Reconnaissance for Uranium in Asphalt-Bearing Rocks in the Western United States

GEOLOGICAL SURVEY BULLETIN 1046-E

This report concerns work done on behalf of the U. S. Atomic Energy Commission and is published with the permission of the Commission

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By W. J. HAIL, Jr.

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

RECONNAISSANCE FOR URANIUM IN ASPHALT-BEARING ROCKS IN THE WESTERN UNITED STATES

By W. J. Hail, Jr.

ABSTRACT

An appraisal of asphalt-bearing rocks as potential sources of uranium was made during 1953 and 1954 in 45 areas in California, Utah, Wyoming, Montana, New Mexico, Texas, Oklahoma, and Missouri. A total of 202 samples from these areas was analyzed for uranium. The oldest rocks sampled are Ordovician in age, and the youngest are Recent. Although none of the deposits are of value at this time as a source of uranium, some of the deposits may constitute a low-grade uranium resource, but recovery of the uranium will depend upon the primary use of the asphalt.

Significant amounts of uranium in the ash of oil extracted from these rocks were found in samples from 7 of the 45 areas examined. These areas are Chalone Creek, McKittrick, Edna, and Los Alamos, Calif.; Vernal, Utah; Sulphur, Okla.; and Ellis, Mo. The average uranium content in the ash of the extracted oil of samples from these 7 areas ranges from 0.028 to 0.376 percent. All except the Chalone Creek area contain large estimated reserves of asphalt-bearing rock, ranging from 15 million to almost 2 billion tons. The average uranium content of samples from 13 additional areas ranges from 0.020 to 0.068 percent in the ash of the extracted oil. Many of these areas contain very large reserves of asphalt-bearing rocks.

It is believed that most of the asphalt deposits are oil residues, and that the uranium was introduced during or after the late stages of oil movement and loss of the lighter oil fractions.

INTRODUCTION

The term "asphalt-bearing rocks" as used here designates surface and near-surface rocks which contain a wide variety of naturally occurring solid, semisolid, and liquid petroliferous organic materials variously termed asphalt, asphaltite, gilsonite, bitumen, tar, brea, heavy oil, and others. This report presents the results of field investigations of uranium in asphalt-bearing rocks, together with laboratory analyses of the samples collected. These investigations were carried on during 1953 and 1954 by the U. S. Geological Survey, on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. Previous work by the Geological Survey (Erickson, Myers, and Horr, 1954) showed that the uranium content of the ash of natural asphalt and oil extracted from petroliferous rock is significantly higher than that of crude oil, sea water, and granitic rock. This suggested that some of the numerous deposits of asphalt-bearing rock of the Western United States might contain appreciable amounts of uranium. Selected deposits of asphalt-bearing rocks were examined and sampled in eight Western States to evaluate this type of rock as a possible source of uranium (fig. 14).

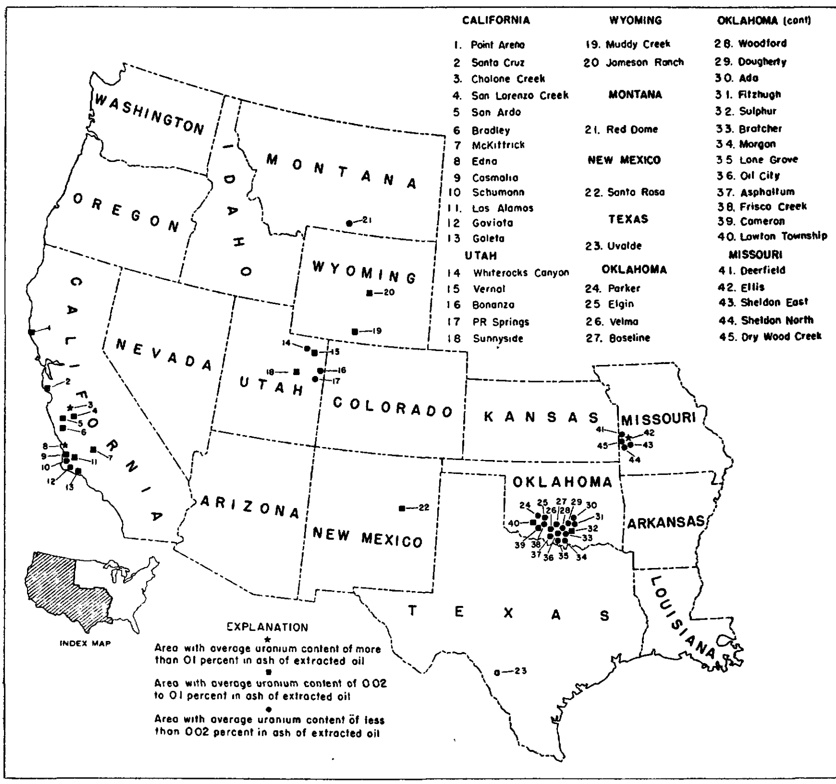

FIGURE 14.—Map of the Western United States showing areas examined for uranium in asphalt-bearing rocks.

Analyses of asphalt-bearing rocks by Erickson, Myers, and Horr (1954, p. 2215) showed that the uranium is concentrated in the ash of the oil and not in the rock. Similar analyses of the extracted asphalt from several selected samples collected during the present study also showed that the uranium is concentrated in the ash of the asphaltic portion of the sample. Significant amounts of uranium occur only in the ash of the oil extracted by solvents from the asphalt-bearing rocks, and these amounts constitute only a minute fraction of the bulk sample. For example, the most highly uraniferous sample collected contained 1.9 percent uranium in the ash of the extracted oil but this represents only about 0.0005 percent uranium in the bulk sample.

The descriptions of the deposits are based on many published reports, in addition to direct field observations. Estimates of reserves of asphalt-bearing rocks, taken from published reports, are given where available.

Analyses of samples were furnished by A. T. Myers, C. A. Horr, and M. C. Curtiss of the Geological Survey. The samples of asphalt-bearing rocks were crushed and the oil was exhaustively extracted with a hot mixture of 75 parts benzene, 15 parts acetone, and 10 parts methanol. The extract was evaporated to reduce possible loss of ash by rapid burning of the benzene-acetone-methanol mixture and then was dry ashed with final ignition at 500°C under oxidizing conditions. The ash was weighed, ground in an agate mortar, and analyzed chemically for uranium by standard fluorimetric methods. The uranium content of the oil was calculated from the amounts of oil ash and uranium in the oil ash.

FIELD WORK

Asphalt-bearing rocks were examined in 45 selected areas in California, Utah, Wyoming, Montana, New Mexico, Texas, Oklahoma, and Missouri. Many of the areas examined contain easily accessible deposits from which asphalt has been produced commercially. The individual deposits contain reserves ranging from a few thousand to about 2.8 billion tons. A total of 202 representative samples from the 45 areas was analyzed for uranium and for oil content. These samples were taken from 23 geologic formations of Ordovician, Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, Eocene, Miocene, Pliocene, Pleistocene, and Recent age. (See table 1.)

All the rocks sampled were tested for radioactivity with a scintillation counter or Geiger counter and none was noticeably radioactive.

TABLE 1.—*Asphalt-bearing formations sampled for uranium in the Western States*

State	Age	Stratigraphic unit	Predominant lithologic character of formation in areas examined.
California	Recent	Alluvium	Unconsolidated surface material.
	Pliocene and Pleistocene(?).	Tulare formation	Clay, silt, sand, and gravel. Gravel consists of siliceous shale, chert, granite, and quartzite.
	Pliocene	Etchegoin formation	Sandstone, silty claystone, and pebble conglomerate.
	do	Unnamed formation	Arkosic conglomerate and sandstone.
	Miocene and Pliocene	Pismo formation	Conglomerate, arkosic sandstone, diatomaceous sandstone, sandy and silty shale, diatomaceous shale, siliceous shale, and chert.
	do	Sisquoc formation	Diatomaceous mudstone, sandstone, micaceous siltstone, and claystone.
	Miocene	Santa Margarita sandstone.	Arkosic sandstone.
	do	Monterey shale	Diatomaceous shale and siltstone, porcelaneous diatomite, siliceous shale, and sandstone.
	do	Vaqueros sandstone	Arkosic sandstone.
Utah	Eocene	Uinta formation	Quartzose sandstone, shale, and conglomerate.
	do	Green River and Wasatch formations.	Sandstone, shale, minor amounts of limestone.
	Jurassic and Jurassic(?)	Navajo sandstone	Sandstone.
Wyoming	Eocene	Wasatch formation	Sandstone, shale, and conglomerate.
	Cretaceous	Teapot sandstone member of Mesaverde formation.	Sandstone.
Montana	Triassic	Chugwater formation	Sandstone and sandy shale.
New Mexico	do	Santa Rosa sandstone	Sandstone and shale.
Texas	Cretaceous	Anacacho limestone	Limestone.
Oklahoma	Permian	Wichita formation	Sandstone and shale.
	Pennsylvanian	Ada formation	Sandstone, conglomerate, shale, and limestone.
	do	Deese formation	Do.
	do	Springer formation	Shale and sandstone.
	Ordovician	Viola limestone	Limestone.
	do	Oil Creek formation	Sandstone.
Missouri	Pennsylvanian	Bartlesville(?) sand of Cherokee shale.	Do.

