginia, West Virginia, Maryland, and North Carolina. The Devonian Catskill and Mississippian Mauch Chunk Formations and the arkosic sediments of the Newark Group in the Triassic basins contain small sandstone-type deposits and are favorable for additional deposits (Klemic, 1962; Turner-Peterson, 1980).

The eastern Central Plains uraniferous Devonian marine black shale basins, map province no. 13, in which the Chattanooga Shale and correlative formations were formed as part of a blanket of black shales in early Late Devonian (or possibly late Middle Devonian) to Early Mississippian times cover much of the interior of North America (Conant and Swanson, 1961). The Chattanooga Shale was deposited in an area of epicontinental seas. It is composed of marine, black, siliceous, low-grade oil shale and gray claystone and has abundant plant remains, such as stems, spores, and macerated debris. The Chattanooga Shale as a formation averages 0.007 percent U_3O_8, and is estimated to contain 7,000,000 metric tons U_3O_8 (Swanson, 1961; U.S. Dept. Energy, 1980b). Uraniferous shales correlative with the Chattanooga (Vine and Tourtelot, 1970) have been found in Indiana, Ohio, Pennsylvania, New York, West Virginia, and Kentucky (Broadhead and others, 1980; Leventhal, 1978, 1979, 1980a,b; Leventhal and Goldhaber, 1978; Leventhal and others, 1978; Wallace and others, 1977). Leventhal (1980a,b) observed that core samples from Devonian shales from the Illinois and Michigan Basins appear to show the same ranges of chemical compositions and geochemical controls as those from the Appalachian Basin. Uraniferous black shales were not considered to be viable sources for uranium in 1980.

The Precambrian Shield area, map province no. 14, contains no known economic uranium deposits, but just across the border in Canada both classical vein and quartz-pebble conglomerate types are known. Areas of the Precambrian Shield in Michigan, Minnesota, Wisconsin, and New York may have deposits similar to the large Precambrian quartz-pebble conglomerate uranium deposits of Elliot Lake-Blind River district, Ontario, Canada. In addition, vein-type uranium deposits related to the Lower to Middle Proterozoic unconformity may occur in the areas of Idaho, Montana, Wyoming, Utah, South Dakota, Iowa, Minnesota, Wisconsin, and Michigan (Kalliokoski and others, 1978; F. A. Hills, oral communication, 1981). Finally, the area is possibly favorable for intermediate-grade deposits of disseminated type in crystalline rocks (F. A. Hills, oral communication, 1981; Houston and Karlstrom, 1979; Kalliokoski and others, 1978; Button and Addams, 1981).

Extensive marine phosphorites of Miocene age, which are commonly radioactive, are present in a number of places in California in the southern Pacific Coast Ranges, Pacific Coast, map province no. 15, and along the west side of the San Joaquin Valley (Walker and Butler, 1966). Compared to the large economic deposits in other parts of the United States, most of the uranium deposits of the Pacific Coast area are small, and none are thought to contain large reserves of minable uranium, or are likely to contribute appreciably to total resources in the United States.

Certain provinces (map province nos. 11, 12, 13, 14, and 15) have less potential for uranium production than others. Many of the deposits in these provinces are either small or are large, very low-grade occurrences. Size alone, however, will not determine which deposits might become producers. Some, which may permit uranium to be recovered by bulk mining methods or as a byproduct could probably be mined before some larger and higher grade deposits. Some, because of their isolated location, may never be mined.

REFERENCES CITED

Adams, S. S., and Saucier, A. E., 1981, Geology and recognition criteria for uraniferous humate deposits, Grants uranium region of New Mexico: U.S. Department of Energy, Grand Junction Office, Colorado, Bendix Field Engineering Corporation, GJBX-2(81), 225 p.

Adams, S. S., and Smith, R. B., 1981, Geology and recognition criteria for sandstone uranium deposits in mixed fluvial shallow marine sedimentary sequences, South Texas--final report: U.S. Department of Energy, Grand Junction Office, Colorado, Bendix Field Engineering Corporation, GJBX-4(81), 146 p.

Altschuler, Z. S., Jaffe, E. B., and Cuttitta, Frank, 1956, The aluminum phosphate zone of the Bone Valley Formation, Florida, and its uranium deposits, in Page and others: U.S. Geological Survey Professional Paper 300, p. 483-487.

Altschuler, Z. S., Cathcart, J. B., and Young, E. J., 1964, Geology and geochemistry of the Bone Valley Formation and its phosphate deposits: Geological Society of America Annual Meeting, Miami Beach, 1964, Guidebook Field Trip 6, 68 p.

Anderson, D. C., 1969, Uranium deposits of the Gas Hills (Wyoming), in Wyoming uranium issue: Wyoming University Contributions to Geology, v. 8, no. 2, pt. 1, p. 93-103.

Armstrong, F. C., 1970, Geologic factors controlling uranium resources in the Gas Hills district, Wyoming: Wyoming Geological Association, 22nd Field Conference Guidebook, p. 31-44.

