Reconnaissance for uranium in asphalt-bearing rocks in the western states

By W. J. Hail, Jr.

Trace Elements Investigations Report 559

UNITED STATES DEPARTMENT OF THE INTERIOR
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W. J. Hail, Jr.

September 1955

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

By W. J. Hail, Jr.

ABSTRACT

An appraisal of asphalt-bearing rocks as potential sources of uranium was made during 1953 and 1954 by examining deposits 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 whose recovery will depend upon the primary use to which the asphalt is placed.

Significant amounts of uranium in the ash of the extracted oil were found in samples from 7 of the 45 areas examined. These areas are: Chalone Creek, McKittrick, Edna, and Los Alamos areas, California; Vernal area, Utah; Sulphur area, Oklahoma; and the Ellis area, Missouri. The average uranium content of samples from these seven areas ranges from 0.028 to 0.376 percent in the ash of the extracted oil. All except the Chalone Creek area contain large estimated reserves of asphalt-bearing rock, ranging from 15,000,000 to almost 2,000,000,000 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.

Evaluation of field data indicates that naturally occurring asphalts with a relatively high uranium content probably originated in, or migrated through, rocks that contain more than average amounts of uranium. It is believed that some of the uranium was present as an original constituent of the oil but that some uranium may have been introduced during migration of the oil.

INTRODUCTION

Field investigations and laboratory research on uranium in asphalt-bearing rocks 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. The results of the field investigations are presented in this report. 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 the possibility 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 for uranium (fig. 1).

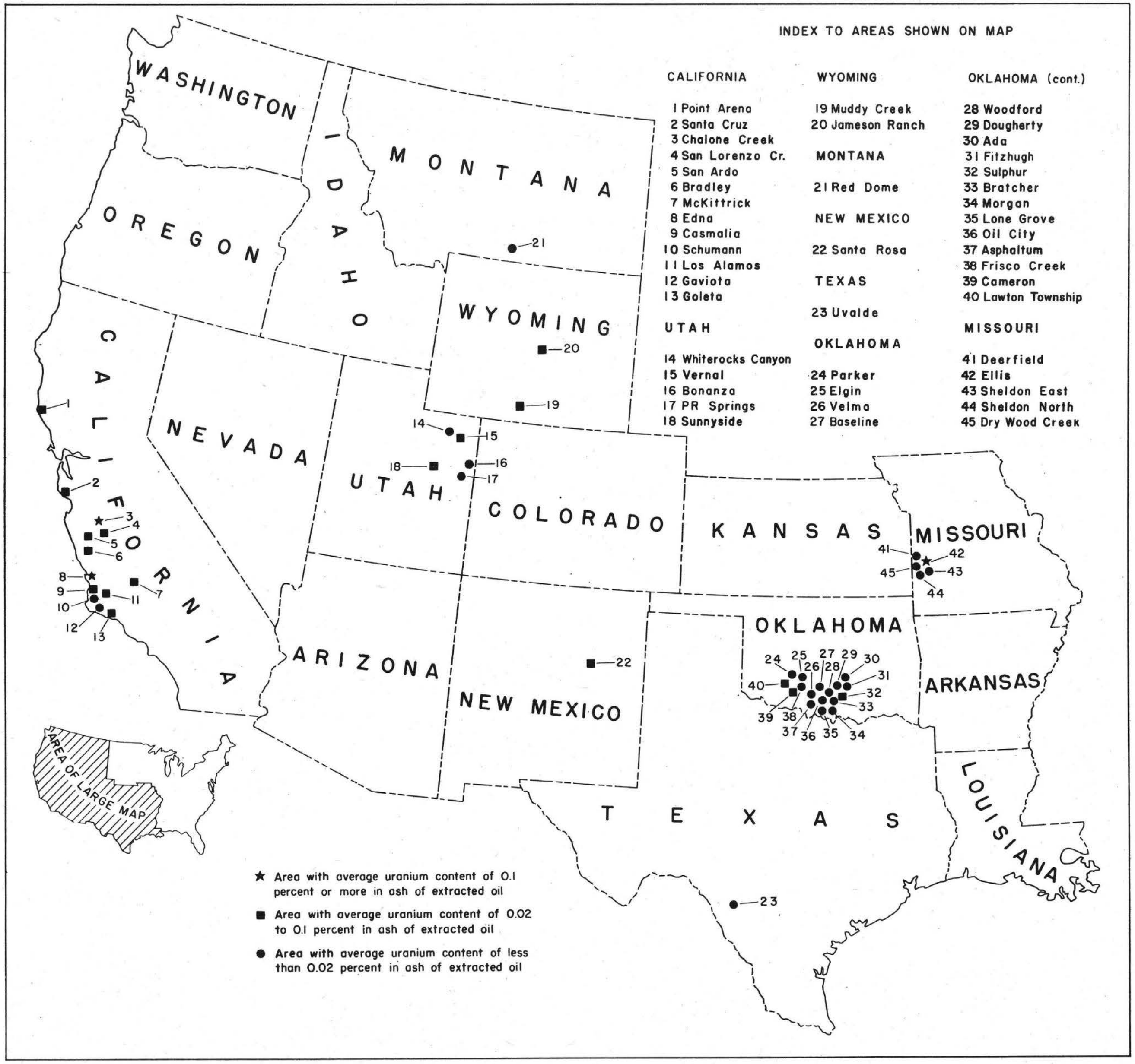


FIGURE 1 —MAP OF WESTERN UNITED STATES SHOWING AREAS EXAMINED FOR URANIUM IN ASPHALT-BEARING ROCKS

0 100 200 300 400 MILES
SCALE

Chemical analyses for uranium of several selected samples of the extracted asphalt and of the rock residue showed that the uranium is mainly concentrated as an organo-uranium complex in the asphaltic portion of the sample and not in the rock residue. Similar analyses by Erickson, Myers, and Horr (1954, p. 2215) also showed that the uranium is concentrated in the oil and not in the rock residue. Inasmuch as significant amounts of uranium occur only in the ash of the oil extracted from the host rocks, 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 contained only about 0.0005 percent uranium in the bulk sample. It is apparent that the importance of these asphalt deposits as a source for uranium is in the ash of the extracted oil. Therefore, tables of sample analyses in this report show the amount of oil in the rock, the amount of ash in the oil, and the amount of uranium in the oil ash.