DEPOSITS

SUMMARY

Uranium was found in asphalt-bearing rocks in all of the 45 areas examined; average concentrations range from 0.001 to 0.376 percent in the ash of the extracted oil. The uranium content of the extracted oil ranges from 0.03 to 70.3 parts per million, and the uranium content of the ash of the extracted oil ranges from 0.001 to 1.9 percent. The average uranium content of the extracted oil is 2.0 parts per million, and the average uranium content of the ash of the extracted oil is 0.037 percent. None of the areas contains asphalt deposits of value as a source of uranium at this time. Whether any of the deposits may provide a low-grade source of uranium in the future probably depends upon recovery methods in the utilization of the asphalt for other purposes. Table 2 summarizes analytical data and other information on the asphalts from all the areas examined.

TABLE 2.—*Summary of data on uranium in asphalt-bearing rocks*

Locality number on fig. 14	Area	Stratigraphic unit	Age	Number of samples	Average oil in samples (percent)	Average ash in oil (percent)	Average U in ash (percent)	Average U in oil (ppm)
California								
1	Point Arena	Monterey shale	Miocene	6	4.13	0.80	0.030	2.4
2	Santa Cruz	Vaqueros sandstone.	do	8	10.34	.39	.027	1.0
3	Chalone Creek	Unnamed formation.	Pliocene	3	11.18	.48	.182	8.7
4	San Lorenzo Creek.	do	do	3	10.54	.23	.032	.7
5	San Ardo	Santa Margarita sandstone.	Miocene	2	6.24	.49	.068	3.3
6	Bradley	Unnamed formation.	Pliocene	1	10.49	.44	.045	2.0
7	McKittrick	Etchegoin formation. / Tulare formation / Alluvium	do / Pliocene and Pleistocene(?). / Recent	5	26.91	1.66	.047	7.8
8	Edna	Pismo formation	Miocene and Pliocene.	7	6.29	.56	.376	21.1
9	Casmalia	Sisquoc formation.	do	3	29.57	.19	.040	.8
10	Schumann	do	do	1	17.88	.23	.009	.2
11	Los Alamos	do	do	7	12.40	.78	.081	6.3
12	Gaviota	Monterey shale	Miocene	1	23.32	1.04	.002	.2
13	Goleta	do	do	2	18.94	2.05	.023	4.7
Utah								
14	Whiterocks Canyon.	Navajo sandstone	Jurassic and Jurassic(?).	4	5.59	0.66	0.009	0.6
15	Vernal	Uinta formation	Eocene	21	8.10	2.68	.028	7.5
16	Bonanza	Green River and Uinta formations.	do	7	100.00	.48	.003	.1
17	PR Springs	Green River formation.	do	10	6.55	1.11	.014	1.6
18	Sunnyside	Green River and Wasatch formations.	do	11	5.38	1.10	.021	2.3
Wyoming								
19	Muddy Creek	Wasatch formation.	Eocene	4	6.04	0.36	0.040	1.4
20	Jameson Ranch	Teapot sandstone member of Mesaverde formation.	Cretaceous	2	3.81	.59	.023	1.4
Montana								
21	Red Dome	Chugwater formation.	Triassic	5	4.91	0.60	0.010	0.6
New Mexico								
22	Santa Rosa	Santa Rosa sandstone.	Triassic	6	3.99	1.24	0.025	3.1
Texas								
23	Uvalde	Anacacho limestone.	Cretaceous	11	8.52	0.43	0.002	0.1

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TABLE 2.—*Summary of data on uranium in asphalt-bearing rocks*—Continued

Locality number on fig. 14	Area	Stratigraphic unit	Age	Number of samples	Average oil in samples (percent)	Average ash in oil (percent)	Average U in ash (percent)	Average U in oil (ppm)
			Oklahoma					
24	Parker	Wichita formation	Permian	1	2.16	1.62	0.004	0.6
25	Elgin	do	do	1	1.76	1.98	.006	1.2
26	Velma	do	do	1	.94	1.68	.001	.2
27	Baseline	do	do	2	.98	2.85	.005	1.4
28	Woodford	Springer formation	Pennsylvanian	3	2.79	4.95	.010	4.9
29	Dougherty	Viola limestone	Ordovician	3	3.18	.66	.001	.07
30	Ada	Ada formation	Pennsylvanian	4	3.29	1.95	.014	2.7
31	Fitzhugh	do	do	2	1.35	2.00	.002	.4
32	Sulphur	Oil Creek formation.	Ordovician	7	4.56	.70	.043	3.0
33	Bratcher	Deese formation	Pennsylvanian	3	8.72	.59	.008	.5
34	Morgan	do	do	1	5.71	.76	.005	.4
35	Lone Grove	Wichita formation	Permian	1	.87	3.31	.010	3.3
36	Oil City	do	do	1	12.28	4.49	.002	.9
37	Asphaltum	do	do	5	6.15	1.60	.007	1.1
38	Frisco Creek	do	do	2	2.08	10.39	.004	4.2
39	Cameron	do	do	1	5.70	2.06	.054	11.1
40	Lawton Township.	do	do	1	1.19	3.14	.020	6.3
			Missouri					
41	Deerfield	Bartlesville(?) sand zone.	Pennsylvanian	7	4.63	0.79	0.006	0.5
42	Ellis	do	do	3	4.64	.62	.145	9.0
43	Sheldon East	do	do	5	3.99	1.46	.016	2.3
44	Sheldon North	do	do	3	1.43	1.27	.004	.5
45	DryWoodCreek	do	do	16	2.30	1.58	.004	.6

Deposits in seven of the areas yielded individual samples with a significantly high uranium content in the ash of the extracted oil. These areas (with the uranium content of their richest samples) are Chalone Creek (0.50 percent), McKittrick (0.15 percent), Edna (1.9 percent), and Los Alamos (0.33 percent), Calif.; Vernal, Utah (0.15 percent); Sulphur, Okla. (0.22 percent), and Ellis, Mo. (0.40 percent). The average uranium content of ash of the oil ranges from 0.028 percent in the Vernal area to 0.376 percent in the Edna area. All the deposits except those in the Chalone Creek area contain large estimated reserves of asphalt-bearing rock, ranging from 15 million to almost 2 billion tons. The most uraniferous deposits found are in the Edna area.

The average uranium content of samples from 13 other areas ranges from 0.020 to 0.068 percent in the ash of the extracted oil. These areas are Point Arena, Santa Cruz, San Lorenzo Creek, San Ardo, Bradley, Casmalia, and Goleta, Calif.; Sunnyside, Utah; Muddy Creek and Jameson Ranch, Wyo.; Santa Rosa, N. Mex.; and Cameron and Lawton Township, Okla. Reserves of asphalt-bearing rocks in these 13 areas range from a few thousand tons to about 2.8 billion tons.

CALIFORNIA

The asphalt-bearing rocks in California generally appear to be more favorable for the occurrence of uranium than those examined in the other Western States. In 11 of the 13 California areas, the average uranium content in the ash of the extracted oil ranged from 0.023 percent to 0.376 percent (table 2). Almost all the California asphalts examined occur in formations of Miocene or Pliocene age, and it is probable that the asphalt in most of these formations originated in bituminous marine shales of Miocene age, represented mainly by the Monterey shale and equivalent formations (Hoots, 1943, p. 270–275). Table 3 shows analyses of samples from areas in California.

POINT ARENA AREA

Asphalt-bearing sandstone beds in the Monterey shale of Miocene age crop out on the seacoast just west of the town of Point Arena, Mendocino County. A sequence of interbedded shale, siltstone, and sandstone, 500 feet thick, contains 6 asphalt-bearing sandstone beds ranging in thickness from 1 to 30 feet. The beds crop out along parts of the east and south rim of a small northwestward-plunging syncline and underlie an area of less than one-half a square mile. Reserves of asphalt-bearing sandstone are estimated to be about 3.2 million tons (Holmes, Page, and Duncan, 1951).

SANTA CRUZ AREA

Asphalt-bearing sandstone beds in the Vaqueros sandstone and Monterey shale of Miocene age crop out about 5 miles west of Santa Cruz, Santa Cruz County. The two deposits in the area underlie about 3 square miles. The asphalt-bearing beds occur in a transition zone between the Vaqueros sandstone and the overlying Monterey shale. These formations vary greatly in thickness and lithology and lie unconformably on siliceous quartz diorite of pre-Cretaceous age. The asphalt-bearing beds are discontinuous and occur both as bedded sandstone and as sandstone "dikes" intruded into overlying shale beds. Total reserves of asphalt-bearing sandstone are estimated to be about 1.6 million tons (Page, Williams, Henrickson, and others, 1945). There is no production at the present time.

CHALONE CREEK AND SAN LORENZO CREEK AREAS

Asphalt-bearing arkose crops out along a small tributary of Chalone Creek, San Benito County, and along a small tributary of San Lorenzo Creek, Monterey County. The arkose in both areas is the basal part of a marine Pliocene formation which is in fault contact with pre-Cretaceous granite from which the arkose was derived (Bramlette and Daviess, 1944).

In the Chalone Creek area the asphalt-bearing arkose bed dips 40° E. and crops out for a distance of about a quarter of a mile along both sides of the valley. The bed is 37 feet thick on the west side of the valley and 21 feet thick in a small abandoned quarry on the east side of the valley.

In the San Lorenzo Creek area the asphalt-bearing arkose beds are as much as 30 feet thick and dip about 14° SW. Two abandoned quarries and several prospect pits mark the line of outcrop.

