Reconnaissance of Uranium and Copper Deposits in Parts of New Mexico, Colorado, Utah, Idaho, and Wyoming

Trace Elements Investigations Report 232

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology - Mineralogy

This document consists of 33 pages.
Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

RECONNAISSANCE OF URANIUM AND COPPER DEPOSITS IN PARTS OF NEW MEXICO, COLORADO, UTAH, IDAHO, AND WYOMING*

By

Garland B. Gott and Ralph L. Erickson

June 1952

Trace Elements Investigations Report 232

GS-C-219

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*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission

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By Garland B. Gott and Ralph L. Erickson

ABSTRACT

Because of the common association of uranium and copper in several of the commercial uranium deposits in the Colorado Plateau Province, a reconnaissance was made of several known deposits of copper disseminated through sandstone to determine whether they might be a source of uranium. In order to obtain more 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, eight in Utah, two in Idaho, and one each in Wyoming and Colorado.

No uranium deposits of commercial grade are 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 from the standpoint of commercial uranium production.

Spectrographic analyses of crude oil, asphalt, and bituminous shales show a rather consistent suite of trace metals including vanadium, nickel, copper, cobalt, chromium, lead, zinc, and molybdenum. The similarity of the metal assemblage, including uranium of 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, the hypothesis that uranium minerals were already present before the hydrocarbons were introduced and that some sort of replacement of uranium minerals by carbon compounds was effected after the petroleum migrated into the uranium deposit should not be disregarded.

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 studied further both in the field and in the laboratory.

INTRODUCTION

Copper, in varying proportions, is associated with uranium in many of the sandstones on the Colorado Plateau. This association is thought to have resulted from the deposition of these two metals under similar chemical conditions. Because of the association of copper and uranium in many deposits, a reconnaissance was made of some of the known copper deposits in sandstones of other areas on and adjacent to the plateau to determine whether or not they might be a source of uranium.

The location, age of host rock, mineralogy, radioactivity, chemical analyses, and a brief description of the deposits that were examined are tabulated in table 1. Arbitrary numbers have been assigned to each deposit and these numbers refer to the same deposits on both table 1 and figure 1. The information about the deposits in each state is briefly summarized below.

This reconnaissance was made on behalf of the Atomic Energy Commission during the summer of 1951 by two field parties: (1) A two months reconnaissance in parts of New Mexico, Colorado, Utah, Idaho, and Wyoming by the writers, the results of which are summarized in this report, and (2) A reconnaissance in parts of Oklahoma, Texas, New Mexico, and Arizona by Russell Gibson. [1]

[1] Gibson, Russell, Reconnaissance of some red bed copper deposits in the southwestern United States: U. S. Atomic Energy Commission RMO 890, February 1952.

ACKNOWLEDGMENTS

The writers wish to express their appreciation to Charles B. Read of the Geological Survey, for unpublished maps and reports of many of the deposits that were examined during this investigation. They are also indebted to various members of the U. S. Geological Survey, Denver laboratory, particularly Lewis F. Rader, Jr., and A. T. Myers for chemical, spectrographic and radiometric analyses.

THE COPPER AND URANIUM DEPOSITS

The deposits examined during this investigation are in northern New Mexico, southeastern Utah, southwestern Colorado, southeastern Idaho, and southwestern Wyoming. Within this region post-Cretaceous intrusive and extrusive rocks cover large areas and pre-Cambrian rocks are exposed in many of the major

Paleozoic orogenic belts. However, late and post-Paleozoic sedimentary rocks, principally of continental origin, are most abundant. Thousands of feet of varicolored, but predominantly reddish, aeolian and fluvial sandstones and conglomerates that alternate with lesser amounts of shales, sandy shales, and clays are the most prominent components of the sedimentary sequence. The rocks of this sequence range in age from Pennsylvanian to Recent.

The copper deposits appear to fit into a classification consisting of two general types: (1) Deposits in which the controlling factors of deposition appear to have been the presence of carbonaceous material and relatively high porosity, and (2) deposits in which the predominant controlling factor appears to have been faulting or fracturing.

The deposits, for the most part, range in size from a small amount of copper distributed through an aggregate of a few cubic inches of sandstone to many thousands of tons of copper-bearing rock. Some of the deposits have been intermittently mined in the past but under present conditions it is doubtful if any of them could be mined profitably.

The copper minerals are most abundant in light-gray, fluvial, carbonaceous, argillaceous, porous sandstones of Permian and Triassic age. Chalcocite is probably the primary copper mineral of most of the deposits in their present form. It occurs as a replacement of carbonized plant remains, as interstitial grains and nodules disseminated through the sandstones, and as fracture fillings. The secondary carbonates and silicates have been deposited adjacent to the chalcocite but in some places they cement the sand grains where copper sulfides are not present.

The most abundant copper minerals in the deposits that were examined by the writers are malachite, chalcocite, azurite, and chrysocolla. Malachite is the most prominent mineral but its bright color and its presence, in some places, as a coating or halo around chalcocite grains and nodules may result in disproportional estimates of the two minerals. Azurite is present in much smaller quantities than is malachite but, nevertheless, is widespread. Chrysocolla is most abundant in the Copper City and Pintada-Pastura districts in New Mexico. Covellite was identified in about one-third of the deposits that were examined. Chalcopyrite, cuprite, copper sulfates, and native copper, are sparingly present in only a few deposits.

During a two-day reconnaissance of the San Rafael Swell in Utah, a few of the uraniferous asphaltite deposits were briefly examined. The deposits about which the writers have obtained information are not known to be extensive but a similar deposit at Temple Mountain, on the southeastern corner of the San Rafael Swell, apparently contains comparatively large resources. The asphaltic material occurs as rounded grains, stringers, pods, and irregular masses in the Shinarump conglomerate. Small quantities of uranium-bearing carbonized wood are also present. The hydrocarbons apparently range from an asphalt largely soluble in organic reagents to residual asphaltites (or pyrobitumens?) that are only slightly soluble in carbon disulfide. The residual asphaltites contain more uranium and other metals than do the soluble asphalts but the metal content of their ash is comparable.

Several metals are present in the asphaltites including Fe, Ti, Co, Cu, Mo, Ni, Pb, U, V, and Zn. Compounds of these metals are present in the asphaltite-bearing rock and include pyrite, arsenopyrite (?), zinc-nickel-cobalt sulfate, chalcopyrite, bornite, chalcocite, covellite, malachite, azurite, paraschoepite (?) and metatorbernite.

Spectrographic analyses of a few asphaltite samples from this area show that the metal suite in the asphaltites is the same as is present in crude oils. This suggests that the metals in the asphaltites may have been concentrated from a crude oil by a combination of volatilization, oxidation, and polymerization resulting in a concentration of the metal-bearing asphaltenes and other heavy hydrocarbons. More extensive investigations to determine the metal compounds and their relationship to the organic constituents in a greater number of bituminous materials are needed, however, before the source of the metals can be established definitely.

New Mexico

Cuba, Abiquiu, and Gallina districts

The deposits in the Cuba district, on the west flank of the Sierra Naciemiento uplift (deposits Nos. 1, 2, and 3), and in the Abiquiu and Gallina districts, on the east flank of this uplift (deposits Nos. 4 and 5), are in the Poleo sandstone of Triassic age, an equivalent of the Shinarump conglomerate. Deposits Nos. 1, 2, and 3 have been productive mines; No. 4 has been prospected by means of six short tunnels; and deposit No. 5 consists of insignificant amounts of copper minerals that were accidentally exposed during road construction. The attitude of the Poleo sandstone at these deposits ranges from horizontal to a dip of about 30°. Carbonized wood, carbonaceous clay beds, and high permeability are features that are common to all these deposits. Copper minerals, chiefly malachite, chalcocite, azurite, and chrysocolla are concentrated in fractures, disseminated through the sandstone, and surround and replace carbonized wood. Some of the carbonized wood is slightly radioactive but no uranium minerals are visible. The Poleo sandstone consists of sub-angular to sub-rounded quartz grains and a minor amount of feldspar. Many of the quartz grains show secondary growth producing sharp crystal faces. Chalcocite grains occur chiefly in the interstices between quartz grains and are largely oxidized to malachite which forms the cement of the sandstone. Chalcocite also fills fractures in, and replaces, quartz and feldspar. Feldspar, which comprises 5 to 10 percent of the rock, is preferentially replaced by malachite, whereas fractured quartz grains are preferentially veined with chrysocolla.

Undistorted cell structure is prominent in polished sections of chalcocitized wood. A few residual grains of pyrite in chalcocite show ice-cake texture and suggest that the wood was originally replaced by pyrite and later by chalcocite. Small amounts of covellite replace chalcocite to form rim texture.

Jemez Springs district

The copper deposits at the Spanish Queen mines (deposits Nos. 6 and 7) in the Jemez Springs district, on the east flank of the Sierra Naciemiento uplift, are in the Abo formation of Permian age. The Abo at this locality is a yellow to reddish-brown, medium-grained, massive, fluvial, arkosic sandstone that contains several carbonaceous shale layers as much as 4 inches thick and a small quantity of carbonized wood fragments. Chalcocite, malachite, and azurite are associated with the carbonaceous shale and carbonized wood. Selected pieces of the most radioactive carbonized plant remains from the easternmost mine contain as much as 0.01 percent uranium. Radon has accumulated in the west mine.

