Geology of Epigenetic Uranium Deposits in Sandstone in the United States

GEOLOGICAL SURVEY PROFESSIONAL PAPER 538

Prepared partly on behalf of the U.S. Atomic Energy Commission

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By WARREN I. FINCH

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A review of the geologic studies and explorations of uranium deposits in sandstone in the United States from 1943 to 1959

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By Warren I. Finch

ABSTRACT

Epigenetic uranium deposits in sandstone and related rocks are formed by the precipitation of uranium minerals from solutions. These deposits are widespread in the United States; they have yielded most of the uranium ore produced in this country and contain nearly all the domestic ore reserves.

Most deposits are tabular layers that lie nearly parallel to the bedding and for that reason are called peneconcordant deposits. In these, the ore minerals mainly fill the pore spaces of the host rocks, but they partly replace the sand grains, plant fossils, and acccessory and cementing minerals of these rocks; in some deposits the uranium occurs in asphaltic material that impregnates and partly replaces the sandstone. Other deposits are mainly localized along fractures that are discordant to bedding and are referred to as vein deposits. In these, the ore minerals occupy the fracture partings and impregnate the adjacent wallrock.

Ore bodies range from small masses only a few feet across to those that are hundreds of feet across and contain a million tons or more of ore.

Nearly all peneconcordant deposits are in beds of Devonian age or younger and correlate with the evolutionary development of woody land plants, which occur in abundance as fossils in most of the host rocks. Most of these deposits are in lenticular sandstone beds that accumulated from fresh-water streams in one of three environments: (1) shallow depressions in foreland belts which lie between the stable interior of the continent and geosynclinal belts, (2) intermontane basins, and (3) coastal plains near shorelines. Drainage was poor in each of these environments; as a result, the pore waters remained in the beds, at least until structural deformation caused draining or flushing of these solutions. Through reaction with the rocks these pore waters probably became enriched in dissolved metals. Tuffaceous rocks are commonly associated with beds containing peneconcordant deposits, and this volcanic material could have furnished uranium and many of the associated metals.

Vein deposits, however, occur in beds ranging in age from Precambrian to Tertiary, and are nearly as abundant in sandstone of marine origin as in that of fresh-water origin.

Because of their common geologic relations, the peneconcordant uranium deposits probably had a similar origin, though one that differed in detail from place to place. The metals probably were derived from trace amounts in solution in the pore waters when the host rocks and associated strata began to accumulate, and from trace amounts dissolved from these rocks by pore water during diagenesis. The resulting solutions then probably moved slowly through the rocks, precipitating the metals in spots of relatively strong reducing environments. Most deposits seem to have formed before regional deformation and have since remained stable, but others are believed to represent the redissolved and reprecipitated materials of those early deposits that became unstable owing to changes in environmental conditions.

Some vein deposits, however, are probably of hydrothermal origin from a hypogene source, some probably formed by the concentration of secondary or oxidized minerals derived from nearby sources, and some are of undetermined origin.

INTRODUCTION

SCOPE AND ACKNOWLEDGMENTS

Epigenetic uranium deposits in sandstone and related rocks are numerous and widespread in the United States; they have yielded most of the uranium ore produced in this country, and they contain nearly all the domestic ore reserves. This report reviews the geology of these deposits. It summarizes information obtained from the author's field examination of hundreds of deposits from 1949 to 1961 and information from more than a thousand published and unpublished reports. Most of the detailed data are presented in tables and illustrations. The text merely presents the general picture and collates the whole.

Among the published reports are many summaries of the geology of uranium deposits in sandstone, generally described as "sandstone-type deposits." They include Coffin (1921); Fischer (1942, 1950); McKelvey and others (1952); Nininger (1954, p. 59–86); McKelvey and others (1955); McKelvey (1955); Schnabel (1955); Wright (1955); many reports in Page, Stocking, and Smith (1956); Klepper and Wyant (1957, p. 126); Melin (1957); Heinrich (1958, p. 357–452, 534, 547–551); Finnell and Parrish (1958); many reports in United Nations (1958); Finch (1959a, 1964); and Garrels and Larsen (1959).

The author appreciates the encouragement and useful suggestions received from many of his Geological Survey associates, and also the contributions of R. E. Melin, T. L. Finnell, I. S. Parrish, and Carolyn E. Fix, who helped compile data from 1955 to 1957. Special acknowledgment is made of the help of R. P. Fischer, who not only contributed greatly to the clarity of the text and the tabulated material, but also added some pertinent data that became available after the author had completed his report.

GEOCHEMICAL DISTRIBUTION OF URANIUM

Uranium is rather ubiquitous in the earth's crust and occurs in all major types of rock in about the same average amount. It averages about 2 ppm (parts per million) (0.002 percent) in crustal rocks, about 2 ppm also in sandstone, a little more in clay and shale, felsic igneous rocks, and volcanic glass, and a little less in other rocks (table 1).

TABLE 1.—*Average uranium content of selected crustal rocks and major rock types*

Rock	Mean uranium (ppm)	Reference
Crustal rocks	2	Mason (1958).
Mafic igneous rocks	.8	Vinogradov (1956).
Intermediate igneous rocks	1.8	Do.
Felsic igneous rocks	3.5	Do.
Volcanic glass	5.6	Adams (1954).
Clay and shale	3.2	Vinogradov (1956).
Limestone	1.3	Rankama and Sahama (1950).
Sandstone	[1] 2.2	Evans and Goodman (1941).

[1] Average of 5 samples, probably all marine, of Mississippian, Pennsylvanian, Cretaceous, and Oligocene ages. An average of 1.2 ppm uranium for sandstone has been cited as a computation of Evans and Goodman (1941) by several authors, but this figure is an average for samples of roadway gravel, soil, sand, and quartzite, in addition to sandstone.

The original source of most of the uranium in the earth's crust is magmas and igneous rocks. Uranium in magmas is mostly in the low-valent (+4) state. As the magmas crystallize, part of the uranium is taken up in the rock-forming minerals, especially the accessory minerals such as zircon, apatite, and monazite, and part is deposited as film on the rock-forming crystals. Some uranium remains in residual magmas that form pegmatites and in solutions that form hydrothermal veins (Larsen and Phair, 1954); in both pegmatites and veins it generally forms uranium-rich minerals, such as uraninite (pitchblende), which—in sufficient quantity—are of economic value.

The accessory minerals of igneous rocks are generally resistant to weathering and commonly are washed into beds of detrital sediments, especially sand; some of these placer accumulations contain appreciable uranium (McKeown, 1954; Murphy and Houston, 1955; Murphy, 1956a; Chenoweth, 1956, 1957). Most of the uranium-rich minerals in veins and pegmatites, and the uranium-bearing films on igneous rocks, however, oxidize readily and release water-soluble uranium in the high-valent (+6) state, which goes into solution in surface and ground waters. If these waters circulate through rocks, especially sandstone, some uranium may be removed from solution by being adsorbed on clay minerals and on carbonaceous matter or may be precipitated by chemical reaction or evaporation. Because these waters probably have a very low uranium content, at least initially, unusual conditions of extraction and considerable time are probably required to concentrate much uranium. The uranium remaining in solution is either trapped in the rocks or moves to the surface and eventually to the oceans. There it is precipitated in moderate concentrations only, largely in the mud containing organic material or in phosphatic sediments.

For a more detailed description of the geochemical cycle of uranium, the reader is referred to Bell (1954) and McKelvey, Everhart, and Garrels (1955).

Vanadium, chromium, and copper are commonly associated with uranium in deposits in sandstone, where they behave geochemically somewhat like uranium. However, in igneous rocks, neither vanadiaum nor chromium, which are most abundant in mafic and ultramafic rocks (Kiss, 1958; Fischer, 1959), is closely associated with uranium. In most vein deposits, vanadium and chromium are sparse, but in typical hydrothermal veins, uranium and copper are commonly associated.

DEFINITIONS

Because uranium concentrations in amounts above the average for the earth's crust occur in many kinds of rock and result from various geologic processes, they form several types of deposits. The deposits described in this report—epigenetic uranium deposits in sandstone and related rocks—are somewhat arbitrarily defined.

Uranium deposit.—A uranium deposit, as used in this report, either is a body of rock that contains at least 0.01 percent chemically determined U_3O_8—a concentration at least 50 times the average concentration in crustal rocks, or is a body of rock which contains recognized uranium minerals but which has not been sampled adequately to establish its grade.

Ore.—Ore, as used here, is a body of rock that contains at least 0.1 percent chemically determined U_3O_8—a concentration at least 500 times the average in crustal rocks. No consideration is given to the many other factors that determine whether a body of rock can be exploited profitably.

Epigenetic deposit.—Epigenetic, as used in this report, refers to the uranium deposits that were formed by precipitation from solutions that moved through the host rocks. The uranium was either introduced from sources remote from the host sandstone or was derived from uranium-bearing materials or connate water in the host and associated rocks.

The host rocks of the deposits described in this report are chiefly beds of sandstone, but they also include other detrital rocks that commonly grade into or are interbedded with the sandstone, such as conglomerate, siltstone, tuff, and mudstone. Many host rocks contain much carbonate, and a few consist dominantly of detrital carbonate fragments. Limestone, carbonaceous shale, lignite, and coal also contain epigenetic uranium deposits, but these deposits are not described in this report, even though some are similar to and in places are closely associated with deposits in sandstone (Gabelman, 1956b). The geology of uranium in carbonate rocks has been reviewed by Bell (1963), and the uranium deposits in coaly carbonaceous rocks have been described by Vine (1962).

HISTORY OF MINING AND PRODUCTION

The first reported discovery of a uranium deposit in sandstone in the United States was in 1874 at Mauch Chunk (now Jim Thorpe), Carbon County, Pa. (Genth, 1875, p. 144B). In 1898 a deposit of uranium-bearing vanadiferous sandstone was found at Roc Creek, Montrose County, Colo. This deposit was soon exploited for the radium content of its ore, and its discovery led to other successful searches for similar deposits in western Colorado and eastern Utah. From 1898 to 1924 these deposits yielded about a quarter of a million short tons of ore, part of which was mined mainly for radium and part mainly for vanadium. From 1924 to 1945 about 1 million tons of ore was mined, chiefly for vanadium; most of this ore came from deposits in Colorado and Utah, but some came from Arizona and a little from New Mexico.

The stimulus of the U.S. Atomic Energy Commission program in the late 1940's and the 1950's led to the discovery of many more deposits of uranium-bearing sandstone in the Colorado Plateau region and in many States outside the Plateau region as well, especially Wyoming, South Dakota, and Texas. From 1948 to 1961 about 35 million tons of ore was mined from deposits in sandstone, chiefly for uranium, although some ores yielded the byproduct vanadium. The production of U_3O_8 from deposits in sandstone increased from about 110 short tons of concentrates in 1948 to about 17,000 short tons in 1958. In 1962 uranium ore reserves in the United States, nearly all of which were in epigenetic deposits in sandstone and related rocks, totaled nearly 70 million short tons—almost a 10-year supply at the 1962 mining rate.

Parts of the history of exploration and mining are presented in many technical reports, especially those of Hillebrand and Ransome (1900), Moore and Kithil (1913), Coffin (1921, 1954), Fischer (1942), and the Utah Geological Society (1954). A popular account of the history of these events is given by Bruÿn (1955). Data on production are given in statistical publications of the U.S. Geological Survey and the U.S. Bureau of Mines.

GENERAL DESCRIPTION OF DEPOSITS

The deposits in sandstone consist chiefly of fine-grained uranium minerals that mainly fill the pores of the host rock and replace plant fossils, but also partly replace the sand grains and the cementing minerals of that rock. Other deposits of uranium occur in asphaltic material that impregnates and replaces the sandstone. Still other deposits fill fractures in the sandstone. Vanadium and copper are abundant in many deposits, chromium and molybdenum occur conspicuously in some, and trace amounts of certain other elements are common in most. Ore bodies range from small masses containing a few tons of ore to large masses containing a million tons or more. Most ore bodies are tabular masses that lie nearly parallel to the bedding of the host rocks and are called "peneconcordant" (Finch, 1959b). Some deposits are localized along fractures or other structural features that cut the host beds at steep angles; these are called vein deposits.

Most peneconcordant deposits are in lenticular sandstone beds that were deposited under continental conditions, chiefly by fresh-water streams. Fossil plant material and sedimentary features in the host sandstone obviously influenced the localization of many of these deposits. Vein deposits, however, occur in about equal abundance in sandstone beds that were deposited under marine conditions and in those that were deposited under continental conditions. Most vein deposits occur along steep-angle fractures associated with normal faults; a few are in collapsed sandstone plugs or pipes.

GEOGRAPHIC DISTRIBUTION OF DEPOSITS

Nearly 4,600 uranium deposits in sandstone are known in the United States. The locations of individual deposits and groups of deposits (independently numbered by State) are shown on plate 1. Table 2 summarizes the major characteristics of individual deposits and groups and cites references that describe them in more detail; map numbers correspond to those on plate 1.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*

[Deposits are arranged by State and by map No. on pl. 1; on pl. 1, the map symbols show type of deposit, production and grade of largest deposit in each group, and associated ore metals. If individual deposits differ from group type shown on pl. 1, † indicates vein deposits; §, peneconcordant deposit; ‡, type questionable. # indicates grade or size of deposit is questionable. For description of host-rock formation see table 3. For explanantion of symbols designating minerals, see table immediately following; all minerals were identified by field methods (mainly observation) except those shown in *italic*, which were identified by precise laboratory methods. Asterisk (*) by date of source of data indicates written commun.; double asterisk (**), oral commun.]

Symbol	*Mineral*
A	Uranium-arsenate mineral.
A-1	Zeunerite.
	Metazeunerite.
A-2	Abernathyite.
A-4	Novacekite.
A-5	Troegerite.
A-6	Uranospathite.
C	Uranium-carbonate mineral.
C-1	Schroeckingerite.
C-2	Andersonite.
C-3	Bayleyite.
C-4	Rutherfordine.
C-5	Liebigite
C-6	Rabbittite.
C-7	Swartzite.
M	Uranium-molybdate mineral.
M-1	Umohoite.
N	No uranium minerals recognized.
O	Uranium-oxide mineral.
O-1	Uraninite.
O-2	Becquerelite.
O-3	Gummite.
O-4	Schoepite.
O-5	Fourmarierite.
O-6	Ianthinite.
P	Uranium-phosphate mineral.
P-1	Autunite.
	Meta-autunite.
P-2	Torbernite.
	Metatorbernite.
P-3	Uraniferous carbonate-fluorapatite.
P-4	Uranocircite.
P-5	Phosphuranylite.
P-6	Sabugalite.
P-7	Bassetite.
P-8	Saléeite.
P-9	Dewindtite.
Si	Uranium-silicate mineral.
Si-1	Coffinite.
Si-2	Uranophane.
	Beta-uranophane.
	Uranophane-like mineral.
Si-3	Uraniferous opal.
Si-4	Cuprosklodowskite.
Si-5	Sklodowskite.
Si-6	Soddyite.
Si-7	Boltwoodite.
Si-8	Kasolite.
Si-9	Weeksite.
Su	Uranium-sulfate mineral.
Su-1	Johannite.
Su-2	Uranopilite.
Su-3	Zippeite.
	Zippeite-like minerals.
U	Unidentified uranium mineral.
Up	Unidentified primary uranium mineral.
Us	Unidentified secondary uranium mineral.
V	Uranium-vanadate mineral.
V-1	Carnotite.
V-2	Tyuyamunite.
	Metatyuyamunite.
V-3	Rauvite.
V-4	Uvanite.
V-5	Sengierite.

Map No.	Name o flocality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			ARIZONA			
			Apache County			
1	Jerome Chee prospect	Morrison [1]	Fine-grained quartzose sandstone.	Carbonized plant remains	V-1	J. W. King (1951).
2	Red Rock bridge prospect	do.[1]	do	do	V-1	Do.
3	Upper Red Wash mine (Naka Chee Begay).	do.[1]	do	do	V-1	Do.
4	Unnamed prospects	do.[1]	do	do		
5	Oak Springs, Syracuse, and unnamed mines.	do.[1]	do	do	V-1, *V-2*	Stokes (1951); Gruner, Gardiner, and Smith (1954).
6	Zona No. 1‡	do.[1]	do	do	*V-2*	Chew (1956a).
7	North Mesa mines	do.[1]	do	do	V-1	Stokes (1951).
8	Hogan, Martin, Rattlesnake, Sah Tah, and unnamed mines.	do.[1]	Fine-grained shaly and limy sandstone and greenish-colored mudstone.	Carbonized logs and other plant remains abundant.	*C-1*, *V-1*, *V-2*	Stokes (1951); Chenoweth (1955).
9	Eurida and unnamed mines	do.[1]	Fine-grained sandstone		V-1	Stokes (1951).
10	Unnamed mines on Sunnyside, Friday, and Segi-ho-cha Mesas.	do.[1]	Medium-grained shaly sandstone.	Carbonized plant remains	V-1	Do.
11	Alcove Mesa mines	do.[1]	Fine-grained sandstone	do	V-1	Do.
12	Kinusta (Tree) Mesa	do.[1]	Fine- to medium-grained sandstone.	do	V-1	J. W. King (1951).
13	Cove Mesa group	do.[1]	Fine- to medium-grained limy sandstone.	Carbonized logs and other plant remains.	*V-2*	Jones (1954); Masters (1955).
14	East, West, and Mexican Cry Mesas.	do.[1]	Fine-grained sandstone	do	V-1	Dodd (1956).
15	Black No. 1, Cisco No. 1, Flag Mesa Nos. 1 and 2, Frank No. 1, Mesa I through VII groups, and unnamed mines.	do.[1]	Fine-grained quartzose sandstone and gray mudstone.	do	*O-1*, *V-1*, *V-2*	Ellsworth and Hatfield (1951); King and Ellsworth (1951); Masters (1955); Lowell (1955); Dodd (1956); Laverty and Gross (1956).
16	Sweetwater Trading Post prospect.	do.[1]	Fine-grained sandstone			
17	Barton No. 3 and unnamed claims.	do.[1]	do			
18	Garnet Ridge (Keith Francis)†	Navajo	Very fine grained sandstone	None	*V-2*	Malde (1954); Shoemaker (1956b).
	Prospect west of Dinnehotso §	Morrison [1]	Gray friable sandstone		V-1	
19	Blackwater's claim, Monument No. 2 mine, South Extension, Tract No. 1 (Cato Sells), and Yazzie No. 1.	Chinle [2]	Medium- to coarse-grained sandstone and conglomerate.	Carbonized and silicified plant remains abundant.	*A-1*, *O-1*, *O-2*, *O-5*, *P-1*, *Si-2*, *V-1*, *V-2*, *V-3*.	Butler and Allen (1921); Witkind (1956a); Finnell (1957); Isachsen and others (1955); Witkind and Thaden (1963).
	Monument No. 2 mine (also above).	Cutler [3]	Fine-grained sandstone	None	V-1	Isachsen and others (1955).
20	Tom Wilson and Tom Klee mine, and unnamed claims.	Morrison	Sandstone	Carbonized logs and other plant remains abundant.	Us	
21	Yale Point claims	Toreva	Light-gray fine-grained quartzose sandstone.	Abundant carbonaceous seams.	V-1 or V-2	Clinton and Carithers (1956).
22	Etsitty No. 1 (M. 0.5)	do	Fine-to medium-grained quartzose sandstone.	Abundant carbonized plant remains and coal seams.	V-1, *V-3*	Do.
23	Charlie James No. 1 mine, Salina No. 4, and unnamed prospects.	do	Light-gray fine- to coarse-grained quartzose sandstone.	do	V-1 or V-2	Do.
24	Polacca Wash prospects	do	do	do	V-1	Do.
25	Zealy-Tso drilling block (approximate location).	Chinle [2]	Light-brown and gray sandstone.	Some carbonaceous trash	V-1	
26	Anomaly 15-30.1	Chinle	Greenish-gray siltstone	Abundant carbonized and silicified plant remains.	N	
27	Name unknown	do	Conglomeratic sandstone	Abundant carbonized plant remains.	N	
28	Grant prospect	do	Sandy clay and shale	Carbonized plant remains	V-1	

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
			ARIZONA—Continued			
			Navajo County			
29	Tract No. 2	Chinle	Mudstone	Silicified plant remains	V-1	
30	Little John claim, and Ruth claims.	Chinle [4]	Gray medium- to coarse-grained sandstone and gray mudstone.	Abundant carbonaceous trash.	*A-1*, C-1, *O-1*, *P-2*, *Si-1*, Su.	Gruner, Gardiner, and Smith (1954); Gregg and Moore (1955).
31	Curry Jones prospect	do.[4]	Sandstone(?)	Carbonaceous trash	Su-3	
32	Hanson No. 1	do.[4]	Light-brown coarse-grained bentonitic sandstone.	Abundant charcoal and coal	N	
33	Gerwitz prospect (Spurlock-Westler ranch).	do.[4]	Muddy sandstone	Abundant plant remains	O-2, Up	Gruner, Gardiner, and Smith (1954).
34	Name unknown (sec. 23, T. 20 N., R. 17 E.).	Chinle	Sandstone and mudstone	Abundant carbonized plant remains.	U	
35	O'Haco ranch	Chinle [4]	Siltstone(?)			
36	O'Haco-Robinson prospect	Chinle [2]	Conglomerate(?)		P-1, V-2	
37	Sun No. 14	Bidahochi	Siltstone		P-3?	Shoemaker (1956b).
38	Bidahochi Butte	do	Massive claystone			Do.
39	Morale claim	do	Laminated siltstone, coarse-grained volcanic sandstone, tuff breccia, and agglomerate.	None	Us	Shoemaker (1956b); Lowell (1956).
40	Blue Lake claim	Morrison [17]	Sandstone		V-1	
41	Koley Black No. 1 (Ben No. 2)	Chinle [2]	Conglomerate	Plant remains, mostly silicified but some carbonized.	N	Witkind (1956a).
42	Brodie No. 5	do.[2]	Conglomerate(?)		Us	
43	Koley No. 2, and Sam Charlie No. 1, Hunts Mesa.	Chinle [2]	Green siltstone and shale and conglomeratic sandstone.	Abundant carbonized, some silicified plant remains.	P-2, V-1, V-2	Chester (1951); Witkind and Thaden (1963).
44	Mitchell Mesa claims	do.[2]	Conglomeratic coarse-grained sandstone.	Some silicified and carbonized logs and other plant remains.	P-2, V-1, V-2	Witkind (1956a, p. 107); Witkind and Thaden (1963).
45	Monument No. 1, Mitton (Mitten) No. 2, and Fern and Moonlight.	do.[2]	Conglomerate and medium-grained sandstone.	Abundant carbonized logs and plant remains.	*P-1*, *P-2*, *Su-3*, *V-1*, *V-2*, *V-3*.	Gruner and Smith (1955a); Holland and others (1958); Witkind (1961); Witkind and Thaden (1963).
46	Azansoso prospect	Chinle	Light-gray coarse-grained sandstone.	Abundant carbonized plant remains.	N	
47	James Sonny claim	Chinle [2]	Sandstone(?)			Gregg (1952).
			Coconino County			
48	Calvin Chee	Chinle [4]	Sandstone(?)	Very abundant carbonized plant remains.	C-1?	
49	Huskon No. 4 and other mines§	do.[4]	Medium-grained sandstone	Abundant carbonized plant remains.	A-1?, *P-1*, P-2?.	Gruner and Knox (1957); Bollin and Kerr (1958).
	River View collapse†	Chinle(?)	Sandstone(?)			Bollin and Kerr (1958); Kerr (1958a).
50	Huskon No. 17 mine, Ramco group, and other mines.	Chinle [4]	Fine- to medium-grained sandstone.	Abundant carbonized logs and plant remains.	*C-2*, *O-1*, O-2?, O-3?, *P-1*, *P-2*, P-4?, *P-5*, Si-5?, Su-3?.	Austin (1957); Gruner and Knox (1957); Bollin and Kerr (1958).
	Black Point-Murphy		Gravel. (Pleistocene)	None	*O-4*, *P-1*, *Si-2*, Su-3.	Austin (1957).
		Chinle [4]	Fine- to medium-grained sandstone and mudstone.	Abundant carbonized logs and other plant remains.	*P-1*, *V-2*	
51	Hosteen Nez and Yellow Jeep mines.	Kayenta(?)	Coarse-grained sandstone, conglomerate, and shale.	Abundant carbonized plant remains.	*O-1*, O-2?, *V-2*.	Gruner and Gardiner (1952); Gruner, Gardiner, and Smith (1954); Granger and Raup (1962).
52	Huskon No. 3, Huskon No. 7, Yazzie 102, Huskon No. 10, and other mines.	Chinle [4]	Sandy and silty mudstone	do	*C-1*, *O-1*, *O-2*, *P-2*, *Si-1*, *Su-3*, *V-1*.	Gruner and Smith (1955a); Isachsen and Evensen (1956); Gruner and Knox (1957); Bollin and Kerr (1958); Holland and others (1958).
53	A & B Nos. 2 and 3, and Blackhair prospect.	Chinle [2]	Conglomerate		N	
54	Huskon No. 1, Huskon No. 2, Yazzie 101, and other mines.	Chinle [4]	Light-brown fine- to medium-grained sandstone.	Abundant carbonized logs and other plant remains.	*O-1*, *O-2*, *P-9*, *Su-3*.	Bollin and Kerr (1958).
55	Jack Daniels No. 1, Huskon No. 5, and other mines.	do.[4]	Sandstone	Abundant carbonized plant remains.	*A-1*, *C-1*, *O-1*, *P-2*, *P-5*, *P-6*, *Si-2*, *Su-3*.	Gruner, Gardiner, and Smith (1954); Gruner and Smith (1955a); Gruner and Knox (1957); Bollin and Kerr (1958).
56	Shadow Mountain collapse deposit.	Chinle(?)	Sandstone(?)			Bollin and Kerr (1958); Kerr (1958a).
57	Arizona claim, White Mesa area.	Navajo	White to gray sandstone	None	P-2	Russell Gibson (1952*).
58	F & B claim	Chinle	Sandstone(?)		*O-2*	Gruner and Smith (1955a).
59	El Pequito mine and other Lees Ferry occurences.	do	Sandstone, conglomerate, and mudstone.	Sparse to abundant carbonaceous material.	*O-1*, *P-2*, *Su-3*.	Everhart (1950); Phoenix (1963)
60	Sun Valley mine	Chinle [2]	Chert- and quartzite-pebble conglomerate.	Some carbonized plant remains.	*O-1*, *P*, *Su-3*	Petersen and others (1959); Petersen (1960).
61	Vermillion No. 1 mine and Jasper group.	do.[2]	Conglomerate and siltstone	Some soft black carbonaceous material.	*P-2*, Us	Petersen (1957).
62	Orphan (lode) mine	Coconino, Hermit(?), Supai(?)	Gray very fine grained quartzose sandstone, shale, and limestone.	Some black asphaltic(?) blebs.	*O-1*, *P-2*	Isachsen and others (1955); Gabelman and Boyer (1958); Granger and Raup (1962).
63	Ridenour mine	Supai	Greenish-gray fine-grained sandstone.	None	V-1	Miller (1954).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
	ARIZONA—Continued					
	Mohave County					
64	Hack Canyon mine	Coconino; Hermit	Fine-grained sandstone and siltstone.	None	*O-1*, *P-2*, *V-2*.	De Ment and Dake (1948); Gruner, Gardiner, and Smith (1954); Isachsen and others (1955); Granger and Raup (1962).
65	Katy J. claims	Moenkopi(?)	Medium-grained sandstone	Abundant carbonized plant trash.	P-2?	
66	Rainbow (Last Chance)	Chinle [2]	Conglomeratic sandstone			Everhart (1950).
67	Radon claims	Chinle [2?]	Conglomerate		Us.	
68	Dreamer group‡		Sandstone. (Tertiary.)		V-1	
69	Wharton property‡	Muddy Creek	Clay		V-1?	
70	Copper Mountain (Cox and Ross claim) mine.	Supai	Very fine to fine grained sandstone.	None	A-1, O-1?	C. G. Tillman (1954*).
71	Copper House Coalition No. 2	do	Yellow-brown and white sandstone.	do	N	C. S. Bromfield (1952*).
72	Lucky 44 claims		Bentonitic clay and sandy conglomerate. (Tertiary?)		Si-2 or V-1?	
73	Red Hills (Tate)	Artillery	Fault or sedimentary breccia	None	Us	Wright (1950); Hart (1955); Granger and Raup (1962).
74	Masterson group‡	do	Mudstone	Some carbonized palmlike fragments.	N	
	Yavapai County					
75	Uranium Aire group		Vitrified and silicified fine-grained tuff. (Pliocene.)	No carbonized material, but abundant opalized palmlike wood impressions.	P-2?, *V-1*	Reyner and others (1956); Davis and Sharp (1957).
76	Pretty Folly group‡	Verde	White tuff	None	V-1	
	Gila County					
77	Promontory claim	Supai	Sandstone(?)	Carbonaceous zones 1–4 feet thick.		R. J. Schwartz (1957*).
78	Roxy (Roxies) and Q Ranch group.	Dripping Spring.	Siltstone(?)		*P-2*, P-8	H. C. Granger and R. B. Raup (1959*).
79	Shepp No. 2 mine	do	Dark-gray flaggy indurated siltstone.	Some organic carbon	*P-2*	Granger and Raup (1959).
80	Rick	do	Siltstone(?)			R. J. Schwartz (1957*).
81	Able mine, North Star, and other prospects.	do	Clayey siltstone		*P-2*, *P-7*, *P-8*.	R. J. Schwartz (1957*); H. C. Granger and R. B. Raup (1959*).
82	Blevins Canyon, Fairview, Great Gain, and other deposits.	do	Mainly shale and flaggy siltstone, rarely fine-grained feldspathic quartzite.		*P-2*, P-4?, P-7, *Si-2*.	Granger and Raup (1959); H. C. Granger and R. B. Raup (1959*).
83	Giger claims		Grayish-yellow limy and sandy silt. (Pliocene?).	Abundant carbonized plant remains; also fossil bones.	V-1?	R. J. Schwartz (1957*).
84	Hope, Workman, Little Joe, and other deposits.	Dripping Spring.	Gray to pink hornfels, partly coarse-grained and recrystallized.		*O-1*, *P-1*, *P-2*, *Si-1*, *Si-2*, Si-3.	Granger and Raup (1959); H. C. Granger and R. B. Raup (1959*).
85	Snakebit, Tomato Juice, and other deposits.	do	Very fine grained and medium- to coarse-grained quartzite, and siltstone.		*O-1*, P-2, Si-2.	R. J. Schwartz (1957*); Granger and Raup (1959); H. C. Granger and R. B. Raup (1959*).
86	Donna Lee, Sue, and other deposits.	do	Gray siltstone and very fine grained sandstone and quartzite.		*P-1*, *P-2*, *P-7*, Si-2.	Granger and Raup (1959).
87	Red Bluff mine, Rainbow, and other deposits.	do	Dark-gray laminated siltstone and very fine grained quartzite.	Some fine-grained graphite and carbon.	*O-1*, *P-1*, P-2, *P-7*, *P-8*, *Si-2*, *Si-3*.	Kaiser (1951); Granger and Raup (1959).
88	Lucky Boy ‡, Sky, and Lucky King deposits.	do	Gray siltstone, shale, and very fine grained quartzite.		*P-2*, *P-7*, *Si-2*.	R. J. Schwartz (1957*); Granger and Raup (1959); H. C. Granger and R. B. Raup (1959*).
89	Dale claim	Dripping Spring.	Siltstone(?)			R. J. Schwartz (1957*).
	Graham County					
90	White Bluffs Uranium Co	Gila	Light-gray siliceous lake beds		Si-2	
	Maricopa County					
91	Los Cuatros group		Silicified volcanic ash. (Tertiary.)		N	
92	Golden Duck group		Rhyolitic tuff. (Tertiary.)	Some sooty material	C-1, P-2	
93	Milton Ray group (Aquila, Black Butte Uranium Corp.).		Drab thin-bedded tuff. (Tertiary.)	Some fresh-water shells and bone.	*V-1*	Hewett (1925); Granger and Raup (1962).
	Jar claim		Marl, limestone, mudstone, and sandstone. (Tertiary.)		V-1?	

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			ARIZONA—Continued			
			Yuma County			
94	Red Knob claims		Opalized mudstone. (Tertiary.)		Si-9, *V-1*	Outerbridge and others (1960).
	St. Louis group		Mudstone. (Tertiary.)		Si-2?	
	Wooley group		Vein quartz in brown sandstone and basic flow rock. (Tertiary.)		Si-2	
	Other prospects in Muggins Mountains.		Mudstone and tuff. (Tertiary.)		Si-2	
			Pima County			
95	Half Moon No. 3		Reddish-brown opalized clay. (Tertiary?)		Si-3	
96	Red Hills		Silicified brecciated quartz-pebble conglomerate. (Precambrian?)		Si-2	
97	Hopeful No. 1		Silicified quartzite. (Cretaceous?)		Us	
			Santa Cruz County			
98	Duranium claims		Arkosic sandstone. (Cretaceous.)		P-1, Si-2, Si-8.	
99	Santa Clara claim	(?)	Sandstone and conglomerate		O-1?	
			ARKANSAS			
			Crawford County			
1	Unnamed	Atoka	Black loosely cemented medium-grained quartzose sandstone.	Abundant black organic material.	*P-1*	
			Montgomery County			
2	Unnamed‡		Sandstone. (Ordovician?)		V-2	
			Pike County			
3	Rankin prospect	([5])	Siltstone	Abundant carbonized plant remains.	N	Arkansas Geol. and Conserv. Comm. (1959).
			CALIFORNIA			
			Lassen County			
1	Donald Q 1 & 2 and Independence group.		Poorly cemented coarse-grained sandstone and conglomerate, and tuff. (Tertiary?).	Abundant carbon locally	P-1	
2	Lola G		Coarse-grained granite wash. (Tertiary?)	Seams of carbonaceous material.	Us	
	Noma J. group		Tuff. (Tertiary?)		Us	
3	Jeanne K (Cornelia C)† and Herbal claims§.		Tuffaceous sandstone, micaceous sandstone, and claystone. (Tertiary.)	Carbon seams and beds	P-1, *P-6*	Walker and others (1956, p. 34); Troxel and others (1957).
4	Black Jack Nos. 1 and 2 and Daisy Mae claims.		Light-gray sedimentary(?) tuff. (Tertiary?)	None	P-1?, P-2?, Si-2?.	
			Alpine County			
5	Mary E		Granite and andesite boulder gravel in clay matrix. (Pleistocene?)		P-1	
			Tuolume County			
6	Autunite placer and lode claims and Carnotite group.		Sandstone and conglomerate of andesite, basalt, and pumice. (Tertiary?).	Abundant carbonized plant remains.	*P-1*	H. K. Stager (1956*).

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TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
	CALIFORNIA—Continued					
	Calaveras County					
7	Radium No. 1	(?)	Coarse-grained calcareous sandstone.	Thin carbon bands	O-1, P-1	
	Madera County					
8	Johnson group, Patsy Nos. 1 and 2, and Sierra Mining Co. properties.		Granite wash and poorly sorted sand, clay, and gravel. (Recent.)	Abundant carbonized plant remains.	P-1	
	Inyo County					
9	Green Velvet group, Easter group, Jackson and Linda, Harrybuck, and Valley View group.	Coso	Light-gray bentonitic clay and fine-sand, coarse-grained arkosic sandstone.	None	*P-1*, Si-3, V-1.	Walker and others (1956, p. 35); Davis and Hetland (1956); Troxel and others (1957).
10	Coso Uranium, Inc., Seneca No. 2, and Inland Oil Co.	do	Poorly cemented arkosic sandstone and conglomerate, and multicolored bentonitic clay.		*P-1*, *Si-2*	Troxel and others (1957); Power (1958).
	Monterey County					
11	Arajo		Gouge and breccia in shale and sandstone. (Tertiary.)		V-1?	
	San Luis Obispo County					
12	Santa Margarita prospects		Sandstone and siltstone. (Tertiary.)		N	Walker and others (1956, p. 33).
13	E. Campedonico ranch ‡		Light-gray to white siliceous and calcareous shale. (Miocene.)		N	
14	Front Door group		Brecciated conglomeratic sandstone. (Cretaceous.)		N	
15	Hillbilly No. 10 claim†, Owen No. 3 mine†, and Mitchell property§.		Gypsiferous shale and siltstone. (Miocene.)		*P-1*, V-1?	Walker and others (1956, p. 33); Troxel and others (1957).
	Kern County					
16	McClananan group		Tan siltstone. (Tertiary.)		Us	
17	Four Horsemen claims‡	Monterey	Shale		*Si-2*	
	Sunny Valley		Brecciated shale and gypsite. (Tertiary?).		Si-2	
18	Twisselman ranch	Monterey	White and gray shale		V-1	
19	K group		Brecciated shale and siltstone. (Tertiary.)		Us	
20	High Hat		Brecciated highly silicified shale. (Miocene.)		*P-1*	
21	Surprise No. 1 and Loperna property.		Brown brecciated siltstone and shale. (Miocene.)		*P-1*, Si-2?, V-1?.	Walker and others (1956, p. 33); Troxel and others (1957).
22	Houtz and Stone‡§		Shale(?). (Miocene?)			
	Quality Oil Co. property†		Brecciated siltstone and shale. (Miocene.)		N	Walker and others (1956, p. 33),
23	Tres Amigo No. 1§ and Three Friends.‡		Porous fine-grained tuffaceous(?) sandstone. (Miocene.)		P-1, V-1	
	Phanton No. 1 ‡		Shale(?). (Miocene?)			
24	Geeslin and Fiscus property †		Siltstone and shale. (Miocene.)		*P-1*	Walker and others (1956, p. 34).
	Hi-Lo †		Shale. (Miocene?)		P-1?	
	Red Cap§ and Watson§		Soft brown silty shale. (Miocene?)		N	
25	Kern County Land Co		Siltstone. (Pliocene.)		P-1	
26	Emerald Queen claims	Rosamond	Tuffaceous sandstone		N	Walker and others (1956, p. 17).
27	Bluett property	do	Tuffaceous sandstone. (Also quartz monzonite, Cretaceous?)		*P-1*	Do.
28	Rosamond prospect	do	Tuffaceous sandstone		O-3, *P-1*	Walker (1953); Walker and others (1956, p. 15); Troxel and others (1957).
29	Vanuray claim‡	Ricardo or Rosamond.	Sandy clay		*V-1*	Walker and others (1956, p. 19).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			CALIFORNIA—Continued			
			San Bernardino County			
30	Carnotite No. 1		Limy nodules in tuff or shale. (Tertiary.)		Si-2?	
31	Kramer Hills prospects, Fiend claim, and Yellow Tiger claim.	(6)	Shale, marly clay, sandy limestone, and tuff.		*V-1*	Walker and others (1956, p. 19, 20); Troxel and others (1957); Dibblee (1960).
32	Coon claims	Barstow	Calcareous sandstone	Fossil bones	P-3?	Walker and others (1956, p. 20).
33	Dogtag		Iron-stained shale. (Miocene.)		N	
34	Norris claims	Rosamond(?)	Lake-bed rubble		V-1?	
35	Harvard Hills	Barstow	Tuffaceous sandstone, chert, and limestone.		*P-1*, V-1?	Walker and others (1956, p. 20); Troxel and others (1957).
36	United Locators		Silt and mud. (Recent.)		N	
37	Gopher Hole group		Tuff. (Tertiary.)		A-2?, P-1	
			Los Angeles County			
38	Good property		Sheared coaly grit. (Pliocene.)	Abundant carbonized plant remains.	N	
			Ventura County			
39	Hidden Springs group		Clay. (Miocene.)		C-1	
40	Lucky Saddle No. 1		Gray poorly sorted micaceous sandstone. (Oligocene.)	Some carbon along bedding planes.	N	
	Bertram lode (Florence)		Iron-stained concretions in sandstone. (Eocene.)		Us	
41	Gamma Queen	Tejon [7]	Buff fine-grained micaceous sandstone.	Carbonized plant remains	P-1	
	Hoot Mon No. 4 and Lamar group.	Sespe; Tejon [7]	Buff to light-gray coarse-grained arkosic sandstone.	do	V-1	
42	Beer Can No. 12, Payoff, Coyote No. 1, and Chismahoo East No. 1.	Sespe	Gray poorly sorted course-grained arkosic sandstone.	Some carbonized plant remains.	*V-1*	
43	Strathearn Cattle Co.‡		Light-brown siltstone. (Miocene.)		N	
			COLORADO			
			Logan County			
1	Name unknown	White River	Sandstone			
			Larimer County			
2	Carter Lake	Dakota	Claystone		Up	E. L. Grossman and B. C. Smith (1956*).
3	Horsetooth Reservoir	do	Sandstone	Very thin seams of asphaltic material coating fractures.	N	Do.
4	Wahketa lease	do	do		V-1	Do.
			Jackson County			
5	Sheep Mountain prospect	Dakota	Sandstone and conglomerate		N	
			Routt County			
6	Dead Horse claims	(8?)	Well-sorted fine-grained sandstone.		P-1	
7	Willow Creek claims ‡	Morrison(?)	Mudstone	Abundant carbonized plant remains.	O-1?, P-1	
			Moffat County			
8	Big Gulch and Golden Grain	Wasatch	Conglomeratic sandstone		*P-1*	Bergin (1957).
9	Bobcat and Eskridge	Browns Park	Siltstone			P. K. Theobald, Jr., and R. T. Chew 3d (1955*).
10	Buffalo Head Mining Co. property and Sugarloaf mine.	do	Light-gray friable fine-grained clayey sandstone, and gouge.		*P-1, Si-2*	Gruner and Smith (1955b); Bergin (1957); M. J. Bergin (1959*).
	Leon Henderson claim‡§	do	Sandstone		*V-2*	Gruner and others (1956).
11	Gertrude mine§ and Lucky claims§.	do	Light-gray friable fine- to medium-grained sandstone.	Black carbonaceous(?) interstitial matter.	*C-5, O-1, O-2, O-4, P-1, P-3, Si-2.*	Gruner and Smith (1955b); Bergin (1956).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
	COLORADO—Continued					
	Moffat County—Continued					
11	—Continued Marge (Margie) mine‡†	Browns Park	Gray very fine to fine grained sandstone.		*P-1, P-5, V-1, V-2.*	Gruner and others (1956); Bergin (1957); Woodmansee (1958).
	Name unknown†	do	Silicified zone		*V-1*	Gruner and others (1956).
12	Shell group‡	do	Medium-grained silty sandstone.			P. K. Theobald, Jr., and R. T. Chew 3d (1955*).
13	Little Dazy Lede group ‡	Morrison	Sandstone(?)			
14	Little Den group‡	do	do			
15	Jacobsen group	([8])	do			
16	Blue Mountain No. 4 (also called Little Emma, Bozo No. 1, Dorothy No. 2)†.	Curtis	Very fine grained sandstone	Abundant carbonized plant remains.	V-1	Gale (1908); Moore and Kithil (1913); Beroni and McKeown (1952); Clinton and Carithers (1956).
	Biles shaft§	Entrada(?)	Gray friable medium-grained sandstone.	Carbon along bedding planes		Noble and Annes (1957).
17	Elk Springs	Browns Park	Medium-grained sandstone	Oil seep		P. K. Theobald, Jr., and R. T. Chew 3d (1955*).
18	Cedar Mining Co. (Claim No. 1).	do	Grit		P-6, *Si-2,* Si-3.	Gruner and Smith (1955b); P. K. Theobald, Jr., and R. T. Chew 3d (1955*).
	Rio Blanco County					
19	North Midnight (Caywood No. 1), South Midnight (Caywood No. 2), Last Day (Uriv), and other mines.	Morrison [1]	Gray and brown medium-grained sandstone.	Abundant coalified and silicified plant remains.	*V-2*	Gale (1907); Moore and Kithil (1913); Isachsen (1955).
20	Burrell group and various prospects.	do.[1]	Light-gray medium-grained sandstone, and mudstone.	do	V-2	W. H. Boyer (1956*).
21	Riland mine (Stealy claims)	Chinle	Gray gritty calcareous conglomerate.	Abundant carbonized logs and other plant remains.	V-1	Do.
	Garfield County					
22	Name unknown	Morrison [1]	Sandstone	Silicified logs	V-1	Fischer (1960).
23	Rifle and Garfield mines	{Entrada / Navajo(?)}	Light-brown and light-gray fine-grained sandstone.	Sparse small asphaltlike pellets.	*C-3, C-5,* O-1, *V-1, V-2.*	Burwell (1932); Botinelly and Fischer (1959); Fischer (1960).
		Chinle	Brown to greenish-gray mudstone.			Fischer (1960).
24	End of Trail No. 2 claim and other mines.	Morrison [1]	Gray medium-grained limy sandstone.	Some carbonized logs and seams.	V-1	D. R. MacLaren (1952*).
	Grand County					
25	Alaska Humes group	Dakota	Friable fine-grained sandstone	Abundant carbonaceous seams.	P-1, V-1	Malan (1957).
26	Lucky Jack prospect	Middle Park	Arkosic carbonaceous regolith	Locally abundant carbonized plant trash.	P-1	Do.
	Undecided claims ‡	do	Bouldery regolith, red shale, medium- to coarse-grained sandstone, and weathered granite.	do	P-1, Up	Do.
27	Alta No. 4, Lucky Strike No. 1, and other prospects, Troublesome Creek area.	Troublesome	Arkosic sandstone, carbonaceous shale, and conglomerate(?).	Abundant carbonized plant trash in some, but none in others.	C-1, P-1, V-1	Beroni and McKeown (1952); Schlottmann and Smith (1954); Malan (1957).
28	Engels ranch	Dakota	Gray and black shale	Abundant coaly material	Si-2 or V-2	
	Eagle County					
29	Tipton ranch		Bluish-gray shale. (Pennsylvanian.)	Abundant coaly and asphaltic(?) material.	C-5	
30	Lady Bell and Ground Hog No. 1.	Entrada	Gray fine-grained quartzose sandstone.		V-1?	Moore and Kithil (1913); Henderson (1926, p. 47); Hess (1933, p. 455); R. U. King (1956*).
31	Arrowhead No. 1, Lucky Strike No. 1, and Skyline Exploration Co. mine.	Dolores	Conglomeratic sandstone and white conglomerate.	Carbonized plant remains	V-1	H. S. Stafford (1955*).
	Boulder County					
32	Rose Mary No. 1	Dakota	Sandstone	None	N	E. L. Grossman and B. C. Smith (1956*).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			COLORADO—Continued			
			Jefferson County			
33	Leyden coal mine†	Laramie	Silicified coal and sandstone	Abundant coal	*Si-1*, V-1	Berthoud (1875); Wilson (1923); Gude and McKeown (1953).
	Lindsay clay pits§	do	Gray claystone	Abundant carbonized plant remains.	Us	
34	Pallaoro (Morrison)† and Vanadium Queen (Mann) mines†.	South Platte	Gray medium-grained quartzose sandstone.	Abundant black asphalt and carbonized plant remains; some brown coal.	*O-1*, V-1	Wood (1956); Goldstein (1957).
	Stevenson prospect§	do	Sandstone		V-1	
			Park County			
35	Garo (Shirley May) deposit‡	Maroon	White fine- to coarse-grained calcareous and micaceous sandstone, and conglomeratic sandstone.	None	O-1?, *Si-2*, *V-1*, *V-2*.	Wilmarth (1959).
36	Carson Mining and Development Corp. prospect.	Antero	Gray fine-grained tuffaceous sandstone.		P-1	
			Mesa County			
37	La Sal group, Lumsden group, Pack Rat group, and other mines.	Morrison [1]	Buff fine- to medium-grained sandstone.	Carbonized plant remains	*O-1*, *Si-1*, *V-1*	Weeks and Thompson (1954).
38	Black Mamma, Liberty Bell, and other mines.	do.[1]	Mostly buff fine- to medium-grained sandstone; some mudstone.	do	*O-1*, *Si-1*, V-1	Weeks and Thompson (1954); Cater (1955a).
	Mammoth	do.[2]	Conglomeratic sandstone	do	V-1	Cater (1955a).
39	Calamity group, Arrowhead group, Maverick group (includes Hidden Treasure, Small Spot, and other mines), Depression group, and other mines.	do.[1]	Buff to white medium-grained sandstone, shaly sandstone, and mudstone pebbles in sandstone.	Abundant carbonized logs and other plant remains.	*O-1*, *Si-1*, *V-1*, *V-2*, *V-3*.	Coffin (1921); Huleatt and others (1946); Weeks and Thompson (1954); Cater (1955b, 1955c); Shoemaker (1955); Stern and others (1956); Phoenix (1956); Bush and Stager (1956).
40	Outlaw, G-1 (Ronnie), and other mines.	do.[1]	Buff to white medium-grained sandstone and green mudstone.	do	V-1	Cater (1955c); Phoenix (1956).
41	Blue Creek mines, Yellow Bird group, Elizabeth group, and other mines.	do.[1]	Pink to white fine-grained sandstone, light-brown medium-grained sandstone, and green mudstone.	Abundant carbonized plant remains.	V-1	Cater (1955c).
42	Cave Canyon group and other mines.	do.[1]	Buff and white medium- to coarse-grained sandstone.	Some carbonized logs	V-1	
			Montrose County			
43	Rajah (Roc Creek) mine†	{Morrison [1] Wingate}	Sandstone and fault breccia		V-1	Curran (1913); Shoemaker (1956a).
	Various mines§	Morrison [1]	Sandstone		V-1	Do.
	Big Chief †	Kayenta	Light-gray fine- to medium-grained sandstone, and gouge.	None	V-1	Isachsen and others (1955); Shoemaker (1956a).
	Various deposits†	{Summerville Kayenta Wingate Chinle}	Gray sandstone and fault gouge.		V-1	Kimball (1904); Shoemaker (1956a).
44	Radium Cycle mine, Buckhorn No. 3, and other mines.	Morrison [1]	Mudstone, mudstone-pebble conglomerate, gray fine- to medium-grained sandstone, and limy sandstone.	Some carbonized, calcitic, and silicified logs and other plant remains.	V-1	Do.
45	Radium King mine, Middle Red Canyon group, and other mines.	do. [1]	Gray fine- to medium-grained sandstone, and shaly sandstone.	Abundant carbonized plant remains.	V-1	McKay (1955b): Shoemaker (1956a).
	Dean and Redbed claims	Moenkopi	Gray to light-brown mudstone-gall conglomeratic sandstone.		V-1	
46	North Star, Black Rock, and other mines.	Morrison [1]	Sandstone	Some carbonized plant trash	V-1	McKay (1955b).
47	Dolores mines (Ophir, Bluebird, Little Dick, and others).	do.[1]	Brown medium-grained sandstone.	Abundant carbonized logs and trash pockets.	V-1	Curran (1913): Coffin (1921); McKay (1955b).
48	Club group, Wright group, Shamrock group, and other mines.	do.[1]	Buff massive medium-grained sandtsone and thinly laminated sandstone and mudstone.	Sparse to abundant carbonized logs and other plant remains.	*Si-1*, *V-1*, V-2.	Curran (1911); Moore and Kithil (1913); Coffin (1921); Fischer (1942); Huleatt and others (1946); McKay (1955a, 1955b); Cater (1955d); Boardman and others (1956; 1958).
	Rock Raven mine	do.[2]	Cherty conglomeratic sandstone and gray medium- to coarse-grained sandstone.	Plant remains	V-1	Cater and others (1955).
49	Bitter Creek and other mines	do.[1]	Light-brown to gray medium- to coarse-grained sandstone.	Some logs and abundant carbonized plant remains.	*O-1*, *V-1*, *V-2*. *V-3*.	Cater and others (1955); Heyl (1957).
	Berties Beauty No. 1	Burro Canyon.	Conglomeratic sandstone and green mudstone.	Abundant carbonized trash and sparse silicified logs.	V-1	Isachsen and others (1955).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			COLORADO—Continued			
			Montrose County—Continued			
50	Long Park group, Virgin No. 3 mine, Whitney mine, and other mines.	Morrison [1]	Gray and buff medium-grained sandstone, and mudstone.	Abundant carbonized logs and plant-trash pockets.	*O-1, Si-1, V-1, V-2.*	Weeks and Thompson (1954); Cater (1955d); Cater and others (1955); Boardman and others (1956); Garrels and others (1959).
51	Cashin mine (primarily a copper-silver mine).	Wingate / Chinle	Massive fine-grained quartzose sandstone, breccia, and siltstone(?).	Sparse asphaltite(?)	*O-1*	Fischer (1936); Withington (1955); Riley and Owens (1957).
	Morning Glory and other deposits.	Morrison [9]	Conglomerate(?)			
	Rainbow	do.[1]	Sandstone		V-1	Withington (1955).
52	Gramlich group (Morning Star and others), Vanadium Queen mine, Yellow Bird mine, and other mines.	do.[1]	Brown fine- to coarse-grained sandstone and green mudstone.	Some carbonized plant remains and sparse logs.	V-1	Fischer (1944).
	Lucky No. 1, Sumner, Brushy Basin Nos. 1 and 3, and Too High mines.	do.[9]	Conglomerate, mudstone, and fine-grained and medium- to coarse-grained sandstone.	Carbonized plant remains	C-1, *Si-2,* V-1, *V-2.*	Zareski (1954); Carter and Gualtieri (1957).
53	Monogram group, Happy Thought, Wild Steer (Vaden View), and other mines.	do.[1]	Fine- to medium-fine-grained sandstone.	Abundant carbonized plant remains; logs common.	*O-1, Si-1, V-1.*	Moore and Kithil (1913); Coffin (1921); Hess (1924); Cater (1954); Weeks and Thompson (1954).
	Ground Hog mine and Gray and Black Point prospect.	do.[9]	Mostly fine-grained sandstone, locally coarse-grained, and conglomerate.	Abundant carbonized logs and plant trash.	V-1	J. E. Morgan (1953*); Cater (1954).
54	Jo Dandy group, J. J. mine, Thunderbolt mine, Hummer mine, and other mines.	do.[1]	Light-gray and brown fine- to medium-grained sandstone, shaly sandstone, and shale-pebble conglomerate.	Abundant carbonized plant remains, and sparse carbonized logs.	*C-3, O-1, Si-1, V-1, V-2, V-3.*	Curran (1911); Moore and Kithil (1913); Coffin (1921); Hess (1924); Cater (1954; 1955f); Weeks and Thompson (1954); Newman (1957); Elston and Botinelly (1959).
55	Peanut mine, Wedding Bell group, Tea Pot Dome mines, and other Bull Canyon mines.	do.[1]	Gray very fine- to medium-grained sandstone.	Abundant carbonized plant remains.	*O-1, Si-1, V-1, V-2.*	Curran (1911); Moore and Kithil (1913); Cater (1954); Dodd (1956); Roach and Thompson (1959).
56	Gyp group, Raven mine, Terrible mine, and other mines.	do.[1]	Fine- to medium-fine-grained sandstone.	Abundant carbonized plant remains; some logs.	V-1	Coffin (1921); Huleatt and others (1946); Cater (1954; 1955e).
	Joker mine‡§	Entrada	Sandstone	None	V-1	Isachsen and others (1955).
	Franklin group†	Morrison [1] / Summerville / Entrada	Brown fine- to medium-grained sandstone, and carbonaceous shale.	Disseminated in shale	V-1	
57	Name unknown	Morrison [1]	Sandstone			Fischer (1944).
			San Miguel County			
58	Lost, Pay Day, Faultless No. 1, and other mines.	Morrison [1]	Red-brown fine-grained sandstone, shaly sandstone, and carbonaceous shale.	Some carbonized plant remains.	V-1	Huleatt and others (1946); Cater (1955e; 1955g; 1955h).
59	Lookout mine and other mines	do.[1]	Light-gray fine- to medium-grained sandstone.	Sparse to abundant carbonized logs and other plant remains.	V-1	Cater (1955h).
	Mexico group	do.[1]	do		V-1	Do.
		do.[9]	Conglomeratic sandstone		V-1	Do.
	Spaniard No. 1†	Wingate	Gray and brown very fine grained sandstone.	None	V-1	Do.
60	Long Ridge group, Cliff Dwellers mine, and other mines.	Morrison [1]	Fine- to medium-grained sandstone.		V-1	Cater (1955i).
61	Pitchfork No. 1 and other mines.	do.[1]	Light-brown and gray sandstone.		V-1	Huleatt and others (1946); Cater (1955i).
62	Empire group, Pinto mine, and other mines.	do.[1]	Sandstone		V-1	
63	Charles T group, Golden Rod group, Lower group, Cougar mine, Middle group, and other mines.	do.[1]	Gray and brown shaly sandstone and fine- to medium-grained sandstone.	Abundant carbonized logs and other plant remains.	*V-1, V-2*	Fleck and Haldane (1907); Huleatt and others (1946); Gruner, Gardiner, and Smith (1954); Weeks and Thompson (1954); Cater (1955g; 1955j); Archbold (1959); Shawe and others (1959).
64	Upper group, Moon group, Spud Patch group, and other mines.	do.[1]	Buff and gray medium-grained sandstone, shaly sandstone, grit, and conglomerate.	Abundant carbonized plant remains and sparse logs.	V-1	Fleck and Haldane (1907); Cater (1955g; 1955h; 1955j); Rogers and Shawe (1962).
65	Horseshoe group and other mines.	do.[1]	Sandstone and mudstone	do	V-1	Huleatt and others (1946); Cater (1955k).
	Shinarump Rim group and other prospects.	Chinle	Light-green conglomerate	Some coaly and sooty seams, and silicified plant remains.	V	Cater (1955k).
66	Legin group, Mercantile group, Ownbey group, Frenchy incline deposit, and other mines.	Morrison [1]	Light-brown fine- to medium-grained sandstone, and gray and green mudstone.	Abundant carbonized plant remains and sparse logs.	O-1, *V-1, V-2.*	Huleatt and others (1946); Cater (1955j); Bush and Stager (1956); Miesch (1963).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			COLORADO—Continued			
			San Miguel County—Continued			
67	Leopard No. 3#, Omega, and other mines.	Entrada	Light-gray to buff fine-grained sandstone.	None		Fischer and others (1947).
	Black King No. 5 (Weatherly)†.	Dolores; Cutler	Fault breccia and gouge in quartz conglomerate and sandy shale.	Abundant hard "hydrocarbon" and sparse viscous asphalt.	*O-1, P-1, P-2, Si-1, Si-2.*	Hess (1913); Wilmarth and Vickers (1953); Rosenzweig and others (1954); Bush and others (1959).
	White Spar (Robinson)†	Cutler	Fault gouge in conglomerate	Abundant hard "hydrocarbon".	*O-1, Si-1*	Moorehouse (1951); Frondel (1958, p. 28); Bush and others (1959).
68	Bear Creek group, Fall Creek group, Donegan group (Joe Dandy), and other mines.	Entrada	White to buff fine-grained sandstone.	None		Fischer and others (1947); Bush and others (1959, 1960).
			Saguache County			
69	Elisha (La Rue) group	Dakota	Silicified fine-grained sandstone boulders.	Sparse asphaltite	*P-1, P-2, Si-2.*	Malan and Ranspot (1959).
70	Los Ochos (Thornburg) mine	Morrison	Silicified white fine-grained sandstone and silicified mudstone.	None(?)	*O-1, P-1, P-2, Si-2, Su-1, Su-2, Su-3.*	Derzay (1956); Malan and Ranspot (1959).
			Gray Precambrian granite and schist.			
	East mine (Kathy Jo claims)	Morrison	Silicified and brecciated sandstone and mudstone.		*O-1, P-1, Si-2.*	Malan and Ranspot (1959).
71	Little Indian No. 36§	Harding	Carbonaceous fossiliferous silty sandstone.	Abundant asphalt pellets	*P-1*	W. N. Sharp and E. W. Buel (1956*); Gruner and Knox (1957).
	Big Indian group§	do	Porous fossiliferous fine- to medium-grained sandstone.	do	*O-1, O-3, Su-3.*	Gruner and Knox (1957).
	Various deposits‡†	do	do	do		
			Fremont County			
72	Perry DeLellis claim		Gray to brown arkosic sandstone. (Permian.)	Carbonized plant remains	V-1	
	Armstrong	Maroon(?)	Sandstone	do	V-1	
73	Unnamed prospect‡	(?)	Conglomerate and sandstone			
74	Dickson-Snooper mine§#		Tuffaceous sandstone (?). (Tertiary.)		*O-1*	Gruner and Knox (1957).
	Mary L‡†		Arkosic conglomeratic sandstone. (Tertiary.)	Abundant carbonized plant remains.	O-1, P-1, P-2.	Simon (1956).
	Sunshine mine§		Volcanic and Precambrian boulders cemented by tuff. (Tertiary.)	Some carbonized plant remains.	P-1	Do.
75	Jesus lode‡	Dakota	Sandstone		P-2	Wyant and others (1952).
76	Colexco	do	Iron and manganese concretions in black shale.		Si-2, V-1	R. U. King and R. L. Palmer (1955*); King and Theobald (1955).
77	Brandt claims‡†	Dakota	Poorly consolidated sandstone.		V-1	
	Beaver Creek‡§	do	Sandstone(?)		V-1	
			El Paso County			
78	Burgess prospect	Dawson	Arkose		U	
79	Mike Doyle prospect†	Morrison	White quartzitic sandstone	Abundant carbonized plant remains.	Si-2, V-1	Beroni and King (1952).
	Various prospects§		White fine- to medium-grained sandstone. (Cretaceous and Jurassic.)		V-1	
			Pueblo County			
80	Avery ranch	Dakota	Well-indurated sandstone		V-1	Nash and Brown (1954).
			Bent County			
81	Name unknown‡	Morrison(?)	Sandstone(?)			
82	Name unknown‡	do	do			

