Radioactivity in some Oil Fields of Southeastern Kansas

GEOLOGICAL SURVEY BULLETIN 988-E

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By GARLAND B. GOTT *and* JAMES W. HILL

A CONTRIBUTION TO THE GEOLOGY OF URANIUM

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By Garland B. Gott and James W. Hill

ABSTRACT

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.

INTRODUCTION

Abnormally high radioactivity in oil and gas wells in southeastern Kansas was noted in 1948 during an investigation to determine the value of commercial gamma-ray well logs in the search for radioactive ore deposits. Because of these high radioactivity anomalies, a detailed investigation of the Augusta field in Butler County and a reconnaissance investigation of oil wells in Cowley, Butler, Marion, Sedgwick, and Greenwood Counties were undertaken in 1949. Radiometric determinations with portable field counters were made at more than 300 oil, natural gas, and helium wells, and 132 samples of oil-well precipitates were analyzed radiometrically or chemically; 125 brine samples were analyzed chemically; 115 gamma-ray and neutron logs were examined; drill cuttings from about 70 wells were examined, and samples from 50 wells were analyzed radiometrically; surface outcrops of many of the exposed formations, including coals, were radiometrically examined, and two gamma-ray logs were made. The general area investigated and some of the results are shown on plate 8.

During the field investigations, uncalibrated standard portable gamma-beta survey meters were used for preliminary radioactivity determinations, but all equivalent uranium oxide (eU_3O_8) percentages were determined in the Denver laboratory of the U. S. Geological Survey.

An approximate calibration of the deflections on gamma-ray logs was made by comparing the equivalent uranium in 212 core samples of the Weber formation from uncased wells in the Rangely field, Colorado, with the corresponding gamma-ray logs. A 1-in. deflection was caused by about 0.0007 percent equivalent uranium at a 10-in. sensitivity scale. Part of the calibration data is shown graphically in figure 29. The correlation between the two types of radiometric measurements was satisfactory and indicated that the calibration is reasonably reliable for use in interpreting the degree of radioactivity represented on Lane-Wells gamma-ray logs through the Weber formation in the Rangely field. Many complicating factors exist, however, which might cause erroneous interpretations, and it is doubtful if the calibration can be strictly applied to the gamma-ray logs of wells in the southeastern Kansas area. The most important of these factors are the thickness versus the grade of the bed, the fluid content of the

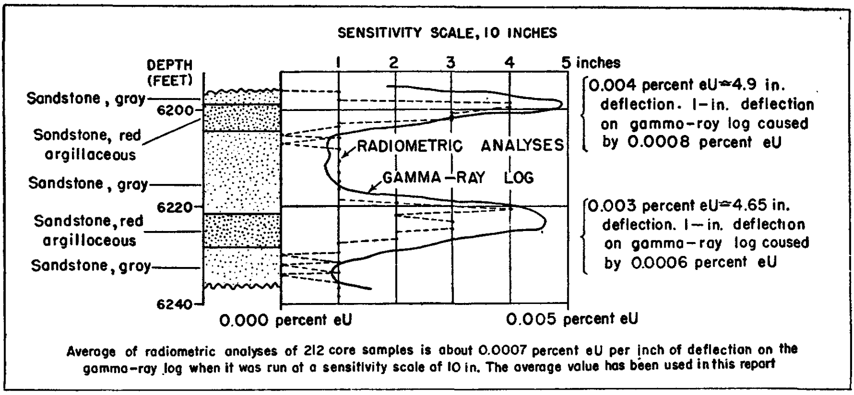

FIGURE 29.—Comparison of a Lane-Wells gamma-ray log with radiometric analyses.

well, the shielding effect of casing in cased wells, differences in individual instruments, and the rate of movement of the ionization chamber. Nevertheless, semiquantitative data obtained by using the approximate calibration were helpful in estimating the order of magnitude of the equivalent uranium in the rocks from which the gamma-ray logs were obtained.

The radioactivity anomalies represented on gamma-ray logs seemed to indicate that the drill holes had penetrated radioactive host rocks. After it was found that the radioactivity at the surface was caused by radium-bearing precipitates, however, the possibility was suggested that the radioactivity anomalies represented on gamma-ray logs might have been caused by a similar type of deposit that had accumulated on the casing in the rock face at depth. Because of this possibility, it seemed desirable to obtain radiometric data of newly drilled wells located adjacent to a radioactive well. The recently completed Rex and Morris—Loomis nos. 6 and 7 wells, located near old radioactive wells in the SW¼NE¼ sec. 21, T. 27 S., R. 4 E., in the North Augusta field were chosen and gamma-ray and neutron logs were made before a radioactive deposit had time to accumulate on the casing. Although one basal Pennsylvanian black shale bed caused a greater deflection than was expected, there were no radioactivity anomalies comparable to those recorded on logs of the older wells. It was therefore concluded that the abnormal deflections shown on other gamma-ray logs in this field were caused by radioactive precipitates on the casing or on the walls of the drill hole.

ACKNOWLEDGMENTS

The investigation of radioactivity in southeastern Kansas was made by the U. S. Geological Survey as part of the comprehensive investigation of uranium resources that is being carried out for the Atomic Energy Commission.

The writers are indebted to many persons who have contributed information and assistance relative to this investigation. George J. Petretic and the staff of the Denver Trace Elements laboratory of the U. S. Geological Survey made all the radiometric and chemical analyses. Joseph Berman of the same laboratory is reponsible for most of the mineralogic identifications. The Magnolia Petroleum Co., Cities Service Oil Co., Sohio Petroleum Co., and Sinclair-Prairie Oil Co. provided gamma-ray logs, maps, drill samples, and stratigraphic information. In addition the following organizations and individuals have cooperated by contributing copies of radioactivity logs, samples, helium data, or general information: A. D. Allison and Co., Aikman and Braden, Continental Oil Co., C. R. Colpitt, H. E. Colpitt, Dilworth and Miller, Eagle Picher Mining and Smelting Co., Hammer and McClain Drilling Co., Lane-Wells Co., Rex and Morris Drilling Co., Socony Vacuum Oil Co., Inc., the State Geological Survey of Kansas, and the U. S. Bureau of Mines.

