Selected Annotated Bibliography of the Geology of Uraniferous and Radioactive Native Bituminous Substances, Exclusive of Coals in the United States

GEOLOGICAL SURVEY BULLETIN 1059-D

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BIBLIOGRAPHY, URANIFEROUS AND RADIOACTIVE NATIVE BITUMINOUS SUBSTANCES, UNITED STATES—Geological Survey Bulletin 1059-D

Selected Annotated Bibliography of the Geology of Uraniferous and Radioactive Native Bituminous Substances, Exclusive of Coals in the United States

By HARRIET NELL JONES

SELECTED BIBLIOGRAPHIES OF URANIUM GEOLOGY

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SELECTED ANNOTATED BIBLIOGRAPHY OF THE GEOLOGY OF URANIFEROUS AND RADIOACTIVE NATIVE BITUMINOUS SUBSTANCES, EXCLUSIVE OF COALS, IN THE UNITED STATES

By Harriet Nell Jones

ABSTRACT

This bibliography of 49 annotated references lists reports of work that appeared before June 30, 1956. The annotations, arranged alphabetically by author, emphasize the geologic and mineralogic aspects of uraniferous and radioactive bituminous substances, exclusive of coals, in the United States. Indexes to the annotations are provided according to author, geographic area, stratigraphic unit, and subject.

INTRODUCTION

By definition (Abraham, 1945) native bituminous substances are divided into two groups, bitumens and pyrobitumens. Bitumens are composed principally of hydrocarbons substantially free from oxygenated bodies, are fusible, and are soluble in carbon disulfide. Native bitumens occur in liquid and solid forms. The native liquid bitumens include all petroleums or crude oils. Native solid bitumens include native waxes, such as ozocerite, asphalts or petroleum tars, and asphaltites, such as gilsonite and grahamite. Pyrobitumens are composed principally of hydrocarbons which may contain oxygenated bodies. They are infusible and are insoluble, or nearly insoluble, in carbon disulfide. Native pyrobitumens are divided into an oxygen-containing group including peats, lignites, and coals, and a virtually oxygen-free, asphaltic group including such substances as wurtzilite, albertite, impsonite, and ingramite. Thucholites, which are carbonaceous substances that contain uranium and thorium, and perhaps rare earths, are pyrobitumens. The composition of thucholite is variable and may cause a specimen to fall into either the oxygen-containing or oxygen-free group. All varieties of native bituminous substances may be associated with mineral matter.

The nomenclature of bitumens and pyrobitumens is used very loosely in the literature. This is due to the difficulty in classifying many of these substances according to the classification of Abraham merely by visual examination. Geologists generally have not obtained precise identifications but rather have used names that seemed most appropriate. The nomenclature used by the authors of the various references of this bibliography is followed without deviation or further discussion. The stratigraphic nomenclature also is that used by the authors and does not necessarily follow that of the Geological Survey.

In this bibliography emphasis is placed on reports dealing with the uranium contents and radioactivity of native bituminous substances rather than on mineralogical and chemical studies of these substances. Annotations were made of reports that were publicly available before June 30, 1956. The distribution of the substances described in the references is shown on plate 1. The indicated presence of these substances does not imply that they contain sufficient radioactive elements to constitute ores.

The occurrence of uranium in bituminous substances is not fully understood, but probably it is either suspended as an oxide or is present in complex organo-uranium compounds. The uranium content of crude oils ranges from a fraction of a part per billion to a few thousand parts per billion, but the equivalent uranium content (measured radiometrically) may be considerably higher because radium and radon may be present in amounts in excess of equilibrium quantities. Asphalts may contain larger amounts of uranium than crude oils. No true asphaltites or asphaltic pyrobitumens are known to contain more than a few hundred parts per billion of uranium. Some of the materials called thucholite contain a few percent uranium but do not occur in sufficient abundance to constitute ores. In the San Rafael Swell area, Emery County, Utah, and particularly at Temple Mountain within this area, organic materials that have been called "asphaltite," "glance pitch," "asphaltic sandstone," and other names occur in sufficient abundance and carry enough uranium to be mined as ores. It is probable that several varieties of bituminous materials are present in the district.

In this bibliography references are arranged in alphabetical order by the first author and are numbered consecutively. Where the author's abstract is used, it is so indicated. Explanatory notes that are not in the original authors' abstracts are placed in brackets.

The accompanying map shows the location of deposits of bituminous substances referred to in the references. The numbers beside the symbols indicate the reference where each occurrence is mentioned.

Mr. Kenneth G. Bell gave valuable assistance in the preparation of this bibliography.

This bibliography was compiled by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

BIBLIOGRAPHIES OF URANIUM

Additional references to the geology of uranium deposits may be found in the following general bibliographies:

Allen, R. E., 1953, Uranium and its compounds, a bibliography of unclassified literature: U. S. Atomic Energy Comm. TID-3041, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

Cooper, Margaret, 1951, Preliminary bibliography on uranium and thorium and radioactive carbonaceous deposits: U. S. Atomic Energy Comm. RMO-835, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

——— 1953, Selected bibliography on uranium exploration and the geology of uranium deposits: U. S. Atomic Energy Comm. RME-4007, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

——— 1953, Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States, Part 1, Arizona, Nevada, and New Mexico; Part 2, California, Idaho, Montana, Oregon, Washington, and Wyoming: Geol. Soc. America Bull., v. 64, p. 197–234, 1103–1172.

——— 1954, Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States, Part 3, Colorado and Utah: Geol. Soc. America Bull, v. 65, p. 467–590.

——— 1955, Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States, Part 4, Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas: Geol. Soc. America Bull,. v. 66, p. 257–326.

Postell, P. E., and Voress, H. E., 1953, Unclassified bibliographies of interest to the atomic energy program: U. S. Atomic Energy Comm. TID-3043, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

Wallace, J. H., and Smith, H. B., 1955, Bibliography of U. S. Geological Survey trace elements and related reports to June 1, 1954: U. S. Geol. Survey Bull. 1019-B, p. 63–144.

ANNOTATED BIBLIOGRAPHY

1 Abraham, Herbert, 1945, Asphalts and allied substances, their occurrence, modes of production, uses in the arts and methods of testing: New York, D. Van Nostrand Co., Inc., 5th ed., v. 1 and 2, 2142 p. See v. 1, p. 264–265.

These two volumes contain only one brief mention of uranium in asphalts. On pages 264–265 of volume 1, uraniferous asphaltite from the Temple Mountain district in the San Rafael Swell area, Utah, is described. These volumes contain the most complete information on asphalts of any publication to date. They contain a complete review of the history, terminology and classification, chemistry, geology and origin, production, and methods of mining, transporting, refining, and testing of bituminous substances; also, there are brief descriptions of many of the known occurrences of native asphalt in the world.

2 Bain, G. W., 1952, Uranium in the Dirty Devil Shinarump channel deposit: U. S. Atomic Energy Comm. RMO–66, 40 p., issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

A twelve-kilogram specimen of Dirty Devil No. 6 deposit [San Rafael Swell area, Emery County, Utah] had 0.105 percent uranium in two hydrocarbons, jasperoid, clay and water soluble components. Another bulk specimen averaged 0.069 percent uranium. Hydrocarbons comprise 0.75 percent of the rock with an average of 0.30 percent uranium or 0.002 percent of the deposit. Jasperoid comprises 38.5 percent of the rock and has an average of 0.089 percent uranium for a total uranium equivalent to 0.034 percent of the deposit. Clay and dissolved components comprise 20.5 percent of the rock and carry most of the remaining uranium or equivalent to about 0.066 percent for the deposit. The low residue of uranium is in heavy minerals.

The ores occur in a river channel deposit of composite type. About 42.5 percent is a normal gravel alluvium. This is diluted by 35 percent of dune sand which helped form pools and filtered out fines that make the remaining 22.5 percent. The fluviatile fraction is over 60 percent jasperoid pebbles and sand.