A radioactive travertine has been deposited around Jemez Springs, 5.7 miles upstream from the Spanish Queen mines. No uranium was detected in the travertine by chemical analyses and, accordingly, it is believed that the radioactivity is caused by radium.

Zuni Mountain and Scholle districts

The copper minerals in the Zuni Mountain district in Valencia County (deposits Nos. 13, 14, and 15) and the Scholle district in Torrance County (deposits Nos. 17 and 18) are also in the Abo formation. Copper minerals in these districts are localized by carbonized wood fragments and are present along the contacts between gray shale and arkosic sandstone beds. The woody material is slightly radioactive.

Pintada-Pastura district

The deposits at the Guadalupe mine and the Pintada lode in the Pintada-Pastura district, Guadalupe County, are in the San Andres limestone member of the Chupadera formation of Permian age and the Santa Rosa formation of Triassic age. The Guadalupe mine (deposit No. 9), is in a structural depression which Read [1] attributes to subsidence resulting from solution of evaporites in the underlying San Andres limestone member. Copper sulfides partly replace carbonized wood and are disseminated through the Santa Rosa sandstone. Patches of massive sandstone beds are silicified and impregnated with black manganese oxides. Malachite forms botryoidal surfaces along cracks and joints and is disseminated in the sandstone.

[1] Read, C. B., personal communication.

The Pintada Lode (deposit No. 8), near San Ignacio in Guadalupe County, is in the San Andres member of the Chupadera formation. The copper minerals, chalcocite and secondary carbonates and silicates, are in a calcareous, fine-grained, light-gray sandstone. The chalcocite occurs as tiny, intergranular grains; the secondary copper carbonates and silicates occur along bedding planes, as fracture fillings, as disseminations in the sandstone, and in association with stringers of gypsum. No carbonaceous material was observed at this prospect.

Tecolote district

Only one small prospect, the Bonanga (?) (deposit No. 10), was located in the Tecolote district near Las Vegas. Small patches of malachite are in the Permian arkosic sandstone at this locality. No abnormal radioactivity was detected.

Guadalupita district

A copper-uranium-bearing black shale (deposit No. 12) of Permian age, 2 to 3 miles south of Guadalupita on Coyote Creek, contains 2 percent copper and 0.01 percent uranium. The abnormal radioactivity of the shale was first discovered in 1951 by Charles B. Read and George O. Bachman, both of the Geological Survey. The shale is about 5 feet thick, dips about 90°, is non-marine, and is overlain and underlain by arkosic sandstones of Permian age. Chalcocite, pyrite, and malachite are the most abundant minerals. The shale is a potential source of commercial copper and uranium. If it could be mined for copper, the uranium might be recovered as a byproduct of the copper. These deposits will be described more fully by Bachman and Read in Trace Elements Memorandum Report 435, to be submitted shortly.

San Acacia district

A deposit near San Acacia (No. 16, table 1) in shear zones in volcanic rocks, contains small quantities of torbernite (?) and carnotite (?), together with secondary copper minerals, calcite and quartz. One sample selected from the dump material contained 0.026 percent uranium.

Colorado

The Cashin mine

The Cashin mine (deposit No. 19) in Montrose County consists mainly of a 3,000-foot tunnel along a mineralized brecciated zone of vertical or near vertical fractures in cross-bedded, massive Wingate sandstone of Jurassic age. The original ore body, now mined out, was 1 to 20 feet wide and contained argentiferous copper sulfides. Chalcocite, azurite, malachite, blue copper sulfate, and black manganese oxides coat the walls of the tunnel. The copper minerals are concentrated mostly along the fractures but, in places they are also concentrated along bedding planes in the more porous unfractured sandstone. The presence of a heavy coating of copper salts on the walls and roof of the tunnel illustrates the effects of recent solution and redeposition. No abnormal radioactivity was detected in the tunnel. The deposit is probably of hydrothermal origin.

Utah

The copper and uranium deposits that were examined in Utah include the Big Indian mine 5 miles south of La Sal, two small copper prospects in the Capitol Reef area near Torrey, and five deposits of uraniferous asphaltites along the west side of the San Rafael Swell in Emery County. A brief description of these deposits follows.

The Big Indian mine

The Big Indian mine, 5.2 miles south of La Sal (deposit No. 20), is developed by an open cut about 200 feet long, 100 feet wide, and 20 to 30 feet deep. The abandoned shafts are not accessible. The deposit is in sandstone beds of the Dakota (?) formation. The copper-bearing sandstone is about 20 feet thick. It is a porous, coarse- to medium-grained sandstone that is overlain and underlain by dark-gray carbonaceous shale. The deposit is not abnormally radioactive.

The deposit is in a northwest-trending fault zone. The movement along this fault zone has resulted in a series of fractures in the sandstone that are exposed in the open pit. Copper carbonates with small amounts of chalcocite and chrysocolla are concentrated in fractures and along bedding planes and are disseminated through the sandstone. Manganese oxide stains give the rock a black and white speckled appearance. Small amounts of carbonaceous material are scattered through the sandstone and in some places copper minerals have been deposited around lenses of this material.

Although the genesis of the deposit is not clear because most of the ore has been mined out, the occurrence of the copper minerals along fractures and faults and the absence of appreciable amounts of carbonaceous material suggest that this deposit may be of hydrothermal origin. This conclusion was reached previously by Read,[1] who suggested a telethermal origin for this deposit.

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[1] Read, C. B., Personal communication.

Torrey district

Two copper prospects were examined in the Torrey district in Wayne County, Utah. No abnormal radioactivity was detected and very little copper was observed at either prospect. Deposit No. 21 is in siltstones and limestone of the Moenkopi formation of Triassic age. The workings of the deposit consist of an inclined adit and a tunnel, both of which are caved near the portals. Ten feet of flaggy, calcareous siltstone, overlain by 10 to 12 feet of well-bedded, vuggy limestone are exposed in the adit. A weathered zone about 6 inches thick separates these two units. Malachite and azurite are concentrated mostly in one 18-inch bed of vuggy limestone. Secondary copper minerals occur spottily on the walls of the shaft.

Large boulders of vuggy, recrystallized, and brecciated limestone on the dump suggest that this deposit was localized in fractures or along a fault zone, and perhaps was formed by hydrothermal solutions.

Deposit No. 22 contains small amounts of copper carbonate stain on a buff sandstone of the Moenkopi formation. The prospect has been developed by an open cut, 30 feet long, 30 feet wide, and 7 feet deep; and by a 25-foot shaft in the bottom of the pit. No copper minerals were observed in the bottom of the shaft and no abnormal radioactivity was detected at the prospect.

The San Rafael Swell district

The San Rafael Swell is a northeast-trending elongate dome that is about 70 miles long and 25 to 30 miles wide. Sedimentary rocks of Permian age are exposed along the crest of this anticline and progressively younger rocks ranging from Triassic to upper Cretaceous in age are exposed along the flanks. Five uranium deposits along this anticline were examined by the writers. The deposits consist of uraniferous asphaltites locally disseminated through the Shinarump conglomerate. Although this investigation of the San Rafael Swell district is incomplete, the data that were obtained are included in this report because it might aid in current and future studies.

Uranium-bearing hydrocarbons with physical characteristics similar to those along the west flank of the San Rafael Swell have been known by a variety of names including anthraxolite, carburan, huminite, and thucholite. In 1928 Ellsworth [1] gave the name thucholite to a uranium- and thorium-bearing hydrocarbon from a pegmatite in the Parry Sound district in Ontario. Since that time the term thucholite has been generally used to include all uranium-bearing hydrocarbons. By custom, however, the term thucholite seems to have a genetic conotation implying that the material is of hydrothermal origin. Inasmuch as the writers are not prepared to assign the uraniferous asphaltites of the San Rafael Swell to a specific type of deposit, the term will not be used in this report with reference to these particular deposits.

In the San Rafael Swell area uranium and a small amount of copper are associated with hard, lustrous asphaltite pellets, stringers, and small irregular masses, and to a lesser extent with carbonized plant material. This uranium-bearing carbonaceous material is disseminated in the Shinarump conglomerate which in this area is predominantly composed of poorly sorted, silty, conglomeratic sandstone.

The Lone Tree deposit (No. 27) is in the lower part of the Shinarump conglomerate. Uranium is associated with hard, lustrous pellets of asphaltite as much as 1/2 inch in diameter, and with discontinuous stringers of asphaltite as much as 1 inch thick. These pellets and stringers are contained in the more porous parts of a 3-foot bed of coarse-grained argillaceous sandstone and conglomerate. A small fault with about 3 feet of displacement appears to define one boundary of the deposit. The asphaltite-bearing bed is overlain and underlain by compact gray shale. Individual asphaltite pellets contain as much as 3.28 percent uranium and spectrographically detectable amounts of Ag, As, Co, Ni, Cr, Cu, Mo, V (table 2, Nos. 14 and 16); the overlying shale bed contains 0.015 percent equivalent uranium, and the underlying shale bed contains 0.008 percent equivalent uranium.