GENERAL GEOLOGY

The geologic history of southeastern Kansas from Late Cambrian through Mississippian time is one of long periods of marine deposition interrupted by comparatively shorter periods of emergence and erosion. The deposition of the relatively thick sections of carbonate rocks, which are interbedded with a few beds of shale and coarser clastics, was interrupted several times by uplift. While uplifted, the land mass was subjected to erosion and was reduced nearly to base level.

The sequence of sedimentary rocks in this area consists of the dolomite of the Arbuckle group of Cambrian and Ordovician age; the Simpson group, Viola limestone and Maquoketa shale of Middle and Late Ordovician age; the dolomites and limestones of Silurian and Devonian age; Chattanooga shale of Late Devonian and Mississippian age; the Kinderhook group overlain by the cherty limestones of Mississippian age; the interbedded shales, limestones, and sandstones of Pennsylvanian age, which are, in ascending order: Cherokee and Marmaton formations, Pleasanton, Kansas City, Lansing, Douglas, Shawnee, and Wabaunsee groups; and the interbedded shales, limestones, and sandstones of early Permian age.

Oil wells in southeastern Kansas have been drilled into these rocks, but in many of the oil fields along the Nemaha anticline in which radioactivity anomalies have been detected, the Mississippian, Silurian, Devonian, and Upper Ordovician rocks were removed by pre-Pennsylvanian erosion, and consequently radiometric and chemical data are not available for some parts of the stratigraphic section in all the oil fields in this area. Radioactive limestones in areas of folded and faulted rocks and the higher-than-normal radioactivity in several places along the pre-Pennsylvanian erosional surface suggest that the structural and erosional history may have played an important role in the localization or introduction of uranium-bearing minerals into the dolomite of the Arbuckle group and the limestones of the Kansas City group.

The Nemaha anticline, the major structural feature in southeastern Kansas, was formed during late Mississippian or early Pennsylvanian time. This structure is an asymmetrical linear uplift. The north end is in southeastern Nebraska, and the anticline extends across the central part of Kansas into Oklahoma. The pre-Pennsylvanian beds along the east flank of the uplift are reported to have been displaced several hundred feet by faulting, but the beds on the west flank dip comparatively gently toward the west. The structural development of the Nemaha anticline has been illustrated by Lee and others (1946, sheet 7), through the use of cross sections.

During deposition of the earliest Pennsylvanian sediments the Nemaha anticline was undergoing erosion, and by the time the initial Pennsylvanian sea had invaded southern and central Kansas the pre-Pennsylvanian sediments had been partly removed from the crest of the anticline and pre-Cambrian rocks had been exposed on the higher parts of the structure. Elsewhere a karst topography had developed on the surface underlain by Mississippian limestone, and a mantle of residual chert was concentrated on the erosional surface. Later, much of this residual mantle was reworked into the basal Pennsylvanian formations.

The shallow Pennsylvanian seas advanced and retreated over the land, leaving relatively thin limestones, shales, sandstones, and some coals. This cyclic sedimentation was repeated many times throughout Pennsylvanian time and into Permian time.

MINERALOGY

Chemical analyses of radioactive precipitates indicated that neither uranium nor thorium is present in these deposits in amounts sufficient to account for the observed radioactivity. This suggested that the radioactivity was caused by radium, and its presence was established by measuring the radon in six samples. These measurements showed that there was enough radium in the samples to account for most of the radioactivity. Table 1 shows percent equivalent uranium, percent uranium, radium content, and calculated percent equivalent uranium. The percent equivalent uranium and percent uranium were determined by direct measurements in the laboratory. The radium content was calculated from direct measurements of radon. The calculated percent equivalent uranium was determined from the radium content.

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The close agreement between the equivalent uranium content and the calculated equivalent uranium content of each sample demonstrates conclusively that the radioactivity of the samples was caused largely by radium. The assumption that the abnormal radioactivity throughout the southeastern Kansas area is also caused largely by radium is, therefore, substantiated.

TABLE 1.—*Radium content of the precipitates*

Serial no.	Equivalent uranium (percent)	Uranium (percent)	Radium content [1] (g Ra/g)	Calculated equivalent uranium (percent) [2]
15539	1.17	0.003	9.4×10^{-9}	1.6
15543	1.14	.003	7.5×10^{-9}	1.3
18377	1.20	.000	1.1×10^{-8}	2.0
18446	8.11	.001	4.6×10^{-8}	7.8
18448	7.10	.000	3.2×10^{-8}	5.5
18452	4.37	.001	2.5×10^{-8}	4.3

[1] Calculated from radon measurements.
[2] Calculated from radium content. The radium content of a sample that contains 1 percent uranium in equilibrium is 3.11×10^{-9} g/g. This amount of radium would measure 0.52 percent equivalent uranium.

In an attempt to locate the radium host rocks, an extensive study was made of cable-tool drill samples and a few surface samples from rocks of Pennsylvanian and Ordovician age. Minerals that resemble a contact-metamorphic assemblage were identified in samples collected from four localities in this area. A sample consisting of altered shales, sandstones, and limestones was collected from exposures of metamorphic rocks in the Silver City dome area, sec. 29, T. 26 S., R. 15 E., in Woodson County, Kans. It contained amphiboles, titaniferous magnetite, sphene (and leucoxene), epidote, and phlogopite. In addition, Knight and Landes (1932, p. 7) have identified galena and sphalerite in well cuttings from this area.

An unusually large number of minerals that may have been formed as the result of the introduction of hydrothermal solutions has been identified in dolomite of the Arbuckle group and limestone of the Kansas City group in drill cuttings from wells in the Augusta field. Magnetite is one of the more abundant minerals in these samples and is present in fine magnetite-rich laminae, which suggests a partial replacement of the limestone or dolomite. The minerals that have been identified in samples from this field are magnetite, pyrite, chalcopyrite, hematite, "limonite," oligoclase, garnet, chalcedony, glauconite, chlorite, fluorite, talc, barite, and radioactive celestite. All these minerals, except talc, are found in clastic sedimentary rocks, but it is improbable that such an assemblage would be deposited along with carbonate sediments. Most of these minerals were in samples from just below the Pennsylvanian and Arbuckle contact and in limestone of the Kansas City group. Cavities in masses of finely crystalline celestite, commonly less than one-tenth of an inch in diameter, were found in limestone and dolomite samples from some wells, but in samples from other wells the celestite lined the interior of the limestone and dolomite "cavities." Magnetite, finely crystalline calcite, with lesser amounts of chlorite, fluorite, and possibly some organic material also are present in the "cavities."