The jasperoid pebbles, sand, and silt are the primary uranium carrier and represent detritus from a leptothermal uranium deposit of Permian age. The hydrocarbon is a relatively stable uranium accumulator; enrichment of its uranium content occurred during the times of active artesian circulation initiated by the Laramide revolution, Oligocene age disturbances, and Pliocene warping of the Rocky Mountain peneplain.

Uranium and its daughter elements segregate during migration and each has its own accumulator. The entire deposit stays close to radioactive equilibrium, but individual mineral components have departures up to 1,000 fold.—*Author's abstract*

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3 Bell, K. G., 1956, Uranium in precipitates and evaporites: Internat. Conf. on Peaceful Uses of Atomic Energy, Geneva 1955, Proc., v. 6, p. 520–524; U. S. Geol. Survey Prof. Paper 300 p. 381–386.

Heavy hydrocarbon residues are found in many kinds of rocks and in several places these asphaltic materials are uraniferous whereas in other areas they are mostly nonuraniferous.

"Solid asphaltite residues and pellets occur in the lower Permian dolomites of the Panhandle gas field, Texas, and in dolomites of the Seven Rivers gypsiferous member of the Chalk Bluff formation which crop out near Carlsbad, New Mexico." The pellets are small, in some areas are uraniferous and in other areas are not, and nowhere is there a sufficient concentration of uraniferous pellets in the rocks to constitute uranium ore.

4 Bell, K. G., Goodman, Clark, and Whitehead, W. L., 1940, Radioactivity of sedimentary rocks and associated petroleum: Am. Assoc. Petroleum Geologists Bull., v. 24, p. 1539–1547.

Determinations of the radioactivity of 21 sedimentary rocks and seven associated crude oils have been made by the precision method developed by R. D. Evans. The specimens consisted of cuttings and cores from wells in the Bartlesville, Cromwell, Frio, Woodbine, and Viola-Simpson formations * * *. The radon content of the crude oils [0.47 to 0.05 $\times$ 10^{-12} curies/gm of oil] was in one sample 38 times and averaged 10 times, the amount in equilibrium with the radium present. The results corroborate the inferences of former investigators that radon tends to concentrate in crude oils. Maximum radon content and maximum ratio of radon to radium were found in petroleum produced from a permeable, Oligocene (Frio) sandstone of high radioactivity. Cracking of hydrocarbons with generation of hydrogen has been proved by S. C. Lind to result from bombardment with alpha rays. The amounts of radioactivity found in these crude oils are quantitatively sufficient to cause appreciable cracking by alpha radiation during geologic time. These reactions, together with subsequent hydrogenation, may account for important changes in petroleum. This hypothesis would also explain the presence of hydrogen in some natural gases. The hydrogen content of soil gases is suggested as a possible method of geochemical prospecting for oil fields.—*Authors' abstract*

Crude oil samples were obtained from the Sun field, Starr County, Tex.; Navarro Crossing, Navarro County, Tex.; and the Fitts pool, Pontotoc County, Okla.

5 Beroni, E. P., 1954, Reconnaissance for uranium in the United States, south-central district, *in* Geologic investigations of radioactive deposits, Semiannual progress report, December 1, 1953 to May 31, 1954: U. S. Geol. Survey TEI–440, p. 168–171 (see p. 170), issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

An asphaltic sandstone collected in sec. 35, T. 17 N., R. 26 W., near Huntsville, Madison County, Ark., contained 2.51 percent oil, 1.11 percent ash in oil, 12 ppm (parts per million) uranium in the oil, and 0.11 percent uranium in the ash. The asphaltic material occurs in the Hale formation of Pennsylvanian age, which is overlain by the mildly radioactive Bloyd shale of Pennsylvania age.

Uraniferous asphaltic material has now been found on three sides of the Ozark dome: Huntsville occurrence on the south, an albertite deposit on the east, and a tar seep in the zinc mines on the west. The largest amounts of uranium in ashes of samples from these occurrences are 0.11, 3.79, and 0.072 percent, respectively.

6 Beroni, E. P., 1956, Recent uranium discoveries in western Oklahoma: Mines Mag. [Colorado], v. 46, no. 3, p. 68–71.

Uraniferous asphaltic pellets occur in Permian red beds along the north flanks of the Wichita-Amarillo uplift in Kiowa and Caddo Counties, Okla. The pellets range from 1 mm to 5 cm in diameter and are combustible, hard, brittle, highly lustrous, and insoluble in carbon disulfide or benzene. A few of the larger pellets contain small nuclei of pyrite or limonite. Autoradiographs show that the uranium is uniformly distributed within the asphaltite. Spectrographic analyses reveal that the most abundant metals in the pellets are uranium, vanadium, iron, nickel, cobalt, lead, and arsenic.

7 Branson, C. C., Burwell, A. L., and Chase, G. C., 1955, Uranium in Oklahoma, 1955: Oklahoma Geol. Survey Mineral Rept. 27, 22 p.

Uranium in Oklahoma occurs in bituminous sandstone lenses in Permian red beds in asphaltic materials, in phosphatic black shales, in oil field brines, and in some thin coal seams.

Sandstone lenses of Permian age containing radioactive bituminous material occur locally beneath a gray crossbedded bituminous sandstone in part of Jefferson and Cotton Counties, Okla. The sandstones are near the base of the Garber sandstone.

Uranium in asphaltic pellets has been noted near and north of the Wichita Mountains in southwestern Oklahoma. The description of the asphaltite occurrences mentioned in this report is quoted directly from the abstract by Hill (1954, see reference 27).

8 Breger, I. A., 1956, Association of uranium with a naturally occurring coal extract [abs.]: Geol. Soc. America Bull., v. 66, pt. 2, p. 1534.

Uranium and vanadium are associated with several types of carbonaceous material on the Colorado Plateau. Besides coalified wood and crude oil, there is also a black lustrous carbonaceous material that usually contains sufficient uranium to classify it as an ore. No cellular structure has been identified in this material, which occurs either as an impregnation in sandstone or as pellets ranging from several millimeters to several centimeters in diameter. In some regions the material—variously called asphaltite, thucholite, or glance pitch in the literature—is in apparent association with crude oil, leading to the suggestion that it is a petroleum residue. Because of its apparent importance in the geochemistry and emplacement of uranium on the Colorado Plateau, investigations of this material have been carried out in some detail.

Ultimate analysis, differential thermal analysis, and infrared absorption analysis all show the carbonaceous material to be similar to a low-rank coal in composition and chemical structure and to be unlike other asphaltites such as gilsonite or wurtzilite. Autoradiographic studies also show that the uranium is nearly homogeneously dispersed in the carbonaceous matter. The evidence obtained to date shows that this so-called asphaltite is not related to crude oil but rather is a coal extract derived from coalified wood in the region and precipitated under the proper physical and chemical conditions. The highly insoluble nature of the coal extract is thought to result from cross-linkage of coal molecules as a result of irradiation by alpha particles.—*Author's abstract*

9 Breger, I. A., and Deul, Maurice, 1956, The organic geochemistry of uranium: Internat. Conf. on Peaceful Uses of Atomic Energy, Geneva 1955, Proc., v. 6, p. 418–421; U. S. Geol. Survey Prof. Paper 300, p. 505–510.

Uranium is not genetically associated with carbonaceous substances, but it is collected by these substances from uranium-bearing solutions that have been in contact with them.

Petroleum has the ability to collect and carry uranium; it seems likely that asphaltenes and naphthenic acids are important carriers for uranium in petroleum.

Little is known of the processes whereby uranium is concentrated in such carbonaceous substances as "uraniferous hydrocarbon," "asphaltite," "carbocer," and "thucolite." Much of the difficulty is due to the fact that there is no definitive information on the origin and interrelationship of these substances.

Coal and coalified wood fragments collect uranium, and in many uranium deposits, particularly those of the Colorado Plateau, are highly uraniferous.