Descriptions of the various deposits are based on numerous published reports in addition to direct field observations. Reserve estimates of asphalt-bearing rocks, also taken from published reports, are given where available.

Results of sample analyses were furnished by A. T. Myers, C. A. Horr, and M. M. Curtis of the Geological Survey Trace Elements Denver Laboratory, whose work on laboratory research on uranium in asphalt-bearing rocks will be described in a separate report.

The term asphalt-bearing rocks as used in this report designates rocks which contain any type of naturally occurring petroleum residue.

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 of asphalt-bearing rock, which have been produced commercially for asphalt, and contain reserves ranging from a few thousand to about 2,800,000,000 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 representing rocks of Ordovician, Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, Paleocene, Eocene, Miocene, Pliocene, Pleistocene, and Recent age. Table 1 summarizes the formations sampled.

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

Table 1.--Summary of asphalt-bearing formations sampled for uranium in the western states.

State	Age	Formation	Predominant lithology of formation in areas examined
California	Recent	Alluvium	Unconsolidated surface material.
	Pliocene-Pleistocene	Tulare fm.	Clay, silt, sand, and gravel. Gravel consists of siliceous shale, chert, granite and quartzite.
	Pliocene	Etchegoin fm.	Sandstone, silty claystone, and pebble conglomerate.
	Pliocene	Unnamed fm.	Arkosic conglomerate and sandstone.
	Miocene-Pliocene	Pismo fm.	Conglomerate, arkosic sandstone, diatomaceous sandstone, sandy and silty shale, diatomaceous shale, siliceous shale, and chert.
	Miocene-Pliocene	Sisquoc fm.	Diatomaceous mudstone, sandstone, micaceous siltstone, and claystone.
	Miocene	Santa Margarita ss.	Arkosic sandstone.
	Miocene	Monterey sh.	Diatomaceous shale and siltstone, porcelaneous diatomite, siliceous shale, and sandstone.
	Miocene	Vaqueros ss.	Arkosic sandstone.
Utah	Eocene	Uinta fm.	Quartzose sandstone, shale, and conglomerate.
	Eocene	Green River fm.	Sandstone, shale, minor amounts of limestone.
	Jurassic(?)	Navajo ss.	Sandstone.
Wyoming	Paleocene	Fort Union fm.	Sandstone, shale, and conglomerate
	Cretaceous	Teapot ss. member of Mesaverde fm.	Sandstone

Table 1. --Summary of asphalt-bearing formations sampled for uranium in the western states. --Continued

State	Age	Formation	Predominant lithology of formation in areas examined
Montana	Triassic	Chugwater fm.	Sandstone and sandy shale.
New Mexico	Triassic	Santa Rosa ss.	Sandstone and shale.
Texas	Cretaceous	Anacacho ls.	Limestone.
Oklahoma	Permian	Wichita fm.	Sandstone and shale.
	Pennsylvanian	Ada fm.	Sandstone, conglomerate, shale, and limestone.
	Pennsylvanian	Deese fm.	Sandstone, conglomerate, shale, and limestone.
	Ordovician	Viola ls.	Limestone.
	Ordovician	Oil Creek fm.	Sandstone.
Missouri	Pennsylvanian	Bartlesville sand of Cherokee sh.	Sandstone.

SUMMARY OF RESULTS OF THE INVESTIGATION

Uranium was found in asphalt-bearing rocks in all of the 45 areas examined in average concentrations ranging from 0.001 to 0.376 percent in the ash of the extracted oil. None of the areas contains asphalt deposits of value at this time as a source of uranium. Whether any of the deposits might provide a low-grade source of uranium probably depends upon recovery methods in the utilization of the asphalt for other purposes. Table 2 briefly summarizes analytical data and other information on the asphalts from all the areas examined.

Deposits in seven of the areas yielded samples significantly high in uranium in the ash of the extracted oil. These areas, listed with the uranium content of their richest samples, are: Chalone Creek (0.50 percent U), McKittrick (0.15 percent U), Edna (1.9 percent U), and Los Alamos (0.33 percent U) areas, California; Vernal area, Utah (0.15 percent U), Sulphur area, Oklahoma (0.22 percent U); and the Ellis area, Missouri (0.40 percent U). The average uranium content of samples from these seven areas ranges from 0.028 percent in the Vernal area to 0.376 percent in the Edna area. All of these deposits except those in the Chalone Creek area contain large estimated reserves of asphalt-bearing rock, ranging from 15,000,000 tons to almost 2,000,000,000 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 areas in California; Sunnyside area, Utah; Muddy Creek and Jameson Ranch areas, Wyoming; Santa Rosa area, New Mexico; and the Cameron and Lawton Township areas, Oklahoma. Reserves of asphalt-bearing rocks in these 13 areas range from a few thousand tons to about 2,800,000,000 tons.

Those areas containing asphalts with a relatively large content of uranium, such as the Edna area, may be favorable areas in which to prospect for commercial-grade deposits of uranium in other types of rock.