Between depths of 1,400 and 1,700 ft in the Bird and Hanley-Shipley no. 1 well, located in sec. 15, T. 30 S., R. 12 E., are several minerals that may have resulted from the metamorphism of limestone. They were clintonite, corundophilite, diopside-hedenbergite partly altered to a tremolite-actinolite asbestos, and some orthoclase and calcite.

The sample from 3,230 ft in the Derby–Rimel no. 2 well in sec. 30, T. 27 S., R. 2 E., contains garnet, magnetite, actinolite, and possibly some chlorite.

A dolomite and sandy black shale sample from between 3,287 and 3,309½ ft in the James-Rimel no. 1 well, in sec. 20, T. 27 S., R. 2 E., contained pyrite, chalcopyrite, magnetite, covellite(?), and an unidentified malachite-green mineral.

Table 2 lists these minerals, together with the general locality in which they have been found. They may have been formed in dolomites and limestones that were being altered by hydrothermal solutions, perhaps guided by obscure fissures and fractures. Igneous activity in southeastern Kansas is shown by the granite that has intruded middle Pennsylvanian sediments at the Rose dome in sec. 13, T. 26 S., R. 16 E., and by the metamorphosed rocks that are thought to be closely underlain by intrusive rocks in the Silver City dome area (Knight and Landes, 1932). The minerals identified in the drill cuttings may be closely associated with similar bodies of intrusive rocks.

TABLE 2.—*Contact-metamorphic-type minerals*

Locality	Minerals identified	Country rock
Silver City area, sec. 29, T. 26 S., R. 15 E.	Amphibole, titaniferous magnetite, sphene (and leucoxene), epidote, phlogopite, sphalerite, and galena.	Metamorphosed sedimentary rocks consisting of altered shales, sandstones, and limestones, which appear to have been affected by silicic hydrothermal solutions.
Augusta field T. 27 S., R. 4 E.	Pyrite, chalcopyrite, magnetite, hematite, "limonite," celestite, oligoclase, garnet, chalcedony, glauconite, chlorite, talc, fluorite, and barite.	Pennsylvanian limestones and Ordovician dolomites.
Bird and Hanley-Shipley no. 1, sec. 15, T. 30 S., R. 12 E.	Clintonite, corundophilite, diopside-hedenbergite partly altered to a tremolite-actinolite asbestos, orthoclase, and calcite.	Limestone and shale samples from 1,435 to 1,670 ft.
Derby-Rimel no. 2, sec. 30, T. 27 S., R. 2 E.	Garnet, magnetite, actinolite, and chlorite (?).	Chalcedonic limestone sample from 3,230 to 3,235 ft.
James-Rimel no. 1 sec. 20, T. 27 S., R. 2 E.	Altered pyrite, chalcopyrite, magnetite, covellite (?), and a malachite-green mineral with low birefringence and refractive index of 1.80 ± .03.	Dolomite and sandy black shale sample from between 3,287 and 3,309½ ft.

Introduction of minerals by hydrothermal solutions is strongly indicated, and the products of uranium decay in this area indicate that uranium minerals were deposited probably by the same process.

RADIOACTIVITY

Abnormal radioactivity in several southeastern Kansas oil and gas fields first was detected because of unusually large deflections on gamma-ray well logs and later was detected in separator tanks and oil-well pipes on the surface by portable beta-gamma survey meters. Chemical and spectrographic analyses indicated insufficient uranium or thorium in the samples to account for the radioactivity. Radium determinations, however, showed that radium and its decay products were the principal radioactive elements present. The presence or absence of ionium has not been established.

The radium-bearing precipitates were derived directly from oil or brines and were deposited on the interior of oil pipes and in the bottom of separator tanks. The radioactivity of the precipitates that have been tested ranges from 0.000 to 10.85 percent equivalent uranium oxide.

The oil and gas fields that were radiometrically traversed are shown on plate 8, and those fields that are located in Cowley, Butler, and Marion Counties are also on plates 13, 14, and 15. The fields in which the radium-bearing precipitates originated overlie or are roughly marginal to the Nemaha anticline. However, a few gamma-ray logs of wells in fields as far as 35 miles from the crest of the anticline indicate that the area in which the radioactive precipitates were formed is greater than that indicated on plate 8.

With few exceptions, the rocks that have been microscopically examined, radiometrically analyzed, or studied indirectly through the use of gamma-ray logs, are comparable in degree of radioactivity to other rocks of similar lithologies in the midcontinent region. Usually the limestones, dolomites, and sandstones are the least radioactive, and the shales contain the greatest proportion of radioactive elements. This general relationship is shown by the comparison of the percent equivalent uranium estimated from a gamma-ray log and the corresponding lithology in figure 30. Some significant exceptions to the general relationship have been noted, however, and are illustrated by the comparatively high radioactivity of limestones and sandstones shown graphically on plate 12.

PRE-CAMBRIAN ROCKS

Metamorphic and igneous pre-Cambrian rocks have been penetrated by many drill holes, particularly by those wells on the Nemaha anticline. Landes (1927) has shown that the pre-Cambrian rocks of

Kansas consist principally of granite, granite gneiss, and schist, but that locally other types of igneous and metamorphic rocks occur.