See footnotes at end of table.

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TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			COLORADO—Continued			
			Las Animas County			
83	Booster No. 1	Dakota, Morrison	Sandstone and shale		N	Simon (1956).
84	Fan Dyke No. 1		Sandy shale. (Permian.)	Abundant carbonized logs and plant trash.	V-1	Do.
			Huerfano County			
85	Spanish Peaks		Conglomerate. (Permian.)	Sparse carbonized plant trash and logs.	V-1?	
86	City Slicker claim and other prospects.		Buff shaly arkosic sandstone. (Permian.)	Carbonized logs and plant trash; thin coal seams.	P-1, V-1	Brown and Malan (1954).
	McGuire lode		Buff arkosic sandstone. (Permian and Pennsylvanian.)		Us	Do.
87	Stumbling Stud†	Dakota	Purplish fine- to medium-grained fluorite-cemented quartzose sandstone.		P-1, V-1	Boyer (1961).
	Various prospects§	(?)	Fine-grained sandstone	Some carbonized plant remains.		Do.
88	Security Exploration Co. property, Buckhorn and Mitzy claims, and other prospects.	Farisita	Gray sandy shale and medium- to coarse-grained arkosic sandstone.	Abundant carbonized plant remains.	O-1, P-1	
89	McIntire and Santa Rosa claims.		Brownish-red micaceous medium- to coarse-grained sandstone, and mudstone. (Permian?)	do	P-1, V-1	Wyant and others (1952).
			Costilla County			
90	Parks lode claim § and Loco Alice (Blanca Trinchera ranch)†		Medium- to coarse-grained arkosic sandstone. (Permian.)		V-1, V-2?	
			Custer County			
91	King Midas No. 8		Fine-grained sandstone. (Permian.)	Organic odor when struck	Us	
92	Horn Peak (Little Horn Peak) and other prospects.		Very hard fine- to medium-grained quartzose sandstone. (Permian and Pennsylvanian.)	None(?)	Us, Up	
			San Juan County			
93	Graysill group	Entrada	Sandstone	None visible; specimen contained 1.25 percent carbon.	V-1	Bain (1952b); Gruner, Rosenzweig, and Smith (1954).
			Dolores County			
94	Barlow group	Entrada	Sandstone			
			La Plata County			
95	Good Hope and Nevada groups.	Entrada	Sandstone			
			Montezuma County			
96	Pay Day No. 3	Morrison	Sandstone and conglomerate	Some silicified logs	V-1	
97	Karla Kay	do.[9]	Brown medium-grained sandstone.	Some carbonized plant trash		
			CONNECTICUT			
			Hartford County			
1	English property	([10])	Light-brown to gray sandstone.	None	N	

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			IDAHO			
			Lemhi County			
1	Blackbird and Musgrove Creeks area.	Challis [11]	Sedimentary tuff	Carbonized plant remains	Si-2	Cook (1957).
2	White Horse and other prospects, Pahsimeroi Valley.	do.[11]	Tuffaceous siltstone and fanglomerate, and carbonaceous sandstone.	Present	*C-1*, P-1, Si-2, V-1.	Weis and others (1958).
			Bonneville County			
3	Unnamed prospect, Fall Creek area.	Wayan	Limestone-pebble conglomerate.	Some fossil bones		Vine (1959, p. 266).
			Custer County			
4	Coal Creek, East Basin, and other claims, Stanley area.	Challis [11]?	Soft dark-gray and white noncalcareous arkosic conglomerate and tuffaceous sandstone.	Carbonized plant remains	*O-1, P-1*	Kern (1959).
			MONTANA			
			Broadwater County			
1	Cobban claim (locality A)#, Sampson claims (locality F?), and unnamed localities.		Tuffaceous sandstone, gray fine-grained bentonitic tuff, and carbonaceous shale. (Oligocene.)	Sparse to abundant carbonized plant remains.	*P-2*, V-1	Jarrard (1957); Becraft (1958).
			Beaverhead County			
2	Moida claims		Gray tuffaceous sandstone. (Tertiary.)	Abundant carbonized plant remains.	P-1	
3	Trapper No. 4		Fine-grained impure silicified sandstone. (Paleozoic.)			Vhay (1951).
			Carbon County			
4	Weaver property	Flathead	Sandstone		P-1	Stow (1953).
5	Green Streak claim	Fort Union(?)	Sandstone and shale		P-1	
6	Royse claim	Flathead	Sandstone, quartzite, and dark shale.		Us	Stow (1953); Armstrong (1957); Weis and others (1958).
7	Windmill No. 3	Tensleep	Sandstone		V-2	
			Big Horn County			
8	Unnamed prospect	Morrison	Shale			Jones (1952).
			Carter County			
9	A. Richardson ranch	Hell Creek(?)	Tan to gray and greenish fine-grained sandstone.	Some carbonized plant remains(?).	N	
10	Lewis Nos. 1–5	Hell Creek	Brown carbonaceous mudstone.	Abundant carbonized plant remains.	O-1, O-4	Gruner and others (1956).
11	Vada Dee No. 2 and Rock No. 1	do	Light-brown medium-grained sandstone.	Some seams and fragments	Us	Gill (1954).
12	School section	Fort Union	Gray very hard (silicified?) arkosic sandstone.	Locally abundant carbonized plant remains.	N	
			Fallon County			
13	Cox Fee land, Waldron Fee land and other deposits#.	Fort Union	White to buff medium-grained sandstone, partly micaceous.	Some carbonized plant remains.	*P-1, V-2*	Gruner and others (1956); Towse (1957).
			NEBRASKA			
			Dawes County			
1	Chadron occurrence	Brule	Gypsiferous clay	Abundant carbonized plant remains.	*P-1, P-6, V-1.*	Dunham (1955).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
	NEVADA					
	Humbolt County					
1	Virgin Valley opal district (Crane claims).		Greenish-gray vitric tuff, chalk-white fine-grained ash, and gray, brown, and other colors of opal. (Tertiary.)		C-1, *Si-3*, *V-1*.	Staatz and Bauer (1951); Lovering (1954); Davis (1954).
	Lander County					
2	Boon Uranium		Chert layers in sedimentary tuff. (Tertiary?)		P-1	
3	Pinto and Hart groups‡		Sedimentary tuff. (Tertiary?)		Us	
	Washoe County					
4	Hopeless		Tuff. (Tertiary?)		Us	
5	Barbara L.‡ and Yellow Jacket group‡.		Poorly sorted arkosic sandstone, clay (tuff) and conglomerate. (Tertiary?)	Some carbon	P-1, P-2	
6	Good Luck group		Brecciated rhyolitic(?) tuff. (Tertiary?)	Plant remains(?)	Us	
	Lyon County					
7	Little Red Head group		Silicified rhyolite and tuff. (Tertiary.)		Us	
8	White Rose No. 1 and White Rose.		Diatomaceous earth. (Pliocene or Miocene.)		V-1	
	Mineral County					
9	Robinson claims		Opalized beds. (Tertiary.)	Opalized plant remains	V-1	Davis (1954).
	Bubbles claims		Altered sedimentary rhyolitic tuff. (Tertiary?)	Very abundant opalized plant remains.	V-1	
10	Broken Bow		Well-indurated sandstone. (Tertiary?)		A-4, P-2, P-8.	
11	Carol R. (Hawthorne, Wespac)	Esmeralda	Fine- to medium-grained tuffaceous sandstone, and conglomerate.		V-1	Davis and Hetland (1956).
	Esmeralda County					
12	Gap Strike, Sammy, and Wolf groups.‡		Tuff and unconsolidated ferruginous sandstone. (Tertiary?)		P-1, V-1	
13	Esmeralda Uranium Co		Buff tuff and medium-grained sandstone. (Tertiary?)		P-1, Us	
14	Silver Queen group (Silver Queen Nos. 2 and 3, Bonanza No. 2, and United Tonapah No. 1).	Esmeralda	White and brown sandy clay	None	*P-3*	Davis and Hetland (1956); Finch (1956).
	Nye County					
15	Jeep No. 2, Bobby Jack claims, and other claims.	Esmeralda	Light-gray claystone, tuff, and arkosic sandstone.	None	Us	
	Lincoln County					
16	White Cloud, Dorothy claim, and Pay zone.	Panaca	Light-colored sedimentary tuff (lutite or pyrolutite) and green opalized tuff.	Some carbonized plant remains.	*V-1*	Myerson (1956); Davis and Hetland (1956).
	Clark County					
17	Carnotite No. 1 (Overton property, Perkin Brothers claim, Golden Glow).	Willow Tank	Sandstone and clay, and carbonate veins.	Abundant carbonized plant remains.	V-1	Longwell (1928, p. 65); Barrett and Mallory (1955).
18	First Chance group ‡	(?)	Gray clayey sandstone		Si-2 or V-1	
19	Little Snake, Purple, Valentine, and other claims.†	{Kaibab / Supai(?)}	Sandstone		*V-1*	
	Unnamed locality (No. 3)§		Gravel. (Quaternary.)		V-1	Barton and Behre (1954); Lovering (1954, p. 80).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
			NEVADA—Continued			
			Clark County—Continued			
20	Goodsprings occurrence (locality 27).	Toroweap	Pale-yellow sandstone and dark-reddish-brown shaly sandstone.		*V-1*	Hewett (1923); Barton and Behre (1954).
21	Unnamed localities, Erie to Sloan (Nos. 4, 5, 11, and 14).		Gravel and well-sorted medium-grained sand. (Quaternary.)		*V-1*	Barton and Behre (1954); Lovering (1954, p. 80).
22	Lakeview, Lakeview No. 1, Humdinger, and Willabelle prospects.	Toroweap	Buff and red fine-grained sandstone.	None	V-1	Hewett (1923); Barton and Behre (1954).
	Nunn, Sieber, and other prospects.	Supai	Red sandy shale and buff argillaceous and calcareous sandstone.		V-1	Do.
	Unnamed prospects (localities 15 and 16).		Gravel. (Quaternary.)		V-1	Barton and Behre (1954).
			NEW JERSEY			
			Hunterdon County			
1	Stockton deposit‡, Rock Haven quarry, and Reading School occurrence. (See also No. 19, Bucks County, Pa.)	([10])	White and brown fine-grained arkosic sandstone and red-brown mudstone.	None	*P-2*, Si-2	F. A. McKeown, P. W. Choquette, and R. C. Baker (1954*); Widmer and Markewicz (1957); Stieff (1958).
			NEW MEXICO			
			Colfax County			
1	Blasted Pine claim	Dakota	Sandstone			
			Rio Arriba County			
2	Name unknown	Dakota or ([12])	Limonitic fine-grained sandstone.		N	Collins and Freeland (1956).
3	Vargas-Jaramillo	([12])	Gray tuffaceous sandstone		C-1	
4	Lucky Dog group‡	Morrison	White friable fine-grained sandstone.	None	Us	
5	Trejo and Sanches No. 1	Chinle or Abo	Light-gray fine-grained calcareous sandstone.	Abundant carbonaceous seams	N	
6	Corral No. 1 and E and B Nos. 1 and 3.	Abo	Light-gray fine- to coarse-grained calcareous arkose.	Absent to abundant carbonized plant remains.	Us	H. G. Brown, 3d (1955*).
	State lease sec. 16, T. 23 N., R. 1 W.	Wasatch	Gray-green mudstone		P-1	Do.
7	Hillfoot No. 1, Red Bird, and Red Head No. 2 mines.		Sandstone. (Permian.)		U	Soulé (1956, p. 55); L. S. Hilpert (1959*).
8	R. A. Nos. 1 and 2	Chinle	Sandstone		U	Hilpert and Corey (1955).
			San Juan County			
9	Kimbeto T. P. prospect	Ojo Alamo	Gray very fine grained sandstone and siltstone.	Abundant carbonaceous plant remains.	N	
10	Chitton and Son	San Jose(?)	Yellowish-brown very fine to fine grained sandstone.	Abundant carbonaceous seams.	N	
11	Boyd deposit	Fruitland	Pinkish tuffaceous sandstone	None in ore; abundant plant remains beneath.	N	Clinton and Carithers (1956).
12	B. B., Beclabito lease, Rocky, and other mines.	Morrison [1]	Sandstone and mudstone	Abundant carbonized plant remains.	V-1	Stokes (1951); Hilpert and Corey (1955).
13	Canyon group and Cottonwood Butte.	do.[1]	Light-gray fine-grained sandstone and blue-green clay.	Some carbonized plant remains.	V-1	Stokes (1951); Lovering (1956).
14	Begay No. 1, Eastside mines, King Tutt group, and Shadyside mine.	do.[1]	Sandstone and mudstone	Abundant carbonized plant remains.	O-1, V-1, *V-2*	J. W. King (1951); Stokes (1951); Gruner, Gardiner, and Smith (1954); Hilpert and Corey (1955).
	Eastside diatreme prospect†	 Navajo	Minette tuff (Pliocene?) Sandstone and mudstone(?)		V	Shoemaker (1956b).
15	Enos Johnson Nos. 1, 2, and 3, and other mines.	Morrison [13]	do	Carbonized plant remains absent to very sparse in ore, sparse above ore.	*Si-2*, V-1	Droullard and Jones (1951); Hilpert and Corey (1955); Isachsen and others (1955); Gruner and Smith (1955a).
	Joe Ben Nos. 1 and 3, and other mines.	do.[1]	do		V-1	Hilpert and Corey (1955).
16	Adee B. Dodge and other claims, Toadlena area.	Dakota	Sandstone		U	L. S. Hilpert (1959*).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			NEW MEXICO—Continued			
			McKinley County			
17	Hogback No. 4	Dakota	Mainly black fissile carbonaceous shale; also sandstone.	Abundant carbonized plant remains.	N in shale; Us in sandstone.	Mirsky (1953); Gabelman (1956a).
18	Becenti and Diamond No. 2 (Largo No. 2) mines.	do	Brown and gray fine- to medium-grained quartzose sandstone.	do	*P-1*, Si-2, *V-2*.	Mirsky (1953); Gruner, Gardiner, and Smith (1954); Gruner and Smith (1955a); Gabelman (1956a).
19	Church Rock mine	Morrison [9?]	Sandstone			L. S. Hilpert (1959*).
	Various prospects	{Dakota Morrison [14]	} do			Do.
20	Christian 16 (U) mine and Delter prospect.	Dakota	Light-gray fine-grained sandstone.	Abundant carbonized plant remains.	V-1	Gabelman (1956a); Konigsmark (1958).
	Foutz No. 3 (Yellow Jacket) and other mines.	Morrison [14]	Gray fine-grained sandstone	Abundant coaly seams and carbonized plant remains.	V-1	Hilpert and Corey (1955); Sharp (1955); Konigsmark (1958).
21	Last Chance No. 2 and Tietjen-Lewis No. 2.	do.[13]	Medium-grained sandstone, and green mudstone and siltstone.	Abundant carbonized plant remains.	C-1, V-1	
22	Silver Bit group	do.[9?,14]	Sandstone			L. S. Hilpert (1959*).
23	Alta, Evelyn, and Francis mines.	do.[14]	White and yellow coarse-grained sandstone.		*0-1*, *0-3*, *Si-1*, *V-1*.	Hilpert and Corey (1955); Konigsmark (1958).
24	Silver Spur No. 5 and other mines.	Dakota	Coarse-grained sandstone	Abundant carbonized plant remains.	*V-2*	Mirsky (1953); Gruner, Gardiner, and Smith (1954); Hilpert and Corey (1955); Gabelman (1956a); Konigsmark (1958).
	Pat mine	Morrison [14]	Sandstone			
25	Poison Canyon, Mesa Top No. 18, and other mines.	do.[14]	Medium- to coarse-grained arkosic sandstone.	Some "asphaltic" material and carbonized plant remains.	*P-1*, *Si-1*, *V-1*, *V-2*.	Gruner, Gardiner, and Smith (1954); Gruner and Smith (1955a); Dodd (1956); Gruner (1956a); Zitting and others (1957); Hilpert and Moench (1960).
26	Dysart No. 1 mine and other mines.	do.[14]	Medium- to coarse-grained sandstone.	Abundant "asphaltic" material.	*Si-1*	Gabelman and others (1956); Birdseye (1957); Hilpert and Moench (1958); Huttl (1958).
27	Green Pick 20 or 21	([15])	Fine-grained sandstone		C-1	
28	Section 32, T. 14 N., R. 9 W., and other mines.	Morrison [14]	Sandstone	Abundant "asphaltic" material.		Zitting and others (1957); Huttl (1958); L. S. Hilpert (1959*).
29	Cliffside and other deposits	do.[14]	do	do		Huttl (1958); L. S. Hilpert (1959*).
30	Marquez mine and various deposits.	do.[14]	do	do		Do.
			Sandoval County			
31	Dory	Morrison	White medium-grained feldspathic sandstone.	Abundant asphalt	N	
32	Geymar lease (Collins?) #	do	Sandstone	Carbonized logs	Us	
33	Collins	do.[9]	Mudstone(?)			
34	Name unknown (A.E.C. anomaly No. 5?).	do.[13?]	Gray fine- to medium-grained sandstone.	Abundant carbonized plant remains.	N	
35	Maldin group	Dakota	Sandstone	Abundant coaly(?) seams		
36	Spanish Queen mines	Abo	Yellowish-colored medium-grained arkosic sandstone.	Sparse carbonized plant remains.		Gott and Erickson (1952); Lovering (1956); Soulé (1956).
37	Don Dial Exploration Co	([8?])	Sandstone and shale		Us, C-1	
			Santa Fe County			
38	Rogers and J. C. Roybal claims.	([12])	Claystone and clay-gall sandstone.	Abundant carbonized and opalized plant remains.	V-1	Collins and Freeland (1956).
39	Gilliland claims	([12])	Coarse-grained conglomeratic arkosic sandstone.		Si-3	Do.
40	Name unknown (secs. 32 and 33, T. 20 N., R. 9 E.).	([12])	Gray limonitic sandstone	Abundant carbonized plant remains.	N	Do.
41	Cuyamungue area	([12])	Clay and sand	do	C-1, P-1, V-1	
42	Name unknown (sec. 36, T. 19 N., R. 9 E.).	([12])	Coarse-grained conglomeratic arkosic sandstone.		Si-3	Collins and Freeland (1956).
43	Name unknown	Chinle	Bluish-gray conglomerate		V-1	
			Mora County			
44	Arturo Le Deux, Blas Medina, and other properties, Coyote district.	Sangre de Cristo.	Pink medium-grained limy micaceous arkosic sandstone, siltstone, and shale.	Some carbonized plant remains.	V-2	Tschanz and others (1958).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
	NEW MEXICO—Continued					
	San Miguel County					
45	Windy No. 9 (San Carlos Uranium Co.) and Hammontree-Burns.	Chinle	Gray shale and shaly sandstone.	Abundant carbonized plant remains.	V-1, V-2	
46	Hunt Oil Co. lease and F. Lujan Cattle Co.	do	Green siltstone and gray fine-grained sandstone.	Abundant carbonized logs and other plant remains.	V-1	Baltz (1955).
47	C. Lujan ranch	do	Gray micaceous sandstone and conglomerate.	Some carbonized plant remains.	P-2?, V-1	
48	Neafus (Santa Rosa Uranium Co.).	do	Sandstone	Abundant carbonized plant remains.	V-1	
	Quay County					
49	Bel-Aro (Bell)	Morrison	Light-brown medium-grained sandstone.	Abundant silicified logs; some bones.	V-1	Griggs (1955).
50	Bill Breen claim	Dakota(?)	Sandstone	Silicified and carbonized plant remains.	V-1	
51	G. Troutman ranch	Chinle	Gray fine-grained sandstone	Some carbonized logs	Us	Anderson (1955).
52	Little Rattlesnake Mining Co	do	Brown fine-grained sandstone.	Abundant carbonized and silicified plant remains.	Us	
53	Gilstrep-Truesdall ranch, and A.E.C. anomaly No. 5.	Chinle	Light-brown fine-grained sandstone, and conglomerate.		N	
54	Bill Wallace ranch	do	Chert nodules in claystone	Abundant carbonized plant remains.	P-2?, V-1	Anderson (1955); Soulé (1956, p. 24).
55	Lucky group	([15])	Gray conglomeratic sandstone.	do	Us	Griggs (1955).
	Torrance County					
56	Uranium prospect, Scholle district‡	Abo	Sandstone and black shale	Some carbonized plant remains.	N	Russell Gibson (1952*); Lovering (1956); Soulé (1956).
57	Abo Mining Co. and Pioneer claim.	do	Siliceous conglomerate, abundant chert and limestone pebbles, and conglomeratic sandstone.	do	P-1, P-2, Si-2, V-1.	
58	Copper Girl	Abo(?)	Coarse-grained calcareous arkose.		Up	
	Bernalillo County					
59	Name unknown	Abo	Silty clay and very fine to medium grained sandstone.	Silicified logs	N	
	Valencia County					
60	Chavez (Canoncito)	Morrison [9]	Sandstone		Si-1?	Moench and Schlee (1957a).
61	Jackpile and other mines	do. [16]	Gray medium-grained quartzose sandstone. Altered diabase minor.	Abundant carbonized plant remains and black brittle disseminated organic substance.	*O-2*, O-3, O-4, *P-1*, *Si-1*, *Si-2*, *Si-6*, *Si-9*, *V-1*, *V-2*.	Gruner and Smith (1955a); Fitch and Herndon (1957); Hilpert and Moench (1958; 1960).
	Woodrow mine†	do. [9] [14]	Heterogeneous mixture of sandstone and mudstone.	Abundant disseminated organic substance.	*A-4*, *P-1*, *P-2*, *Si-1*, Su-3.	Argall (1954); Gruner, Gardiner, and Smith (1954); Stern and Annell (1954); Hilpert and Moench (1958; 1960).
62	Sandy mine	Entrada	Light-colored fine-grained calcareous quartzose sandstone.	Sparse organic substance	*O-1*	Moench and Schlee (1957a); Hilpert and Moench (1958; 1960); Moench (1962).
63	Paraje	Morrison [9]	Sandstone(?)			Hilpert and Corey (1955).
64	Ingerson Copper	Abo	do			Do.
	Catron County					
65	Hogback No. 4	([8])	Gray sandy shale	Abundant carbonized plant remains.		G. O. Bachman, E. H. Baltz, and R. L. Griggs (1958*).
66	Midnight No. 2 (McPhaul ranch) and name unknown (sec. 11, T. 2 N., R. 11 W.).	Point Lookout(?).	Ferruginous sandstone and sandy shale.	Abundant carbonaceous shale and carbonized logs and other plant remains.	Us	Griggs (1954); Griggs and Baltz (1955); New Mexico Geol. Soc. (1959).
	Red Basin No. 1 (Tietzen)	Baca	Light-gray fine- to medium-grained quartzose sandstone.	Abundant carbonized plant remains.	Us	G. O. Bachman, E. H. Baltz, and R. L. Griggs (1958*); New Mexico Geol. Soc. (1959).
67	Name unknown (sec. 31, T. 2 N., R. 9 W.).	do	Gray sandstone			Do.
	Name unknown (sec. 27, T. 2 N., R. 10 W.).	Point Lookout(?).	Sandstone			Do.

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			NEW MEXICO—Continued			
			Socorro County			
68	Hook ranch	Baca	Medium- to coarse-grained arkosic sandstone.	Abundant asphaltic material and carbonized plant trash.	P-1?, V-1	Griggs and Baltz (1955).
	Rusty Atom	Baca(?)	Sandstone			Hilpert and Corey (1955).
69	Luciel Nos. 1 through 8, Riley area, and King.	Baca	Buff sandstone	Abundant carbonized plant remains.	Us	Hilpert and Corey (1955); Collins and Smith (1956).
70	Charlie (Jeeter) No. 2	Popotosa	Light-gray bentonite, dark-gray shale, and Precambrian granite.	None	*O-4, P-1, P-2, Si-2, V-1?.*	Hilpert and Corey (1955).
71	Four Jokes, Polvadera Mountain area.	do	Cherty layer in gray sandstone and siltstone.	do	Us	Collins and Smith (1956).
72	Contreras Mining Co.	Abo	Light-gray gypsiferous shale	Abundant fine-grained carbon.		Russell Gibson (1952*).
73	Marie† and Aqua Torres‡§	do	Sandstone		*A-4*	L. S. Hilpert (1959*).
			Lincoln County			
74	Name unknown	Dakota	Limonitic sandstone		N	
			Lea County			
75	Moreland and Hooper	Ogallala	Clay		V-1	Waltman (1954).
			Dona Ana County			
76	Jordan‡	(?)	Red and green mudstone and associated travertine.	Abundant carbonaceous zones.		
			Sierra County			
77	Red Tiger	Abo	Bleached siltstone		Us	
78	Mitchell-Price No. 1#, Good Luck No. 1, and Sherry No. 3 claims.	do	Gray carbonaceous shale	Abundant carbonized plant remains.	N	
79	Empire group#	do	Siltstone		P-1, P-2	Boyd (1955).
			Grant County			
80	Oil Center Tool Co. claims #	Beartooth	Quartzite	None	Si 2?	
81	Hines No. 1 prospect	Bliss(?)	Brecciated quartzite	do	P-1?, Si-1	Lovering (1956, p. 352).
			NORTH DAKOTA			
			Stark County			
1	Unnamed prospect, Little Badlands area.	Chadron	Opal and clay		*Si-3, V-1*	Gill and Denson (1956); Bergstrom (1956).
			Adams County			
2	Whetstone Buttes	Fort Union [17]	Sandstone	Abundant carbonized plant remains.		Gill (1955); Bergstrom (1956).
			OKLAHOMA			
			Pawnee County			
1	Lee Uto prospect	Wichita	Sandstone	Lignitic lenses	Us	Hill (1953); Curtis (1956).
			Roger Mills County			
2	Western Oklahoma Uranium partnership.	Quartermaster.	Buff limy sandstone		N	Beroni (1956).
			Custer County			
3	Red Rock Co. property	Quartermaster.	Fine-grained calcareous sandstone			Beroni (1956); Curtis (1956).
	Dipple and Roser farm	do	do		Us	Do.

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
			OKLAHOMA—Continued			
			Washita County			
4	Unnamed prospect, Western Oklahoma Uranium partnership.	Quartermaster.	Light-yellowish-gray siltstone.		V-2	Beroni (1956); Curtis (1956).
			Beckham County			
5	Miller-Curtis property	Quartermaster.	Grayish-green fine-grained sandstone, and clay seams and galls.	Sparse carbonized plant remains.	V-1 or V-2	
			Caddo County			
6	Cement deposit †§	Rush Springs	Yellow to brown fine- to medium-grained calcareous feldspathic sandstone.		*V-2*	Reeves (1922); McKay and Hyden (1956); Russell (1958).
			Johnston County			
7	Angel prospect	Paluxy	Fine- to medium-grained sandstone and siltstone.	Abundant carbonized plant remains.	N	Curtis (1956).
			Jefferson County			
8	Unnamed prospect	Wichita	Arkosic conglomerate			Eargle and McKay (1956).
9	Eisele prospect	do	Ferruginous sandstone			
10	Miller ranch	do	Brownish-red to grayish-brown sandstone.	Overlain by bituminous sandstone.	U	Branson and others (1955).
			Cotton County			
11	Randlett property (Byars farm)	Wichita	Medium-grained sandstone and claystone.	Abundant carbonized plant remains.	C-3?, *O-1*, *P-1*, *P-2*, *Si-2*, *V-1*.	Chase (1954); Beroni (1954b); Branson and others (1955); Beroni (1956); Curtis (1956); E. J. McKay (1958*).
			Tillman County			
12	Mathias and Oberlander property.	Wichita	Arkosic conglomerate and sandstone.	Some asphalt	V-1	Beroni (1954b); E. J. McKay (1958*).
			OREGON			
			Clackamus County			
1	Johnson and Laird		Friable tuffaceous sandstone. (Tertiary.)		V-1	
			Marion County			
2	Speerstra farm	Illahe	Tuffaceous sandstone		P-1, Su-3, V-2.	Schafer (1956).
			Crook County			
3	Bear Creek area (Sage Hollow Mining Co.)	Clarno	Clay and porous silicified tuff.		A-2, Si-2	Schafer (1956); Matthews (1956).
			Malheur County			
4	Valley View (Rasmussen)	Idaho (?)	Clayey rock		U	Matthews (1955).
			Jackson County			
5	Shaknis farm	Umpqua	Medium-grained to conglomeratic calcareous and arkosic sandstone.		U	H. F. Albee (1957*).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
	PENNSYLVANIA					
	Bedford County					
1	Juniata occurrence	Catskill	Gray sandstone	Carbonized plant remains	Us	Klemic (1962).
	Fulton County					
2	Unnamed occurrence	Catskill	Sandstone and siltstone	Carbonized plant remains	Us	Klemic (1962).
	Huntington County					
3	Maddensville occurrence	Pottsville	Light-yellow-green sandstone.	Some carbonized plant remains.	V-1	McCauley (1957).
4	Unnamed occurrences	{Mauch Chunk / Catskill}	Gray sandstone	do	Us	Klemic (1962).
	Dauphin County					
5	Unnamed occurrence	Catskill	Gray sandstone	Carbonized plant remains	Us	Klemic (1962).
	Northumberland County					
6	Hummel		Sandstone. (Paleozoic.)	Abundant carbonized plant remains.		
	Montour County					
7	Unnamed occurrence (29)	Catskill	Gray sandstone	Carbonized plant remains	Us	Klemic (1962).
	Lycoming County					
8	Shoemaker property		Sandstone. (Paleozoic.)		P-2	
9	Bart property	Catskill	do			
	Sullivan County					
10	Myers property	Catskill	Gray sandstone	Carbonized trash and fish scales(?).	Us	Klemic (1962).
	Bradford County					
11	Pridmore	Catskill	Shale			
	Columbia County					
12	Buttles property and Fritz farm.	Catskill	Gray sandstone and siltstone	Abundant carbonized plant remains.	Us	Klemic (1962).
13	Unnamed occurrence	do	Gray sandstone		Us	Do.
	Carbon County					
14	Fourth Run occurrence	Catskill	Gray sandstone		*O-1*, P-9?	Klemic (1962).
15	Penn Haven Junction prospects	do	Gray to greenish-gray medium grained graywacke.	Some carbonized plant remains.	*O-1*, *Si-2*, *Si-8*.	Dyson (1954); McCauley (1957); Klemic (1962); Klemic and others (1963).
	Butcher Hollow (‡†)	do	Shaly and silty sandstone		Us	Klemic and Baker (1954); McCauley (1957); Klemic (1962); Klemic and others (1963).
16	Mauch Chunk (Jim Thorpe, Mount Pisgah).	Pottsville	Gray coarse-grained sandstone and conglomerate, and greenish-gray siltstone.	Abundant carbonized plant remains; includes logs.	*C-1*, *C-2*, *C-5*, O-1?, Si-1?, *Si-2*, Si-8?, *V-1*, *V-2*.	Wherry (1912; 1915); Dyson (1954); Klemic and Baker (1954); Montgomery (1954); Walthier (1955); McCauley (1957); Stieff (1958); Klemic (1962); Klemic and others (1963).
	Mauch Chunk Ridge occurrences.	Catskill	Greenish-gray sandstone (graywacke) and siltstone.	Unidentified black (carbon?) material.	*P-1*, *P-2*, *P-4*, *Si-2*, *Si-8*.	Klemic and Baker (1954); Dyson (1954); McCauley (1957); Klemic (1962); Klemic and others (1963).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
	PENNSYLVANIA—Continued					
	Schuylkill County					
17	Atlas Powder Co. property	Catskill	Gray sandstone		Us	Klemic (1962).
	Bucks County					
18	Delaware quarry	[10]	Medium- to dark-gray argillite and shaly argillite.		N	F. A. McKeown, P. W. Choquette, and R. C. Baker (1954*); McCauley (1957); Klemic (1962).
19	Kieffer and Lipman quarries (See also No. 1 Hunterdon County, N.J.).	[10]	Yellow-white fine- and medium-grained arkosic sandstone and purple-gray to dark-purple mudstone.		P-2	Do.
	SOUTH DAKOTA					
	Harding County					
1	Lonesome Pete mine	Fort Union[18]	Gray to brownish-black phosphatic silty claystone.		P-1, *P-3*	King and Young (1956); Kepferle and Chisholm (1956); Pipiringos and others (1957).
2	Daisy Mae No. 6	do [18]	Mudstone and fine-grained micaceous sandstone.	Mudstone, slightly carbonaceous.	N	U.S. Atomic Energy Comm. (1956).
3	Thybo§ and C. Robbins lease†	do [18]	Light-brown to gray very fine to fine grained quartzose sandstone.		*Si-2*	Gill (1955).
4	Square Top Butte‡	Chadron	Opalized clay		*V-1*	Gill and Moore (1955).
5	Cedar Canyon	do	White fine-grained silicified tuffaceous sandstone.	None	*V-1*	Gill and Moore (1955).
6	Lucky Strike No. 2	{Arikaree / Chadron}	Light-green very fine grained sandstone, and mudstone-gall conglomerate.		Us	U.S. Atomic Energy Comm. (1956).
7	Daisy Mae No. 5	Arikaree	Light-gray very fine grained sandstone.		V-1	Gill (1955).
	Butte County					
8	Bonato mine, Kling No. 2 mine, Apland mine, and various prospects.	Fall River	Light-gray to brown fine-grained sandstone, sandy shale, and shale.	Abundant carbonized plant remains.	*V-1*	Vickers (1957).
	Meade County					
9	U.S. Government land and Lamberton prospect.	Fall River	Medium-grained iron-stained sandstone and phosphatic sandstone.		*P-3*, Us	A. L. Nash (1955*); Vickers (1955).
	Lawrence County					
10	Annie Creek	Whitewood(?)	Phosphatic siltstone		*P-1*	Vickers (1953; 1954).
	Dakota mine and Mill lode (Montesuma claim).	Deadwood	Altered siltstone and very hard quartzite.		P-1?	Vickers (1954).
	Pennington County					
11	Caylor-Preston ranch	Colorado [19]	Fine-grained sandstone	Abundant carbonized plant remains.	Us	
12	Baxter lease (Rube claims) and Hart Table occurrence.	Chadron	Yellowish-gray fine- to medium-grained and coarse-grained sandstone.		*P-4*, V-1, V-2	Moore and Levish (1955).
13	Unnamed occurrence	Brule	Chalcedony veins in siltstone and very fine grained sandstone.		*V-1*	Do.
	Shannon County					
14	Cedar Butte	White River	Light-brown and white chalcedony in siltstone.		*V-1*	

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			SOUTH DAKOTA—Continued			
			Custer County			
15	Lost Canyon Nos. 1-3 and other prospects.	Lakota	White medium-grained sandstone, and siltstone.	Abundant	V-1	Braddock (1963).
16	Freezeout No. 4	Fall River	Fine-grained quartzose sandstone.	Abundant carbonaceous seams.	*O-1*, *Su-2*	Schnabel (1963).
	Lucky Strike No. 2 and various mines.	([20])	Fine-grained sandstone and gray shale.		*V-1*	W. R. Horner (1952*); Schnabel (1963).
			Fall River County			
17	Coal Canyon group, Virginia C, Road Hog Nos. 1A and 3A, and other mines.	Fall River	Light-brown to dark-gray very fine to fine grained sandstone, siltstone, and mudstone.	Abundant carbonized plant remains.	*O-1*, *V-1*, *V-2*, *V-3*.	Weeks and Thompson (1954); Bell and Bales (1955); Braddock (1955); King (1956).
18	Hot Point No. 3, Pictograph, Imogene, Holdup No. 15, Matias Peak Nos. 1 and 2, and other mines.	Lakota	White, gray, and brown fine- to medium-grained sandstone, and mudstone.	do	*V-1*, *V-2*, *V-3*.	Page and Redden (1952); W. P. Horner (1952*); W. P. Horner and J. B. Ridlon (1952*); Bell and Bales (1955); Braddock (1955; 1957).
	Unnamed occurrence	Chadron(?)	Reworked Inyan Kara sandstone fragments.	Carbonized plant remains in sandstone fragments.	Us	Gott and others (1956).
19	Runge mine	{Fall River / Lakota}	Fine-grained calcareous sandstone.	Sparse carbonized plant remains.	*O-1*, *Si-1*, *V-1*, *V-2*.	Gott (1956); Shawe (1957); Wilmarth and Gott (1958); Myers and others (1960).
20	Lion group	Fall River	Calcareous and ferruginous quartzose sandstone.		*O-1*, *V-1*	Gott and others (1953).
	Gould lease, Marty's Timber claim, Pabst No. 3, and other mines.	Lakota	Gray to brown fine- to coarse-grained sandstone, and silt-gall conglomerate.	Absent	*V-1*, *V-2*	W. L. Cummings (1952*); Gott an others (1953; 1956); Braddock (1955); Hall (1955); Bright (1955); King (1956); Cuppels (1962).
21	Accidental Nos. 1 and 10, Gull, Damsite, and other mines.	do	White to brown well-sorted very fine and fine grained sandstone.	Some carbonized plant remains.	V-1	Gott and others (1953); Braddock (1955).
22	Darnell lease (Hot Brook Canyon).	Minnelusa	Shale and limestone	Coaly and petroliferous shale	Us	Bell and Bales (1955).
23	Canyon lode	Fall River	Sandstone		Up	Post (1956).
24	Lake No. 1	do	Medium-grained sandstone and mudstone.		V-1	Do.
			TEXAS			
			Oldham County			
1	Hart-Mansfield ranch prospect	([15])	Sandstone		*A-4*, O-1, *P-1*, *P-4*.	Wood (1956, fig. 177, locality 48).
			Deaf Smith County			
2	Mosure ranch	([15])	Sandstone		U	
			Brisco County			
3	Saul ranch	([15])	Sandstone	Carbonized and silicified plant remains.	V-1 or V-2	
			Wilbarger County			
4	Unnamed prospect	([21])	Sandstone		U	
5	Do	([21])	do		V-1	
			Wichita County			
6	Unnamed prospect	Wichita	Ferruginous sandstone		U	Eargle and McKay (1956).
			Clay County			
7	Unnamed prospect	Wichita	Sandstone		U	Eargle and McKay (1956).
8	Do	do	do		U	

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
			TEXAS—Continued			
			Montague County			
9	Unnamed prospect	Wichita	Sandstone		U	
10	Do	do	do		U	
			Archer County			
11	Unnamed prospect	Wichita	Sandstone	Abundant carbonized plant remains.	U	E. J. McKay (1957*).
12	Do	do	Ferruginous and manganiferous sandstone.		U	Eargle and McKay (1956).
13	Do	do	Sandstone	Carbonized plant remains		E. J. McKay (1957*).
			Kent County			
14	McArthur ranch	(15)	Sandstone		U	
			Garza County			
15	Sanderson ranch	(15)	Sandstone		U	
16	Swensen ranch	(15)	do		U	
17	Eubank ranch	(15)	do			
18	Long ranch	(15)	do			
19	Roddy ranch	(15)	do			
20	Kirkpatrick ranch and Post estate.	(15)	do			
21	Caprock prospect	(15)	do			
			Fisher County			
22	Unnamed prospect	(15)	Micaceous siltstone	Abundant carbonaceous flakes.	N	Beroni (1954a).
			Brewster County			
23	Big Bend Exploration Co.‡	Pruett	Highly altered limonitic sandstone; also tuff, limestone, and conglomerate.	Some carbonized plant remains.	C-1, Si-2, V-1, V-2.	R. U. King and C. C. Knox (1956*).
			Fayette County			
24	Robinson lease	(22)	Siltstone		N	
			Gonzales County			
25	Jacobs ranch	Catahoula	Coarse-grained quartzose sandstone.	Abundant silicified wood	P-1, V-1	Steinhauser and Beroni (1955); Steinhauser (1956).
			Karnes County			
26	Harper (Harmony) property	(22)	Bentonitic shale		O-4, *P-1*	Steinhauser and Beroni (1955); Steinhauser (1956).
27	Brysch and Jaskinia prospects	Whitsett [23]	Very fine to medium tuffaceous sand.	Some carbonized plant remains.	Us	Steinhauser and Beroni (1955); Steinhauser (1956); Eargle and Snider (1957).
28	Sczepanik prospect	(22)	Sandstone			Do.
29	Bargmann prospect	Whitsett [24]	Medium clayey sand		P	Do.
	Hackney (Bozo), Korzekwa, and Lyssy deposits.	do.[23]	Light-gray very fine grained sandstone, laminated clay, and clayey and silty sand.	Sparse to abundant carbonized plant remains.	*M*, P-1, *V-1*, *V-2*.	Steinhauser and Beroni (1955); Steinhauser (1956); Eargle and Snider (1957); de Vergie (1958); MacKallor and others (1962).
	Sickenius prospect	do.[25]	Brown friable lignitic clay, and opalized sandstone.	Abundant carbonized plant remains.	V-1	Steinhauser and Beroni (1955); Steinhauser (1956); Eargle and Snider (1957).
30	Hoffman prospect	Oakville	Coarse-grained sandstone and bentonitic clay.	None	V-2	Do.

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			TEXAS—Continued			
			Atascosa County			
31	Thane prospect	Whitsett [23]	Friable sand		*V-1*	Steinhauser and Beroni (1955); Steinhauser (1956); Eargle and Snider (1957).
	Shaefer prospect	{do [25] / do [23]}	Light-gray clayey silt, lignitic tuff, and gray sand.	Carbonized plant remains	Us	Do.
			Live Oak County			
32	New ranch	Whitsett [26]	Friable fine to medium sand	Some organic matter	N	Eargle and Snider (1957).
33	McLean prospect	Oakville	Sand		N	
			Duval County			
34	Pursch ranch	Catahoula	Medium-grained sandstone and tuff.		*V-2*	
35	Wiederkehr ranch	do	Sandstone		Si-2	Steinhauser and Beroni (1955); Steinhauser (1956).
36	Peters ranch	do	Sandstone		*V-2*	Do.
37	Palangana salt dome deposit	Goliad	Light-gray fine-grained calcareous sandstone, and calcareous clay-ball conglomerate.	Sparse carbonized(?) plant remains and oil.	*O-1*	Uranium Digest (1958); Russell (1958); Weeks and Eargle (1960).
38	Piedras Pintas salt dome deposit.	do	White clay		Us	
			Starr County			
39	Salinas ranch	([22])	Silicified medium-grained sandstone.		Us	
40	Kelsey ranch		Sandstone. (Miocene and Oligocene.)		V-2	
			UTAH			
			Summit County			
1	M. B. C. No. 6 mine	Wasatch	Gray to light-brown friable coarse-grained sandstone.	Some carbonized plant remains.	N	
	Uranium Queen	Wasatch(?)	Brown conglomerate and gray sandstone.	do	N	
2	Big K	Kelvin	Grit	do	Us	
			Daggett County			
3	Name unknown	Navajo(?)	Highly ferruginous sandstone		N	
4	Dutch John Nos. 1-3	Navajo	Sandstone			
			Uintah County			
5	Blackie No. 1	Morrison	Sandstone(?)			
6	Steinaker Draw	do	Dark-brown shale	Abundant carbonized plant remains.		Vine and Moore (1952).
7	Jensen Draw and Miracle prospects.	do	Dense black and gray-green laminated betonitic mudstone.	do	P-1?	Noble and Annes (1957).
8	Devil group (Devil's Cave)	([8])	Sandstone(?)			
9	Eaglenest Nos. 1 and 6	Chinle	Poorly sorted clayey gritstone.	Abundant carbonized plant remains.	V-1?	Noble and Annes (1957).
10	Bonniebell and Snow groups	([8])	White to buff-medium-grained clayey sandstone.	do	*P-1*, P-5	Beroni and McKeown (1952); Gruner, Gardiner, and Smith (1954).
11	Colute Mining Co. claims	([8])	Sandstone(?)			
12	Happy Landing group (Pay Day and other claims).	Uinta	Crossbedded sandstone	Abundant carbonized logs and other plant remains and turtle shells.		H. C. Granger and H. L. Bauer (1950*).
13	Keg prospect	do	Dark-brown carbonaceous shale.	Abundant; disseminated		
14	Blue Sky No. 1	do	Sandstone(?)			
15	Canary Bird claim, Eureka group, and Stain Nos. 1 and 2.	do	Buff sandstone, sandy shale, and carbonaceous shale.	Sparse to abundant carbonized plant remains and turtle shells.	P-2	H. C. Granger and H. L. Bauer (1950*).
16	Split Canyon claim	do	Sandstone and shale	Abundant carbonized plant remains.	Us	
17	Horse Ear	do	Sandstone(?)			
18	Willow Creek claim	do	Clayey and sandy calcareous siltstone.		C-1	Noble and Annes (1957).
19	Blanca No. 1† and Tokay No. 9§.	do	Silty fine- to medium-grained sandstone.	None	Si-2, Si-3	Do.
20	Blue Knolls No. 28	Green River	Mudstone	Disseminated carbon		Do.