Uranium may be collected by carbonaceous materials in three ways: (a) The soluble uranyl ion may be reduced by organic material to the insoluble uranous ion. (b) The soluble uranyl ion may be reduced by the sulfide ion, which is generally associated with carbonaceous material, to the uranous ion. (c) Uranium may combine chemically with organic compounds to form insoluble compounds.

10 Burton, E. F., 1904, A radioactive gas from crude petroleum: Philos. Mag., v. 8, p. 498–508.

The petroleum used in the experiment was obtained from wells near Petrolia, Ontario, Canada, in the Corniferous limestone. An electroscope was used to measure the radioactivity of the gas.

It was found that the crude petroleum contains a strongly radioactive gas, which is similar to the emanation from radium, and that it may contain a slight trace of a radioactive substance more persistent than the radium emenation.

This reference is thought to be the first description of the radioactivity of crude petroleum.

11 Chase, G. W., 1954, Occurrence of radioactive material in sandstone lenses of southwestern Oklahoma: Oklahoma Geol. Survey Mineral Rept. 26, 8 p.

Sandstone lenses of Permian age containing radioactive bituminous material occur locally beneath a gray crossbedded bituminous sandstone in part of Jefferson and Cotton Counties, Okla. The sandstones are near the base of the Garber sandstone.

This article is reprinted with modifications in Mineral Report 27 of the Oklahoma Geological Survey (see reference 7, Branson and others, 1955).

12 Davidson, C. F., 1955, Concentration of uranium by carbon compounds: Econ. Geology, v. 50, p. 879–880.

Article is a short discussion prompted by an earlier discussion (see reference 22, Gruner, 1955), of the origin of hydrocarbons in certain uranium ores on the Colorado Plateau. It is suggested that the uraniferous asphaltites on the Colorado Plateau may have been "formed by the polymerization or condensation of simpler hydrocarbons under the influence of radioactive emanations."

13 Davidson, C. F., and Bowie, S. H. U., 1951, On thucholite and related hydrocarbon-uraninite complexes, with a note on the origin of the Witwatersrand gold ores: Great Britain Geol. Survey Bull. 3, p. 1–19.

Uranium in mineral hydrocarbons was first noted in 1868 in specimens from bitumen-impregnated granite gneisses and mica schists of Archean age in Sweden. Since this discovery, uraniferous hydrocarbons have been discovered elsewhere in Sweden, Australia, Canada, Karelia (Russia), Japan, Great Britain, and South Africa. Uraniferous hydrocarbons have been found in granite, pegmatite, quartz veins, metalliferous veins, and the gold ores of the Witwatersrand.

The article consists mostly of a complete mineralogic description of the occurrence of uraniferous hydrocarbons at an abandoned mine on the Isle of Man and in the gold ores of the Witwatersrand, South Africa. The mineragraphy of uraniferous hydrocarbons from Monnta, South Australia, and Parry Sound, Ontario, is also described.

The authors conclude that thucholite and other uraniferous solid hydrocarbons originated from the polymerization of petroleum by the action of radioactive emanations.

14 Erickson, R. L., Myers, A. T., and Horr, C. A., 1954, Association of uranium and other metals with crude oil, asphalt, and petroliferous rock: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 2200–2218.

Twenty-nine samples of crude oil, 22 samples of natural asphalt, and 27 samples of oil extracted from petroliferous rock were analyzed for uranium, vanadium, nickel, copper, cobalt, molybdenum, lead, chromium, manganese, arsenic, and zinc. Most of the crude-oil samples were collected from Kansas, Colorado, Texas, and California, most of the asphalt from Utah, and most of the petroliferous rocks from Utah and Colorado. Exact locations for the samples are given in analytical tables. The data may have important implications on the origin of oil and the migration of both oil and the contained metals.

Ash of crude oil does not contain as great a concentration of uranium as does ash of asphalt and of oil extracted from petroliferous rock. Ash of asphalt and ash of oil extracted from petroliferous rock were found to contain the nearly constant suite of metals named above, and these are the same metals that are common in the uranium deposits of the Colorado Plateau.

The results suggest that uranium, like other metals, is concentrated in the heavier, more asphaltic, portions of petroleum. The data also suggest that uraniferous asphaltic deposits may be formed through volatilization, oxidation, and polymerization of a petroleum whose ash was enriched in uranium, vanadium, copper, arsenic, molybdenum, nickel, and other metals at the time the petroleum was formed.

15 Everhart, D. L., 1951, Geology of uranium deposits, a condensed version with mineral tables by Muriel Mathez: U. S. Atomic Energy Comm. RMO–732, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

Uranium ore deposits are in a wide variety of geologic environments in igneous, metamorphic, and sedimentary rocks. The article briefly describes the most important geologic features of 11 classes or types of uranium deposits.

One of the classes or types of deposits is called "uranium-bearing asphalt deposits." The deposits described consist of uraniferous lenses, globules, and irregular masses in certain Triassic rocks of the San Rafael Swell, Utah. The asphalt cements the grains of the sandstone and forms replacement masses. At some places in the swell the principal metal in the asphalt is uranium, whereas at other places vanadium or copper occurs with uranium in the asphalt. Gypsum is almost universally associated with these deposits.

The presence of thucholite in some pegmatites is noted.

16 Faul, Henry, Gott, G. B., Manger, G. E., Mytton, J. W., and Sakakura, A. Y., 1954, Radon and helium in natural gas: Internat. Geol. Cong., 19th, Algiers 1952, Comptes rendus, sec. 9, v. 9, p. 339–348.

Radon has been discovered in some of the helium-bearing natural gas in the United States. So far, the radon content of about 500 producing gas wells has been explored. Concentrations up to 500×10^{-12} curies per liter (STP) were observed. The more highly radioactive wells are clustered in several groups. Measurements of radon content under conditions of transient gas flow and theoretical analysis of steady-state conditions indicate that the radon originates in the immediate vicinity of the bore in most wells. This result is tentatively confirmed by gamma-ray logs in two wells, but so far it has not been possible to obtain adequate samples of the gas-producing beds. A few grains of uraniferous solid asphalt and radioactive petroleum residues have been found disseminated in several drill samples of dolomite from above the gas-producing zones. At the present time, it is not clear whether the radioactive concentration is sufficient to explain the high helium content of the gas. The research continues, and comprehensive studies of subsurface geology and reservoir characteristics of the gas field are in progress.—*Authors' abstract*

17 Finch, W. I., 1953, Geologic aspects of the resource appraisal of uranium deposits in pre-Morrison formations of the Colorado Plateau, an interim report: U. S. Geol. Survey TEI–328–A, 35 p., issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

A preliminary resource appraisal was made of uranium deposits in pre-Morrison formations, particularly the Shinarump conglomerate, on the Colorado Plateau and the adjoining regions. The uranium deposits were divided on the basis of their major metal content into vanadium-uranium, copper-uranium, and uranium types. The types of deposits and overall geology of the region are described in detail.

The most important guides for ore locating were (a) thickening of sandstone and conglomerate beds, (b) mudstone alteration, (c) carbonaceous material, (d) iron staining, (e) clay and mudstone, and (f) sulfides. No one guide was sufficient to find ore deposits.

Three belts of ground favorable for containing higher grade and larger-than-average deposits were roughly outlined in the region studied. One belt includes the Temple Mountain-San Rafael district, which contains significant deposits of uraniferous "asphalt."

Carbonaceous material is associated with all sandstone-type uranium deposits, but no obvious relationship seems to exist between the amount of carbonaceous material and uranium-bearing material, nor is all the carbonaceous material within or near a uranium deposit radioactive. One type of carbonaceous substance, an asphaltlike material, is an important guide for locating ore in the San Rafael Swell area, but asphaltlike material occurs outside favorable areas and ore deposits, and therefore it must be used with other guides.

18 Gott, G. B., and Erickson, R. L., 1952, Reconnaissance of uranium and copper deposits in parts of New Mexico, Colorado, Utah, Idaho, and Wyoming: U. S. Geol. Suivey Circ. 219, 16 p.