The only radiometric data obtained by the writers regarding the pre-Cambrian rocks in this area are from a gamma-ray log of the Shell Oil Company—J. V. Taton no. 8 well in the NE¼NW¼ sec. 36, T. 31 S., R. 2 E., and from a few fragments of drill cuttings from the

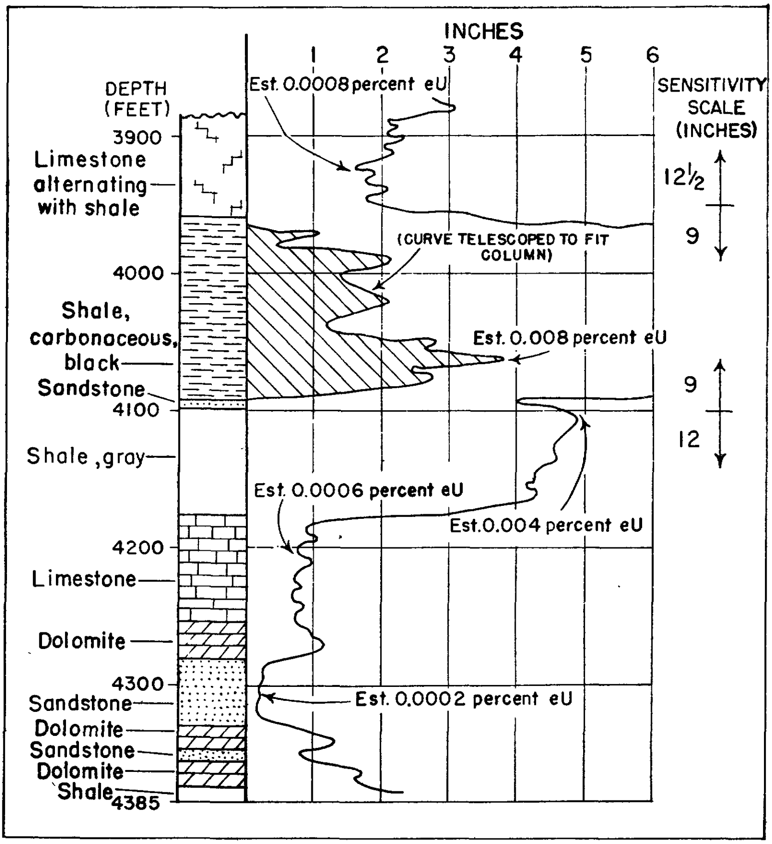

FIGURE 30.—Typical radioactivity anomalies of different sedimentary-rock types as recorded on gamma-ray logs in estimated percent eU. (Ruled area of gamma-ray curve is telescoped to fit column.)

Kaufman well in the NW¼NE¼ sec. 2, T. 20 S., R. 7 E. Both of these wells are on the Nemaha anticline.

The gamma-ray log of the Shell Oil Company well indicates that the pre-Cambrian rocks penetrated by the drill bore contain about 0.01 percent equivalent uranium. A portion of this log is shown in figure 31 and illustrates the relative radioactivity of the pre-Cambrian, Cambrian and Ordovician, and lower Pennsylvanian rocks penetrated by this drill hole. The drill cuttings from the Kaufman well were

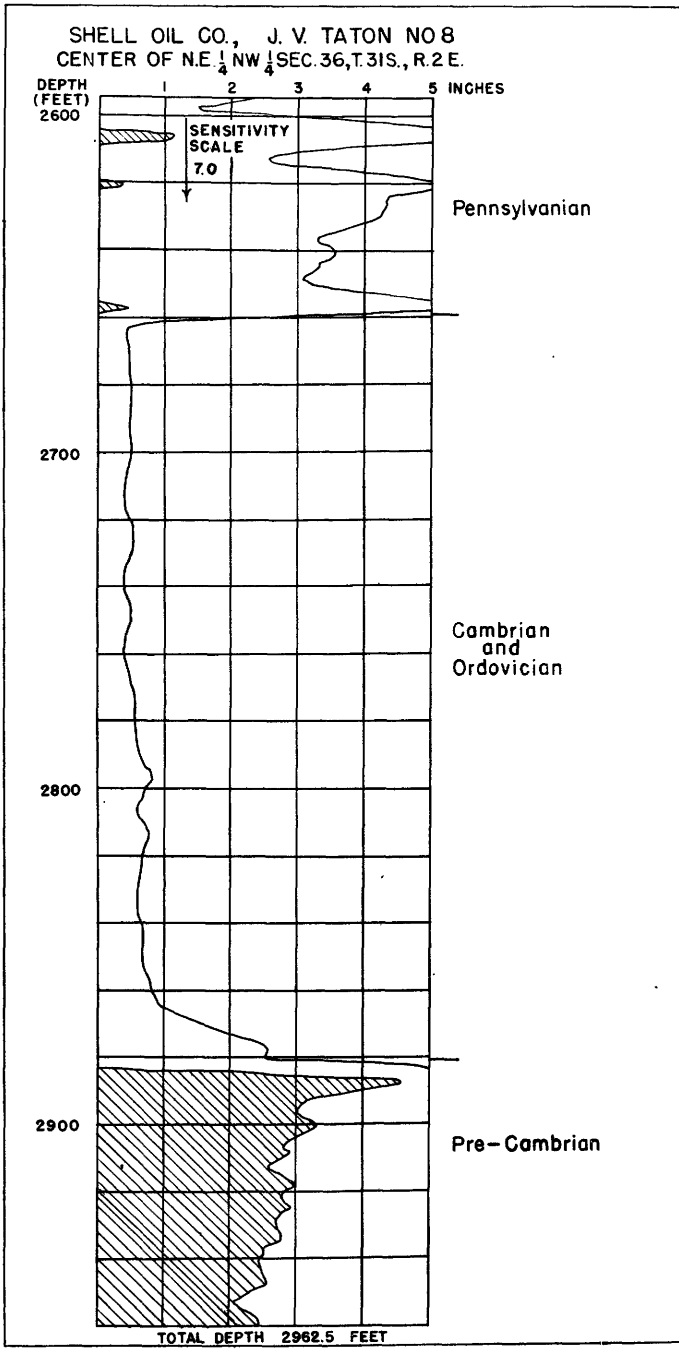

FIGURE 31.—Radioactivity of pre-Cambrian, Cambrian and Ordovician, and basal Pennsylvanian rocks.

fragments of a pre-Cambrian quartz diorite and contained only about 0.001 percent equivalent uranium.

CAMBRIAN AND ORDOVICIAN ROCKS

ARBUCKLE GROUP

The basal Paleozoic formations in this region are included in the Arbuckle group. Because of differential erosion the dolomite of the Arbuckle in some places is overlain by Pennsylvanian sedimentary rocks, but over most of the area is overlain by rocks of the Simpson group of Ordovician age.