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
			UTAH—Continued			
			Duchesne County			
21	Lone Peak (Rainbow Ridge)	Uinta	Sandstone(?)			
			Juab County			
22	Spider No. 1 prospect‡		White tuff (red and black fine-grained volcanic fragments in a rhyolitic matrix). (Tertiary.)	None	P-1, Si-2	Staatz and Bauer (1950).
23	Goodwill claim		Friable coarse-grained quartzose and volcanic sandstone, and limestone boulder conglomerate with an ashy clay matrix. (Miocene.)	do	*C-1*, *Si-2*, *Si-9*.	Staatz (1955); Outerbridge and other (1960); Staatz and Carr (1964).
24	Yellow Chief		Altered sedimentary rhyolitic tuff. (Tertiary.)		O-1?, Si-2	
			Sanpete County			
25	Cotton No. 1 and Hot Spot	Morrison(?)	White fine-grained sandstone and shale.	Some organic matter	U	
			Emery County			
26	Helm	Summerville	Siltstone			
27	Dog group	Cedar Mountain.	Sandy and shaly bentonitic siltstone.			
28	Name unknown	Summerville	Yellowish-brown mudstone	Some carbonaceous material		
29	Copper Rock No. 1	Entrada	Grayish-green mudstone	Some asphaltum and carbonized plant remains.	U	Johnson (1959a).
	White Star No. 8	Morrison [1]	Porous conglomeratic sandstone.	Abundant carbonized plant remains and sparse asphaltite.	Us	Do.
30	South Rim No. 1 mine‡	do.[9]	Carbonaceous siltstone and claystone.	Abundant disseminated carbonaceous material.	Us	Do.
31	Buckhorn group	Chinle [27]	Sandstone(?)			Johnson (1957).
32	Dalton group, Dexture group, Lone Tree mine, and other mines.	do.[27]	Fine- to coarse-grained locally argillaceous sandstone, and conglomerate.	Abundant blebs, stringers, and fracture fillings of asphaltite and carbonized plant remains.	*A-1*, O-1, *O-4*, P-1, *P-2*, *Su-3*, *V-1*.	Reyner (1950); Gott and Erickson (1952); Gruner, Gardiner, and Smith (1954); Johnson (1957).
33	Wickiup group, Donna B No. 1, and various prospects.	do.[27]	Brown sandstone and mudstone.	Abundant asphaltite and silicified plant remains.	Us	Reyner (1950); Johnson (1957).
34	Consolidated Nos. 1 and 2, Pay Day, Green Vein No. 5, and other mines.	do.[27]	Light-gray fine- and coarse-grained sandstone, limestone-pebble conglomerate, and siltstone.	Abundant carbonized logs and other plant remains and asphaltite seams.	*A-1*, *O-1*, *O-2*, *O-4*, *P-2*, *Su-1*, *Su-3*.	Gruner, Gardiner, and Smith (1954); H. N. Jensen and R. K. Pitman (1956*); Johnson (1957).
	Little Joe prospect†	Wingate / Chinle [27]	Brecciated sandstone	Abundant pisolites, pods, and streaks of asphaltite.	Us, Up	Kerr and others (1957).
35	Lucky Strike Nos. 1 and 2, and Conrad No. 1 mines.	do.[27]	Gray and brown medium-grained to conglomeratic sandstone.	Abundant asphaltite pellets and carbonized plant remains.	*C-6*, *O-1*, *O-2*, *O-5*, *Su-3*.	Weeks and Thompson (1954); Thompson and others (1955).
36	Dirty Devil Nos. 4 and 6, and other mines.	do.[27]	Gray and brown coarse-grained sandstone, conglomerate, and mudstone.	do	*P-2*, *V-1*, *V-2*.	Reyner (1950); H. N. Jenson and R. K. Pitman (1951*); Bain (1952a); Gruner, Gardiner, and Smith (1954); Johnson (1957).
37	Delta (Hidden Splendor) and other mines.	do.[28]	Gray to light-brown fine- to medium-grained quartzose sandstone, and mudstone.	Abundant carbonized plant remains and logs.	A-1, *C-3*, *C-4*, *O-1*, *O-2*, *O-5*, P-2, *P-5*, *Su-3*, *V-1*.	Keys (1954); Gruner, Gardiner, and Smith (1954); Isachsen and Evensen (1956); Stokes and Cohenour (1956); Johnson (1957).
38	Canary prospects (Little Wild Horse Mesa) and Alpha claims.	Morrison [1]	Medium- to coarse-grained sandstone, and hard quartzitic sandstone.	Abundant carbonized plant remains.	V-1	Boutwell (1905); Hinckley and Volgamore (1953).
39	Desolation (Virginia Valley), Little Erma No. 2, and Little Wild Horse group.	Chinle [27]	Gray and light-brown coarse-grained to conglomeratic, locally calcareous, sandstone, conglomerate, and mudstone.	Sparse to abundant carbonized plant remains and asphaltite.	*O-1*, *P-1*, *P-5*.	Gruner, Gardiner, and Smith (1954); Johnson (1957).
40	Black Beauty (Thunderbird), Temple Mountain Calyx mines, Campbird No. 13 (North Mesa group), Flattop Mesa group, South Temple Mountain workings, Rex (Vanadium King) group, and other Temple Mountain mines.	do. [27]	Gray fine- to coarse-grained sandstone and green conglomerate (mudstone matrix).	Abundant asphaltite and some carbonized plant remains.	*A-1*, *C-1*, *P-2*, *O-1*, *Si-1*, *Su-3*, *V-1*, *V-2*, *V-3*, *V-4*.	D. G. Wyant (1953*); Weeks and Thompson (1954); Isachsen and Evensen (1956); Keys and White (1956); Kelley and Kerr (1958); Hawley, Wyant, and Brooks (1965).
	Denny† and other mines†	Wingate	Gray fine-grained sandstone.	Abundant gray to black bands of disseminated asphaltite.	V-1	
	Fumerole (Fumerol) No. 2†#	Wingate(?) / Chinle [27] / Coconino	Gray to greenish-gray fine-grained quartzose sandstone and chert-geode conglomerate.	Abundant asphaltite pellets, pods, and veins.	*A-3*, *P-7*	Gruner, Gardiner, and Smith (1954); Keys and White (1956); Thompson and others (1956).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
	UTAH—Continued					
	Emery County—Continued					
41	Name unknown	Chinle [27]	Sandstone			
42	Cliff Dweller	do. [27] / Moenkopi	Gray conglomeratic sandstone and greenish-gray shale.	Some carbonized plant remains.		Johnson (1957).
43	Name unknown	Chinle [27]	Sandstone			Do.
44	Do	do. [27]	do			Do.
45	Green Tree mine	Morrison [1]	do		V-1	
46	Betty A, San Rafael, Vanura Nos. 1 and 5 (Four Corners Uranium Corp.), Wedding Bell, and other mines.	do. [1]	Sandstone, conglomeratic sandstone, and silty to sandy mudstone.	Abundant carbonized plant remains and silicified logs.	*C-1*, *C-3*, *C-5*, *O-1*, *Si-1*, *Su-2*, V-1, *V-2*.	Clark and Million (1956); Johnson (1959b).
47	Bear Claw, Cat Bird No. 2 (Blue Jay), Yellow Queen No. 1, and other mines.	do. [1]	Buff to gray medium- to coarse-grained sandstone.	Abundant carbonized plant remains.	V-1	Johnson (1959b).
	Name unknown	do. [9]	Siltstone	Abundant disseminated carbon.	N	Johnson (1959b, p. 98).
48	Nona Bee No. 1, School Section 2, and other mines.	do. [1]	Friable dark-gray sandy mudstone and light-gray fine- to medium-grained sandstone.	Abundant carbonized plant remains.	*Si-1*, V-1	Johnson (1959b).
49	Mohawk and other claims	do. [1]	Brown to white fine-grained silty sandstone.	Some dark carbon streaks	V-1	
50	Danise (Denise) No. 1 mine, Aileen, and Willow No. 1. (See also Grand County.)	Chinle	Greenish-gray siltstone and gray medium-grained sandstone.	Abundant carbonized blebs and seams.	*A-1*, *O-1*, *P-2*, *P-7*, *Si-1*, Su-3.	Weeks and Thompson (1954); Gruner, Gardiner, and Smith (1954).
	Grand County					
50	Larry group and other prospects. (See also Emery County.)	Chinle	Siltstone	Carbonized seams		
51	Copper King and Lone Point	Summerville (?).	Sandstone			
	Highboy group and other prospects#.	Morrison [1]	Sandy shale and sandstone		N	
52	Sunday mine	do. [1]	Gray calcareous sandstone		V-1	
53	Lion No. 5 (or No. 6?)	Wasatch	Gray to buff fine- to medium-grained sandstone.	Abundant carbonized plant remains.	O-1, P-1	
54	Pine Tree No. 1	Tuscher	Buff conglomeratic sandstone and gray fine-grained calcareous sandstone.	Some carbonized logs and other plant remains.	V-1	
55	Eagle§ and other claims †§	Morrison [1]	Sandstone			
56	Antelope mine and various prospects.	do. [1]	do			
57	Yellow Cat group (Allor and other mines), Parco group, Telluride group, and other mines.	do. [1]	White to gray fine- to coarse-grained sandstone, and grit.	Abundant carbonized plant remains, some silicified and carbonized logs, and sparse asphaltite.	*C-1*, *C-2*, *C-5*, *O-1*, *V-1*, *V-2*.	Moore and Kithil (1913); Dane (1935); Stokes (1952a); Stokes and Mobley (1954); Weeks and Thompson (1954); Cannon (1964).
	School section 32, T. 22 S., R. 22 E.	do. [9]	Mudstone			
58	Cactus Rat group, Flattop No. 1 mine, and other mines.	do. [1]	Grit and medium-grained sandstone.	Carbonized plant remains	*C-1*, *O-1*, *P-5*, *Si-1*, *V-1*, *V-2*, *V-3*.	Huleatt and others (1946); Stokes (1952a); Weeks and Thompson (1954); Stokes and Mobley (1954); Cannon (1964).
59	Squaw Park group and other mines.	do. [1]	Medium-grained sandstone	Very sparse carbonized plant remains.	V-1	Stokes (1952a).
60	Cuesta No. 3, Junction group, and other mines.	do. [1]	Sandstone	Some small carbonized logs and other plant remains.	V-1	
61	School section 32 and Buckhorn claim, Glory Hole (King), and other mines.	do. [1]	Black fissile shale and white sandstone.	Very abundant carbonized plant remains.	V-1	
62	Polar No. 3, Elva M, and other mines.	do. [1]	Yellow-brown sandstone	Very abundant carbonized logs and other plant remains.	*V-1*, *V-2*	Dane (1935); Stokes and others (1945); Huleatt and others (1946); Redmond and Kellogg (1954).
63	Corvusite group and other mines.	do. [1]	White to gray medium-grained sandstone.	Abundant carbonized plant remains.	*O-1*, *Si-1*, *V-1*, *V-2*, *V-3*.	Stokes and others (1945); Huleatt and others (1946); Weeks and Thompson (1954).
64	Red Head group (Richardson Basin, Jesse D).	Kayenta / Wingate	White to light-gray fine- to medium-grained sandstone.	None	V-1, *V-2*	Boutwell (1905); Parsons (1933); Gruner, Gardiner, and Smith (1954); Shoemaker (1956c).
65	Cobalt No. 2†	Morrison [1]	Sandstone	do	P-1, *P-2*, *P-5*	Weeks and Thompson (1954).
	Slick Rock group (Tenderfoot and Desert Rat claims).§	do. [1]	Gray to light-green hard sandy limestone.	Thin carbonaceous seams.	V-1	
66	Dime mine and various prospects.	do. [1]	Gray fine-grained to conglomeratic sandstone and clay-ball layers.	Silicified logs and carbonized plant remains.	V-1	
	Shinarump Nos. 1 and 3, and other mines.	Chinle	Greenish-gray siltstone, sandstone, and limestone-pebble conglomerate.	Abundant coaly seams and plant remains.	*C-1*, *O-1*, *O-2*, *O-3*, *Si-8*, *Su-3*, *V-1*, *V-2*.	Stieff and Stern (1952); Finch (1954); Gruner, Gardiner, and Smith (1954); Hurlbut (1954).
67	Copper group and various prospects.	do	Medium to very coarse grained sandstone.	Some carbonized logs and other plant remains.	O-1, Su-3	

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			UTAH—Continued			
			Grand County—Continued			
68	"A" group, Mineral group, and other mines.	Chinle [27?]	Greenish conglomeratic and sandy mudstone, siltstone, and limestone-pebble conglomerate.	Abundant carbonized plant remains.	*O-1, P-2, P-5, P-9,* Si-2.	Rosenzweig and others (1954); Weeks and Thompson (1954).
69	Mile High group	Chinle	Sandstone(?)	do	C-1, P-1, V-1.	
70	North Mesa group, Skeeter group, and other Wilson Mesa mines.	Morrison [1]	Gray to brown fine-grained sandstone and green shale.	Carbonized logs and other plant remains locally abundant.	V-1	
71	School sec. 32, T. 26 S., R. 21 E. (See also San Juan County.)	Chinle [27]	Green shale and sandy shale	Abundant carbonized plant remains.	*C-2, O-1, Si-7, Su-3.*	A. S. Corey (1959*).
			San Juan County			
71	Atomic King (Honeybee)†	Chinle Cutler [29] Rico	Fault gouge ("biotite-quartz schist"), and brecciated sandstone and medium-grained arkose.	Abundant pyrobitumen	*C-1, C-2, C-3, O-1, O-2, Si-2, Su-3, V-1, V-2.*	Hinrichs (1954; 1956); Isachsen and others (1955).
	Various mines†	Rico	Fault gouge and white arkose	do	V-1	O. M. McRae and Y. W. Isachsen (1958*).
	Unnamed prospects‡ (See also Grand County.)	Chinle [27]	Limy mudstone-pellet conglomerate and sandstone, and clayey limestone.	Some pyrobitumen pellets and stringers, and carbonized plant remains.	*O-1, C-2, Si-7, Su-3, V-1.*	A. S. Corey (1958*).
72	Blue Goose group, Chess Ridge group, and other Brumley Ridge and Pack Creek mines.	Morrison [1]	Grayish-white fine- to medium-grained sandstone, shale seams, and clay-gall zones.	Abundant carbonized plant remains.	V-1	Baker (1933).
73	Sunflower-Snowflake, Yellow Circle group, and other mines.	do. [1]	do	Abundant carbonized, silicified, and calcified plant remains.	V-1	Baker (1933); Huleatt and others (1946); Farrow and others (1955).
74	Blue Jay, Prince Albert, and other Bliss Pasture and Brown's Hole mines.	do. [1]	Gray to brown fine- to medium-grained sandstone, and clay galls and bands.	Abundant carbonized plant remains.	V-1	Baker (1933).
75	Rattlesnake mine	do. [1]	Medium-grained sandstone and siltstone.	Abundant carbonized logs and other plant remains.	V-1	
76	Fault No. 1, Lucky Strike No. 1, and other Bridger Jack Mesa mines.	do. [1]	Grayish-white fine- to medium-grained sandstone, and light-green clay seams and gall zones.	do	V-1	Baker (1933) Farrow and others (1955).
77	Cane Creek prospects	Chinle	Sandstone(?)			
78	Discovery No. 2, Shade Tree, and other prospects.	do [27]	Fine- to medium-grained sandstone, mudstone, and conglomerate.	Sparse carbonized plant fragments.	N	
79	Taylor No. 1	do. [27]	Gray medium-grained sandstone and mudstone.	Abundant carbonized plant remains.	Us	
80	Count, Crabapple, and other "C" group mines.	do. [27]	Gray medium- to coarse-grained sandstone and conglomerate.	do	*C-1, C-4, O-1, Su-3.*	de Vergie and Carlson (1953); Weeks and Thompson (1954).
	Comoose	Cutler [29]	Arkose			
81	Lockhart Lulu No. 1, Range, and other claims.	do. [29]	White coarse-grained arkose, and greenish-colored mudstone and siltstone.	None	*A-1, A-5*	Dix (1953).
	Rico Flat claim	Rico	Sandy limestone		V	E. N. Hinrichs (1957**).
82	Sodaroll claim, Sailor group, and other prospects.	Chinle [27]	Gray coarse-grained to conglomeratic sandstone, and mudstone.	Abundant carbonized plant remains, some silicified.	Su-3	Weeks and Thompson (1954).
83	Airlift and Pagoda claims	Cutler [29]	Whitish-colored arkose and sandstone.		*Si-1, P-1*	Hinrichs (1958); E. N. Hinrichs (1957**).
84	Jet Crash and other claims	do. [29]	White arkose	None		Dix (1953).
85	Cutler mine	do. [29]	White coarse-grained arkose and greenish-colored mudstone.	do	*A-1, A-5, P-2, Si-2.*	Dix (1953); Gruner, Gardiner, and Smith (1954).
	Salt Cedar claim	Rico	Silty impure limestone			
86	Queen of Harts claim and Smith group.	Cutler [29]	White arkose and gray to brown coarse-grained sandstone and sandy mudstone.	None	Us	Dix (1953).
87	Smokey No. 3	do. [29]	Sandstone and arkose		Us	E. N. Hinrichs (1957**).
88	Unnamed prospect	Cutler [30]	Silty sandstone		Up	R. Q. Lewis (1957**).
89	Conglomerate group and various prospects.	Chinle [27]	Conglomerate, gray medium-grained sandstone, and yellowish-brown to green mudstone.	Abundant carbonized and silicified logs and other plant remains.	O-1, V-1	
	Unnamed prospect	Cutler [29]	Arkose and sandstone		Us	E. N. Hinrichs (1957**).
90	Grey Daun (Dawn), Vanadium Queen, and other mines.	Morrison [1]	Buff fine-grained sandstone and shaly sandstone.	Abundant carbonized plant remains.	*A-1, A-4, A-6, O-1, O-3, P-2, P-5, P-8, Si-1, Si-2, Si-7, V-1, V-2.*	Rasor (1952); Weeks (1957).
91	MiVida mine, San Juan shaft, and other mines.	Chinle [27?]	Gray fine-grained calcareous micaceous sandstone and greenish calcareous siltstone.	do	*C-3, C-5, O-1, Si-1, Su-3, V-1, V-2.*	Steen and others (1953); Gruner and Smith (1955a); Laverty and Gross (1956), Gross (1956); Weir and Puffett (1960).
	Big Buck group and other mines.	Cutler [29]	Mottled brown, white, and purple medium- to coarse-grained arkosic sandstone.	None	*O-1, O-2,* Si-2, *V-1.*	Dix (1954); Isachsen (1954); Weir and Puffett (1960).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			UTAH—Continued			
			San Juan County—Continued			
92	Utah, Wyoming, and other mines.	Morrison [1]	Sandstone			
93	Divide mines, Sec. 36, T. 30 S., R. 25 E. (Continental), and Serviceberry mine.	Chinle [27]?	Gray fine- and coarse-grained micaceous sandstone, and conglomerate.	Abundant carbonized plant remains.	*O-1*, V-1	Gruner and Smith (1955a); Weir and others (1957).
	Bench group and various prospects.	Morrison [1]	Sandstone		V-1	
94	Liberty group	do.[1]	do			
95	Waterfall group, Wilson group, and other mines.	do.[1]	Light-gray poorly sorted fine- to coarse-grained sandstone and gray mudstone.	Sparse to abundant carbonized logs and other plant remains	V-1	
96	None Such and other mines	do.[1]	Buff medium-grained sandstone.		V-1	
97	Frisco group, Sunset mine, and other mines.	do.[1]	Light-gray fine-grained sandstone.	Sparse carbonized logs and other plant remains.	V-1	
98	Happy Jack and other mines	do.[1]	Sandstone		V-1	Huleatt and others (1946).
99	Antler, Indian Creek group, and various prospects.	do.[1]	Brown and gray fine- to medium-grained sandstone.	Abundant carbonized plant remains.	V-1, V-2	Witkind (1964).
100	Blue (Shay Mountain) group and various claims.	do.[1]	Light-gray fine-grained sandstone and shaly sandstone.	Some carbonized logs and other plant remains.	V-1, V-2	Do.
101	Horseshoe No. 1, Hot Spot No. 1, and other mines.	Chinle [27]	Light-green conglomeratic mudstone and quartz-pebble conglomerate.	Some silicified and carbonized plant remains.	Su-3, V-1	
102	Blue Eagle, Verdure, and various prospects.	Morrison [1]	Gray medium-grained sandstone.	Abundant carbonized logs and other plant remains.	V-1	Huff and Lesure (1965).
103	Canary, Long Shot, and other mines.	do.[1]	Gray medium-grained calcareous sandstone.	Carbonized plant remains	V-1	
104	Cottonwood, Lucky Boy, Rock, and other mines.	do.[1]	White and gray fine- to medium-grained sandstone with some clay pellets and seams.	Abundant carbonized logs and other plant remains.	*Su-3*, *V-1*, *V-2*.	Do.
105	Rusty Can, Monument No. 2, West Cliff House No. 8, and other mines.	do.[1]	Buff to white medium-grained sandstone and mudstone partings.	Abundant carbonized plant remains and sparse logs.	*V-1*, *V-2*	Do.
106	Bradford Canyon No. 2, Mill, and other mines.	do.[1]	Gray to white medium-grained sandstone.	Abundant carbonized plant remains and small logs.	V-1	
107	Blue Jay, Margarite, and other mines.	do.[1]	do	do	*O-1*, *Si-1*, *V-1*, *V-2*, *V-3*.	Weeks and Thompson (1954); Huff and Lesure (1962).
108	Lone Wolf, Moab, and other mines.	Morrison [1]	Gray calcareous sandstone		*V-1*, *V-2*	Huff and Lesure (1962).
109	Pete mine, Red Hot, and School sec. 16, T. 39 S., R. 25 E.	do.[9]	Gray and buff siltstone and mudstone and very fine grained sandstone.		*O-1*, *Si-1*	Gruner (1956c).
110	Tree group	do.[9]	Conglomerate	Silicified logs	V-1	J. V. A. Sharp (1954*).
111	Hole-in-the-rock and other mines.	do.[13]	Light-gray to buff fine-grained sandstone.	Very abundant carbonized plant remains.	V-1	Do.
112	Sandy mine, Sebastapol group, and Birthday claim.	do.[1]	Light-gray fine-grained sandstone.	Locally abundant carbonized logs.	V-1	Do.
113	Sunshine (Sunrise) mine	do.[1]	Light-gray fine- to coarse-grained sandstone.	Locally abundant carbonized plant remains.	V-1	Do.
114	Gold Butte (Lonesome) group	do.[1]	do	Abundant carbonized logs	V-1	Do.
115	Big Hole mine, Dinosaur group, Basin No. 1, and other Blanding mines.	do.[1]	Light-gray and brown fine- to medium-grained calcareous sandstone.	Abundant carbonized logs and other plant remains.	*O-1*, *V-1*, *V-2*.	Huleatt and others (1946); Weeks and Thompson (1954); Dodd (1956).
116	Brushy mine and various prospects.	do.[1]	Sandstone		V-1	
117	High Hopes and Pretty Girl No. 3 mines and various prospects.	do.[1]	Light-gray shaly sandstone		V-1	
118	King James mine and various prospects.	Chinle [2]	Conglomerate			
119	Carl, Notch group, and other mines.	do.[2]	Conglomeratic and muddy sandstone, claystone, and siltstone.	Abundant carbonized plant remains and asphaltite blebs.	*A-1*, *C-1*, *C-3*, *C-7*, *O-1*.	Weeks and Thompson (1954); Rosenzweig and others (1954); Gruner, Gardiner, and Smith (1954); Laverty and Gross (1956); Lewis and Campbell (1965).
	Notch No. 5	Moenkopi	Gray to brown well-sorted fine-grained sandstone and siltstone.	Abundant asphaltite	*O-1*	Isachsen and others (1955).
120	Sandy No. 3 mine, Wooden Shoe No. 1, and other prospects.	Chinle [2]	Sandstone, conglomeratic sandstone, and blue clay.	Some carbonized plant remains and asphaltite(?).	*O-1*, Us	Frondel (1958, p. 27); Kleinhampl (1962).
121	Hideout No. 1 (Tiger), W. N., and other mines.	do.[2]	Gray and brown coarse-grained sandstone and conglomerate, and bluish-gray sandy mudstone.	Abundant carbonized plant remains.	*C-1*, *C-2*, *C-3*, *O-1*, *P-1*, *Si-2*, *Su-3*.	Stern and Weeks (1952); Gruner, Gardiner, and Smith (1954); Finnell and Gazdik (1958); Froelich and Kleinhampl (1960); Finnell and others (1963).
122	White Canyon No. 1 and Scenic No. 4 mines, and various prospects.	do.[2]	Conglomerate, brown sandstone, and gray mudstone.	do	*O-1*, *P-1*, *Si-2*, *Su-1*.	Weeks and Thompson (1954); Gruner, Gardiner, and Smith (1954); Thaden and others (1964).
123	Found Mesa prospects	do.[2]	Grayish-white medium- to coarse-grained quartzose sandstone.			
124	Jacob Chair claims	do.[2]	Gray and brown coarse-grained sandstone.	Sparse carbonized plant remains.	A-1	Gruner, Gardiner, and Smith (1954).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			UTAH—Continued			
			San Juan County—Continued			
125	Happy Jack (Blue Dike), Gonway No. 1, North Point, and other mines.	Chinle [2]	Gray and brown coarse-grained to conglomeratic quartzose sandstone.	Abundant carbonized plant remains.	*A-1, C-2, O-1, O-2, O-4, P-2, P-5, P-6, Si-2, Su-1, Su-2, Su-3.*	Butler and others (1920, p. 621-622); Dodd (1950); Miller (1952; 1955); Gruner, Gardiner, and Smith (1954); Weeks and Thompson (1954); Trites and Chew (1955); Mace and Oertell (1958); Trites and others (1959).
126	Jomac mine	do.[2]	Sandstone, conglomerate, and siltstone.	do	*A-1, P-1, P-2.*	Trites and Hadd (1958).
127	Four Aces and Hidden Valley prospects.	do.[2]	Sandstone and conglomeratic sandstone.	Some carbonized plant remains.	N	
128	Cub group	do.[2]	Gray coarse-grained sandstone.	do		
129	Nash Car (Scenic No. 2), and other prospects.	do.[2]	Gray sandstone and conglomerate.	do	*Si-2, Si-4,* Su-1.	deVergie (1953); Kelley (1954).
130	Allen No. 1 and other prospects	do.[2]	Sandstone		*O-1*	
131	Blue Lizard, Joe Bishop, Posey, Markey (Markie), and Red Canyon No. 2 mines.	do.[2]	Light-brown to gray fine- to medium-grained and coarse-grained sandstone and conglomeratic mudstone.	Abundant carbonized logs and other plant remains.	*A-1, O-1, O-2 P-2, P-5, Si-2, Si-4, Su-1.*	Gruner and Gardiner (1952); A. F. Trites, Jr. (1953*); Gruner, Gardiner, and Smith (1954); Weeks and Thompson (1954).
132	Gizmo group, Maybe, and other mines.	do.[2]	Sandstone	Carbonized plant remains	Su-2, Su-3	Dahl and MacDonald (1957).
133	Bell Nos. 1 and 2 mines, Frey No. 4 mine, Jerry group, Yellow John (Sandy) mine, and other mines.	do.[2]	Brown to gray medium- to coarse-grained sandstone.	Sparse carbonized logs, and other plant remains.	*O-1, O-2, O-4, P-2, Si-2, Si-4, Su-1, Su-3*	F. J. Frankovich (1952*); Gruner, Gardiner, and Smith (1954); Weeks and Thompson (1954).
134	Red Mesa copper pit	Navajo	Light-gray fine-grained sandstone, and minette.	None		
135	Mitten No. 1, Skyline, and other mines.	Chinle [2]	Brown conglomeratic sandstone and clay.	Abundant carbonized plant remains.	*O-1, O-2, P-2, Si-2, Si-3, V-1, V-2.*	Weeks and Thompson (1954); Lewis and Trimble (1959).
136	Taylor Reid No. 1 and other mines	do.[2]	Light-brown medium- to coarse-grained calcareous pebbly sandstone.	Sparse carbonized plant remains.	O-1, *Si-2, V-1, V-2.*	Lewis and Trimble (1959).
137	Monument No. 3 mine, and various prospects.	do.[2]	Light-brown medium-grained sandstone and conglomerate.	Sparse carbonized and silicified plant remains.	V-1	Do.
138	Charlie No. 1 (Horsetrail claim) and other prospects.	do.[2]	Greenish-colored clay in conglomerate and sandstone(?).	do	O-1, Us	Gregg (1952); Lewis and Trimble (1959).
139	Whirlwind mine	do.[2]	Green mudstone-pebble conglomerate and brown calcareous sandstone.	Sparse carbonized plant remains.	V-1	Lewis and Trimble (1959).
140	Rincon prospect	do.[2]	Conglomerate(?)			
141	Happy Canyon prospects	do.[2,7]	Sandstone	Sparse carbonized plant remains.	*P-2*	McKeown and Hawley (1955).
142	Copper Queen (Hunt)	Entrada	Greenish- and brownish-colored fine-grained sandstone.	None	Us	Johnson (1959b, p. 80).
143	Big Jim Nos. 1 and 2	Morrison [1]	Sandstone(?)			
144	Billy's Dream	do.[1]	Light-tan medium- to coarse-grained pebbly quartzose sandstone.		V-1	Smith and others (1963).
145	All American No. 3, Floral Reef (Green Monster)‡, and Capitol claims.	Chinle [2]	Sandstone, claystone, siltstone, and jasper layers.	Sparse carbonized plant remains and asphaltite(?).		Smith and others (1952; 1963).
146	Oyler mine (Old Dixon prospect) and various prospects.	do.[2]	Gray-green clay, gray-brown coarse-grained sandstone, and conglomerate.	Abundant carbonized logs and other plant fragments.	*O-1, O-2, O-4, P-2, Si-5, Su-1, Su-3.*	Butler and others (1920, p. 633); Hess (1924); Smith and others (1952); Gruner, Gardiner, and Smith (1954); Weeks and Thompson (1954); Huff (1955).
147	Blue Bell and Birch Springs	do.[2]	Sandstone, mudstone, and gray claystone.	Sparse to abundant carbonized plant fragments.	O-1	Smith and others (1952).
	Black's claim	Moenkopi	Yellow-gray fine-grained sandstone.	Asphaltic(?) carbon streaks and spots.	O-1, P-2	
148	Tunison and Unda groups	Moenkopi(?)	Bleached fine-grained sandstone.		O-1	
			Sevier County			
149	Mt. Terrel group		Coarse-grained sandstone. (Tertiary.)		N	
150	Wooley group		Decomposed tuff and calcareous clay. (Tertiary.)		Si-2	
151	BBB claims		Light-gray soft water-laid tuff. (Tertiary.)		V-1	
152	Tiger Eye No. 1		White to gray siliceous tuff. (Tertiary.)		N	D. G. Wyant, F. Stugard, Jr., and E. P. Kaiser (1950*).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
			UTAH—Continued			
			Garfield County			
153	Oak Creek No. 1 mine and various prospects.	Chinle [2]	Friable sandstone, shale, and siltstone.	Carbonized plant remains	*O-1*, P-2	Everhart (1950).
154	Lampstand No. 1 and other prospects.	do.[2]	Light-brown medium- to fine-grained sandstone.	Abundant carbonized plant remains.		H. N. Jensen (1953*).
155	Centipede prospect	do.[2]	Sandstone			Do.
156	Blue Goose and other prospects	do.[2]	Sandstone, siltstone, and mudstone.	Abundant carbonized plant remains.	O-1, P-1, P-2	Stewart (1956).
157	Black Widow mine and various prospects.	do.[2]	Gray siltstone, mudstone, and sandstone.	Asphaltite and carbonized plant remains.	O-1, P-1, P-2	Do.
158	Hot Shot No. 1, Silver Falls No. 2 (Sneaky), Yellow Jacket, and other mines.	do.[2]	Gray fine- to medium-grained and brown coarse-grained sandstone, and sandy mudstone.	Abundant carbonized plant remains.	C-1, O-1, P-1, P-2, Su-1.	Everhart (1950); Kleinhampl and Koteff (1960).
159	Moody No. 1 claim	do.[2]	Brown sandstone	do		Everhart (1950).
160	Tulip and other prospects	do.[2]	Sandstone(?)			
161	Rainy Day mine	Moenkopi	Gray siltstone and mudstone	Some asphaltic material	*O-1*	Davidson (1959).
162	Dream	Morrison [1]	Sandstone(?)			Johnson (1959b); Kleinhampl and Koteff (1960).
163	Pardner mine	Chinle [2] Moenkopi	Siltstone and shale		P-2	
	Stud Horse and other prospects	Chinle [2]	Dark-gray silty mudstone	Abundant carbonized plant remains.	*O-1*	Stewart (1956).
164	Congress group, Daisy June group, and other mines.	Morrison [1]	Brown fine- to medium-grained sandstone and green mudstone.	Abundant silicified logs and carbonized plant remains.	V-1	Hunt and others (1953); Johnson (1959b).
165	Trachyte Nos. 11–19, Blitz group, and other mines.	do.[1]	Gray medium-grained sandstone.	do	V-1	Butler and others (1920, p. 630); Brooke and others (1951); Hunt and others (1953); Johnson (1959b).
166	Trachyte Nos. 1–10, June Bell group, and other mines.	do.[1]	White coarse-grained sandstone, locally conglomeratic.	do	V-1	Do.
167	Walter group and other mines	do.[1]	Buff medium-grained sandstone.		V-1	Johnson (1959b).
168	Delmonte group and other mines.	do.[1]	Buff medium-grained sandstone and gray clay.	Abundant carbonized plant remains.	V-1	Butler and others (1920, p. 630); Johnson (1959b).
169	Lucky Strike group and other Shootaring (Shitamaring) Canyon mines.	do.[1]	Buff medium-grained sandstone.	do	V-1	Hunt and others (1953); Johnson (1959b).
170	Poison Spring Canyon mines	Chinle [28]	Gray limestone-pebble conglomerate and siltstone.	do	*P-1*, P-8	Gruner, Gardiner, and Smith (1954).
171	Hatch Canyon prospects	do [28]	Siltstone and sandstone	Sparse carbonized plant remains.	P-1, P-2	
172	South Block prospects	do [28]	Sandstone and chert	do	O-1, V-1	McKeown and Hawley (1955); McKeown and Orkild (1958).
173	Unnamed prospect	Chinle	Sandstone(?)			
174	Colorado River group	do [2]	Medium- to coarse-grained sandstone, grit, and conglomerate.	Abundant carbonized plant remains.	O-1, *P-1*	P. C. deVergie (1952*).
			Kane County			
175	Pyramid group	Morrison(?)	Sandstone		V-1	
176	Radiance No. 2 (Cocks Comb)	Kayenta Moenave [31]?	Gray fine-grained silicified sandstone.	None	A-2, *P-1*, *P-2*.	
177	Balboa	Chinle	Shale, mudstone, and claystone.		P-1, P-2	
178	Lynn No. 1	Winsor	Gray clay and iron-oxide concretions.	Sparse carbonized plant remains.	N	Beroni and others (1953).
	Lynn No. 3 and other Bulloch claims.	Dakota Winsor	Gray clay, white fine-grained sandstone, and conglomerate.	Silicified logs and carbonized plant remains common.	P-1, P-2, V-1, V-2.	Do.
			Washington County			
179	Caliente No. 5 and name unknown.	Chinle	Shale and sandstone(?)	Carbonized logs	N	
180	Fort Pierce	do	Sandstone(?)			Everhart (1950).
181	Chloride Chief (Doyle shaft) and other Silver Reef mines.	Moenave [31]	Very fine grained quartzose sandstone and clayey seams.	Abundant carbonized plant remains.	V-1, *V-2*	Stugard (1951; 1953); Poehlmann and King (1953); Proctor (1953); Gruner, Gardiner, and Smith (1954).
			WASHINGTON			
			Pend Oreille County			
1	De Chenne prospect #	Tiger	Conglomerate; arkosic clayey sand matrix.	None	*P-1*, Si-2	Weis and others (1958).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
	WASHINGTON—Continued					
	Stevens County					
2	Northwest Uranium prospect and Big Smoke mine.	----------------	Arkosic, tuffaceous, and conglomeratic sandstone and interbedded carbonaceous shale. (Oligocene.)	Abundant fine-grained carbonized material.	*O-1*, *O-3*, P-1, *P-2*, Si-2.	Becraft and Weis (1957); Davis and Sharp (1957); Norman (1957); Huntting (1957).
	WEST VIRGINIA					
	Webster County					
1	Carpenter	Mauch Chunk(?).	Sandstone	----------------	----------------	
	WYOMING					
	Crook County					
1	Helmer, Nelson, and other properties.	Fall River	Gray to buff fine-grained sandstone.	Abundant carbonized plant remains.	P-1, V-1	Gray and Tennissen (1953); Thomas (1954); A. L. Nash, (1955*).
2	Richards property and A. H. claim.	do	Sandstone	----------------	V-1	A. L. Nash (1955*).
3	J. C. Viergutz	Lakota	Light-gray fine-grained sandstone.	Abundant carbonized plant remains.	N	
4	C. Cochrun	Fall River(?)	Dark-gray clay	----------------	----------------	W. P. Horner and D. F. Olsen (1953*).
5	Virginia No. 16	Fall River	Gray sandstone and mudstone.	----------------	N	
6	Ackerman and other prospects	do	Limy sandstone	----------------	V-1	W. P. Horner and D. F. Olsen (1953*).
7	Busfield mine, Vickers (Kay) mine, and various prospects.	do	Yellow-gray medium-grained sandstone, and siltstone.	Abundant carbonized plant remains.	*O-1*, *Si-1*, *V-1*, *V-2*.	MacPherson (1956); Wilson (1959; 1960); Davis and Izett (1962).
8	New Haven (Homestake group), Lewis Dennis (Sodak), and other mines.	do	Fine- and medium-grained sandstone, locally calcitized and silicified.	do	*O-1*, *P-1*, *Si-1*, *Si-2*, *Si-5*, *V-1*, *V-2*.	Gruner and Smith (1955b); Robinson and Goode (1957a; 1957b); Robinson and others (1964).
9	Poison Creek	do	Sandstone	----------------	*A-1*, *P-6*	Gruner and Smith (1955b).
10	Jubilee (Wolfskill)	do	Fine-grained silty sandstone	Abundant carbonized plant remains.	P-2, V-1	Robinson and others (1964).
11	Name unknown	do	Sandstone	----------------	Us	Vickers and Izett (1955).
12	Myers#	Lakota	Dark-brown friable fine-grained sandstone and light-gray conglomeratic sandstone.	Abundant carbonized plant remains.	V-1	
13	Carlile (Homestake 2) mine, Thorne Divide, and various deposits.	do	Gray to buff medium- to coarse-grained sandstone, conglomeratic sandstone, and shaly siltstone.	do	Si-1, *V-1*, *V-2*, V-3.	Thomas (1954); Bodine (1954); King (1956); Bergendahl and others (1961).
14	Cabin Creek No. 6, Claims Nos. 5 and 11‡, and Graves No. 1.	Fall River	White to brown very fine to fine grained sandstone.	do	V-1	
	Weston County					
15	Cambria	([20])	Gray fine- to medium-grained quartzose sandstone.	Coal and abundant carbonized plant remains.	N	
16	Alray and Wicker-Baldwin (Elk Mountain) mines.	Fall River	Light-gray to yellow fine- to medium-grained quartzose sandstone, gray clay, and carbonaceous siltstone.	do	*V-2*	Brobst (1961); Gruner and others (1956); Cuppels (1957; 1963); Wilson (1959; 1960).
	Campbell County					
17	Big Tar (Kelly) mine and unnamed prospects.	Wasatch	Buff medium-grained arkosic sandstone and gray fine-grained sandstone.	Abundant carbonized and silicified plant remains.	*V-2*	Gruner and Smith (1955b).
18	Christenson ranch	do	Buff medium-grained sandstone.	Abundant carbonized plant remains.	V-1	Sharp and White (1957).
19	Unnamed prospects	do	Sandstone	----------------	----------------	Troyer and others (1954).
20	Orr lease, Anomaly 26 (sec. 17, T. 45 N., R. 74 W.), and K.I.S.U. mine.	do	Buff fine-grained micaceous sandstone, coarse-grained sandstone, and medium-grained arkosic sandstone.	Sparse carbonized plant remains.	*V-1*, *V-2*	D. N. Magleby and J. G. Biggins (1952*); Gruner and Smith (1955b).
21	Blowout (anomaly 119), Jeanette No. 1, and other mines.	do	Gray to brown fine- to coarse-grained arkosic sandstone.	Some carbonized plant remains.	*O-1*, *P-5*, *Si-2*, *V-1*, *V-2*.	Troyer and others (1954); Grutt (1956); Sharp and White (1957); Mrak (1958); Sharp and others (1964).
22	Dome Butte and other mines	do	Buff fine- to medium-grained arkosic sandstone.	Abundant carbonized plant remains.	*Si-2*, *V-1*, *V-2*.	Troyer and others (1954); Geslin and Bromley (1957); Mrak (1958).
23	Joe No. 1, Black Star, and other mines.	do	Gray to brown sandstone	None with ore	N	Mrak (1958).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			WYOMING—Continued			
			Campbell County—Continued			
24	Axe, Camblin West, and other mines.	do	Gray and buff fine- and medium-grained calcareous arkosic sandstone.	Some carbonized seams	*C-5*, V-1	Mrak (1958).
25	Pete group and other deposits	do	Reddish fine- to coarse-grained calcareous arkosic sandstone.		Us	Mrak (1958); Sharp and others (1964).
26	Nero, South school section, and other mines.	do	Red to buff coarse-grained calcareous arkosic sandstone.	Some carbonized plant remains.	*Si-2*, *V-1*, *V-2*.	Do.
27	Blue Hill and other mines	do	Buff to gray coarse-grained arkosic sandstone.	do	Us	Mrak (1958).
28	Sable group and other mines	do	Buff to gray medium-grained micaceous arkosic sandstone.		Us	Do.
29	Locality No. 99 and other localities.	do	Sandstone			Troyer and others (1954).
30	Locality No. 140 and other localities.	do	do			Do.
31	Triangle group and various localities.	do	White to yellow-brown poorly sorted coarse-grained sandstone.	Underlain by coal bed	V-1	Do.
32	Jake (Pete) mine, Key (North American Uranium Co.) mine, and various prospects. (See also Converse County.)	do	Gray coarse-grained calcareous arkosic sandstone.	Abundant carbonized plant remains.	*O-1*, Si-2, *V-2*.	Gruner and others (1956); Sharp and Gibbons (1964).
			Johnson County			
33	Happy No. 1 and other prospects.	Fort Union	Gray and light-brown medium-grained sandstone.	Some carbonized plant remains.	Us	
34	Hanna group, Greenlee No. 1, and various prospects.	Wasatch	Buff to gray coarse-grained calcareous silty sandstone.	Abundant carbonized plant remains.	*V-2*	Gruner and others (1956); Mrak (1958.)
35	Jim Dandy and other prospects.	Fort Union	Light-gray to brown medium-grained silty sandstone.	do	V-1	Mrak (1958).
36	Del No. 1 (Linch), Kell-Roy mine, and various prospects.	do	Gray to buff fine- and medium-grained sandstone, locally calcareous.	Abundant carbonized plant remains and some black vitreous asphaltite(?).	*O-1*, *P-1*, *P-6*, *Si-1*, *V-1*, V-2.	Gruner and Smith (1955b).
37	Ty Fy (Tyfil) mine and various prospects.	Wasatch	Yellow to brown coarse-grained micaceous arkosic sandstone.	Some carbonized plant remains.	Us	Mrak (1958).
38	Alice Mae, Antelope group, and various prospects.	do	Gray to red very coarse- and medium-grained micaceous calcareous arkosic sandstone.	do	Us	Do.
39	Van (Vance) No. 1 and various prospects.	do	Brown to gray medium-grained calcareous sandstone.	do	*Si-1*, V-1	Sharp and others (1964).
40	Lucky 7 No. 2	do	Buff fine-grained sandstone containing some clay.		Us	Mrak (1958).
41	Moe No. 14, Ray (Channel), and other mines.	do	Yellow-brown to gray fine- to coarse-grained sandstone.	Abundant carbonized plant remains.	*Si-2*, *V-1*, *V-2*.	Geslin and Bromley (1957); Sharp and White (1957); Sharp and others (1964).
42	Sunset and other mines	do	Gray and buff fine- to coarse-grained sandstone containing clay.	Some carbonaceous plant remains.	*Si-2*, *V-1*, *V-2*.	Mrak (1958); Sharp and others (1964).
43	Campbell No. 1	do	Sandstone		*V-2*	Gruner and Smith (1955b).
44	Desert Queen (J. Heigis ? property) and C. Maynor property.	Fort Union	Gray to light-brown medium- and fine-grained to conglomeratic sandstone.	Abundant carbonized plant remains.	*P-1*, *V-1*, *V-2*.	Gruner and others (1956).
45	Jerrie-Marie No. 1	Tensleep	Hard buff fine-grained sandstone.		*Si-1*, Us	Gruner and Knox (1957).
			Washakie County			
46	Gag claims		Light-colored calcareous sandstone. (Cretaceous and Jurassic.)	Abundant carbonized plant remains.	Us	
47	Packer group (Arlostan)	Morrison	Shale		P-1	Wilson (1959; 1960).
48	Scorpion claims		Light-colored coarse-grained sandstone. (Cretaceous and Jurassic.)	Abundant carbonized plant remains.	Si-2	
			Big Horn County			
49	Unnamed prospects	Morrison	Sandstone(?)			G. L. Brooke (1953*).
50	Sanguine No. 12‡	{Cloverly {Morrison	}Shaly sandstone			
	Shell Creek prospects	Morrison	Gray medium-grained sandstone and fossil bones.	Carbonized plant remains and silicified logs.		Wilson (1959; 1960).
51	Big Hill group and Lucky Strike claim.	{Cloverly {Morrison	}Gray clay	Abundant carbonized plant remains.	*Su-3*	Gruner and Smith (1955b).
52	Sun Up group	Morrison	Gray silty sandstone	Some carbonized and silicified plant remains.	Us	Do.
53	Unnamed (anomaly No. 1)	Morrison(?)	Dark-green shale		P-1	Barrett (1953).

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock: Formation	Host rock: Description	Host rock: Kind and abundance of carbonaceous materials	Uranium minerals	Sources of data
			WYOMING—Continued			
			Big Horn County—Continued			
54	Asay-Egbert claim and Dry Creek.	Morrison	Siltstone, sandstone, and shale.	Carbonized seams	U	
55	Crooked Creek group	Cloverly Morrison	Sandstone and shale	Carbonized plant remains		
56	Unnamed anomaly	([8])	Sandstone(?)			G. L. Brooke (1953*).
			Hot Springs County			
57	Name unknown	([8])	Sandstone(?)			G. L. Brooke (1953*).
			Park County			
58	Spirit Mountain Uranium Exploration, Inc.	Cloverly Morrison	Sandstone and shale	Carbonized plant remains	P-1	Wilson (1959; 1960).
59	Gail claim‡	Phosphoria	Shale(?)			G. L. Brooke (1953*).
60	Waggoner claims‡	Flathead	Quartzite(?)			Do.
61	Big Wind	Cloverly Morrison	Greenish-gray shale	Abundant carbonized plant remains.	P-1	Wilson (1959; 1960).
			Teton County			
62	3-R mine	Morrison	Sandstone(?)	Carbonized plant remains	U	
			Fremont County			
63	Name unknown‡	Aycross	Carbonaceous shale	Abundant, disseminated		Wilson (1959; 1960).
64	Arrowhead (Little Mo) mine, Hesitation No. 1, and other prospects.	Tepee Trail	Granite boulder conglomerate; bentonitic claystone matrix; partly eluvial.		*O-1, P-1, Si-1, Si-2.*	Love (1954a); Gruner and Smith (1955b); Wilson (1959; 1960).
65	Kermac No. 1 mine, Mac, and other prospects.	Tepee Trail	Green bentonitic claystone and gray coarse-grained arkosic sandstone.		A-2?, *C-1, P-1, Si-1.*	Love (1954a); Gruner and Smith (1955b).
	Bonanza mine and Gem No. 1 prospect.	Wind River	Carbonaceous siltstone and brown to yellow medium-grained sandstone.	Abundant in siltstone	*O-1, O-2, O-4, P-1, P-6, Si-1.*	Gruner and others (1956); Wilson (1959; 1960).
66	Pan group #		Mudstone concretions and dark-gray fissile shale. (Jurassic.)		N	
67	Big Red No. 4§	Tensleep	Well-sorted fine-grained sandstone.		V-1	Wilson (1959; 1960).
	Little Story group ‡ †	do	Gray to black variegated fine- to medium-grained quartzose sandstone.		*V-1*	Gruner and others (1956).
68	Popo Agie No. 1 ‡	do	White fine-grained quartzose sandstone.		*V-1, V-2*	Gruner and Smith (1955b).
	Two C No. 1	Phosphoria	White silty to fine-grained cherty sandstone.		V-1	
69	King ‡		Sandstone(?). (Eocene.)		Us	
70	B & H No. 1 claim ‡ #	Wind River	Gray sandy mudstone		N	
71	Skrubal No. 14		Light-buff to brown friable sandy mudstone. (Eocene.)	Abundant asphaltite(?)		Zeller and Soister (1956).
72	Canary		Light-gray to buff very fine to coarse grained arkosic sandstone. (Eocene.)		*V-2*	Gruner and others (1956).
73	Cochan (Cochran) mine		Coarse-grained sandstone and gray conglomeratic arkosic sandstone. (Eocene.)	Abundant asphaltite	*P-1, Si-1*	Zeller and Soister (1955); Gruner and others (1956); Wilson (1959; 1960).
74	Hades No. 17		Light-gray fine- to medium-grained conglomeratic arkosic sandstone. (Eocene.)		*V-1*	Gruner and others (1956).
75	B & H group	Wasatch	Gray to brown sandstone		Us	
76	Sno-Ball and other mines	do	Poorly sorted coarse-grained arkosic sandstone, and mudstone.	Sparse to abundant carbonized plant remains.	*C-1, O-1, P-1, P-5, Si-2,* Su-2.	Gruner and Smith (1955b); Grutt (1956); Gruner and others (1956); Whalen (1956); Stephens (1964).
77	Hazel No. 3† and Beatrice†	Cody Chugwater	Light-gray to buff mudstone and siltstone, and gray to green glauconitic gypsiferous shale.	Abundantly disseminated in mudstone.	*P-1, P-5, Si-2.*	Stephens (1955, 1964); Gruner and Smith (1955b); Melbye (1957).
	Mountain Mesa Uranium Co. property (sec. 9)†.		Gray to light-brown medium-grained sandstone. (Cambrian.)		*P-1, Si-2*	Stephens (1964); Melbye (1957).
	Helen May mine§, Shinkolobwe (sec. 16)§, and other deposits§.	Wasatch	Light-gray to buff fine- to coarse-grained and medium-grained arkosic sandstone, and conglomerate.	Sparse to abundant carbonized plant remains.	*O-1, O-2, P-1, P-5, Si-1, Si-2, V-2.*	Gruner and Smith (1955b); Whalen (1956); Melbye (1957); Stephens (1964).
78	Loma Uranium Co. property#	do	Sandstone(?)			