SAN ARDO AREA

Asphalt-bearing sandstone crops out 2 to 3 miles west of San Ardo, Monterey County. The asphalt-bearing beds may be as much as 125 feet thick and extend for 5 miles (Eldridge, 1901, p. 410). They occur in a transition zone between the Monterey shale and the Santa Margarita sandstone, both of Miocene age (Bramlette and Daviess, 1944). The beds dip eastward and crop out along the east flank of the hills bordering the Salinas River. At the sampled locality a 22-foot-thick bed of asphalt-bearing sandstone is exposed and dips 12° E.

BRADLEY AREA

Asphalt occurs in the basal bed of marine Pliocene rocks, which unconformably overlie the Monterey shale, about 6 miles southwest of Bradley, Monterey County (Eldridge, 1901, p. 411–12; Bramlette and Daviess, 1944). The asphalt-bearing bed crops out on both sides of the San Antonio River and dips about 12° NE. It is mainly a fine- to medium-grained sandstone, but some layers are conglomeratic. Part of the outcrop is obscured by slump, but the asphalt-bearing bed appears to be about 15 to 20 feet thick.

McKITTRICK AREA

Large deposits of asphalt in the form of asphalt-bearing sandstone, asphalt-bearing alluvium, oil seeps, and vein asphalt, crop out near McKittrick, Kern County. The deposits occur in a number of rock types in the Monterey shale of Miocene age, the Etchegoin formation of Pliocene age, the Tulare formation of Pliocene and early Pleistocene(?) age, and Recent alluvium. The rocks in the area are highly folded and faulted, and the asphalt deposits, as well as a small producing oilfield, are associated with these structures. The total reserves in the area are about 15.7 million tons of asphalt-bearing rock (Page, Henrickson, Williams, and others, 1945).

EDNA AREA

The deposits of asphalt-bearing sandstone in the Edna area, San Luis Obispo County, contain the highest concentration of uranium of all the deposits examined in the Western States. The uranium content of 7 samples collected in the Edna area ranges from 0.035 to

1.9 percent and averages 0.376 percent in the ash of the extracted oil. Localities from which samples were collected and the extent of the asphalt-bearing rocks are shown on the geologic map of part of the Edna area (fig. 15).

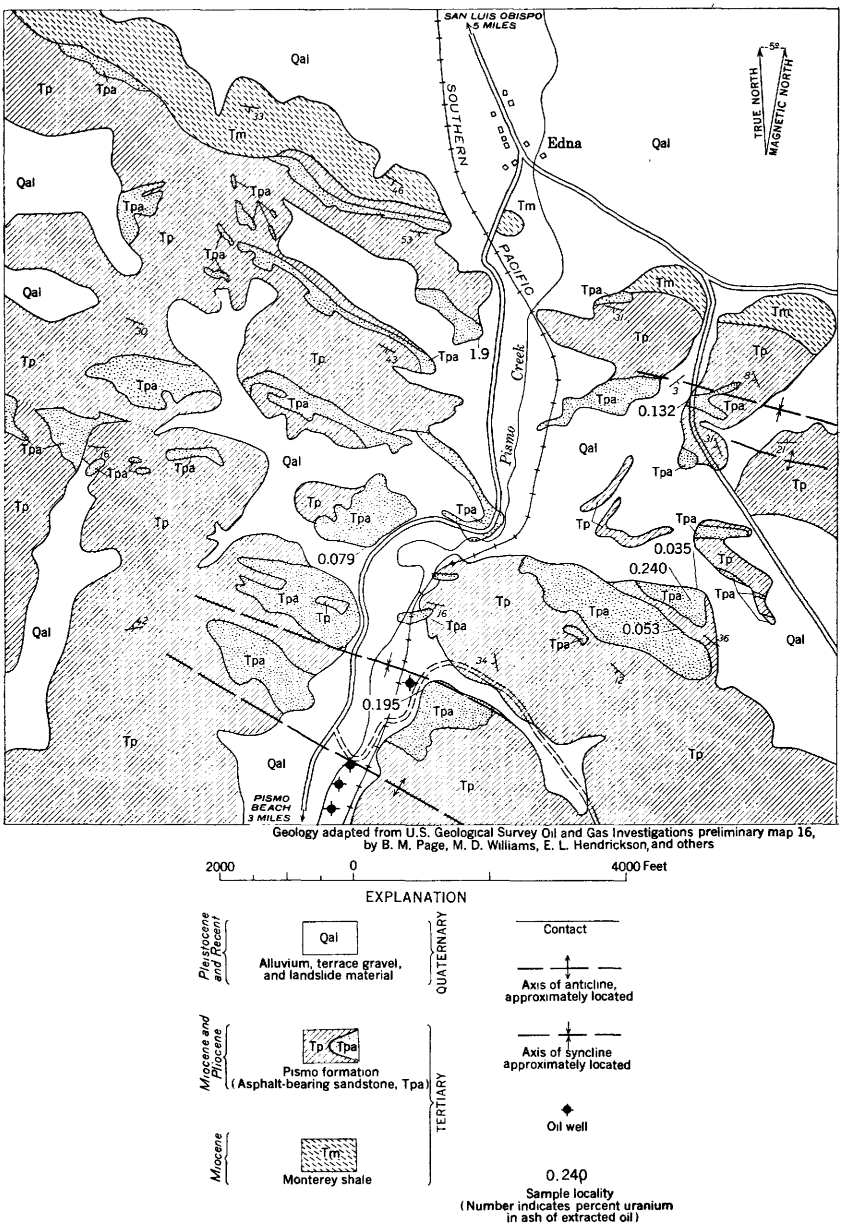

FIGURE 15.—Geologic map of part of the Edna area, San Luis Obispo County, Calif.

The asphalt occurs in the Pismo formation of late Miocene and Pliocene age, which unconformably overlies the Monterey shale of Miocene age. The Monterey shale in the Edna area consists of tuff, diatomaceous and siliceous shale, and chert. The Pismo formation consists of varied rock types including conglomerate, arkosic sandstone, diatomaceous sandstone, sandy and silty shale, diatomaceous shale, siliceous shale, and chert. The asphalt is irregularly distributed in lenticular and discontinuous beds of arkosic sandstone which range in thickness from a few feet to almost 300 feet. The irregular distribution appears to be related to the variation in the permeability of the sandstone.

The largest deposits of asphalt-bearing sandstone crop out on the northeast flank of a northwestward-trending syncline near Pismo Creek. The total reserves of asphalt-bearing sandstone are about 280 million tons (Page, Williams, Henrickson, and others, 1944). No asphalt-bearing sandstone is being produced at the present time.

CASMALIA AREA

A deposit of asphalt-bearing diatomaceous mudstone is exposed about 4 miles north of Casmalia, Santa Barbara County, at the N. T. U. open-pit mine, now abandoned. Similar beds crop out half a mile northeast of the N. T. U. mine and in the Schumann area, 3 miles to the southeast; the asphalt-bearing beds may be continuous throughout these areas.

The asphalt impregnates northeastward-dipping beds of diatomaceous mudstone in the upper part of the Sisquoc formation, of Miocene and Pliocene age. The asphalt-bearing beds are as much as 20 feet thick at the N. T. U. mine, but the extent of downdip impregnation is not known. Estimated reserves at the mine are only about 100,000 tons of asphalt-bearing rock (Williams and Holmes, 1945), but reserves for the entire area are undoubtedly much greater.

LOS ALAMOS AREA

Thick beds of asphalt-bearing sandstone crop out along the front of the San Rafael Mountains in the vicinity of Asphaltum and La Zaca Creeks, about 9 miles northeast of Los Alamos, Santa Barbara County (Eldridge, 1901, p. 429–39). The asphalt-bearing sandstone beds are in the Sisquoc formation, of Miocene and Pliocene age. An angular unconformity separates the Sisquoc formation from the underlying Monterey shale of Miocene age, which is composed mainly of porcelaneous diatomite and siliceous shale. The Sisquoc formation in this area is composed mainly of medium- to fine-grained sandstone, with thin beds of conglomerate containing pebbles of chert and silicified shale similar to that in the underlying Monterey shale.

In the cliffs southeast of Asphaltum Creek, the exposed asphalt-bearing beds have an aggregate thickness of about 225 feet, and the intervening barren zones an aggregate thickness of about 35 feet. The asphalt-bearing beds extend about 5 miles along their outcrop and probably underlie an area of at least 5 square miles.

OTHER AREAS

Deposits of asphalt-bearing rocks were also examined in the Schumann, Gaviota, and Goleta areas, Santa Barbara County. In the Schumann area, about 2 miles north of Casmalia, asphalt occurs throughout a section of diatomaceous mudstone reported to be as much as 340 feet thick. These beds are in the Sisquoc formation of Miocene and Pliocene age, and the occurrence is similar to that in the Casmalia area, 3 miles to the northwest.

Beds of shale in the Monterey shale of Miocene age contain seeps of asphalt along bedding planes and joints in exposures on the seacoast at the mouth of Gaviota Canyon, Santa Barbara County. A bed of asphalt-bearing sandstone is associated with the shale.

Asphalt-bearing siltstone in the Monterey shale of Miocene age crops out along the seacoast at Goleta Beach County Park, about 5 miles west of Santa Barbara, Santa Barbara County. Several beds of lenticular asphalt-bearing siltstone, the thickest of which is 20 feet, occur within a section about 100 feet thick.