Drill samples of the Arbuckle group from several places along the Nemaha anticline are radioactive. These samples contain minerals that may have been formed by the introduction of hydrothermal solutions into the sediments. An example of this type of material is a radioactive black vuggy limestone sample from between 2,529 and 2,530 ft deep in the Magnolia-South Anderson no. 7 well in sec. 15, T. 27 S., R. 4 E., in the North Augusta field (pl. 12, index no. 344; and pl. 16). This limestone is several feet below the top of the Arbuckle group and in the bottom 6 ft of the well. The vuggy fragments contained circular cavities similar to those that would be left after oolites had been removed, although in many places such a small arc of the walls enclosing the spherical cavities has been removed that any solid particle that originally might have occupied these spaces would have been larger than the openings leading from the spaces, and therefore could not have fallen out. Almost all the sample was finely laminated with dark and light bands, and a few of the fragments were brecciated and recemented. The banding was caused by alternating layers of the lodestone variety of magnetite and finely crystalline calcite. Chlorite and celestite were identified, and it is thought that some organic material also was present. Radiometric measurements of the magnetic fraction showed that it was more radioactive than the nonmagnetic fraction. The samples from this interval were contaminated with a high percentage of shale caved from a higher place in the drill hole, and, therefore, the equivalent uranium oxide content of 0.03 percent was probably less than the actual content. Hand-picked fragments of the banded limestone contain about 0.1 percent equivalent uranium oxide and more nearly represent the degree of radioactivity in this zone.

An Arbuckle group sample from between depths of 2,513 and 2,514 ft in the Magnolia-Foster no. 14 well had 0.008 percent equivalent uranium. About 50 percent of the sample was a gray crystalline dolomite and the remaining part was composed of a dark vuggy material, magnetite, limonite, pyrite, and a minor amount of fibrous celestite. Tiny spherical cavities were observed in many of the iron oxide fragments. A magnetic concentrate, including the dark vuggy material, contained 0.25 percent equivalent uranium. The lithology and radioactivity of the samples from this well are shown graphically on plate 12, index no. 29.

Although the samples were significantly radioactive, chemical analyses have shown that uranium is not present. Because the radioactivity was undoubtedly caused by radium, it is probable that a uranium-bearing mineral originally occupied the cavities. As the half-life of radium is only 1,580 yr, its presence in the limestone indicates that the uranium has been removed during recent time. The only environmental change to which the hypothetical uranium mineral could have been so recently subjected was that brought about by drilling.

ORDOVICIAN ROCKS

Little data have been obtained relative to the radioactivity of the Viola limestone of Middle and Late Ordovician age or the Maquoketa shale of Late Ordovician age, but radiometric measurements of drill samples indicate that the green shale and glauconitic sandstones of the Simpson group contain as much as 0.006 percent equivalent uranium. The radioactivity of the sandstones and shales of the Simpson group are illustrated graphically on plate 12, index nos. 70, 72–76, and 310–312.

CARBONIFEROUS ROCKS

MISSISSIPPIAN ROCKS

The Mississippian rocks consist of the cherty "Mississippi" limestone of Meramec and Osage age underlain by the Kinderhook group. Although the Chattanooga shale is in part of Devonian age, for convenience it is included with the Kinderhook group.

SHALE

Because the Chattanooga shale has been removed by pre-Pennsylvanian erosion in most of the fields in which wells have been gamma-ray logged, only meager information regarding its radioactivity is available. A few gamma-ray logs and some radiometric analyses of samples from southeastern Kansas have indicated that the equivalent uranium content of the Chattanooga in that area ranges from about 0.002 to 0.007 percent equivalent uranium.

LIMESTONE

Radioactive "Mississippi" limestone may be represented by abnormal deflections on the gamma-ray logs of the Dilworth no. 2 Fee well in the Dexter field and the C. R. Colpitt-Spier no. 1 well in the Peabody field. The gamma-ray logs of both these wells show high radioactivity anomalies at depths correlative with the "Mississippi" limestone, but there is evidence that radium-bearing precipitates are the source of radioactivity.

A portion of the gamma-ray log of the Dilworth no. 2 Fee well located in sec. 8, T. 33 S., R. 7 E., is shown in figure 32. It reveals a marked radioactivity anomaly between depths of 2,685 and 2,710 ft, an interval which should represent part of the Cherokee shale of early Pennsylvanian age. A smaller radioactivity anomaly at depths correlative with the "Mississippi" limestone is represented on the log between 2,815 and 2,856 ft. Radiometric measurements of samples from 2,700 to 2,706 ft, in the zone of greatest deflection, and of other samples from that part of the adjacent Olds no. 1 well represented in figure 32, indicate that the sediments are only normally radioactive. Inasmuch as a radium-bearing precipitate was collected from the tubing that had been removed from the bottom of the Dilworth well, it is believed that all the abnormal radioactivity recorded on the gamma-ray log had a similar source.

A gamma-ray log of the C. R. Colpitt-Spier no. 1 well (pl. 9) located in the Peabody field, in sec. 8, T. 22 S., R. 4 E., shows a greater radioactivity anomaly at the top of the "Mississippi" limestone than was indicated on the Dilworth, no. 2 Fee log. However, as radium-bearing precipitates also are being formed at depth in the tubing of this well it is probable that the deflection between 2,350 and 2,370 ft also is caused by a radium-bearing precipitate.

PENNSYLVANIAN ROCKS

SHALES

The radioactivity of the exposed black shales of Pennsylvanian age was investigated by Slaughter.[1] He found that phosphatic nodules disseminated in shales contain as much as 0.095 percent uranium, but the uranium content of the shale is much lower.

Black fissile shales, some of which contain phosphatic nodules, are present throughout the Pennsylvanian rocks. These shales range in thickness from a few inches to about 6 ft and usually are represented on the gamma-ray logs by large deflections. In degree of radioactivity most of these shales resemble the Chattanooga shale, and estimates based upon gamma-ray logs, supplemented by some radiometric analyses of drill samples, indicate that they contain from about 0.004 to 0.01 percent equivalent uranium oxide. The radioactivity of the black shales is compared with other Pennsylvanian rocks on plates 9, 10, 11, and 12.