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			WYOMING—Continued			
			Fremont County—Continued			
78	—Continued Various prospects		White to gray coarse-grained arkosic sandstone. (Eocene.)	Abundant carbonized plant remains.	Us	
79	Western Nuclear (sec. 32, T. 32 N., R. 91 W.).	Wind River	Sandstone			Zeller and Bergin (1957).
80	Day Loma pit, Phil group, Bart group, and other mines.	do	Gray to buff medium- to coarse-grained arkosic sandstone, and granite-pebble conglomerate.	Some carbonized plant remains.	*A-2, P-1, P-2, P-5, P-6,* Si-2.	Love (1954b); Gruner and Smith (1955b); Zeller and others (1956).
81	Bull Rush, Stan, and other mines.	do	Medium to very coarse grained arkosic sandstone.		*P-1, P-3, Si-2, Si-3, V-1, V-2.*	Love (1954b); Gruner and Smith (1955b); Zeller and others (1956); Gruner and others (1956); Grutt (1957).
82	Lucky Mc, John No. 2 (Vitro), and other mines.	do	Grayish-yellow to brown coarse-grained arkosis sandstone, conglomeratic sandstone, coal, and carbonaceous shale.	Coal disseminated in shale	*A-1, C-4, C-5, M-1, O-1, P-1, P-2, P-3, P-5, P-6, Si-1, Si-2, Si-3, Si-6, Su-3.*	Love (1954b); Gruner and Smith (1955b); Gruner and others (1956); Zeller and others (1956); Grutt (1956, 1957); Coleman and Appleman (1957); Zeller and Bergin (1957).
	Lucky Mc (See also above.)	Morrison	Light-greenish-gray fine-grained, well-sorted sandstone.	None	*P-1,* Si-5?	Gruner and Smith (1955b); Zeller and others (1956).
83	P-C and other mines (See also Natrona County.)	Wind River	Arkosic sandstone		*P-1, P-6*	Love (1954b); Gruner and Smith (1955b); Zeller and others (1956); Erickson (1957); Zeller (1957b).
			Natrona County			
83	Al Job (Pay) No. 9, Ranrex, and other mines. (See also Fremont County.)	Wind River	Yellowish-gray fine- and coarse-grained sandstone, reddish-brown granite- and quartzite-pebble conglomerate, and brown micaceous carbonaceous shale.	Abundantly disseminated in shale; some petroliferous concretions in sandstone.	*O-1, P-1, P-2, P-6, V-2.*	Love (1954b); Gruner and Smith (1955b); Gruner and others (1956); Zeller and others (1956); Erickson (1957); Zeller (1957b).
84	Wentz mine and various prospects.	do	Sandstone		P-2	Gruner and others (1956).
85	Dick and other claims	do	Light-buff coarse to very coarse grained and conglomeratic arkosic sandstone, carbonaceous siltstone, and brown sandy mudstone.	Abundantly disseminated in siltstone.	N	
86	Bridger Trail No. 1 claim and T-bone mine.	do	Light-gray to brown coarse-grained arkosic sandstone.	Abundant carbonized plant remains.	P-2. V-1	Rich (1955).
87	Split Rock		White tuffaceous shale, and limestone. (Pliocene.)			Love (1953b).
88	Last Chance		Sandstone. (Miocene and Oligocene.)			
89	Verna Bell claims	Wind River	Conglomeratic sandstone	Carbonized plant remains	N	Gruner and Smith (1955b); Rich (1956).
90	Name unknown‡	[8]	Sandstone(?)			
91	Phyllis claims	Wind River	Gray to buff medium- to coarse-grained sandstone.	Abundant carbonized plant remains.	P-1, P-4	Rich (1956); Wilson (1959; 1960).
92	Pine Tree group and Pipe Dream claims.	do	Arkosic sandstone with clay galls.	Some lignite	*P-1*	Gruner and others (1956).
	Clarkson Hill occurrence	White River	Carbonaceous siltstone, and sandstone.	Abundantly disseminated in siltstone.		Rich (1956); Wilson (1959; 1960).
93	Black Cat group	Wind River	Buff to brown coarse-grained arkosic sandstone and carbonaceous shale.	Abundantly disseminated in shale.	U	
94	Dyper-Bar-Mac group	Morrison(?)	White siltstone and mudstone.	Fossil bones	P-6	Gruner and others (1956).
95	Dry Lake (Lybyer) claims	Mesaverde [32]	Buff fine-grained sandstone and gray to black shale.	Abundant carbonized plant remains.	*V-1*	Do.
	Meyers	[8]	Sandstone (?)		V-1	
96	Baker group	Lance	Light-gray to buff fine-grained quartzose sandstone.	Sparse carbonized plant remains.	Us	
			Converse County			
32	Betty mine and various prospects (See also Campbell County.)	Wasatch	Gray coarse-grained calcareous sandstone, arkosic sandstone, and clay-gall conglomerate.	Some carbonized plant remains.	*P-1, Si-2, V-2.*	Sharp and Gibbons (1964).
97	Great Pine Ridge anomaly No. 4	Fort Union	Brown coarse-grained sandstone.		Us	D. N. Magleby and G. M. Collins (1952*).
98	Wm. Moore Fee land	Wasatch	Buff to light-gray coarse-grained arkosic sandstone.	Some carbonized plant remains.	Us	Mrak (1958).
99	Birthday group	do	Buff medium-grained arkosic sandstone.	Abundant carbonized plant remains.	Us	

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			WYOMING—Continued			
			Converse County—Continued			
100	Pat, D-10, Hardy Fee land, Dead Cow (D-9), and other mines.	Wasatch	Gray calcareous grit, and dark-gray coarse-grained calcareous sandstone.	Abundant carbonized plant remains.	*C-5, O-1, O-2, S-2, V-1, V-2.*	Gruner and Smith (1955b); Gruner and others (1956); McDaniel and others (1956); Sharp and Gibbons (1964); Mrak (1958).
101	D-7 mine and various prospects.	do	Light-colored medium-grained sandstone.	Some carbonized plant remains.	V-1	Mrak (1958).
102	D-5	do	Sandstone			
103	Box No. 4, Lamb No. 3, and other mines.	do	Buff to light-gray fine-grained to conglomeratic arkosic sandstone.	Some carbonized plant remains.	*V-2*	Geslin and Bromley (1957); Sharp and Gibbons (1964); Mrak (1958).
104	Trading Post (Lila Buzz?) mine and Mesa No. 5 claims.	do	Buff coarse-grained to conglomeratic arkosic sandstone, locally calcareous.	None	Us	
105	E. Simon and J. Keenan prospect.	Fort Union	Claystone	Some carbonized plant remains.	*P-1*	
106	Betzer lease	White River	Conglomerate			
107	Name unknown‡		Sandstone(?). (Miocene and Oligocene.)			
108	Lucky Ann Nos. 1 and 3, Catus No. 4 claim‡, and various prospects.		Opalized siltstone, brecciated, and gray to green conglomeratic sandstone and shale. (Miocene and Oligocene.)		*V-2*	Gruner and others (1956);
109	Judy No. 14, Lost Springs, and Henry Reese Fee land.	Fort Union	Reddish-brown to gray medium-grained sandstone.	Seams of carbonaceous material.	*A-1, P-2*	Gruner and Smith (1955b).
			Niobrara County			
110	Walts No. 2 (Clark) claim, George Storey claim, and other prospects.	Lakota	Buff to gray fine-grained to silty sandstone.	Abundant along bedding planes.	*O-1, Si-2, V-1.*	Gruner and others (1956); Wilson (1959; 1960); Gruner (1959).
111	Scott group	White River	Calcareous conglomerate		V-1	
112	Moore group	do	Poorly consolidated conglomeratic sandstone and bentonite.	Some carbonized plant remains and silicified bones.	C-1, *Su-3, V-2.*	Bromley (1955); Gruner and Smith (1955b).
113	Old Rocky claims, Davis Fee land, and other prospects.	do	White and gray coarse-grained to conglomeratic arkosic sandstone.		*P-1, Si-2, V-2.*	Gruner and Smith (1955b); Gruner and others (1956).
114	Happy Jack claims (Nelson ranch), Western Uranium Co. mine, and various prospects.	do	White to light-brown coarse-grained conglomeratic sandstone.	None	Si-2, V-2	Bromley (1955).
115	Drifter	do	Sandstone(?)			
116	Alter‡	do	Chalcedony in sandstone(?)			
117	Allsup	do	Gray medium- to coarse-grained arkosic quartzose sandstone.		N	
118	Silver Cliff mine		Brown to black calcareous quartzose sandstone. (Cambrian?)	None	*C-5, O-1, O-3, P-2, Si-2, Si-9.*	Lind and Davis (1919); George (1949); Wilmarth and Johnson (1954); Outerbridge and others (1960).
			Goshen County			
119	Spoon Buttes locality	Ogallala(?)	Gravel	Fossils		Love (1953).
			Platte County			
120	Unnamed locality‡		Sandstone. (Miocene.)			
			Albany County			
121	Desert Rose claim	Cloverly	Buff very fine to medium grained sandstone.	Abundant carbonized streaks.	*V-2*	Love (1955b).
122	Unnamed prospects	Morrison	Hard dark-gray mudstone	Abundant carbonized plant remains.	N	
123	Unnamed locality	Wind River	Conglomeratic sandstone	do		Love (1956).
124	Nu-Hot Spot No. 7	White River	White to buff very coarse grained tuffaceous sandstone.		N	

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and groups of deposits of uranium in sandstone in the United States by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			WYOMING—Continued			
			Carbon County			
125	Shirley Basin deposits, south area.	Wind River	Coarse-grained arkosic sandstone.			Wilson (1959; 1960).
126	Shirley Basin deposits, north area.	do	White to light-gray very coarse grained to conglomeratic arkosic sandstone.		*V-2*	Gruner and Knox (1957); Wilson (1959; 1960).
127	Shirley Basin deposits, west area.	do	Coarse-grained arkosic sandstone.			Wilson (1959; 1960).
128	Union Pacific prospect†	Tensleep	Calcite veins in sandstone		*V-2*	Wood (1956, table 1, no. 59).
	Unnamed locality§	North Park(?).	Gray bentonitic sandstone and waxy claystone.		*V-1*	Love (1955a).
129	Lucky Annie (Anne?)#	Medicine Bow.	Sandstone(?)		*V-2*	Gruner and Smith (1955b).
130	Sunset No. 1 claim	Fort Union	Light-gray to brown fine- to coarse-grained arkosic sandstone.	Carbonaceous shale underlies the sandstone.	Us	
131	Unnamed prospects†	Browns Park	Light-brown to gray fine-grained tuffaceous sandstone, carbonaceous shale, and white chalcedonic limestone.		V-1	Love (1954a).
	Unnamed prospect§	North Park	Fine-grained calcareous sandstone.		Us	Magleby and Mallory (1954).
132	Unnamed (locality 1), Snipper (locality 2), and unnamed (locality 18).	North Park(?).	Light-brown very fine to coarse grained sandstone, light-gray clayey siltstone, and ash.		Us	Magleby and Mallory (1954); Stephens and Bergin (1959).
133	Unnamed (locality 16)	do	Limy sandstone			Stephens and Bergin (1959).
134	Unnamed (locality 35)	North Park	Dark-gray fine-grained silicified sandstone.		Us	Magleby and Mallory (1954).
135	Unnamed (locality 37)	Browns Park(?).	Fine-grained calcareous sandstone.			Do.
	Unnamed (locality A-2)	North Park	Brown sandstone			Vine and Prichard (1959).
136	Unnamed (locality 25)	North Park(?).	Fine-grained sandstone			Magleby and Mallory (1954).
137	Cloudy and other claims	do	Silty sandstone		P-2?	
138	Del Oro No. 2# and other Ketchum Butte claims.	North Park	Buff to brown medium-grained sandstone.		C-1, *P-6*, V-1	Magleby and Mallory (1954); Gruner and others (1956).
139	Crescent Uranium group	Browns Park.	Conglomerate		N	
140	Poison Basin group, Teton group (includes school section), Cedar Hills (pit 1), and various prospects.	do	Light-brown medium-grained quartzose sandstone and light-gray fine-grained calcareous sandstone.	Sparse carbon	*C-1, P-1, Si-1, Si-2, V-1.*	Vine and Prichard (1954); Magleby and Mallory (1954); Grutt and Whalen (1955); Gruner and Smith (1955b).
			Sweetwater County			
141	Hays claims	Wasatch	White to gray coarse-grained arkosic sandstone.		N	
142	Unnamed (anomaly B17-69)	do	Coarse-grained arkosic sandstone.		Us	
143	Unnamed (anomaly B17-73)	Wasatch(?)	Light-brown poorly consolidated arkosic gravel.		Us	
144	Lost Creek (Golden Arrow group).	Wasatch	Green to gray-green siltstone and shale.		*C-1, Si-2*	Wyant and others (1956); Sheridan and others (1961)
145	Lone Wolfe and unnamed prospects.	Wasatch(?)	Sandstone(?)		*O-2, Si-2*	Gruner and others (1956).
146	Lone Wolf Nos. 6 and 13	Wasatch	Buff to gray medium- to coarse-grained sandstone.	Abundant carbonized plant remains.	Us	
147	Bison Basin prospect	do	Conglomerate		U	
148	Superior occurrence		Conglomeratic tuffaceous sandstone. (Cretaceous.)			Theobald and King (1954).
	Mud Nos. 1 and 2 claims	Ericson	Fine- to medium-grained sandstone and dark-gray sandy shale.	Abundant coal and carbonaceous shale.	*C-1, P-1*	Gruner and Knox (1957).
149	Unnamed (anomaly 57-7)	do	Medium-grained sandstone and brown carbonaceous shale.	Abundant in shale	Us	
150	Sand Rock claims	do	Gray fine-grained sandstone, carbonaceous shale, and coal.	Abundant in shale and coal		
151	Lucky Turk claims and Yellow Rose Nos. 1 and 2.	do	Gray fine- to medium-grained quartzose sandstone.	Interbedded carbonaceous shale.	*Si-2*	Gruner and Knox (1957).
152	John group	Bridger	Buff to brown fine-grained sandstone.		C-1	
153	Mud claims	Ericson	Gray sandstone	Carbonized plant remains	Us	
154	Pine group	{Green River / Wasatch	}Claystone and fine-grained sandstone.	do	N	
	Star Nos. 5 and 6 claims	Wasatch(?)	Buff fine- to coarse-grained sandstone.		N	

See footnotes at end of table.

TABLE 2.—*Major characteristics of individual deposits and gro ups of deposits of uranium in sandstone in the United States, by States*—Continued

Map No.	Name of locality	Host rock			Uranium minerals	Sources of data
		Formation	Description	Kind and abundance of carbonaceous materials		
			WYOMING—Continued			
			Sweetwater County—Continued			
155	Little Mountain	Green River, Wasatch	Gray calcareous sandstone			Theobald and King (1954).
156	Red Jeep No. 1 claim	Fort Union(?)	Gray fine- to medium-grained sandstone.	Very abundant carbonized plant remains.	N	
157	Unnamed (anomalies B-16-1, -2, -3).	Green River	Sandstone(?)			Magleby and Meehan (1955).
158	Spirit, Uinta, and Indian Paintpot claims.	Green River or Bridger.	Clastic rock	Abundant carbonized plant remains.		

1. Salt Wash Sandstone Member.
2. Shinarump Member.
3. DeChelly Sandstone Member.
4. Petrified Forest Member.
5. Trinity Group.
6. Tropico Group.
7. Coldwater Sandstone Member.
8. Mesaverde Group.
9. Brushy Basin Shale Member.
10. Newark Group.
11. Germer Tuffaceous Member.
12. Sante Fe Group.
13. Recapture Shale Member.
14. Westwater Canyon Sandstone Member.
15. Dockum Group.
16. Jackpile sandstone of local usage.
17. Sentinel Butte Member.
18. Ludlow Member.
19. Newcastle Sandstone Member.
20. Inyan Kara Group.
21. Clear Fork Group.
22. Jackson Group.
23. Stone's Switch sand.
24. Falls City shale.
25. Dubose sand and clay.
26. Olmos sand.
27. Moss Back Member.
28. Monitor Butte Member.
29. Arkose facies.
30. Cedar Mesa Sandstone Member.
31. Springdale Sandstone Member.
32. Teapot Sandstone Member.

Most of the peneconcordant deposits are in four general regions. About 95 percent of these are in the west-central part of the United States and extend over an L-shaped region stretching southwestward from eastern Montana and western North Dakota through parts of South Dakota, Wyoming, Colorado, and Utah into Arizona and New Mexico and thence eastward into northern Texas and southern Oklahoma. The southwest-trending arm in this region includes the highly productive deposits of the Colorado Plateau and of the intermontane basins of Wyoming. The principal mining districts in this arm are identified on figure 1. The other 5 percent of the peneconcordant deposits are clustered chiefly in southern California, on the Texas Coastal Plain, and in eastern Pennsylvania.

Of the 4,600 known deposits, about 200 are classed as veins. The known vein deposits are widely scattered in the Western States, and are a little more abundant in the Basin and Range province of southern California, Nevada, and southern Arizona than elsewhere (pl. 1). Some are geographically close to peneconcordant deposits, but many are remote.

STRATIGRAPHIC DISTRIBUTION OF DEPOSITS

AGE OF HOST ROCKS

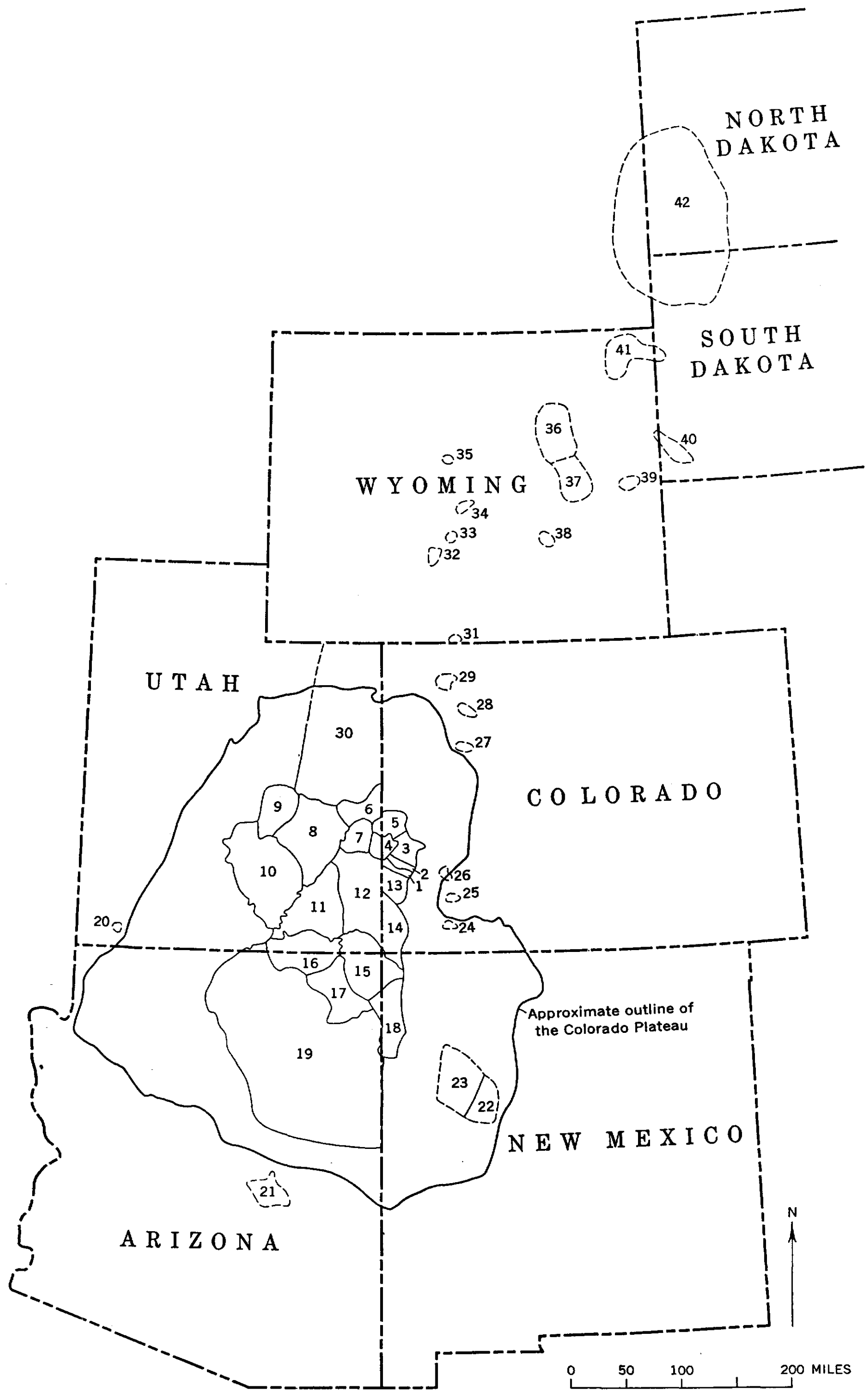
Uranium deposits in sandstone in the United States occur in stratigraphic units of every geologic system except Silurian. Beds of Late Jurassic age contain the most deposits—about 60 percent of the total ore, calculated in terms of produced ore plus reserves (fig. 2). Beds of Eocene and Late Triassic ages contain about the same number of deposits, but the Eocene rocks contain about 25 percent of the total ore and Triassic rocks only about 10 percent. The age distribution of the host rocks of vein deposits differs strikingly from that of the peneconcordant deposits.

Sandstone beds of Precambrian age, which contain no peneconcordant deposits, contain about 30 percent of the 200 vein deposits of uranium in sandstone in the United States; and those of Miocene age, which contain only 1½ percent of the peneconcordant deposits, contain 15 percent of the vein deposits. The age distribution of the host rocks of the rest of the vein deposits probably should be considered as haphazard, though figure 2 suggests a possible crude correlation of this distribution with that of the peneconcordant deposits. Some vein deposits are closely associated with peneconcordant ores and result from the localization of secondary uranium minerals along fractures that cut the peneconcordant ore bodies; such occurrences may contribute to this possible crude correlation.

In rocks of late Paleozoic age and younger, the abundance of peneconcordant deposits correlates partly with the evolutionary development of land plants in late Paleozoic time and with the abundance of plant fossils in them and in younger rocks.

The several members of the Morrison Formation of Late Jurassic age in the Colorado Plateau region contain most of the peneconcordant deposits. In this region, the members of the Chinle Formation of Late Triassic age also contain abundant deposits. Deposits in rocks of Eocene age occur mostly in the intermontane basins of Wyoming, mainly in the Wasatch and Wind River Formations. Most of the deposits in formations of Cretaceous age are in units of the Inyan Kara Group around the Black Hills of South Dakota and Wyoming, but some are in the Dakota Sandstone at widely scattered places in Colorado and New Mexico. The deposits in beds of Permian age are mainly in Colorado, New Mexico, Oklahoma, and northern Texas. Deposits in Texas in the Coastal Plain are in rocks of Eocene, Miocene, and Pliocene ages. The deposits in Pennsylvania are in rocks of Devonian, Pennsylvanian, and Triassic ages.

About 140 stratigraphic units contain the known deposits of uranium in sandstone in the United States. These units are listed in age sequence in table 3, which also summarizes information on the composition and depositional environment of these units and cites reports that describe these units in more detail.



1. Gypsum Valley.
2. Bull Canyon.
3. Uravan.
4. Paradox.
5. Gateway.
6. Thompsons.
7. Moab.
8. Green River (Desert).
9. San Rafael (Sinbad).
10. Henry Mountains.
11. White Canyon.
12. Monticello.
13. Slick Rock.
14. Cortez
15. Shiprock.
16. Monument Valley.
17. Chilchinbito.
18. Chuska.
19. Little Colorado.
20. Silver Reef (Harrisburg).
21. Sierra Ancha.
22. Laguna.
23. Ambrosia Lake (Grants).
24. La Plata.
25. Rico.
26. Placerville.
27. Rifle.
28. Meeker.
29. Maybell-Lay.
30. Uinta.
31. Poison Basin (Baggs).
32. Lost Creek.
33. Crooks Gap.
34. Gas Hills.
35. Owl Creek Mountains.
36. Central Powder River Basin.
37. Southern Powder River Basin.
38. Shirley Basin.
39. Lance Creek.
40. Edgemont.
41. Northern Black Hills.
42. Dakota Plains.

FIGURE 1.—Index map showing location of uranium-mining districts in West-Central United States described in this report Indefinite boundaries indicated by dashed lines.

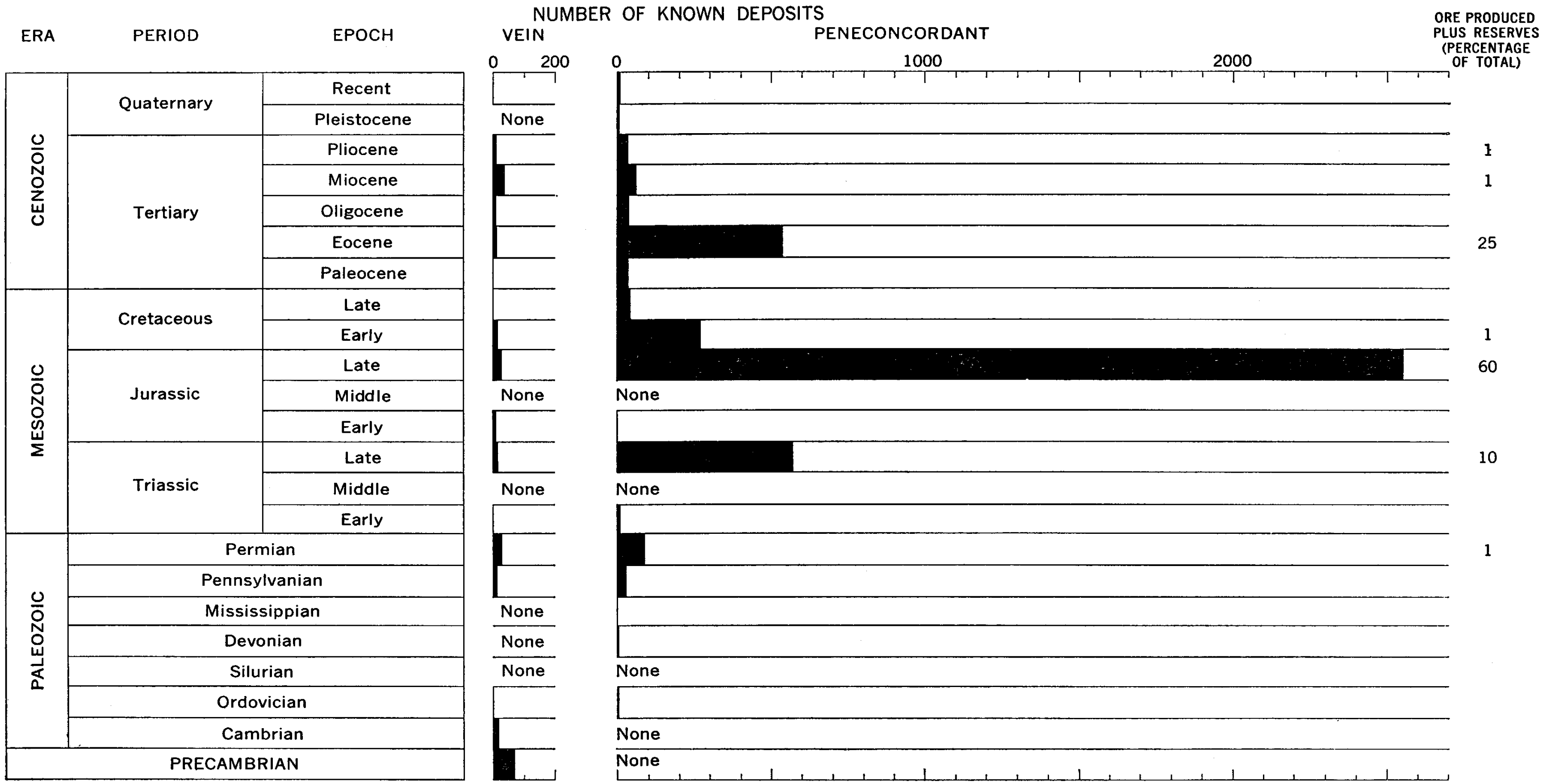


FIGURE 2.—Distribution of uranium deposits and ore in sandstone in the United States by geologic age of the host formation.

TABLE 3.—*Stratigraphic units that contain uranium deposits in sandstone in*

[The stratigraphic nomenclature used in this table is from many sources and may or may not agree with that currently accepted by the U.S. Geological Survey. Stratigraphic shown in *italic* have produced or have reserves of more than 1,000 tons of uranium ore; those marked by a dagger (†) have produced or have reserves of 1–1,000 tons of ore. units is an interpretation made by the author based on the descriptions given in the sources of data. A brief description of the environment is given where possible. The conditions such as terrestrial, fluvial, paludal, and lacustrine. Asterisk (*) by date of source of data indicates written commun.; double asterisk (**), oral commun.]

	Stratigraphic unit	Age	States where uranium bearing	Description	Thickness (feet)
			Quaternary and Tertiary Systems		
1	Coso Formation†	Early Pleistocene or late Pliocene.	California	Poorly cemented fine- to coarse-grained arkosic sandstone, tuffaceous and bentonitic beds, and basal fanglomerate.	300+
2	Gila Conglomerate	Pleistocene and Pliocene	Arizona	Red and gray clay and silt grade laterally into fanglomerate	0–200
3	Idaho Formation	do	Oregon	Light-colored poorly consolidated shale, sandy near top and bottom, few volcanic ash and diatomite beds.	Several thousand.
4	*Santa Fe Group*	Pleistocene(?) to middle(?) Miocene.	New Mexico	Tuff; sandstone; red and green clay, silt, and gravel; basalt and rhyolite flows.	2,000+
5	Verde Formation	Pleistocene or Pliocene(?)	Arizona	White sand, clay, limestone, gravel, and saline materials	1,400–2,000
			Tertiary System		
6	Antero Formation	Oligocene	Colorado	Upper member—conglomerate and sandy interbeds Middle member—fine-grained tuff, shaly beds, and limestone Lower member—conglomerate and thin beds of limestone	2,000−
7	Arikaree Formation	Miocene	South Dakota	Gray tuffaceous siltstone and sandstone, a few thin beds of conglomerate and volcanic ash.	0–500
8	Artillery Formation	Early(?) Eocene	Arizona	Chiefly conglomerate, arkose, sandstone, shale, and limestone; sparse clay and tuff; a widespread basalt member.	2,500+
9	Aycross Formation	Middle Eocene	Wyoming	Brightly variegated clay, shale, sandstone, conglomerate, and tuff; great lateral variations in lithology.	100–1,000
10	Baca Formation†	Eocene(?)	New Mexico	Maroon to brick-red and variegated shale, siltstone, graywacke, sandstone, and conglomerate; some volcanic sediments.	80–140
11	Barstow Formation	Late or middle Miocene	California	Coarse to fine rock fragments, pumice, and tuff; local basalt flows	60±
12	Bidahochi Formation†	Pliocene	Arizona	Upper member—fine- to medium-grained clayey sandstone and rhyolitic ash. Middle member—basaltic flows, tuffs, and ashes Lower member—mudstone, clayey fine-grained sandstone and rhyolitic ash.	0–450
13	Bridger Formation	Late(?) and middle Eocene.	Wyoming	Greenish-gray to white tuffaceous sandstone and shale; marlstone and conglomerate.	0–2,500
14	*Browns Park Formation*	Miocene(?)	Wyoming, Colorado	Buff to light-gray soft friable very fine to medium grained sandstone; few thin beds of claystone. Two facies: upper is tuffaceous and basal is conglomerate.	1,800+
15	Brule Formation	Late and middle Oligocene.	Nebraska	Pinkish siltstone, silty clay, and sandstone; locally gypsiferous	250–500
16	Catahoula Tuff	Miocene(?)	Texas	Gray and brownish medium to coarse sand (20–30 percent), tuff (60 percent), and bentonitic clay (10–20 percent); minor conglomerate and lignite.	150–1,000
17	Chadron Formation	Early Oligocene	North Dakota, South Dakota.	Gray silty clay, some of which is bentonitic and opalized; minor sandstone.	0–160

the United States and a summary of the geologic characteristics of these units

unit listed alphabetically under systems; where uranium content justifies such listing, members are listed individually and from younger to older within formations. Units All other units contain either any amount of rock having a grade less than 0.10 percent U_3O_8 or less than 1 ton of ore. Environment of sedimentation of many stratigraphic term "nonmarine" is used where the environment may include transitional conditions such as littoral, deltaic, lagoonal, and estuarine, as well as or instead of continental

Host rocks of uranium		Plant fossils	Sedimentary structure	Environment of sedimentation	Sources of data	
Character	Mineral content					
Quaternary and Tertiary Systems—Continued						
Arkosic sandstone		None reported	Well stratified, thinly bedded.	Sandstone and tuff are lacustrine; fanglomerate is fluvial. Source of sediment was underlying granite and nearby tuffs.	Schultz (1937); Hopper (1947); Troxel and others (1957); Oakeshott and others (1954).	1
Siliceous clay		Some silicified wood (sassafras?).	Clay and silt, thinly bedded; conglomerate, lenticular.	Lacustrine, alluvial fans, and delta.	Knechtel (1937)	2
Clayey rock		Abundant carbonized(?) and silicified wood.	Well stratified	Chiefly ephemeral lakes; locally flood-plain, alluvial-fan, and deltaic environments.	Kirkham (1931)	3
Tuff and sandstone		Some plant remains (legume and rush); waterworn silicified wood.	Lenses, crossbedded	Alluvial fan, fluvial. Depositional areas were fault block(?) basins.	Denny (1940); Dane and Bachman (1957).	4
Tuffaceous sediments		None reported	Horizontally and evenly bedded.	Lacustrine	Jenkins (1923)	5
Tertiary System—Continued						
Tuffaceous sandstone		Carbonized and silicified wood (*Pinus* and others) very abundant in some beds, especially near top of upper member.	Lenses and irregular beds of sandstone, thinly bedded shale.	Fresh-water lacustrine	Stark and others (1949)	6
Sandstone		Present(?)	Medium to thickly bedded; some channel fills.	Fluvial	Darton (1951); Gill and Moore (1955).	7
Mudstone, limestone, and conglomerate.		Rare silicified and calcitized palm roots.	Indistinctly bedded	Conglomerates were alluvial fans; other rocks were partly lacustrine. Depositional area was a fault valley(?).	Lasky and Webber (1949)	8
Carbonaceous shale		Abundant in some shale; less abundant in tuff.	Crossbedded and massive or thinly bedded.	Fluvial	Love (1939)	9
Sandstone Arkosic sandstone Conglomerate	Quartz, feldspar; calcareous cement.	Abundant fossil wood near the base.		do	Wilpolt and others (1946); Dane and Bachman (1957).	10
Clayey shale, tuffaceous marly sandstone.		Present(?)	Well stratified	Nonmarine	Hewett (1954); Oakeshott and others (1954).	11
Fine-grained clastics and lapilli tuff.		Plant impressions and petrified wood in lower member.	Upper member—crossbedded, channel fills. Lower member—horizontally and thinly bedded, ripple marked.	Upper member fluvial. Middle member volcanic. Lower member lacustrine.	Repenning and Irwin (1954); Shoemaker (1956b).	12
Sandstone		Present(?)	Lenticular	Fluvial and fresh-water lacustrine.	Sears and Bradley (1924); Love and others (1955).	13
Tuffaceous and nontuffaceous sandstone.	Quartz, feldspar, volcanic glass; clay and calcium carbonate cements.	None reported	Poorly stratified, massive, crossbedded.	Fluvial and eolian facies distinct from lacustrine facies. Uranium deposits are in rocks where the two facies interfinger.	Bergin (1957)	14
Gypsiferous clay		Locally abundant macerated carbonized plant fragments.	Thinly bedded, channel fills.	Fluvial and lacustrine	Lugn (1939); Condra and Reed (1943); Dunham (1955).	15
Quartzose sandstone	Quartz	Some silicified wood (*Palmoxylon*) and carbonized plant(?) remains.	Crossbedded, lenticular	Fluvial	Plummer (1933, p. 710–727); Steinhauser and Beroni (1955); Eargle and Snider (1957).	16
Clay and sandstone		Some lignitic material	Channel fills, lenses	Fluvial. Sources of sediment were Pierre, Hell Creek, and Fort Union Formations and volcanoes in the Yellowstone region.	Wood (1949); Gill and Moore (1955).	17

TABLE 3.—*Stratigraphic units that contain uranium deposits in sandstone in the*

	Stratigraphic unit	Age	States where uranium bearing	Description	Thickness (feet)
			Tertiary System—Continued		
18	Challis Volcanics, Germer Tuffaceous Member.	Early Miocene or late Oligocene.	Idaho	Tuff, tuffaceous sandstone, conglomerate, and rhyolite flows	0–2,000+
19	Clarno Formation	Late Eocene	Oregon	Coarse and fine rock and volcanic debris; local basalt flows	7,000
20	Esmeralda Formation	Early Pliocene and late Miocene.	Nevada	White rhyolitic tuff and flows; sandstone, siltstone, and claystone.	600+
21	Farisita Conglomerate †	Oligocene(?)	Colorado	Buff conglomerate, conglomeratic sandstone, and siltstone	0–1,200
22	Fort Union Formation †	Paleocene	Wyoming, Montana, North Dakota, South Dakota.	{Sentinel Butte Member—see No. 23 Tongue River Member—gray to tan sandstone, siltstone, and shale; quartzite lenses; persistent lignite beds. Cannonball Member—dark-gray and brown sandstone and shale. Ludlow Member—see No. 24	0–660 600+ 0–300 350
23	Sentinel Butte Member	do	North Dakota	Dark-gray bentonitic claystone and shale and buff to brown sandstone containing numerous lignite beds.	0–660
24	Ludlow Member	do	South Dakota	Gray to light-yellow-tan sandstone, gray shale, and thick lignite beds.	350
25	Green River Formation †	Middle and early Eocene.	Utah, Wyoming	Gray fissile shale and oil shale, gray to buff sandstone and limestone, oolitic layers, and algae reefs.	1,200–4,900
26	*Goliad Sand*	Pliocene	Texas	Limy clay, very fine to medium sand, and gravel	250±
27	Illahe Formation	Oligocene	Oregon	Tuffaceous sandstone and shale intruded by basaltic dikes and sills.	800–1,000
28	*Jackson Group* (see also Whitsett Formation, Nos. 51–54).	Eocene	Texas	{Upper part—chiefly tuffaceous sandstone interbedded with bentonitic claystone. Middle and lower parts—chiefly claystone with some interbedded sandstone; lignitic claystone common.	} 500±
29	Monterey Formation	Late and middle Miocene.	California	Light-brown to gray shale and siltstone; minor sandstone and limestone.	6,500±
30	Muddy Creek Formation	Miocene(?)	Arizona	Yellowish and cream-colored silt, fine sand, and clay; grades laterally into coarser slope deposits; some gypsum and salt.	0–2,000
31	North Park Formation	Late Miocene	Wyoming	Pumicite, calcareous siltstone, tuffaceous or calcareous sandstone, and conglomerate; some colluvium.	1,300+
32	Oakville Sandstone	Miocene	Texas	Light-gray sand (40 percent), sandy and ashy or bentonitic clay (30 percent), marl (20 percent), coquina (5 percent), and gravel (5 percent).	200–500
33	Ogallala Formation	Pliocene	New Mexico	Mainly silt and fine sand; scattered lentils of coarse sand, gravel, volcanic ash, and limestone.	10+–550
34	Panaca Formation	do	Nevada	Light-colored tuff, some sand, some dark-colored concretions	1,000+
35	*Popotosa Formation*	Late Miocene	New Mexico	Red, brown, and gray sandstone, silt, tuff, and gravel	3,000+
36	Pruett Formation (Buck Hill Volcanic Series).	Eocene	Texas	Chiefly grayish calcareous tuff; also includes basal limestone-pebble conglomerate, tuffaceous sandstone and breccia, limestone, and trachyte flows.	900–1,000
37	Ricardo Formation	Early Pliocene	California	Arkosic conglomerate, sand, silt, white tuff, cherty limestone, and basalt flows.	7,000−
38	Rosamond Formation	Miocene(?)	do	White tuff, gray sandstone, conglomerate, volcanic flows, and agglomerate.	1,500–4,500+
39	San Jose Formation	Eocene	New Mexico	Red, tan, and variegated clay, siltstone, sandstone, and conglomerate.	1,200±
40	Sespe Formation	Early Miocene to late Eocene.	California	Red, brown, and yellow sandstone and conglomerate; interbedded shale.	3,500–4,000±
41	Tejon Formation, Coldwater Sandstone Member.	Eocene	do	White friable arkosic sandstone interbedded with reddish sandy shale and coquina.	400–2,500
42	*Tepee Trail Formation*	Late Eocene	Wyoming	Green or brown strata: fine-grained tuff (southeast) to conglomerate and coarse breccia (northwest).	2,000−
43	Tiger Formation†	Tertiary	Washington	Conglomerate, sandstone, and claystone; some lignite. Thickness very erratic.	1,000−
44	Tropico Group	Pliocene(?) and Miocene(?).	California	{Upper unit—fanglomerate or sequence of dolomite, limestone, chert, shale, and sandstone. Middle unit—basalt flows. Lower unit—pyroclastic rocks, rhyolitic intrusives, and flow breccia.	} 2,800−

United States and a summary of the geologic characteristics of these units—Continued

Host rocks of uranium		Plant fossils	Sedimentary structure	Environment of sedimentation	Sources of data	
Character	Mineral content					
Tertiary System—Continued						
Tuffaceous sandstone	Quartz, plagioclase, potash feldspar, and biotite; glassy ash matrix.	Abundant carbonized and silicified plant remains (*Sequoia*?).	Well stratified	Water-laid sediments and extrusive igneous rocks.	Ross (1934; 1937); Anderson (1956).	18
Silicified tuff		Abundant		Nonmarine	Stock (1948, p. 332)	19
Tuffaceous sandstone claystone.	Bentonite, collophanite	Some silicified wood (dicotyledon *Cupressus*).	Thinly bedded, sparely crossbedded.	Subaerial and fresh-water lacustrine. Depositional basin was formed in part by block faulting.	Turner (1900); Spurr (1905, p. 51–54); Ferguson and Muller (1950).	20
Carbonaceous sandstone.		Locally abundant carbonized plant remains.	Lenticular and highly crossbedded.	Alluvial fan	Johnson and Wood (1956); Johnson, Wood, and Harbour (1958).	21
Sandstone, siltstone, shale, and lignite.		Abundant plant remains in lignite and shale, and, locally, in sandstone (*Cupressinoxylon*).	Lenses, horizontally bedded.	Cannonball Member (void of uranium deposits) is marine; other members are fluvial, lacustrine, and paludal.	Denson and Gill (1956)	22
Sandstone and lignite		Carbonized plant fragments locally abundant in sandstone and lignite.	Lenses, horizontally bedded.	Fluvial, lacustrine, and paludal.	do	23
Sandstone, phosphatic shale, and lignite.		Abundant plant remains in lignite.	Lenses and thin and flaggy beds of sandstone.	Fluvial, lacustrine, and paludal.	do	24
Sandstone, sandy shale, and mudstone.		Locally thin coal beds and shale containing carbonized plant remains.	Thinly bedded, ripple marked, crossbedded, lenticular.	Lacustrine, minor fluvial	Sears and Bradley (1924); Bradley (1931); Dane (1954).	25
Sandstone	Calcite cement (20 percent).	Some carbonized and silicified wood.	Lenticular, crossbedded	Host beds are either fluvial or deltaic; overlying clay is marine.	Barton (1925); Plummer (1933, p. 750–761).	26
Tuffaceous sandstone		Silicified wood(?)	Thinly bedded, crossbedded.	Mainly marine, alternated with continental environments.	Thayer (1933; 1939); Schafer (1956); R. Q. Lewis (1960**).	27
See Whitsett Formation, Nos. 51–54.		Some lignite beds and locally abundant carbonized wood and flecks.	Lenticular, crossbedded	Cyclic—partly fluvial, deltaic, and swampy; partly marine. Sediments accumulated while volcanoes ejected ash and coarser fragments.	Eargle and Snider (1957); Eargle (1959).	28
Siltstone and shale		None reported	Well stratified; lenses sparse.	Marine	Simonson and Krueger (1942).	29
Clay		do	Regularly bedded, rhythmic banding common.	Mostly lacustrine (interior basin) and alluvial fan sediments.	Longwell (1949, p. 936)	30
Calcareous and tuffaceous sandstone; claystone.		Contains root casts	Crossbedded and channel-fill sandstone and conglomerate; laminated siltstone.	Flood plain, alluvial fan, lacustrine, and sheetwash.	Montagne and Barnes (1957).	31
Sandstone	Quartz, bentonitic clay, volcanic glass(?).	Some silicified wood	Crossbedded, lenticular	Lacustrine, lagoonal, and swampy.	Plummer (1933, p. 734); Eargle and Snider (1957).	32
Clay and sandstone		Fossil grass seeds and fruits of herbs and trees (rare) are widespread.	Lenses, poorly to well stratified.	Chiefly fluvial; locally eolian and lacustrine.	Frye and others (1956); Barker and Scott (1958).	33
Tuff		None reported	Thinly bedded, locally crossbedded.	Water-laid tuff	Westgate and Knopf (1932); Myerson (1956).	34
Sandstone, siltstone, and tuff.		do	Crossbedded and lenticular sandstone; thinly bedded tuff.	Alluvial fan in a closed basin.	Denny (1940); Dane and Bachman (1957).	35
Sandstone, tuff, limestone, and conglomerate.		Petrified tree trunks and carbonized wood fairly common.	Thickly to thinly bedded, crossbedded, lenses.	Fluvial, lacustrine (fresh water).	Goldich and Seward (1948); Goldich and Elms (1949); Moon (1953).	36
Sandy clay		Abundant plant remains (*Robinia, Palmoxylon, Pinus*).	Thinly bedded, lenticular	Alluvial fan, locally lacustrine.	Webber (1933); Gale (1946); Dibblee (1952).	37
Tuff and tuffaceous sandstone.		Some reeds, calcareous algae, and fragments of silicified wood.	Thinly bedded tuff and sandstone, thickly bedded conglomerate.	Nonmarine	Simpson (1934)	38
Sandstone		Abundant silicified and carbonized wood (including logs).	Crossbedded; channel fills.	Continental	Simpson (1948); Dane and Bachman (1957).	39
Arkosic sandstone		None reported	Well stratified, thinly bedded.	Nonmarine	Kew (1924); Oakeshott and others (1954).	40
do		do	Horizontally and evenly bedded.	Marine	Kerr and Schenck (1928); Oakeshott and others (1954).	41
Arkose, conglomerate, and claystone.		Abundant tree, reed, and grass remains throughout.	Well stratified	Tuff is water laid; other rocks are fluvial. Slight transprt of sediments.	Love (1939)	42
Arkosic conglomerate		Abundant leaves (*Sequoia* and others); some thin beds of lignitic material.	Poorly stratified	Continental, alluvial fan, local swampy conditions.	Park and Cannon (1943)	43
Shale, marly clay, tuff, and sandy limestone.		Some plant remains (reeds, palms(?), and silicified roots).	Thinly bedded; some lenses.	Nonmarine, fluvial and lacustrine.	Dibblee (1958; 1960)	44

TABLE 3.—*Stratigraphic units that contain uranium deposits in sandstone in the*

	Stratigraphic unit	Age	States where uranium bearing	Description	Thickness (feet)
				Tertiary System—Continued	
45	Troublesome Formation	Oligocene	Colorado	Dominantly variegated tuffaceous and gritty claystone and sandstone, some dark shale and white tuff; locally, in lower part, conglomerate and basaltic agglomerate.	960–
46	Uinta Formation†	Late Eocene	Utah	Brown fine-grained sandstone; gray, green, and variegated shale; white marlstone and limestone.	2,000+
47	Umpqua Formation	Eocene	Oregon	Mainly white to brown tuffaceous sandstone, some shale and conglomerate, local coal beds.	8,000–
48	*Wasatch Formation*	Eocene	Wyoming, Utah, New Mexico.	Central Wyoming—poorly sorted, very fine to coarse grained feldspathic sandstone; siltstone; claystone; and carbonaceous shale. Utah and New Mexico—variegated clay shale; gray, buff, and pink sandstone; grit and conglomerate; coal beds.	1,500–2,000
49	*White River Formation*	Oligocene	North Dakota, South Dakota, Nebraska, Colorado, Wyoming.	For North Dakota, South Dakota, Nebraska, and eastern Wyoming see descriptions of Brule (No. 15) and Chadron (No. 17) Formations. Central Wyoming—nearly uniform volcanic tuff facies	250–600
50	White River Group (see Brule, No. 15, and Chadron, No. 17, Formations).				
	Whitsett Formation:				
51	Olmos sand	Eocene	Texas	Brown-weathering loose medium sand	10—15
52	Dubose sands and clays	do	do	Light-gray sandstone interbedded with green, gray, and pink clay; some lignite.	200+
53	*Stone's Switch sand*	do	do	Fine-grained tuffaceous sandstone and bentonitic claystone	12–40
54	Falls City shale	do	do	Gray to chocolate-colored bentonitic claystone; minor sand	70±
55	*Wind River Formation*	Early Eocene	Wyoming	Upper facies—poorly sorted coarse-grained arkosic sandstone and granite pebble and boulder conglomerate, minor mudstone, siltstone, and carbonaceous shale.	300–800
				Lower facies—siltstone, fine-grained sandstone, and claystone	0–130
				Tertiary and Cretaceous Systems	
56	Dawson Arkose	Paleocene and Late Cretaceous.	Colorado	Varicolored clay, shale, coal, arkosic conglomerate, and sandstone; rhyolite flows.	2,000
57	Middle Park Formation†	do	do	Upper member—conglomerate, grit (abundant carbonaceous matter), sandstone, and shale. Lower member—volcanic breccia	2,500
				Cretaceous System	
58	Beartooth Quartzite	Late(?)	New Mexico	Brownish quartzose sandstone and greenish glauconitic sandstone, calcareous near top.	180±
59	Burro Canyon Formation†	Early	Colorado	White, gray, and red sandstone and conglomerate; some mudstone, shale, and limestone.	150–260
60	Cedar Mountain Formation	do	Utah	Variegated red, purple, gray, and white shale, some sandstone; abundant concretions and nodules.	0–270
61	Cloverly Formation†	do	Wyoming	Light-gray sandstone, chert-pebble conglomerate, and variegated claystone.	110–250
62	Cody Shale	Late	do	Gray shale, some sandstone, and bentonitic beds	600–2,000

United States and a summary of the geologic characteristics of these units—Continued

Host rocks of uranium: Character	Host rocks of uranium: Mineral content	Plant fossils	Sedimentary structure	Environment of sedimentation	Sources of data	
Tertiary System—Continued						
Arkosic sandy conglomerate.		Locally carbonized plant remains.	Lenses	Fluvial and lacustrine	Richards (1941); Tweto (1957); Malan (1957).	45
Sandstone, siltstone, and shale.		Abundant carbonized wood.	Lenticular and massive or crossbedded sandstone; other rocks regularly bedded.	Chiefly fluvial; minor lacustrine.	Walton (1944); Dane (1954).	46
Arkosic sandstone		Some leaves	Generally massive channel fills, crossbedded.	Fluvial, alluvial flats, swamps and bogs.	Williams (1949); Wells (1956).	47
Feldspathic sandstone.	Quartz, quartzite, and chert (40–70 percent); feldspar (15 percent); muscovite, biotite, ilmenite, garnet, tourmaline, epidote, hornblende, aegirine, rutile, hypersthene, monazite, and zircon; mainly carbonate cement, some montmorillonite cement.	Widely scattered plant fossils in numerous coal and carbonaceous shale seams and as finely divided carbon (*Ficus*, dicotyledon).	Festoon bedded planoconvex channel fills, lenses, massive.	Fluvial	Reeside (1924); Sears and Bradley (1924); Sharp and White (1957); Sharp and others (1964).	48
Tuffaceous sandstone		(See Brule, No. 15, and Chadron, No. 17, Formations.)	(See Brule, No. 15, and Chadron, No. 17, Formations.)	Predominantly fluvial, minor eolian. Source of tuff was probably the Yellowstone National Park region.	Wanless (1922); Wood (1949).	49
						50
Sand	Quartz, bentonitic clay	Some carbonized plant remains.	Crossbedded	(See Jackson Group, No. 28.)	Ellisor (1933); Eargle and Snider (1957).	51
Sandstone and lignitic clay.		Some carbonized plant fragments.	do	do	Eargle and Snider (1957); Eargle (1959).	52
Tuffaceous sandstone	Quartz (30 percent), bentonite (20 percent), volcanic glass shards (30 percent), chert (10 percent), ashy carbon (10 percent).	Some carbonized wood fragments.	Lenticular	do	Ellisor (1933); Eargle and Snider (1957); deVergie (1958); Eargle (1959).	53
Sand	Calcareous cement	Some lignitic material	Laminated lenses	do	Ellisor (1933); Eargle and Snider (1957); Eargle (1959).	54
Arkose (coarse-grained, locally conglomeratic). Siltstone, mudstone, lignite, and carbonaceous shale.	Quartz (60–80 percent), feldspar (20–40 percent, mainly perthite and microcline), chert, micas (biotite); zircon main heavy mineral; mostly calcareous cement, some carbonate-fluorapatite cement. (Siltstone etc.: —)	Abundant plant remains in coal and carbonaceous shale interbedded with sandstone.	Channel fills, crossbedded.	Fluvial. Source of upper facies was Precambrian granite, lower facies was Mesozoic sedimentary rock.	Zeller and others (1956); R. G. Coleman (1959*).	55
Tertiary and Cretaceous Systems—Continued						
Arkosic sandstone		Abundant land-plant fossils.	Well stratified	Continental	Brown (1943)	56
Arkosic carbonaceous regolith.		Sandstone and tuff contain abundant plant impressions and carbonaceous matter.	Flaggy, crossbedded, highly lenticular, and poorly stratified.	Volcanic and continental	Tweto (1957)	57
Cretaceous System—Continued						
Quartzite		Some coalified plant remains.	Massive, thinly bedded, and crossbedded.	Marine(?)	Paige (1916); Spencer and Paige (1935).	58
Conglomeratic sandstone.		Sparse carbonized and silicified wood.	Massive, irregularly bedded, lenticular, crossbedded, and festoon bedded.	Fluvial	Stokes and Phoenix (1948); Stokes (1952b); Cater and others (1955).	59
Siltstone		None reported	Elongated lenses, horizontally bedded.	Fluvial, littoral, and lacustrine.	Stokes (1944)	60
Gypsiferous or arkosic sandstone.		Some carbonized wood	Basal conglomerate lenses; thinly bedded sandstone and shale.	Continental	Curtis (1951)	61
Shale		None reported	Well stratified	Marine	Love and others (1955)	62