Table 2.--Summary of data from areas examined for uranium in asphalt-bearing rock

Map no. (fig. 1)	Area	Formation sampled	Age	No. of samples	Average oil in samples (percent)	Average ash in oil (percent)	Average U in ash (percent)
California							
1	Point Arena	Monterey sh.	Miocene	6	4.13	0.80	0.030
2	Santa Cruz	Vaqueros ss.	Miocene	8	10.34	.39	.027
3	Chalone Creek	Unnamed fm.	Pliocene	3	11.18	.48	.182
4	San Lorenzo Creek	Unnamed fm.	Pliocene	3	10.54	.23	.032
5	San Ardo	Santa Margarita fm.	Miocene	2	6.24	.49	.068
6	Bradley	Unnamed fm.	Pliocene	1	10.49	.44	.045
7	McKittrick	Etchegoin fm.,	Pliocene	5	26.91	1.66	.047
		Tulare fm.,	Pliocene and Pleistocene				
		Alluvium	Recent				
8	Edna	Pismo fm.	Pliocene	7	6.29	.56	.376
9	Casmalia	Sisquoc fm.	Pliocene	3	29.57	.19	.040
10	Schumann	Sisquoc fm.	Pliocene	1	17.88	.23	.009
11	Los Alamos	Sisquoc fm.	Pliocene	7	12.40	.78	.081
12	Gaviota	Monterey sh.	Miocene	1	23.32	1.04	.002
13	Goleta	Monterey sh.	Miocene	2	18.94	2.05	.023
Utah							
14	Whiterocks Canyon	Navajo ss.	Jurassic	4	5.59	.66	.009
15	Vernal	Uinta fm.	Eocene	21	8.10	2.68	.028
16	Bonanza	Green River and Uinta fms.	Eocene	7	100.00	.48	.003
17	PR Springs	Green River fm.	Eocene	10	6.55	1.11	.014
18	Sunnyside	Green River fm.	Eocene	11	5.38	1.10	.021
Wyoming							
19	Muddy Creek	Fort Union fm.	Paleocene	4	6.04	.36	.040
20	Jameson Ranch	Teapot ss. member of Mesaverde fm.	Cretaceous	2	3.81	.59	.023

Table 2. --Summary of data from areas examined for uranium in asphalt-bearing rocks. --Continued

Map no. (fig. 1)	Area	Formation sampled	Age	No. of samples	Average oil in samples (percent)	Average ash in oil (percent)	Average U in ash (percent)
Montana							
21	Red Dome	Chugwater fm.	Triassic	5	4.91	0.60	0.010
New Mexico							
22	Santa Rosa	Santa Rosa ss.	Triassic	6	3.99	1.24	.025
Texas							
23	Uvalde	Anacacho ls.	Cretaceous	11	8.52	.43	.002
Oklahoma							
24	Parker	Wichita fm.	Permian	1	2.16	1.62	.004
25	Elgin	Wichita fm.	Permian	1	1.76	1.98	.006
26	Velma	Wichita fm.	Permian	1	.94	1.68	.001
27	Baseline	Wichita fm.	Permian	2	.98	2.85	.005
28	Woodford	Springer fm.	Pennsylvanian	3	2.79	4.95	.010
29	Dougherty	Viola ls.	Ordovician	3	3.18	.07	.001
30	Ada	Ada fm.	Pennsylvanian	4	3.29	1.95	.014
31	Fitzhugh	Ada fm.	Pennsylvanian	2	1.35	2.00	.002
32	Sulphur	Oil Creek fm.	Ordovician	7	4.56	.70	.043
33	Bratcher	Deese fm.	Pennsylvanian	3	8.72	.59	.008
34	Morgan	Deese fm.	Pennsylvanian	1	5.71	.76	.005
35	Lone Grove	Wichita fm.	Permian	1	.87	3.31	.010
36	Oil City	Wichita fm.	Permian	1	12.28	4.49	.002
37	Asphaltum	Wichita fm.	Permian	5	6.15	1.60	.007
38	Frisco Creek	Wichita fm.	Permian	2	2.08	10.39	.004
39	Cameron	Wichita fm.	Permian	1	5.70	2.06	.054
40	Lawton Township	Wichita fm.	Permian	1	1.19	3.14	.020
Missouri							
41	Deerfield	Bartlesville sand	Pennsylvanian	7	4.63	.79	.006
42	Ellis	Bartlesville sand	Pennsylvanian	3	4.64	.62	.145
43	Sheldon East	Bartlesville sand	Pennsylvanian	4	3.99	1.46	.016
44	Sheldon North	Bartlesville sand	Pennsylvanian	3	1.43	1.27	.004
45	Dry Wood Creek	Bartlesville sand	Pennsylvanian	16	2.30	1.58	.004

ORIGIN OF THE URANIUM

Little direct evidence on the origin of the uranium in asphalt is available. On the basis of field observations, however, it is believed that some of the uranium in the asphalt was present as an original constituent of the oil but that some uranium may have been introduced during the migration of the oil.

The concentration of uranium in the asphalts appears to bear no consistent relationship to the age of the host rock nor to the age of the original oil. Relatively high concentrations of uranium were found in one or more samples of asphalt-bearing rocks representing almost all the geologic ages examined, ranging from Ordovician to Pliocene. Comparison may best be made of the deposits in California and Oklahoma, the two states for which the most data are available. Most of the California deposits, which are Tertiary in age, are relatively high in uranium, whereas most of the Oklahoma deposits, which are Paleozoic in age, are relatively low in uranium, but this difference is believed due not so much to the relative age of the deposits as to the geologic environment during the origin or migration of the oil.

Goldschmidt (1954, p. 495 497) suggests that the marine environment of deposition of organic material, which is transformed into oil, is a reducing environment capable of precipitating various metals, including uranium, from the water. The hydrocarbons forming California asphalts originated in a marine environment which was probably rich in uranium and other metals derived from the abundant volcanic materials being deposited at the time of origin. All the California asphalts occur in formations of Miocene or later age and probably originated during the middle or late Miocene, a time of widespread and intense volcanic activity (Taliaferro in Jenkins, 1943, p. 142). The Miocene and younger formations contain large amounts of volcanic material, and granitic debris derived from the erosion of pre-Tertiary granite. The resulting rock types include arkosic conglomerate and sandstone, tuffaceous sandstone, diatomaceous sandstone and shale, and chert. Most of these rock types are relatively rich in uranium.

The hydrocarbons from which most of the Oklahoma asphalts were formed originated during Ordovician or Pennsylvanian time in a marine environment which was probably low in uranium. Rock types associated with the Oklahoma asphalts include quartzose sandstones, limestones, conglomerates, and shales. Although some asphalt-bearing formations contain granitic material, it is in relatively small proportions. In general, the associated rock types are low in uranium and are not likely to have contributed above-average amounts of uranium to the marine waters in which the hydrocarbons now present as asphalt originated.