Because of the common association of uranium and copper in several of the commercial uranium deposits in the Colorado Plateau province, a reconnaissance study was made of several known deposits of copper disseminated through sandstone to determine whether they might be a source or uranium. In order to obtain additional information regarding the relationship between copper, uranium, and carbonaceous materials, some of the uraniferous asphaltite deposits in the Shinarump conglomerate along the west flank of the San Rafael Swell were also investigated briefly.

During this reconnaissance 18 deposits were examined in New Mexico, 8 in Utah, 2 in Idaho, and 1 each in Wyoming and Colorado.

Commercial-grade uranium is not associated with the copper deposits that were examined. The uraniferous asphaltites in the Shinarump conglomerate of Triassic age on the west flank of the San Rafael Swell, however, are promising sources of commercial uranium.

Spectrographic analyses of crude oil, asphalt, and bituminous shales show a rather consistent suite of trace metals including vanadium, uranium, nickel, copper, cobalt, chromium, lead, zinc, and molybdenum. The similarity of the metal assemblage in the San Rafael Swell asphaltites to the metal assemblage in crude oil and other bituminous materials suggests that these metals were concentrated in the asphaltites from petroleum. However, it is possible that uranium minerals were already present before the hydrocarbons were introduced and that some kind of replacement of uranium minerals by carbon compounds was effected after the petroleum migrated into the uranium deposit.

The widespread association of uranium with asphaltic material suggests that it also may have been concentrated by some agency connected with the formation of petroleum. The problem of the association of uranium and other trace metals with hydrocarbons should be further studied both in the field and in the laboratory.—*Authors' abstract*

19 Gott, G. B., and Hill, J. W., 1953, Radioactivity in some oil fields of southeastern Kansas: U. S. Geol. Survey Bull. 988–E, p. 69–122.

Radium-bearing precipitates derived from oil-well fluids have been found in more than 60 oil and gas fields in Cowley, Butler, Marion, Sedgwick, and Greenwood Counties of southeastern Kansas. The abnormal radioactivity of these precipitates has been studied by means of gamma-ray and sample logs; by radiometric, chemical, petrographic, and spectrographic analyses of the precipitates and drill samples; and by chemical analyses of brines collected from oil wells in the areas of high radioactivity. The most radioactive precipitates were collected from a narrow belt, roughly marginal to the Nemaha anticline, that extends from the southern part of Marion County southward to near the Kansas-Oklahoma boundary.

Most of the formations in this area have no higher concentration of radioactive constituents than is normally found in rocks of similar lithology elsewhere, but in a few wells the drill samples from beds just below the eroded top of the Arbuckle group and from some limestones in the Kansas City group have an abnormally high radium content. The highest radioactivity caused by radium in any of the rocks from this area that have been radiometrically analyzed is equivalent to that of 0.26 percent uranium oxide. This analysis indicates as much radium as would be found in equilibrium with about 0.5 percent uranium.

The radioactivity of the precipitates ranges from 0.000 to 10.85 percent equivalent uranium oxide, and the uranium oxide content ranges from 0.000 to 0.006 percent. Radium determinations have shown that radium is the element that causes most of the radioactivity. Brines, collected from oil wells where radium-bearing precipitates have formed, contain as much as 0.2 ppm of uranium.

Radium-bearing samples have been found in many of the fields that originally produced commercial quantities of helium. Radium-bearing precipitates also have been found in the surface pipes of wells that have penetrated rocks containing contact-metamorphic or hydrothermal-type minerals.

The conclusion that significant quantities of uranium may be present in the subsurface rocks is based largely on the following evidence:

1. Vuggy limestones and dolomites that contain as much radium as would be present with 0.5 percent uranium strongly suggest that uranium has only recently been leached, perhaps by the drilling fluids at the time the well was drilled. The radium now present in the precipitates was probably derived from these rocks.
2. Contact-metamorphic or hydrothermal-type minerals in altered limestones indicate that hydrothermal solutions have penetrated the limestones and suggest that uranium may have been deposited from those solutions.
3. The large amount of radium in some of the precipitates suggests that it was derived from rocks that contain an abnormal concentration of uranium.
4. The association of helium with other uranium-decay products suggests that the helium is radiogenic. So much radiogenic helium would require a large body either of uranium or thorium, and the presence of radium indicates that uranium rather than thorium is present.—*Authors' abstract*

20 Gott, G. B., Wyant, D. G., and Beroni, E. P., 1952, Uranium in black shales, lignites, and limestones in the United States: U. S. Geol. Survey Circ. 220, p. 31–35.

Uranium is present in small amounts in black marine shales, principally of Paleozoic age, and in lignite beds of Tertiary age in certain Western States. Uranium deposits are rare in limestones but minable deposits are known in Jurassic limestone in the Grants area, New Mexico.

"The association of uranium with bituminous shales, asphaltic sandstones, and petroliferous limestones suggests that some crude oils may also serve as distributing agents during the process of dissemination and concentration of uranium.

"The presence of relatively large quantities of radium and radon in some oil and gas fields indicates a possible genetic relationship between the products of uranium and hydrocarbons.

"Some of the many problems that are deserving of further investigations, therefore, are (1) the possible migration of uranium in hydrocarbon solutions derived from carbonaceous shales; (2) the possibility of precipitation of uranium compounds from oil solutions; and (3) the effect of polymerization of the hydrocarbons by alpha radiation."

21 Gruner, J. W., 1956, A comparison of black uranium ores in Utah, New Mexico, and Wyoming: Internat. Conf. on Peaceful Uses of Atomic Energy, Geneva 1955, Proc., v. 6, p. 530–532; U. S. Geol. Survey Prof. Paper 300, p. 203–205.

Important geologic features of uranium deposits at Lisbon anticline (Utah), Temple Mountain (Utah), Poison Canyon mine (New Mexico), and Gas Hills (Wyoming) are compared, and it is suggested that the deposits are similar in origin.

It is noted that petroleum residues, asphaltite, and associated pyrite are present in the uranium ores at both Temple Mountain and Poison Canyon.

22 ——— 1955, Concentration of uranium by carbon compounds: Econ. Geology, v. 50, p. 542–543.

On the Colorado Plateau the widespread association of uranium with carbonaceous compounds derived from plants and the lack of association of uranium with oil indicate that the uraniferous asphaltites of the San Rafael Swell were derived from carbon compounds of plant origin.

23 Gruner, J. W., Gardiner, Lynn, and Smith, D. K., Jr., 1953, Uranium-bearing carbonaceous and asphaltic materials of the Colorado Plateau, Part 2, *in* Annual report for July 1, 1952 to March 31, 1953: U. S. Atomic Energy Comm. RME–3044, p. 14–19, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

In the San Rafael Swell, Utah, uranium is associated with the following types of organic materials:

1. Carbonaceous lignitic plant material.
2. Asphaltite, or as it also has been called, thucholite.
3. Gilsonite and similar hydrocarbons.
4. Liquid hydrocarbons.

The liquid hydrocarbons stain and penetrate many sandstones along pervious bedding planes. They are not appreciably uraniferous.

The gilsonite and similar hardened hydrocarbons fill joints and fissures and, like the liquid hydrocarbons from which they are derived, contain no appreciable uranium.

The asphaltite occurs as pure globules or balls ranging in size from pinheads to marbles and as filling between sand grains. It contains vanadium oxide in an unknown form, as much as 7 percent U_3O_8, and does not contain thorium; therefore it is not properly a true thucholite, for, by definition, thucholite contains thorium. The asphaltite replaces the grains of sand leaving highly corroded remnants of quartz. Uranium occurs in asphaltite as uraninite and probably as an urano-organic complex. Not all of the asphaltite is uranium bearing.

Carbonized plant material contains uranium at some places, and at others it is nonuraniferous. Where asphaltite also is present, the carbonized plant material invariably is nonuraniferous; but there are many places where carbonized plant material is nonuraniferous and asphaltite is absent.