The gray shales of Pennsylvanian age contain a smaller proportion of radioactive elements than the black shales. However, the gamma-ray log that is partially reproduced in figure 33 indicates that one of

[1] Slaughter, A. L., Radioactivity of Pennsylvanian black shales and coals in Kansas and Oklahoma: U. S. Geol. Survey Trace Elements Inv. Rept. 18, September 1945. [Unpublished.]

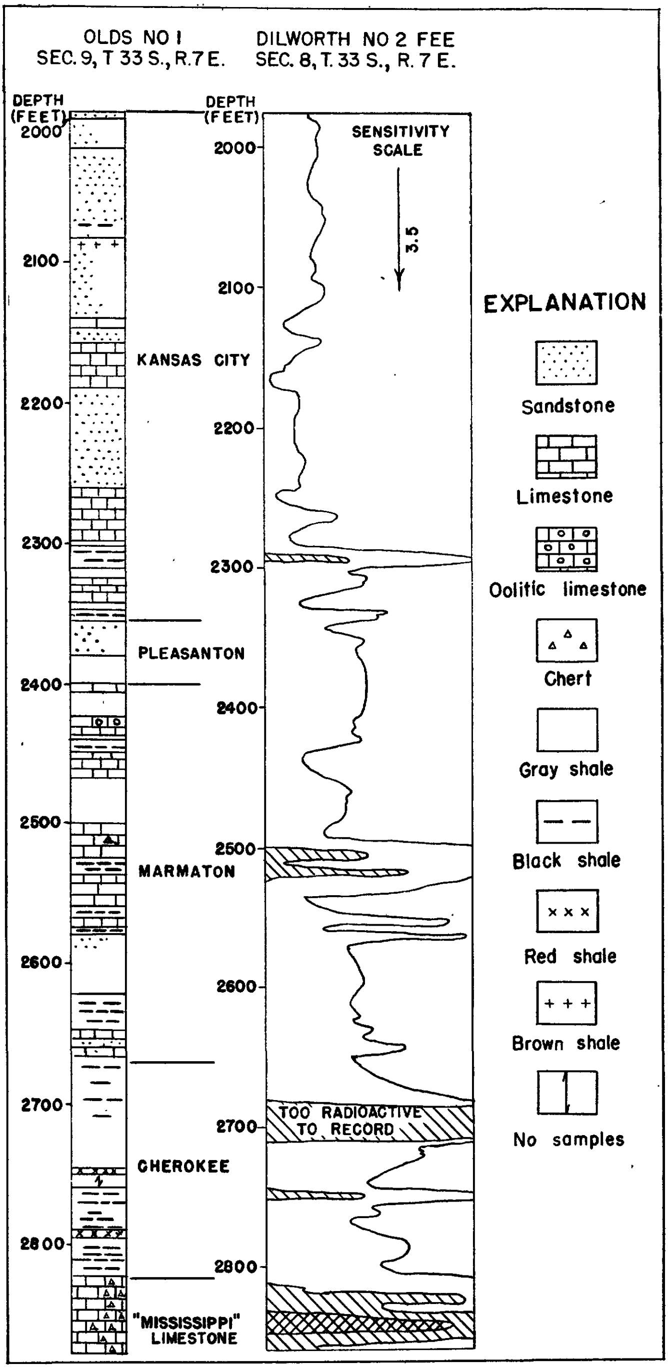

FIGURE 32.—Radioactivity of Dilworth, no. 2 Fee well.