The influence of associated rock types on the uranium content of asphalt is likewise significant if it is assumed that the uranium was acquired by the oil during its migration to the present reservoir rocks. The California rocks would provide a more abundant source of uranium than the Oklahoma rocks.

Another factor favoring a higher concentration of uranium in the California asphalts is that California crude oils are generally heavy oils and uranium tends to concentrate in the heavier, more asphaltic portions of petroleum (Erickson, Myers, and Horr, 1954, p. 2211).

DESCRIPTION OF DEPOSITS

California

The asphalt-bearing rocks in California appear to be generally more favorable for the occurrence of uranium than those examined in the other western states. In 11 of the 13 California areas sampled, the average uranium in the ash of the extracted oil ranged from 0.023 percent to 0.376 percent. 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 (H. W. Hoots *in* Jenkins, 1943, p. 270-275).

Point Arena area

Asphalt-bearing sandstone beds in the Monterey shale of Miocene age crop out on the sea coast 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 square mile. Reserves of asphalt-bearing sandstone are estimated to be about 3,200,000 tons (Holmes and others, 1951).

Samples collected in the Point Arena area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U ash in oil	Remarks
Just north of	97756	4.21	0.52	0.039	Base of 15' bed
Arena Cove	97757	3.34	.77	.022	Middle of 15' bed
Coast Guard	97758	3.67	.64	.027	Top of 15' bed
Station	97759	5.52	.72	.030	Base of 30' bed
	97761	3.71	1.06	.016	16' above base of 30' bed
	97762	6.08	1.10	.044	26' above base of 30' bed

Santa Cruz area

Asphalt-bearing sandstone beds in the Vaqueros sandstone and Monterey shale of Miocene age crop out about 5 miles west of the city 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 a siliceous quartz-diorite of pre-Cretaceous age. The asphalt-bearing beds are discontinuous and occur both as normally bedded sandstone and as sandstone dikes intruded into overlying shale beds. Total reserves of asphalt-bearing sandstone are estimated to be about 1,600,000 tons (Page and others, 1945b). There is no production at the present time.

Samples collected in the Santa Cruz area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
About 5 miles west of Santa Cruz	97763	6.01	0.37	0.031	Sylva quarry; 6' above base of 28' bed
	97764	9.62	.59	.012	18' above base of 28' bed
	97765	16.20	.42	.096	Top of 28' bed
	97766	9.75	.27	.011	Calrock quarry; 5' above base of 32' bed
	97767	7.03	.43	.005	16' above base of 32' bed
	97768	9.25	.28	.015	22' above base of 32' bed
	97769	14.43	.45	.024	Top of 32' bed
	97770	11.40	.31	.026	Sylva quarry;3" vein Monterey shale

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° eastward and crops out for a distance of about a quarter of a mile along both sides of the creek 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° to the southwest. Two abandoned quarries and several prospect pits mark the line of outcrop.

Samples collected in the Chalone Creek area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SE 29 17 S 8 E	97772	14.43	0.44	0.010	8' above base of 37' bed
	97773	13.40	.21	.036	4' above base of 21' bed
	97774	5.70	.80	.50	19' above base of 21' bed

Samples collected in the San Lorenzo Creek area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SE 15 19 S 9 E	97746	8.57	.15	.043	Middle of 13' bed
	97747	14.41	.26	.037	25' above base of 30' bed
	97748	8.63	.28	.017	4' above base of 30' bed

San Ardo area

Asphalt-bearing sandstone crops out 2 to 3 miles west of the town 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 formation, both of Miocene age (Bramlette and Daviess, 1944). The beds dip to the east and crop out along the east flank of the hills bordering the Salinas River. One locality was examined, where a thickness of 22 feet of asphalt-bearing sandstone, dipping 12° to the east, is exposed in a gulley.

Samples collected in the San Ardo area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SE 13 22 S 9 E	97749	3.58	0.60	0.072	16' above base of 22' bed
	97750	8.90	.39	.064	4' above base of 22' bed

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° to the northeast. It is mainly a fine- to medium-grained sandstone, but some layers are conglomeratic. The outcrop is poorly exposed but the asphalt-bearing bed appears to be about 15 to 20 feet thick.

Samples collected in the Bradley area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SW 35 24 S 10 E	97751	10.49	0.437	0.045	5' above base of 15' bed

McKittrick area

Large deposits of asphalt in the form of asphalt-bearing sandstone, asphalt-bearing alluvium, oil seeps, and vein asphalt, crop out near the town of McKittrick, Kern County. The deposits occur in various 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 oil field, are associated with these structures. The total reserves in the area are about 15,700,000 tons of asphalt-bearing rock (Page and others, 1945a).