Bailey, R. V., 1969, Uranium deposits in the Great Divide Basin-Crooks Gap area, Fremont and Sweetwater Counties, Wyoming, in Wyoming uranium issue: Wyoming University Contributions to Geology, v. 8, no. 2, pt. 1, p. 105-120.

Bowles, C. G., 1977, Economic implications of new hypothesis of origin of uranium and copper-bearing breccia pipes, Grand Canyon, Arizona, in Campbell, J. A., ed., Short Papers of the U.S. Geological Survey Uranium-Thorium Symposium, 1977: U.S. Geological Survey Circular 753, p. 25-27.

Broadhead, R. F., Kepferle, R. C., and Potter, P. E., 1980, Lithologic descriptions of cores and exposures of Devonian shale and associated strsta in Ohio along Lake Erie: U.S. Geological Survey Open-File Report 80-719, 96 p.

Brookins, D. G., 1976, The Grants mineral belt, New Mexico--Comments on the coffinite-uraninite relationship, clay mineral reactions, and pyrite formation: New Mexico Geological Society Special Publication No. 6, p. 158-166.

Bunker, C. M., and Mackallor, J. A., 1973, Geology of the oxidized uranium ore deposits of the Tordilla Hill-Deweesville area, Karnes County, Texas; a study of a district before mining: U.S. Geological Survey Professional Paper 765, 37 p.

Butler, A. P., Jr., 1964, Miscellaneous metals--Uranium, in Mineral and Water Resources of Colorado: U.S. 88th Cong., 2d sess., p. 136-144.

Butler, A. P., Jr., and Byers, V. P., 1969, Uranium, in Mineral and water resources of Arizona: U.S. Cong., 90th, 2d sess., Senate Comm. Interior and Insular Affairs Comm. print (Arizona Bur. Mines Bull. 180, p. 282-292).

Butler, A. P., Jr., and Fischer, R. P., 1978, Uranium and vanadium resources in the Moab $1^o \times 2^o$ quadrangle, Utah and Colorado: U.S. Geol. Survey Prof. Paper 988-B, p. B1-B22.

Butler, A. P., Jr., Finch, W. I., and Twenhofel, W. S., 1962, Epigenetic uranium deposits in the United States, exclusive of Alaska and Hawaii: U.S. Geol. Survey Mineral Inv. Resource Map MR-21, 42 p.

Button, Andrew, and Adams, S. S., 1981, Geology and recognition criteria for uranium deposits of the quartz-pebble conglomerate type--final report: U.S. Department of Energy, Grand Junction Office, Colorado, Bendix Field Engineering Corporation, GJBX-3(81), 390 p.

Byers, V. P., 1978, Principal uranium deposits of the world: U.S. Geological Survey Open-File Report 78-1008, 312 p.

Cathcart, J. B., 1963, Economic geology of the Keysville Quadrangle, Florida: U.S. Geol. Survey Bull. 1128, 82 p.

Chapman, Wood, and Griswold, Inc., 1977 (1974 revised), Geologic map of the Grants uranium region: New Mexico Bureau of Mines and Mineral Resources Geologic Map 31.

Chenoweth, W. L., 1977, Uranium in the San Juan Basin--An overview: New Mexico Geological Society Guidebook, 28th Field Conference, San Juan Basin III, p. 257-262.

Chenoweth, W. L., and Malan, R. C., 1969, Significant geologic types of uranium deposits--United States and Canada: U.S. Atomic Energy Commission, Uranium Workshop, Grand Junction, Colorado, Paper No. 5., 50 p.

Cohenour, R. E., 1960, Geology and uranium occurrences near Lakeview, Oregon: U.S. Atomic Energy Commission, RME-2070, 33 p.

Conant, L. C., and Swanson, V. E., 1961, Chattanooga shale and related rocks of central Tennessee and nearby areas: U.S. Geological Survey Professional Paper 357, 91 p.

Coney, P. J., and Reynolds, S. J., and contributions by Davis, G. H., Keith, S. B., Trever, P. F., Lingrey, S. H., Kluth, C. F., Ferris, D. C., DuBois, J. F., and Hardy, J. J., 1980, Cordilleran metamorphic core complexes and their uranium favorability, final report: U.S. Department of Energy Report GJBX-258(80), 627 p.

Craig, L. C., Holmes, C. N., Cadigan, R. A., Freeman, V. L., Mullens, T. E., and Weir, G. W., 1955, Stratigraphy of the Morrison and related formations, Colorado Plateau region, a preliminary report: U.S. Geol. Survey Bull. 1009-E, p. 125-168.

Crawford, E., 1975, Developers eye Texas potential for in situ uranium leaching: Eng. Min. Jour., v. 176, no. 7, p. 81-82.

Cunningham, C. G., and Steven, T. A., 1978, Postulated model of uranium occurrence in the central mining area Marysvale district, west-central Utah: U.S. Geological Survey Open-File Report, 78-1093, 20 p.