TABLE 3.—*Analyses of samples from areas in California*

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
			Point Arena			
97756	4.21	0.52	0.039	2.0	Just north of Arena Cove Coast Guard Station.	Base of 15-ft.-thick bed.
97757	3.34	.77	.022	1.7	do	Middle of 15-ft.-thick bed.
97758	3.67	.64	.027	1.7	do	Top of 15-ft.-thick bed.
97759	5.52	.72	.030	2.2	do	Base of 30-ft.-thick bed.
97761	3.71	1.06	.016	1.7	do	16 ft. above base of 30-ft.-thick bed.
97762	6.08	1.10	.044	4.8	do	26 ft. above base of 30-ft.-thick bed.
			Santa Cruz			
97763	6.01	0.37	0.031	1.1	About 5 miles west of Santa Cruz.	Sylva quarry; 6 ft. above base of 28-ft.-thick bed.
97764	9.62	.59	.012	.7	do	18 ft. above base of 28-ft.-thick bed.
97765	16.20	.42	.096	4.0	do	Top of 28-ft.-thick bed.
97766	9.75	.27	.011	.3	do	Calrock quarry; 5 ft. above base of 32-ft.-thick bed.
97767	7.03	.43	.005	.2	do	16 ft. above base of 32-ft.-thick bed.
97768	9.25	.28	.015	.4	do	22 ft. above base of 32-ft.-thick bed.
97769	14.43	.45	.024	1.1	do	Top of 32-ft.-thick bed.
97770	11.40	.31	.026	.8	do	Sylva quarry; 3-inch-thick vein in Monterey shale.

TABLE 3.—*Analyses of samples from areas in California*—Continued

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
					Chalone Creek	
97772	10.89	0.44	0.010	0.4	SE¼ sec. 29, T. 19 S., R. 8 E.	8 ft. above base of 37-ft.-thick bed.
97773	13.40	.21	.036	.8	do	4 ft. above base of 21-ft.-thick bed.
97745	5.70	.80	.50	40.0	do	19 ft. above base of 21-ft.-thick bed.
					San Lorenzo Creek	
97746	8.57	0.15	0.043	0.6	SE¼ sec. 15, T. 19 S., R. 9 E.	Middle of 13-ft.-thick bed.
97747	14.41	.26	.037	1.0	do	25 ft. above base of 30-ft.-thick bed.
97748	8.63	.28	.017	.5	do	4 ft. above base of 30-ft.-thick bed.
					San Ardo	
97749	3.58	0.60	0.072	4.3	SE¼ sec. 13, T. 22 S., R. 9 E.	16 ft. above base of 22-ft.-thick bed.
97750	8.90	.39	.064	2.5	do	4 ft. above base of 22-ft.-thick bed.
					Bradley	
97751	10.49	0.44	0.045	2.0	SW¼ sec. 35, T. 24 S., R. 10 E.	5 ft. above base of 15-ft.-thick bed.
					McKittrick	
97752	5.27	3.32	0.060	19.9	SW¼ sec. 28, T. 30 S., R. 22 E.	Middle of 6-ft.-thick bed of asphalt-bearing sandstone.
97753	79.50	.51	.019	1.0	do	Asphalt vein 2½-ft.-thick.
97754	39.00	1.54	.006	.9	NE¼ sec. 29, T. 30 S., R. 22 E.	Asphalt seep in alluvium.
97755	5.65	2.85	.002	.6	do	Do.
255611[1]	5.13	.19	.150	2.8	do	Asphalt-bearing sandstone.
					Edna	
99133	3.16	1.00	0.195	19.5	See figure 15	Lower part of bed more than 100 ft. thick.
99134	4.86	.76	.079	6.0	do	Upper part of bed more than 300 ft. thick.
99135	7.60	.37	1.9	70.3	do	Thickness of bed not known; probably between 50 and 100 ft.
99136	10.15	.14	.132	1.8	do	Upper part of bed about 50 ft. thick.
99137	6.48	.70	.053	3.7	do	Base of 120-ft.-thick bed.
99138	4.80	.51	.240	12.2	do	Upper part of 230-ft.-thick bed.
99139	7.01	.46	.035	1.6	do	Lower part of 230-ft.-thick bed.
					Casmalia	
99140	27.80	0.18	0.014	0.7	N. T. U. mine, sec. 3, T. 9 N., R. 35 W.	Base of 20-ft.-thick bed.
99141	29.20	.22	.033	.7	do	Middle of 20-ft.-thick bed.
99142	31.70	.18	.047	.8	do	Upper part of 20-ft.-thick bed.

[1] Sample submitted by P. D. Snavely.

TABLE 3.—*Analyses of samples from areas in California*—Continued

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
			Los Alamos			
99148	3.20	1.75	0.038	6.6	About 2 miles northeast of junction of Foxen Canyon and Alisas Canyon roads.	Thickness of bed not known.
99149	10.81	.83	.330	27.4	do	8 ft. above base of 93-ft.-thick bed.
99150	14.60	.57	.073	4.2	do	63 ft. above base of 93-ft.-thick bed.
99151	15.70	.28	.059	1.7	do	Middle of 33-ft.-thick bed.
99152	16.10	.68	.010	.7	do	95 ft. above base of 99-ft.-thick bed.
99153	17.50	.05	.036	.2	do	42 ft. above base of 99-ft.-thick bed.
99154	8.90	1.34	.023	3.1	do	5 ft. above base of 99-ft.-thick bed.
			Schumann			
99146	17.88	0.23	0.009	0.2	Airox quarry, 2 miles north of Casmalia.	158 ft. above base of 200-ft.-thick bed.
			Gaviota			
99156	23.22	1.04	0.002	0.2	Mouth of Gaviota Canyon.	Seep in shale joints.
			Goleta			
99157	16.18	2.00	0.023	4.6	Sec. 20, T. 4 N., R. 28 W.	Middle of 20-ft.-thick bed.
99158	21.70	2.11	.024	5.1	do	Top of 15-ft.-thick bed.

UTAH

All five of the asphalt-bearing areas sampled in Utah are in the Uinta Basin in the east-central part of the State. The deposits in the Vernal, Bonanza, PR Springs, and Sunnyside areas are in the Wasatch, Green River, and Uinta formations of Eocene age, and the deposit in the Whiterocks Canyon area is in the Navajo sandstone of Jurassic and Jurassic(?) age. The asphalt deposits in the Bonanza area are gilsonite, and the deposits in the other areas are asphalt-bearing sandstone. Table 4 shows analyses of samples from areas in Utah.

VERNAL AREA

The asphalt in the Vernal area, Uintah County, was the most uraniferous of those examined in Utah. The uranium content of 21 samples ranges from 0.001 to 0.150 percent and averages 0.028 percent in the ash of the extracted oil.

The deposits occur mainly in the Uinta formation of Eocene age, exposed along Asphalt Ridge, just west of Vernal. The asphalt impregnates lenticular sandstone beds ranging in thickness from a few feet to 190 feet within a section which may be as much as 300 feet thick. Most of the asphalt-bearing beds are in the basal part of the Uinta formation, but some of the lowest beds may be in the upper part of the Mesaverde formation of Cretaceous age. The Uinta formation lies unconformably on the Mesaverde in this area. The Uinta formation consists of red and cream-colored shale and sandstone and coarse siliceous conglomerate. The upper part of the Mesaverde formation consists mainly of medium-grained buff sandstone. Where they contain asphalt, the sandstones of the two formations are indistinguishable. Estimated reserves of asphalt-bearing sandstone in the area are 1.97 billion tons (Spieker, 1930, p. 96–97). One quarry was operating in 1953 and the product was used locally for road construction.

The Vernal deposits were sampled by Vine and Moore (1952) and by Vine and Flege (1953), who took 12 samples from 9 localities along most of the 14-mile length of Asphalt Ridge. Nine additional samples were collected in 1953 for the present investigation.

SUNNYSIDE AREA

One of the largest known asphalt-bearing sandstone deposits in the United States is that near Sunnyside, Carbon County (Holmes, Page, and Averitt, 1948). The total measured, indicated, and inferred reserves in beds more than 10 feet thick are about 2.8 billion tons of asphalt-bearing sandstone. The asphalt occurs in lenticular sandstone beds ranging in thickness from a few inches to 350 feet within a stratigraphic interval of about 1,000 feet in the lower part of the Green River formation and in the upper part of the Wasatch formation of Eocene age. The beds dip northeastward and crop out for a distance of about 9 miles along the steep scarp of the Book Cliffs, which form the south rim of the Uinta Basin. No asphalt-bearing sandstone has been produced from the Sunnyside area since about 1948, but quarrying and prospecting have been extensive in the past. The material was used for road paving.

OTHER AREAS

Deposits of asphalt-bearing sandstone were also examined in the PR Springs area, Grand and Uintah Counties, and the Whiterocks Canyon area, Uintah County; deposits of gilsonite were examined in the Bonanza area, Uintah County. Samples collected from these areas had a generally low uranium content.

The asphalt of the PR Springs area is in sandstone beds in the lower part of the Green River formation of Eocene age (W. B. Cashion, oral communication), and the occurrence is similar to that in the Sunnyside area. The asphalt of the Whiterocks Canyon area impregnates sandstone beds of the Navajo sandstone of Jurassic and Jurassic(?) age, which in this area is about 936 feet thick (Kinney and Rominger, 1947). The gilsonite of the Bonanza area occurs in veins chiefly in the Wasatch, Green River, and Uinta formations of Eocene age (Cashion and Brown, 1956).