Samples collected in the McKittrick area

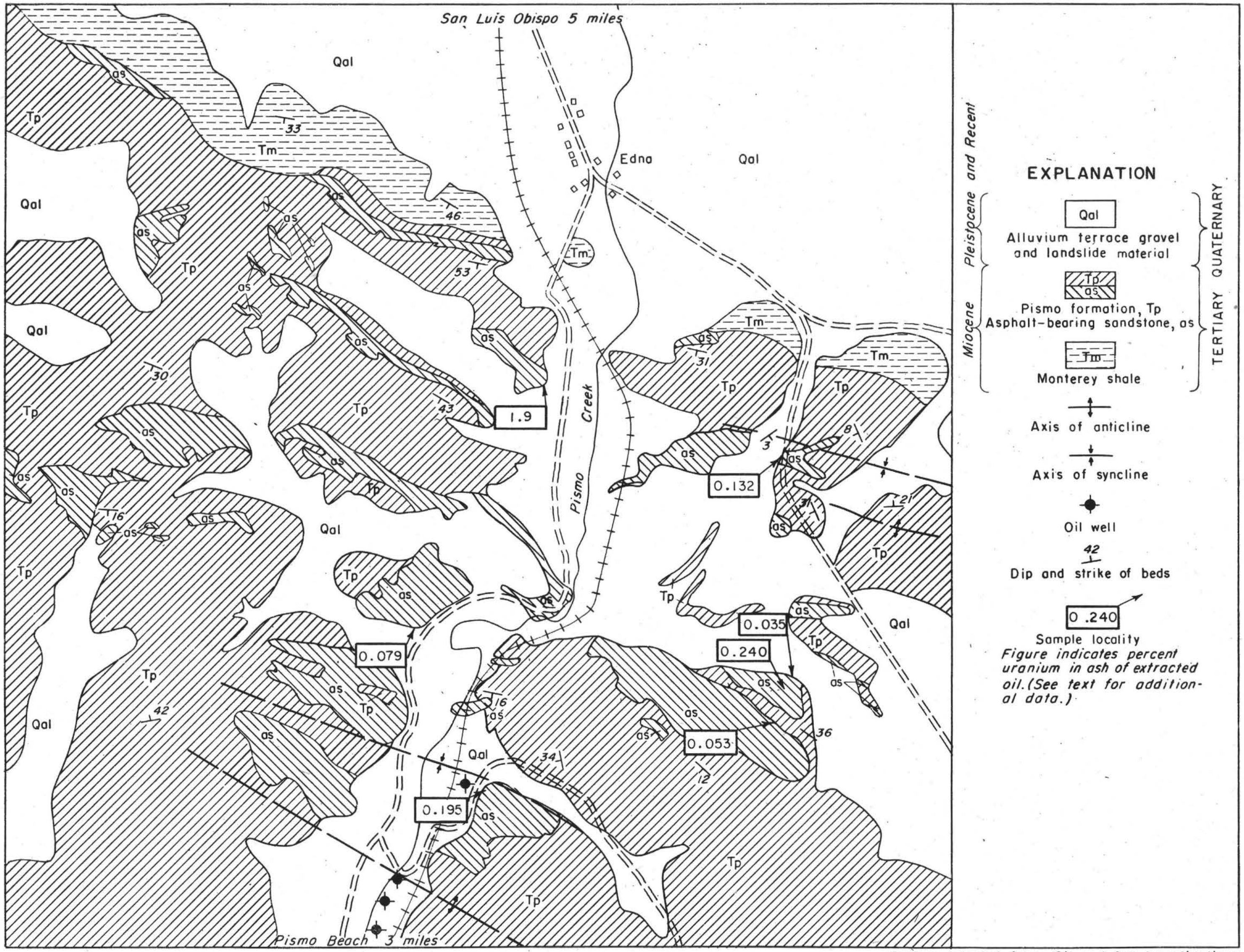
Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SW 28 30 S 22 E	97752	5.27	3.32	0.060	Middle of 6' bed of asphalt-bearing sandstone
	97753	79.50	.51	.019	Asphalt vein 2-1/2' thick
NE 29 30 S 22 E	97754	39.00	1.54	.006	Asphalt seep in alluvium
	97755	5.65	2.85	.002	Asphalt seep in alluvium
	255611	5.13	.19	.150	Asphalt-bearing sandstone (Sample was submitted by P. D. Snavely)

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 seven 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. The location of sample localities and the extent of the asphalt-bearing rocks are shown on the geologic map of part of the Edna area (fig. 2).

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 sandstones.

The largest deposits of asphalt-bearing sandstone crop out on the northeast flank of a northwest-trending syncline near Pismo Creek. The total reserves of asphalt-bearing sandstone are about 280,000,000 tons (Page and others, 1944). There is no production of asphalt-bearing sandstone at the present time.



Geology adapted from Oil and Gas Investigations Preliminary Map 16, by B. M. Page and others.

FIGURE 2.- GEOLOGIC MAP OF PART OF THE EDNA AREA, SAN LUIS OBISPO COUNTY, CALIFORNIA

2000 1000 0 2000 4000 feet

Samples collected in the Edna area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
See fig. 2 for locations	99133	3.16	1.00	0.195	Lower part of bed more than 100' thick
	99134	4.86	.76	.079	Upper part of bed more than 300' thick
	99135	7.60	.37	1.9	Thickness of bed not known; probably between 50' and 100'
	99136	10.15	.14	.132	Upper part of bed about 50' thick
	99137	6.48	.70	.053	Base of 120' bed
	99138	4.80	.51	.240	Upper part of 230' bed
	99139	7.01	.46	.035	Lower part of 230' bed

Casmalia area

A deposit of asphalt-bearing diatomaceous mudstone is exposed about 4 miles north of the village 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 through these areas.

The asphalt impregnates northeastward-dipping beds of diatomaceous mudstone in the upper part of the Sisquoc formation, which in this area is Miocene and Pliocene in age. The asphalt-bearing beds may be as much as 20 feet thick at the N. T. U. mine, but the extent of down-dip impregnation is not known. Estimated reserves at the N. T. U. 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.

Samples collected in the Casmalia area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
N. T. U. mine 3 9 N 35 W	99140	27.80	0.18	0.041	Base of 20' bed
	99151	29.20	.22	.033	Middle of 20' bed
	99152	31.70	.18	.047	Upper part of 20' bed

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 the town of Los Alamos, Santa Barbara County (Eldridge, 1901, p. 429-39). The asphalt-bearing sandstone beds are in the Sisquoc formation which in this area is Pliocene in 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 for a distance of about 5 miles along their outcrop and probably underlie an area of at least 5 square miles.

Samples collected in the Los Alamos area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
2 miles NE of junction of Foxen Canyon and Alisas Canyon roads	99148	3.20	1.75	0.038	Thickness of bed not known
	99149	10.81	.83	.330	8' above base of 93' bed
	99150	14.60	.57	.073	63' above base of 93' bed
	99151	15.70	.28	.059	Middle of 33' bed
	99152	16.10	.68	.010	95' above base of 99' bed
	99153	17.50	.05	.036	42' above base of 99' bed
	99154	8.90	1.34	.023	5' above base of 99' bed

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 the village 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.

A bed of weathered asphalt-bearing sandstone in the Monterey shale of Miocene age is exposed on the seacoast at the mouth of Gaviota Canyon, Santa Barbara County. The asphalt-bearing bed is about 12 feet thick and is enclosed between beds of shale which contain small amounts of asphalt along bedding planes and joints.