Polished sections of asphaltite pellets from the Lone Tree group show two types of hydrocarbon: a gray, isotropic part that is fractured, possibly as a result of contraction and oxidation, during the last stages of volatilization and a later, much less abundant, light-gray hydrocarbon that fills some of the fractures. Other fractures are filled with a non-opaque gangue mineral, probably gypsum. Pyrite, the most abundant metallic mineral in the section, occurs as small, irregular grains and patches in the older hydrocarbon. Examination of the sections with oil immersion lens (X 560) reveals tiny grains of chalcopyrite and a few grains of a white metallic mineral that may be arsenopyrite. Spectrographic analyses indicate that 0.1 to 1.0 percent arsenic (table 2, Nos. 14 and 16) is present in the asphaltite pellets.

At this locality the Shinarump conglomerate is an argillaceous conglomeratic sandstone that contains shale fragments and uraniferous asphaltite pellets and stringers. The essential constituents of the rock are poorly sorted, angular to sub-rounded quartz grains, pieces of porphyritic volcanic flow rock as much as 1/2 inch in diameter, and gray shale fragments that were probably incorporated from the underlying gray shale bed. These constituents are in a clay matrix that turns blue after application of benzidine. This suggests the presence of some montmorillonitic material. The larger quartz grains are subrounded and many of them are heavily fractured; others are mosaic patches of sutured grains. Patches of secondary calcite surround quartz grains and are partially replaced along cleavage planes by iron oxides.

Visible secondary uranium minerals are relatively rare. A yellow uranium mineral, tentatively identified as paraschoepite, occurs as patches along bedding planes, as discontinuous stringers in the clay matrix, and as a replacement of calcite. Inasmuch as the paraschoepite (?) is obviously the last mineral to have formed, it seems evident that it was deposited from solutions that leached the uraniferous asphaltite.

Reyner _/ examined the Lone Tree deposit in 1950 and estimated that it contained no more than

_/ Reyner, M. L., Preliminary report on some uranium deposits along the west side of the San Rafael Swell, Emery County, Utah: U. S. Atomic Energy Commission, RMO 673, October 1950.

100 tons of 0.20 percent uranium oxide. This estimate, however, was largely based on samples obtained from an adit 18 feet long and 10 feet wide.

The Dalton group (deposit No. 26) is about 1 mile south of the Lone Tree group and about 20 feet above the base of the Shinarump conglomerate. Gray shale is exposed in the roof of three short adits and this is underlain by lenticular alternating fine- to medium-grained sandstone and pebble conglomerate. Uraniferous asphaltite in the form of grains, blebs, stringers, elongate pods, and fracture fillings occurs through a thickness of about 3 feet and is particularly abundant in the conglomeratic parts of the sandstone. Radioactivity is apparently restricted to the asphaltite which contains as much as 5.0 percent equivalent uranium and 1.34 percent uranium. Individual grains are as much as 1/2 inch in diameter and pods and lenses are as much as 20 inches long and 4 inches thick. Some of the pods and lenses have a center core of granular pyrite and in other pods and lenses the pyrite is disseminated but appears to replace the asphaltite.

Polished sections of the uraniferous asphaltite show that pyrite invades the hydrocarbon and replaces the quartz grains producing embayed, irregular grains. Most of the pyrite masses have exploding bomb texture and are surrounded by gangue minerals, probably carbonates. Minute blebs of chalcopyrite, chalcocite, and covellite can be detected in the asphaltite with the oil immersion lens (X 560). Covellite chiefly occurs in tiny discontinuous fractures in the asphaltite.

A similar association of uranium with hard, lustrous asphaltite occurs at the Ronnie, Jerry, and Frenchy mine (deposit No. 23) in SW1/4 sec. 20, T. 23 S., R. 10 E. Small, vitreous, uraniferous asphaltite grains, 0.5 to 1.0 mm in diameter, are disseminated through a thickness of about 25 feet of gray sandstone in the lower part of the Shinarump formation. The asphaltic sandstone is overlain by a nonradioactive conglomerate that contains numerous clay layers. The mine workings consist of a short tunnel about 7 feet high that has been driven into the asphaltic sandstone. In addition to uraniferous asphaltite, numerous fossil logs with silicified centers and radioactive, carbonized rims as much as 15 inches in diameter are imbedded in the lower part of the sandstone. The carbonized material in these logs contains from 0.1 to 1.0 percent uranium. A 7-foot channel sample of the sandstone contained 0.03 percent uranium and a concentrate of the asphaltite grains contained 0.30 percent equivalent uranium. Spectrographic analyses of the asphaltite concentrate are given in table 2, No. 18.

Above the entrance to the tunnel, a recently formed deposit of pink zinc-nickel-cobalt sulfate coats the nearly vertical sandstone cliff. The metals probably were derived from the asphaltite and carbonized wood.

Polished sections of the asphaltic sandstone show minute grains of metallic minerals, chiefly chalcopyrite and cobalt-nickel minerals, in quartz grains, along fractures, and along the contact of asphaltite and quartz. These minerals were not observed in the hydrocarbon.

Pyrite with cell, ice cake, and exploding bomb textures is the chief metallic mineral observed in polished sections of the carbonized wood. Minute blebs of chalcopyrite are scattered at random in the wood.

The host rock is an argillaceous, medium-grained, gray, asphaltic sandstone. Quartz grains are strongly fractured. Malachite, azurite, metatorbernite, gypsum, and chalcedonic quartz are the secondary minerals.

About 1/2 mile south of the Ronnie, Jerry, and Frenchy mine in the SW1/4 sec. 20, T. 23 S., R. 10 E., 1,000 feet of uranium- and copper-bearing Shinarump sandstone and shale has been exposed by bulldozer exploration (deposit No. 24). The exposed beds consist of red clay and shale, at the base, overlain by the following rocks: 4 feet of radioactive asphaltic sandstone; 5 to 15 feet of gray, green, and red shales; 5 feet of brown pebble conglomerate; as much as 6 feet of lenticular, cross-bedded, soft white sandstone; and 5 to 15 feet of conglomeratic sandstone. The highest degree of radioactivity occurs in the asphaltic sandstone in a rather persistent 4-inch thick zone of sooty fossil plant fragments. A few isolated woody fragments are strongly radioactive.

At the time of the writers' examination of the deposit, no minable thickness of ore had been exposed.

Ground waters have redistributed copper and uranium as copper carbonates and metatorbernite on joints and fractures in the sandstone and the underlying shale beds. Two small adits, one 5 feet long and the other 15 feet long, have been excavated in the shale. The radioactivity in these adits averages between 0.10 and 0.15 milleroentgens per hour.

Bornite, chalcopyrite, covellite, and chalcocite were observed in a polished section of uraniferous black material which is either asphaltite or carbonized wood. Bornite and chalcopyrite show a texture that may be due either to exsolution or to replacement of bornite by chalcopyrite along preferred crystallographic directions. The latter interpretation is favored. Covellite preferentially replaces bornite; chalcocite replaces chalcopyrite and bornite, and is partly replaced along the margins by covellite.

Deposit No. 25, an operating mine in the NE1/4 sec. 31, T. 23 S., R. 10 E., is one of the most promising deposits examined. The mine workings consist of a 50-foot tunnel, 6 to 15 feet wide, in the lower part of the Shinarump conglomerate. An 8-foot channel sample cut in the tunnel contained 0.31 percent uranium. One selected sample of carbonaceous material that is either asphaltite or carbonized wood contained 1.2 percent equivalent uranium. Abnormally high radioactivity is associated with numerous 1/16 to 1/8 inch thick layers of carbonized plant remains and with disseminated asphaltite grains in light-gray, medium-grained sandstone. No secondary uranium minerals were identified in the mine but small amounts of yellow and blue-green stain and copper carbonates are present near and at the base of surface exposures of the Shinarump.

The Shinarump conglomerate is about 150 feet thick at this locality and consists of alternating lenticular beds of sandstone and conglomerate. The lower 1 to 15 feet of the exposed beds is abnormally radioactive for about 400 feet along the outcrop. The radioactivity of these rocks ranges from 0.15 to 20.0 milleroentgens per hour.

Source of the uranium in the asphaltites. -- It has been suggested that the rounded uraniferous asphaltite pellets in the San Rafael Swell are detrital and were eroded from a previously existing but unknown uraniferous asphaltite deposit.[/] The conclusion was reasonable because any alternative to a detrital hypotheses would require a rather complicated mechanism by which the cavities could have formed prior to the introduction of hydrocarbons. Nevertheless, the writers consider that the following evidence contradicts the view that the asphaltite grains are detrital:

_/ Gilluly, James, and Reeside, J. B., Jr., Sedimentary rocks of the San Rafael Swell and some adjacent areas in eastern Utah: U. S. Geol. Survey, Prof. Paper 150-D, pp. 93-94, 1927 (1928).

_/ Hess, F. L., Uranium-bearing asphaltite sediments of Utah: Ore deposits of the western states (Lindgren Volume): Am. Inst. Min. Met. Eng., p. 458, 1933.

_/ Wyant, Donald G., Uranium deposits at Shinarump mesa and some adjacent areas, Temple Mountain district, Emery County, Utah: U. S. Geol. Survey Trace Elements Investigations Rept. 51 (in preparation).

(1) Although much of the uraniferous asphaltite is in the form of rounded grains, some of it is in the form of stringers, elongate pods, lenses, heavy stains, and irregular masses that conform to the shape of the sand grains.

(2) Some of the rounded grains have a botryoidal surface. Such a surface is inconsistent with a detrital hypothesis.