Cunningham, C. G., Steven, T. A., and Rasmussen, J. D., 1980, Volcanogenic uranium deposits associated with the Mount Belknap Volcanics, Marysvale volcanic field, west-central Utah [abs.]: American Association of Petroleum Geologists Bulletin, v. 64/4, p. 767.

Davidson, C. F., and Atkin, D., 1953, On the occurrence of uranium in phosphate rock: Internat. Geol. Cong., 19th, Algiers 1952, Comptes Rendues, Sec. 11, p. 13-31.

Davis, D. L., and Hetland, D. L., 1956, Uranium in clastic rocks of the Basin and Range province, in Page and others: U.S. Geol. Survey Prof. Paper 300, p. 351-359.

Davis, J. F., 1969, Uranium deposits of the Powder River Basin, in Wyoming uranium issue: Wyoming Univ. Contributions to Geology, v. 8, no. 2, pt. 1, p. 131-141.

Denson, N. M., and Gill, J. R., 1956, Uranium-bearing lignite and its relation to volcanic tuffs in eastern Montana and the Dakotas, in Page and others: U.S. Geological Survey Professional Paper 300, p. 413-431.

______1965, Uranium-bearing lignite and carbonaceous shale in the southwestern part of the Williston basin--A regional study: U.S. Geological Survey Professional Paper 463, 75 p.

Derzay, R. C., 1956, Geology of the Los Ochos uranium deposit, Saguache County, Colorado, in Page and others: U.S. Geol. Survey Prof. Paper 300, p. 137-141.

Dickinson, K. A., 1976a, Sedimentary depositional environments of uranium and petroleum host rocks of the Jackson Group, south Texas: U.S. Geological Survey Journal of Research, v. 4, no. 5, p. 615-629.

______1976b, Uranium potential of the Texas Coastal Plain: U.S. Geological Survey Open-File Report 76-879, 7 p.

______1976c, Geological control of uranium deposition, Karnes County, Texas: U.S. Geological Survey Open-File Report 76-331, 16 p.

Duncan, D. C., 1953, A uranium-bearing rhyolite tuff deposit near Coaldale, Esmeralda County, Nev.: U.S. Geol. Survey Circ. 291, 7 p.

Eargle, D. H., and Weeks, A. M. D., 1968, Factors in the formation of uranium deposits, Coastal Plain of Texas: South Texas Geological Society Bulletin, v. 9, no. 3, p. 3-13.

Eargle, D. H., Dickinson, K. A., and Davis, B. O., 1975, South Texas uranium deposits: Mining Engineers, v. 59, no. 5, p. 766-779.

Eargle, D. H., Hinds, G. W., and Weeks, A. M. D., 1971, Uranium geology and mines, South Texas, in Houston Geological Society Field Trip, Houston, Texas, 1971: Houston Geological Society, 59 p.; Texas Univ. Bureau of Economic Geology Guidebook, no. 12, 61 p.

Finch, W. I., 1959, Geology of uranium deposits in Triassic rocks of the Colorado Plateau region: U.S. Geological Survey Bulletin 1074-D, p. D125-D164.

_____1965, Epigenetic uranium deposits in sandstone, in U.S. Geol. Survey Research 1964: U.S. Geol. Survey Prof. Paper 501-D, p. D76-D78.

_____1967, Geology of epigenetic uranium deposits in sandstone in the United States: U.S. Geological Survey Professional Paper 538, 121 p.

_____1972, Uranium in eastern New Mexico: U.S. Geol. Survey Open-File Report, 19 p.

_____1975, Uranium in west Texas--Paper delivered June 3, 1975, AAPS-SEPM Rocky Mountain Section Meeting, Albuquerque, New Mexico: U.S. Geol. Survey Open-File Report 75-356, 20 p.

Finch, W. I., Butler, A. P., Jr., Armstrong, F. C., Weissenborn, A. E., Staatz, M. H., and Olson, J. C., 1978, Uranium, in Brobst, D. A., and Pratt, W. P., eds., Mineral resources of the United States: U.S. Geological Survey Professional Paper 820, p. 456-468.

Finch, W., I., Parrish, I. S., and Walker, G. W., 1959, Distribution of epigenetic uranium deposits and continental sedimentary rocks: U.S. Geol. Survey Miscellaneous Geologic Investigations Map I-299.

Fischer, R. P., 1968, The uranium and vanadium deposits of the Colorado Plateau region, in Ridge, J. D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales Volume), v. 1: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 735-746.

_____1970, Similarities, differences, and some genetic problems of the Wyoming and Colorado Plateau types of uranium deposits in sandstone: Economic Geology, v. 65, p. 778-784.

_____1974, Exploration guides to new uranium districts and belts: Economic Geology, v. 69, p. 362-376.

Fischer, R. P., and Hilpert, L. S., 1952,' Geology of the Uravan mineral belt: U.S. Geological Survey Bulletin 988-A, p. 1-13.