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 the city 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.

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
Sample collected in the Schumann area					
Airox Quarry, 2 miles north of Casmalia	99146	17.88	0.23	0.009	158' above base of 200' bed
Sample collected in the Gaviota area					
Mouth of Gaviota Canyon	99156	23.32	1.04	.002	Seep in shale joints
Samples collected in the Goleta area					
20 4 N 28 W	99157	16.18	2.00	.023	Middle of 20' bed
20 4 N 28 W	99158	21.70	2.11	.024	Top of 15' bed

Utah

All five of the asphalt-bearing areas sampled in the Utah area 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 Uinta and Green River formations of Eocene age, and the deposit in the White-Rocks Canyon area is in the Navajo sandstone of Jurassic(?) age. The asphalt deposits in the Bonanza area are gilsonites, and the deposits in the other areas are asphalt-bearing sandstones.

Vernal area

The asphalt in the Vernal area, Uintah County, was the most uraniferous examined in Utah. The uranium content of 21 samples ranges from less than 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 the town 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 in this area consists of red and cream colored shale and sandstone, and coarse siliceous conglomerate. The upper part of the Mesaverde formation in this area 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 1,970,000,000 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 in 1951 by Vine and Moore (1952) and in 1952 by Vine and Flege (1953), who took 13 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.

Samples collected in the Vernal area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
25 4 S 20 E	85728	16.0	1.77	0.002	Samples 85728
	85729	11.4	5.90	.001	through 85739
	85730	3.1	.96	.021	were collected
11 4 S 20 E	85731	12.3	6.31	.001	by J. D. Vine
	85732	13.0	3.82	.005	and others in
30 4 S 21 E	85733	10.8	3.68	.007	1951 and 1952,
31 4 S 21 E	85734	11.6	8.42	.001	and reported in
	85735	6.6	1.35	.026	TEI-336.
4 5 S 21 E	85736	10.0	2.66	.001	
9 5 S 21 E	85737	7.4	3.45	.005	
23 5 S 21 E	85738	8.0	2.75	.017	
25 5 S 21 E	85739	9.4	3.24	.002	
29 4 S 21 E	96056	1.35	2.46	.013	Lower part of 12'bed
	96057	1.85	2.04	.034	Upper part of 55'bed
	96058	5.50	2.21	.005	Lower part of 55'bed
	96059	2.09	.49	.177	Upper part of 66'bed
32 4 S 21 E	96061	.98	.83	.008	Upper part of 26' bed
	96062	7.04	1.50	.015	Middle of 19' bed
	96063	4.76	.93	.150	Lower part of 38'bed
	96064	8.63	1.13	.141	Lower part of 7' bed
20 4 S 21 E	96065	10.10	.53	.010	Mill pile

Sunnyside area

The largest known asphalt-bearing sandstone deposits in the United States are those 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 2,800,000,000 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 upper part of the Wasatch and lower part of the Green River formations of Eocene age. The beds dip northward 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. There has been no production of asphalt-bearing sandstone from the Sunnyside area since about 1948, but quarrying and prospecting have been extensive in the past. The material was used for road paving.

Samples collected in the Sunnyside area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
NE 15 14 S 14 E	94103	1.80	1.17	0.046	Upper part of 45' bed
	94102	6.17	.90	.041	Lower part of 28' bed
	94101	6.93	1.59	.012	Middle of 50' bed
	94100	10.65	.75	.020	Lower part of 18' bed
NW 10 14 S 14 E	94106	5.46	3.68	.010	Middle of 25' bed
	94105	1.56	.83	.014	Middle of 60' bed
	94104	3.10	1.27	.005	Middle of 30' bed
4 14 S 14 E	94108	6.05	.45	.003	17' below top of 82' bed
	200931	5.88	.30	.048	33' below top of 82' bed
	94109	9.60	.30	.015	77' below top of 82' bed
	94107	1.97	.87	.015	Lower part of 22' bed

Other areas

Deposits of asphalt-bearing sandstones 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 were generally low in uranium.

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, personal 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(?) age, which in this area aggregates about 936 feet in thickness (Kinney and Rominger, 1947). The gilsonites of the Bonanza area occur in veins chiefly in the Green River, Uinta, and Wasatch formations of Eocene age (Cashion and Brown, in press).

Samples collected in the PR Springs area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
5 15 1/2 S 23 E	96044	12.0	0.24	0.011	Base of 22' bed
	96045	9.50	.55	.063	5' above base of 22'bed
	96046	7.13	.37	.025	10'above base of 22'bed
	96047	9.86	3.05	.005	15'above base of 22'bed
	96048	4.99	1.40	.009	20'above base of 22'bed
36 15 S 23 E	96050	4.22	.73	.006	9' above base of 52'bed
	96051	4.45	1.08	.003	18'above base of 52'bed
	96053	4.76	1.46	.009	36'above base of 52'bed
	96054	3.82	.76	.004	45'above base of 52'bed
	96055	4.89	1.46	.009	Top of 52' bed

Samples collected in the Whiterocks Canyon area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
18 2 N 1 E	94110	5.60	0.72	0.024	Lower part of 936' section
19 2 N 1 E	94111	9.72	.24	.003	300' above base of 936' section
19 2 N 1 E	94112	2.93	1.00	.005	600' above base of 936' section
19 2 N 1 E	94113	4.13	.68	.003	800' above base of 936' section

Samples collected in the Bonanza area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
7 9 S 25 E	96037	(100)	.31	.003	Gilsonite, Cowboy Vein
16 9 S 25 E	96038	(100)	1.02	.004	Gilsonite, Cowboy Vein
30 9 S 25 E	96039	(100)	.45	.004	Gilsonite, Tabor Vein
25 9 S 24 E	96040	(100)	.49	.002	Gilsonite, Independent Vein
25 9 S 24 E	96041	(100)	.56	.001	Gilsonite, Chapetta Vein
35 9 S 24 E	96042	(100)	.31	.005	Gilsonite, Wagonhound Vein
24 11 S 24 E	96043	(100)	.23	.003	Gilsonite, Rainbow Vein

Wyoming

Muddy Creek area

Lenticular beds of highly weathered asphalt-bearing sandstone in the Fort Union formation of Paleocene age crop out near Muddy Creek about 17 miles south of Creston, Carbon County (Jamison, 1912, p. 47). In this area the Fort Union formation dips southwest about 4°. The asphalt occurs throughout a section of sandstone about 100 feet thick, but the richest impregnation is in the lower 15 feet and in a 5-foot zone in the upper part of the section. The outcrop of asphalt-bearing sandstone extends about 2 miles along Wyoming highway 330 in secs. 3, 10, and 15, T. 17 N., R. 92 W. The most complete 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.