If the hydrocarbons are epigenetic, as the writers believe, either of the following two general hypotheses can be postulated to account for the concentration of uranium in the asphaltite. (1) The uranium was present in the Shinarump conglomerate before the hydrocarbons migrated into it. When the hydrocarbons did come in contact with the uranium minerals, the uranium was transferred into the hydrocarbon fluids. The hydrocarbons most closely associated with the uranium was then polymerized by alpha particles to a high polymer. When the anticline was breeched by erosion, the unpolymerized liquid and gaseous hydrocarbons escaped, leaving the immobile solid uraniferous hydrocarbons behind. (2) The uranium and other metals were transported in solution by migrating petroleum from more distant uranium deposits including the petroleum source bed.

A discussion of these hypotheses follows: the hypothesis that thucholite results when alpha particles polymerize hydrocarbons that have been introduced into a uraniferous deposit has apparently received considerable support from Ellsworth, _/ Spence, _/ and Davidson and Bowie. _/ After a study of the

_/ Ellsworth, H. V., Thucholite, a remarkable primary carbon mineral from the vicinity of Parry Sound, Ontario: Am. Mineralogist, vol. 13, pp. 419-441, 1928.

_/ Spence, Hugh S., A remarkable occurrence of thucholite and oil in a pegmatite dike, Parry Sound district, Ontario: Am. Min., vol. 15, no. 11, pp. 499-520, 1932.

_/ Davidson, C. F., and Bowie, S. H. U., On thucholite and related hydrocarbon uraninite complexes: Great Britain Geol. Survey Bull. 3, pp. 1-9, 1951.

thucholite-bearing pegmatites in the Parry Sound district of Ontario, Ellsworth concluded that both the uranium and the hydrocarbons were of hydrothermal origin. He believed that alpha radiation from uraninite crystals polymerized gaseous hydrocarbons and that the higher polymer replaced the uraninite crystals resulting in thucholite in the form of uraninite pseudomorphs. In a discussion of a similar deposit in the same district, Spence noted that the thucholite was in the form of cubic crystals, irregular masses, nodules, pellets, minute veinlets, and is associated with a "petroleum-like" oil. He differed somewhat from Ellsworth in concluding that the thucholite probably "is not a primary constituent of the pegmatite" but was formed later by the replacement of uranium by carbon and the effects of radiation on oil that had migrated into the pegmatite.

After a study of the thucholite in the Rand conglomerate of the South African goldfields, Davidson and Bowie (p. 1) concluded "that thucholite is not a true mineral but a complex of uraninite with hydrocarbon of hydrothermal origin, resulting from a polymerization or condensation of hydrocarbon fluids effected by radiations from uranium ore." They believe that the Rand thucholite represents a replacement of mesothermal pitchblende by late hydrothermal hydrocarbons.

Thus, the investigators of other uranium-bearing hydrocarbon deposits have concluded that the first step in the formation of thucholite is the presence of uranium minerals and that the second step is the introduction of hydrocarbons (gaseous in the opinion of Ellsworth, and of Davidson and Bowie, and fluid in the opinion of Spence) around a uranium mineral. Although a hydrothermal origin for both the uranium and hydrocarbons has been postulated for most of the deposits studied by the authors referred to above, the effects would be the same if uranium and hydrocarbons of any origin were brought together.

The asphaltite pellets in the Lone Tree deposit of the San Rafael Swell are as much as 1/2 inch in diameter. The presence of such large grains can be interpreted to mean that a uranium mineral formerly occupied the space now filled with the asphaltite pellet, and that the hydrocarbon replaced the uranium, possibly in much the same manner as suggested by Ellsworth, Spence, Davidson, and Bowie. Autoradiographs, however, indicate that the radioactive elements are homogeneously distributed throughout the asphaltite and this seems to contradict the view that hydrocarbon gases or fluids were polymerized around a radioactive nucleus.

The San Rafael Swell was a structure ideally suited to the accumulation of petroleum compounds before it was breeched by erosion. Within this structure the uraniferous asphaltites are in the Shinarump conglomerate, a stratigraphic unit well known for the many uranium deposits that occur within its boundaries. If we accept the prerequisite that hydrocarbons must be brought into an area affected by alpha radiation before a thucholite-type deposit can be formed, it is not suprising that uraniferous hydrocarbons are present along the flanks of the San Rafael Swell.

The hypothesis that the uranium and other metals were transported by fluid hydrocarbons is strongly supported by the presence of the same suite of metals in the asphaltites as are present in crude oils, gilsonite, and black shales. Spectrographic analyses tabulated in table 2 show that, so far as known, all of these materials contain rather consistent quantities of vanadium, nickel, copper, cobalt, molybdenum, lead, zinc, and chromium.

Numerous other analyses of crude oils and the ash of crude oils indicate that vanadium, nickel, and copper are concentrated in the asphaltic portion of the crudes. Analyses of 17 oils from the Second Baku and two oils from the Apsheron Peninsula show that vanadium, nickel, and copper oxides comprise 50 to 90 percent of the ash. _/ It is noteworthy that these metals are equally high in the ash of filtered oils,

_/ Gulyaeva, L. A., Itkina, E. S., and Romm, I. I., Vanadium, nickel, and copper in petroleum of the Urals and Volga region: C. R. (Doklady) Acad. Sci., vol. 32, no. 6, pp. 406-409, 1941.

suggesting that they are present as organic compounds and are not present as mechanical admixtures. Romm _/ demonstrated that the vanadium content of sedimentary rocks of the Ural-Volga region was

_/ Romm, I. I., On the content of vanadium in solid bituminous rocks of the Urals and the near Volga area: C. R. (Doklady) Acad. Sci., vol. 51, no. 1, pp. 47-50, 1946.

roughly proportional to the bitumen content of the rocks. Bituminous limestones and dolomites contained 18 to 119 ppm vanadium; non-bituminous limestones and dolomites contained only a trace or no vanadium.

Dunstan reported that the ash of crude oil from Maidon-i-Naftun, Persia, contained 5.03 percent

/ Dunstan, A. E., The crude oil of Maidon-i-Naftun: Jour. Inst. Pet. Technologists, vol. 10, pp. 51-82, London, 1924.

vanadium pentoxide and 2.70 percent nickel oxide, and that 15 grams of ash showed two-thirds as much radioactivity as one gram of uranium-nitrate.

Unkovskaya has found that waters related to petroleum are 5,000 times higher in uranium than

/ Unkovskaya, P., C. R. Acad. of Science URSS, 1940, vol. 29, p. 380.

is sea water and petroleum itself is 50,000 times higher.

A crude oil extract from the Spergen limestone collected in St. Genevieve County, Missouri, contains between 0.01 and 0.1 percent uranium (table 2, No. 12). A petroliferous limestone in the Uinta formation in northeastern Utah contains about 0.02 percent uranium. Uraniferous asphaltites that are associated with structures favorable for the accumulation of oil are known in several places within the United States, including the deposits along the San Rafael Swell, and in limestones and dolomites in the Texas Panhandle helium-bearing natural gas field. Many black marine shales, commonly considered to be the source beds for much of our petroleum, contain significant quantities of uranium.

The known data, therefore, clearly indicate that appreciable quantities of the metallic constituents of the San Rafael Swell asphaltites, including uranium, are present in heavy fractions of petroleum, asphalt, and bituminous shales perhaps, as suggested by Rankama and Sahama, in the form of metal-

/Rankama, K., and Sahama, Th. G., Geochemistry: Univ. of Chicago Press, 1949.

organic-porphyrin compounds. This suggests that most, if not all, of the metals in the asphaltite of the San Rafael Swell area were concentrated from petroleum.

The high concentration of metals in the asphaltites may have been the result of natural fractionation caused by pressure, temperature, and porosity differences, perhaps resulting in the concentration of the heavier fractions in some parts of the reservoir. After the reservoir was exposed by erosion all of the lighter fractions would have been flushed out and the immobilized, heavier, metal-bearing fractions would have been left behind.

If future investigations show that the metals normally found in hydrocarbons have a genetic relationship with crude oil and its source beds, new methods and techniques might be developed that would assist in the discovery of uranium deposits.

Idaho

Two copper prospects were examined in southeastern Idaho; (1) the Evening Star claim (deposit No. 28), and (2) the Bonneville claim (deposit No. 29). The Evening Star claim is 7 miles east of Montpelier along U. S. Highway 89. Malachite and azurite, the principal copper minerals in this deposit are associated with carbonaceous material in a sandstone bed in the Ankareh shale of Triassic age. One adit, 20 feet long, 4 feet wide, and 4 feet deep, follows the bed, which dips 25 degrees and strikes S. 80° W. A trench extends for 20 feet in front of the portal.

The mineralized bed is a 4-foot thick, medium-grained, arkosic, well-indurated quartz sandstone. It weathers dull brown but fresh surfaces are light gray. Scattered fragments of carbonized plant material have been crushed into thin films parallel to the bedding planes. Pieces of carbonaceous material selected for their radioactivity contain 0.003 percent uranium. Most of the copper minerals are localized along the bedding planes by the residual plant material but small amounts of malachite are disseminated through the sandstone. The prospect probably contains less than 1 percent copper.