TABLE 4.—*Analyses of samples from areas in Utah*

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
Vernal						
85728	16.0	1.77	0.002	0.4	Sec. 25, T. 4 S., R. 20 E	See Vine and Flege (1953).
85729	11.4	5.90	.001	.6	do	Do.
85730	3.1	.96	.021	2.0	do	Do.
85731	12.3	6.31	.001	.6	Sec. 11, T. 4 S., R. 20 E	Do.
85732	13.0	3.82	.005	1.9	do	Do.
85733	10.8	3.68	.007	2.6	Sec. 30, T. 4 S., R. 21 E	Do.
85734	11.6	8.42	.001	.8	Sec. 31, T. 4 S., R. 21 E	Do.
85735	6.6	1.35	.026	3.5	do	Do.
85736	10.0	2.66	.001	.3	Sec. 4, T. 5 S., R. 21 E	Do.
85737	7.4	3.45	.005	1.7	Sec. 9, T. 5 S., R. 21 E	Do.
85738	8.0	2.75	.017	4.7	Sec. 23, T. 5 S., R. 21 E	Do.
85739	9.4	3.24	.002	.6	Sec. 25, T. 5 S., R. 21 E	Do.
96056	1.35	2.46	.013	3.2	Sec. 29, T. 4 S., R. 21 E	Lower part of 12-ft-thick bed.
96057	1.85	2.04	.034	6.9	do	Upper part of 55-ft-thick bed.
96058	5.50	2.21	.005	1.1	do	Lower part of 55-ft-thick bed.
96059	2.09	.49	.177	8.6	do	Upper part of 66-ft-thick bed.
96061	.98	.83	.008	.7	Sec. 32, T. 4 S., R. 21 E	Upper part of 26-ft-thick bed.
96062	7.04	1.50	.015	2.2	do	Middle of 19-ft-thick bed.
96063	4.76	.93	.150	13.9	do	Lower part of 38-ft-thick bed.
96064	8.63	1.13	.141	15.9	do	Lower part of 7-ft-thick bed.
96065	10.10	.53	.010	.5	Sec. 20. T. 4 S., R. 21 E	Mill pile.
Sunnyside						
94103	1.80	1.17	0.046	5.4	NE¼ sec. 15, T. 14 S., R. 14 E.	Upper part of 45-ft-thick bed.
94102	6.17	.90	.041	3.7	do	Lower part of 28-ft-thick bed.
94101	6.93	1.59	.012	1.9	do	Middle of 50-ft-thick bed.
94100	10.65	.75	.020	1.9	do	Lower part of 18-ft-thick bed.
94106	5.46	3.68	.010	3.7	NW¼ sec. 10, T. 14 S., R. 14 E.	Middle of 25-ft-thick bed.
94105	1.56	.83	.014	1.2	do	Middle of 60-ft-thick bed.
94104	3.10	1.27	.005	.6	do	Middle of 30-ft-thick bed.
94108	6.05	.45	.003	.1	Sec. 4, T. 14 S., R. 14 E	17 ft below top of 82-ft-thick bed.
200931	5.88	.30	.048	1.4	do	33 ft below top of 82-ft-thick bed.
94109	9.60	.30	.015	.4	do	77 ft below top of 82-ft-thick bed.
94107	1.97	.87	.015	1.3	do	Lower part of 22-ft-thick bed.
PR Springs						
96044	12.0	0.24	0.011	0.3	Sec. 5, T. 15½ S., R. 23 E	Base of 22-ft-thick bed.
96045	9.50	.55	.063	3.5	do	5 ft above base of 22-ft-thick bed.
96046	7.13	.37	.025	.9	do	10 ft above base of 22-ft-thick bed.
96047	9.86	3.05	.005	1.5	do	15 ft above base of 22-ft-thick bed.
96048	4.99	1.40	.009	1.3	do	20 ft above base of 22-ft-thick bed.
96050	4.22	.73	.006	.4	Sec. 36, T. 15 S., R. 23 E	9 ft above base of 52-ft-thick bed.
96051	4.45	1.08	.003	.3	do	18 ft above base of 52-ft-thick bed.
96053	4.76	1.46	.009	1.3	do	36 ft above base of 52-ft-thick bed.
96054	3.82	.76	.004	.3	do	45 ft above base of 52-ft-thick bed.
96055	4.89	1.46	.009	1.3	do	Top of 52-ft-thick bed.
Whiterocks Canyon						
94110	5.60	0.72	0.024	1.7	Sec. 18, T. 2 N., R. 1 E	Lower part of 936-ft-thick section.
94111	9.72	.24	.003	.1	Sec. 19, T. 2 N., R. 1 E	300 ft above base of 936-ft-thick section.
94112	2.93	1.00	.005	.5	do	600 ft above base of 936-ft-thick section.
94113	4.13	.68	.003	.2	do	800 ft above base of 936-ft-thick section.
Bonanza						
96037	100	0.31	0.003	.1	Sec. 7, T. 9 S., R. 25 E	Gilsonite, Cowboy vein.
96038	100	1.02	.004	.4	Sec. 16, T. 9 S., R. 25 E	Do.
96039	100	.45	.004	.2	Sec. 30, T. 9 S., R. 25 E	Gilsonite, Tabor vein.
96040	100	.49	.002	.1	Sec. 25, T. 9 S., R. 24 E	Gilsonite, Independent vein.
96041	100	.56	.001	.1	Sec. 25, T. 9 S., R. 24 E	Gilsonite, Chepetta vein.
96042	100	.31	.005	.2	Sec. 35, T. 9 S., R. 24 E	Gilsonite, Wagonhound vein.
96043	100	.23	.003	.1	Sec. 24, T. 11 S., R. 24 E	Gilsonite, Rainbow vein.

WYOMING

MUDDY CREEK AREA

Lenticular beds of highly weathered asphalt-bearing sandstone in the Wasatch formation of Eocene age (J. D. Love, written communication) crop out near Muddy Creek about 17 miles south of Creston, Carbon County (Jamison, 1912, p. 47). In this area the Wasatch formation dips about 4° SW. The asphalt occurs irregularly in a section of sandstone about 100 feet thick. The richest impregnation is in the lower 15 to 30 feet and in a 5-foot-thick zone in the upper part of the section. The outcrop of asphalt-bearing sandstone extends about 2 miles along U. S. Highway 789 in secs. 3, 10, and 15, T. 17 N., R. 92 W. The most compete exposures are in several outliers forming low hills a few hundred feet east of the highway. The westward underground extent of the asphalt-bearing beds is not known. Table 5 shows analyses of samples from the Muddy Creek area.

JAMESON RANCH AREA

The Teapot sandstone member of the Mesaverde formation of Cretaceous age is saturated with asphalt along its outcrop in secs. 4, 5, and 9, T. 33 N., R. 87 W., Natrona County (Hares, 1917, p. 247). The asphalt-bearing sandstone forms a prominent hogback which dips about 24° NE. on the east flank of the Rattlesnake Range. The outcrop extends about a quarter of a mile and has a maximum exposed thickness of about 50 feet. The asphalt is highly weathered and is now represented only by brown staining throughout the exposed beds. No similar exposures of the asphalt-bearing Teapot sandstone member have been reported in this area. Table 5 shows analyses of samples from the Jameson Ranch area.

TABLE 5.—*Analyses of samples from areas in Wyoming*

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
			Muddy Creek			
213818	6.35	0.29	0.091	2.6	NE¼ sec. 5, T. 17 N., R. 92 W.	Lower part of 15-ft-thick bed.
213819	5.70	.42	.032	1.3	NE¼ sec. 10, T. 17 N., R. 92 W.	Upper part of 30-ft-thick bed.
213820	6.00	.34	.021	.7	do	Middle of 5-ft-thick bed.
213821	6.11	.38	.015	.6	N½ Sec. 3, T. 17 N., R. 92 W.	Top of 15-ft-thick bed.
			Jameson Ranch			
213827	4.00	0.84	0.014	1.2	Sec. 5, T. 33 N., R. 87 W.	27 ft above base of 50-ft-thick bed.
213828	3.62	.34	.032	1.1	do	7 ft above base of 50-ft-thick bed.

MONTANA—RED DOME AREA

Asphalt-bearing sandstone in the Chugwater formation of Triassic age crops out along the rim of the breached top of Red Dome, Carbon County (Knappen and Moulton, 1930, p. 58). The asphalt contains relatively small amounts of uranium. The Chugwater formation is exposed in an irregular area of about one and one-half square miles at the crest of Red Dome. The asphalt impregnates the top 20–27 feet of the uppermost sandstone of the Chugwater immediately below clay of the Sundance formation of Jurassic age. Asphalt-bearing sandstone is exposed only along the steep inner rim of the dome; the underground extent of the beds is unknown. Table 6 shows analyses of samples from the Red Dome area.

TABLE 6.—*Analyses of samples from the Red Dome area, Montana*

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
213834	4.74	0.58	0.012	0.7	E½ sec. 20, T. 7 S., R. 24 E.	5 ft above base of 27-ft-thick bed.
213835	6.60	.50	.013	.6	do	Middle of 27-ft-thick bed.
213836	2.45	.66	.003	.2	do	Top of 27-ft-thick bed.
213837	6.60	.45	.012	.5	W½ sec. 20, T. 7 S., R. 24 E.	5 ft above base of 19-ft-thick bed.
213838	4.16	.81	.009	.7	SW¼ sec. 20, T. 7 S., R. 24 E.	Middle of 20-ft-thick bed.