Galloway, W. E., and Kaiser, W. R., 1979, Catahoula Formation of the Texas Coastal Plain: Origin, geochemical evolution and characteristics of uranium deposits: Grand Junction Office, Colorado Bendix Field Engineering Corporation, GJBX-131(79), 139 p.

Galloway, W. E., Finley, R. J., and Henry, C. D., 1979b, South Texas uranium province geologic perspectives: University of Texas, Austin, Bureau of Economic Geology Guidebook, 18, 81 p.

Galloway, W. E., Kreitler, C. W., and McGowen, J. H., 1979a, Depositional and ground-water flow systems in the exploration for uranium--A research colloquium September 8-9, 1978: Texas Bureau of Economic Geology, 267 p.

Goldhaber, M. B., and Reynolds, R. L., 1977, Geochemical and mineralogical studies of a south Texas roll front uranium deposit: U.S. Geological Survey Open-File Report 77-821, 34 p.

_____1979, Origin of marcasite and its implications regarding the genesis of roll-front uranium deposits: U.S. Geological Survey Open-File Report 79-1696, 38 p.

Goldhaber, M. B., Reynolds, R. L., and Rye, R. O., 1978, Origin of a south Texas roll-type uranium deposit: II. Sulfide petrology and sulfur isotope studies: Economic Geology v. 73, p. 1690-1705.

_____1979a, Formation and resulfidization of a south Texas roll-type uranium deposit: U.S. Geological Survey Open-File Report 79-1651, 41 p.

Goldhaber, M. B., and Reynolds, R. L., Rye, R. O., and Grauch, R. I., 1979b, Petrology and isotope geochemistry of calcite in a south Texas roll-type uranium deposit: U.S. Geological Survey Open-File Report 79-828, 21 p.

Gott, G. B., and Pipiringos, G. N., 1964, Metallic mineral resources--Uranium, in Mineral and water resources of South Dakota: U.S. Cong., 88th 2nd sess., Comm. Print p. 50-56. (Also South Dakota State Geological Survey Bulletin 16.)

Gott, G. B., Wolcott, D. W., and Bolwes, C. G., 1974, Stratigraphy of the Inyan Kara Group and localization off uranium deposits, southern Black Hills, South Dakota and Wyoming: U.S. Geological Survey Professional Paper 763, 57 p.

Granger, H. C., 1963, Mineralogy, in Geology and technology of the Grants uranium region: New Mexico Bureau of Mines and Mineral Resources Memoir 15, p. 21-37.

_____1968, Localization and control of uranium deposits in the southern San Juan basin mineral belt, New Mexico--An hypothesis, in Geological Survey research 1968: U.S. Geological Survey Professional Paper 600-B, p. B60-B70.

Granger, H. C., and Warren, C. G., 1969, Unstable sulfur compounds and the origin of roll-type uranium deposits: Economic Geology, v. 64, p. 160-171.

_____1981, Genetic implications of the geochemistry of vanadium-uranium deposits in the Colorado Plateau region: Rocky Mountain Section American Association of Petroleum Geologists 29th Annual Meeting April 12-15, 1981, Albuquerque, New Mexico, Abstracts of Papers, p. 15.

Granger, H. C., Santos, E. S., Dean, B. G., and Moore, F. B., 1961, Sandstone-type uranium deposits at Ambrosia Lake, New Mexico--an interim report: Economic Geology, v. 56, no. 7, p. 1179-1210.

Harshman, E. N., 1968a, Uranium deposits of the Shirley Basin, Wyoming, in Ridge, J. D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales Volume), v. 1: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 849-856.

_____1968b, Uranium deposits of Wyoming and South Dakota, in Ridge, J. D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales Volume), v. 1: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 816-831.

_____1972, Geology and uranium deposits, Shirley Basin area, Wyoming: U.S. Geological Survey Professional paper 745, 82 p.

Harshman, E. N., and Adams, S. S., 1980, Geology and recognition criteria for roll-type uranium deposits in continental sandstones--final report: U.S. Department of Energy, Grand Junction Office, Colorado, GJBX-1(81) 181 p.

Hart, O. M., 1968, Uranium in the Black Hills (South Dakota and Wyoming), in Ridge, J. D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales volume): New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 832-837.

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

Hilpert, L. S., and Moench, R. H., 1960, Uranium deposits of the southern part of the San Juan Basin, New Mexico: Economic Geology, v. 55, p. 429-464.

Hostetler, P. B., and Garrels, R. M., 1962, Transportation and precipitation of uranium and vanadium at low temperatures, with special reference to sandstone-type uranium deposits: Economic Geology, v. 57, p. 137-167.

Houston, R. S., and Karlstrom, K. F., 1979, Uranium-bearing quartz-pebble conglomerates: Exploration model and United States Resource potential: U.S. Department of Energy, Grand Junction Office, Colorado, GJBX-1(80), 509 p.

Kalliokoski, Jorma, Langford, F. F., and Ojakangas, R. W., 1978, Criteria for uranium occurrences in Saskatchewan and Australia as guides to favorability for similar deposits in the United States: Development of Geology and Geological Engineering, Michigan Technological University, Houghton, Michigan 49931, and U.S. Department of Energy Grand Junction Office, GJBX-114, 480 p.