Samples collected in the Muddy Creek area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
NE 15 17 N 92W	213818	6.35	0.29	0.091	Lower part of 15' bed
NE 10 17 N 92W	213819	5.70	.42	.032	Upper part of 30' bed
	213820	6.00	.34	.021	Middle of 5' bed
N 3 17 N 92W	213821	6.11	.38	.015	Top of 15' bed

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° to the northeast off the east flank of the Rattlesnake Range. The outcrop extends about a quarter of a mile, and the maximum exposed thickness of the asphalt-bearing beds is about 50 feet. The asphalt is highly weathered and is now represented only by brown staining throughout the exposed beds. No similar exposures of asphalt-bearing Teapot sandstone have been reported in this area.

Samples collected in the Jameson Ranch area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
5 33 N 87 W	213827	4.00	0.84	0.014	27' above base of 47' bed
	213828	3.62	.34	.032	7' above base of 47' 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 1-1/2 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 clays of the Sundance formation of Jurassic age. There are no other exposures of the asphalt-bearing sandstone in the area other than those along the steep inner rim of the dome, and the underground extent of the beds is unknown.

Samples collected in the Red Dome area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
E 20 7 S 24 E	213834	4.74	0.58	0.012	5' above base of 27' bed
	213835	6.60	.50	.013	Middle of 27' bed
	213836	2.45	.66	.003	Top of 27' bed
W 20 7 S 24 E	213837	6.60	.45	.012	5' above base of 19' bed
SW 20 7 S 24 E	213838	4.16	.81	.009	Middle of 20' 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 Company, 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 unconconformably by the Chinle formation, also of Triassic age, and underlain unconformably by the San Andres limestone of Permian age. The rocks dip generally southwestward at a low degree. The average thickness of the Santa Rosa sandstone is 250 feet. The beds of asphalt-bearing sandstone range in thickness from 4 to 18 feet in quarry exposures, and to a maximum of 100 feet in a core hole. The total reserves of asphalt-bearing sandstone are 102,000,000 tons (Gorman and Robeck, 1946). There has been no production since 1939.

Samples collected in the Santa Rosa area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
Quarry No. 1	94094	1.73	3.13	0.002	12' above base of 20' bed
	94095	2.63	1.08	.008	2' above base of 20' bed
Quarry No. 2	94096	3.58	.70	.052	Thickness of bed not known
Quarry No. 3	94097	5.12	1.31	.012	23' above base of 41' bed
	94098	8.42	.15	.051	Base of 41' bed
Mill pile	94099	2.44	1.12	.025	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 averaging 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 340,000,000 tons (Gorman and Robeck, 1945).

Samples collected in the Uvalde area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
Original No. 1 Quarry	99579	12.160	0.28	0.002	Thickness of bed not known
South Quarry	99580	8.02	.63	.002	Quarry dump
Gato Quarry	99581	5.75	.22	.002	Mill concentrate
	99582	7.53	.56	.002	Top of 80' bed
East end of Gato Quarry	99583	8.82	.42	.001	Base of 80' bed
West end of Gato Quarry	99584	10.42	.37	.002	Base of 80' bed
White's Uvalde Mine Quarry	99585	9.18	.43	.002	18' above base of 40' bed
	99586	7.65	.55	.001	Base of 40' bed
White's Mine	99587	5.54	.22	.002	Mill concentrate
	99589	8.93	.69	.004	Middle of 130' bed
	99590	9.39	.35	.004	Upper part of 130' 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 rest occur 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.

Sulphur area

Asphalt-bearing sandstone and limestone beds crop out about 5 miles south of the town of Sulphur, Murray County, and the deposits cover 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 highly faulted northeastward-trending anticline. Surface exposures of asphalt-bearing sandstone range in thickness from about 6 to 90 feet, although there are few places where an asphalt-bearing bed is fully exposed. 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 and others, 1944). There was some production of asphalt in 1953 by the Southern Rock Asphalt Sand Mines company.

Samples collected in the Sulphur area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SE 15 1 S 3 E	99607	7.95	0.41	0.004	West end of Barnes No. 1 Pit; middle of 6' bed
	99608	3.62	.71	.039	North end of Pit No. 80; upper part of 60' bed
	201552	4.80	.72	.032	South end of Pit No. 80; upper part of 60' bed
NE 22 1 S 3 E	201553	6.05	.41	.001	Northeast end of Barnes No. 2 Pit; middle of 18' bed
SW 15 1 S 3 E	201555	3.05	.78	.22	Rock Asphalt Sand Mines Quarry; middle of 90' bed
NW 22 1 S 3 E	201556	4.00	1.12	.002	Griffith No. 1 Pit; middle of 20' bed
	201557	2.44	.61	.004	East Kirby Pit; thickness of bed not known

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.

Samples collected in the Cameron area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
NE 34 2 N 12 W	201588	5.70	2.06	0.054	Middle of 5' bed

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 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 sandstones of Pennsylvanian age were sampled in the Ada and Fitzhugh areas (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 sandstones in the Wichita formation of Permian age were 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.