NEW MEXICO—SANTA ROSA AREA

Beds of asphalt-bearing sandstone in the Santa Rosa sandstone of Triassic age crop out in northern Guadalupe County at the abandoned quarries of the New Mexico Construction Co., about 10 miles north of Santa Rosa. The asphalt occurs in the upper and middle sandstone members of the Santa Rosa sandstone. The Santa Rosa sandstone is overlain unconformably by the Chinle formation, also of Triassic age, and underlain unconformably by the San Andres formation of Permian age. The rocks dip generally southwestward at a low angle. The average thickness of the Santa Rosa sandstone is 250 feet. The beds of asphalt-bearing sandstone range in thickness from 4 to 41 feet in quarry exposures and are 100 feet thick in a core hole. The total reserves of asphalt-bearing sandstone are 102 million tons (Gorman and Robeck, 1946). None has been produced since 1939. Table 8 shows analyses of samples from the Santa Rosa area.

TABLE 7.—*Analyses of samples from the Santa Rosa area, New Mexico*

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
94094	1.73	3.13	0.002	0.6	Quarry No. 1	12 ft. above base of 20-ft.-thick bed.
94095	2.63	1.08	.008	.9	do	2 ft. above base of 20-ft.-thick bed.
94096	3.58	.70	.052	3.6	Quarry No. 2	Thickness of bed not known.
94097	5.12	1.31	.012	1.6	Quarry No. 3	23 ft. above base of 41-ft.-thick bed.
94098	8.42	.15	.051	.8	do	Base of 41-ft.-thick bed.
94099	2.44	1.12	.025	2.8	Mill pile.	

TEXAS—UVALDE AREA

Large deposits of asphalt-bearing limestone in the Anacacho limestone of Late Cretaceous age crop out in an area of about 60 square miles in the vicinity of Blewett in the western part of Uvalde County. The uranium content of the asphalt is exceptionally low, ranging from 0.001 to 0.004 percent, and averages 0.002 percent in the ash of the extracted oil.

The asphalt impregnates porous coquina beds which range in thickness from 10 to 135 feet in quarry exposures and are as much as 200 feet thick in drill holes. The distribution of the asphalt in the limestone is highly variable both horizontally and vertically. Two companies were quarrying the rock in 1953. The total reserves of minable asphalt-bearing limestone in the area are about 340 million tons (Gorman and Robeck, 1945). Table 8 shows analyses of samples from the Uvalde area.

TABLE 8.—*Analyses of samples from the Uvalde area, Texas*

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
99579	12.16	0.28	0.002	0.06	Original No. 1 quarry	Thickness of bed not known.
99580	8.02	.63	.002	.1	South quarry	Quarry dump.
99581	5.75	.22	.002	.04	Gato quarry	Mill concentrate.
99582	7.53	.56	.002	.1	do	Top of 80-ft.-thick bed.
99583	8.82	.42	.001	.04	East end of Gato quarry	Base of 80-ft.-thick bed.
99584	10.42	.37	.002	.07	West end of Gato quarry	Base of 80-ft.-thick bed.
99585	9.18	.43	.002	.09	White's Uvalde Mines quarry.	18 ft above base of 40-ft.-thick bed.
99586	7.65	.55	.001	.05	do	Base of 40-ft.-thick bed.
99587	5.54	.22	.002	.04	White's mine	Mill concentrate.
99589	8.93	.69	.004	.3	do	Middle of 130-ft.-thick bed.
99590	9.39	.35	.004	.1	do	Upper part of 130-ft.-thick bed.

OKLAHOMA

The 17 asphalt deposits examined in Oklahoma occur in formations of Ordovician, Pennsylvanian, and Permian age. One of the deposits occurs in limestone; the remainer are in quartzose sandstones. Most of the areas examined do not contain above-average amounts of uranium in the ash of the extracted oil. Only the Sulphur, Cameron, and Ada areas yielded samples containing appreciable amounts of uranium. Asphalt-bearing limestone from the Dougherty area is exceptionally low in uranium. Table 9 shows analyses of samples from areas in Oklahoma.

SULPHUR AREA

Asphalt-bearing sandstone and limestone beds crop out about 5 miles south of Sulphur, Murray County, over an area of about 1 square mile. Most of the asphalt occurs in the Oil Creek formation of Ordovician age. The major structure in the area is a complexly faulted northeastward-trending anticline. Surface exposures of asphalt-bearing sandstone range in thickness from about 6 to 90 feet, although asphalt-bearing beds are fully exposed in few places. A well drilled in the northern part of the area is reported to have penetrated 242 feet of asphalt-bearing sandstone beginning at a depth of 101 feet (Gorman, Flint, Decker, and Ham, 1944). Some asphalt was produced in 1953 by the Southern Rock Asphalt Sand Mines.

CAMERON AREA

Asphalt-bearing sandstone is exposed in an abandoned quarry or prospect pit just across the road from Cameron College, Comanche County. The bed is 5 feet thick and lies between beds of barren sandstone in the Wichita formation of Permian age. The lateral extent of the asphalt-bearing bed is not known but it probably does not extend over a very large area.

OTHER AREAS

Deposits of asphalt were also examined in 15 other areas in Oklahoma, but most of the samples from these deposits contained relatively small amounts of uranium. A sample representing a 1-foot-thick bed of asphalt-bearing sandstone in the Ada area, Pontotoc County, contained 0.042 percent uranium in the ash of the extracted oil. The Dougherty area, Murray County, contains large deposits of asphalt-bearing limestone in the Viola limestone of Ordovician age (Gorman and Flint, 1944), but the uranium content of the asphalt is exceptionally low. Asphalt-bearing sandstone of Pennsylvanian age was sampled in the Ada and Fitzhugh area (Ada formation), Pontotoc County; in the Bratcher and Morgan areas (Deese formation), Carter County; and in the Woodford area (Springer formation), Carter County. Asphalt-bearing sandstone in the Wichita formation of Permian age was sampled in the Parker, Elgin, Frisco Creek, and Lawton Township areas, Comanche County; in the Velma area, Stephens County; in the Baseline area, Garvin County; in the Lone Grove and Oil City areas, Carter County; and in the Asphaltum area, Jefferson and Stephens Counties. The Ada, Bratcher, Woodford, and Asphaltum areas probably contain large reserves of asphalt-bearing sandstone; the other areas contain only small reserves.

TABLE 9.—*Analyses of samples from areas in Oklahoma*

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
			Sulphur			
99607	7.95	0.41	0.004	0.2	SE¼ sec. 15, T. 1 S., R. 3 E., west end of Barnes No. 1 pit.	Middle of 6-ft.-thick bed.
99608	3.62	.71	.039	2.8	SE¼ sec. 15, T. 1 S., R. 3 E., north end of No. 80 pit.	Upper part of 60-ft.-thick bed.
201552	4.80	.72	.032	2.3	SE¼ sec. 15, T. 1 S., R. 3 E., south end of No. 80 pit.	Upper part of 60-ft.-thick bed.
201553	6.05	.41	.001	.04	NE¼ sec. 22, T. 1 S., R. 3 E., northeast end of Barnes No. 2 pit.	Middle of 18-ft.-thick bed.
201555	3.05	.78	.22	17.2	SW¼ sec. 15, T. 1 S., R. 3 E., Rock Asphalt Sand Mines quarry.	Middle of 90-ft.-thick bed.
201556	4.00	1.12	.002	.2	NW¼ sec. 22, T. 1 S., R. 3 E., Griffith No. 1 pit.	Middle of 20-ft.-thick bed.
201557	2.44	.61	.004	.2	NW¼ sec. 22, T. 1 S., R. 3 E., East Kirby pit.	Thickness of bed not known.
			Cameron			
201588	5.70	2.06	0.054	11.1	NE¼ sec. 34, T. 2 N., R. 12 W.	Middle of 5-ft.-thick bed.
			Dougherty			
99599	3.92	0.42	0.001	0.04	SE¼ sec. 25, T. 1 S., R. 2 E.	40 ft. above base of 80-ft.-thick bed.
99601	3.63	.52	.001	.05	SW¼ sec. 30, T. 1 S., R. 3 E.	75 ft. above base of 80-ft.-thick bed.
99603	2.00	1.04	.001	.1	do	Upper part of 100-ft.-thick bed.
			Ada			
99591	4.08	4.09	0.002	0.8	NW¼ sec. 6, T. 3 N., R. 6 E.	6 ft. above base of 16-ft.-thick bed.
99592	1.87	.81	.005	.4	NW¼ sec. 1, T. 3 N., R. 5 E.	Lower part of 12-ft.-thick bed.
99593	3.00	2.13	.042	8.9	SW¼ sec. 19, T. 4 N., R. 6 E.	1-ft.-thick bed.
99594	4.20	.75	.007	.5	NW¼ sec. 36, T. 4 N., R. 6 E.	Thickness of bed not known.
			Fitzhugh			
99596	1.68	1.85	0.003	0.6	Sec. 32, T. 3 N., R. 5 E	Thickness of bed not known.
99597	1.02	2.16	.001	.2	Sec. 5, T. 2 N., R. 5 E	2-ft.-thick bed.
			Bratcher			
201571	9.58	0.77	0.015	1.2	SW¼ sec. 16, T. 4 S., R. 1 E.	Quarry dump.
200933	7.29	.91	.005	.5	NW¼ sec. 21, T. 4 S., R. 1 E.	Upper part of 22-ft.-thick bed.
201572	9.30	.09	.003	.03	do	Quarry dump.
			Morgan			
201569	5.71	0.76	0.005	0.4	NE¼ sec. 14, T. 5 S., R. 1 E.	Middle of 6-ft.-thick bed.