24 Hail, W. J., Jr., Myers, A. T., and Horr, C. A., 1956, Uranium in asphalt-bearing rocks: Internat. Conf. on Peaceful Uses of Atomic Energy, Geneva 1955, Proc., v. 6, p. 489–493; Uranium in asphalt-bearing rocks of the western United States: U. S. Geol. Survey Prof. Paper 300, p. 521–526.

Asphalt-bearing rocks in 45 areas in California, Utah, Wyoming, Montana, New Mexico, Texas, Oklahoma, and Missouri were examined as potential sources of uranium. A total of 202 samples from these areas was analyzed for uranium. The oldest rocks sampled were Ordovician in age, and the youngest were Recent. Host rocks containing the asphalt include sandstone, arkose, conglomerate, limestone, diatomite, and alluvium. The asphalt was extracted from the host rock, reduced to dry ash, analyzed chemically for uranium, and analyzed spectrographically for other elements by semi-quantitative methods.

Significant amounts of uranium in the ash of the extracted oil, whose average uranium contents range from 0.028 to 0.376 percent, were found in samples from 7 of the 45 areas examined. All except 1 area contain large estimated reserves of asphalt-bearing rock, ranging from 15 million to almost 2 billion (10^9) tons. The average uranium content of samples from 13 additional areas ranges from 0.02 to 0.068 percent uranium in the ash of the extracted oil. Many of these areas contain very large reserves of asphalt-bearing rock.

It is believed that most of the uranium was present either as an original constituent of the oil or was introduced during the migration of the oil. Chemical analyses of the extracted asphalt and of the rock residue show that the uranium is concentrated as an organo-uranium complex in the asphalt and not in the host rock. Preliminary evaluation of the field data indicates that the amount of uranium in the asphalts may be closely related to the mineralogical composition of the sediments in which the oil originated, or the rocks through which the oil migrated.—*Authors' abstract*

25 Hess, F. L., 1933, Uranium, vanadium, radium, gold, silver, and molybdenum sedimentary deposits, *in* Ore deposits of the Western States (Lindgren volume): New York, Am. Inst. Mining Metall. Engineers p. 450–481. See p. 456–462.

Uranium occurs in asphaltic material in the Shinarump conglomerate in the San Rafael Swell area of Utah and in the La Plata sandstone [now called the Entrada sanstone] and Dolores formation near Placerville, Colo.

In the Shinarump conglomerate the distribution of uranium in asphaltite is apparently as erratic as the deposition of the sandstone in the conglomerate, and the ore lies in shoots as distinct as those in ordinary metalliferous veins. Some shoots have formed through the weathering of the asphaltite and the concentration of uranium and vanadium minerals in the soft sand left after the removal of a part of the asphaltite. The quantity of asphaltite is large in places and has prevented other cementation.

The origin of uranium and vanadium in the Shinarump conglomerate is puzzling. Possibly the asphalt may have absorbed uranium and other metals from extremely dilute solutions in a shallow sea.

Near Placerville, Colo., two types of asphalt-bearing veins occur: one containing chalcocite, azurite, and malachite in a gangue of barite and calcite with pellets of asphaltite; another containing alternating layers of a shiny black asphaltic material and calcite with barite on the hanging wall, and here and there on the footwall irregular lenses of asphaltic material. One specimen of asphaltite contained uranium and vanadium; another contained only uranium. Hess suggests that the metals in the La Plata beds [now called the Entrada sandstone] were carried upward by vein-forming solutions. The gold and silver deposits in the limestone near Saw Pit, Colo., contained neither uranium nor vanadium.

26 Hess, F. L., 1922, Uranium-bearing asphaltite sediments of Utah: Eng. Mining Jour., v. 114, no. 7, p. 272–276.

Deposits of uraniferous asphaltite occur in the Shinarump conglomerate at Temple Mountain and adjacent localities on the eastern flank of the San Rafael Swell, Emery County, Utah.

The distribution of uranium and vanadium in the asphaltite and of the asphaltite in sandstone is apparently erratic. The ore lies in ellipsoidal shoots as distinct as those in ordinary veins. The ellipsoidal shapes appear to be caused by weathering, which proceeded from the outside toward the centers leaving rounded cores of comparatively unchanged material. The primary asphaltic ore bodies apparently were laid down with the beds. The asphaltite seems to have been deposited in a soft condition with coarse sands. Some secondary ore shoots have been formed through weathering of the asphaltite and concentration of uranium in nearby sand.

In the "Flopover," a large collapsed mass of sandstone lying against the southwest side of the mountain, the asphaltite and its accompanying metals of the Shinarump conglomerate were leached by hot sulfur-bearing waters and partly redeposited in the porous overlying beds of Jurassic sandstone. The leaching apparently occurred before the collapse and was caused by hot-spring activity. Outcrops of the leached rock are white and can be traced directly into unaltered red sandstones.

The origin of the ores is puzzling. The asphaltites that contain volatile hydrocarbons do not contain uranium. Perhaps only asphalt that absorbed the metals became hard quickly and only part of the asphalt was exposed to the metals. The hot springs that invaded these rocks may have brought in uranium, vanadium, and other metals, and the asphalt may have absorbed the metals from them. However, none of the present-day hot springs in the area contains any unusual metals. It seems more probable that the metals and the asphaltites were laid down at the same time and that an evanescent sheet of water kept the metals in solution until the asphalt extracted them. The location of the veins that fed the metals to the water is not known.

27 Hill, J. W., 1954, Uraniferous asphaltic materials of southwestern Oklahoma [abs.]: Geol. Soc. America Bull., v. 65, p. 1377.

Asphaltic deposits of southwestern Oklahoma were studied as part of the U. S. Geological Survey's reconnaissance for radioactive materials. The most uraniferous materials were small, black, asphaltic pellets, which occur in bentonitic and arkosic red shale and sandstone of early Permian age. The relatively flat-lying Permian sedimentary rocks overlie steeply dipping petroliferous Ordovician limestone and dolomite and rounded ridges of Precambrian rhyolite porphyry on the north flank of the Wichita Mountains.

The asphaltic pellets are insoluble in organic reagents, are botryoidal in shape, and range in diameter from 1 mm or less to 5 cm. Many of these pellets contain smaltite and uraninite and an unidentified uranium mineral.

The uranium and total radioactivity are evenly distributed within a pellet.

The asphaltic pellets are largest and most numerous in permeable zones and along fracture openings and are associated with ground-water deposits. They are surrounded by leached haloes in the enclosing rock and appear to be epigenetic. The internal structure of some pellets is similar to that of marcasite concretions. Their proximity to asphalt seeps suggest that the pellets may have been derived from that source. The presence of uraninite in the pellets, concentrations of rare earths in nearby asphalt, and similar concentrations in nearby hydrothermally altered granite suggest that some of the trace metals were derived indirectly from igneous sources.—*Author's abstract*

28 Hill, J. W. 1953, regional reconnaissance for uranium and thorium in the United States, south-central district, *in* Search for and geology of radioactive deposits, Semiannual progress report, December 31, 1952 to May 31, 1953: U. S. Geol. Survey TEI–330, p. 200–204, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

The quantity of uraniferous asphaltites in the Fredericktown lead-mining region of Madison County, Mo., proved to be below commercial amounts and apparently not related to fresher more viscous oil that occurs in small quantities as cavity fillings in the overlying Bonneterre dolomite of Cambrian age.

In the Picher field of Ottawa County, Okla., tar containing 0.04 percent uranium in the 0.073 percent ash, seeps into zinc mines from the overlying Cherokee formation of Pennsylvanian age. The quantity of tar is too small to be of commercial significance.

In the Wichita Mountains of southwestern Oklahoma asphaltic pellets, which contain as much as 9.38 percent uranium in the 9.20 percent ash, are found in the Permian red beds of the Hennessey, Garber, and Wellington formations or their equivalents along the Wichita-Amarillo uplift for a distance of more than 300 miles. The oil residue in the Permian formations probably was deposited after the deposition of the formations and probably was derived from Paleozoic rocks. The source of the uranium may be related to nearby igneous rocks. The quantity of asphaltic pellets is too small to be economically recoverable at present.