Samples collected in the Dougherty area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SE 25 1S 2E	99599	3.92	0.42	0.001	40' above base of 80'bed
SW30 1S 3E	99601	3.63	.52	.001	75' above base of 80'bed
	99603	2.00	1.04	.001	Upper part of 100' bed

Samples collected in the Ada area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
NW6 3N 6E	99591	4.08	4.09	0.002	6' above base of 16'bed
NW1 3N 5E	99592	1.87	.81	.005	Lower part of 12' bed
SW19 4N 6E	99593	3.00	2.13	.042	1' bed
NW36 4N 6E	99594	4.20	.75	.007	Thickness of bed not known

Samples collected in the Fitzhugh area

32 3N 5E	99596	1.68	1.85	.003	Thickness of bed not known
5 2N 5E	99597	1.02	2.16	.001	2' bed

Samples collected in the Bratcher area

SW16 4S 1E	201571	9.58	.77	.015	Quarry dump
NW21 4S 1E	200933	7.29	.91	.005	Upper part of 22' bed
	201572	9.30	.09	.003	Quarry dump

Sample collected in the Morgan area

NE14 5S 1E	201569	5.71	.76	.005	Middle of 6' bed

Samples collected in the Woodford area

3 3S 1W	201574	2.26	6.49	.017	Middle of 60' bed
	201575	4.44	6.60	.010	Middle of 40' bed
SW11 3S 1W	201576	1.66	1.77	.004	Prospect dump

Sample collected in the Parker area

SW15 4N 11W	201593	2.16	1.62	.004	2' bed

Sample collected from the Elgin area

SW26 4N 11W	201592	1.76	1.98	.006	Upper part of 5' bed

Samples collected from the Frisco Creek area

SW9 3N 11W	201590	1.57	2.96	.005	Base of 18' bed
	201591	2.58	17.83	.002	Upper part of 18'bed

Sample collected in the Lawton Township area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
NW21 2N 12W	201589	1.19	3.14	0.020	Sandstone 4' bed

Sample collected in the Velma area

SE36 1S 5W	201586	.94	1.68	.001	Thickness of bed not known

Samples collected in the Baseline area

E36 1N 3W	201558	.79	2.71	.007	4' bed
NW 17 1N 3W	201560	1.17	2.98	.002	Lower part of 5' bed

Sample collected in the Lone Grove area

NW32 4S 1W	201573	.87	3.31	.010	3' bed

Sample collected in the Oil City area

21 3S 2W	201577	12.28	4.49	.002	Lower part of 8' bed

Samples collected in the Asphaltum area

SE23 3S 5W	201579	4.27	1.64	.006	Lower part of 30'bed
	201580	7.47	.66	.002	Middle of 30' bed
	201581	9.72	2.08	.006	Upper part of 30'bed
NW25 3S 5W	200934	8.07	.97	.013	20' above base of 30' bed
NW11 4S 4W	201584	1.21	2.64	.006	3' bed

Missouri

The asphalt deposits in all five areas examined in Vernon County, Missouri, occur in one or more lenticular sandstone beds in the Cherokee shale of Pennsylvanian age. These sandstone beds probably correlate with the Bartlesville sand of the midcontinent oil fields, which is the surface equivalent of the Bluejacket sandstone in Oklahoma, and the probable equivalent of the Graydon sandstone in Missouri (Dane and Hendricks, 1936, p. 312, and Greene and Pond, 1926, p. 45). The rock containing the asphalt is mainly a fine-grained, micaceous, quartzose sandstone. Where asphalt is absent, the sandstone is quite friable. Large reserves of asphalt-bearing sandstone extend under shallow cover 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.

Ellis area

Asphalt-bearing sandstone is exposed in an abandoned water-filled 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 recently enough so that the asphalt-bearing rock is not greatly weathered.

Samples collected in the Ellis area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SE 10 35 N 32 W	91576	5.38	0.75	0.40	Samples 91576 and 207078 were collected by N. W. Bass and H. J. Hyden
	207078	4.08	.70	.013	
	224923	4.47	.40	.011	Sample 224923 was collected by N. W. Bass and N. M. Denson

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.

Samples collected in the Deerfield area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SW 6 35 N 32 W	219691	4.73	0.44	0.010	1' above base of 9' bed
	219692	4.65	.44	.010	Upper part of 8-1/2' bed
	219693	5.54	.68	.006	Lower part of 8-1/2' bed
	219694	4.37	.78	.003	Lower part of 6' bed
	219695	4.57	.93	.008	Upper part of 11' bed
	219696	4.56	.84	.002	Middle of 11' bed
	219697	3.96	1.43	.002	Lower part of 6' bed

Samples collected in the Sheldon East area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
NW 33 34 N 30 W	219661	4.56	1.45	0.033	Upper part of 2' bed
	219662	3.00	1.95	.013	Lower part of 2' bed
	219663	3.75	1.22	.009	1' bed
	219665	4.63	1.21	.008	2' bed
	219668	5.58	.26	.008	Lower part of 6' bed

Samples collected in the Sheldon North area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
W 15 34 N 31 W	219669	1.58	1.58	.002	Upper part of 8' bed
	219670	1.12	1.59	.005	Middle of 8' bed
	219671	1.60	.65	.006	Lower part of 8' bed

Samples collected in the Dry Wood Creek area

Location	Sample no.	Percent oil	Percent ash in oil	Percent U in oil ash	Remarks
SE 24 35 N 33 W	219673	1.73	1.15	.002	Middle of 3-1/2' bed
	219674	.98	1.35	.004	Middle of 2-1/2' bed
	219675	2.24	1.09	.007	Upper part of 5' bed
	219677	2.60	1.36	.009	Lower part of 5' bed
	219678	1.74	1.20	.002	Upper part of 5' bed
	219679	1.23	1.11	.004	Lower part of 5' bed
	219680	1.66	1.14	.005	Middle of 4' bed
	219681	2.60	1.94	.001	Lower part of 3' bed
	219682	5.42	.74	.001	Lower part of 5' bed
	219683	2.58	2.26	.004	Lower part of 5-1/2' bed
	219684	4.07	3.06	.001	Middle of 6' bed
	219685	3.79	3.40	.001	Middle of 5-1/2' bed
	219686	2.32	1.59	.003	Middle of 5' bed
	219687	1.37	1.45	.005	Middle of 6-1/2' bed
	219688	3.41	.91	.006	Base of 6-1/2' bed
	219689	4.23	1.50	.003	Lower part of 6-1/2' bed

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