TABLE 9.—*Analyses of samples from areas in Oklahoma*—Continued

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
Woodford						
201574	2.26	6.49	0.017	11.0	Sec. 3, T. 3 S., R. 1 W	Middle of 60-ft.-thick bed.
201575	4.44	6.60	.010	6.6	do	Middle of 40-ft.-thick bed.
201576	1.66	1.77	.004	.7	SW¼ sec. 11, T. 3 S., R. 1 W.	Prospect dump.
Parker						
201593	2.16	1.62	0.004	0.6	SW¼ sec. 15, T. 4 N., R. 11 W.	2-ft.-thick bed.
Elgin						
201592	1.76	1.98	0.006	1.2	SW¼ sec. 26, T. 4 N., R. 11 W.	Upper part of 5-ft.-thick bed.
Frisco Creek						
201590	1.57	2.96	0.005	1.5	SW¼ sec. 9, T. 3 N., R. 11 W.	Base of 18-ft.-thick bed.
201591	2.58	17.83	.002	3.6	do	Upper part of 18-ft.-thick bed.
Lawton Township						
201589	1.19	3.14	0.020	6.3	NW¼ sec. 21, T. 2 N., R. 12 W.	4-ft.-thick bed.
Velma						
201586	0.94	1.68	0.001	0.2	SE¼ sec. 36, T. 1 S., R. 5 W.	Thickness of bed not known.
Baseline						
201558	0.79	2.71	0.007	1.9	E½ sec. 36, T. 1 N., R. 3 W.	4-ft.-thick bed.
201560	1.17	2.98	.002	.6	NW¼ sec. 17, T. 1 N., R. 3 W.	Lower part of 5-ft.-thick bed.
Lone Grove						
201573	0.87	3.31	0.010	3.3	NW¼ sec. 32, T. 4 S., R. 1 W.	3-ft.-thick bed.
Oil City						
201577	12.28	4.49	0.002	0.9	Sec. 21, T. 3 S., R. 2 W	Lower part of 8-ft.-thick bed.
Asphaltum						
201579	4.27	1.64	0.006	1.0	SE¼ sec. 23, T. 3 S., R. 5 W.	Lower part of 30-ft.-thick bed.
201580	7.47	.66	.002	.1	do	Middle of 30-ft.-thick bed.
201581	9.72	2.08	.006	1.2	do	Upper part of 30-ft.-thick bed.
200934	8.07	.97	.013	1.3	NW¼ sec. 25, T. 3 S., R. 5 W.	20 ft. above base of 30-ft.-thick bed.
201584	1.21	2.64	.006	1.6	NW¼ sec. 11, T. 4 S., R. 4 W.	3-ft.-thick bed.

MISSOURI

The asphalt deposits in all five areas examined in Vernon County, Mo., occur in one or more lenticular sandstone beds in the Cherokee shale of Pennsylvanian age. These sandstone beds probably correlate with the Bartlesville sand zone of the midcontinent oilfields (Greene and Pond, 1926, p. 45), which is the subsurface equivalent of the Bluejacket sandstone member of the Boggy formation in Oklahoma (Dane and Hendricks, 1936, p. 312, and Bass, Leatherock, Dillard, and Kennedy, 1937, p. 40). The rock containing the asphalt is mainly fine-grained micaceous quartzose sandstone. Where asphalt is absent the sandstone is quite friable. Large reserves of asphalt-bearing sandstone under shallow cover extend over a wide area in Vernon County. Most of the samples collected in Missouri did not contain above-average amounts of uranium. One sample from the Ellis area, however, yielded 0.40 percent uranium in the ash of the extracted oil. Table 10 shows analyses of samples from areas in Missouri.

ELLIS AREA

Asphalt-bearing sandstone is exposed in an abandoned waterfilled quarry at Ellis, Vernon County. The quarry is about 160 feet wide and 265 feet long, and the exposed thickness of the asphalt-bearing bed ranges from 15 to 30 feet. The base of the bed is covered by water in the quarry; the top is obscured by soil. The quarry has been operated so recently that the asphalt-bearing rock is not greatly weathered.

OTHER AREAS

Deposits of asphalt-bearing sandstone were also examined in the Deerfield, Sheldon East, Sheldon North, and Dry Wood Creek areas, Vernon County. Exposed asphalt-bearing beds in these areas range from 1 to 9 feet in thickness. The exposures in the Deerfield, Sheldon East, and Dry Wood Creek areas are in abandoned quarries, indicating some production of asphalt-bearing rock in the past. The exposure in the Sheldon North area is in a road cut.

TABLE 10.—*Analyses of samples from areas in Missouri*

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
					Ellis	
91576	5.38	0.75	0.40	30.0	SE¼ sec. 10, T. 35 N., R. 32 W.	Collected by N. W. Bass and H. J. Hyden.
207078	4.08	.70	.013	.9	do	Do.
224923	4.47	.40	.011	.4	do	Collected by N. W. Bass and N. M. Denson.

TABLE 10.—*Analyses of samples from areas in Missouri*—Continued

Sample No.	Oil (percent)	Ash in oil (percent)	U in ash (percent)	U in oil (ppm)	Location	Remarks
			Deerfield			
219691	4.73	0.44	0.010	0.4	SW¼ sec. 6, T. 35 N., R. 32 W.	1 ft above base of 9-ft-thick bed.
219692	4.65	.44	.010	.4	do	Upper part of 8½-ft-thick bed.
219693	5.54	.68	.006	.4	do	Lower part of 8½-ft-thick bed.
219694	4.37	.78	.003	.2	do	Lower part of 6-ft-thick bed.
219695	4.57	.93	.008	.7	do	Upper part of 11-ft-thick bed.
219696	4.56	.84	.002	.2	do	Middle of 11-ft-thick bed.
219697	3.96	1.43	.002	.3	do	Lower part of 6-ft-thick bed.
			Sheldon East			
219661	4.56	1.45	0.033	4.8	NW¼ sec. 33, T. 34 N., R. 30 W.	Upper part of 2-ft-thick bed.
219662	3.00	1.95	.013	2.5	do	Lower part of 2-ft-thick bed.
219663	3.75	1.22	.009	1.1	do	1-ft-thick bed.
219665	4.63	1.21	.008	1.0	do	2-ft-thick bed.
219668	5.58	.26	.008	.2	do	Lower part of 6-ft-thick bed.
			Sheldon North			
219669	1.58	1.58	0.002	0.3	W½ sec. 15, T. 34 N., R. 31 W.	Upper part of 8-ft-thick bed.
219670	1.12	1.59	.005	.8	do	Middle of 8-ft-thick bed.
219671	1.60	.65	.006	.4	do	Lower part of 8-ft-thick bed.
			Dry Wood Creek			
219673	1.73	1.15	0.002	0.2	SE¼ sec. 24, T. 35 N., R. 33 W.	Middle of 3½-ft-thick bed.
219674	.98	1.35	.004	.5	do	Middle of 2½-ft-thick bed.
219675	2.24	1.09	.007	.8	do	Upper part of 5-ft-thick bed.
219677	2.60	1.36	.009	1.2	do	Lower part of 5-ft-thick bed.
219678	1.74	1.20	.002	.2	do	Upper part of 5-ft-thick bed.
219679	1.23	1.11	.004	.4	do	Lower part of 5-ft-thick bed.
219680	1.66	1.14	.005	.6	do	Middle of 4-ft-thick bed.
219681	2.60	1.94	.001	.2	do	Lower part of 3-ft-thick bed.
219682	5.42	.74	.001	.1	do	Lower part of 5-ft-thick bed.
219683	2.58	2.26	.004	.9	do	Lower part of 5½-ft-thick bed.
219684	4.07	3.06	.001	.3	do	Middle of 6-ft-thick bed.
219685	3.79	3.40	.001	.3	do	Middle of 5½-ft-thick bed.
219686	2.32	1.59	.003	.5	do	Middle of 5-ft-thick bed.
219687	1.37	1.45	.005	.7	do	Middle of 6½-ft-thick bed.
219688	3.41	.91	.006	.5	do	Base of 6½-ft-thick bed.
219689	4.23	1.50	.003	.4	do	Lower part of 6½-ft-thick bed.

ORIGIN OF THE ASPHALT

The asphalt described in this report may have originated within the present host rocks essentially in its present form, or it may be residue of petroleum which moved into the host rocks from other source beds. The author believes that two or three of the deposits herein described may represent asphalt which originated in the host rocks, but that most of the deposits are residues of petroleum which moved into the host rocks from other source beds.

The deposits believed to have originated in the present host rocks are those in the Casmalia, Schumann, and Gaviota areas in California. Asphalt in these deposits occurs in richly organic shales. Even so, the occurrence of free oil in the Casmalia (N. T. U. mine) deposit appears to be controlled by the permeability of the host rocks (Williams and Holmes, 1945), indicating movement of oil within the source rocks.