The Bonneville (?) prospect west of Montpelier (deposit No. 29), also is a submarginal copper deposit and is not detectably radioactive. The underground workings are inaccessible. The mine dump, about 100 feet long and 20 to 30 feet wide, consists chiefly of light-gray, well-cemented, Ankareh (?) sandstone with small amounts of copper carbonate stain. Fragments of carbonized plant material are disseminated through the rock. The beds strike north and dip 57° E.

Wyoming

The Old Copper mine (deposit No. 30), 30 miles northeast of Cokeville, was the only copper prospect examined by the writers in Wyoming. The mine workings are inaccessible and the dump material was not detectably radioactive. The lessee, Mr. Dan S. Shickich of Kemmerer, Wyo., reported that a 600-foot tunnel and 125-foot shaft constitute the mine workings.

The dump material is composed of light-gray, well-cemented sandstone. A few pieces of sandstone are stained with malachite and one specimen contained chalcopyrite, covellite, and chalcocite. No carbonaceous material was observed.

CONCLUSIONS

Variation in the factors that controlled the deposition of copper and uranium minerals apparently has resulted in two general types of deposits: (1) Deposits in which deposition of the ore minerals was controlled by permeability and carbonaceous material, and (2) deposits in which the deposition of the minerals was structurally controlled.

The copper and uranium in many deposits have been localized by carbonaceous materials, including carbonized plants and hydrocarbons. Copper has been re-distributed as carbonates along joints, fractures, and disseminated in sandstones adjacent to carbonaceous material. Most of the enclosing sandstones are light in color, porous, micaceous, often arkosic, and most of the areas of mineralization are near large folds or orogenic belts. In contrast, the structurally controlled deposits are localized along faults, shear zones, and associated joints and fractures where carbonaceous material is not present. The Cashin mine (No. 19) represents this type of deposit.

The source of the uranium in the uraniferous asphaltites is questionable but it either had been concentrated at its present point of localization before the introduction of the hydrocarbons or it was transported by the hydrocarbons from an unknown source. On the basis of the available information the latter hypothesis is preferred by the writers.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TRACE ELEMENTS INVESTIGATION
REPORT 232

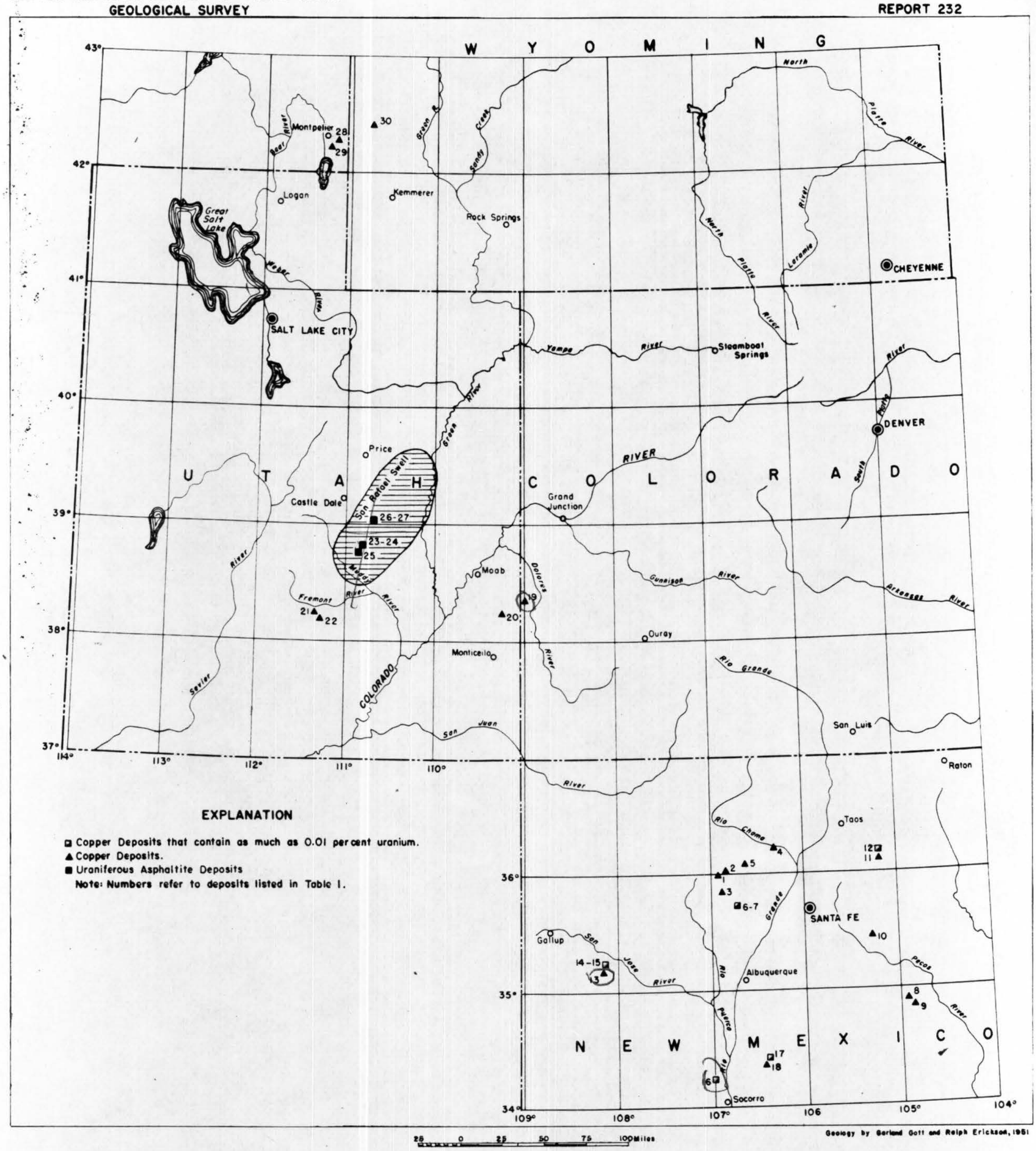

Fig. 1. SOME COPPER AND URANIUM DEPOSITS IN PARTS OF NEW MEXICO, COLORADO, UTAH, AND WYOMING.

Table 1.--Radiometric and chemical analyses of samples from some uranium and copper deposits in sandstones

Number	District, mine name, State	Location	Formation	Type of sample	Radioactivity: Milleroentgens per hour 1/ (maximum)	Radioactivity: Equivalent uranium (percent)	Chemical analyses (percent): U	Chemical analyses (percent): V_2O_5	Chemical analyses (percent): Cu	Serial number	Mineralogy	Remarks
1	Cuba district, Copper City mines, N. Mex.	C. NW1/4 sec. 1, T. 20 N., R. 1 W.	Poleo (Triassic)	--------	0.07	--------	----	----	----	-------	Chalcocite, covellite, pyrite, malachite, azurite, chrysocolla, cuprite(?), hematite.	Copper minerals are concentrrated in fractures, in sandstone marginal to fractures, in porous light-gray sandstone along bedding planes, around and in carbonized wood fragments. Some of the wood is slightly radioactive. In thin section, silicic feldspar is preferentially attacked by malachite whereas fractured quartz grains are preferentially veined with chrysocolla. Chalcocite occurs chiefly in the interstices between quartz grains, fills and replaces fractures across quartz and feldspar grains, and replaces wood preserving undeformed cell structure. Wood cells originally filled and replaced by pyrite.
2	Cuba district, Eureka mines, N. Mex.	NE1/4 sec. 32, T. 21 N., R. 1 E., 3/4 mile NE of Eureka Lodge which is on State highway 126.	do.	--------	0.04	-------	----	----	----	-------	do.	The mine developement consists of about 400 feet of underground workings in nearly flat-lying, light-gray sandstone. Repeated cycles of sedimentation are represented. The cycles begin with coarse conglomerate in which carbonaceous material is sparsely present and range through progressively finer grained sandstones, some of which contain carbonaceous material. Two factors appear to have influenced deposition of the copper minerals: (1) porosity, and (2) presence of carbonaceous material. Copper is more concentrated in the highly porous, slightly carbonaceous conglomerate than it is in the more carbonaceous but less porous sandstone.
3	Cuba district, San Miguel mine, N. Mex.	NE1/4 sec. 24, T.19 N., R.1 W.	do.	--------	0.03	--------	----	----	----	--------	Chalcocite, covellite, pyrite, sphalerite(?), malachite, azurite, chrysocolla.	Extensive underground workings are abandoned and inaccessible. Plant fragments have been replaced by chalcocite and later oxidized to malachite and azurite. The copper carbonates also fill fractures and in some places are disseminated in non-carbonaceous sandstone. Secondary copper minerals fill fractures and replace quartz and feldspar grains. Iron-rich sphalerite(?) has mutual boundary texture with chalcocite; both contain relict grains of pyrite.
4	Abiquiu district, Cobre Basin mines, N. Mex.	About 7 miles NE of Abiquiu, center of W1/2, of T.24 N., R. 6 E.	do.	--------	0.04	-------	----	----	----	-------	Chalcocite, malachite, azurite.	The light gray Poleo sandstone has been prospected by at least six short tunnels on the east side of Copper Canyon. Copper mineralization is in carbonaceous sandy clay, light gray sandstone, and as halos surrounding clay galls. Most of the carbonaceous material is in the form of carbonized wood.
5	Gallina district, near Jarossa, N. Mex.	Southern part of T. 22 N., R.3 E.	do.	--------	0.02	-------	----	----	----	------	Chalcocite, covellite malachite.	Copper-stained sandstone has been exposed during road construction. The copper minerals are associated with carbonized wood and the carbonates are also disseminated in non-carbonaceous, arkosic sandstone. The chalcocite and malachite fill fractures in quartz grains.
6	Jemez Springs district, Spanish Queen mine (east), N. Mex.	4 miles south of Jemez Springs. (Unsurveyed)	Abo (Permian)	Slightly radioactive carbonized wood.	0.3	0.01	0.01	0.03	5.45	52320	Chalcocite, covellite, pyrite, malachite, azurite.	The principal workings consist of a tunnel about 100 feet long in nearly flat-lying, medium-grained, iron-stained, arkosic sandstone. Carbonized wood is in part chalcocitized. Slightly radioactive beds as much as one inch thick contain abundant malachite and some azurite. The quartz grains are fractured and veined with malachite. Malachite and azurite also coat and impregnate layers of muscovite.
7	Jemez Springs district, Spanish Queen mine (west), N. Mex.	do.	do.	--------	0.2	-------	----	----	----	------	do.	An east-west tunnel and one cross-cut are in massive, buff, argillaceous, arkosic sandstone that contains gray carbonaceous shale beds up to four inches thick. Copper carbonates fill open fractures, coat the tunnel walls, and are associated with carbonized wood. The radioactivity of one small patch of carbonized plant fragments near the portal of the mine is 0.2 milleroentgens per hour. The radioactivity caused by radon within the mine is 0.1 milleroentgens per hour. No uranium minerals were recognized.
8	Pintada-Pastura district, Pintada lode, N. Mex.	NW1/4 sec. 14, T.8 N., R.19 E., about 3 miles east of the village of San Ignacio.	Chupedera (Permian)	--------	0.04	-------	----	----	----	-------	Chalcocite, malachite, azurite, chrysocolla.	Copper has been mined from a roughly elliptical-shaped pit about 100 feet long, 50 feet wide, and 10 to 15 feet deep. The copper minerals are disseminated through the sandstone and are present in open fractures. The sandstone is much finer-grained than it is at any of the other localities examined. Chalcocite fills the interstices between quartz grains and partly replaces quartz.
9	Pintada-Pastura district, Guadalupe mine, N. Mex.	Sec. 6, T.7 N., R.20 E. Approximately 15 miles southwest of Santa Rosa.	Santa Rosa (Triassic)	Mineralized sandstone.	0.03	0.000	0.000	0.02	0.22	52327	Chalcocite, covellite, pyrite, malachite, azurite, chrysocolla, secondary phosphate.	The mine workings consist of a series of open pits 15 to 20 feet deep in a deposit about 1500 feet long. The copper minerals are in a well-bedded to massive sandstone. Steeply dipping and broken beds have been attributed by C. B. Read to slumping as a result of removal of underlying Permian evaporites. The copper minerals occur as disseminations parallel to bedding planes, as botryoidal masses in open fractures, and in association with carbonized plant fragments. The sandstone is silicified and the feldspars are sericitized. Chalcocite replaces pyritized wood, occurs in intergranular spaces in the sandstone, and is in veinlets cutting quartz grains. A secondary phosphate of the apatite group fills pore spaces between quartz grains.