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

Kelley, V. C., Kittel, D. F., and Melancon, P. E., 1968, Uranium deposits of the Grants region (New Mexico), in Ridge, J. D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales vol.): New York, American

Institute of Mining, Metallurgical and Petroleum Engineers, p. 747-769.
Kelly, T. E., 1977, Geohydrology of the Westwater Canyon Member, Morrison Formation, of the southern San Juan Basin, New Mexico, in New Mexico Geological Society Gudebook: 28th Field Conference, San Juan basin III, 1977, p. 285-290.
Kerr, P. F., 1968, The Marysvale, Utah, uranium deposits, in Ridge, J. D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales volume) v. 2: New York, Am. Inst. Mining, Metall., and Petroleum Enginners, p. 1020-1042.
Kerr, P. F., Brophy, G. P., Dahl, H. M., Green, Jack, and Woolard, L. E., 1957, Marysvale, Utah, uranium area--Geology, volcanic relations, and hydrothermal alterations: Geol. Soc. America Special Paper 64, 212 p.
Kirk, W. S., 1980, Depleted uranium, in Mineral Facts and Problems, 1980 Edition: U.S. Bureau of Mines Bulletin 671, 997-1003 p.
Klemic, Harry, 1962, Uranium occurrences in sedimentary rocks of Pennsylvannia: U.S. Geol. Survey Bull. 1107-D, p. 243-288.
Klepper, M. R., and Wyant, D. G., 1956, Uranium provinces, in Page and others: U.S. Geol. Survey Prof. Paper 300, p. 17-25.
Klepper, M. R., and Wyant, D. G., 1957, Notes on the geology of uranium: U.S. Geol. Survey Bull. 1046-F, p. 87-148.
Klohn, M. L., and Pickens, W. R., 1970, Geology of the Felder uranium deposit, Live Oak County, Texas: New York, Soc. Mining Engineers Preprint No. 70-1-38, 19 p.
_____1974, Geology of the Felder uranium deposit, Live Oak County, Texas: Econ. Geology, v. 69, p. 151.
Krymm, R., and Charpentier, J. P., 1980, Nuclear power development: present role and medium-term prospects: Vienna, International Atomic Energy Agency Bulletin, v. 22. no. 2, p. 11-22.
Leo, G. W., 1960, Autunite from Mount Spokane, Washington: American Mineralogist, v. 45, no. 1-2, p. 99-128.
Leventhal, J. S., 1978, Trace elements, carbon, sulfur, and uranium in Devonian black shale cores from Perry County, Kentucky, Jackson and Lincoln Counties, West Virginia, and Cattaraugus County, New York: U.S. Geological Survey Open-File Report 78-504, 32 p.
_____1979, Chemical analysis and geochemical associations in Devonian black shale core samples from Martin county, Kentucky, Carroll and Washington Counties, Ohio, Wise County, Virginia and Overton County, Tennessee: U.S. Geological Survey Open-File Report 79-1503, 51 p.
_____1980a, Comparative geochemistry of Devonian shale cores from the Appalachian Basin, Mason, Monongalia, and Upshur Counties, West Virginia; Illinois Basin, Tazwell County, Illinois; Clark County, Indiana; and Michigan Basin Sanilac Cocunty, Michigan: U.S. Geological Survey Open-File Report 80-938, 34 p.
_____1980b, Organic geochemistry and uranium in the Grants Mineral Belt: New Mexico Bureau of Mines and Mineral Resources Memoir 38, p. 75-85.
Leventhal, J. S., and Goldhaber, M. B., 1978, New data for uranium, thorium, carbon, and sulfur in Devonian black shale, from West Virginia, Kentucky and New York: First Eastern Gas Shales Symposium (Oct. 17-19, 1977), Morgantown, MERC/SP-77-5, p. 183-221.
Leventhal, J. S., Crock, J. G., Mountjoy, W., Thomas, J. A., Shaw, V. E., Briggs, P. H., Wahlberg, J. S., and Malcolm, M. J., 1978, Preliminary analytical results for a new U.S. Geological Survey Devonian Ohio shale standard, SDO-1: U.S. Geological Survey Open-File Report 78-447, 11 p.
Malan, R. C., 1968, The uranium mining industry and geology of the Monument Valley and White Canyon districts, Arizona and Utah, in Ridge, J. D., Ore deposits of the United States, 1933-1967 (Graton-Sales vol.): New York, American Institute of Mining, Metallugical and Petroleum Engineers, p. 790-804.