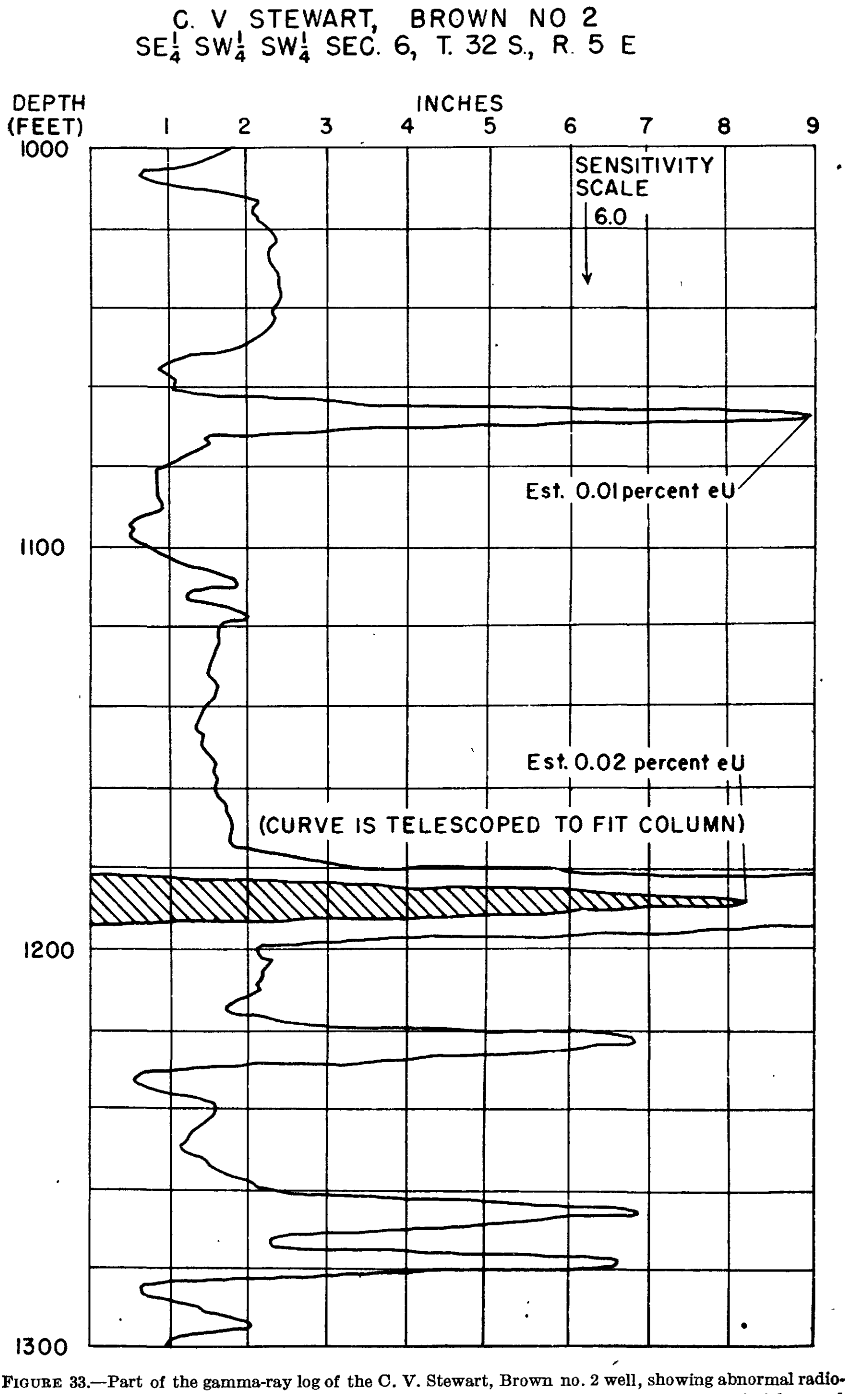

FIGURE 33.—Part of the gamma-ray log of the C. V. Stewart, Brown no. 2 well, showing abnormal radioactivity in Wabaunsee group in estimated percent eU. (Ruled area of gamma-ray curve is telescoped to fit column.)

the upper gray shales of the Wabaunsee group may have an equivalent uranium oxide content of about 0.02 percent, but the abnormal deflection, like those previously mentioned, may be caused by a radioactive precipitate.

LIMESTONES

Abnormally radioactive limestones were detected by routine radiometric scanning of drill samples and are illustrated by the comparison of sample and radiometric logs shown on plate 12. The most radioactive limestone sample detected in this manner was from a limestone of the Kansas City group and contained 0.012 percent equivalent uranium oxide. The sample was one of a set of cable-tool drill cuttings from between 2,027 and 2,031 ft deep in the Aikman and Braden-South Anderson no. 1 well located in the NE¼NW¼NW¼ sec. 15, T. 27 S., R. 4 E., in the North Augusta field. (See pl. 12, index no. 22; and pl. 16.) The sample was composed principally of brown crystalline limestone cut by small veinlets of dark fluorite and magnetite. It also contained about 5 percent of gray talc and a lesser amount of soft vuggy celestite, encrusted with magnetite and limonite. Minor amounts of sericite and gypsum were associated with the limestone, and oligoclase and garnet were identified in one small fragment. The celestite contained spherical cavities as much as one-eighth of an inch in diameter, but some of the openings were so small that the original filling could have been removed only by solution. No uranium was found in the vuggy fragments by chemical analysis, although 0.22 percent equivalent uranium oxide was determined by radiometric analysis. Talc, magnetite, and fluorite in this sample indicate an introduction of minerals by hydrothermal solutions, and the cavities possibly represent the mold from which a mineral or a hydrocarbon compound was removed, perhaps upon contact with the drilling solutions. The presence of talc, which generally forms in zones of stress, would seemingly indicate that the spherical cavities were formed later than the talc. The mineral assemblage suggests that solutions of magmatic origin have altered the limestone, and one or more uranium minerals probably were introduced during the process. Solutions would have had easy access, for much fracturing of the limestones would have resulted from the folding and faulting.

COALS

Inasmuch as coal samples from drill cuttings were not available for radiometric analyses, a few of the Pennsylvanian coals were sampled at their outcrops in eastern Kansas. Radiometric analyses of the coal samples shown in table 3 indicate that their uranium content is uniformly low. The Mulky coal containing 0.004 percent equivalent uranium oxide is the most radioactive of the coals sampled; a black shale, with phosphatic nodules containing 0.011 percent uranium oxide, overlies this coal.

TABLE 3.—*Radiometric analyses of Pennsylvanian coals from southeastern Kansas and adjacent areas*

Sample no.	Location	Percent eU_3O_8	Name of coal	Group or formation	Remarks
18383	SE¼SE¼SW¼ sec. 16, T. 16 S., R. 15 E.	0.001	Nodaway	Wabaunsee	Strip pit.
18384	SW¼SW¼NW¼ sec. 27, T. 17 S., R. 17 E.	.000	Upper Williamsburg.	Douglas	Outcrop, slacked, wet.
18385	SW¼ sec. 14, T. 17 S., R. 19 E.	.001	Ottawa	do	Outcrop.
18386	SW¼NW¼ sec. 29, T. 16 S., R. 18 E.	.000	Lower Williamsburg.	do	Do.
18387	Center sec. 11, T. 23 S., R. 25 E.	.000	Mulberry	Marmaton	Strip pit.
18388	NE¼SW¼SW¼ sec. 17, T. 27 S., R. 25 E.	.000	Bevier	Cherokee	Do.
18390	NW¼SW¼ sec. 5, T. 26 S., R. 25 E.	.004	Mulky	do	Outcrop.
18391	SE¼ sec. 19, T. 31 N., R. 33 W.	.000	Weir-Pittsburgh	do	Strip pit. One mile south of Mindenmines, Mo.
18392	NW¼ sec. 13, T. 29 S., R. 25 E.	.000	Mineral	do	Strip pit.
18393	SW¼SE¼ sec. 34, T. 28 S., R. 25 E.	.000	Croweburg	do	Abandoned strip pit.
18394	SW¼SE¼SE¼ sec. 16, T. 28 S., R. 25 E.	.001	Bevier	do	Abandoned strip pit; slacked.
18395	SW¼SE¼SE¼ sec. 16, T. 28 S., R. 25 E.	.000	do	do	Slacked.
18396	Center W½ sec. 32, T. 31 S., R. 25 E.	.000	Rowe	do	Strip pit.
18397	NW¼SE¼ sec. 7, T. 33 S., R. 24 E.	.000	Columbus	do	Abandoned strip pit.
18398	SW¼SE¼ sec. 23, T. 31 S., R. 16 E.	.000	Thayer	Kansas City	Outcrop.

PERMIAN ROCKS

The upper Permian rocks in this area have been removed by erosion, and the remaining lower Permian rocks are composed of alternating limestone, sandstone, and calcareous gray, red, or variegated shales. Evaporites consisting principally of rock salt and gypsum are present at shallow depths in some parts of the area.