1/ Field determination made with a Nuclear Corporation Survey Meter equipped with a six-inch gamma-beta probe.

Table 1.--Radiometric and chemical analyses of samples from some uranium and copper deposits in sandstones--Continued

Number	District, mine name, State	Location	Formation	Type of sample	Radioactivity: Milleroentgens per hour 1/ (maximum)	Radioactivity: Equivalent uranium (percent)	Chemical analyses (percent): U	Chemical analyses (percent): V_2O_5	Chemical analyses (percent): Cu	Serial number	Mineralogy	Remarks
10	Tecolote district, Bonanza(?) prospect, N. Mex.	2-1/2 miles S-SW of Tecolote Mountain; on NW slope of mesa known as Burro Hill; 8 miles SW of Las Vegas.	(Permian)	--------	0.02	--------	----	----	----	-------	Malachite.	Malachite stains a Permian arkosic sandstone at one small prospect.
11	Coyote Creek district, N. Mex.	2-3 miles south of Guadalupita on west side of Coyote Creek. (Unsurveyed)	Sangre de Christo (Permian)	Manganese-stained, copper-bearing sandstone.	0.05	0.005	0.001	0.04	2.85	52321	Chalcocite, malachite, azurite.	Five to ten tons of copper ore are near the east side of the road that is parallel to Coyote Creek. The mine from which the ore was transported was not located. The copper minerals are in a porous, medium- to coarse-grained arkosic, Permian sandstone. The copper carbonates are disseminated in the sandstone and apparently are more concentrated in the most porous beds. In thin section, the sandstone has a sutured-mosaic texture. Abundant silicic feldspar grains are strongly sericitized. Chalcocite and malachite preferentially replace feldspar. Malachite coats and impregnates layers of muscovite.
12	do.	do.	do.	Permian black shale.	0.1	0.010	0.009	0.20	2.15	52326	Chalcocite, pyrite, malachite.	Chalcocite and malachite are disseminated in a poorly exposed, five-foot thick, non-bituminous black shale that is overlain and underlain by Permian arkosic sandstones.
13	Zuni Mountain district, N. Mex.	20 miles west of Grants, N. Mex., west side of T.11 N., R.12 W.	(Pre-Cambrian)	--------	0.03	--------	----	----	----	----	Malachite, azurite.	Copper carbonates are in a nearly vertical shear zone that cuts a granite gneiss. The underground workings apparently are extensive, but they are inaccessible.
14	do.	West side of T.11 N., R.12 W.	At the contact of Permian and pre-Cambrian.	--------	0.2	--------	----	----	----	----	Malachite, azurite, chrysocolla, fluorite, calcite.	The contact between a red gneissic granite and the Permian arkose-conglomerate is exposed in a shallow prospect pit. Copper carbonates, fluorite, and calcite occur as fillings in open fractures. The copper minerals also are disseminated through the conglomerate, and are along biotite-rich layers in the granite gneiss.
15	Zuni Mountain district, N. Mex., Mirabel mine.	do.	Abo (Permian)	Mineralized sandstone. Manganese-stained sandstone.	0.15 0.06	0.009 0.004	0.009 0.002	0.02 0.02	4.50 0.32	52322 52323	Chalcocite, malachite, azurite, chrysocolla, hematite.	Two strip pits each about 50 feet long, 25 feet wide, and 10 to 15 feet deep contain secondary copper minerals. These minerals are most abundant in open fractures, in porous arkosic sandstone beds that alternate with impervious unmineralized clay beds, and in thin bands immediately above and below the impervious clay beds. Slightly radioactive material is present in a few thin beds but for the most part the deposit is not radioactive. Quartz and sericitized feldspar grains are veined and replaced by chalcocite and malachite.
16	San Acacia district, N. Mex.	Sec.10, T. 1 S., R. 2 W., 6 miles west of San Acacia.	Andesitic lavas (Tertiary)	Slightly radioactive dump material.	0.2	0.031	0.026	0.03	4.78	52324	Native copper, chalcocite, chrysocolla, malachite, cuprite, torbernite(?), carnotite(?).	The mine workings consist of a shaft that is now filled with water to about the 40-foot level. Carbonate- and copper-bearing rock is on the dump. These minerals are in a brecciated shear zone in an amygdaloidal trachyandesite and are concentrated mostly along the andesite-carbonate contacts. The original flow rock is almost totally replaced by calcite which is cut by stringers of vein quartz.
17	Scholle district, N. Mex.	Sec. 3 or 4, T. 2 N., R. 5 E.	Abo (Permian)	Grab sample from the pit that contains radioactive material.	0.15	0.021	0.014	0.03	0.25	52325	Chalcocite, covellite, malachite, azurite.	The mine is about 1/4 mile south of the railroad in the second canyon east of the Scholle post office. The stripping operations have been on a limited scale but the local inhabitants report that the underground operations were extensive. The copper minerals are associated with radioactive and non-radioactive carbonized wood and are disseminated through the matrix of the sandstone. The sandstone in one shallow pit is radioactive. This material contains carbonized wood and small irregular pellets of lustrous asphaltite. The feldspars are partly altered to sericite and are preferentially replaced along cleavage planes by copper carbonates. Patches of white secondary phosphate locally cement the sandstone.
18	do.	Sec. 3 or 4, T. 2 N., R. 5 E.	do.	--------	0.03	--------	----	----	----	----	Malachite.	The deposit is about 1 mile east of Scholle post office on east side of the highway. Copper carbonate stains joint planes in a massive, flat-lying, brown sandstone that is exposed in several shallow prospect pits.
19	Cashin mine, Colorado.	Near Utah and Colorado boundary and 3-1/2 miles south of Colorado highway 90.	Wingate (Triassic)	--------	0.03	--------	----	----	----	----	Chalcocite, malachite, azurite, copper sulfate.	A tunnel about 3000 feet long is in a nearly vertical breccia zone. The greatest concentration of ore minerals is in the most intensely brecciated part of this zone. The copper minerals were deposited in the open fractures and in the porous sandstone near the fractures. The effects of recent solution and re-deposition are apparent throughout the mine. This deposit is probably of hydrothermal origin.
20	Big Indian mine, Utah.	T.29 S., R.24 E., 5.2 miles south of La Sal, Utah.	Dakota (Cretaceous)	--------	0.02-0.03	--------	----	----	----	----	Chalcocite, malachite, azurite.	An open cut approximately 200 feet long, 100 feet wide, and 20 to 30 feet deep constitutes the accessible workings. The deposit is in Dakota sandstone and is on the northeast side of a northwest-trending fault. Copper occurs along fractures and joints, and also is disseminated in the sandstone. The most conspicuous minerals are malachite and azurite but some chalcocite is present.
21	Torrey district, Utah.	Approximately 11 miles east of Teasdale, sec.31(?), T.29 S., R.6 E.	Moenkopi (Triassic).	--------	0.02-0.04	-------	----	----	----	----	do.	A tunnel and an inclined adit, both caved, constitute the development. The copper minerals are in siltstones and limestones of the Moenkopi formation. Copper carbonates are concentrated mostly in an 18-inch porous limestone bed.