McKelvey, V. E., 1967, Phosphate deposits: U.S. Geol. Survey Bulletin 1252, 21 p.
McKelvey, V. E., and Carswell, L. D., 1956, Uranium in the Phosphoria formation, in Page and others: U.S. Geological Survey Professional paper 300; p. 483-487.
McKelvey, V. E., and Carswell, L. D., 1967, Uranium in the Phosphoria Formation, in Anatomy of the western phosphate field--Intermountain Association of Geologist, 15th Annual Field Conference 1967: Salt Lake City, Utah, Intermountain Association of Geologists, p. 119-123.
Melin, R. E., 1969, Uranium deposits in Shirley Basin, Wyoming, in Wyoming uranium issue: Wyoming University Contributions to Geology, v. 8, no. 2, pt. 1, p. 143-149.
Mining Magazine, 1976, International mining survey: Mining Magazine, v. 135, no. 3, p. 233-244.
Moench, R. H., and Schlee, J. S., 1967, Geology and uranium deposits of the Laguna district, New Mexico: U.S. Geol. Survey Prof. Paper 519, 117 p.
Motica, J. E., 1968, Geology and uranium-vanadium deposits in the Uravan mineral belt, southwestern Colorado, in Ridge, J. D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales Volume), v. 1: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 805-813.
Nash, J. T., 1981, Geology of dolomite-hosted uranium deposits at the Pitch mine, Saguache County, Colorado, in New Mexico Geological Society Guidebook, 32nd Field Conference, Western Slope Colorado: p. 191-198.
Nash, J. T., and Lehrman, N. J., 1975, Geology of the Midnite uranium mine, Stevens County, Washington--a preliminary report: U.S. Geol. Survey Open-File Report 75-402, 36 p.
Nash, J. T., Granger, H. C., and Adams, S. S., 1981, Geology and concepts of genesis of important types of uranium deposits, in Skinner, B. J., ed., Seventy-Fifth Anniversary Volume, 1905-1980: The Economic Geology Pub. Co., Landcaster Press, Inc., Lancaster, Penn., 17604, p. 63-116.
Olson, J. C., 1976a, Geologic map of the Iris quadrangle, Gunnison and Saguache Counties, Colorado: U.S. Geol. Survey Geol. Quad. Map GQ-1286, 1:24,000.
_____1976b, Uranium deposits in the Cochetopa District, Colorado, in relation to the Oligocene erosion surface: U.S. Geol. Survey Open-file Report 76-222, 13 p.
Osterwald, F. W., 1956, Relation of tectonic elements in Precambrian rocks to uranium deposits in the Cordilleran foreland of western United States, in Page and others: U.S. Geol. Survey Prof. Paper 300, p. 329-335.
Osterwald, F. W., and Dean, B. G., 1961, Relation of uranium deposits to tectonic pattern of the central Cordilleran foreland, in Contributions to Geology: U.S. Geological Survey Bulletin 1087-I, p. I337-I390.
Otton, J. K., 1981a, Geology and genesis of the Anderson mine, a carbonaceous lacustrine uranium deposit, western Arizona, A summary report: U.S. Geol. Survey Open-File Report 81-780, 24 p.
_____1981b, Structural geology of the Date Creek basin area, west-central Arizona, in Howard, K. A., Carr, M. C., and Miller, D. M. eds., Tectonic framework of the Mohave and Sonoran Deserts: U.S. Geol. Survey Open-File Report 81-503, p. 82-84.
_____1981c, Geology of lacustrine carbonaceous uranium deposits: Appendix A, in Gaschgnig, J., Reiter, J., and Reboh, R., Development and application of a knowledge-based expert system for uranium resource evaluation: Menlo Park, CA, SRI International, p. 86-93.
Page, L. R., Stocking, H. E., and Smith, H. B., compilers, 1956, Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations international conference on peaceful uses of atomic energy, Geneva, Switzerland, 1955: U.S. Geol. Survey Prof Paper 300, 739 p.
Rautman, C. A., 1980, ed., Geology of the Grants Uranium Region: New Mexico Bureau of Mines and Mineral Resources Memoir 38, 400 p.