TABLE 3.—*Stratigraphic units that contain uranium deposits in sandstone in the*

	Stratigraphic unit	Age	States where uranium bearing	Description	Thickness (feet)
	Cretaceous System—Continued				
63	Colorado Shale, Newcastle Sandstone Member.	Early	South Dakota	Mostly very fine to fine grained sandstone, some shale and siltstone near top, bentonitic. Noncarbonaceous phase dominant in South Dakota; carbonaceous phase becomes dominant in Wyoming.	0–100
64	Dakota Group (See South Platte Formation, No. 81).				
65	*Dakota Sandstone*	Late and Early	Colorado, New Mexico, Utah.	Very fine to medium grained sandstone, locally interbedded with carbonaceous shale and coal.	0–400
66	Ericson Formation†	Late	Wyoming	Upper member—massive sandstone Middle member—carbonaceous shale, lignite, and sandstone Lower member—medium-grained well-sorted quartzose sandstone.	800–1, 000
67	*Fall River Formation*	Early	South Dakota, Wyoming.	Well-sorted fine-grained iron-stained sandstone interbedded with shale and siltstone.	150
68	Fruitland Formation	Late	New Mexico	Gray, brown, and black shale containing coal; brown to white sandstone.	194–530
69	Hell Creek Formation	do	Montana	Gray sandstone, greenish-colored shaly clay and mudstone, and a few thin lignite and subbituminous coal beds.	600–650
70	*Inyan Kara Group* (see also Fall River, No. 67, and Lakota, No. 72, Formations).	Early	South Dakota, Wyoming.	Fall River Formation (see No. 67) Lakota Formation (see No. 72)	150 200–400
71	Kelvin Formation	Late	Utah	Interbedded shale, sandstone, and bouldery conglomerate	Several hundred.
72	*Lakota Formation*	Early	South Dakota, Wyoming.	Well-sorted to poorly sorted fine- to coarse-grained buff to white quartzose sandstone and conglomeratic sandstone alternately interbedded with variegated claystone. Southern Black Hills only—two discontinuous lithic members, the Fuson Shale and the Minnewaste Limestone Members.	200–400
73	Lance Formation	Late	Wyoming	Gray and brown sandstone, gray shale, thin coal beds	3, 200±
74	*Laramie Formation*	do	Colorado	Sandstone and shale containing interbedded coal and fire clay near base.	250–1, 200
75	Medicine Bow Formation†	do	Wyoming	Alternating light-colored to gray carbonaceous shale, gray to brown sandstone, and thin irregular coal beds.	6, 200±
76	Mesaverde Formation†, Teapot Sandstone Member.	do	do	Gray and buff sandstone, some carbonaceous shale	50–160
77	*Mesaverde Group* (See also Ericson Formation, No. 66; Point Lookout Sandstone, No. 80; Toreva Formation, No. 82; and Tuscher Formation, No. 84.)	do	New Mexico, Utah, Colorado, Wyoming, Arizona.	Gray and brown sandstone, shale, and coal beds	1, 000–3, 000
78	Ojo Alamo Sandstone	do	New Mexico	Gray to brown coarse-grained sandstone containing lenses of siliceous pebbles and variegated shale.	0–400
79	Paluxy Sand	Early	Oklahoma	White to yellow fine sand, clay, and basal arkosic conglomerate where it rests on granite.	400+
80	Point Lookout Sandstone	Late	New Mexico	Fine- to coarse-grained sandstone	100–
81	*South Platte Formation*	Early	Colorado	Predominantly fine-grained sandstone interbedded with black shale.	200–350

United States and a summary of the geologic characteristics of these units—Continued

Host rocks of uranium		Plant fossils	Sedimentary structure	Environment of sedimentation	Sources of data	
Character	Mineral content					
Cretaceous System—Continued						
Sandstone		Abundant carbonized leaves and wood fragments (also silicified) in carbonaceous phase.	Thinly bedded; small-scale crossbeds.	Near-shore shallow-water environments, close to an island in the Cretaceous sea.	Grace (1952)	63
						64
Quartzose sandstone	Quartz; calcite cement	Abundant carbonized plant impressions in coal, carbonaceous shale, and locally in sandstone; some silicified wood.	Channel fills, crossbedded	Fluvial, deltaic, and lacustrine. Transitional to marine environments.	Gregory (1938, p. 62); Craig and others (1955); Gabelman (1956a).	65
Quartzose sandstone	Quartz; some ilmenite and zircon.	Locally abundant carbonized plant remains.	Massive and lenticular crossbedded sandstone, thinly bedded shale.	Upper member was either inland flood plain or alluvial fan. Lower member was either beach or fluvial.	Hale (1955); Murphy and Houston (1955).	66
Quartzose sandstone and carbonaceous siltstone.	Quartz	Carbonized plant fragments common.	Tabular beds, ripple marked.	Fluvial, tidal-flat, and coastal-swamp conditions in front of a transgressive sea. Sources of sediments were mostly preexisting sedimentary rocks and partly metamorphic rocks.	Waagé (1959); M. H. Bergendahl, W. A. Chisholm, and W. J. Mapel (1957*).	67
Tuffaceous sandstone		Abundant silicified wood and other plants (*Sequoia*, *Ficus*, and others).	Lenticular	Brackish- and fresh-water environments.	Darton (1928, p. 48); Dane and Bachman (1957).	68
Sandstone and mudstone.		Abundant carbonized plant remains.	Massive, thinly bedded, lenticular.	Fluvial	Thom and others (1935); Bartram (1940); Ross and others (1955).	69
(See Fall River, No. 67, and Lakota, No. 72, Formations.)		*Cycadeoidea*, silicified wood. (See Fall River, No. 67, and Lakota, No. 72, Formations.)	(See Fall River, No. 67, and Lakota, No. 72, Formations.)	(See Fall River, No. 67, and Lakota, No. 72, Formations.)	Waagé (1959); Mapel and Gott (1959).	70
Grit		Present(?)	Lenses	Fluvial, littoral, and lacustrine.	Stokes (1944)	71
Quartzose sandstone	Quartz; carbonate cement	Carbonized plant fragments common.	Lenticular, channel fills, crossbedded.	Dominantly lacustrine, partly fluvial, some swampy conditions. Source of sediments was preexisting sedimentary rocks.	Gott and Schnabel (1963); Waagé (1959).	72
Quartzose sandstone	Quartz, mica; carbonate(?) cement.	Abundant land-plant flora (70 species).	Thinly bedded	Fresh-water continental environments.	Wegemann (1912); Bartram (1940); Love and others (1955).	73
Sandstone, claystone, and coal.		Abundant carbonized plant remains (dicotyledons abundant, cycads not abundant).	do	Nonmarine	Brown (1943); Lovering and Goddard (1950).	74
Sandstone(?)		Contains land plants similar to those in Laramie Formation.	Crossbedded and ripple-marked sandstone.	Fresh- and brackish-water invertebrates. Sediments were derived from both igneous and sedimentary rocks and transported rapidly.	Bowen (1918)	75
Sandstone and siltstone.		Some plant leaves in sandstone.	Thinly bedded	Continental(?)	Barnett (1915)	76
Sandstone and shale		Locally very abundant land-plant remains (dicotyledon, *Cycadeoidea*).	Irregularly bedded, lenticular and massive sandstone beds.	Intertonguing marine and continental.	Sears and others (1941); Pike (1947); Heaton (1950); Curtis (1951).	77
Sandstone and siltstone.		Silicified logs locally abundant, carbonized leaves (ferns and other types) sparse.	Lenticular	Fluvial	Reeside (1924)	78
Arkosic grit		Sand locally contains silicified and carbonized wood.	Lenticular, thinly bedded	Beach or near-shore environments.	Melton (1930, p. 463); Miser (1954).	79
Ferruginous sandstone.	Quartz	Locally abundant carbonized wood fragments, including logs.	Channel fills	Near-shore and beach environments.	Pike (1947); G. O. Bachman, E. H. Baltz, and R. L. Griggs (1957*).	80
Quartzose sandstone	Quartz, kaolinite	Fairly abundant plant remains in nonmarine sandstone and shale facies.	Thinly bedded and laminated shale, crossbedded and massive sandstone.	Deltaic deposition in front of transgressing sea. Uranium deposits are in the nonmarine facies.	Waagé (1955)	81

TABLE 3.—*Stratigraphic units that contain uranium deposits in sandstone in the*

	Stratigraphic unit	Age	States where uranium bearing	Description	Thickness (feet)
				Cretaceous System—Continued	
82	*Toreva Formation*	Late	Arizona	Upper member—thin quartzose sandstone Middle member—thin carbonaceous shale Lower member—light-gray to buff fine- to coarse-grained arkosic sandstone.	250-300+
83	Trinity Group (See also Paluxy Sand, No. 79.)	Early	Arkansas	Gravel, fine-grained sandstone, limestone, and red or variegated clay.	0-1,000+
84	Tuscher Formation†	Late	Utah	Light-colored friable sandstone interbedded with minor shale	130-600
85	Wayan Formation	Late and Early(?)	Idaho	Upper unit—chiefly alternating red and gray sandstone and shale Lower unit—limestone, red shale, and minor yellow sandstone	11,800±
86	Willow Tank Formation	Late	Nevada	Gray and buff clay interbedded with tuffaceous sandstone; coarse conglomerate at base.	300±
				Jurassic System	
87	Curtis Formation†	Late	Colorado	Grayish- and greenish-colored glauconitic sandstone and shale; some light-brown very fine grained basal sandstone.	0-250
88	*Entrada Sandstone*	do	Colorado, Utah, New Mexico.	White to light-gray and orange "clean" fine-grained sandstone, normally about 50 feet thick, that weathers to smooth bare rim.	50±-1,000
89	*Morrison Formation*	do	Colorado, New Mexico, Utah, Arizona, Wyoming, Montana.	Colorado Plateau—(See Nos. 90-94) Wyoming and Montana—predominantly shale	500-900 500−
90	*Jackpile sandstone of local usage.*	do	New Mexico	Very pale orange and white fine- to medium-grained sandstone	1-190
91	*Brushy Basin Member*	do	Colorado, Utah New Mexico	Eastern Utah and western Colorado—predominantly red, green, and blue mudstone; conglomeratic lenses most commonly near base. New Mexico—bluish-green mudstone and fine-grained sandstone, mudstone-pebble layers.	250-400 150-370
92	*Westwater Canyon Sandstone Member.*	do	New Mexico	Interstratified gray, orange, and brown fine- to medium-grained sandstone and minor amounts of claystone; locally stringers and lenses of pebbles of quartz, feldspar, granite, and quartzite.	0-300
93	*Recapture Member*	do	Utah, New Mexico	Conglomeratic sandstone facies in south part, sandstone facies surrounding the conglomeratic facies, and claystone and sandstone facies to north and east—pinkish-gray to light-brown fine- to medium-grained sandstone and red silty and sandy claystone.	0-600
94	*Salt Wash Sandstone Member.*	do	Colorado, Utah, Arizona, New Mexico.	Conglomeratic facies confined to south-central Utah, sandstone and mudstone facies surrounding the conglomeratic facies on the north and east, and dominantly claystone facies farther to the northeast. Sandstone and mudstone facies—white, gray, brown, and red fine- to medium-grained sandstone; interstitial, galls, and seams of mudstone.	200-400

United States and a summary of the geologic characteristics of these units—Continued

Host rocks of uranium: Character	Host rocks of uranium: Mineral content	Plant fossils	Sedimentary structure	Environment of sedimentation	Sources of data	
Cretaceous System—Continued						
Quartzose sandstone	Quartz; minor hematite, pyrite, and feldspar; heavy minerals—rutile, ilmenite, tourmaline, zircon, garnet, and magnetite; calcium carbonate cement (0.50–0.75 percent).	Locally abundant carbonized plant remains (water lilies, ferns, and dicotyledons).	Crossbedded and lenticular sandstone.	Upper member is littoral. Lower member is fluvial, beach, and floodplain.	Repenning and Page (1956); Clinton and Carithers (1956).	82
Tuffaceous(?) sandstone.		Small amount of carbonized and silicified wood fragments locally (*Cycadeoidea*, conifer).	Lenticular and crossbedded sandstone; platy and ripple-marked limestone.	Sandstone and conglomerate are marginal marine; limestone is brackish-water and shallow marine.	Dane (1929); Miser and Purdue (1929); Wieland (1931).	83
Sandstone		Absent	Massive, crossbedded	Fluvial(?)	Fisher (1936); Fisher and others (1960).	84
do		Locally sparse to abundant silicified wood, few carbonized leaves (dicotyledon) and bark fragments.	Massive	Fresh-water lacustrine, fluvial(?).	Mansfield (1927).	85
Carbonaceous sandstone, clay, and limestone.		Some silicified and carbonized wood, some fern species.	Medium to thickly bedded, lenticular.	Fluvial, quiet ponds	Longwell (1949)	86
Jurassic System—Continued						
Sandstone		Very rare carbonized wood at uranium locality.	Thinly bedded; ripple-marked sandstone beds at base.	Mainly marine; basal beds containing uranium deposits are a marginal marine facies.	Craig and others (1955); Clinton and Carithers (1956).	87
Orthoquartzite or feldspathic orthoquartzite.	Quartz (well-rounded), chert, potash and sodic feldspar; heavy minerals—zircon, tourmaline, rutile, anatase, muscovite, epidote, ilmenite, magnetite, and leucoxene; carbonate and clay cements.	Absent	Large curving and sweeping crossbeds.	Eolian	McKee and others (1956); Cadigan (1959).	88
(See Nos. 90–94)	(See Nos. 90–94)	Flora includes *Araucarioxylon* and *Cycadeoidea*. (See Nos. 90–94.)	Lenses, channel fills, scour-and-fill structures, crossbedded, festoon bedded.	Fluvial and flood plain. Sources of sediments were igneous, metamorphic, and older sedimentary rocks. Volcanic ash falls contributed, particularly to the Brushy Basin Member.	Craig and others (1955); McKee and others (1956).	89
Sandstone	Quartz, feldspar, volcanic fragments; calcite and clay cements.	Carbonized wood fragments locally abundant.	Lenses, channel fills; crossbedded, some horizontally bedded.	Deltaic-plain environment.	Freeman and Hilpert (1956); Moench and Schlee (1957b); Schlee (1957).	90
Conglomerate and conglomeratic sandstone. Mudstone and siltstone. Graywacke and arkose to orthoquartzite.	Quartz, chert pebbles. — (Mudstone:) — Quartz, feldspar; kaolinite and montmorillonite cement.	Carbonized and silicified wood fragments locally abundant.	Conglomeratic lenses; channel fills in New Mexico.	Conglomerate and sandstone are fluvial; mudstone is volcanic ash fall, lacustrine, and fluvial. Northeast direction of sediment transport.	Craig and others (1955); Freeman and Hilpert (1956); Poole and Williams (1956); Schlee (1957).	91
Arkosic sandstone	Quartz (30–65 percent), feldspar (10–50 percent), rock fragments (2–10 percent), chert (1–2 percent), illite and montmorillonite clay; heavy minerals—biotite, leucoxene, garnet, apatite, zircon, and rutile; calcite and kaolinite cements.	Carbonized and silicified wood sparse.	Scour-and-fill structures, sweeping and wedging crossbeds.	Fluvial. Main source of sediments was silicic igneous rocks. Northeast direction of sediment transport.	Craig and others (1955); Poole and Williams (1956); Gruner and Knox (1957).	92
Feldspathic orthoquartzite and arkose.	Quartz, potash feldspar, plagioclase, silicified and altered tuff, igneous rock, quartzite, hydromica, montmorillonite, kaolinite; carbonate, iron oxide, and silica cements.	Carbonized and silicified wood locally very abundant.	Poorly displayed lenses; crossbedded; scour-and-fill structures.	Fluvial and flood plain. Main source of sediments was silicic igneous rocks. Northeast direction of sediment transport.	Craig and others (1955); Poole and Williams (1956); Cadigan (1959).	93
Quartzitic sandstone	Quartz (86 percent), feldspar (7 percent), silicified tuff and chert (7 percent); heavy minerals—zircon, tourmaline, garnet, rutile, anatase, staurolite, biotite, spinel, and apatite; calcite (13 percent) and silica (4 percent) cements.	Carbonized wood fragments locally very abundant. Silicified and carbonized logs (*Araucarioxylon*) abundant.	Crossbedded; scour-and-fill structures; lenticular.	Fluvial (braided streams) and flood plain. Sources of sediments were mainly older formations to the south and subordinately volcanic debris from west.	Craig and others (1955); Poole and Williams (1956); R. A. Scott (1957**).	94

TABLE 3.—*Stratigraphic units that contain uranium deposits in sandstone in the*

	Stratigraphic unit	Age	States where uranium bearing	Description	Thickness (feet)
			Jurassic System—Continued		
95	Summerville Formation	Late	Colorado, Utah	Red silty shale; minor light-colored sandstone	0–400
96	Winsor Formation†	do	Utah	White and red-banded fine-grained sandstone	180–300
			Jurassic and Jurassic(?) Systems		
97	Navajo Sandstone		Utah, Arizona, Colorado.	Light-colored massive medium-grained sandstone	0–2,000
			Jurassic(?) System		
98	Kayenta Formation†	Early	Arizona, Utah	Reddish fine-grained sandstone and siltstone, generally less than 100 ft thick.	100–300
			Triassic System		
99	*Chinle Formation*	Late	Utah, Arizona, Colorado, New Mexico.	Colorado Plateau—Church Rock*, Owl Rock*, Petrified Forest, Moss Back, Monitor Butte, Shinarump, and Temple Mountain* Members (not all present in any one place); members having an asterisk contain no deposits and consist of red and green mudstone and siltstone, and minor limestone. Northern New Mexico—entire section similar and correlative to the Church Rock Member of the plateau region.	300–1,200 ------
100	*Petrified Forest Member*	do	Arizona	Variegated red, green, and yellow bentonitic claystone and clayey sandstone; poorly consolidated and cemented sandstone.	0–700
101	*Moss Back Member*	do	Utah	Light-brown and light-gray well-sorted fine- to medium-grained sandstone and conglomeratic sandstone; subordinates arkose, conglomerate, siltstone, and mudstone. Blanket of fairly uniform thickness of 60 ft.	0–150
102	*Monitor Butte Member*	do	do	Greenish-gray and pale-reddish-brown bentonitic claystone and clayey sandstone; a few well-cemented, poorly sorted, very fine grained sandstone lenses; locally conglomeratic.	0–250
103	*Shinarump Member*	do	Arizona, Utah	Light-brown or light-gray medium- to coarse-grained sandstone; conglomeratic sandstone; subordinate conglomerate, mudstone, and siltstone. Blanket of fairly uniform thickness of 50 ft except where it either pinches out or thickens by filling channels.	0–225
104	Chugwater Formation		Wyoming	Upper member—red and yellow siltstone containing intercalated sandstone; and conglomerate. Middle member—thin persistent limestone Lower member—dark-red sandstone and shale	1,250±
105	Dockum Group†	Late	New Mexico, Texas	Red siltstone and claystone containing minor sandy lenses and thick light-colored basal sandstone and conglomerate beds.	1,000
106	Dolores Formation†	do	Colorado	Interbedded red sandstone and siltstone, some conglomerate, minor mudstone and limestone.	300–600
107	*Moenave Formation, Springdale Sandstone Member.*	do	Utah	Pale-red to brown very fine to fine grained sandstone containing greenish-gray siltstone interbeds. Top member of formation.	100±
108	*Moenkopi Formation*	Middle(?) and Early	Utah, Colorado	Mainly pale-reddish-brown siltstone, minor very fine grained sandstone, limestone member in southeast Utah.	50–1,000

United States and a summary of the geologic characteristics of these units—Continued

Host rocks of uranium: Character	Host rocks of uranium: Mineral content	Plant fossils	Sedimentary structure	Environment of sedimentation	Sources of data	
Jurassic System—Continued						
Siltstone, mudstone, and sandstone.		None reported	Horizontally and thinly bedded.	Marginal marine, relatively quiet shallow water.	Craig and others (1955)	95
Carbonaceous clay		Absent(?)	Regularly bedded	Marine(?)	Gregory (1950)	96
Jurassic and Jurassic(?) Systems—Continued						
Quartz sandstone	Quartz, feldspar (a few grains); carbonate and silica cements.	Absent	Large curving and sweeping crossbeds.	Eolian. Southeast direction of sediment transport.	Craig and others (1955); McKee and others (1956); Poole and Williams (1956).	97
Jurassic(?) System—Continued						
Sandstone		Some well-worn silicified wood; carbonized remains very rare.	Horizontally and thinly bedded.	Fluvial	Craig and others (1955)	98
Triassic System—Continued						
Calcarenite (grit)	Carbonate and clay pebbles; carbonate cement.	Flora includes Araucarian conifers, *Cycadeoidea*, tree ferns, and scouring rushes. (See Nos. 100–103.)	(See Nos. 100–103)	(See Nos. 100–103)	Finch (1954); Stewart (1957).	99
Limestone pebble conglomerate.	Carbonate and clay pebbles; carbonate cement.					
(See also Nos. 100–103.)						
Orthoquartzitic tuff	Quartz, tuff, feldspar, clay; iron-oxide cement.	Carbonized and silicified wood (including logs) locally very abundant.	Lenses	Dominantly lacustrine, minor stream action. Greatest volcanic activity of Chinle time. Prevailing wind was from northwest.	Stewart (1957); Poole (1957).	100
Feldspathic orthoquartzite.	Quartz, felspar, chert, clay, tuff; carbonate and iron oxide cements.	Carbonized and silicified wood (including logs) locally very abundant.	Channel fills; lenses; crossbedded; scour-and-fill structures.	Fluvial, streams flowed from southeast. Small-scale volcanic activity. Prevailing wind was from northwest.	Stewart (1957); Poole (1957); Cadigan (1959).	101
Mudstone and siltstone.	Carbonate cement.					
Conglomerate	Quartz (12 percent), quartzite (37 percent), chert (51 percent).					
Feldspathic orthoquartzite.	Quartz, feldspar, tuff, clay; carbonate and iron oxide cements.	Carbonized and silicified wood (including logs) locally very abundant.	Ripple-marked, contorted beds, thinly bedded.	Dominantly lacustrine, minor stream action. Large-scale volcanic activity. Prevailing wind was from northwest.	Stewart (1957); Poole (1957); Cadigan (1959); Stewart and others (1959).	102
Conglomeratic mudstone.	Limestone and siltstone pebbles.					
Feldspathic orthoquartzite.	Quartz, feldspar, tuff, clay; carbonate, clay, iron oxide, and barite cements.	Carbonized and silicified wood (including logs) locally very abundant.	Channel fills; crossbedded; festoon bedded; scour-and-fill structures.	Fluvial (streams flowed from south and east), pediment or alluvial fan. Small-scale volcanic activity. Prevailing wind was from northwest. Widespread planation preceded sedimentation.	Stokes (1950); McKee and others (1953); Miller (1955); Albee (1957); Poole (1957); Stewart (1957); Stewart and others (1959); Cadigan (1959)	103
Conglomerate	Quartz (82 percent), quartzite (16 percent), chert (2 percent).					
Mudstone and siltstone.		Some plant remains in upper part.	Thinly bedded	Dominantly marine; littoral and continental in upper parts.	Downs (1952); Reeside and others (1957).	104
Sandstone		Locally abundant plant fragments and lignite.	Crossbedded and lenticular sandstone and conglomerate.	Continental, chiefly flood plain.	Darton (1928, p. 32); Adkins (1933, p. 244); Reeside and others (1957, p. 1456).	105
do		Some carbonized leaves and twigs (primitive palm and conifer).	Crossbedded, horizontally or irregularly bedded, cut-and-fill structures common.	Fluvial. Deposited under semiarid conditions on an aggrading plain of low relief.	Bush and others (1959)	106
do	Quartz (about 90 percent), orthoclase, plagioclase, kaolinite(?); heavy minerals—hypersthene, garnet, muscovite, zircon, and tourmaline; calcite cement.	Locally very abundant carbonized and silicified remains (rushes, reeds, trees); numerous logs.	Crossbedded, lenticular, horizontally and thinly bedded.	Eolian and subaerial, fluvial.	Proctor (1953); Averitt and others (1955); Wilson and Stewart (1959).	107
Siltstone and mudstone.	Quartz, kaolinite, mica; iron oxide cement.	Traces of impressions of stems and pieces of silicified wood (reeds and conifer).	Horizontally bedded and ripple-marked siltstone. Lenticular and crossbedded sandstone.	Partly marine and partly continental in west, entirely continental in east. Includes streams, lagoons, playas, flood plains, tidal flats, and shallow sea floors.	McKee (1954); Reeside and others (1957); Stewart and others (1959); Davidson (1959).	108
Sandstone						

TABLE 3.—*Stratigraphic units that contain uranium deposits in sandstone in the*

	Stratigraphic unit	Age	States where uranium bearing	Description	Thickness (feet)
				Triassic System—Continued	
109	Newark Group (See also No. 110).	Late	Pennsylvania, Connecticut.	Red arkosic sandstone, shale, and conglomerate formations, a black shale formation, and interbedded basic flows.	Many thousands.
110	Stockton Formation	do	New Jersey	Light-colored arkosic fine- to medium-grained sandstone and conglomerate containing interbedded red sandstone and shale. Base of Newark Group.	2,300-3,100
111	Wingate Sandstone†	do	Utah, Colorado	Yellow-gray and red fine-grained quartzose sandstone; red mudstone near base; forms massive cliffs.	250±-400±
				Permian System	
112	*Abo Sandstone*	Early	New Mexico	Red shale (60 percent) and red to purple coarse-grained sandstone and arkosic conglomerate.	600-1,000
113	Clear Fork Group		Texas	Mainly evaporite and dolomite; in northern Texas also contains arkosic sandstone.	1,200-1,500
114	*Coconino Sandstone*		Arizona, Utah	Light-colored massive well-sorted very fine grained quartzose sandstone.	40-1,000
115	*Cutler Formation*		Utah, Arizona, Colorado.	Colorado and east-central Utah—arkosic facies (see No. 116), some conglomerate, and sandy siltstone. Arizona and southern Utah—De Chelly Sandstone, White Rim, Organ Rock, Cedar Mesa Sandstone, and Halgaito Members. (See Nos. 117-118.).	0-1,250
116	*Arkosic facies*		Utah	Dark-red, purple, and locally light-colored coarse-grained arkose and sandstone; conglomeratic to north and east.	150-650
117	De Chelly Sandstone Member†.		Arizona	Red and light-brown massive fine- to coarse-grained sandstone	0-825
118	Cedar Mesa Sandstone Member.		Utah	Orange and gray very fine to fine grained sandstone	0-1,250
119	Hermit Shale†		Arizona	Dark-red sandy shale; some layers of shaly sandstone	350±
120	Kaibab Limestone		Arizona, Nevada	Dominantly gray limestone and dolomite, abundant chert beds and nodules, some gray fine grained sandstone.	0-360
121	Phosphoria Formation		Wyoming	Alternating red shale and gray limestone and dolomite; phosphate rock; minor sandstone near base.	200-300
122	Quartermaster Formation†		Oklahoma	Thin beds of red sandstone and sandy shale; gypsiferous shale near base.	200-300
123	*Rush Springs Sandstone*		do	Fine-grained well-sorted feldspathic quartz sandstone; thickness varies greatly in short distance.	40-250
124	Toroweap Formation		Nevada	Interbedded white sandstone, red beds, gypsum, and limestone	250-900
125	Whitehorse Group (See Rush Springs Sandstone, No. 123.)				
126	Wichita Formation (of group rank in Texas).		Oklahoma, Texas	Red and gray sandstone and shale, divided near middle by the "t" bed—a persistent sandstone zone; upper part—randomly distributed sandstone lenses; lower part—thick sandstone lenses in zones. Most deposits in upper part. Blue shale and limestone to south.	1,500+

United States and a summary of the geologic characteristics of these units—Continued

Host rocks of uranium: Character	Host rocks of uranium: Mineral content	Plant fossils	Sedimentary structure	Environment of sedimentation	Sources of data	
Triassic System—Continued						
Arkosic sandstone	Quartz (50 percent), feldspar (5–40 percent), limonite and clay (10–45 percent); heavy minerals—pyrite, zircon, mica (trace to 10 percent).	Abundant carbonized plant fragments (*Cycadoidea*, ginkgo, conifer, and monocotyledon).	Lenses	Lacustrine and alluvial-fan sedimentation in long narrow intermontane troughs.	F. A. McKeown, P. W. Choquette, and R. C. Baker (1954*); Reeside (1957, p. 1491).	109
do	Quartz (50 percent), microcline and plagioclase feldspars (20–40 percent); minor zircon and muscovite; clay cement (20 percent).	Abundant plant remains (cycad and conifer).	Crossbedded, lenses, channel fills.	Fluvial. Source of sediments was crystalline rocks to southeast.	Kummel (1940); F. A. McKeown, P. W. Choquette, and R. C. Baker (1954*).	110
Feldspathic orthoquartzite.	Quartz, quartzite, feldspar, clay.	Absent	Crossbedded	Subaerial, eolian. Southeast direction of transport.	Baker and others (1936, p. 53); Poole and Williams (1956).	111
Permian System—Continued						
Arkosic siltstone, sandstone, and conglomerate.		Some plant remains	Massive, thinly to thickly bedded, locally crossbedded.	Fluvial	Lee (1909, p. 12); Needham and Bates (1943, p. 1656).	112
Arkosic sandstone	Quartz, feldspar	do	Thinly bedded	Mostly marine; plant and vertebrate fossils in sandstone indicate some nonmarine sedimentation.	Sellards (1933, p. 174); Roth (1949, p. 1663).	113
Sandstone		Absent	Crossbedded (huge scale)	Eolian	Baker and Reeside (1929); McKee (1934); McNair (1951).	114
(See Nos. 116–118.)	(See Nos. 116–118.)	(See Nos. 116–118.)	(See Nos. 116–118.)	Fluvial, eolian, and lacustrine.	Gregory (1938, p. 41–46); Sears (1956); Witkind (1956a); Stewart and others (1959).	115
Arkose	Quartz, feldspar	Locally silicified logs and fossil plants (*Pecopteris tenuinervis*?); none are carbonized.	Lenticular, horizontally bedded.	Fluvial. Source of sediments was granitic and metamorphic rocks of the Uncompahgre highland.	Baker (1933).	116
Quartzose sandstone	Quartz	Absent	Crossbedded, large-scale	Eolian	Gregory (1938); Stewart and others (1959).	117
Silty sandstone		do	Crossbedded, lenticular	do	Baker (1933; 1946); Stewart and others (1959).	118
Siltstone		Poorly preserved and widespread plant impressions (fern and other).	Horizontally bedded, thickly massive and thinly bedded sandstones.	Fluvial	Noble (1922); Moore (1933, p. 38–39); McNair (1951).	119
Sandstone		Absent	Limestone—thinly to thickly and horizontally bedded. Sandstone—crossbedded.	Marine	Stewart and others (1959)	120
do		do	Horizontally bedded	do	Thomas (1934)	121
{Calcareous sandstone {Siltstone	Quartz; carbonate cement.	Locally sparse plant remains.	Well stratified	Nonmarine	Lloyd and Thompson (1929, p. 953); Sellards (1933, p. 186).	122
Arkosic sandstone	Quartz, feldspar; heavy minerals—leucoxene, staurolite, garnet, zircon, tourmaline, and rutile; carbonate cement.	None reported	Festoon-bedded and ripple-marked, crossbedded, horizontally bedded.	Continental	Reeves (1922); Roth (1949, p. 1684); E. J. McKay (1958*).	123
Sandstone and shaly sandstone.		Absent	Poorly stratified, thinly bedded, and crossbedded sandstone.	Cyclic—continental, brackish water, and marine.	McKee (1938)	124
						125
Arkosic sandstone	Quartz, feldspar, clay, limestone; heavy minerals—leucoxene, staurolite, garnet, zircon, tourmaline, and rutile.	Carbonized fossil wood locally abundant.	Channel fills; lenses; crossbedded; thinly bedded; slump features.	Red-bed series are nonmarine; blue shales and limestones are marine.	Sellards (1933, p. 166, 170); Miser (1954); E. J. McKay (1958*).	126

TABLE 3.—*Stratigraphic units that contain uranium deposits in sandstone in the*

	Stratigraphic unit	Age	States where uranium bearing	Description	Thickness (feet)
			Permian and Pennsylvanian Systems		
127	Maroon Formation†		Colorado	Maroon to bright-red sandstone, conglomerate, sandy shale, and some shale; local interbedded limestone.	8,500
128	Minnelusa Sandstone		South Dakota	Red shale; flaggy and massive light-colored sandstone; impure limestone.	450±
129	Sangre de Cristo Formation		New Mexico	Upper conglomeratic sandstone; variegated sandstone; red siltstone; gray to brown well-sorted fine- to coarse-grained sandstone; transitional arkosic conglomerate, limy shale, and siltstone; basal red arkose.	3,300
130	Supai Formation†		Arizona, Nevada	Alternating beds of red soft sandstone and shaly sandstone, buff hard sandstone, and calcareous sandstone; some thin limestone beds in lower two-thirds.	900±
131	Tensleep Sandstone†		Wyoming, Montana	Massive white, tan, and pink fine- to medium-grained sandstone; minor beds of dolomite, limestone, shale, and anhydrite.	180–450
			Permian(?) and Pennsylvanian Systems		
132	Rico Formation		Utah	Red and pale-reddish-brown medium-grained sandstone, siltstone, and conglomerate; several thin limestone beds.	0–575
			Pennsylvanian System		
133	Atoka Formation	Middle	Arkansas	Series of beds of sandstone and shale, a few thin coal seams. Thickens greatly to the south and west from northwest Arkansas.	1,750–2,250+
134	Pottsville Formation†	Middle to Early	Pennsylvania	Coarse-grained sandstone, conglomerate, numerous coal measures, thin limestone.	1,300
			Mississippian System		
135	Mauch Chunk Formation		West Virginia	Alternating red shale and sandstone; some gray and green strata	3,300−
			Devonian System		
136	Catskill Formation	Late and Middle	Pennsylvania	Predominantly red sandstone, shale, and conglomerate; some gray rocks; shale dominant in western part.	4,500±
			Ordovician System		
137	*Harding Sandstone*	Middle	Colorado	Interbedded gray to reddish quartzose sandstone and green to brownish shale, some silty and shaly sandstone, some carbonaceous and fossiliferous (fish scales) beds.	40–150
138	Whitewood(?) Limestone	Late	South Dakota	Green fissile shale and gray siltstone is classified as part of Whitewood Limestone, which is pinkish mottled hard massive fossiliferous limestone, 0–80 ft. thick.	80

United States and a summary of the geologic characteristics of these units—Continued

Host rocks of uranium: Character	Host rocks of uranium: Mineral content	Plant fossils	Sedimentary structure	Environment of sedimentation	Sources of data	
Permian and Pennsylvanian Systems—Continued						
Sandstone	Calcite cement	Widespread and locally abundant carbonized and silicified wood and other plants (includes conifers, *Calamites*, and others).	Thinly to thickly and horizontally bedded; sparse lenses.	Nonmarine; periodic marine invasions.	Stark and others (1949); Langenheim (1954).	127
Shale		Absent	Thinly bedded, crossbedded.	Mainly marine, minor continental.	Connolly and O'Harra (1929); Dillé (1930); Bartram (1940, p. 116); Condra and Reed (1958).	128
Limy arkosic sandstone.	Quartz (30-40 percent), feldspar (30-40 percent), calcite cement (20-30 percent).	Locally abundant carbonized and silicified remains (conifer, *Calamites*, and *Lepidodendron*).	Channel fills, scour-and-fill structures, lenses.	Deltaic, flood plain, and fluvial; first cycle: some thin marine limestones. Uranium deposits are in fluvual sandstone filling channels on a flood plain.	Tschanz and others (1958).	129
Micaceous siltstone and sandstone.						
Sandstone	Quartz, mica: iron oxide(?) cement.	Trace of plants (*Walchia*, *Cordaites*, *Calamites*, and others).	Crossbedded, laminated, massive.	Mainly continental, minor marine.	Noble (1922); Stoyanow (1936).	130
Quartzose sandstone	Quartz	Absent	Crossbedded; some channel fills.	Shallow-water marine, stable shelf conditions; beach and shore facies indicate periodic regressions of the sea.	Agatston (1952)	131
Permian(?) and Pennsylvanian Systems—Continued						
Sandstone, sandy and silty limestone.		Absent	Horizontally bedded	Shallow marine	Baker (1933); Gregory (1938, p. 41).	132
Pennsylvanian System—Continued						
Quartzose sandstone	Quartz, kaolinite(?)	Macerated and fragmentary plant remains common. Chiefly *Lepidodendron* and *Sigillaria* (lycopods).	Thinly to thickly bedded, ripple-marked, crossbedded.	Marine and locally continental(?).	Croneis (1930)	133
Arkosic sandstone and conglomerate.	Quartz, alkalic feldspar (altered to sercite and chlorite), shale fragments; calcite cement.	Locally abundant carbonized plant remains, including logs.	Channel fills, massive sandstone; thinly bedded shale and coal.	Sandstone is dominantly continental, chiefly fluvial; coal is paludal; limestone is marine. Cyclic sedimentation.	Moore (1933, p. 294); Dyson (1954).	134
Mississippian System—Continued						
Sandstone		Impressions of leaves, stems, and roots (reeds, *Cordaites*).	Medium to thickly bedded sandstone, thinly bedded shale.	Flood plain, passes into marine formation in northwestern Pennsylvania.	Barrell (1907); Willard (1946).	135
Devonian System—Continued						
Graywacke (low-rank).	Quartz, quartzite, rock fragments, feldspar; heavy minerals—magnetite, allanite, zircon, ilmenite, and leucoxene; carbonate (slight) and ferric iron oxide cements.	Some carbonized plant fragments (*Psilophyta*, *Lepidodendrales*).	Lenticular, crossbedded, ripple-marked, scour-and-fill structures, thickly bedded.	Eastern part is continental, fluvial, and deltaic; western part is marine. Uranium deposits are in the continental facies.	Barrell (1913), Willard (1939, p. 276); Klemic and Warman (1957).	136
Ordovician System—Continued						
Sandstone and silty sandstone.		Absent	Thinly bedded, massive	Near-shore littoral environment of a transgressive sea.	Walcott (1892); Lovering and Goddard (1950).	137
Quartzitic and phosphatic siltstone.		do	Massive	Marine	Connolly and O'Harra (1929); Vickers (1954).	138

TABLE 3.—*Stratigraphic units that contain uranium deposits in sandstone in the*

	Stratigraphic unit	Age	States where uranium bearing	Description	Thickness (feet)
			Ordovician and Cambrian Systems		
139	Bliss Sandstone	Ordovician and Late Cambrian.	New Mexico	Brown and gray fine-grained sandstone; conglomerate common at the base.	0-300
140	Deadwood Formation†	Early Ordovician and Late Cambrian.	South Dakota, Wyoming(?).	Upper reddish sandstone, sandy shale, brownish coarse-grained quartzitic sandstone, and, locally, a basal conglomerate.	40-500
			Cambrian System		
141	Flathead Quartzite	Middle	Montana	Red sandstone, sandy shale, green shale; limestone in upper parts, basal conglomerate.	900±
			Precambrian System		
142	*Dripping Spring Quartzite (Apache Group).*		Arizona	Upper member—gray to red alternating units of siltstone and very fine grained orthoquartzite; most uranium deposits are in siltstone unit below the middle of the member. Lower member—red, very fine to medium grained arkosic to feldspathic sandstone; conglomerate near base.	600±

STRATIGRAPHY OF THE HOST ROCKS

Host rocks of continental origin contain about 97 percent of the peneconcordant deposits, those of mixed continental and marine origin contain 2 percent, and those of marine origin contain 1 percent. In contrast, rocks of continental origin contain 45 percent of the vein deposits, those of mixed continental and marine origin 37 percent, and those of marine origin 18 percent.

The formations that contain these uranium deposits are considerably different in character. Most of those of continental origin accumulated by stream action and consist of lenticular sandstone beds that formed in the stream channels; these are interbedded with mudstone layers that accumulated on flood plains. Some formations formed in shallow lakes, where the sand lenses were deposited in deltas and along the shorelines. A few host formations of continental origin accumulated by wind action, and these consist of relatively clean and massive sandstone layers. Some formations were deposited along the margins of seas, and these are composed of lenses of sand and mud that accumulated in deltaic, lagoonal, and shoreline environments; some of these formations contain a mixture of marine and continental sediments. The host sandstone beds of marine origin are all near-shore deposits of sand distributed by wave action. None of the host sandstone beds formed in geosynclinal basins.

Peneconcordant deposits are most abundant in stratigraphic units of mixed lithology, chiefly interbedded sandstone and mudstone (table 3). About equal proportions of sandstone and mudstone seem to be optimum for uranium occurrence in many formations. In the Morrison Formation in the Colorado Plateau region, most of the ore deposits in the Salt Wash, Westwater Canyon, and Brushy Basin Members are in a mixed sandstone-mudstone facies (pl. 2), but ore deposits are lacking in these members where sandstone and conglomeratic facies dominate near the sources of the sediments and also where shale or mudstone facies dominate in areas most remote from the sources (Jones, 1954; Craig and others, 1955; Mullens and Freeman, 1957). In the Inyan Kara Group in the Edgemont district, South Dakota, sandstone layers interbedded with shale are host to the uranium deposits (Bell and Bales, 1955). In the Powder River Basin, Wyo., the uranium deposits are near the center of the basin where the Wasatch Formation is composed of coarse-grained sandstone interbedded with shale and siltstone (Davidson, 1953). In the Browns Park Formation in the Maybell-Lay and Poison Basin districts, Colorado and Wyoming, the ore deposits are in nontuffaceous sandstone layers where they interfinger with finer grained tuffaceous beds (Prichard, 1956; Bergin and Chisholm, 1956; Bergin, 1957).

Although uranium deposits in sandstone occur in many stratigraphic units, in any one area the known deposits are commonly restricted to one stratigraphic unit. Field conditions in many areas prevent certain determination of the number of ore-bearing units, as, for example, where younger potential units have been removed by erosion or where older potential units are not exposed. Uranium deposits in more than one unit

United States and a summary of the geologic characteristics of these units—Continued

Host rocks of uranium		Plant fossils	Sedimentary structure	Environment of sedimentation	Sources of data	
Character	Mineral content					
Ordovician atd Cambrian Systems—Continued						
Silicified sandstone		Absent	Massive, locally cross-bedded.	Shallow-water marine, littoral. Sea transgressed northwest across Texas into New Mexico.	Richardson (1904, p. 27); Sellards (1933, p. 62).	139
Quartzose siltstone	Quartz	do	Thinly and horizontally bedded.	Mainly marine; basal conglomerate is a beach deposit.	Connolly and O'Harra (1929); Moore (1933, p. 119); Thomas (1952).	140
Cambrian System—Continued						
Quartzite and sandstone.		Absent	Thinly bedded	Marine and littoral	Thom and others (1935); Thomas (1952).	141
Precambrian System—Continued						
{Siltstone Arkosic sandstone and hornfels.	Montmorillonite clay abundant. Quartz, feldspar (as much as 60 percent).	}Absent	{Upper member—thinly bedded; scour-and-fill structures ("pseudo-channels") common near base; sparse crossbedded sandstone. Lower member dominantly cross-bedded.	}Probably littoral and shallow marine. Uranium-bearing beds were deposited in a shallow-water mudflat environment.	Granger and Raup (1959); Granger (1964).	142

could have existed, or possibly do exist, in such areas. The available evidence shows no strong tendency for deposits to overlie one another in a sequence of stratigraphic units. A few exceptions to this general relation, however, are worth noting: along the southern margin of the San Juan Basin, N. Mex., between Gallup and Laguna, very productive deposits occur in the Todilto Limestone and in the Westwater Canyon and Brushy Basin Members of the Morrison Formation; less productive deposits also occur in the Dakota Sandstone (Hilpert and Moench, 1960). Though no direct vertical continuity between peneconcordant deposits in any two stratigraphic units has been shown, certainly areas favorable for ore in these stratigraphic units overlap and perhaps some ore deposits actually overlap. In southeastern Utah, areas favorable for ore deposits in the Morrison overlap favorable areas in the Chinle, but because the Morrison has been eroded in most places where the Chinle is exposed, known deposits in the Morrison are at least a few miles distant from known deposits in the Chinle (Finch, 1955).

Even within a single stratigraphic unit, the ore deposits are commonly restricted to sandstone lenses at one stratigraphic horizon rather than occurring at several, even though similar sandstone beds are present at these other stratigraphic horizons. In Colorado and Utah the uppermost sandstone layer in the Salt Wash Member of the Morrison Formation is host for most of the deposits in this member, although other sandstone layers are present (Fischer, 1942). In the Gas Hills district, Wyoming, the middle part of the upper coarse facies of the Wind River Formation contains the large ore bodies (Zeller and others, 1956). In northeastern Arizona and southeastern Utah, four members of the Chinle Formation contain highly productive uranium deposits, but the sandstone beds in any one member are ore bearing only where they lie at the base of the Chinle and not where they overlap older members. The oldest member, the Shinarump, occupies the southern part of this area. Where it pinches out to the north it is overlapped shingle-fashion by the Monitor Butte Member, which forms the base of the Chinle for a short distance northward, where it in turn pinches out. Here the Monitor Butte is similarly overlapped by the Moss Back Member, which extends still farther north to a locus where it also pinches out; beyond, the sandstone beds of the undifferentiated Chinle lie at the base of the formation. The presence of uranium deposits in whichever sandstone is at the base of the Chinle Formation, and the possible relation of the deposits to the underlying unconformity, have been discussed by Stewart and others (1959). The fact that most of these deposits are within 10–20 miles of the pinchout of each pertinent member suggests that such pinchouts were a factor in ore localization (Trites and others, 1956; Finch, 1959a).

Most of the host formations are 100–1,000 feet thick, but their ore-bearing sandstone layers, most of them less than 100 feet thick, are only a small part of their respective formations. In northeastern Arizona and southeastern Utah, the Chinle Formation averages about 500 feet in thickness; the Shinarump Member averages only about 75 feet where it is ore bearing in Arizona and Utah; and the Moss Back Member, only about 65 feet where it is ore bearing in Utah (Finch, 1959a). The Morrison Formation in western Colorado and eastern Utah averages about 750 feet in thickness, but in western Colorado the uppermost sandstone layer in the Salt Wash Member where it is ore bearing averages only about 55 feet (Weir, 1952) and in parts of Utah probably even less. In northwestern New Mexico, however, where very large deposits occur in the Morrison Formation, the ore-bearing sandstone averages about 125 feet in thickness in the Laguna district and about 200 feet in the Ambrosia district, whereas the Morrison Formation ranges from only 400 to 500 feet in total thickness (Hilpert and Moench, 1960). Within each ore-bearing sandstone lens, the deposits generally occur in the thicker parts, though not necessarily in the thickest part.

Typically the host sandstone layers are lenticular and are interbedded with finer grained rocks of lower permeability: commonly, mudstone, siltstone, and argillaceous tuff. The lower contacts of the sandstone lenses are generally well defined and mark an abrupt change in sedimentation, which commonly occurs on a locally scoured surface. Laterally the sandstone lenses pinch out, grade into or interfinger with finer grained rocks, or coalesce with other sandstone lenses. Upward the sandstone layers generally grade into finer grained rocks. Some lenses are very broad in cross section, perhaps a mile or more, and where these lenses coalesce they form virtually continuous layers of sandstone over wide areas. Such coalescing lenses are common in the upper part of the Salt Wash Member of the Morrison Formation in western Colorado and eastern Utah. This feature may be explained as the product of shifting braided streams. The length of individual lenses is relatively short, rarely exceeding a few miles; some of these lenses in cross section are convex both upward and downward. Some lenses, however, are well defined and are moderately short but relatively narrow—some are only a few times wider than their thickness. Such lenses, probably deposited by trunk streams, are common in the Shinarump Member of the Chinle Formation in Arizona (Witkind, 1956a, fig. 15; Finch, 1959a). Commonly, in cross section these lenses are planar upward and convex downward; in places they occupy rather deep channels cut into the underlying beds.

LITHOLOGY OF THE HOST ROCKS

The host sandstone rocks of uranium deposits are composed mainly of quartz grains (table 3). Feldspar grains or tuff fragments are common, and in some beds they are so abundant that the rocks are appropriately classed as arkose or tuff. Mucsovite and biotite flakes are common but rarely abundant. Accessory mineral grains are chiefly ilmenite, leucoxene, zircon, and magnetite and, subordinately, apatite, tourmaline, garnet, rutile, barite, anatase, staurolite, and hypersthene. Most of these are original detrital constituents, but some grains of luecoxene, anatase, and barite formed during diagenesis. Clay minerals, of which montmorillonite, illite, chlorite, palygorskite, and kaolinite are the most abundant, are present in all sandstone beds and are abundant in some; part of the clay material was deposited with the sandstone, part resulted from the alteration of detrital grains of feldspar and fragments of tuff, and part was introduced epigenetically into the sandstone pores (Keller, 1962; Schultz, 1963). The gritty and conglomeratic sandstone layers commonly contain pebbles of quartz, quartzite, chert, limestone, and shale or mudstone; some formations contain abundant pebbles and boulders of granitic rocks. Grains and fragments of dark-colored minerals and rocks are so sparse in most of the host rocks that only a few approach graywacke in composition.

The cement of the host sandstone is mainly clay and carbonate minerals; less abundant are cryptocrystalline silica and quartz overgrowths, hydromica, iron oxides, and other minerals.

The host rocks range widely in grain size and in degree of sorting. These parameters are controlled by the type of source rocks from which the sediments were derived, the conditions under which the source rocks were weathered and eroded, the distance and character of transport of sediment, and the conditions of sedimentation. A few uranium deposits are in coarse, poorly sorted lenses containing pebbles and boulders of crystalline rocks that were rapidly eroded and which were dumped as fans along mountain fronts. In contrast, a few deposits are in fine-grained, well-sorted sandstone of marine, wind, or even stream origin, the grains of which were probably transported a considerable distance. Some deposits are in beds or lenses of conglomeratic sandstone, which is composed of small pebbles of quartz, quartzite, or chert, and which could have survived transport of considerable distance, and pebbles of limestone and mudstone, which probably were derived from nearby sources; the sand matrix of these conglomerates is quartzose or arkosic. Most of the uranium deposits are in fine- to medium-grained, moderately to well sorted sandstone of quartzose, arkosic, or tuffaceous composition (table 2). Many of these are as much as 100 miles from areas that could have been the sources of the host rock.

Most of the conglomeratic and arkosic sandstone beds probably are composed of first-generation sediments derived dominantly from granitic terranes. Some of the quartzose sandstone beds, however, probably are composed of second-generation sediments derived from preexisting sandstone. The tuffaceous material in the sandstone could have been introduced as airborne volcanic ash, with or without some transport by streams, or it could have been derived by erosion of a volcanic terrane, because it occurs in both the first- and second-generation sediments.

The distribution of peneconcordant-type deposits of copper, vanadium, and uranium in sandstone suggests a correlation between the metal distribution and the type of deposition of the host sandstone. Copper deposits, with or without uranium, are mainly in first-generation arkosic sandstone derived from granitic terranes; deposits rich in vanadium, with or without much uranium, are dominantly in second-generation sandstone derived from sedimentary rocks; and uranium deposits with little or no copper and vanadium are either in first- or second-generation sandstone, much of which is associated with beds containing volcanic ash. This distribution pattern is compatible with the geochemical habits of these metals (Fischer and Stewart, 1960, 1961).

Sedimentary structural features within the ore-bearing beds differ according to conditions of sedimentation. In the host beds of stream origin, the internal structural features are indeed varied but dominantly lenticular; larger lenses are composites of smaller ones, and crossbedding is nearly universal. Conformable and unconformable relations exist between individual lenses; scour-and-fill and festoon lenses are common. Composition, grain size, and degree of sorting may differ from one lens to another. Many bedding planes are filmed with clay, and thin lenses of mudstone and mudstone-pebble conglomerate are common. Patches of irregularly bedded and poorly sorted sandstone, containing fragments of plant fossils and pebbles of mudstone or other rocks, occur in places; they are called "trash pockets" and probably accumulated at points of unusual turbulence in the streams. Sandstone beds that accumulated in lakes or lagoons and along shorelines may also be lenticular, but the individual lenses generally are more extensive and more uniform in composition and texture than deposits that accumulated in streams. Beds deposited by wind action are typically quite uniform in composition and texture, and commonly are massive though strongly crossbedded.

Regardless of the characteristics and origin of the host sandstone, its texture and internal structural features show little or no influence on the small-scale distribution of the ore minerals. Although the tabular layers that form the peneconcordant deposits lie nearly parallel to the major bedding of the standstone, on a small scale they are undulant and cut across bedding planes, crossbedding, or beds of different composition with little or no regard for these breaks or differences. These layers are not localized along any obvious structural feature of tectonic or sedimentary origin. Vein deposits, on the other hand, generally follow fractures that cut across beds at steep angles.

Because many studies of these deposits suggest a genetic relation between uranium and tuffaceous material, plant fossils, and asphaltic material, these components of the host rocks merit special attention. The tuffaceous material could have been a possible source of uranium and other elements, which would have been released during diagenesis or weathering of the ash-bearing sediment. Plant fossils seem to have influenced the precipitation of uranium minerals and the localization of many deposits, possibly either by direct reduction of uranium in the ore-bearing solutions or by supporting bacteria that generated hydrogen sulfide, a reducing agent. The asphaltic material could have served either as a transporting or precipitating agent for uranium.