29 Hyden, H. J., 1956, Uranium and other trace metals in crude oils of the western United States: U. S. Geol. Survey Prof. Paper 300, p. 511–519.

A total of 107 samples of crude oil and 16 samples of refinery residues was collected in the western United States and analyzed for uranium and other trace metals. The uranium content of the crude oil samples commonly was less than one part per billion, but some samples were found to contain a few parts per billion or even a few tens of parts per billion of uranium. The uranium content of refinery residues ranges from 0.33 to 1070.0 parts per billion. The ash of crude oils contained from 0.0001 to 0.045 percent uranium and of the refinery residues from 0.0001 to 0.024 percent uranium. Uranium is, therefore, not present in sufficient quantity in crude oils to be of commercial interest. The presence of an anomalous amount of uranium in crude oils might serve as a guide for uranium prospecting.

Uranium is not preferentially distributed with respect to age, lithologic character, or geographic location of the reservoir rocks, nor does it show any preferential distribution with respect to oil types.

A comparison of vanadium-nitrogen, nickel-nitrogen, and uranium, nitrogen ratios indicates that most of the uranium probably is not present as a porphyrin complex in crude oils.

30a Isachsen, Y. W., 1956, Geology of uranium deposits of the Shinarump and Chinle formations on the Colorado Plateau: Internat. Conf. on Peaceful Uses of Atomic Energy, Geneva 1955, Proc., v. 6, p. 350–357.

30b Isachsen, Y. W., and Evansen, C. G., 1956, Geology of uranium deposits of the Shinarump and Chinle formations on the Colorado Plateau: U. S. Geol. Survey Prof. Paper 300, p. 263–280.

The geology of uranium deposits in the Shinarump and Chinle formations is illustrated by detailed descriptions of deposits at Holiday Mesa district, Happy Jack mine, Calyx mines, Big Indian Wash-Lisbon Valley district, Delta mine, and Cameron mining district. Of these, only the Calyx mines at Temple Mountain, Utah, contain asphaltite.

Asphaltite is the dominant cement of the ore-bearing sandstone at the Calyx mines. Three types of hydrocarbons occur with the ore: (a) liquid hydrocarbon which is nonuraniferous, combustible, and has a viscosity of heavy oil, (b) dull resinous asphalitite which melts and burns when ignited, and is nonuraniferous and plastic, and (c) uraniferous asphaltite, a brittle solid which does not sustain a flame. Liquid hydrocarbon is rarely within the ore and most commonly is in the rocks overlying the ore. The dull resinous asphaltite is principally in barren zones within ore bodies. Brittle asphaltite is only in uranium ore and invariably is uraniferous.

"The distribution of the three classes of hydrocarbons shows that their volatile content decreases in direct proportion to proximity to uranium." The authors postulate that fluid hydrocarbons were introduced into a preexisting uranium deposit and subsequently polymerized to varying degrees by radiations from uranium. During polymerization asphaltite replaced some of the uraninite present, thus forming the present uraniferous asphaltite. This mechanism also explains the apparent replacement of quartz by asphaltite; this anomalous situation is therefore explained as the result of quartz having been replaced by uraninite which later is replaced by asphaltite.

31 Kerr, P. F., and Kelley, D. R., 1956, Urano-organic ores of the San Rafael Swell area, Utah: Econ. Geology, v. 51, p. 386–391.

Two types of uraniferous organic material occur in the ore-bearing rocks of the San Rafael Swell, fossil plant debris and petroliferous substances.

Replacement of plant debris by uraninite is common in the swell, but not all plant debris, even in mineralized districts, contains uranium. The lack of uranium in the plant debris may be due to (a) absence of uranium mineralization, (b) previous mineralization or coalification may have rendered the debris unreceptive to the uranium-bearing solutions, and (c) nearby petroleum-impregnated strata may have selectively absorbed uranium from the ore-bearing solutions.

The uraniferous petroliferous substances are hard, brittle substances, containing as much as 8 percent uranium, which in places has replaced the quartz grains of the host sandstone; this substance seems to belong to the general group of materials to which the name thucholite has been applied. The authors postulate that the uranium-bearing hydrocarbons of the swell have become "indurated by polymerization and oxidation of oil by mineralizing solutions accompanied by more than normal heat."

32 Kerr, P. F., Rasor, C. A., and Hamilton, P. K., 1951, Uranium in Black King prospect, Placerville, Colorado, *in* Annual report for July 1, 1950 to June 30, 1951: U. S. Atomic Energy Comm. RMO–797, p. 24–43, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

The Black King prospect consists of copper, zinc, and uranium minerals along a fault zone in the Dolores formation. A uranium-bearing hydrocarbon resembling thucholite occurs both in the fault and in the adjacent sediments. Minute specks of uraninite can be observed in the hydrocarbon with the microscope.

Three types of radioactive hydrocarbon can be observed with the microscope: a lustrous material which is cracked and invaded by the other two types of hydrocarbon, a sooty material of finer grain than the lustrous material, and a light-gray banded material that veins the other two types and is much less radioactive than they are.

Analyses of 4 specimens of the hydrocarbon show a range of from 44.8 to 69.2 percent carbon and from 2.20 to 3.08 percent hydrogen.

On the basis of the mineralogy of the deposit, the authors conclude that the metallization of the deposit is due to hydrothermal activity. They do not speculate on the origin of the hydrocarbon.

33a Keys, W. S., 1956, Deep drilling in the Temple Mountain collapse, San Rafael Swell, Utah: Internat. Conf. on Peaceful Uses of Atomic Energy, Geneva 1955, Proc., v. 6, p. 371–378.

33b Keys, W. S., and White, R. L., 1956, Investigation of the Temple Mountain collapse and associated features, San Rafael Swell, Emery County, Utah: U. S. Geol. Survey Prof. Paper 300, p. 285–298.

Thirteen holes were drilled in the Temple Mountain collapse to investigate the genesis of its structure, its relationship to the uranium ores, and to test for more ore at deeper horizons. Uraniferous asphaltite [asphaltite is "any solid hydrocarbon of apparent petroliferous derivation," p. 292] was found in the drill cores.

Hard, brittle asphaltite, as pellets, veinlets, or sheets of hydrocarbon ranging from a fraction of an inch to more than 5 feet long, carries the uranium in the Temple Mountain collapse. Most of the mineralized asphaltite discovered by the drilling is distributed along fractures and bedding planes in the conglomerate zone of the Kaibab limestone, some along the bedding and fractures in the Moenkopi formation, and a minor amount is disseminated in the top of the Coconino sandstone.

The uranium ore was deposited either after the collapse was complete or during late stages of subsidence when the accompanying brecciation and fracturing provided channels for the mineralizing solutions. It could not be determined whether the asphaltic ores in the collapse resulted from redistribution of minerals from the Moss Back member of the Chinle formation, or whether mineralizing solutions ascended the channelways.

In the Temple Mountain mineral belt adjacent to the collapse, uranium also occurs in hard asphaltite. Fault control does not appear to be important in this belt. The ore bodies are in the Moss Back member. There may be a significant genetic relationship between the collapse and the mineral belt.

34 McKelvey, V. E., 1955, Search for uranium in the United States: U. S. Geol. Survey Bull. 1030-A, p. 1-64. See p. 12-13 and 33-36.

Asphaltites, hard lustrous hydrocarbons called thucholite, and similar-appearing substances referred to as "asphaltite" may carry uranium in the form of free, evenly disseminated grains of uraninite. These substances occur in some veins and pegmatites, many sandstone deposits, and certain reservoir rocks in oil fields. It is believed by some geologists that the thucholite in many pegmatites, veins, and in the Witwatersrand, South Africa, originated from the polymerization of migrant natural gases by radiation from uranium-bearing minerals already in these deposits. Some occurrences of uraniferous asphaltite in the United States are thought to be a residual petroleum, not a polymerized natural gas. If this is true, then the petroleum fluids could have transported the uranium to places favorable to deposition, particularly in sandstone-type deposits. The uranium content of crude oil, thought to be mostly in asphaltenes, ranges from a fraction of a part per billion to a few thousand parts per billion.