Renfro, A. R., 1969, Uranium deposits in the Lower Cretaceous of the Black Hills (South Dakota and Wyoming), in Wyoming uranium issue: Wyoming University Contributions to Geology, v. 8, no. 2, pt. 1, p. 87-92.

Rich, R. A., Holland, H. D., and Petersen, Ulrich, 1977, Hydrothermal uranium deposits: Elsevier-North-Holland, Inc., New York, 250 p.

Roper, M. W., and Wallace, A. B., 1980, Geology of the Aurora uranium prospect, Malheur County, Oregon [Abs], in Energy exploration in the 80's: American Association of Petroleum Geologists, Southwest Section Annual Meeting, p. 51-52.

Ross, Malcolm, 1963, The crystallography of meta-autunite (1): American Mineralogist, v. 48, nos. 11-12, p. 1389-1393.

Russell, R. T., 1958, Relationship of uranium ore deposits to petroleum - and gas-bearing structures, in Survey of Raw Material Resources: Second United Nations Internat. Conf. Peaceful Uses of Atomic Energy Geneva, 1955, Proc., v. 2, p. 358-366.

Rytuba, J. J., and Glanzman, R. K., 1979, Relation of mercury, uranium, and lithium deposits to the McDermitt Caldera Complex, Nevada-Oregon, in Ridge, S. D., ed., Papers on Mineral Deposits of Western North America: Nevada Bureau of Mines and Geology, Report 33, p. 109-117.

Scarborough, R. B., 1981, Radioactive occurrences and uranium production in Arizona, final report: Arizona Bureau of Geology and Mineral Technology, Geol. Survey Branch, Tucson, Ariz., Prepared for the U.S. Dept. Energy Grand Juction Office, Colorado, under Bendix Field Engineering Corp., Subcontract No. 79-374E, 297 p.

Schnabel, R. W., compiler, 1955, The uranium deposits of the United States: U.S. Geological Survey Mineral Inventory Resource Map, MR-2, scale 1:5,000,000.

Seeland, D. A., 1978, Uranium and hydrocarbon exploration target areas suggested by Eocene stream patterns in the Wind River Basin, Wyoming: U.S. Geological Survey Bulletin 1446, 21 p.

Sharp, B. J., 1956, Uranium deposits in volcanic rocks of the Basin and Range province, in Page and others: U.S. Geol. Survey Prof. Paper 300, p. 79-83.

Sharp, B. J., and Hetland, D. L., 1954, Preliminary report on uranium occurrences in the Austin area, Lander County, Nevada: U.S. Atomic Energy Commission, RME-2010, 13 p.

Sharp, W. N., McKay, E. J., McKeown, F. A., and White, A. M., 1964, Geology and uranium deposits of the Pumpkin Buttes area of the Powder River Basin, Wyoming: U.S. Geological Survey Bulletin 1107-H, p. 541-638.

Shawe, D. R., 1962, Localization of the Uravan mineral belt by sedimentation, in Short papers in geology and hydrology: U.S. Geological Survey Professional Paper 450-C, p. C6-C8.

Shawe, D. R., Simmons, G. C., and Archbold, N. L., 1968, Stratigraphy of the Slick Rock district and vicinity, San Miguel and Dolores Counties, Colorado: U.S. Geol. Survey Prof. Paper 576-A, 108 p.

Sheldon, R. P., 1964, Paleolatitudinal and paleogeographic distribution of phosphorite: U.S. Geological Survey Professional Paper 501-C, p. C106-C113.

Sheridan, D. M., Maxwell, C. H., and Albee, A. L., 1967, Geology and uranium deposits of the Ralston Buttes district, Jefferson County, Colorado, with a section on Paleozoic and younger sedimentary rocks by Van Horn, Richard: U.S. Geol. Survey Prof. Paper 520, 121 p.

Silver, L. T., 1976, A regional uranium anomaly in the Precambrian basement of the Colorado Plateau (abs.): Geological Society of America Abstract with Programs 1976, p. 1107-1108.

Sims, P. K., and Sheridan, D. M., 1964, Geology of uranium deposits in the Front Range, Colorado with sections by King, R. U., Moore, R. B., Richter, D. H., and Schlottman, J. D.: U.S. Geol. Survey Bull. 1159, 116 p.

Southern Interstate Nuclear Board, 1969, Uranium in the southern United States, Washington, Atomic Energy Commission Report, WASH-1128, p. 78-90.

Staatz, M. H., and Carr, W. J., 1964, Geology and mineral deposits of the Thomas and Dugway Ranges, Juab and Tooele Counties, Utah: U.S. Geological Survey Professional Paper 415, 188 p.

Stuckless, J. S., 1979, Uranium and thorium concentrations in Precambrian granites aa indicators of a uranium province in central Wyoming: Contributions to Geology, University of Wyoming, v. 17, no. 2, p. 173-178.

Swanson, V. E., 1961, Geology and geochemistry of uranium in marine black shales, a review: U.S. Geol. Survey Prof. Paper 356-C, p. 67-112.

Thaden, R. E., Trites, A. F., Jr., and Finnell, T. L., 1964, Geology and ore deposits of the White Canyon area, San Juan and Garfield Counties, Utah: U.S. Geological Survey Bulletin 1125, 166 p.

Thamm, J. K., Kovschak, A. A., Jr., and Adams, S. S., 1980, Geology and recognition criteria for sandstone uranium deposits of the Salt Wash type, Colorado Plateau province--final report: U.S. Department of Energy, Grand Junction Office, Colorado, Bendix Field Engineering Corporation GJBX-6(81), 136 p.

Thurlow, E. E., 1956, Uranium deposits at the contact of metasediments and granitic intrusives in the western United States, in Geology of Uranium and Thorium: International Conference on the Peaceful Uses of Atomic Energy [1st], Geneva, 1955, v. 6, p. 288-292.

Tooker, E. W., 1979, Metal provinces and plate tectonics in the conterminous United States, in Ridge, J. D., ed., papers on mineral deposits of western North America: Nevada Bureau of Mines and Geology Report 33, p. 33-38.

_____1980a, Background information to accompany the atlas of some metal and nonmetal mineral provinces in the conterminous United States: U.S. Geological Survey Circular 792, 15 p.