TUFFACEOUS MATERIAL

Volcanic debris, partly glassy shards but more commonly clay altered from volcanic material, is abundant in some ore-bearing sandstone layers of Mesozoic and Cenozoic ages, but it is absent or inconspicuous in most, On the other hand, many of these host layers are interbedded with or underlie stratigraphic units containing bentonitic clay or tuffaceous sandstone. The ore-bearing sandstone layers and associated rocks of Paleozoic age, in contrast, contain little or no recognizable volcanic debris. Furthermore, many uranium-bearing vein deposits in sandstone are not intimately associated with beds containing volcanic debris, regardless of the age of the host rocks.

Important productive deposits in host beds of tuffaceous sandstone include those in the Petrified Forest Member of the Chinle Formation in the Little Colorado district, Arizona (Stewart and others, 1959), and some of the deposits in the Jackson Group in the Texas Coastal Plain (Eargle, 1959). Some of the less productive deposits in beds of Tertiary age in Nevada and California are also in tuffaceous sandstone (table 3), and most are associated with tuffaceous sediments, mainly in overlying beds.

The most productive uranium deposits are in sandstone beds which contain little or no volcanic debris but which are closely associated with beds containing conspicuous volcanic ash or its alteration products.

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These deposits include those in the Shinarump, Monitor Butte, and Moss Back Members of the Chinle Formation in northeastern Arizona and southeastern Utah, where these units are overlain by several hundred feet of dominantly bentonitic argillaceous beds which locally contain tuffaceous sandstone layers; the deposits in the Salt Wash, Westwater Canyon, and Brushy Basin Members of the Morrison Formation, which are overlain by or are interbedded with the bentonitic mudstone of the Brushy Basin Member; and most of the deposits in the Wind River and Wasatch Formations in Wyoming, where the overlying units of Eocene and Oligocene ages are conspiciously tuffaceous. The deposits in the Browns Park Formation in northwestern Colorado are in nontuffaceous sandstone but are close to where it interfingers with tuffaceous sandstone.

PLANT FOSSILS

Fossil remains of woody land plants occur in nearly all peneconcordant uranium deposits in sandstone beds of Devonian and younger ages (table 2); in fact, the absence of such plants before Devonian time may be a significant contributing factor to the near absence of peneconcordant uranium deposits in beds older than Devonian (fig. 2). The remains of conifers and cycads are common in the ore-bearing sandstone beds of Triassic and Jurassic ages (Knowlton, 1927; Daugherty, 1941), whereas the remains of palms are most abundant in the host rocks of Tertiary age (table 3). Some sandstone beds in which plant remains occur contain uranium-bearing vein deposits, but many vein deposits occur in sandstone containing no fossil plant material, particularly in the sandstone older than Devonian.

Plant remains in the ore-bearing beds consist of thin layers of coal, lenses of coaly sandstone and shale, and discrete pieces of woody material, ranging from small fragments to large logs, scattered in the host sandstone. The smaller fragments of woody material tend to be more abundant in "trash pockets." Characteristically the larger logs are water worn and were rafted into place; within a single sandstone lens the longer logs generally are oriented parallel to the long axis of the lens and to the flow of the depositing stream.

Some of the discrete pieces of woody material are replaced by silica or carbonate minerals, but many are carbonized like the coaly material. The chemical composition of the carbonized plant matter is mostly that of lignite or bituminous coal (O'Brien, 1953, 1954; Breger, 1956, 1957; Breger and Deul, 1956, 1959; Pierce and others, 1958). Tested samples of this carbonaceous material are now chemically inert and insoluble in water. In the past, however, this material probably had the capacity of a reducing agent, and its humic components probably were water soluable.

In places the coaly sandstone and shale and lenses of coal contain ore, but most of such material is only weakly mineralized or is barren. In contrast, within the masses of uranium-mineralized sandstone many of the discrete pieces of carbonized woody material are richly replaced by the primary uranium minerals and associated iron and copper sulfides; the cell structure is generally preserved. The barren sandstone surrounding ore deposits, however, also commonly contains pieces of carbonized woody material, and these remains are completely or almost barren, even within a few inches of ore. Fossil wood replaced by silica or carbonate minerals generally is barren of uranium minerals except for secondary ores.

"ASPHALTITE"

The term "asphaltite" embraces all dark noncellular carbonaceous materials, which in the literature on uranium deposits in sandstone have been called asphalt, asphaltite, thucholite, hydrocarbon, bitumen, pyrobitumen, and kerogen. "Asphaltite" was first described by Hess (1922) in the deposits at Temple Mountain, San Rafael district, Utah, but since then this type of material has been found in many deposits in the Western States, though only in sparse amounts in most deposits (Erickson and others, 1954; Bell, 1960). "Asphaltite" is especially abundant in the peneconcordant deposits in the Moss Back Member of the Chinle Formation in the San Rafael district, Utah, and in the Westwater Canyon and Brushy Basin Members of the Morrison Formation in the Ambrosia Lake and Laguna districts, New Mexico. (table 2). Of its occurrences in vein deposits, it is conspicuous at the Black King mine, San Miguel County, and the Pallaoro mine, Jefferson County, both in Colorado.

Physically, "asphaltite" ranges from a black hard vitreous asphaltlike substance prevalent at Temple Mountain to the gray or brown soft dull substance resembling dead oil that is common in the Ambrosia Lake district. These substances emit a fetid odor when freshly broken. They are insoluble in organic solvents and in strong acids and bases, and are infusible except at extremely high temperatures.

In chemical composition, "asphaltite" is more similar to coal than it is to petroleum or hydrocarbons. For this reason, Breger and Deul (1959) and Granger and others (1961) suggested that "asphaltite" is redeposited humic extracts derived from coal and plant remains. Pierce, Mytton, and Barnett (1958) and Pierce, Gott, and Mytton (1964), however, suggested that "asphaltite" was derived from petroleum, and believed that the low hydrogen content results from the loss of hydrogen caused by alpha radiation.

Although now solid, "asphaltite" was certainly introduced in a fluid state; it occurs in much the same manner as do the epigenetic ore minerals; that is, by coating sand grains and filling pore spaces in the sandstone, replacing sand grains and chert pebbles, and filling fracture cavities. In peneconcordant deposits it forms tabular bodies and is coextensive with uranium, although the "asphaltite" and uranium content of the rock do not necessarily correlate closely. In some samples of "asphaltite," the uranium occurs as very fine to submicroscopic grains of uraninite or coffinite, but in others it is probably present as a uranoorganic compound, for no uranium mineral can be detected by X-ray analysis. Some uraniferous "asphaltite" is similar to thucholite (Ellsworth, 1928; Davidson and Bowie, 1951), although it contains no thorium.

DEPOSITION AND HISTORY OF THE HOST ROCKS

Although the tectonic and depositional environments of the host sandstone beds and associated strata (fig. 3) differ somewhat, they caused formation of rocks of similar lithologic character (table 3), which have had a similar postdepositional history. These strata are lenticular and of mixed composition, and they are in areas where, during much of their history after deposition, the pore waters would have been retained rather than drained.

TECTONIC SETTING

Most of the uranium deposits are in rocks that accumulated in foreland belts (Kay, 1951; Lees, 1952) between the stable interior of the continent and the orogenic belts (fig. 3). These foreland belts are low-lying shelves, commonly containing broad shallow basins, where relatively thin and widespread stratigraphic units of continental or shallow-marine origin, or a mixture of the two, accumulated. The sediments possibly were derived from local and mild uplifts in the foreland belt itself or from the stable interior region, but more commonly they probably were derived from folded uplifts of the orogenic belt. The source of these sediments may have been igneous rocks of deep-seated origin, metamorphic rocks, or preexisting sedimentary rocks (Pettijohn, 1949, 1957). The sediments were dominantly clastic and moderately well sorted into muddy, silty, sandy, and pebbly layers. Some of the sandstone beds are arkosic, but chiefly they are quartzose. The low elevation and low relief of the foreland belts and the presence of coal, and even saline deposits in places, indicate poor drainage and perhaps local interior drainage, especially during late stages of deposition. Thus, the pore water in these sediments would have been largely retained as the beds accumulated, and the concentration of salts and humic acid in the waters may have increased during the period of deposition; this water probably was entrapped in the rocks at the close of a sedimentary cycle, and remained so at least until later deformation.

Many uranium deposits, some quite large, occur in host beds that accumulated in intermontane basins and rift valleys. Deformation that caused these basins and valleys consisted chiefly of differential vertical movements of large blocks of the earth's crust; the major structural features are tilted blocks and high-angle faults rather than the compressional folds and thrust faults of deformed geosynclinal belts. Because of the moderately high relief of the surrounding mountains, the sediments in the basins accumulated rather rapidly and are dominantly clastic, commonly very coarse grained arkose and conglomerate along the mountain fronts. The coarser sediments were laid down as piedmont fans and stream-deposited lenses; in places finer sediments accumulated in temporary lakes, some of which were saline. Many of these basins were so poorly drained that the pore water of the sediments tended to be retained.

Some uranium deposits are in sandstone beds deposited on deltaic coastal plains bordering shallow or deep seas. Many formations that accumulated in this environment contain alternating beds of marine and fresh-water origin, but the uranium deposits are mainly in those of fresh-water origin. Being nearly at sea level, the pore waters would have had little tendency to drain from these beds.

A few uranium deposits occur in formations composed of thin beds of sandstone and limestone of marine origin that accumulated in epicontinental seas. No uranium deposits are known in sandstone that was deposited in a geosyncline.

Deformation since the accumulation of the host sandstone beds has been negligible in some uranium-bearing areas, moderate in most, and intense in only a few. It consists mainly of broad tilting, wrinkling, folding of gentle to moderate intensity, and steep-angle faulting, chiefly normal but having some reverse displacement. Details of the tectonic setting of the main uranium region in the west-central States are summarized by Osterwald and Dean (1961) for the central Cordilleran foreland area, and by Kelley (1955, 1956) and Shoemaker (1954, 1956c) for the Colorado Plateau (fig. 1).

Tectonic activity contemporaneous with sedimentation affected many uranium-bearing sandstone formations. Collapse caused sandstone pipes to develop in several formations (Hilpert and Moench, 1958; Puffett and others, 1957). Earlier and concurrent folding and faulting in underlying beds controlled the courses of

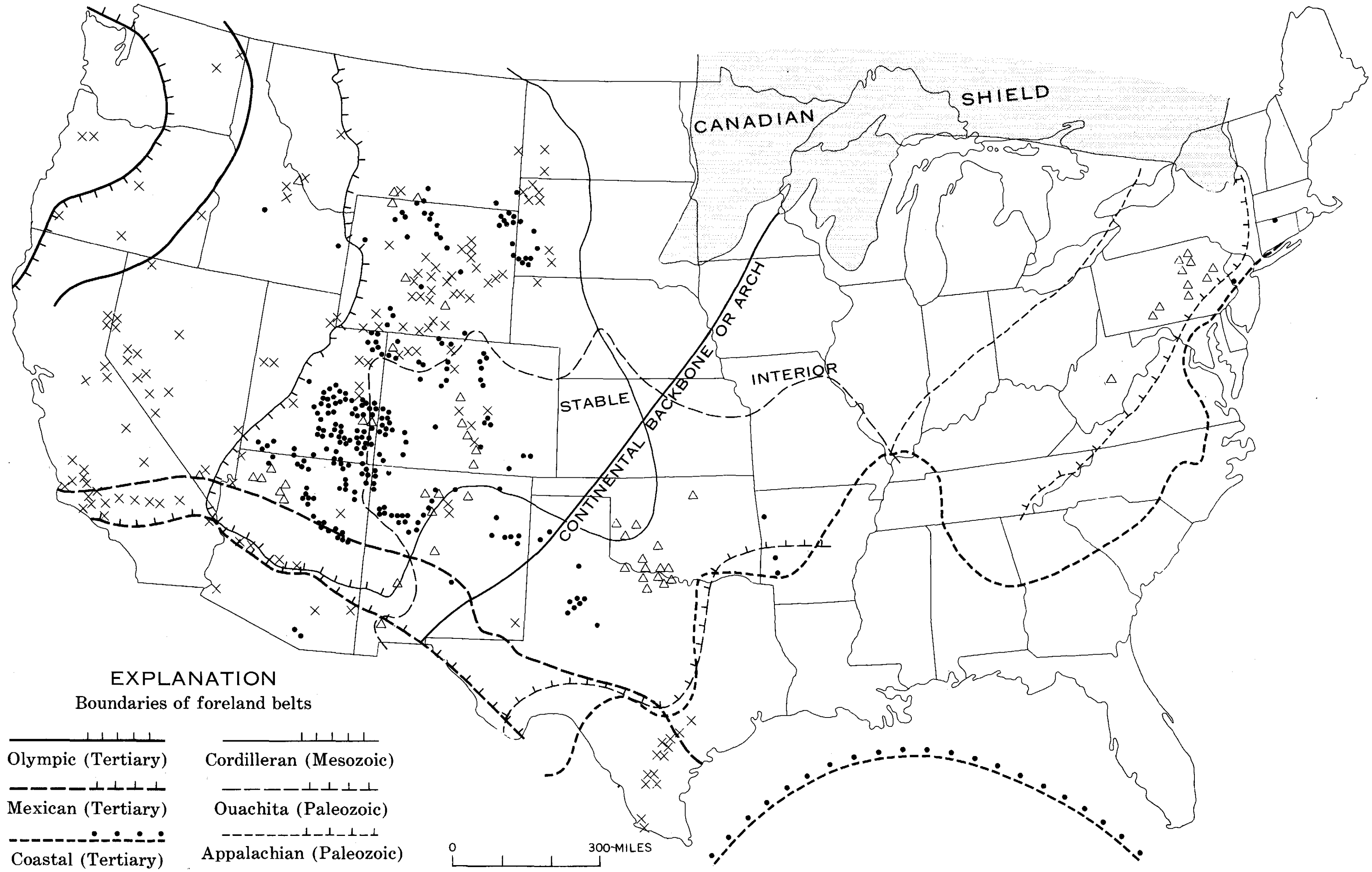


FIGURE 3.—Tectonic setting of uranium deposits in sandstone in the United States. Hachured lines indicate approximate position of orogenic belts. Dotted line indicates appropriate position of Gulf Coast geosyncline. Age of host rock for uranium deposit indicated by symbol: ×, Tertiary; •, Mesozoic; △, Paleozoic. Cordilleran foreland boundaries after Osterwald (1961, fig. 1); other boundaries after G. W. Walker and F. W. Osterwald (written commun., 1957). Continental backbone after Lyons (1950).

many streams that deposited the sediments (Stokes and Phoenix, 1948; Cater, 1953; Stokes, 1953, 1954b, 1954c; Finnell and Gazdik, 1958; MacKallor and others, 1958; Eargle, 1960; Shawe, 1962), and also affected the distribution of various lithologies and sedimentary structure features.

GEOLOGIC HISTORY OF URANIUM-BEARING REGIONS

CORDILLERAN-OUACHITA FORELANDS URANIUM REGION

The name Cordilleran-Ouachita forelands uranium region is applied to the region of abundant deposits extending from Montana and North Dakota to Arizona and New Mexico and then eastward to Oklahoma and Texas. It comprises the Cordilleran and Ouachita forelands of Mesozoic and Paleozoic ages (fig. 3). These forelands border and partly overlap the stable interior region of the continent, and they are bordered on the south and west, respectively, by the Cordilleran and Ouachita geosynclines. Most of the uranium region lies west of the continental backbone—a ridge of Precambrian rocks that extends southwestward from the Canadian shield—and, furthermore, the northeastward trend of the principal mining districts parallels the continental backbone. This forelands uranium region or province also contains other kinds of large uranium ore deposits (Butler and Schnabel, 1956; Klepper and Wyant, 1956) and has been related to tectonic elements in Precambrian rocks of the Cordilleran foreland by Osterwald (1956).

In this forelands uranium region, marine conditions prevailed during early and middle Paleozoic time. The depositional basins were less extensive and shallower than in the geosynclines, where the Paleozoic rocks are several times thicker than in the forelands (Schuchert, 1955; King, 1959). Most of the early and middle Paleozoic host formations in the foreland were deposited in the littoral environment of transgressive epicontinental seas (Sellards, 1933; Thomas, 1952). These formations contain a few uranium vein deposits. By the end of Pennsylvanian time, continental sedimentation became more widespread, especially in Colorado, New Mexico, Oklahoma, and Texas, where fresh-water sediments accumulated adjacent to positive areas of Precambrian rocks in the newly uplifted parts of the ancestral Rocky Mountains and the other mountains to the southeast (fig. 4). Peneconcordant uranium deposits in formations of Late Pennsylvanian and Permian ages occur in arkosic sandstone beds of fresh-water origin near these uplifts. Away from these uplifts and areas of fresh-water deposition, marine and shoreline conditions prevailed. In northwestern Arizona and southern Nevada (fig. 4) vein deposits occur in sandstone beds of shallow-marine and near-shore dune origin.

In Early Triassic time, marine deposits were laid down in the forelands uranium region, whereas continental deposits were laid down during Late Triassic time. In the southern part of the forelands region, widespread erosion preceded the formation of the Late Triassic basins centered in Wyoming, Utah, Arizona, New Mexico, and Texas (pl. 2). The basin in southwestern Utah might have been connected to the Cordilleran geosyncline, where thick sequences of marine and volcanic rocks were deposited. The quartzose, arkosic, and tuffaceous rocks of the Chinle and correlative formations were deposited in the Triassic basins partly as alluvial fans (Miller, 1955) or gravel pediments (Stokes, 1950), and partly as lacustrine beds. Because the prevailing wind in Late Triassic time was from the northwest (Poole, 1957), the tuffaceous material may have been blown into the basins from the volcanic centers (pl. 2) in the Cordilleran geosyncline.

Upper Triassic and Lower Jurassic deposits covered an area about 300 miles wide and 650 miles long and extended from northern Arizona to central Wyoming (pl. 2). The Kayenta and Navajo Formations were deposited in fluvial and eolian environments in this area. During Jurassic time, the deposits became more extensive and eventually covered an area more than 600 miles wide and more than 1,000 miles long that extended from Arizona into Canada (pl. 2). Fluvial and lacustrine environments predominated for most of Jurassic time, although there were several minor marine invasions. The Morrison Formation and the Cow Springs Sandstone were the last Jurassic units deposited. At the southwest limit of Upper Jurassic deposits in Arizona, the rocks are conglomerate and crossbedded dune sandstone; northward into eastern Utah and western Colorado, the rocks grade into a thick sequence of interbedded fluvial sandstone and mudstone (Craig and others, 1955, figs. 21, 28); in the northern two-thirds of the area, the rocks are largely intermixed sandstone and shale and shale that was deposited in lacustrine and mudflat environments (pl. 2). Uranium deposits occur in the thick interbedded sandstone and shale (mudstone) sequence that was deposited in the deepest part of the depositional basin. Tuffaceous material occurs throughout the Jurassic rocks but is most abundant in the upper member of the Morrison (Waters and Granger, 1953, p. 5; Keller, 1959). Volcanoes in western Utah and southern Idaho (pl. 2) were the most likely sources of this tuffaceous material (Livingston, 1932; McKee and others, 1956).

From Late Jurassic to Early Cretaceous time there was a transition from continental to marine deposition.

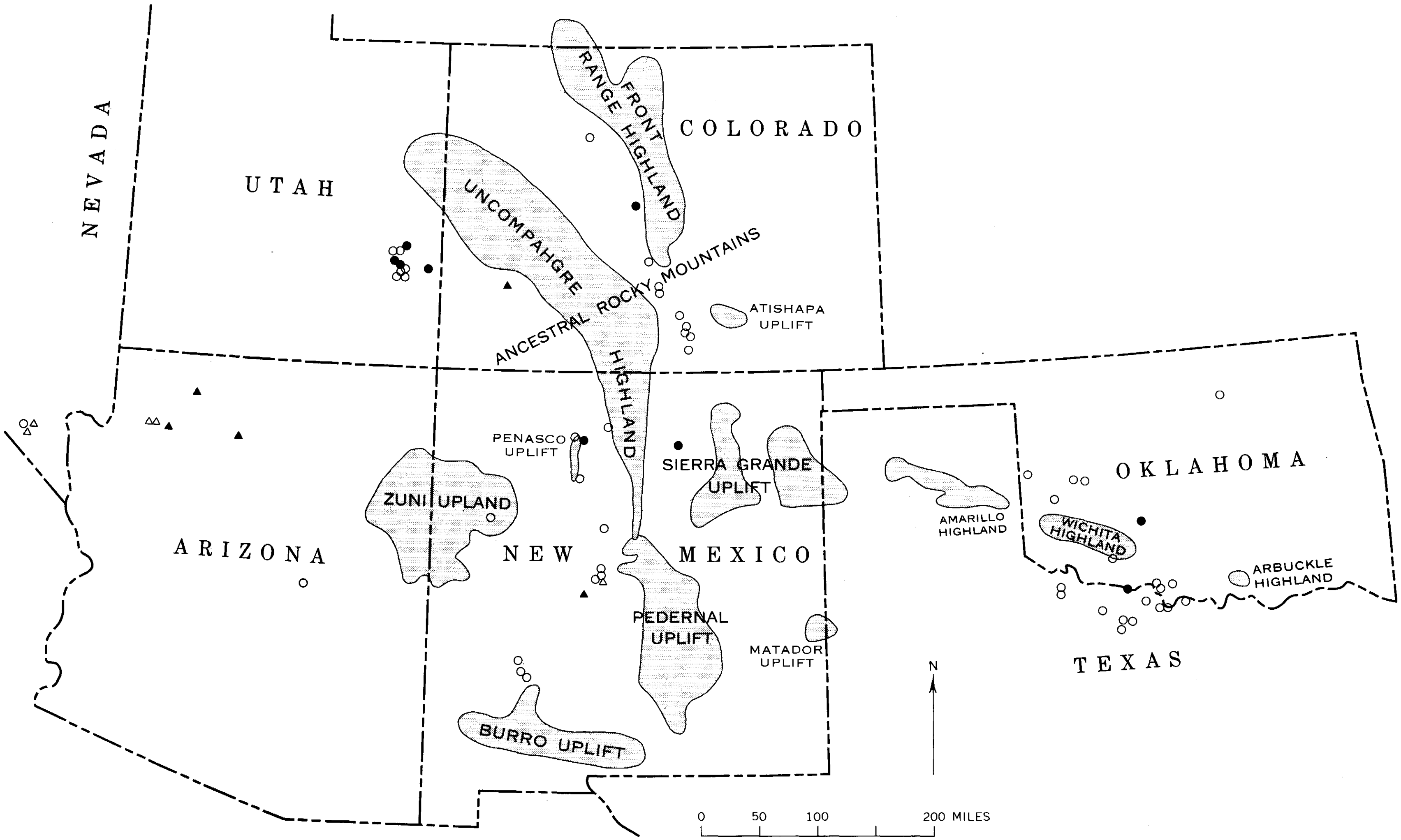


FIGURE 4.—Distribution of peneconcordant (circle) and vein (triangle) uranium deposits in sandstone beds of Pennsylvanian and Permian ages and of areas (shaded) where Precambrian rocks were exposed during Late Pennsylvaniann and Permian time in the Southwestern States. Deposits that have yielded ore shown by solid symbol. Areas of Precambrian rocks compiled from Burbank (1933, fig. 14); Hills (1942, fig. 2); King (1959, fig. 57); McKee (1951, pl. 2*B*); Read and Wood (1947, fig. 2); Roswell Geological Society (1952); and McKee and others (in press).

In the southern part of the region, the Dakota Sandstone was deposited in fluvial, paludal, and lagoonal environments, landward to beaches and offshore bars of the transgressing seas. In the northern part of the region, the fluvial sandstone beds of the Lakota Formation, Inyan Kara Group, show an interruption of the lacustrine desposition prevalent during Morrison time. The Fall River Formation, which overlies the Lakota, was then deposited in fluvial tidal-flat and swamp, estuarine, and deltaic environments landward of the transgressing Cretaceous sea (Waagé, 1959). Uranium deposits occur only in the nonmarine facies of the dominantly marine Cretaceous rocks.

At the beginning of the Tertiary, the ancestral Rocky Mountains stood high above the surrounding area, and then three cycles of sedimentation occurred in the region. Within the Rocky Mountain region, major structural basins—such as the Wind River and Powder River Basins, Wyo.; the Uinta Basin, Utah; the South Park Basin, Colo.; and the San Juan Basin, N. Mex.—were evident by Eocene time (fig. 5). Alluvial fans were deposited along the periphery of the basins, and streams carried coarse, poorly sorted arkosic debris, derived from Precambrian and younger rocks of the surrounding mountains, into the centers of the basins. Volcanic ash was showered into the basins from sources to the west. The Green River Basin, Wyo., was occupied by a lake in which enormous quantities of shale and tuff were deposited. The Rocky Mountains had been beveled by late Eocene, and the first cycle of sedimentation came to an end. Epigenetic uranium deposits are most abundant in the coarse clastic Eocene rocks of the intermontane basins. Lacustrine shales of this cycle contain only syngenetic uranium associated with phosphate (Love and Milton, 1959).

The second cycle of sedimentation, mainly during early Miocene time, spread relatively thin layers of sandstone and finer grained material, much of its tuffaceous, in areas of low elevation, but these beds contain only a few uranium deposits. Erosion and planation of the mountains continued.

In late Miocene time the entire Rocky Mountain region was elevated. Streams carried coarse debris eastward from the mountains onto the gentle eastward slopes of the plains. Volcanic debris also was deposited and, as did that in the older formations, it too probably came from the west. This cycle differed from that of Eocene time in that the sediments were deposited almost exclusively east of the mountains and not in the intermontane basins. An exception, however, was the alluvium deposited in the Browns Park Basin in northwestern Colorado. Sandstones of the cycle are important host rocks of uranium only where they fill intermontane basins.

CALIFORNIA AND NEVADA

The close of marine deposition in the Cordilleran geosyncline and the orogeny at the end of the Mesozoic left the California and Nevada uranium area high and mountainous (Mallory, 1956). During the Tertiary, alluvial and lacustrine rocks accumulated in fault-block basins of the Basin and Range physiographic province, and interbedded and interfingered marine and nonmarine rocks were deposited in the troughs between the Coast Ranges and the Sierra Nevada. Many kinds of rocks were deposited, but the uranium deposits occur mostly in the tuffaceous and arkosic rocks deposited near the close of sedimentation. Most of the deposits in California are in two narrow belts that parallel the intersecting San Andreas and Garlock-Big Pine fault systems.

TEXAS COASTAL PLAIN

Tertiary sediments were deposited in and adjacent to the Gulf Coast geosyncline, whose deepest part was just off the present gulf coastline of the United States (Kay, 1951, p. 79). Marine transgressions northward onto the deltaic plain or coastal foreland (fig. 3) of this geosyncline resulted in the deposition of interfingered and interbedded marine, nonmarine, and intermediate littoral and lagoonal sediments (fig. 5). Plummer (1933, p. 526, fig. 29) described nine major marine transgressions onto the Texas Coastal Plain. As each sea regressed, clastic sediment from older sedimentary rocks and ash from volcanoes to the west and north were deposited by rivers flowing to the sea (Eargle and Snider, 1957). The chief uranium-bearing units are among the ash-bearing fluvial and deltaic sediments laid down on the foreland during the last two or three major regressions.

EASTERN PENNSYLVANIA

The uranium deposits in eastern Pennsylvania and surrounding States are in the Appalachian foreland region, which was the site of the Appalachian geosyncline from late Precambrian through the Ordovician, of the Appalachian foreland (fig. 3) from Devonian to the Early Permian when the Appalachian orogeny occurred, and of various postorogenic troughs in the Late Triassic. The history of sedimentation, orogeny, and igneous activity in the Appalachian foreland is complex (Barrell, 1913; Kay, 1951; P. B. King, 1951). The uranium-bearing rocks of Devonian, Mississippian, and Pennsylvanian ages accumulated under continental and deltaic conditions on foreland plains in front of newly uplifted mountains. The region was positive from Late Permian until Late Triassic when the last

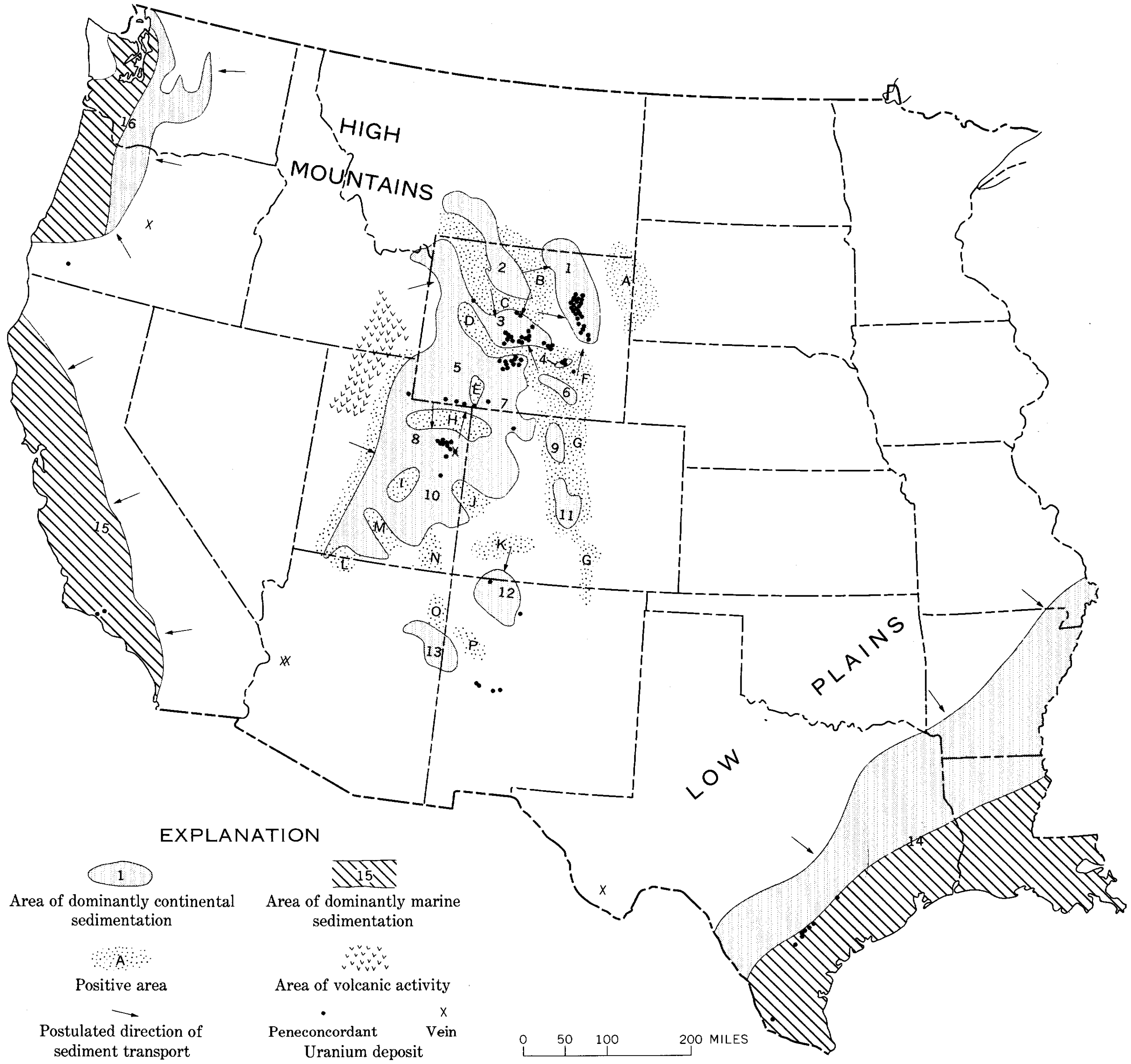


FIGURE 5.—Distribution of uranium deposits in sandstone of Eocene age and the approximate outlines of major sedimentary basins and positive areas in Eocene time in the Western States. Outlines of basins and positive areas modified from maps by Hunt (1956, p. 78), Eardley (1951, p. 371), and Schuchert (1955, maps 78–80).

Positive areas

A. Black Hills uplift.
B. Bighorn Mountains.
C. Owl Creek Mountains.
D. Wind River Range.
E. Rock Springs uplift.
F. Laramie Mountains.
G. Front Range.
H. Uinta Range.
I. San Rafael swell.
J. Uncompaghre upwarp.
K. San Juan Mountains.
L. Kaibab upwarp.
M. Circle Cliffs upwarp.
N. Monument upwarp.
O. Defiance upwarp.
P. Zuni upwarp.

Sedimentary basins

1. Powder River Basin.
2. Bighorn Basin.
3. Wind River Basin.
4. Shirley Basin.
5. Bridger and Green River Basins.
6. Hanna Basin.
7. Washakie Basin.
8. Uinta and Green River Basins.
9. North Park Basin.
10. Green River Basin.
11. South Park Basin.
12. San Juan Basin.
13. Black Mesa Basin.
14. Mississippi embayment.
15. California troughs.
16. Puget trough.

great subsidence occurred. The Newark and other tilt-block or rift troughs were then formed from Nova Scotia to the Carolinas. Accumulation of sediment in the troughs resulted in thick sequences of fluvial and estuarine rocks; these rocks are interlayered with diabase flows and sills (McKee and others, 1959, pl. 4). One such sequence is the uranium-bearing Newark Group.

CHARACTER OF THE DEPOSITS

CHEMICAL COMPOSITION

The chemical elements in uranium deposits in sandstone are classed in two groups. Those elements that are dominantly in the sedimentary and diagenetic components of the host rocks are classed as intrinsic, and those that dominantly have been added by mineralization are classed as extrinsic. The intrinsic-element composition of the deposits varies somewhat because of original lithologic differences in the host rocks, but the major differences in composition are among the extrinsic elements—some extrinsic elements that occur are abundant with uranium in some deposits but sparse in others. Some major differences in the extrinsic composition of deposits have a regional pattern and some have a stratigraphic relation, but generally there is little difference in the composition of deposits at one stratigraphic position within a mining district (Miesch and others, 1960).

The elements that are dominantly intrinsic in the uranium deposits in the Colorado Plateau region, and the components in which they occur, are listed in table 4. The same elements, all occurring in much the same components, are also common in deposits outside the Plateau region. In addition to the listed elements, phosphorus is an intrinsic element in some deposits in sandstone of Tertiary age; in these deposits it occurs mainly in carbonate fluorapatite as a cementing material.

Elements that are dominantly extrinsic in deposits in certain members of the Chinle and Morrison Formations in the Colorado Plateau region, their geometric mean content in barren sandstone and ore, and their enrichment factors are listed in table 5.

The average grade of ore mined from the Chinle and Morrison Formations is about 0.2 percent U_3O_8—an enrichment of about 800 times the amount of uranium in barren sandstone. Uranium has the highest enrichment factor of all extrinsic elements, but its average grade is considerably less than that of vanadium and copper in many deposits.

Most uranium-bearing vein deposits in sandstone contain little or no vanadium, but this metal is widely as-

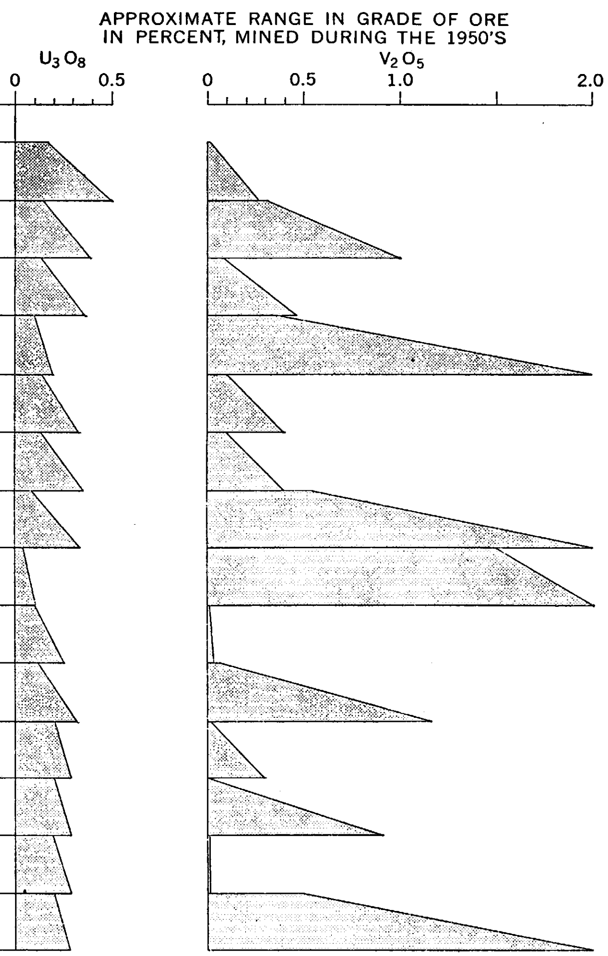
TABLE 4.—*Dominantly intrinsic elements in sandstone and in uranium ore in the Colorado Plateau region*

[Mn, Mg, Ca, Na, Ba, and Sr dominantly authigenic. Abstracted principally from Shoemaker and others (1959)]

Element	Mineralogic occurrence	Comments
Si	Quartz, feldspar, clay, silicified wood, and chert.	
Al	Clay (and vanadium clay in the ores), feldspar, and micas.	
Fe	Oxides, sulfides, carbonates, clay, and detrital heavy minerals.	Some oxides, sulfides, and carbonates may be authigenic and extrinsic.
Mn	Carbonates, oxides, and heavy detrital minerals.	Carbonates and oxides locally form ores not closely associated with uranium (Crittenden, 1951; Baker and others, 1952).
Mg	Clay and dolomite	Dolomite may be authigenic.
Ca	Calcite, dolomite, gypsum, plagioclase, and detrital heavy minerals.	Calcite, dolomite, and gysum extrinsic in some ores.
Na	Clay, bicarbonates, and plagioclase	
K	Feldspar and clay	
Ti	Detrital heavy minerals and alterations thereof; in clay fraction as anatase(?).	
Zr	Zircon	
Ba	Interstitial barite	Questionably extrinsic in some ores.
Sr	Substitute for Ca in calcite and for Ba in barite.	
Cr	Difficult to account for	Extrinsic chrome mica borders certain deposits.
B	Tourmaline	

sociated with uranium in peneconcordant deposits in sandstone. It is more abundant than uranium in deposits in some stratigraphic units and in some areas (fig. 6), and such deposits have been the world's principal source of vanadium. These deposits include all those in the Salt Wash Member of the Morrison Formation in western Colorado and eastern Utah, in the Entrada Sandstone in western Colorado, in the Moss Back Member of the Chinle Formation at Temple Mountain, Utah, and in the Shinarump Member in the Monument Valley area, Arizona. Some vanadium has also been recovered from deposits in the Fall River Formation in South Dakota and from the few uranium-productive deposits in the Brushy Basin Member of the Morrison Formation in western Colorado and part of eastern Utah. Deposits from which vanadium has been recovered yield ores whose average grades range from 1 to 2 percent V_2O_5, except those in the Fall River Formation, whose average grades are a little lower.

Little or no vanadium is present in uranium deposits in sandstone beds of Tertiary age in Texas and Wyoming, and in most deposits in Nevada and California. Deposits in the Shinarump in the White Canyon district, Utah, and in the Petrified Forest in the Little Colorado district, Arizona, contain virtually no vanadium; the same is true of some deposits in the Moss Back in eastern Utah, whereas others contain small amounts. Most deposits in the Morrison Formation in New Mexico contain only small amounts.



SYSTEM	FORMATION	MEMBER	DISTRICT OR AREA	APPROXIMATE RANGE IN RATIO, $U_3O_8:V_2O_5$
TERTIARY	Wasatch and Wind River		Wyoming	1:0.04–1:1
CRETACEOUS	Fall River		Edgemont, S. Dak.	1:1.5–1:7
CRETACEOUS	Lakota		Edgemont, S. Dak.	1:0.2–1:2
JURASSIC	Morrison	Brushy Basin	Colorado and Utah, except Blanding area, Utah	1:2–1:20
JURASSIC	Morrison	Brushy Basin	Laguna and Ambrosia Lake N. Mex.	1:0.5–1:2
JURASSIC	Morrison	Westwater Canyon	Ambrosia Lake, N. Mex.	1:0.5–1:2
JURASSIC	Morrison	Salt Wash	Western Colorado and eastern Utah	1:2–1:20
JURASSIC	Entrada		Western Colorado	1:20–1:40
TRIASSIC	Chinle	Petrified Forest	Little Colorado, Ariz.	1:0.1–1:0.65
TRIASSIC	Chinle	Moss Back	Temple Mountain, Utah	1:2–1:4
TRIASSIC	Chinle	Moss Back	San Rafael, Utah, other than Temple Mountain	1:0.1–1:1
TRIASSIC	Chinle	Moss Back	Monticello and Moab, Utah	1:0.03–1:3
TRIASSIC	Chinle	Shinarump	White Canyon, Utah	1:0.03
TRIASSIC	Chinle	Shinarump	Monument Valley, Ariz.	1:1–1:10

FIGURE 6.—Approximate ranges in grades and in ratios of U_3O_8 and V_2O_5 for ores from selected stratigraphic units and areas.

TABLE 5.—*Geometric mean content of dominantly extrinsic elements in uranium ore and barren sandstone from parts of the Chinle and Morrison Formations, Colorado Plateau region, and their enrichment factors*

[Enrichment factor is the estimated geometric mean concentration in the uranium ore divided by the estimated geometric mean in unmineralized sandstone. ≈, Approximate figures based on fewer samples than shown at top of column. From A. T. Miesch (written commun., 1962)]

Element	Chinle Formation, Shinarump and Moss Back Members			Morrison Formation, Salt Wash Member		
	Geometric mean (percent)		Enrichment factor (rounded)	Geometric mean (percent)		Enrichment factor (rounded)
	Barren sandstone (97 grab samples)	Uranium ore (87 mill-pulp samples [1])		Barren sandstone (97 grab samples)	Uranium ore (215 mill-pulp samples)	
U	≈0.0002	0.16	800	0.00018	0.15	830
V	≈.002	.16	80	.0012	.69	575
Cu	.002	.029	15	.0017	.0090	5
Ag	≈.000002	.00001	5	≈.000003	≈.00005	17
Se	≈.00002	.00067	35	≈.00003	.0014	45
Mo	≈.00003	.0035	120	≈.00003	≈.002	65
Pb	≈.0001	.012	120	≈.00007	.0096	135
Zn	≈.001	.016	16	≈.0005	.010	20
Ni	≈.0003	.0034	10	≈.00008	.00098	12
Co	≈.0002	.0035	17	≈.00005	.0012	25
As	≈.0015	.021	14	≈.0006	.0085	14
Sb	≈.0001	≈.0003	3	≈.00006	≈.00009	----------
Y	≈.001	.0024	2	≈.0002	.0014	7
Ba	.044	.066	----------	.032	.075	2
Cr	.0013	.0031	2	.00086	.0016	2

[1] About ⅛ of these samples are from Temple Mountain, San Rafael district, Utah.

All known vanadium deposits in sandstone contain uranium, although the deposits in the Entrada contain only 0.05–0.1 percent U_3O_8.

Abundant copper is associated with uranium in some vein and peneconcordant deposits (pl. 1). Copper-bearing uranium vein deposits are rather scattered. Copper in peneconcordant uranium deposits, on the other hand, has a more systematic distribution pattern that is partly stratigraphic and partly geographic. Copper is most abundant in uranium ores in sandstone beds of Permian and Triassic ages in the region extending from southern Utah to Oklahoma and northern Texas. Within this region, copper is most conspicuous in the peneconcordant uranium deposits in the Shinarump Member of the Chinle Formation in the White Canyon district, southeastern Utah, where the average copper content of some deposits is as much as 1 percent.

A few scattered uranium deposits in sandstone beds of other geologic ages contain conspicuous amounts of copper (pl. 1), but most deposits contain only trace amounts and many contain no recognizable copper minerals. In general, peneconcordant uranium deposits that are rich in copper contain very little vanadium, though there are exceptions such as the deposits in the lowest sandstone bed in the Salt Wash Member of the Morrison Formation in Montrose County, Colo., where the ore averages about 1 percent copper, 1–2 percent V_2O_5, and 0.2–0.3 percent U_3O_8. Peneconcordant deposits of copper, generally called red-beds type, associated with very little uranium and vanadium, are common in sandstone beds of Permian and Triassic ages in New Mexico, Texas, and Oklahoma; a few deposits of this type occur in other places in the United States.

Silver is very sparse in most peneconcordant uranium deposits in sandstone. In the Silver Reef district, Utah, however, peneconcordant deposits in the Moenave Formation yielded nearly $8 million worth of silver from 1875 to 1910 (Proctor, 1953). This ore probably averaged about 15 ounces of silver per ton, roughly 0.05 percent Ag, an enrichment factor of 25,000 times the geometric mean silver content of samples from the Chinle Formation (table 5). These deposits also contained appreciable amounts of copper, vanadium, and selenium, and in the 1950's they yielded some uranium ore. Small amounts of silver have been recovered from a few uranium-bearing vein deposits—for example, those deposits from the Silver Cliff mine, Niobrara County, Wyo., which also has yielded a little uranium ore, the Lady Bell mine, Eagle County, Colo., and the Cashin mine, Montrose County, Colo. (table 2).

Selenium is abundant in many Colorado Plateau ores, especially in the Thompsons and San Rafael districts, Utah, and in ores from some Tertiary sandstone in Wyoming and other States (Davidson, 1963). Although its average grade is generally less than half the average uranium grade, recovery of selenium from a few uranium ores has been considered. In the Chinle and Morrison ores, its enrichment factor is relatively high (table 5).

Molybdenum is widespread, and it has a moderately high enrichment factor (table 5). Its minerals have been identified in uranium ores from the Jackson Group, Karnes County, Tex.; the Wind River Formation, Gas Hills district, Wyoming; the Inyan Kara Group, Edgemont district, South Dakota; and several formations in the Colorado Plateau region.

Lead occurs in nearly all of the uranium ores and is most noticeable in unoxidized ores as sparse minute particles of galena. Lead and zinc minerals, however, form ore in several veins containing uranium in northern Arizona (pl. 1). The isotopes of lead in the sandstone ores consist of nonradiogenic Pb^{204} and of radiogenic Pb^{206} and Pb^{207}. In addition to the radiogenic lead formed since ore deposition, a considerable amount is present apparently as an original constituent, either intrinsic or precipitated at the time of ore deposition (Stieff and Stern, 1956). The Colorado Plateau ores contain very little of the isotope Pb^{208}.

Although zinc, nickel, cobalt, and arsenic have been enriched in some Colorado Plateau ores more than copper (table 5), their average grades are extremely low and their minerals are rare. Nickel is more abundant than cobalt in iron sulfides from ores and barren rocks of the Wind River and Wasatch Formations in the Gas Hills and Powder River Basin districts, Wyoming (R. G. Coleman, written commun., 1959; Sharp and Gibbons, 1964). In the Colorado Plateau ores, however, nickel is commonly less abundant than cobalt. Studies of sulfides from various metalliferous ores and rocks have shown that nickel-cobalt ratios greater than 1:1 are typical of sulfides of sedimentary origin, whereas those less than 1:1 are typical of sulfides of magmatic origin (Fleischer, 1955, p. 1004).

Few ores have been analyzed for sulfur, but many determinations of sulfur isotope ratios of sulfides ($S^{32}:S^{34}$) have been made on ores from more than 50 uranium deposits in sandstone in the United States. The ranges in isotope ratios of sulfides from peneconcordant and vein ores in various formations are summarized graphically on figure 7. The graph shows that the sulfur isotope ratios of sulfides from sandstone ores are distinctly more variable than those of sulfides from igneous rocks and magmatic ores. The extensive fractionation of the sulfur in the sandstone ores is probably due to anerobic bacteria (Thode and others, 1949; Feely and Kulp, 1957).

Arsenic is particularly abundant at Temple Mountain, Utah, where there is evidence of past strong hot-spring activity. Outside the Colorado Plateau, arsenic shows marked enrichment in sulfides from ore over those from barren rock in the Gas Hills district, Wyoming (R. G. Coleman, written commun., 1959). As much as 0.05 percent arsenic occurs in uranium ores from the Edgemont district, South Dakota (Gott and Schnabel, 1963).

Barium is only slightly enriched in most uranium deposits in sandstone. A single report of barite production is recorded from ores of only one district: the uranium-bearing veins in the Wingate and Kayenta Formations in Richardson Basin, Grand County, Utah (pl. 1, table 2; Parsons, 1913).

The dominantly intrinsic element manganese is very abundant in some uranium ores: namely, those from the Kayenta Formation at the Yellow Jeep mine, Coconino County, Ariz., from the Chinle Formation at the Jasper claim, San Juan County, Utah, and from the Wasatch Formation at many localities in Campbell, Johnson, and Converse Counties, Wyo. (table 2).

Chromium is nearly absent in uranium ore bodies, but it is concentrated in epigenetic bands and layers close to many of them—for example, in the Entrada, Chinle, and Wingate Formations in the Colorado Plateau region (Hawley, 1957; Bush and others, 1959; Fischer, 1960). As much as a few tenths of a percent Cr_2O_3 occurs in some layers. Similar occurrences in sandstone in the Mecsek Mountains, Hungary, have been described by Kiss (1958).

A few elements occur so rarely in noticeable concentrations as to warrant only a mention here; they include rhenium associated with molybdenum in Chinle ores at the Sun Valley mine, Coconino County, Ariz. (Petersen and others, 1959) and in Inyan Kara ores at the Runge mine, Fall River County, S. Dak. (Myers and others, 1960), and cadmium in a few primary vanadiferous Colorado Plateau ores (Weeks and others, 1959).

MINERAL COMPOSITION

The intensive mineralogic studies of uranium during 1948–59 resulted in the description of more than 30 new uranium minerals, many of which came from sandstone ores (Frondel and Weeks, 1958). In addition, several compilations of descriptive uranium mineralogy were published (Weeks and Thompson, 1954; Frondel and Fleischer, 1955; Frondel, 1958), and several detailed discussions of the mineralogy of sandstone ores were written (Weeks, 1956; Laverty and Gross, 1956; Weeks and others, 1959; T. L. Finnell and W. I. Finch, written commun., 1959).

Uranium minerals identified in sandstone ores and their formulas are listed in table 6. Relatively little has been reported on the abundance of the various minerals in individual deposits or districts (Botinelly and Weeks, 1957).

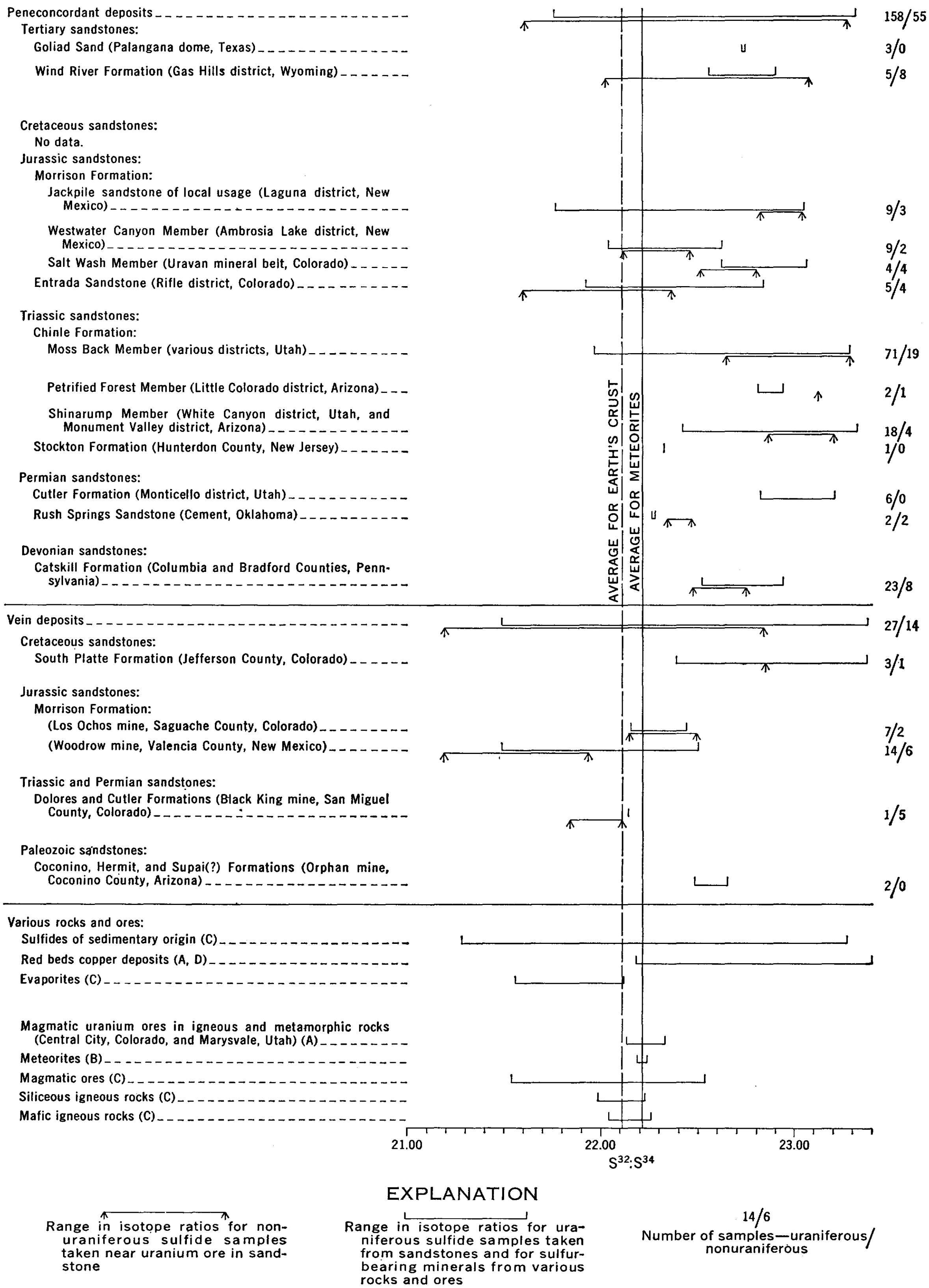


FIGURE 7.—Graph of the ranges in sulfur isotope ratios for uranium deposits in sandstone and for various other types of rocks and ores. Sources of data for other rocks and ores: (A) M. L. Jensen and C. W. Field (written commun., 1960); (B) Jensen (1958); (C) Ault and Kulp (1960); and (D) Phillips (1960).