Table 1.--Radiometric and chemical analyses of samples from some uranium and copper deposits in sandstones--Continued

Number	District, mine name State	Location	Formation	Type of sample	Radioactivity: Milliroentgens per hour 1/ (maximum)	Radioactivity: Equivalent uranium (percent)	Chemical analyses (percent): U	Chemical analyses (percent): V_2O_5	Chemical analyses (percent): Cu	Serial number	Mineralogy	Remarks
22	Torrey district, Utah.	Sec. 8(?),T.30 S., R. 6 E.	Moenkopi (Triassic)	--------	0.02-0.03	--------	----	----	----	--------	Malachite, azurite.	A copper-stained buff sandstone is exposed in an open cut 30 feet long, 30 feet wide, and 4 to 7 feet deep.
23	San Rafael Swell district, Ronnie, Jerry and Frenchy mine, Utah.	SW1/4 sec. 20, T.23 S.,R.10 E., west side of San Rafael Swell.	Shinarump (Triassic)	7-foot channel asphaltic sandstone.	0.4 (average)	0.033	0.030	----	----	53817	Uraniferous asphaltite and carbonized wood, chalcopyrite, chalcocite,pyrite,malachite, azurite,metatorbernite,gypsum.	The mine workings consist of a tunnel in the lower part of the Shinarump conglomerate. The uranium is associated with two types of carbonaceous material: (1) lustrous interstitial grains of asphaltite disseminated through the sandstone, and (2) carbonized wood. The chalcopyrite and chalcocite occur as small blebs in fractures in hydrocarbon and along contacts between quartz grains and hydrocarbon. Autoradiographs indicate that the radioactivity is uniformly distributed through the asphaltite.
				Uraniferous hydrocarbon concentrate.	-------	0.30	----	----	----	53809		
24	San Rafael Swell district, Utah.	SW1/4SW1/4 sec.20, T.23 S.,R.10 E., west side of San Rafael Swell.	do.	--------	15-20	--------	----	----	----	-------	Uraniferous carbonized wood and asphaltite,bornite, chalcopyrite,chalcocite, covellite,pyrite,malachite, azurite,meta-torbernite.	About 1000 feet of bulldozer trenches have been made along the steep slope and near the base of the Shinarump conglomerate. The exposed beds consist of sandstone, conglomerate and gray, green, and red shale. The radioactivity is abnormally high along the excavation. The highest radioactivity is associated with carbonized wood and asphaltic sandstone but some of the shales are also radioactive. As yet no mineable thickness of ore has been revealed. Polished sections show that sulfides fill fractures in the asphaltites. Bornite and chalcopyrite show a texture that may be either exsolution or replacement of bornite by chalcopyrite along preferred crystallographic directions. Chalcocite replaces chalcopyrite and bornite. Covellite replaces the edges of chalcocite.
25	San Rafael Swell district,mine name unknown,Utah.	NE1/4 sec.31, T.23 S., R. 10 E.,west side of San Rafael Swell.	do.	8-foot channel asphaltic sandstone.	1.0 (average)	0.31	0.31	----	----	53818	Uraniferous asphaltite, carbonized wood, pyrite, malachite,copper sulfate(?), unidentified yellow secondary uranium mineral,gypsum.	The development consists of a tunnel 50 feet long and 6 to 15 feet wide in the lower part of the Shinarump conglomerate. The Shinarump conglomerate in the tunnel is made up of white, medium-grained sandstone with carbonaceous material and reworked clay fragments. Both carbonized plant fragments and disseminated asphaltite grains are present. Secondary copper minerals stain the surface rocks near the base of the Shinarump conglomerate.
				Uraniferous hydrocarbon or carbonized wood.	-------	1.2	----	----	----	53810		
26	San Rafael Swell district, Dalton Group of claims, Utah.	About 4 miles south of bridge on San Rafael River. West side of San Rafael Swell. (Unsurveyed)	do.	Asphaltite.	0.5 (average)	5.0	1.34	----	----	53808	Uraniferous asphaltite,pyrite, Chalcopyrite,chalcocite, covellite,malachite.	The development consists of three short adits into the Shinarump conglomerate; the longest adit is at least 20 feet above the base of the sandstone. Uraniferous asphaltite is present as grains up to 1/2 inch in diameter and as lenses and pods up to 20 inches long. Pyrite is abundant and in many places is associated with the uraniferous asphaltite.
27	San Rafael Swell district,Lone Tree claims, Utah.	About 3 miles south of bridge on San Rafael River. West side of San Rafael Swell. (Unsurveyed)	do.	One uraniferous asphaltite pellet.	11	2.9	3.28	----	----	53656	Uraniferous asphaltite, pyrite, chalcopyrite, arsenopyrite(?), paraschoepite(?).	The Lone Tree Group of claims have been prospected in one place by a 30-foot tunnel and a crosscut of about equal length. Uraniferous asphaltite is present in bands as much as 1 inch thick and in disseminated pellets as much as 1/2 inch in diameter. Secondary uranium minerals are sparingly present. Autoradiographs indicate a uniform distribution of radioactivity throughout the asphaltite pellets.
				Gray clay above uraniferous asphaltite.	-------	0.015	----	----	----	53815		
				Gray clay below uraniferous asphaltite.	--------	0.008	----	----	----	53814		
28	Montpelier district, Evening Star claim,Idaho.	Southern part of T.12 S.,R.45 E.	Ankareh (Triassic)	Carbonized plant remains.	0.04-0.05	0.005	0.003	----	----	53819	Malachite, azurite.	The workings consist of one adit about 20 feet long, 4 feet wide, and 4 feet deep. Copper carbonates are associated with carbonized plant fragments in the Ankareh(?) shale of Triassic age. The carbonized plant fragments are detectably radioactive.
29	Montpelier district, Bonneville prospect, Idaho.	Sec. 9,T.14 S., R. 4 E.	do.	--------	20-30c/m 2/	-----	----	-----	----	----	Malachite, chrysocolla, chalcocite.	The mine dump is about 100 feet long and 20 to 30 feet wide. The dump material was derived from underground workings that are now inaccessible. The copper minerals are in a steeply dipping light gray, well cemented sandstone, and they are associated with carbonized plant remains.
30	Cokeville district, "Old Copper" mine,Wyoming.	NW1/4 sec. 7, T.28 N.,R.117 W.	?	--------	0.02-0.03	-----	----	----	----	----	Chalcopyrite,covellite, malachite, azurite.	The lessee, Mr. Dan S. Schickich of Kemmerer, Wyoming, has reported that a 600-foot tunnel and a 125-foot shaft constitute the development at this mine. The dump material is composed of a light gray, well cemented sandstone that contains slight quantities of copper minerals. No fossil wood was observed.

2/ Radioactivity measurement made with an uncalibrated "Lucky Strike" counter, Model 106.

Table 2.--Spectrographic analyses of some crude oils, asphalts, and carbonaceous shales

Number	Serial number	Location	Type material	Ash (percent)	Fe	Ti	As	Co	Cr	Cu	Mo	Ni	Pb	U	V	Zn	Remarks
1	15616	NE1/4NE1/4SE1/4 sec. 9, T. 27 S., R. 4 E., Kansas	Crude oil	0.002	X.	.0X	--	.OOX	.OX	.X	.OOX	X.	.OX	--	X.	.OX	
2	16249	SW1/4SW1/4NE1/4 sec. 11, T. 28 S., R. 4 E., Kansas	do	0.002	.X	.X	--	.X	X.	.X	.OOX	X.	.X	--	X.	.X	
3	16253	NW1/4 sec. 11. T. 28 N., R. 4 E., Kansas	do	0.005	X.	.X	--	.OOX	.X	X.	--	X.	.X	--	X.	.X	
4	16266	NE1/4 sec. 35, T. 18 S., R. 16 W., Kansas	do	0.0025	.X	.X	--	.OX	.X	.OX	.OOX	X.	.X	--	X.	.X	
5	17912	SW1/4 sec. 23, T. 18 S., R. 16 W., Kansas	do	0.0075	X.	.X	--	.OX	.OX	.X	--	X.	.X	--	X.	.X	
6	18331	SW1/4NW1/4 sec. 25, T. 28 S., R. 5 E., Kansas	do	0.0005	.X	.X	--	.OOX	.X	XX.	.OOX	X.	.X	--	X.	.X	Ash of crude oils from Kansas and Texas
7	18345	C. sec. 12, T. 34 S., R. 6 E., Kansas	do	0.002	.X	.X	--	.X	.OX	.X	.OOX	X.	.OX	--	X.	.X	
8	18353	Talco Field, Texas	do	0.001	.X	.OX	--	.OX	.OX	.OX	.OOX	.X	.OOX	--	X.O	--	
9	18356	1 1/2 miles east of Breckenridge, Texas	do	0.003	X.	.X	--	.OOX	.OX	XX.	.OOX	.OX	.X	--	.X	X.	
10	18357	3 miles east of Breckenridge, Texas	do	0.003	X.	.OX	--	.OOX	.OX	X.	.OOX	.X	.X	--	.X	X.	
11	18363	28 miles east of Dumas, Texas	do	0.02	X.	.X	--	.OOX	.OX	.OX	.OOX	X.	.X	--	X.	--	