_____1980b, Preliminary map of copper provinces in the conterminous United States: U.S. Geol. Survey Open-File Report 79-576D.

Turner-Peterson, C. E., 1980, Sedimentology and uranium mineralization in the Triassic-Jurassic Newark basin, Pennsylvania and New Jersey, in Uranium in sedimentary rocks -- application of the facies concept to exploration: The Rocky Mountain Section, Soc. Economic Paleontologists and Mineralogists, Denver, Colorado, U.S.A., p. 149-175.

U.S. Bureau of Mines, 1976, Mineral facts and problems, 1975 ed.: U.S. Bureau of Mines Bulletin 667, 1291 p.

_____1977, Minerals in the U.S. economy: U.S. Bureau of Mines, 99 p.

_____1981, Mineral commodity summaries, 1981: U.S. Bureau of Mines, 189 p.

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

_____1980b, An assessment report on uranium in the United States: U.S. Dept. Energy GJO-111(80), 150 p.

United States Energy Research and Development Administration, 1975, Statistical data of the uranium industry, Grand Junction (Colorado) Office, GJO-100(75), January 1, 1975, 85 p.

_____1976, National uranium resource evaluation, preliminary report: Grand Junction Office, June 1976, U.S. Energy Research and Development Administration, GJO-111(76), 132 p.

Vine, J. D., 1962, Geology of uranium in coaly carbonaceous rocks: U.S. Geological Survey Professional Paper 356-D, p. 113-170.

Vine, J. D., and Tourtelot, E. B., 1970, Geochemistry of black shale deposits--a summary report: Economic Geology, v. 65, p. 253-272.

Walker, G. W., and Butler, A. P., Jr., 1966, Uranium, in Mineral and water resources of California: Calif. Div. Mines and Geology Bulletin 191, p. 437-439.

Walker, G. W., Osterwald, F. W., and Adams, J. W., 1963, Geology of uranium-bearing veins in the conterminous United States: U.S. Geological Survey Prof. Paper 455, 146 p.

Wallace, L. G., Roen, J. B., and de Witt, W., Jr., 1977, Preliminary stratigraphic cross section showing radioactive zones in the Devonian black shales in the

western part of the Appalachian basin: U.S. Geological Survey Oil and Gas investigations Chart OC-80, 2 sheets.
Webber, B. N., 1947, Geology and ore resources of the uranium-vanadium depositional province of the Colorado Plateau region: Union Mines Development Corporation, RMO-437, AEC Open-File Report, 279 p.
Weis, P. L., Armstrong, F. C., and Rosenblum, Samuel, 1958, Reconnaissance for radioactive minerals in Washington, Idaho, and western Montana 1952-1955; U.S. Geological Survey Bulletin 1074-B, p.. 25-29.
Weissenborn, A. E., and Moen, W. S., 1974, Uranium in Washington, in Energy Resources of Washington, State Department of National Resources, Division of Geology and Earth Resources, Information Circular no. 30, p. 83-97.
Weissenborn, A. E., and Weis, P. L., 1976, Geologic map of Mount Spokane Quadrangle, Spokane County, Washington and Kootenai and Bonner Counties, Idaho: U.S. Geological Survey Geologic Quadrangle Map GQ-1336.
White, L., 1975, In-situ leaching opens new uranium reserves in Texas: Eng. Min. Journal, v. 176, no. 7, p. 73-81.
Witkind, I. J., and Thaden, R. E., 1963, Geology and uranium-vanadium deposits of the Monument Valley area, Apache and Navajo Counties, Arizona, with sections on Serpentine at Garnet Ridge, by H. E. Malde and R. E. Thaden, and Mineralogy and paragenesis of the ore deposit at the Monument No. 2 and Cato Sells mines, by D. H. Johnson: U.S. Geol. Survey Bull. 1103, 117 p.
Wood, H. B., 1968, Geology and exploration of uranium deposits in the Lisbon Valley area, Utah, in Ridge, J. D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales Volume) v. 1: New York, Am. Inst. Mining, Metall. and Petroleum Engineers, p. 770-789.
Woodmansee, W. C., 1975, Uranium in mineral facts and problems, 1973 edition: U.S. Bureau of Mines Bulletin 667, p. 1117-1200.
Wright, R. J., and Everhart, D. L., 1960, Uranium, Chap. 5, in Mineral resources of Colorado, 1st sequel: Denver, Colorado Mineral Resources Board, p. 327-365.
Yates, R. G., 1952, Quicksilver deposits of the Opalite district, Malheur County, Oregon, and Humboldt County, Nevada: U.S. Geol. Survey Bull. 931-N, p. 319-348.
Young, E. J., and Lahr, Mel, 1975, The Schwartzwalder uranium mine, Jefferson County, Colorado [abs.]: Geol. Soc. America Abs. with Programs, v. 7, no. 5, p. 653.
Young, R. G., 1964, Distribution of uranium deposits in the White Canyon-Monument Valley district, Utah-Arizona: Econ. Geology, v. 56, p. 850-873.