TABLE 6.—*Uranium minerals identified in sandstone deposits and their formulas alphabetized according to chemical groups*

[Formulas from Frondel (1958)]

Mineral	*Formula*
Uranium arsenate minerals:	
Zeunerite	$Cu(UO_2)_2(AsO_4)_2 \cdot 10\text{–}16H_2O$
Metazeunerite	$Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$
Uranospinite	$Ca(UO_2)_2(AsO_4)_4 \cdot 10H_2O$
Abernathyite	$K_2(UO_2)_2(AsO_4)_2 \cdot 8H_2O$
Novacekite	$Mg(UO_2)_2(AsO_4)_2 \cdot 8\text{–}10H_2O$
Troegerite	$H_2(UO_2)_2(AsO_4)_2 \cdot 8H_2O$
Uranospathite	Probably $Cu(UO_2)_2(AsO_4, PO_4)_2 \cdot 11H_2O$
Uranium carbonate minerals:	
Schroeckingerite	$NaCa_3(UO_2)(CO_3)_3(SO_4)F \cdot 10H_2O$
Andersonite	$Na_2Ca(UO_2)(CO_3)_3 \cdot 6H_2O$
Bayleyite	$Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$
Rutherfordine	$(UO_2)(CO_3)$
Liebigite	$Ca_2(UO_2)(CO_3)_3 \cdot 10H_2O$
Rabbittite	$Ca_3Mg_3(UO_2)_2(CO_3)_6(OH)_4 \cdot 18H_2O$
Swartzite	$CaMg(UO_2)(CO_3)_3 \cdot 12H_2O$
Uranium molybdate mineral: Umohoite	$(UO_2)(MoO_4)$
Uranium oxide minerals:	
Uraninite	UO_2 (ideal)
Becquerelite	$2UO_3 \cdot 3H_2O$
Gummite	Fine-grained mixture consisting in part of hydrated oxides.
Schoepite	Approximately $4UO_3 \cdot 9H_2O$
Fourmarierite	Probably $PbU_4O_{13} \cdot 7H_2O$
Ianthinite	Approximately $2UO_2 \cdot 7H_2O$
Uranium phosphate minerals:	
Autunite	$Ca(UO_2)_2(PO_4)_2 \cdot 10\text{–}12H_2O$
Meta-autunite	$Ca(UO_2)_2(PO_4)_2 \cdot 8?H_2O$
Torbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$
Metatorbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$
Uraniferous carbonate-fluorapatite	
Uranocircite	Unknown.
Phosphuranylite	$Ca(UO_2)_4(PO_4)_2(OH)_4 \cdot 7H_2O$
Sabugalite	$HAl(UO_2)_4(PO_4)_4 \cdot 16H_2O$
Bassetite	$Fe(UO_2)_2(PO_4)_2 \cdot 8H_2O$
Saléeite	$Mg(UO_2)_2(PO_4)_2 \cdot 8\text{–}10H_2O$
Dewindtite	Probably $Pb_3(UO_2)_6(PO_4)_4(OH)_6 \cdot 10H_2O$
Uranium silicate minerals:	
Coffinite	$U(SiO_4)_{1-x}(OH)_{4x}$
Uranophane	$Ca(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$
Beta-uranophane	$Ca(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$
Uraniferous opal	
Cuprosklodowskite	$Cu(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$
Sklodowskite	$Mg(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$
Soddyite	$(UO_2)_5(SiO_4)_2(OH)_2 \cdot 5H_2O$
Boltwoodite	$K_2(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$
Kasolite	Probably $Pb(UO_2)(SiO_3)(OH)_2$
Weeksite	$K_2(UO_2)_2(Si_2O_5)_3 \cdot 4H_2O$
Uranium sulfate minerals:	
Johannite	$Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 6H_2O$
Uranopilite	$(UO_2)_6(SO_4)(OH)_{10} \cdot 12H_2O$
Zippeite	$K_4(UO_2)_6(SO_4)_3(OH)_{10} \cdot H_2O$
Uranium vanadate minerals:	
Carnotite	$K_2(UO_2)_2(VO_4)_2 \cdot 1\text{–}3H_2O$
Tyuyamunite	$Ca(UO_2)(VO_4)_2 \cdot 5\text{–}8\frac{1}{2}H_2O$
Metatyuyamunite	$Ca(UO_2)_2(VO_4)_2 \cdot 3\text{–}5H_2O$
Rauvite	$CaO \cdot 2UO_3 \cdot 5V_2O_5 \cdot 16H_2O$
Uvanite	$2UO_3 \cdot 3V_2O_5 \cdot 15H_2O$
Sengierite	Suggested to be $Cu(UO_2)_2(VO_4)_2 \cdot 8\text{–}10H_2O$

CONCEPT OF PRIMARY AND SECONDARY MINERALS

In all the known deposits below the zone of oxidation, uranium and vanadium occur as low-valent oxides and silicates, and iron, copper, lead, and zinc occur as common sulfide minerals. These minerals are considered to be primary. The vanadium silicates are stable under oxidizing conditions, but the uranium oxide uraninite and the silicate coffinite, the vanadium oxides, and the various sulfides oxidize readily and form simple to complex secondary minerals. This concept of primary and secondary minerals fits well with theoretical chemistry, laboratory experiments, and nearly all the field evidence (Garrels, 1953, 1955; Garrels and Larsen, 1959; Garrels and Christ, 1959; Evans, 1959).

The change from primary to secondary ore is gradual and in vanadiferous ores is very complex. Primary ores are generally black, and the early changes may be scarcely recognizable. Some of these changes are (1) an increase in 6-valent uranium in the uraninite structure, (2) pseudomorphic replacement of montroseite by paramontroseite, and (3) redistribution of ore into postmineralization fractures as a sooty variety of uraninite, as crystals of coffinite, or as crystals of paramontroseite. Redistributed ores have been mapped in the Ambrosia Lake district, New Mexico, and are characteristically purplish brown (Granger and others, 1961).

As oxidation proceeds, uranium in nonvanadiferous ores forms hydrous oxides or is dispersed in a black amorphous colloidal phase (Weeks and Truesdell, 1958). In vanadiferous ores, 3-valent vanadium oxides alter to 4- and 5-valent vanadium minerals. The partly oxidized vanadiferous ores are characteristically bluish and greenish black. Complete oxidation of the uranium ores generally results in a few very insoluble 6-valent uranium minerals. The completely oxidized ores are characteristically yellow or green and mottled brown. The degree of oxidation of a uranium deposit depends upon its nearness to the land surface, its relation to the topography, and the local climatic and ground-water conditions.

In some deposits, 6-valent uranium minerals probably are primary in the sense of forming first rather than resulting from the oxidation of earlier minerals in the deposit. In these deposits, the 6-valent uranium minerals formed from the evaporation of uranium-bearing ground water above the water table; the term "caliche deposits" has been suggested for them by Bell (1954). They are common in California, Nevada, and southern Arizona. Most caliche deposits of uranium are small and nonproductive, but the schroeckingerite deposit at Lost Creek, Sweetwater County, Wyo., and the carnotite-bearing veins at Richardson Basin, Grand County, Utah, have been mined (table 2).

PRIMARY URANIUM MINERALS

Uraninite, an oxide, and coffinite, a silicate, are the principal primary uranium minerals; both are black and contain 4-valent uranium. Uraninite occurs chiefly as hard lustrous grains, either dense and structureless or microbotryoidal, but also as fairly large masses free of associated minerals (Laverty and Gross, 1956). The microbotryoidal uraninite is somewhat similar to the relatively large spheroidal uraninite so characteristic of uranium-bearing veins in igneous and metamorphic rocks (Kidd and Haycock, 1935; Everhart and Wright, 1953; Finch, 1959a, p. 142). Coffinite is softer and less lustrous than uraninite and is mostly very fine grained and intergrown with other minerals. In peneconcordant deposits, coffinite and uraninite mainly replace fossil wood and the sandstone immediately adjacent to it, but they also are disseminated in pores of the sandstone. Uraninite preferentially replaces the cell walls of fossil wood, whereas coffinite fills the cell lumens; in places, both have replaced earlier iron and copper sulfides in the plant fossils. In vein deposits these uranium minerals occur mainly in open fractures. Sooty uraninite occurs in places in fractures in partly oxidized peneconcordant deposits.

Although uraninite and coffinite commonly occur together, one is more abundant than the other in certain groups of deposits. Uraninite dominates in most deposits in the Chinle Formation in the San Rafael, White Canyon, and Monument Valley districts, Utah and Arizona, whereas coffinite dominates in the ores in the Morrison Formation in the Ambrosia Lake and Laguna districts, New Mexico, in the Inyan Kara Group in the Edgemont district, South Dakota, and in many deposits in sandstone of Tertiary age in Wyoming.

Uraniferous carbonate fluorapatite occurs in phosphatic sandstone, siltstone, and tuff in several localities (table 2); it is particularly abundant in deposits in the Gas Hills district, Wyoming. Uranium has been substituted into the carbonate fluorapatite structure (Altschuler and others, 1958), probably during primary mineralization.

ASSOCIATED PRIMARY MINERALS

The primary vanadium minerals are also low-valent oxides and silicates. Häggite $[V_2O_2(OH)_3]$ and the more abundant montroseite $[VO(OH)]$ are black bladed minerals that occur as single crystals, crystal aggregates, and crystalline masses. These minerals occupy pores of the sandstone and replace sand grains and fossil wood. The vanadium silicates are all micaceous and consist of roscoelite $[K(Al, V)_2(Al, Si_3)O_{10}(OH, F)_2]$ and vanadium-bearing chlorite and hydrous mica. These minerals are clearly epigenetic, for they coat sand grains as minute flakes standing normal to the grain surface and partly or completely fill pores of the sandstone. In addition, vanadium also mineralizes sedimentary and authigenic clay minerals in which it substitutes for aluminum in the lattice structure (Foster, 1959).

The primary copper minerals are sulfides, mainly chalcopyrite, bornite, chalcocite, and covellite. Each mineral may occur as discrete particles or in intergrowth and replacement relations with another mineral. Exsolution, lattice intergrowth, or guided replacement occurs in places. The copper sulfides most commonly replace pyrite in plant fossils.

Primary silver minerals are reported in only a few deposits. Eucairite (CuAgSe) occurs as small nodules in the vanadiferous deposit at the Cougar mine, San Miguel County, Colo., and argentite occurs in the deeper workings in the Silver Reef district, Utah. Argentiferous copper sulfides form ore valuable for silver in several uranium-bearing vein deposits in Colorado.

Pyrite and (or) marcasite occur in nearly every unoxidized uranium deposit in sandstone and form as much as 10 percent of the ore in some. These minerals have at least three habits of occurrence. Very small grains of iron sulfide are scattered through the mineralized and barren sandstone and associated beds, and probably these are diagenetic. Coarser grained iron sulfides are intimately associated with some of the ore minerals, especially those that replace plant fossils; some of these sulfides probably replaced the fossils before uranium mineralization occurred and some possibly accompanied this mineralization. In places, iron sulfides, some of which may be younger than the ore minerals, partly fill fractures in the ore and adjacent barren sandstone. Some of the pyrite occurring with uranium minerals and plant fossils in deposits at the Happy Jack (loc. 125, table 2) and Mi Vida mines, San Juan County, Utah, is framboidal (C. W. Field, written commun., 1960). Such texture may be due either to colloidal deposition or replacement of sulfate-reducing bacteria (Bastin, 1950, p. 30–31; Love, 1958). Some of the iron sulfides contain selenium, cobalt, and nickel (Coleman and Delevaux, 1957; Weeks and others, 1959).

Small amounts of galena, sphalerite, jordisite, greenockite (rare), native arsenic, realgar, ferroselite (FeS_2), and other minerals occur in primary ores.

Galena is very widespread and is commonly accompanied by the selenide clausthalite (PbSe) in a solid-solution series in ores from the Colorado Plateau (Coleman, 1959) and from the Catskill Formation in Pennsylvania (Klemic and Warman, 1957). These two minerals are commonly associated with a green chromium-bearing micaceous mineral.

The chief carbonate in primary ore is calcite, but iron, manganese, and magnesium carbonates are locally abundant. Dolomite is especially abundant near ore deposits at Temple Mountain, Utah, and siderite occurs in deposits in the Edgemont district, South Dakota (Bell and others, 1956).

The most abundant sulfate in the primary ore is barite. Gypsum is rare.

Hematite stains calcite associated with uraninite or coffinite in many primary ores, for example, at the Mi Vida mine, San Juan County, Utah, and at several mines in the Edgemont district, South Dakota (Bell and Bales, 1955). These occurrences of hematite may be analogous to those in hydrothermal pitchblende veins (Lang, 1952, p. 25–27; Beck and others, 1958).

SECONDARY MINERALS

The secondary minerals are formed of elements and ions derived from the primary minerals, from the intrinsic host constituents, and from migrating ground and surface waters. (See Garrels and Christ, 1959, for detailed chemical reactions and products.)

The secondary uranium minerals, listed in table 6, consist of a wide variety of 6-valent uranium arsenates, carbonates, hydrous oxides, phosphates, silicates, sulfates, and vanadates. The chief yellow secondary minerals are the hydrous vanadates, carnotite and tyuyamunite, which are abundant in the Colorado Plateau region and in the Northern Black Hills and Edgemont districts, South Dakota and Wyoming, and the hydrous silicate uranophane, which is abundant in the Wyoming Basin ores (table 2). The chief green secondary minerals are the phosphate metatorbernite, which is abundant at the Hack Canyon mine, Coconino County, Ariz., and the arsenate metazeunerite, which occurs in the White Canyon and San Rafael districts, Utah, and in the Owl Creek Mountains and Gas Hills districts, Wyoming. The dark uranium vanadate rauvite is an abundant but inconspicuous mineral in partly oxidized vanadiferous ore. The uranium carbonate and sulfate minerals are rare because they are very soluble. Secondary uranium minerals in deposits containing little or no vanadium, copper, or phosphorus consist mainly of becquerelite and gummite.

In addition to the uranium vanadates, the secondary vanadium minerals consist of the vanadium oxides doloresite ($3V_2O_4 \cdot 4H_2O$), duttonite [$VO(OH)_2$], corvusite ($V_2O_4 \cdot 6V_2O_5 \cdot nH_2O$), and navajoite ($V_2O_5 \cdot 3H_2O$); the vanadite simplotite ($CaV_4O_9 \cdot 5H_2O$); and numerous vanadates, of which pascoite ($Ca_3V_{10}O_{28} \cdot 16H_2O$), hewettite ($CaV_6O_{16} \cdot 9H_2O$), and volborthite [$Cu_3(VO4)_2 \cdot 3H_2O$] are conspicuous (Weeks and others, 1959, p. 68). Many of these vanadates form only if there is more vanadium present than that needed to form uranium vanadates from the uranium available.

The most common secondary copper mineral is malachite; less common are azurite, cuprite, and brochantite. Native copper and some copper sulfides are probably secondary (supergene) in some partly oxidized ores.

The most abundant secondary minerals associated with the ore minerals are hydrous iron oxides; less abundant are oxides, carbonates, and sulfates of iron and other metals. The minerals include goethite, lepidocrocite, jarosite, hematite, calcite, gypsum, manganese oxides, ilsemannite, and various pinkish encrustations containing cobalt.

ORE TEXTURES

The ore and accessory minerals in uranium deposits in sandstone are mostly very fine grained. They mainly coat sand grains, partly or completely filling the available pore spaces. A partial to complete replacement of the sand grains and the cementing minerals occurs in places, especially near fossil wood. Replacement of fossil wood by minerals is common; uraninite, coffinite, montroseite, and iron and copper sulfides are the most common replacing minerals. Many of these replacements form cylindrical masses of rich ore, which are called logs whether or not they contain any fossil wood (Coffin, 1921, p. 164); at the Monument No. 2 mine, Apache County, Ariz., where they are very abundant, they have been called rods (Witkind, 1956a). Partial to complete filling of fractures is common in vein deposits but rare in peneconcordant deposits except in oxidized ore, where secondary minerals are common in fracture fillings.

PARAGENESIS

The general paragenetic sequence consists of numerous overlapping stages that cannot be clearly separated, particularly from the diagenetic stage. The earliest detrital and authigenic constituents of the host rocks include quartz, feldspar, volcanic debris, fossil wood, heavy minerals, sedimentary clay, and pyrite; the common cementing minerals are authigenic carbonate, silica, and clay. Devitrification of glass in the volcanic debris provided silica and resulted in the formation of some clay minerals. Late authigenic or earliest introduced minerals include pyrite, the carbonates, quartz, and feldspar; "asphaltite" was also introduced at this time. A small part of the ore minerals, particularly of vanadium, was deposited before some quartz overgrowths formed and is possibly early authigenic (Garrels and Larsen, 1959, pt. 21, p. 233; Fischer, 1960, p. 26), and in places much of the "asphaltite" was deposited earlier than quartz overgrowths (S. R. Austin, written commun., 1960). Most of the ore minerals and various associated sulfides and carbonates were deposited as void fillings and replacements after diagenesis. Solution and replacement of some silica accompanied the main stage of deposition in places and may have provided silica for some late quartz overgrowths. Some deposition of "asphaltite," or perhaps its redistribution, took place after the deposition of the uranium minerals (Rosenzweig and others, 1954). A posturaninite stage of copper sulfide formation in some ores may be supergene enrichment.

Oxidation produced pseudomorphic secondary minerals and caused a redistribution of some metals and their re-forming into new minerals outward from their original position.

SHAPE AND SIZE OF DEPOSITS

Peneconcordant uranium deposits are dominantly layers, roughly tabular or lenticular, and visually recognizable by the ore and associated minerals that impregnate the sandstone. The concentration of these minerals may fade vertically and horizontally, and such layers are poorly defined; generally, however, these minerals are sharply limited in distribution, and the layers are well defined. The layers are nearly parallel to the bedding of the host sandstone, but in detail they do not follow the bedding consistently and are not restricted to certain beds; rather, they are irregularly undulant in habit, and commonly they cut across bedding and beds with no apparent regard for them. Some layers split in two, in places with a thin bed of mudstone between them, and elsewhere with only barren sandstone between. In other places, two or more overlapping layers occur within a thick sandstone unit, with no apparent connection between them. Generally, however, the deposits consist of only single layers.

The mineralized layers vary greatly in dimension. Some are only a few feet across, whereas others extend many hundreds of feet. In the Placerville district, Colorado, recent erosion has removed some of the ore-bearing Entrada Sandstone, but before erosion the mineralized layer probably extended over an area 1–1½ miles wide and at least 10 miles long (Bush and others, 1959). Layers range in thickness from a few inches to several tens of feet, but mostly they are only a few feet thick. The change in thickness may be either gradual or abrupt. Those parts that are thick enough and rich enough to mine comprise the ore bodies; they have various shapes and sizes.

Most ore bodies tend to be elongate, and their long axes are commonly parallel to the long axis of the sandstone lens or channel in which the deposit occurs. The thicker parts of an ore layer also are commonly elongate and trend in the same direction as the ore body. Many of these thicker masses of ore are in part cylindrical, bounded by one or two well-defined edges of ore that curve smoothly across the bedding. Although their forms are different in detail, these masses are commonly called rolls because of their curved surfaces (fig. 8). The rolls have some concretionary habits; in addition to their curved surfaces, some are composed of concentric bands of rich and lean ore, and some are bordered by thin layers of accessory minerals.

Some deposits are composed virtually of a single roll, commonly C-shaped in cross section. Many of these are only a few feet across and no more than a few tens of feet long, and contain less than 100 tons of ore. In the Shirley Basin, Wyo., however, several million tons of high-grade ore has been developed in large elongate ore bodies that are crudely C-shaped in cross section. These ore bodies are as much as a few tens of feet wide and high and a few thousand feet long. They border and partly enclose the rounded margins of extensive tongues of altered sandstone (Harshman, 1962).

In addition to the elongate rolls having some concretionary habits, small ore bodies even more concretionary are widespread but rarely abundant. In the Powder River Basin, Wyo., however, spherical nodules a few inches to a foot across are abundant; these are referred to locally as "pumpkins." They consist of irregular zones and concentric layers of minerals that impregnate and partly replace sandstone. Uraninite and pyrite, associated or not with oxidized products of these minerals, occupy the central part of the nodules, which generally are encased in a zone of manganese and iron oxides (Sharp and others, 1964). In the Montezuma Canyon area, San Juan County, Utah, ellipsoidal bodies consist of cores of barren iron-stained sandstone as much as 10 feet thick and 40 feet across, which are enclosed by shells of uranium- and vanadium-bearing sandstone a few inches to a few feet thick; the surrounding host rock is barren gray sandstone (Huff and Lesure, 1962).

In many vein deposits the ore bodies are also crudely tabular, but they follow fractures that cross the bedding, commonly at steep angles. In places, however, subordinate masses of ore extend out from fractures as layers or tongues along bedding planes or favorable beds. Ore bodies in sandstone pipes or collapsed plugs are com-

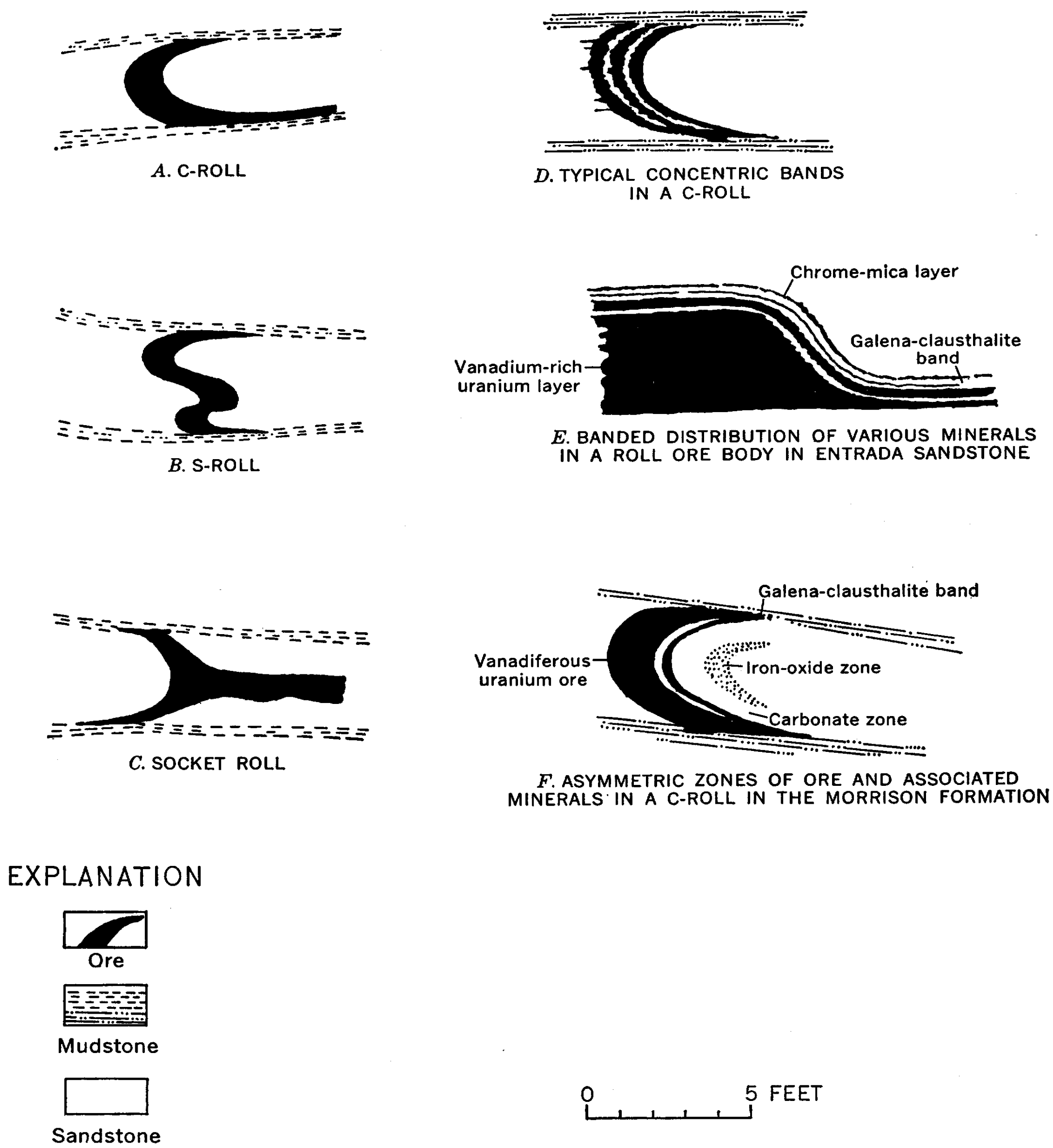


FIGURE 8.—Cross sections of roll ore bodies of the Colorado Plateau region. Modified from Shawe (1956).

monly irregular in shape, but generally their configuration is controlled by the bounding fractures.

Deposits range in size from small pods and logs of less than a ton of mineralized rock to those containing more than a million tons of ore. Peneconcordant deposits span the entire size range, but most vein deposits contain less than 1,000 tons of ore, and only a few contain more than 100,000 tons (Butler and others, 1962). The distribution by size classes of 322 deposits in sandstone beds of Triassic age in the Colorado Plateau region that had been mined or developed through 1953 is shown on figure 9. About 73 percent of these deposits contained less than 1,000 tons each, and in aggregate only about 4 percent of the total tonnage (fig. 10), whereas only 7 (2 percent) of the 322 deposits contained more than 100,000 tons of ore each (fig. 9), but in aggregate 75 percent of the total tonnage.

ALTERATION OF HOST ROCKS

Alteration of the host sandstone beds and associated rocks is common near uranium deposits, but the nature of the alteration differs somewhat from place to place. In places the alteration was moderately intensive, and in some of these places the alteration has been related to ore deposition or some other specific geologic phenomenon. In general, however, the alteration was of low intensity, and is recognized mainly by color changes. In most places this alteration cannot be separated clearly from diagenetic changes in the rocks; for this reason it has not been definitely related to the process of ore mineralization, though the special coincidence of ore deposits and altered rocks strongly suggests mutual genetic relations. In most places the ore-bearing solutions obviously were nearly in equilibrium with the host rocks, and it is difficult to find unequivocal evidence, other than the existence of the ore minerals themselves of effects on the rocks from the solutions that carried the ore minerals (Keller, 1959).

Many of the host rocks and associated strata are characteristically red, but near uranium deposits they commonly are light shades of brown, yellow, gray, or green, or are white. In many sandstone beds this color change is not conspicuous, though it is evident, but mudstone layers within and immediately above and below the ore-bearing sandstone have commonly been changed from bright red to gray or green. Comparative studies of unaltered and altered mudstone show little or no difference in the mineral and chemical composition of the two except less ferric oxide and more ferrous oxide in the altered rock (Weeks, 1953; Finch, 1954; Huff, 1955; Phoenix, 1957; Cadigan, in Stewart and others, 1959, p. 556; Newman and Elston, 1959; Keller, 1959, 1962; Newman, 1962), and in places pyrite in the altered mudstone. Likewise, there is little or no difference in the mineral and chemical composition of the unaltered and altered sandstone except that detrital grains of magnetite were destroyed and some pyrite formed in the altered rock (Shawe and others, 1959; Austin, 1960); it is also obvious that the red (hematite?) stain on sand grains in unaltered sandstone was either originally lacking in the altered rock or was destroyed during alteration.

The alteration in mudstone commonly extends a few hundred feet away from ore deposits and that in sandstone extends a few hundred to several thousand feet away. The dominant reactions causing this alteration were evidently reducing—ferric oxide was reduced to ferrous oxide, and pyrite was formed. The abundance

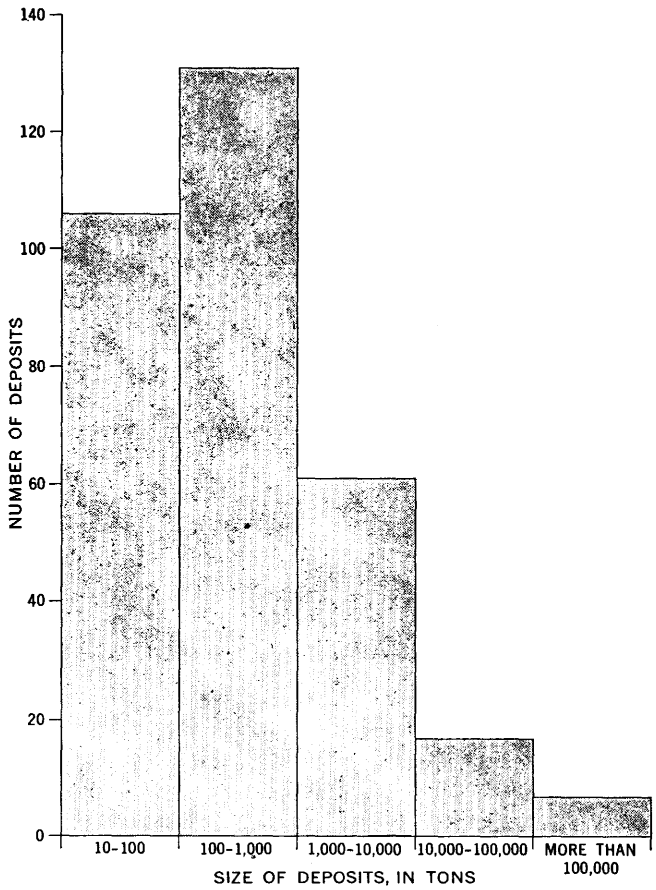


FIGURE 9.—Graph showing distribution of deposits by size in sandstone beds of Triassic age in the Colorado Plateau region. Production through 1953 plus indicated and inferred reserves.

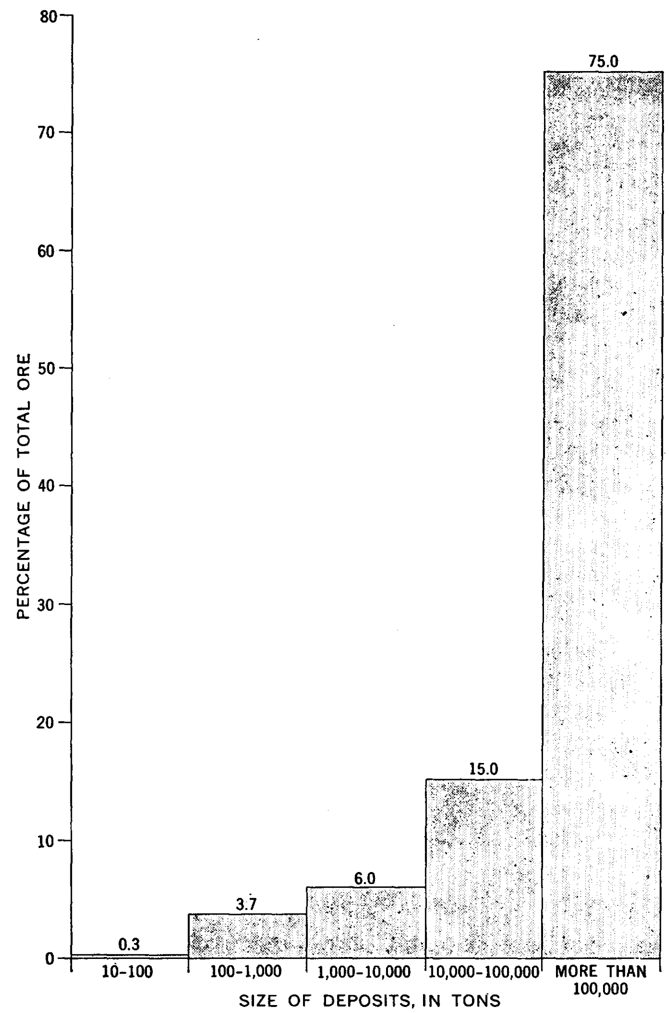


FIGURE 10.—Histogram showing the percentage of total ore by size of deposits in sandstone beds of Triassic age in the Colorado Plateau region. Production through 1953 plus indicated and inferred reserves.

of fossil wood in and near many deposits might have been responsible for or may have contributed to this reducing environment, but evidence is lacking as to the time of this alteration in relation to the time of ore deposition. Nevertheless, the color changes in the sandstone and mudstone caused by alteration have been useful exploration tools in various areas (Weir, 1952; McKay, 1955c; Hilpert and Freeman, 1956; Isachsen and Evensen, 1956).

Somewhat in contrast to the relations just described, in which the deposits are in sandstone where hematite probably was altered or removed by reduction, are those in the Powder River Basin, Wyo. (Sharp and others, 1964), and in the northeastern part of the Black Hills, S. Dak. (Vickers, 1957), where the deposits all border areas of sandstone stained red by hematite; the hematite probably formed at the same time as the uranium deposits.

In the Shirley Basin, Wyo., well-defined and extensive tongues of greenish-yellow altered sandstone, 10–50 feet wide and several miles long, project through thick beds of unaltered gray sandstone. The unaltered sandstone contains low-iron montmorillonite, pyrite, calcite, and vitreous coalified plant fossils, whereas the altered sandstone contains high-iron montmorillonite and sooty plant fossils but lacks pyrite and calcite, which apparently have been largely removed. Uranium ore occurs at the contact of altered and unaltered sandstone, mostly along or near the rounded edges of the tongues; alteration and ore deposition probably occurred together (Harshman, 1962).

Along vein deposits the most common and conspicuous alteration effect is a change in color, mainly from red to yellow or gray, but this change is also common in fracture fillings that are not known to be uranium bearing. Considerable dolomitization has occurred in some of the sandstone beds where they are cut by uranium-bearing fractures in the Temple Mountain area, Emery County, Utah (Keys and White, 1956; Kerr, 1958a). Patchy silicification in slight to moderate amounts is common in many uranium deposits in sandstone, and more intensive silicification is common near deposits, especially vein deposits, in tuffaceous sandstone beds of Tertiary age in Nevada and California. Alunite and jarosite have been added to the host rocks near some deposits, but generally in sparse amounts (Kerr, 1958a). Zeolitic alteration accompanies the deposits in tuffaceous sediments of the Jackson Group in the Texas Coastal Plain (Weeks and others, 1958).

AGE OF DEPOSITS

Data from both geologic relations and isotopic analyses can be used in attempting to establish the age (time of original formation) of a uranium deposit. Geologic relations, however, commonly suggest only a relative age—the time of mineralization relative to one or more other geologic events, which may or may not be closely dated. Determinations of isotopic ratios yield ages in years, but these calculations yield true ages only if the geologic history of the deposit can be accurately interpreted.

Only epigenetic deposits—those having ore minerals which in their present form were introduced after the host rocks accumulated—are considered in this report. Studies based on the geologic field relations of these deposits have yielded only relative ages (relative to other geologic events). Such ages, for most deposits, fall into very broad limits of time.

Many peneconcordant deposits are in areas of slight to moderate deformation, which are characterized by gentle tilting and some faulting and jointing. Although published ideas differ as to the relation of the age of the deposits to the age of this deformation, many geologists believe that most peneconcordant deposits formed before the host rocks were tilted or fractured. Even if this belief is correct, however, the age of these deposits is not thereby closely established, for much of this deformation probably occurred long after the host rocks accumulated, thus a long time span was available for ore deposition. In the Colorado Plateau region, peneconcordant uranium deposits occur in beds of Permian, Triassic, Jurassic, and Cretaceous ages; very little deformation with which these deposits can be related in time occurred until the Tertiary or possibly very late in the Cretaceous. In the Edgemont district, South Dakota, fragements of ore from the Inyan Kara beds of Early Cretaceous age have been deposited in gravels of possible Oligocene age (Gott and others, 1956), which also leaves a long time interval available for ore formation. However, some peneconcordant deposits are younger than regional deformation of the host beds. For example, in the Gas Hills district, Wyoming, at least some of the deposits in the Wind River Formation of Eocene age are younger than the tilting and faulting of post-Miocene age (Zeller, 1957a). Deposits in the Jackson Group of late Eocene age, Karnes County, Tex., may also be younger than the faulting of probable Miocene age (Eargle and Weeks, 1961).

Vein deposits obviously are contemporaneous with or younger than the fractures along which they are localized, but the time of formation of most of the fractures is not clearly established. Deposits in the Sierra Ancha district, Gila County, Ariz., are in sandstone beds of Precambrian age. The ore minerals are closely associated with diabase intrusive bodies, which are older than overlying Cambrian beds. Calculations from isotopic ratios show the uranium minerals to be about 1,000 million years old and hence of Precambrian age (Neuerburg and Granger, 1960). At the Orphan mine, Coconino County, Ariz., the fractures along which minerals are localized cut rocks of Permian age and probably formed before the erosion of the Grand Canyon reached its present stage, but they cannot be dated more closely from geologic relations alone. Isotopic analyses of uraninite in the deposit yield an apparent age of about 100 million years (table 7).

TABLE 7.—*Apparent isotopic ages of selected samples from the Colorado Plateau region and age limits of the geologic periods of the host formations*

[Modified largely from Miller and Kulp (1958, p. 941) and partly from Holmes (1960)]

Sample	Mine		Host unit			Apparent age of samples determined by—		
	Name	Locality	Formaton	Geologic period	Age limits (millions of years)	$Pb^{206}:U^{238}$	$Pb^{207}:U^{235}$	$Pb^{207}:Pb^{206}$
K-168	Orphan	Coconino County, Ariz	Coconino Sandstone	Permian	225–270	94±4	107±6	400±80
153	Cane Creek [1]	San Juan County, Utah	{Cutler Formation {Chinle(?) Formation	do Triassic	} 180?–270	53±2	55±4	175±50
154	Calyx Hole 8	Temple Mountain, Utah	Chinle Formation, Moss Back Member.	do	180–225	84±2	91±5	335±75
155	North Mesa 9	do	do	do	180–225	102±5	107±10	260±75
152	Mi Vida	Lisbon Valley, San Juan County, Utah.	do	do	180–225	190±9	200±10	390±50
169	do	do	do	do	180–225	185±5	208±6	470±60
177	Standard	do	do	do	180–225	112±7	115±7	215±40
177c	do	do	do	do	180–225	294±20	295±20	320±40
167	Cord	do	do	do	180–225	205±7	206±7	245±40
174	Divide	do	do	do	180–225	85±4	96±6	415±40
151	Yazzie 102	Coconino County, Ariz	Chinle Formation, Petrified Forest Member.	do	180–225	170±13	208±16	680±200
178	Alice Tolino	do	do	do	180–225	130±4	219±20	1,400±200

[1] Atomic King vein deposit.

Problems relating to isotopic dating require special explanation. Most of the uranium in nature occurs in two isotopes, each of which breaks down at a known constant rate through certain intermediate products to stable lead isotopes: U^{238} goes to Pb^{206} and U^{235} to Pb^{207}. If these two uranium isotopes only were introduced into a deposit at its time of formation and if the deposit remained a closed system thereafter, the ratios of Pb^{206} to U^{238} and Pb^{207} to U^{235} and also Pb^{207} to Pb^{206} would give the same calculated age for the deposit, which would be the true age in years. If, however, the uranium orginally introduced into the deposit were mixed with intermediate products and lead isotopes, as is common in nature, or if subtractions or additions of those products and isotopes occurred, as can happen, calculations from the three isotopic ratios would give discordant or different ages. The true age of the deposit can be determined only if its original composition and subsequent additions or subtractions can be accurately interpreted and the appropriate corrections can be made in calculations (Kulp and others, 1954; Cannon and others, 1961).

Most isotopic age determinations of uranium deposits in sandstone yield discordant ages, and interpretations of these results have differed. Miller and Kulp (1958), after making certain assumptions and corrections, gave apparent ages for samples from the Colorado Plateau region. These ages are shown in table 7, which also shows the host formations and the age limits of the geologic period in which the host rocks were deposited. In general, the $Pb^{207}:Pb^{206}$ ratios yield apparent ages that are much older than the age of the host rocks, a feature that indicates that lead isotopes were added to the deposit or extracted from it during some episode in its history. Apparent ages calculated from $Pb^{206}:U^{238}$ and $Pb^{207}:U^{235}$ ratios, however, rarely exceed the ages of the host rocks, and in general, in the same sample, the ages determined from these two ratios are about the same. However, samples from any one mining district may show wide spreads in ages; for example, Miller and Kulp (1958) found that samples K–169 and K–177, although from different mines but taken only a few hundred feet apart, showed nearly 100 million years difference in apparent ages.

Analyses made by other workers, who used samples from other deposits in the Colorado Plateau region and who made different assumptions and corrections, yielded somewhat different results. Stieff and others (1953) preferred an age of about 60–70 million years for the formation of many uranium deposits in that region.

Radiochemical determinations indicate a very young age, commonly 5,000–170,000 years, for some unoxidized uranium minerals and all oxidized or secondary minerals (Stern and others, 1956; Stern and Stieff, 1959). Some unoxidized uranium minerals from the Wind River Formation of Eocene age in the Gas Hills area, Wyoming, are calculated to be 11,000–150,000 years old (Zeller, 1957a; Bergin, 1957; Coleman, 1957b). Unoxidized uranium minerals in the deposit in the

Lakota Formation of Early Cretaceous age at the Hauber mine, Crook County, Wyo., began forming from 40,000 to 130,000 years ago (Rosholt, 1961).

LOCALIZATION OF DEPOSITS

RELATIONS TO SEDIMENTARY FEATURES

Peneconcordant deposits are most abundant in stratigraphic units of mixed lithologic character. About equal proportions of interbedded sandstone and mudstone seem optimum, as in the Salt Wash Member of the Morrison Formation of southwestern Colorado and southeastern Utah (Jones, 1954; Craig and others, 1955; Mullens and Freeman, 1957), in the Wasatch Formation in the central part of the Powder River Basin, Wyo. (Davidson, 1953), and in the Inyan Kara Group, Edgemont district, South Dakota (Bell and Bales, 1955). Within these units the uranium deposits are commonly in or near the thicker and more permeable parts of sandstone lenses, the principal channelways for the movement of solutions along beds. The total transmissivity of these stratigraphic units, however, would be only moderate, for the sandstone lenses are discontinuous; they are partly interconnected by interfingering and overlap, but they are largely enclosed in argillaceous beds of low permeability. Nevertheless, deposits are rare in stratigraphic units and facies composed of thick sandstone of uniform permeability and high transmissivity, and in fine-grained beds of low transmissive capacity (Jobin, 1956, 1962; Phoenix, 1956).

Within the ore-bearing sandstone lenses, many deposits occur at or near the bottom, but some are in the middle or upper parts of these strata and, figuratively, seem to be floating in the sandstone without any apparent reason for their specific location. Futhermore, although the peneconcordant deposits form mineralized layers that are nearly parallel to bedding, the layers are not confined to certain beds or even to a single lithologic type of host rock—some layers cross from beds of fine-grained sandstone to beds of coarse-grained sandstone and even into conglomerate. In some deposits, the ore minerals tend to concentrate on certain planes of cross-bedding, and cause conspicuous banding, but the ore minerals do not follow all such favorable planes.

Most deposits are associated with fossil plant remains, which are commonly more abundant in and near the deposits than away from them (Weir, 1952); within a mass of mineralized sandstone, the fossil plant remains are generally richly mineralized, but those outside a deposit, even those within a few inches of ore, are barren or virtually so.

Peneconcordant deposits show rather consistent relations to some large-scale sedimentary features in the host rocks, and, by recognition of these features in other lithologic units, selection of other areas that are favorable for deposits is possible. Within these favorable units and areas the deposits are associated with some smaller scale sedimentary features, but the relations are less consistent, so it is difficult to explain satisfactorily the exact localization of many deposits and ore bodies. The sedimentary features that localize ore minerals within the deposits are generally barren outside the mass of mineralized sandstone.

RELATIONS TO TECTONIC STRUCTURES

By definition, vein deposits are related to and localized by breaks that cut across the bedding of the host rocks, usually at steep angles. Some of these breaks probably are not truly of tectonic origin, but rather are plugs or blocks that have collapsed into underlying solution cavities, but they will be described in this section.

Vein deposits occur along a variety of geologic structures, in host rocks of different lithologic character, and even extend through more than one formation. The ore minerals are mainly fracture fillings, but in places they also impregnate the wallrock and even extend short distances from fractures as tabular layers along favorable beds. The distribution of ore minerals along fractures, both vertically and horizontally, is commonly rather spotty.

At the Los Ochos mine, Saguache County, Colo., ore occurs in brecciated Precambrian granite and schist along a high-angle fault of small displacement and in tabular layers in beds of silicified and brecciated sandstone and mudstone of the Morrison Formation adjacent to the fault (Malan and Ranspot, 1959). At the Atomic King mine, San Juan County, Utah, uranium-bearing "asphaltite" occurs along high-angle faults where they cut the Rico, Cutler, and Chinle Formations (Hinrichs, 1958). In the Sierra Ancha district, Arizona, uranium minerals impregnate quartzite immediately adjacent to high-angle joints and faults of small displacement; all mineralized fractures are close to diabase intrusive bodies (Neuerburg and Granger, 1960).

A plug, 500 feet wide and 2,000 feet long at the surface and having a downward displacement of about 300 feet, occurs at Temple Mountain, Emery County, Utah. Holes drilled in the collapse plug and outcrops adjacent to the plug show a 1,200-foot vertical range of uranium-bearing material. Very little ore has been mined from the plug, but peneconcordant deposits in the Moss Back Member of the Chinle Formation a few thousand feet from it have yielded considerable ore. This plug and several similar ones nearby probably resulted from the collapse of solution cavities in limestone several hundred feet below the surface, and these cavities may have been partly localized by folding and faulting in the area (Keys and White, 1956).

Uranium deposits occur in several sandstone collapsed plugs or pipes in the Grand Canyon area, Arizona; a large tonnage of high-grade ore has been recovered from the pipe at the Orphan mine. The location of these deposits and their approximate positions relative to major faults in the area are shown on figure 11, and the stratigraphic and inferred structural forms of these plugs are shown by the cross sections on figure 12.

Several hundred collapsed pipes or plugs occur in the Laguna area, New Mexico, but only two—one at the Woodrow mine and the other in the Jackpile mine (table 2)—are known to be uranium bearing (Hilpert and Moench, 1960).

Because peneconcordant uranium deposits are so numerous and so widespread, their geologic settings relative to tectonic structural features vary greatly. Some are in areas of virtually no tilting or fracturing of the host rocks. Many, however, are in areas of slight to moderate folding, jointing, and faulting, and opinions expressed in literature differ as to whether a particular structural feature influenced the localization of a deposit or group of deposits or whether the structure was merely coincidental and superposed after mineralization.[1] Certainly as a group, however, peneconcordant deposits are not consistently associated with any single type of tectonic structural feature, except in areas of relatively recent uranium movement, where oxidized and even low-valent uranium minerals commonly occupy fracture linings. In a few places of recent ura-

[1] Authors who concluded that many deposits are at least partly localized by folds include Butler and others (1920, p. 157); Reinhardt (1952, p. 10); Steen and others (1953, p. 6); Gabelman (1956c); Gott and others (1954); Everhart (1956); Lekas and Dahl (1956); Braddock (1957); Hinrichs and Krummel (1957); Robinson and Gott (1958); Russell (1958).

Studies to relate the uranium ores to jointing were made by Benson and others (1952) (fracture control was refuted by Trites and others, 1956); Bucher (1953); Bucher and Gilkey (1953); Gilkey (1953); Finch (1954); Kelley (1955, p. 49–53); Mitcham and Evensen (1955); Finnell (1957); Mitcham (1957); and Kelley and Clinton (1960).

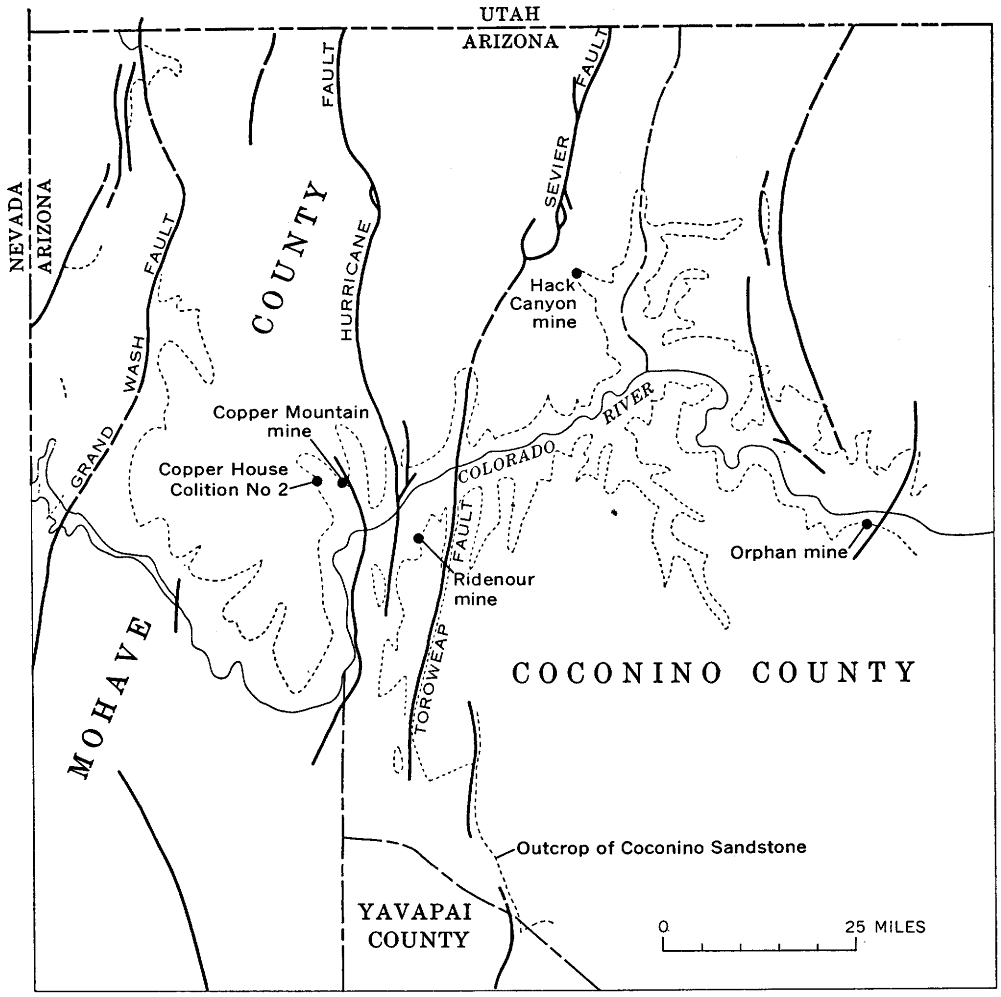


FIGURE 11.—Location of uranium-bearing sandstone pipes, faults, and outcrop of Coconino Sandstone in the Grand Canyon area, Arizona. Modified from Darton and others (1924).