An accompanying map of the United States shows the distribution of asphaltites and related substances that have been tested for uranium. Except for some deposits in the San Rafael Swell area, Utah, none of the deposits is of commercial importance.

35a McKelvey, V. E., Everhart, D. L., and Garrels, R. M., 1955, Origin of uranium deposits, *in* Bateman, A. M., ed., Econ. Geology, 50th anniversary volume, 1905-1955, pt. 1, p. 464-533.

35b McKelvey, V. E., Everhart, D. L., and Garrels, R. M., 1956, Summary of hypotheses of genesis of uranium deposits: Internat. Conf. on Peaceful Uses of Atomic Energy, Geneva, 1955, Proc. v. 6, p. 551-561; U. S. Geol. Survey Prof. Paper 300, p. 41-53.

The occurrence of asphaltite in many uranium deposits of the Colorado Plateau has suggested to many geologists that the asphaltite is residual petroleum and that petroleum fluids may have been transporting media for the uranium in ore deposits in sandstone. Because crude oils characteristically contain only a few parts of uranium per billion, except where they have penetrated uraniferous rocks, it seems unlikely that migrating petroleum is the source of much, if any, of the uranium on the Colorado Plateau.

36 Moore, F. W., and Stephens, J. G., 1954, Reconnaissance for uranium-bearing carbonaceous rocks in California and adjacent parts of Oregon and Nevada: U. S. Geol. Survey Circ. 313, 8 p. See p. 7.

Samples of oil-saturated sandstones from a quarry 1 mile south of Edna, San Luis Obispo County, from Santa Cruz, Santa Cruz County, and from McKittrick, Kern County, Calif., were tested for uranium. The sandstone samples from Edna contained 0.002 percent uranium and 10 percent oil. If all the oil could be leached from this sandstone, it would contain 0.02 percent uranium providing the oil contains all the uranium present. Sandstone samples from the other two localities contained 0.001 percent or less, equivalent uranium.

A sample of asphaltite from See Canyon, San Luis Obispo County, Calif., contained 0.001 percent uranium in the ash and 18.9 percent ash.

37 Morehouse, G. E., 1951, Investigation of thucholite deposits near Placerville, Colorado: U. S. Atomic Energy Comm. RMO-910, 13 p., issued by U. S. Atomic Energy Comm., Tech. Inf. Service Extension, Oak Ridge, Tenn.

Thucholite, a mixture of uraninite and hydrocarbons, occurs on two properties, the Black King No. 5 and the White Spar prospects, near Placerville, San Miguel County, Colo. Thucholite is found along a fault zone, which cuts the Dolores formation, associated with primary sulfides of copper, zinc, molybdenum, and antimony. The wall rock at the Black King is highly altered; the wall rock at the White Spar, 1½ miles southeast, is less altered. A radiometric traverse along the fault zone did not reveal any additional uranium-bearing material. Material of commercial-grade uranium exists on both properties.

Thirteen channel samples and one 100-pound metallurgical sample were taken. Information on the locations of the samples and a list of analyses are given in the report. Samples range from 0.04 to 0.88 percent U_3O_8.

38 Nininger, R. D., 1956, Minerals for atomic energy: New York, D. Van Nostrand Co., Inc., 2d ed., 399 p. See p. 69–70.

Most asphalt deposits do not contain commercial amounts of uranium. However, some uranium deposits in the asphaltic sandstone beds in the San Rafael Swell area of east-central Utah are an exception. This area also has typical carnotite-type deposits and copper-uranium deposits.

At Temple Mountain on the east side of the swell the uranium has been deposited in faults and fissures which control its position, and on the west side the larger ore bodies lie within a few thousand feet of major faults. Most of the uranium forms a part of the pure asphalt, and only a few secondary uranium minerals are found in these deposits.

The asphaltic ores form deposits of no more than a few hundred feet in length and width and not more than 3 feet in thickness. The distribution of these deposits is erratic, and they are very similar structurally to the carnotite-type and copper-uranium deposits. The deposits are confined largely to porous medium- to coarse-grained sandstone lenses or conglomerates. As a rule, the uranium concentrations coincide with the highly asphaltic beds and most of the uranium is closely associated with seams or other accumulations of asphaltic material. Several secondary uranium minerals, including carnotite, have been recognized; but much of the uranium, together with vanadium, occurs as an integral part of the black asphalt.

39 Nordenskiöld, A. E., 1893, Rémarques sur le fer natif d'Ovifak et sur le bitume des roches cristallines de Suede: Extrait d'une Lettre de M. Nordenskiöld a M. Daubree, *in* Acad. sci. [Paris] Comptes rendus, v. 116, p. 677–678.

Analyses of the ash of several bitumens, including a sample of grahamite from sediments in [Pennsylvania] North America, show several parts per hundred of the oxides of nickel, uranium, and rare earths. It appears that uranium is more widespread in occurrence than previously supposed.

40 O'Brien, T. D., 1953, Uranium occurrence in asphaltites. Technical Report—June 1, 1952 to March 31, 1953: U. S. Atomic Energy Comm. RME-3040, 6 p., issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

Samples of asphaltite from uranium ores at Temple Mountain, San Rafael Swell, Utah, were treated with a variety of chemical and physical tests in order to determine the form in which uranium occurs in the asphaltite.

Extractions with organic solvents yielded negligible amounts of uranium. Basic solutions were most effective. A 10 percent sodium carbonate solution at reflux temperatures for 3 days extracted over 20 percent of the contained uranium. Evidently this uranium is present as an organo-uranium compound because, upon acidification, a yellow solid, containing carbon, hydrogen, nitrogen, oxygen, and uranium, is obtained.

Heating of the ore in an inert atmosphere yields a yellow sublimate at 250–300°C. This sublimate seems to be the same organo-uranium compound as obtained in the sodium carbonate extraction.—*Author's abstract, in part*

41 ——— 1953, Uranium occurrence in asphaltites. Technical Report—March 31, 1953 to October 1, 1953: U. S. Atomic Energy Comm. RME-3062, 9 p. (Available in U. S. Atomic Energy Comm. depository libraries.)

The object of this work was to try to establish the form in which uranium occurs in the Colorado Plateau asphaltites. A radioactive yellow sublimate obtained by heating an asphaltic type ore from Calf Mesa in Emery County, Utah, was shown to be arsenic sulfide. Chemical properties of the radioactive substance indicated polonium, but the decay curve indicates a half life of 53 days, while the reported half life of polonium is 140 days. Rather complete differential analysis shows that there is practically no hydrocarbon material in this asphaltite, and that practically all of the carbon is in the uncombined form. Solvent extraction also indicates the absence of organic material, because in no case was more than a few drops of organic material obtained from 25-g samples.—*Author's abstract*

42 ——— 1954, Uranium occurrence in asphaltites. Technical Report—October 1, 1953 to March 31, 1954: U. S. Atomic Energy Comm. RME-3090, 9 p. (Available in U. S. Atomic Energy Comm. depository libraries.)

Treatment of the asphaltite [from Temple Mountain, San Rafael Swell, Utah] with acid, basic, or neutral solutions extracts about the same amount of iron, copper, calcium, uranium, and sulfate. Under similar conditions small volumes of solvent extract the same amount as large volumes. This indicates that the uranium is present in a soluble form, and that the amount extracted is a function of the physical state of the ore and not the solubility of the uranium compound.—*Author's abstract*

43 Pierce, A. P., Mytton, J. W., and Gott, G. B., 1956, Radioactive elements and their daughter products in the Texas Panhandle and other oil and gas fields in the United States: Internat. Conf. on Peaceful Uses of Atomic Energy, Geneva 1955, Proc., v. 6, p. 494–498; U. S. Geol. Survey Prof. Paper 300, p. 527–532.