Table 2.--Spectrographic analyses of some crude oils, asphalts, and carbonaceous shales--Continued

Number	Serial number	Location	Type material	Ash (percent)	Fe	Ti	As	Co	Cr	Cu	Mo	Ni	Pb	U	V	Zn	Remarks
12	57023	Oil extract from Spergen limestone, Ste. Genevieve County, Missouri	Crude oil	Not Ashed	.X	.X	--	.OOOX	.OOX	.OOOX	.OOX	.OX	.OOX	.OX	.OX	.OX	Crude oil
13	58336	Bonanza vein, Uintah County, Utah	Gilsonite	0.3	X.	X.	--	X.	.OOX	.OX	.X	X.	.OX	.X	.X	.OX	Ash of gilsonite
14	58097	Lone Tree claim, San Rafael Swell, Emery County, Utah	Asphaltite pellets	62.0	XX.	.X	X.	.X	.OX	X.	.X	.X	.X	XX.	.OX	--	Ash of asphaltite
15	58100	Dalton claim, San Rafael Swell, Emery County, Utah	do	17.0	X.	.X	X.	.OX	.OOX	X.	.X	.OX	.X	X.	.OOX	--	Do
16	54656	Lone Tree claim, San Rafael Swell, Emery County, Utah	do	Not ashed	.X	.OX	.X	.OOX	.OOOX	.X	.OX	.OOX	.OX	X.	.OOX	--	
17	53808	Dalton claim, Emery County, Utah	do	do	.X	.OOOX	--	--	--	.X	.OOX	.OOOX	.OOX	.X	--	--	
18	53809	Ronnie, Jerry, French mine, San Rafael Swell, Emery County, Utah	do	do	.X	.OX	--	.OOX	.OOOX	.X	--	.OOX	.OOX	.X	.OOOX	.OX	
19	54418	Dirty Devil mine, San Rafael Swell, Emery County, Utah	do	do	.X	.OX	.X	.OOX	.OOOX	X.	.OOX	.OOX	.OOX	X.	.OOX	.OX	Asphaltites
20	55539	Texas Panhandle	do	do	.OX	.OOX	X.	.OX	--	.OOX	.OOX	.X	.OOX	.X	--	--	
21	54415	Laramie County, Wyoming	Graneros shale drill samples	do	X.	X.	--	.OOX	.OX	.OX	.OOOX	.OOX	.OOX	--	.OX	--	

Table 2. --Spectrographic analyses of some crude oils, asphalts, and carbonaceous shales --Continued

Number	Serial number	Location	Type material	Ash (percent)	Fe	Ti	As	Co	Cr	Cu	Mo	Ni	Pb	U	V	Zn	Remarks
22	54289	Locality unknown; Texas	Woodford shale	Not ashed	X.	X.	--	.OOX	.OOX	.OX	--	.OOX	.OOOX	--	.OX	--	Carbonaceous shale
23	58337	North Vernon, Indiana	New Albany shale	do	X.	.X	--	.OOX	.OOX	.OX	.OX	.OOX	.OOX	--	.OX	--	
24	54292	Ste. Genevieve County, Missouri	Black shale in Spergen limestone	do	.X	.X	--	.OOX	.OX	.OOX	.OOX	.OX	.OX	X.	.X		

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ABSTRACT

The San Rafael Swell district is a promising area from the standpoint of commercial uranium production. There is some possibility that economically significant quantities of uranium may be found in a deposit in volcanic rocks near San Acacia, New Mexico, and in a cupriferous black shale deposit near Guadalupita, New Mexico.

Recommendations have been made for additional work in these areas.

ECONOMIC POTENTIALITIES

Except for the San Rafael Swell area, the deposits that have been examined as part of this investigation offer few potentialities for significant quantities of commercial grade uranium ore. Samples of carbonized wood that contain from 0.009 to 0.014 were found in the Jemez Springs (No. 6), Zuni Mountains (Nos. 14 and 15), and Scholle (No. 17) districts. However, as these samples represent the most radioactive material in the deposits and occurs only in significant quantities, the deposits cannot be considered as potential commercial uranium deposits.

The San Acacia deposit (No. 16) is in volcanic flow rocks and contains a small amount of torbernite (?) and carnotite (?) along with the copper minerals. Although the highest concentration of uranium found in any sample from this deposit was 0.026 percent, the presence of prominent vein, fault, and shear structures at the deposit and throughout the area suggests that it may be of hydrothermal origin. Although the chances are probably poor, it is possible that uranium and copper ores might be found at depth.

The black shale along Coyote Creek near Guadalupita, New Mexico (No. 12) contains about 0.01 percent uranium and 2 percent copper. Providing the deposit is sufficiently large and is amenable to large-scale mining operations, the shale is a potential source of copper. If it could be mined for copper, the uranium might be recovered as a byproduct.

Inasmuch as the investigation of the uraniferous asphaltite deposits along the San Rafael Swell was extremely brief, the writers cannot appraise the economic potentialities of the area except in general terms and then only with qualifications. If it can be assumed that the deposits are genetically related to structural traps that have been responsible for the localization of petroleum, the uraniferous asphaltite deposits should be large and eventually of considerable economic importance. If, however, the deposits represent a hydrocarbon replacement of pre-existing uranium minerals, such as carnotite, the size, grade, distribution, and general character of the deposits should be similar, except perhaps of lower grade, to the carnotite deposits of the Colorado Plateau area.

PLANS AND RECOMMENDATIONS

The uranium content of most of the cupriferous deposits examined during this investigation is considerably below that of a commercial grade uranium ore. There are, however, possibilities of finding primary copper and uranium minerals in one deposit near San Acacia, New Mexico; of obtaining uranium as a byproduct from a low-grade cupriferous black shale deposit near Guadalupita, New Mexico; and of obtaining basic data that would be valuable in the appraisal of the uraniferous asphaltite deposits. The following proposals are, therefore, submitted for consideration:

(1) The San Acacia deposit (No. 16): The chances of finding a commercial grade uranium deposit at this locality are probably poor, but, to better evaluate the possibility, a reconnaissance should be made of the most prominent vein, fault, and shear structures in the adjacent area. As much as 10 square miles might be involved in this reconnaissance, and it

would require two geologists for one to two weeks. The Survey plans to make such a reconnaissance as time allows, perhaps under the program for the regional reconnaissance of the United States.

(2) The Guadalupita cupriferous shale deposit (No. 12): One sample of this shale contains 2.0 percent copper and 0.01 percent uranium. Although the shale is poorly exposed, numerous copper prospects along the strike of the bed suggest that the tonnage of copper-bearing rock is large. Tentative plans for additional sampling and trenching are discussed in Trace Elements Memorandum Report 435 by Bachman and Read, to be submitted shortly.

(3) The Jemez Springs radioactive deposits: The spring deposits, 1.7 miles north of Jemez Springs, New Mexico, are radioactive but chemical analyses have shown that uranium is not present. The abnormally high radioactivity, therefore, suggests that uranium decay products (radium ?) are currently being deposited. If techniques applicable to the solution of this problem are known, an investigation of the source of the radioactive material should be seriously considered. The Survey does not plan to investigate this problem in the near future; later, if time permits, some study may be made.

(4) The San Rafael Swell uraniferous asphaltite deposits: The genesis of the uraniferous asphaltite deposits affects their economic significance. If the uranium has not been transported by the hydrocarbons but has simply been transferred into them when they come in contact with already formed uranium minerals, the methods for finding other uraniferous asphaltite deposits should be essentially the same as those that are used for finding carnotite deposits throughout the Colorado Plateau. If the uranium and other metals have been transported by the hydrocarbons, however, it might be possible to develop new methods for finding similar deposits in other places. For this reason the genesis of the uraniferous hydrocarbons

will be further studied in the field and in the laboratory during fiscal year 1953 under the project entitled "Origin of uranium in hydrocarbons." This investigation will utilize chemical, spectrographic, petrographic, and autoradiograph techniques to determine (1) the type and physical characteristics of the hydrocarbons with which the inorganic constituents are associated, (2) the metal compounds in the hydrocarbons, (3) the distribution of the uranium (and as many other metals as is possible) in the hydrocarbons, and (4) the relative abundance of the metallic constituents in the San Rafael Swell asphaltites, asphalt from deposits outside the San Rafael Swell, and crude oils.

In addition, some consideration should be given to the possibility of separating the uraniferous asphaltites from the sandstone and thereby concentrating the uranium and other metals. This would probably be practical only where large tonnages are involved, if at all.