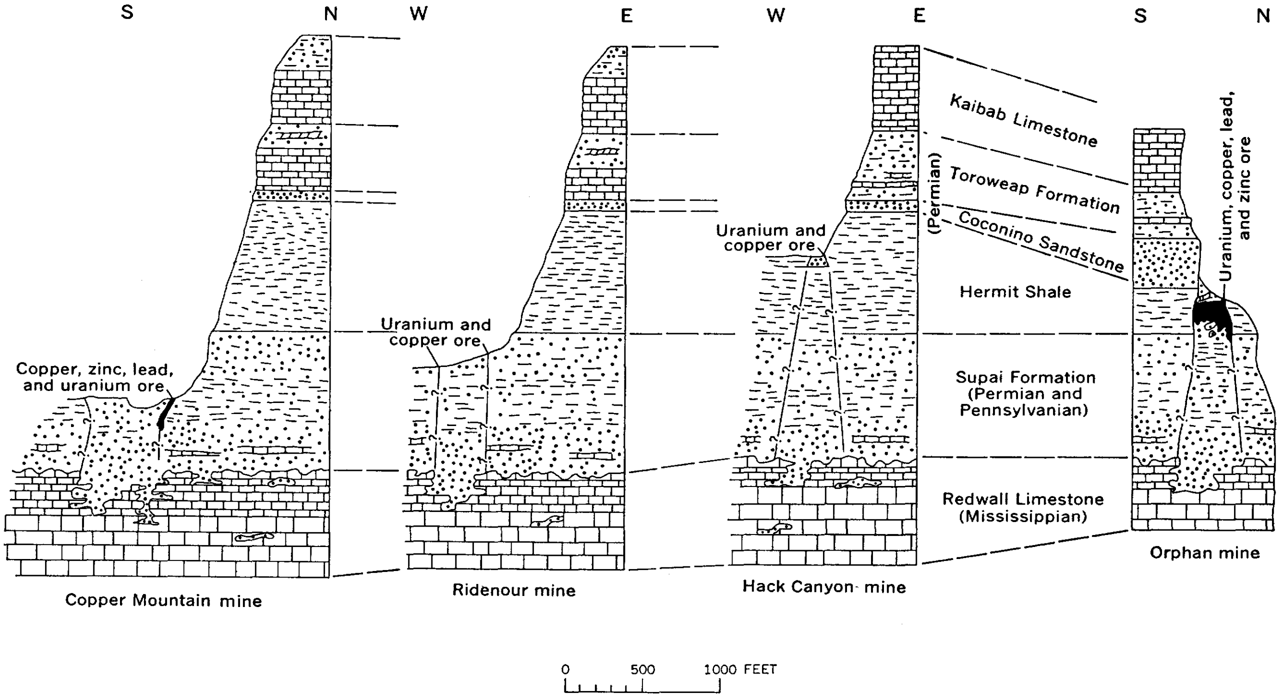


FIGURE 12.—Cross-sectional sketches showing stratigraphic positions and shapes of sandstone pipes in the Grand Canyon area, Arizona. Locations of pipes are shown in figure 11. The karst topography and the size and location of the caverns in the Redwall Limestone are partly hypothetical. Sources of data: McKee (1938); Koons (1945); Miller (1954); C. G. Tillman (written commun., 1954); H. C. Granger and M. E. Kofford (written commun., 1959).

nium movement, such as at some areas in the Gas Hills (Zeller, 1957a) and the northern Black Hills (Rosholt, 1961), some ore bodies abut against faults, but most are cut and displaced by faults, if any are present.

RELATIONS TO IGNEOUS AND METAMORPHIC ROCKS

The distribution of epigenetic uranium deposits (mainly deposits in sandstone) relative to the general distribution and age of igneous and metamorphic rocks is shown on maps of the United States compiled by Finch, Parrish, and Walker (1959, sheets 2 and 3). More detailed maps of Colorado, Wyoming, and Montana are those of Merewether (1960a–c).

Igneous and metamorphic rocks of Precambrian age now crop out in parts of the Appalachian Mountains region of the Eastern States and in some mountain ranges of the Western States; however, in places in the Western States, outcrops of rocks of Precambrian age were even more extensive during late Paleozoic and early Mesozoic time. Some of these exposures contributed debris to some of the uranium-bearing sandstone beds of Paleozoic, Mesozoic, and Tertiary ages. In the Sierra Ancha district, Arizona, the uranium-bearing vein deposits in the Dripping Spring Quartzite are probably genetically related to intrusive bodies of diabase of Precambrian age (Neuerburg and Granger, 1960).

Igneous rocks of Paleozoic age consist of intrusives in the Appalachian region and of extrusives in Maine and the northwestern United States. If any debris were eroded from these rocks and deposited in uranium-bearing formations, it must have been small. None of the known deposits in sandstone of Paleozoic age are within 100 miles of exposures of igneous rocks of that age.

Mesozoic igneous rocks, exclusive of those of Late Cretaceous age, include dioritic and monzonitic intrusions in California, Nevada, and Idaho (Larsen and others, 1956), diabasic intrusions in the central Appalachian region, and volcanic rocks in Montana and California and possibly in southern Arizona. The volcanic activity in California and Idaho almost certainly contributed much of the ash to the Triassic and Jurassic ore-bearing beds in the Colorado Plateau region; the volcanism in Arizona possibly also contributed. Probably, none of the Mesozoic igneous activity in these States contributed hydrothermal solutions that formed uranium deposits in sandstone, with the possible exception of a few deposits in California, for all other deposits in sandstone beds of Mesozoic age or older are more than 100 miles from this igneous activity. In the Eastern United States, however, in Pennsylvania and New Jersey, a few deposits in sandstone beds of Triassic age are close to diabase intrusions of the same general age, and thus conceivably these deposits could have been formed by hydrothermal solutions derived from igneous activity. The deposits in sandstone of Paleozoic age in Pennsylvania could conceivably be genetically related to Triassic igneous activity, though no Triassic igneous rocks are exposed near the known deposits.

Igneous rocks of Late Cretaceous and Cenozoic ages crop out in all the Western States. Extrusive rocks are especially widespread in these States (Waters and Hedberg, 1939), but they contribute little useful information relative to uranium deposits—rather they mask much country and perhaps even cover many uranium deposits. Intrusive igneous rocks also are widespread in the Western States. Although most of the exposed intrusive bodies are of small to moderate size, many of the hydrothermal metaliferous ore deposits of the Western States are credited to them or to related deep-seated magmatic activity (Burbank, 1933; Lovering and Goddard, 1950). Intrusives of Late Cretaceous and Cenozoic ages are absent, or nearly so, from the Central Lowlands uranium region of Texas and Oklahoma, the Texas Gulf Coastal Plain area, the Great Plains area of the Dakotas (except the Black Hills), and most of the uranium-bearing basins in Wyoming. However, in these regions and in the Basin and Range province of Nevada and adjoining States, most of the uranium-bearing sandstone beds of Tertiary age either are tuffaceous or are associated with tuffaceous beds.

In the Colorado Plateau, where most of the known uranium deposits in sandstone occur, intrusive igneous activity was more abundant but still relatively sparse. Activity resulted in widely scattered clusters of stocks, laccoliths, and related bodies of Miocene to Pliocene age in the central part (Hunt, 1956; Strobell, 1956; Bush and others, 1957), numerous diatremes in the southern part (Williams, 1936; Shoemaker, 1956b), and groups of thin dikes and sills locally. Igneous activity of this general period was very intense along the east, south, and west sides of the Plateau, as indicated principally by flows but in places by intrusive bodies of small to medium size. Some of the deposits on the Plateau and along its margins are near intrusive igneous bodies, and a few are even cut by dikes and sills, but such deposits are not obviously different from those that are miles from known intrusive rocks. In northeastern Arizona, sandstone within a few diatremes contains vein uranium deposits, (table 2), one of which has yielded a small amount of ore (Shoemaker, 1956b). If the metals in the uranium deposits in the Colorado Plateau region were introduced by hydrothermal solutions from a magmatic source, the solutions had to have been very pervasive through a few thousand feet of stratigraphic section and over a very large area; the known intrusive masses show no localizing influence on deposits. Furthermore, although the time of intrusion of many of these igneous bodies is not well dated, most probably are younger than the deposits.

In Nevada and Idaho, however, some deposits in sandstone and tuff are closely associated with igneous rocks. Most of these deposits are small, but a few have been moderately productive, such as those in the Stanley area, Custer County, Idaho. Peneconcordant deposits in this area occur in the basal conglomerate of the Challis Volcanics, which rests on an eroded surface on the Idaho batholith. One peneconcordant deposit is directly above a uraninite vein in the batholith. Kern (1959) related the uranium deposits to the volcanic activity that produced nonuraniferous tuffs and lava flows overlying the conglomerate. The Stanley area is near the edge of the uranium-rich Shoshone volcanic province outlined by Coats (1956).

ORIGIN

This report is limited to uranium deposits in sandstone and related rocks in the United States. Genetic concepts, based on geologic evidence, or interpretation, had no influence on their selection. Thus it is hardly to be expected that all deposits included in this report had the same genesis. Nevertheless, most of the deposits have certain common characteristics that suggest a common origin, though one which is different in some detail from place to place. A few deposits almost certainly had a different origin.

Although most of the deposits have common characteristics, these characteristics differ in conspicuousness from place to place, and their significance has been evaluated differently by individual students. As a result, various hypotheses of origin have been proposed. They fall into four principal groups: (1) syngenetic, (2) penesygenetic, (3) lateral secretion, and (4) telethermal hypotheses. The historical development of these hypotheses is given in table 8. No doubt the multiplicity of hypotheses proposed during the uranium studies gave objectivity to the researches and explorations, and produced far more significant results than if one hypothesis had been generally accepted.

Table 8.—*Summary of the historical development of the hypotheses of origin of uranium deposits in sandstone in the United States*

Important scientific developments that affected various hypotheses	Syngenetic hypotheses	Penesyngenetic hypotheses	Lateral-secretino (epigenetic) hypotheses	Telethermal (epigenetic) hypotheses	Miscellaneous hypotheses
			Salient features of hypotheses		
	Mechanical transportation and concentration of uranium-bearing materials and (or) precipitation of uranium from surface solutions at the time of deposition of the enclosing sediments.	Precipitation of uranium from ground-water solutions shortly after the enclosing sediments were deposited.	Redistribution and concentration of uranium contained in the surrounding and (or) overlying rocks by circulating waters, probably long after the enclosing rocks were deposited.	Deposition of uranium at moderate temperatures and pressures at or near the surface from ascending magmatic or other hypogene solutions.	Miscellaneous hypotheses are the outcrop, meteoric-source, and magmatic hypotheses. Each is described below.
			1874-1909		
1. Uranium was discovered in sandstone (Genth, 1875; Berthoud, 1875; Rolker, 1881). 2. Early mining was mostly at the outcrop (Hillebrand and Ransome, 1900; Moore and Kithil, 1913).	Deposits in southwestern Colorado seem to be the result of the "concentration of vanadiferous pitch blende particles by action of water currents and subsequent decomposition" (Fleck and Haldane, 1907, p. 56).	----------	----------	----------	Outcrop hypothesis: Because known deposits were limited to the outcrop, the carnotite deposits in southwestern Colorado were thought to have resulted from "a local concentration of material already existent in the sandstone, and the deposition of this material in the form of carnotite under conditions determined by proximity to the surface, and probably partly dependent upon an arid climate" (Hillebrand and Ransome, 1900, p. 17).
			1910-19		
Mining was extended beyond the outcrop.	At Mauch Chunk, Pa., carnotite is believed to have formed by oxidation of uranium and vanadium minerals that were mechanically concentrated into black sand lenses by circulating surface waters (Wherry, 1912, 1915). In Utah and Colorado it was suggested that uranium and other metals were weathered from veins and were carried in sulfate solution into shallow seas where decaying organic matter possibly reduced the uranium to uranium oxide and that uplift, drainage, and aeration caused oxidation to carnotite deposits. (Hess, 1914).	----------	Examinations of the country rock of carnotite deposits in Colorado and Utah "seem to indicate that the uranium was disseminated in the sandstone country rock and has been concentrated in ore bodies by the action of water." (Moore and Kithil, 1913, p. 31). Vanadium and uranium in sandstone and shale in Colorado and Utah are assuredly epegenetic, are probably the products of concentration by surface waters below the zone of oxidation and at less than 100° C, have been forming since the establishment of active water circulation, and may be in the process of forming now (Lindgren, 1911).	Inconclusive evidence suggests that deposits in the Entrada Sandstone in the Placerville district, Colo., were formed from hot-water solutions of igneous origin (Hess, 1913b).	Chemical experiments on carnotite led Notestein (1918) to conclusions similar to those of Hillebrand and Ransome above.
			1920-29		
	At Temple Mountain, Emery County, Utah, uranium and vanadium were picked up by asphaltite grains before or during sedimentation of sandstone in the Chinle Formation (Hess, 1922). (See also under "Telethermal (epigenetic) hypotheses.")	----------	In Utah, circulating water collected metals disseminated in the surrounding rocks and redeposited them on contact with carbonaceous matter and earlier sulfides in positions controlled by structural features. Mineralization probably began in the Tertiary and in places may still be in progress. Most of the present minerals are alteration products of surface water (Butler and others, 1920, p. 158). In Colorado, uranium and vanadium migrated downward from thick claybeds and impure sandbeds in sulfate waters and were precipitated by carbonaceous material (Burwell, 1920). In southwestern Colorado, the metals were probably introduced into the sandstone beds during sedimentation and later redistributed near carbonaceous material by waters that traveled along the beds rather than across them. Folds did not influence localization (Coffin, 1921, p. 186).	At Temple Mountain, Emery County, Utah, the metals may have been derived from hot springs (Hess, 1922). (See also under "Syngenetic hypotheses.")	

TABLE 8.—*Summary of the historical development of the hypotheses of origin of uranium deposits in sandstone in the United States*—Con.

Important scientific developments that affected various hypotheses	Syngenetic hypotheses	Penesyngenetic hypotheses	Lateral-secretion (epigenetic) hypotheses	Telethermal (epigenetic) hypotheses	Miscellaneous hypotheses
		1930-39			
	----------	In the southwestern States, sedimentary deposits of copper, vanadium, uranium, and silver are syngenetic—in the sense that the metals were concentrated in the host beds at the time of sedimentation from dilute solutions either directly or indirectly by some agent, possibly minute organisms that left no trace—but the present minerals in all cases are believed to be epigenetic (Fischer, 1937, p. 943, 950, 951).	The assuredly epigenetic deposits of copper, lead, vanadium, and uranium in sandstone and shale were concentrated by circulating sodium chloride and calcium sulfate meteoric waters that leached small quantities of metals disseminated in terrigenous sediments, which resulted from disintegration of Precambrian igneous rocks and pegmatites (Lindgren, 1933, p. 404, 414).	----------	
		In the southwestern States the metals accumulated syngenetically in shallow basins from rain water that oxidized thick beds of volcanic ash, which represented magmatic differentiates of metal-rich fluids that ejected explosively as ash rather than entering fractures and permeable rocks as veins and lodes (Koeberlin, 1938).	----------	----------	
		1940-49			
		In Colorado and Utah the primary minerals are thought to have been localized by delicate chemical and physical conditions from ground waters not long after sedimentation. At least three separate periods of mineralization were probably required to account for the ore in the Chinle, Entrada, and Morrison Formations (Fischer, 1942, 1949a).	----------	----------	
		Although no satisfactory origin can yet be given for the ores in the Entrada Sandstone in the Placerville district, Colorado, the ores seem to have formed at a slightly uneven water table or at the contact between ground waters of two types after the sands accumulated (Fischer and others, 1947, p. 127).			

TABLE 8.—*Summary of the historical development of the hypotheses of origin of uranium deposits in sandstone in the United States*—Con.

Important scientific developments that affected various hypotheses	Syngenetic hypotheses	Penesyngenetic hypotheses	Lateral-secretion (epigenetic) hypotheses	Telethermal (epigenetic) hypotheses	Miscellaneous hypotheses
1950-52					
1. Uraninite was identified in several Colorado Plateau ores (Gruner and Gardiner, 1950; Kerr, 1951; Rasor, 1952). 2. Uraninite was synthesized at room temperature by reduction of uranyl ions with H_2S (Gruner, 1952, 1953; Gruner, Rosenzweig, and Smith, 1954; Miller, 1958). 3. Uranium can be and is being leached from tuffaceous sediments by ground water (Denson, 1952).	In the Plateau region the precipitation of uranium by organic matter from surface waters that deposited the basal conglomeratic members of the Chinle Formation is favored by Gruner (1951).	----------	In lignitic rocks in the Rocky Mountain region and in sandstone beds of the Wasatch Formation in the Powder River Basin, Wyo., uranium is believed to have been extracted after lithification by carbonaceous material from downward-percolating ground waters that derived their uranium content from overlying tuffaceous sediments (Denson, 1952; Love, 1952).	The presence of such minerals as uraninite, chalcopyrite, bornite, and gersdorffite in unoxidized Chinle ores at the Happy Jack mine, San Juan County, Utah, suggests a hydrothermal (magmatic) origin of laterally moving mineralizing solutions (Dodd, 1950).	
1953					
Preliminary isotope age determinations on many carnotite ores and a few uraninite ores indicate that uranium was introduced into the sediments not earlier than Late Cretaceous or early Tertiary times—55–80 million years ago (Stieff and others, 1953).	----------	----------	In the Moenave Formation in the Silver Reef district, Utah, silver, vanadium, copper, and uranium were (a) primary constituents in tuffaceous sediments in Triassic time, (b) dissolved as sulfates and (or) mechanically transported by streams eroding these sediments, (c) later precipitated by H_2S derived from decaying plant matter or by sulfate reducing bacteria, and (d) further concentrated by solution in circulating ground waters and precipitated by buried plant matter or bacteria. Folding, erosion, and exposure resulted in the secondary enrichment by meteoric water (Proctor, 1953). (See also under "Telethermal (epigenetic) hypotheses".)	Although leaching of volcanic ash may have contributed some metals to the plateau uranium deposits, hydrothermal solutions given off during the crystallization of large deep-seated magmatic masses that theoretically underlay the laccolithic complexes are believed to have contributed most of the metals, entered the ground-water system reactivated in early Tertiary time because of igneous activity and structural deformation, and precipitated uranium and other metals near organic matter and clay (Waters and Granger, 1953).	
1954					
Experiments show that humic materials such as low-rank coal are markedly more effective in extracting uranium from very dilute solutions than other types of organic materials, and furthermore the process is apparently irreversible (Moore, 1954).	----------	In the Sangre de Cristo Formation in Mora County, N. Mex., uranium and other metals were probably deposited with the sediments and concentrated into deposits by connate water during compaction and lithification (Zeller and Baltz, 1954).	In the Plateau region, marine waters from the Late Cretaceous sea may have saturated the underlying Triassic and Jurassic host sandstones. These waters containing uranium dissolved from tuffaceous material were circulated because of the Laramide deformation, and uranium was concentrated around plant and hydrocarbon material (Gruner, 1954). In the Gas Hills district, Wyoming, uranium in the ores from the Wind River Formation is believed to have been leached from the White River Formation or younger tuffaceous Tertiary rocks by ground water and transported downward and laterally to environments favorable for localization (Love, 1954b).	In Grand County, Utah, the Shinarump No. 1 deposit in the Chinle Formation is believed to be of hydrothermal origin because of minerals that suggest high temperature of deposition and of isotopic age determinations that indicate this deposit was formed in Late Cretaceous or early Tertiary time (Finch, 1954).	

TABLE 8.—*Summary of the historical development of the hypotheses of origin of uranium deposits in sandstone in the United States*—Con.

Important scientific developments that affected various hypotheses	Syngenetic hypotheses	Penesyngenetic hypotheses	Lateral-secretion (epigenetic) hypotheses	Telethermal (epigenetic) hypotheses	Miscellaneous hypotheses
1955					
Thermodynamic relations among uranium oxides and hydroxides are consistent with the view that the primary low-valent mineral assemblage has been superseded to various degrees of completeness by a secondary high-valent mineral assemblage through oxidation (Garrels, 1955).	----------	----------	It was postulated that uranium, vanadium, and copper in sandstone ores were derived from the same provenance as the enclosing sediments; that during sedimentation the metals were removed by surface and ground waters during the weathering and erosion cycles and trapped in certain favorable continental (mainly fluvial) environments; and that the initial syngenetic concentrations of metals were modified by diagenesis by ground water, and perhaps by hydrothermal solutions (Wright, 1955).	The sum total of the facts, especially isotopic age determinations, suggests that deposits in the Colorado Plateau region and Black Hills uplift area were formed from deep-seated solutions, probably originating from igneous rocks that for the most part did not reach the surface (McKelvey, Everhart, and Garrels, 1955). Ores in the Morrison Formation of western Colorado are believed to have been precipitated in favorable beds from solutions that originated at depth from an igneous source, ascended along fractures, and mingled with circulating waters (Cater, 1955a). (See also under "Lateral-secretion (epigenetic) hypotheses," Wright (1955).)	
1956					
Variations in O^{18}/O^{16} ratios indicate that uraninite formed at low temperatures in Chinle ores in Utah (Hoekstra and Katz, 1956).	Multiple-migration-accretion hypothesis: Earliest stage—in arid, poorly drained continental environments uranium was extracted largely as $CaUO_2(CO_3)_3$ from the weathering of granitic or tuffaceous terranes and concentrated by organic matter, H_2S, or possibly phosphate, into very low but extensive accumulations; second stage—some of these accumulations were exposed, oxidized, redissolved, and carried to a new locality for reduction; further sedimentational stages—each new oxidation-solution-migration-precipitation cycle gave rise to a richer concentration; postsedimentational stages—processes of redissolving and reconcentration continued and in the Colorado Plateau region reached their climax with the Laramide orogeny (Gruner, 1956b).			The sum total of the evidence indicates that uranium in deposits in sandstone was derived from a deep-seated source, transported along fractures to permeable layers, formed at low temperatures and pressures possibly equivalent to those for rocks buried several thousand feet, and localized in sedimentary structures by reduction processes (McKelvey, Everhart, and Garrels, 1956).	
1957					
Thermometric evidence indicates that in the Colorado Plateau region the temperatures during mineralization were not vastly different from the "normal" temperatures of the enclosing rocks (Coleman, 1957a).	----------	----------	It was concluded that uranium ores of the "sandstone-type" are generally post-sedimentation, seem to have a nearby sedimentary source as opposed to a distant deep-seated one, were probably derived from tuffaceous sediments and also (but less easy to explain) from arkosic sediments, and were deposited by reducing and (or) acidifying materials (Garrels, 1957).	In the Ambrosia Lake district, New Mexico, liquid hydrocarbons (oil) migrated into domal traps, subsequent faulting caused the release of hydrostatic pressure and the formation of asphalt residue, and then uranium-bearing magmatic fluids rose along these or later faults and deposited uranium ore in the asphaltic rocks (Birdseye, 1957).	Meteoric-source hypothesis: For the Colorado Plateau deposits: "A meteoric source would provide heavy particles that would accumulate in the stream channels but would disintegrate on the adjacent land areas of these lacustrine deposits" (Skerl, 1957).

TABLE 8.—*Summary of the historical development of the hypotheses of origin of uranium deposits in sandstone in the United States*—Con.

Important scientific developments that affected various hypotheses	Syngenetic hypotheses	Penesyngenetic hypotheses	Lateral-secretion (epigenetic) hypotheses	Telethermal (epigenetic) hypotheses	Miscellaneous hypotheses
			1958		
1. The broad spread of S^{32}/S^{34} ratios and the marked enrichment of the lighter isotope in sulfide minerals from sandstone ores are very suggestive of hydrogen sulfide derived from anaerobic bacteria (Jensen, 1958). 2. Ages of uranium minerals determined by uranium-lead isotope methods are apparent only and bear no relation to the time of uranium mineralization (Miller and Kulp, 1958).	----------	----------	Uranium deposits in sandstone of the Sangre de Cristo Formation in Mora County, N. Mex., are believed to have been formed long after sedimentation from a mixture of heated (by tectonic activity) acid solution and normal ground water that (1) leached uranium and other metals from syngenetic concentrations which were derived from Precambrian rocks and that (2) redeposited the metals in favorable sedimentary structures due to changes in pH or Eh, complex-ion destruction, or flocculation of a colloid by dilution or mixing of unlike solutions (Tschanz and others, 1958).	The uranium in the Colorado Plateau ores seems from incomplete data to have been derived from magmatic fluids that mingled with ground water and was precipitated by carbonaceous matter, clay, and their associated chemical constituents (Kerr, 1958a, b).	
			1959		
Experiment shows that the amount of carbonized material in many deposits was probably sufficient to form by reduction the uranium and vanadium minerals, but not necessarily all the associated minerals, especially sulfides (Garrels and Pommer, 1959).	----------	----------	Uranium deposits in Triassic rocks of the Colorado Plateau region are believed to have formed in early Tertiary time by ground water that leached uranium and other ore metals from the overlying mudstone beds or from the ore-bearing rocks themselves and redeposited the metals in favorable sedimentary and tectonic structures (Finch, 1959a). Geologic relations in the Slick Rock district, Colorado, indicate that connate ground water, heated by igneous activity and set into circulation near the end of Cretaceous time, picked up uranium and other ore elements from the sedimentary rocks where they had been faulted and brecciated, and precipitated the ore minerals at solution interfaces where carbonaceous matter provided suitable reducing conditions (Shawe and others, 1959).	----------	Magmatic hypothesis: The vein uranium deposits in the Dripping Spring Quartzite, Gila County, Ariz., are believed to have formed contemporaneously with the cooling of the closely associated diabase bodies and from uranium-bearing hydrothermal solutions emitted by the diabase at a late stage of its differentiation (Granger and Raup, 1959).
			1960		
The maximum temperature coal from ores in the Chinle and Morrison Formations could have undergone is 120° C (Breger and Chandler, 1960).	----------	----------	Concentration of major Colorado Plateau uranium deposits in restricted belts suggests that the uranium was transported in moving ground water, which derived its uranium from local rocks perhaps following devitrification of volcanic debris, and was deposited where a decrease in pressure, which had been built up from compaction of sediments or lateral compression, would permit precipitation; one edge of a belt was determined by a paleoisobaric surface where precipitation began and the other edge was determined where the solutions were depleted of uranium (Noble, 1960a).	The spatial and geochemical correlations of uranium deposits in sandstone with mafic and intermediate igneous rocks as well as certain uranium veins with silicic igneous rocks strongly suggest that emanations from subjacent masses of mafic, intermediate, or silicic compositions enter into chloride-rich ground-water regimes and follow fractures upward in nonporous rocks and laterally in porous sedimentary rocks to sites of deposition (Page, 1960).	

The idea of a syngenetic origin has been discarded by all or most geologists because of the epigenetic characteristics of the deposits.

The concept of a penesyngenetic origin is primarily concerned with the time of ore deposition—a time designated as relatively early in the history of each ore-bearing sandstone bed, probably during diagenesis and before deep burial rather than late in the history, after possible deformation and after the resulting changes in channelways which aided solution movement in the rocks. Of course this hypothesis cannot be applied to deposits formed by relatively recent movement of uranium and to deposits of secondary uranium minerals, but it might still apply to earlier formed deposits if their destruction were the source of uranium in the later deposits. The concept of a penesyngenetic origin, in itself, does not imply a particular source of the metals in the deposits. Logic, however, requires either (1) the injection of hydrothermal (or hypogene) solutions from a magmatic source contemporary with the general period of diagenesis of each ore-bearing bed, which might be unlikely because of the geographic and stratigraphic distribution of the deposits, or (2) it requires a source more universally present, such as the metals dispersed in the ore-bearing and associated beds and transported by means of ground-water solutions. If the latter idea is accepted, the penesyngenetic concept must also incorporate the principal idea of the lateral-secretion hypothesis.

The lateral-secretion hypothesis mainly concerns the source of metals in the deposits. According to this hypothesis, metals are derived from dispersed traces in minerals and other materials of ore-bearing and adjacent beds and are collected and transported by migrating solutions whose dominant movement is lateral. The solutions may be either hypogene or ground water, but hypogene solutions might not be present everywhere, whereas ground water would be. The lateral-secretion idea is not concerned with time except that relative to the geologic events which might influence the lateral movement of solutions.

One specific idea that has been proposed—the multiple migration-secretion hypothesis (Gruner, 1956b)—incorporates the principal features of the penesyngenetic and lateral-secretion concepts. It suggests the derivation of the metals from metal-bearing minerals and materials incorporated in the host beds and associated rocks as they were laid down, and perhaps even from metals in solution in the pore waters. This hypothesis suggests that these metals were then transported in solution by the waters in the rocks and that they were precipitated and concentrated at favorable places, possibly to be later redissolved and reprecipitated in richer concentrations (processes that conceivably could recur several times). Inherently, time is not a significant factor in this hypothesis—the processes could begin early and continue late in the history of the host rocks. Accepting the general principles of this concept, Garrels (1957) suggested that some uranium ore deposits might be "one shot" affairs that formed relatively early in the history of the host rocks, as, for example, many of the deposits in the Colorado Plateau region, which he suggested may have formed before the end of Mesozoic time. He suggested that, in contrast, many deposits elsewhere might have had a more complex history, including migration in rather recent time.

The telethermal hypothesis encompasses the concept that the metals were derived from a deep-seated magmatic source and were transported by hydrothermal solutions to sites of deposition in the host beds. The concept assumes relatively low temperatures and pressures at the site of deposition; it implies movement of solutions across strata, probably in through-going channelways such as fractures; and it permits migration of solutions along beds and mixing of the original solutions with ground water in these beds. Most uranium-bearing areas lack many of the characteristics which normally identify hydrothermal solutions, such as conspicuous mineralization or alteration along the channelways and deposition of abundant gangue minerals with the ore minerals. The telethermal hypothesis requires hydrothermal mineralization in areas remote from any other areas that show evidence of magmatic activity. These requirements present distinct obstacles to the acceptance of this concept for many uranium deposits in sandstone. Nevertheless, some uranium deposits in sandstone are almost certainly of hydrothermal origin, as, for example, those in the Sierra Ancha district, Arizona (Neuerburg and Granger, 1960).

One of the earliest ideas proposed for the origin of the carnotite deposits of the Colorado Plateau was the "outcrop" or "rim rock" hypothesis. At the time of proposal the only known deposits were at and near outcrops, and it was assumed that the ore minerals were precipitated from mineralized ground water evaporating at these locations. Although this hypothesis is no longer applicable to most deposits in the Colorado Plateau region, it probably explains the origin of caliche uranium deposits in dry areas (Bell, 1956). Few, if any, of these caliche deposits have yielded commercial ore.

On the basis of geologic settings, habits of deposits, and geochemical relations, a migration-accretion type of hypothesis, which includes the principal aspects of the penesyngenetic and lateral-secretion concepts and involves one or more periods of migration, is favored by the author to explain the origin of all typical peneconcordant deposits and most vein deposits intimately associated with them. This hypothesis embraces the major concepts of Gruner (1956b) and Garrels (1957). (Additional literature pertinent to this hypothesis includes: Bramlette and Posjnak (1933; Fischer (1942); Ross and Hendricks (1945); Schouten (1946); McKay (1946); Hembree and others (1952, p. 49); Miholić (1952); Hubbert (1953, p. 1955); Garrels (1953, 1955); Grim (1953); Coombs (1954, p. 102); Manger (1954, 1958); Goldsztaub and Wey (1955); Ross and Smith (1955); Garrels and Richter (1955); Denson and Gill (1956); Turekian and Kleinkopf (1956); Keller (1956); Hurley and Fairbairn (1957); Katayama and Sato (1957); Zitting and others (1957); Chervet and Coulomb (1958); Szalay (1958); Vine and others (1958); Weeks and others (1957, 1958); Carroll (1959); Phoenix (1959); Noble (1960a, b); Austin (1960); and Bowers and Shawe (1961).)

The ore metals were derived from the ordinary trace amounts of these metals in minerals and materials deposited in the host rocks and associated strata and from the trace amounts of metals in solution in the pore waters when these rocks accumulated. The devitrification of volcanic ash, where it is present, could have contributed much of the uranium and some of the accessory elements in the deposits; vanadium could have been derived from the destruction of the black heavy minerals (mainly magnetite) in the sandstone as well as from the detrital clay minerals; and copper could have been derived from the arkosic minerals and the black heavy minerals. Although these metals are normally present in sedimentary rocks only in small traces, the total amounts present in moderate to large volumes of rocks far exceed the amount of metals in the ore deposits.

The waters from which the various sediments accumulated undoubtedly were different in composition, but because most of these sediments are of continental origin the waters probably contained a moderate amount of alkaline bicarbonates. Inasmuch as these waters remained with the ore-bearing beds during diagenesis, their alkaline bicarbonate content probably increased and made the solutions capable of dissolving and transporting moderate amounts of uranium and vanadium (Hostetler and Garrels, 1962). Such solutions would have contained considerably larger amounts of these metals than do most modern ground waters. During compaction of the sediments, especially of the mudstone beds, these solutions would have been squeezed out, and would have tended to flow downward and along more permeable parts of the sandstone beds. The flow would have been dominantly lateral along beds, at least until fractures resulting from tectonic deformation disrupted this flow and offered through-going crosscutting channelways. Movement along the beds would have tended to be very slow, but intermittent and more rapid flow would have resulted from ground-water recharge at distal outcrops of the sandstones and from reactivation by tectonic or igneous activity.

Precipitation of low-valent ore minerals from these solutions would have occurred in rocks of intense to moderate reducing capacity and under conditions of temperature and pressure about the same as the enclosing strata. Carbonized plant fossils, asphaltic material, H_2S gas generated by anaerobic bacteria feeding on organic matter, and iron sulfides could have created a reducing environment of patchy distribution, possibly like that of the deposits. If the chemical environment changed appreciably, especially if it became oxidizing, a deposit could have been destroyed by solution of uranium which, moving on, might have reprecipitated at another reducing spot. Precipitation of primary ore minerals would have ceased when the mineral-bearing solutions were flushed out and replaced by normal ground water.

GUIDES TO URANIUM ORE IN SANDSTONE

Many summaries of guides to ore in sandstone have been published (Fischer, 1949b; Weir, 1952; Fischer and Hilpert, 1952; Reinhardt, 1952; Konigsmark, 1955; McKelvey, 1955; Mitcham and Evensen, 1955; McKay, 1955c; Chew, 1956b; Bell and others, 1956; Page, 1956, 1958; Wood and Grundy, 1956; Klepper and Wyant, 1957; Phoenix, 1958; Bates, 1959; Finch, 1959a; and Cannon, 1960). The important guides are listed below with a brief explanation of their application. These guides are based chiefly on empirical relations of the ores to geologic features. The indication of favorableness for uranium by several guides is considerably more useful than indication by a single guide.

Anomalous radioactivity.—The radioactive equilibrium of each anomaly should be studied carefully to determine the causes and significance of the radioactivity (Wright, 1954; Rosholt, 1959). In humid climates, low-intensity anomalies may be the surface expression of highly leached uranium ore, and pitting or drill exploration is advisable to obtain an unleached sample.

Secondary minerals of iron, vanadium, copper, molybdenum, cobalt, or selenium.—These colorful minerals are a visual guide to associated uranium ore in many areas.

Carbonized plant remains and "asphaltite."—In sandstone units that have other characteristics favorable for ore, abundant carbonized plant remains or "asphaltite" may indicate nearby uranium deposits. If uranium mineralized only the carbonized wood and did not impregnate the adjacent sandstone, however, or if the plant fossils are dominantly silicified, large ore bodies are probably not present.

Sandstone and mudstone bleached from red to light gray, light green, or other light colors.—Mapped color intensities and thicknesses of bleached rocks, particularly mudstone within and beneath sandstone, are very useful in guiding exploration. In prospecting, bleached rocks are a visual guide to favorable outcrops. Bleached rocks are the chief guide to ore in Tertiary rocks in California, Nevada, and southern Arizona.

Lenticularity.—In formations characterized by trunk channel systems, the area underlain by channels may be only a small percentage of the total area. Delineation of the edges of channels would outline the areas favorable for ore. A further aid in formations of this kind is the mapping of buried swales or broad valleys (Witkind, 1956b; Witkind and others, 1960; Black and others, 1962). In formations characterized by braided systems of lenses, the area underlain by the lenses may be a large percentage of the total. Isopachs of the thickness of sandstone would indicate the thicker parts where initial search for ore should be concentrated.

Heterogeneous rock.—Thick beds of clean sandstone, having relatively large transmissive capacity, and argillaceous beds of low transmissivity are less favorable for uranium occurrence than are sandstone beds that contain seams and lenses of mudstone. Isopleth maps of sandstone-mudstone ratios aid in locating the more heterogeneous parts of a lens or channel. Where two facies intertongue, the more permeable one is generally more favorable for deposits.

Pinchout of a sandstone unit.—Lenses and channels near a pinchout are commonly more favorable for uranium than those farther away.

Regional unconformity.—Fluvial conglomerate and sandstone immediately above a regional unconformity are more favorable for ore than those farther above.

Faults and shear zones.—These structural features are good guides to ore in beds of marine and eolian sandstone and in areas already known to contain vein deposits. This guide is particularly useful in the Pacific Coast States, Nevada, and southern Arizona.

Sandstone pipe.—Sandstone pipes are a guide to ore in Permian and Pennsylvanian sandstones in the Grand Canyon area, Arizona. Many pipes occur in Jurassic sandstone overlying the gypsiferous facies of the Todilto Limestone in northewestern New Mexico (Schlee, 1963), but only a few are known to be mineralized; possibly other mineralized pipes exist in this area.[2]

[2] After this report was written, two uranium-ore-bearing cylindrical structural features were reported in the Ambrosia Lake district, New Mexico: by Granger and Santos (1963) at the Doris 1 mine (sec. 21, T. 13 N., R. 9 W.) and by Clark and Havenstrite (1963) at the Cliffside mine (table 2, loc. 29).

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Diatremes.—Uranium-bearing vein deposits are associated with a few diatremes in northeastern Arizona; possibly others will be found.

Salt domes.—A moderately large uranium deposit occurs in Goliad Sand above the Palangana salt dome in southeast Texas (table 2); uranium deposits may be associated with other salt domes if a favorable host rock is present.

FAVORABLE AREAS AND FORMATIONS FOR URANIUM DEPOSITS IN SANDSTONE

Sandstone beds that contain most of the peneconcordant uranium deposits are of continental origin and were deposited in poorly drained areas or in basins. In composition they are quartzose, arkosic, or tuffaceous, and many are interbedded with or are overlain by tuffaceous beds. Fossil plant remains are present in almost all of these ore-bearing beds. The ore-bearing beds may be slightly to moderately deformed, but few, if any, deposits occur in areas in which they are intensely deformed. These criteria and certain of the guides to ore listed above may help designate some areas and formations that may be favorable for uranium ore but which contain few or no known deposits.

The most general criterion of favorableness—continental sandstone formed in a foreland region—would be most useful in selecting areas for prospecting in large unexplored regions, probably on continents other than North America. In South America, for example, uranium deposits similar to the highly productive deposits in the United States are known only in central Argentina (Linares, 1956; Angelelli, 1956; Regairaz and Pozzo, 1958). Other areas favorable for prospecting may exist in a belt extending northward from Argentina through Colombia, west and south of the Brazilian and Guiana Precambrian shields. A study of the tectonic history and stratigraphy of these areas should reveal the sandstone beds most favorable for prospecting.

In the United States, the Appalachian, Coastal, Ouachita, and Cordilleran forelands (fig. 3) have been rather intensely prospected. The Mexican and Olympic forelands of Tertiary age, however, contain beds of continental sandstone that have been very little prospected. Because of the transitory nature of forelands and the varied later geologic history of parts of these regions, careful studies and more detailed maps than figure 3 are needed to aid in selecting areas for possible prospecting.

Extension of the belt of uranium deposits along the Cordilleran foreland of the United States into the Canadian part of the Cordilleran foreland seems unlikely. Tuffaceous rocks in the Canadian part are sparse, and marine sediments are more abundant than beds of continental sandstone, most of which crop out in areas of rather intense deformation (Goodman, 1951; Ross, 1955; Sikabonyi, 1957; King, 1959, p. 137; Chamberlain, 1960).

In compiling a map showing the general distribution of continental sedimentary rocks in the United States, Finch, Parrish, and Walker (1959, sheet 1) checked the environment of sedimentation of hundreds of formations. More than 100 formations containing uranium deposits in continental sandstone beds are listed in table 3. Table 9 lists 55 formations containing continental sandstone beds in which uranium deposits are unknown. About 25 of these 55 formations are in the Cordilleran-Ouachita forelands uranium region and adjacent areas; the others are in the Gulf Coastal and Mississippi Alluvial Plains and the Appalachian Highlands. This list is incomplete; notable omissions are Tertiary continental formations deposited in numerous fault-block and intermontane basins in the Basin and Range province and in parts of California, Oregon, and Washington (fig. 5).

TABLE 9.—*Continental sandstone formations in which uranium deposits are unknown*

[Dominant environment of sedimentation: Rocks formed under conditions transitional from continental to marine are also listed. The term "nonmarine" is used where environment may include transitional conditions such as littoral, deltaic, lagoonal, and estuarine]

Stratigraphic unit	Dominant environment of sedimentation	States where unit or equivalent rocks crop out	References
Cordilleran-Ouachita forelands uranium region and adjacent areas			
Ankareh Shale	Nonmarine	Wyoming	Adkins (1933, p. 241).
Aztec Sandstone	Eolian	Nevada	McKee and others (1956).
Bishop Conglomerate	Fluvial	Wyoming	Bradley (1936.)
Cheyenne Sandstone	Continental	Kansas	Moore and others (1951, p. 21).
Chuska Sandstone	Eolian	Arizona, New Mexico	Wright (1956).
Cimarron Group	Mostly nonmarine, partly lacustrine or shallow marine.	Kansas	Moore (1933, p. 322).
Denver Formation	Lacustrine, nonmarine	Colorado	Moore (1933, p. 453); Brown (1943).
Double Mountain Formation.	Continental(?) (red-bed facies).	Texas	Sellards (1933, p. 166).
Eagle Sandstone	Nonmarine	Montana	Weed (1899); Hatcher and Stanton (1903); Armstrong (1957).
Fountain Formation	Alluvial, nonmarine	Colorado	Bartram (1940); Lovering and Goddard (1950).
Gannett Group	Largely fresh water	Idaho	Ross and Forrester (1947)
Golden Valley Formation	Continental (land plants).	North Dakota	Benson and Laird (1947); Johnson and Kunkel (1954).
Hanna Formation	Fresh water (land plants and vertebrates).	Wyoming	Bowen (1918).
Harper Sandstone	Nonmarine	Kansas	Moore and others (1951).
Horsethief Sandstone	Continental	Montana	Armstrong (1957).
Judith River Formation	Mostly fresh water, some brackish water, locally marine at top.	do	Stanton and Hatcher (1905); Armstrong (1957).
Kootenai Formation	Continental (fossil plants).	do	Dawson[?] (1885); Armstrong (1957).
Lennep Sandstone	Shallow water, fluvial	do	Knappen and Moulton (1931); Armstrong (1957)
Lykins Formation	Continental?	Colorado	Fenneman (1905).
Lyons Sandstone	Littoral and shoreline	do	Thompson (1949, p. 17).
North Boulder Group	Shoreline facies	Montana	Ross (1949, oral commun., 1957).
Nugget Sandstone	Eolian and waterlaid	Idaho, Wyoming, Utah	McKee and others (1956); Oriel, in McKee and others (1959, p. 23).
St. Mary River Formation	Continental	Montana	Armstrong (1957).
Spearfish Formation	do	South Dakota, Wyoming	
Uinta Mountain Group	Alluvial fan, shallow water, and subaerial.	Colorado, Utah	Hansen (1957, p. 52).
Willow Creek Formation	Continental	Montana	Armstrong (1957).

TABLE 9.—*Continental sandstone formations in which uranium deposits are unknown—Continued*

Stratigraphic unit	Dominant environment of sedimentation	States where unit or equivalent rocks crop out	References
Gulf Coastal and Mississippi Alluvial Plains			
Citronelle Formation	Continental	Alabama, Florida	Stose (1932).
Claiborne Group	Continental and marine, cyclic.	Arkansas, Louisiana, Texas	Moore (1933, p. 525); Plummer (1933, p. 610).
Tuscaloosa Formation	Brackish water, swamp, lagoonal.	Alabama, Georgia, Mississippi, North Carolina, Tennessee.	Eargle (1955, p. 90–94).
Wilcox Group	Largely continental (littoral, fluvial, lacustrine, and lagoonal).	Arkansas, Kentucky, Louisiana, Mississippi, Missouri, Tennessee, Texas.	Moore (1933, p. 525); Plummer (1933, p. 573).
Appalachian Highlands			
Allegheny Formation	Fresh water and marine, cyclic.	Maryland, Pennsylvania, West Virginia.	Reger (1931).
Bald Eagle Conglomerate	Dominantly continental	Pennsylvania	Willard (1943, p. 1084).
Bellingham Conglomerate	do	Massachusetts, Rhode Island	Emerson (1917, p. 51).
Bloomsburg Formation	Continental, presumed alluvial.	Pennsylvania	Willard (1938); Swartz (1948).
Conemaugh Formation	Continental, fresh water; some thin marine beds.	Maryland, Ohio, Pennsylvania, West Virginia.	Moore (1933, p. 295); Stout (1931, p. 201); Reger (1931).
Dighton Conglomerate	Continental	Massachusetts, Rhode Island	Emerson (1917, p. 51).
Dunkard Group	Fresh water and swamps	Ohio, Pennsylvania, West Virginia.	Stauffer (1916).
High Falls (Shale) Formation.	Continental	New Jersey, New York	Willard (1938, p. 10).
Juniata Formation	Alluvial plain, continental.	Maryland, Pennsylvania, Virginia, West Virginia.	Willard (1943, p. 1084); Butts (1940, p. 228); Woodward (1951, p. 388).
Loudoun Formation	Continental	Maryland, Pennsylvania, Virginia.	Butts (1940, p. 471).
Monongahela Formation	Fresh water, cyclic	Maryland, Ohio, Pennsylvania, West Virginia.	Stout (1931, p. 201); Reger (1931).
Oswego Sandstone	Fresh water, subaerial, deltaic.	Virginia, West Virginia	Butts (1949, p. 221); Woodward (1951, p. 381).
Pocono Formation	Nonmarine, deltaic	Maryland, Pennsylvania, Virginia, West Virginia.	Cooper (1948); Willard (1946, p. 786); Dunbar (1949).
Pondville Conglomerate	Continental	Massachusetts, Rhode Island	Emerson (1917, p. 51).
Potomac Group	Continental, swamps, stream.	Delaware, Maryland, Virginia.	Moore (1933, p. 434).
Purgatory Conglomerate	Continental	Massachusetts, Rhode Island	Emerson (1917, p. 51).
Raritan Formation	do	Delaware, Maryland, New Jersey, New York.	Moore (1933, p. 436).
Rhode Island Formation	do	Massachusetts, Rhode Island	Emerson (1917, p. 51).
Shawangunk Conglomerate	Alluvial plain, fresh water.	New Jersey, New York	Thomson (1957); Amsden (1955).
Skunnemunk Conglomerate	Continental	do	Willard (1939, p. 262).
Unicoi Formation	Continental, fluvial	Alabama, Georgia, North Carolina, Tennessee.	Barrell (1925).
Wamsutta Formation	Continental	Massachusetts, Rhode Island	Emerson (1917, p. 51).
Weverton Sandstone	do	Maryland, Pennsylvania, Virginia.	Butts (1940, p. 471).

Many of the known uranium-bearing sandstone formations extend into States where, in these formations, uranium has not yet been found. Notable in the Gulf Coastal and Mississippi Alluvial Plains are the Jackson Group, Catahoula Tuff, and Oakville Sandstone; in Maryland, Virginia, and West Virginia of the Appalachian Highlands, the Catskill Formation (Chadwick, 1936); in States from Alabama northeastward to West Virginia, the Pottsville Formation (Wanless, 1946); and in States northward from North Carolina, the Newark Group.

Paleotectonic maps, such as shown in figures 4 and 5 and plate 2, may reveal some areas and formations where uranium ore may occur. For example, in Upper Jurassic rocks the lithofacies patterns of the Morrison Formation in central and western Wyoming are similar to those in the Colorado Plateau region, the most productive part of the Cordilleran foreland (pl. 2). This similarity suggests that large productive deposits may yet be found in Morrison rocks in western Wyoming. A second example, shown on plate 2, is the Cotton Valley Group in the Gulf Coastal Plains, which has lithofacies and environmental features similar to those of the Morrison Formation in the Colorado Plateau region (McKee and others, 1956, p. 3, col. 2), and this similarity suggests the possible occurrence of uranium in the Cotton Valley Group. Because the Cotton Valley Group does not crop out, the presence of uranium is unknown and would have to be determined by drill-hole exploration, which should be preceded by careful study of available subsurface data.

Regional intertonguing of facies is known in places where uranium has not yet been discovered. Two examples are: (1) the west flank of the Powder River Basin in Wyoming, where conglomerate of the Kingsbury and Moncrief Members of the Wasatch Formation pass laterally and downdip into sandstone and siltstone (J. D. Vine, written commun., 1955); and (2) Texas and States along the Mississippi embayment, where marine and continental rocks interfinger (fig. 5, basin 14).

A knowledge of the distribution of tuffaceous sedimentary rocks would be of great value in locating new areas favorable for uranium. Ross (1955, fig. 1) published a small-scale map showing the distribution of pyroclastic materials east of the Rocky Mountains.

A search of the geologic literature for reports of occurrences of fossil plants might aid in the discovery of uranium deposits in formations and areas that are not known to be uranium bearing. Murata (1940) compiled a list of 66 formally named formations containing silicified wood, and he noted that two-thirds of them contained some tuffaceous material. At that time uranium was known in only 2 of the 66 formations (Murata listed the Morrison, Chinle, Dockum, and Shinarump separately, but the latter three are now considered partly or completely equivalent rocks), but in 1959 it was known in 30! Of the 28 formations containing recently discovered uranium deposits, the Jackson and Inyan Kara (Lakota) Groups are the most productive. Furthermore, some fossil localities in these 28 formations are in areas where uranium has not been found; notable are the Jackson Group in Louisiana and the Trinity Group in Texas. Although silicified wood alone is not a guide to ore, it is commonly associated with carbonized wood and also tuffaceous material, both of which are guides. Therefore the 36 formations remaining in Murata's list may be considered potentially favorable for uranium. The formations and their locations, listed by State, are as follows (asterisk indicates formations containing some volcanic material; Murata gave published references describing each locality):

State	*Formation*	*Location*
California	Horsetown	Shasta County.
	*Sonoma Andesite	Sonoma and Napa Counties.
	*Weaverville	Trinity County.
	Wildcat	Humboldt County.
Colorado	*Animas	San Juan Basin.
	Kirtland	Do.
	*McDermott	Do.
	Vermejo	
Gulf Coast States.	Wilcox	
Idaho	*Aspen	
	*Hagerman Lake Beds.	Snake River plain.
	*Payette	Do.
Indiana	New Albany Shale	Scott County.
Iowa	Eldora Sandstone	Hardin County.
Kentucky	Mahoning Sandstone Member, Conemaugh Formation.	
Maryland	Potomac Group	
Mississippi	*Eutaw	
	Forest Hill Sand	
	McNairy Sand Member, Ripley Formation.	
Montana	*Judith River	Ingomar anticline.
	Kootenai	Near Geyser.
Nevada	*Upper Cedarville	Washoe County.
New Mexico	*Animas	San Juan Basin.
	Kirtland	Do.
	*McDermott	Do.
	Playas Peak	Little Hatchet Mts.
	*Ringbone Shale	Do.
	*Torrejon	San Juan Basin.
Ohio	Mahoning Sandstone Member, Conemaugh Formation.	
Oklahoma	Woodford Chert	
Oregon	*Calapooya	Southwestern part of State.
	*Eagle Creek	Columbia River Gorge.
	*John Day	Central part of State.
	*Mehama Volcanics	Near Mehama.
	*Trout Creek	Southeastern part of State.

State	Formation	Location
Texas	*Rockdale	
	*Tornillo Clay	
	*Yegua	
Virginia	Otterdale Sandstone	Richmond Basin.
	Potomac Group	
Washington	*Eagle Creek	Columbia River Gorge.
	*Yakima Basalt	Central part of State.
Wyoming	*Aspen	
	*Frontier	
	*Meeteetse	Park County.
	Parkman Sandstone	Sheridan County.
	*Wiggins	Absaroka Range.

Murata also listed 10 unnamed rock units in which uranium has not been found.

Traces of uranium have been found in many formations in which further search might find ore-grade material. (pl. 1; tables 2, 3).

Peneconcordant deposits so commonly occur in clusters that places containing only one or two known deposits warrant extensive exploration (pl. 1). Exploration downdip from known deposits in the Texas Coastal Plain is especially recommended. Thorough geologic study should precede this exploration.

As a result of a study of the uranium content of water in Fremont County, Wyo., Murphy (1956b) suggested two possible uranium-bearing areas.

Another area that might be considered favorable for uranium by reason of its analogy to the one in the Powder River Basin is the red zone in the Wasatch Formation parallel to the Forebear anticline in Park County, Wyo. (Pierce and Andrews, 1941).

Climate is a factor in the preservation of outcrops of uranium ore; arid and semiarid climates preserve them best, as in the Cordilleran-Ouachita forelands uranium region, where the rainfall is about 15 inches a year. Many large deposits in sandstone in countries other than the United States, however, are exposed to more humid climates. For example, the annual rainfall in the Blind River district, Canada, and at Witwatersrand, Union of South Africa, is 30–40 inches; at Mounana, Gabon in Africa, 60–80 inches; and at Buller Gorge, New Zealand, 80–200 inches. Klepper and Wyant (1957, p. 136–137) stressed that areas of extremely wet climates deserve a low priority in the search for uranium. The author, however, contends that a humid climate makes prospecting only more difficult—not futile; if an area has the geologic features favorable for uranium outlined above, it deserves prospecting regardless of its climate (Lecoq and others, 1958).

Consideration of all valid geologic factors can yield a negative as well as a favorable evaluation of prospecting possibilities. East of the Rocky Mountains, beds of continental origin of Oligocene and Miocene ages are widespread. Lithologically, these beds are similar to productive rocks of Tertiary age in the intermontane basins to the west, and they even contain a few known occurrences of uranium. Nevertheless, they are considered unlikely to contain deposits of uranium of economic value, because they were laid down on a sloping plain having a homoclinal dip. As a result, their connate waters may have drained out or been flushed out by meteoric water. This draining or flushing also would have permitted the oxidation and destruction of plant fossils and other reducing agents.

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