The other California deposits occur predominantly in sandstone and other coarse clastic rocks. The occurrence of these deposits is in no way different from that of nearby oil-producing rocks except that they are exposed at the surface. Their occurrence is controlled by the same structural and stratigraphic features and proximity to source beds that control the occurrence of oil-producing rocks. Oil has been recovered from two of the deposits, Edna and McKittrick, at depth. The rock of the productive oil zones in the Edna area is identical to the asphalt-bearing rock exposed at the surface (Krueger, 1943, p. 452). That movement of oil has and is taking place in the Edna area is indicated by a record of continuous production over a period of 50 years. In the McKittrick area some of the asphalt saturation occurs in fluviatile gravels of the Tulare formation of Pliocene and Pleistocene(?) age, and in Recent alluvium, which are not likely source beds for oil formation.

The Los Alamos asphalt deposits occur in sandstone in the lower part of the Sisquoc formation, which is a producing horizon of the four nearby oilfields (West Cat Canyon, Doheny-Bell, East Cat Canyon, and Gato Ridge). All the other California asphalt deposits are in sandstone or other clastic rocks closely associated with, or within, the Monterey shale, which was probably the source of the oil from which the asphalt deposits formed. Hoots (1943, p. 274–275) regards the Monterey shale as the likely source of oil for the Santa Maria district oilfields, and Bramlette and Daviess (1944) regard the Monterey as the probable source of the oil in the Salinas Valley.

The occurrence of asphalt deposits in other states likewise appears to be identical with that of typical oil-producing rocks; the only difference is that they are exposed at the surface. For example, the Red Dome, Mont., deposit occurs at the crest of a breached anticline. The Sulphur and Dougherty, Okla., deposits are clearly associated with faults. The Sunnyside, Utah, deposits occur in interfingering fluviatile and lacustrine sandstone beds. Oil shale in the lacustrine sequence is the probable source of the oil. The fact that asphalt impregnates both fluviatile and lacustrine sandstone suggests that permeability, which implies movement, was the controlling factor in the emplacement of the original oil. The asphalt-bearing sandstone beds of Pennsylvanian age in Vernon County, Mo., are typical of oil-bearing beds described as "shoestring sands" (Bass, Leatherock, Dillard, and Kennedy, 1937) that derive their oil from the enclosing marine shale, and Bass (oral communication, 1956) believes that the asphalt in the Vernon County deposits is petroleum residue.

ORIGIN OF THE URANIUM

On the basis of the small amount of available evidence, conclusions bearing on the origin of the uranium in asphalt are necessarily speculative. The uranium content of crude oil is consistently low (Erickson, Myers, and Horr, 1954, p. 2211–2212; H. J. Hyden, written communication) whereas the uranium content of asphalt is generally high relative to that of crude oil. The uranium content of the least uraniferous asphalt samples listed in this report may be accounted for by normal processes of concentration from crude oil by loss of the lighter fractions. The uranium content of the more uraniferous samples, however, is so much higher than that of crude oil that it cannot be accounted for by simple concentration, and some other explanation must be postulated.

Erickson, Myers, and Horr (1954, p. 2212) suggested that discrepancies in uranium content of asphalt and crude oil may be due to the retention of uranium-bearing oil fractions as insoluble coatings on sand grains of the reservoir rocks. No information bearing on this explanation is available from the present study, but the possibility does not seem likely for many of the samples collected during the present investigation inasmuch as the asphalt does not merely coat the sand grains but thoroughly impregnates the host rock and may be readily separated from the constituent grains.

Another possible explanation of the difference in uranium content of asphalt and crude oil is based on the assumption that the asphalt is formed in place in the present host beds (thus it is not oil residue) and, therefore, may have a uranium content comparable to that of closely associated marine organic shale which has a relatively high uranium content.

The author, however, believes that most of the asphalt in deposits described in this report is oil residue, and that the uranium, at least in those samples with above-average uranium content, was introduced during or after the late stages of oil movement and loss of the lighter oil fractions. The source of the uranium is believed to be the rocks in which the asphalt came to rest. It is believed that the uranium was emplaced by adsorption directly from the host rocks by the oil after the loss of most of the lighter fractions. Some addition of uranium to the asphalt by circulating uranium-bearing ground water is possible where such water could come into contact with asphalt-bearing beds, but this mechanism could not account for the emplacement of uranium within an asphalt-saturated rock. Breger and Deul (1955, p. 184) in their investigations of the Temple Mountain, Utah, uranium deposits showed that heavy oil, probably from a common source, moved through uranium ore-bearing rocks and adsorbed uranium from these rocks.

Although the following comparisons of the ash and uranium contents of crude oil with those of asphalt derived from crude oil cannot be expected to furnish a completely accurate indication of the oil-asphalt concentration factor, and of the uranium enrichment factor, it is believed that such comparison does furnish at least an indication of the order of magnitude of these factors.

Detailed considerations regarding the origin of uranium in asphalt are given to the Edna, Calif., area because it yielded asphalt samples relatively high in uranium and because more data on this area are available. A sample of crude oil (Serial No. 235033, K. G. Bell, written communication) was collected from the Edna area and may be compared directly with the Edna asphalt samples, inasmuch as it is a composite sample of crude oil produced at depth from the Edna deposits. This crude oil sample contains 0.0536 percent ash, 0.0003 percent uranium in the ash, and 0.0016 parts per million uranium in the oil (calculated). The average ash content of the Edna asphalt is 0.563 percent, and the average uranium content of the original asphalt is 16.44 parts per million.

The apparent oil-asphalt concentration factor for the Edna deposits is about 10.5. However, a comparison of the uranium content of the crude-oil sample with the average uranium content of the Edna asphalt samples shows the asphalt samples to be enriched in uranium by a factor of about 10,000 rather than 10.5. For all 7 Edna asphalt samples this factor ranges from 1,125 to 43,750. If it is assumed that the Edna asphalt derived its uranium by concentration from the parent crude oil, the relative uranium contents of crude oil and asphalt should not be expected to differ by more than the concentration factor of 10.5. The Pismo formation in the Edna area contains many rock types such as arkosic sandstone, diatomaceous sandstone and shale, and siliceous shale, which are known to have a relatively high uranium content.

Although the available data do not permit a direct comparison of ash and uranium contents of oil and asphalt from other California areas, and from some Utah, Oklahoma, and Missouri areas, indirect comparisons may be made which demonstrate the magnitude of the discrepancy between apparent oil-asphalt concentration factors, and apparent uranium enrichment factors.

Comparison of the average ash content (0.047 percent) and uranium content (0.0036 parts per million, calculated) of 7 samples of California crude oil (H. J. Hyden and K. G. Bell, written communications) with the average ash and uranium content of asphalt samples from each of the other California areas (Edna area excluded), as shown in table 2, indicates apparent oil-asphalt concentration factors ranging from about 4 to 40, and apparent uranium enrichment factors ranging from about 55 to 2,400.

Five crude-oil samples (H. J. Hyden, written communication) from the Uinta Basin, Utah, produced from reservoir rocks of Eocene age, may be compared with the asphalt samples collected from the Vernal, Bonanza, PR Springs, and Sunnyside areas in the Uinta Basin. The 5 crude-oil samples contain an average of 0.093 percent ash, and an average of 0.001 parts per million uranium (calculated). A comparison of average ash content of these crude-oil samples with asphalts from each of the Uinta Basin areas (see table 2) shows apparent oil-asphalt concentration factors ranging from 5 to 29. Corresponding apparent uranium enrichment factors, however, range from 100 to 7,500.

Ten samples of crude oil (H. J. Hyden, written communication) collected from Kansas and Oklahoma, and produced from reservoir rocks of Pennsylvanian age, contain an average of 0.019 percent ash and 0.0007 parts per million uranium (calculated). A comparison of these figures with the average ash and uranium content of asphalt in Oklahoma and Missouri occurring in rocks of Pennsylvanian age (see table 2) shows apparent oil-asphalt concentration factors ranging from about 30 to 260, and corresponding apparent uranium-enrichment factors ranging from about 570 to 12,580. It is noteworthy that the uranium content of the crude oil of Pennsylvanian age does not reflect the relatively high uranium content of the marine shale of Pennsylvanian age, from which much of the oil presumably was derived.

The relation of the uranium content of the asphalt to the lithologic character of the host rocks is indicated by the unusually low average uranium content of samples from the Bonanza, Utah, the Uvalde, Tex., and the Dougherty, Okla., areas. Asphalt from the Bonanza area is pure gilsonite which is not intermixed with any mineral or rock material, but occurs as joint fillings in the surrounding rock. The low uranium content of the gilsonite probably reflects the absence of any rock or mineral material from the gilsonite. The Uvalde and Dougherty asphalt deposits occur as impregnated porous limestone beds, and the low uranium content of these deposits is probably due to the low uranium content of limestone (Bell, 1954, p. 109–110). All the other deposits, except those believed to have originated in place, are asphalt which impregnates clastic rocks such as sandstone, siltstone, and arkose. The uranium content of these deposits probably gives a rough indication of the uranium content of the host rocks. Relatively pure quartz sandstone is low in uranium, but sandstone and other clastic rocks containing such material as volcanic ash, arkose, or diatomite may have relatively large uranium contents.

Bell (1954, p. 104) points out that the uranium content of clastic sediments ranges from a small fraction of a part per million to tens of parts per million. These amounts are of the same order of magnitude as the uranium in the asphalt described in this report.

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