Abnormal concentrations of radioelements and their daughter products, including radon, helium, argon, radium, uranium, and thorium, are present in some oil and gas fields of the United States. Different natural hydrocarbon gases contain as much as 10^4 micromicrocuries of radon per liter (at reservoir pressure), several percent of helium, and several tenths of 1 percent of argon. Oil-field brines have fairly high concentrations of radium, some containing as much as 10^{-9} grams of radium per liter. Precipitates from these waters on pipes in oil wells contain as much as 10^{-8} grams of radium per gram. The uranium content of oil-field brines that have been analyzed is as much as 0.2 parts per million uranium.

Analyses of uranium and trace metals have been made of a number of crude oils, oil seeps, and petroliferous rocks throughout the central and western United States. The results indicate that uranium is generally enriched in oil-seep soil and in the heavy surface-active fractions of petroleum which adhere to the rocks, as compared with the crude-oil fraction of petroleum that is produced at the wellhead. Epigenetic concentrations of uranium in the form of metalliferous asphaltite, a carbonaceous mineraloid similar to thucholite, carburan, and huminite, have been found in oil and gas reservoirs and associated rocks in the Wichita-Amarillo uplift of Oklahoma and Texas and in other areas. Abnormal concentrations of radon and helium in the natural gases of the Panhandle oil field of Texas are associated with uraniferous asphaltite nodules and impregnations in and adjacent to the reservoir rocks. The minerals uraninite, coffinite, and thorite have been found in some nodules, but in many the uranium-bearing compound, which may be an organometallic complex, has not been identified. The trace-metal suite of the asphaltite is similar to that found in the ash of associated crude oils and in crude oil in general.

More information about the geochemistry of uranium in petroleum and petroleum waters is necessary to a complete understanding of the genesis of the helium and the associated uraniferous asphaltites. The evidence now available on the origin of the asphaltite indicates that the process responsible for its localization must have operated in the presence of petroleum or in a combination of petroleum and water within the rock pores, must have been capable of concentrating uranium and the other metals in the form of disseminated small segregations, must have operated independently of the type of rock in which concentration took place, and must have been effective over broad structural provinces.—*Authors' abstract*

44 Prigmore, G. T., 1955, Prospects and possibilities for Texas uranium: Mining World, v. 17, no. 9, p. 60–62.

In Burnet County, Tex., a concentration of uranium has been reported in an asphaltic coquina in the Glen Rose limestone of Early Cretaceous age.

45 Reyner, M. L., 1950, Preliminary report on some uranium deposits along the west side of the San Rafael Swell, Emery County, Utah: U. S. Atomic Energy Comm. RMO–673, 31 p., issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

Twelve uranium-bearing asphaltite-type deposits distributed along 30 miles of the western border of the San Rafael Swell, Emery County, Utah, were examined. This area extends from T. 20 S. to T. 24 S., and R. 8 E. to R. 11 E. These 12 deposits are described in detail. All the deposits are near the base of the Shinarump conglomerate. Most of the uranium is in intimate association with asphalt and very little carnotite was noted. The best deposits examined are in areas that lie within a few thousand feet of faults.

The uranium appears to have been introduced laterally along bedding planes and other permeable zones. The mode of origin of the deposits is not definitely known.

The vanadium content of the deposits increases from almost nil in the northern part of the area to a ratio of about 1:1 with uranium in the southern part. Within individual deposits the vanadium distribution may be very erratic.

46 Rosenzweig, Abraham, Gruner, J. W., and Gardiner, Lynn, 1954, Widespread occurrence and character of uranium in the Triassic and Jurassic sediments of the Colorado Plateau: Econ. Geology, v. 49, p. 351–361.

Uranium deposits on the Colorado Plateau may be grouped into three types: copper-uranium deposits, vanadium-uranium deposits, and asphaltite deposits. The typical minerals of asphaltite deposits are uraninite, "asphaltite," and pyrite. Vanadium is abundant in asphaltite deposits but copper is rare. The origin of the asphaltite is not known. It appears to be later than the primary uranium minerals, for it replaces them as well as quartz grains of the sandstone host rock.

47 Wilmarth, V. R., and Vickers, R. C., 1953, The Robinson and Weatherly uraniferous pyrobitumen deposits near Placerville, San Miguel County, Colorado: U. S. Geol. Survey TEI–176, 43 p. (open-file report).

The Weatherly and Robinson properties near Placerville, San Miguel County, Colo., contain uraniferous pyrobitumen of possible hydrothermal origin.

Uraniferous pyrobitumen is the only uranium-bearing material found on the Robinson property which is one-half mile east of Placerville and consists of the White Spar, New Discovery Lode, and Barbara Jo claims. The pyrobitumen occurs in the gouge and brecciated zone of a normal fault that cuts the Cutler formation of Permian age and the Dolores formation of Triassic age. The pyrobitumen, associated with base-metal sulfides, is localized in a gouge zone as much as 40 feet long and 6 feet wide. The average uranium content of 11 samples ranged from 0.001 to 0.045 percent and averaged 0.02 percent. Most of the uranium is concentrated within 3 feet of the fault plane, and this zone is richest in pyrobitumen.

The Weatherly property is about a mile northwest of Placerville and consists of the Black King claims 1, 4, and 5. Uranium-bearing pyrobitumen is the most abundant uraniferous material. Uranophane and autunite have been identified in dump material, and uranophane has been found sparingly coating fracture surfaces. Pyrobitumen occurs in lenses along the gouge zone of a northwest-trending steeply dipping, normal fault and in replacement lenses and nodules in the sedimentary rocks on the hanging wall of the fault. Channel samples taken across the fault zone contained from 0.001 to 0.014 percent uranium. The lens-shaped deposits in the fault zone are as much as 6 feet long and 2 feet wide and contain as much as 9 percent uranium in selected samples of pyrobitumen. The replacements lenses of uranium-bearing pyrobitumens are as much as 8 inches wide and 6 feet long; the nodules are as much as 6 inches in diameter and as much as 100 feet from the fault. Samples taken from the replacement bodies in the hanging wall contained from 0.007 to 1.4 percent uranium.

48 Wilmarth, V. R., 1953, District studies, Placerville hydrocarbons, Colorado, *in* Search for and geology of radioactive deposits, Semiannual progress report, December 1, 1952 to May 31, 1953: U. S. Geol. Survey TEI–330, p. 107–108, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

In the hydrocarbon-bearing veins of the Placerville area, San Miguel County, Colo., the first minerals deposited were calcite, barite, and pyrite, followed by the hydrocarbons, and then base-metal sulfide minerals. The hydrocarbons occur as both nonradioactive and radioactive deposits in fault zones, fracture fillings, and disseminations in the Cutler and Dolores formations.

The hydrocarbons occurring as fracture fillings contain a maximum of 0.078 percent equivalent uranium, and hydrocarbons from the fault zones and disseminations contain a maximum of 9.0 percent uranium. In general, hydrocarbon ash that is rich in uranium also contains relatively more copper, lead, molybdenum, and yttrium. The trace-metal constituents are believed to occur in the hydrocarbon as grains of coffinite and as metallo-organic compounds.

49 Wyant, D. G., Beroni, E. P., and Granger, H. C., 1952, Some uranium deposits in sandstones: U. S. Geol. Survey Circ. 220, p. 26–30. See p. 29.

In the Temple Mountain district, San Rafael Swell area, Utah, uraniferous asphaltite occurs as void fillings, rounded pellets, veinlike fillings, and as detrital grains in friable sandstone lenses of the Shinarump conglomerate. The asphaltite ore bodies are localized in ancient stream channels. The asphalt may be the mineral thucholite.

Highly radioactive asphalt pellets have also been found in the Oyler mine, the Oak Creek prospect, and at the Four Aces mine in White Canyon area, Utah.

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