The relative radioactivity of the lower Permian rocks, as represented on gamma-ray logs, is shown on plates 9 and 10. The no. 2 and 3 gamma-ray logs (pl. 3) indicate abnormally high radioactivity at depths of less than 500 ft. Part of the abnormal radioactivity recorded on the log of the no. 2 well may have been caused by marine evaporites. Whether the radioactivity anomalies recorded on these two logs represent radioactive elements in the sediments, or radioactive precipitates on the casing is uncertain. The radioactivity anomalies shown on the no. 5 log on plate 9 probably reflect the presence of radium-bearing precipitates on the casing.

Another gamma-ray log on which has been recorded an abnormal deflection at a depth correlative with Permian rocks, but which may also have been caused by a radioactive precipitate on the casing, is that of the Cities Service-Pierpoint no. 77 well located in sec. 33,

T. 25 S., R. 5 E. The radioactivity represented by the deflection on this log is on the order of 0.02 percent equivalent uranium, which would be significant only if the radioactive deposit is associated with one of the sedimentary beds penetrated by the well bore.

Aside from the abnormal radioactivity indicated by the gamma-ray logs of these wells, the radioactivity of the Permian sedimentary rocks, as interpreted from gamma-ray logs and from radiometric measurements of samples, probably grades downward from about 0.004 percent equivalent uranium.

RADIUM-BEARING PRECIPITATES

Radium-bearing precipitates derived from oil-well fluids have been found in 60 oil fields in southeastern Kansas. The general distribution of the fields in which these precipitates have been found is shown on plate 8. However, abnormal deflections on several gamma-ray logs indicate that the area in which these precipitates might be present is larger than is indicated on the map.

Radiometric data consisting of field determinations and of the percent equivalent uranium oxide of samples collected in Cowley, Butler, and Marion Counties are shown on plates 13, 14, and 15. Some disagreement is shown by comparison of the relative radioactivity obtained by field determinations with the equivalent uranium oxide content of samples collected from the same locality. This disagreement was caused by the dissemination of finely broken precipitates in the surface material, which made it difficult to collect representative samples and to make field radiometric measurements of the material. The field determinations are recorded in terms of meter divisions and exclude the average background readings. Those field readings, recorded in table 6 and on plate 16, that were observed on the 20.0 or 2.0 sensitivity scales, were converted to the comparable number of units on the 0.2 sensitivity scale. Although the conversion is not exact because the portable survey meters were uncalibrated, the field determinations give a general idea of the relative radioactivity in those areas where samples were not collected.

The radium-bearing precipitates are composed chiefly of celestite, iron oxide, gypsum, and barite. The radioactivity ranges from a few hundredths of a percent to 10.85 percent equivalent uranium oxide. Radiometric measurements have shown (p. 6) that the radioactivity is largely caused by radium and its decay products, and chemical analyses have shown that the greatest amount of uranium oxide in any of the samples that have been analyzed is 0.006 percent.

The radium-bearing precipitates have been deposited on the interior of oil and water pipes, in the bottom of oil and brine separator tanks, and in ditches and ponds used for the disposal of brine. Most of the precipitates are laminated with alternating dark and light bands. The light bands are made up chiefly of celestite, gypsum, or barite. The dark bands are composed principally of magnetic iron oxide, fine-grained pyrite, limonite, calcite, and in a few samples some hydrocarbons. In most of the specimens that were examined the coloring of the darker bands was caused by iron oxide, but in some specimens it was caused largely by hydrocarbons. Autoradiographs and radiometric measurements show that the celestite is the principal radium-bearing mineral.

Several representative specimens of radioactive precipitates from this area have been examined by Joseph Berman, of the Geological Survey laboratory, and his identifications are tabulated in table 4.

Spectrographic analyses (table 5) have been made of several samples and show that the principal elements in the radium-bearing precip-

TABLE 4.—*Description of radium-bearing precipitates*

Serial no.	Percent eU_3O_8	Percent U_3O_8 *	Description
18447	0.32	0.001	Sample collected from a salt-water disposal ditch in the Graham field in sec. 9, T. 33 S., R. 3 E. "The sample consists of a large fragment of recemented detrital pebbles and sand. The cementing agent is primarily porous quartz and chalcedony, although minor amounts of opal, gypsum, and clay are present. The cemented particles are predominantly limonite-stained quarts sand." (Mineralogy by Berman, Joseph, 1950.)
18448	8.15	.000	A limonite-stained pipe scale collected from a well in the Graham field located in the NW¼ sec. 10, T. 33 S., R. 3 E. "The minerals present are predominantly magnetic material, celestite, limonite, and minor amounts of gypsum." (Mineralogy by Berman, Joseph, 1950.)
15558	.24	.005	Pipe scale. The pipe from which this sample was collected was removed from the bottom of the Dilworth no. 2 Fee well located in sec. 8, T. 33 S., R. 7 E., in the Dexter field. "The scale is composed predominately of fine-grained precipitated celestite, probably containing some physically intermixed hydrocarbons that give the specimen its dark color. No other minerals were observed." (Mineralogy by Berman, Joseph, 1949a.)
15548	.38	.000	The sample was collected from the interior of a pipe at the Sinclair-J. C. Scully no. 2 well located in the NE¼NE¼ sec. 16, T, 27 S., R. 4 E., in the North Augusta field. "The chief mineral appears to be a form of radiating and fibrous * * * celestite containing inclusions of iron which can be removed, when the sample is ground fine enough, by concentrated HCL. * * * The sample is made up of alternating gray and black bands. The color of these bands is due largely to the presence of iron but some hydrocarbons are also present." (Mineralogy by Jones, R. S., 1949.)
13165	.029	.000	Random sample collected from the ground surface on the Magnolia-North Anderson lease in the SE¼ sec. 9, T. 27 S., R. 4 E., in the North Augusta field. The sample was contaminated with surface material and consists of oil-impregnated debris. "The greater part of the oil was removed at a moderate temperature (300°) leaving an ash that is composed predominantly of subangular quartz silt and lesser quantities of feldspar, chlorite, clay, and iron oxide." (Mineralogy by Berman, Joseph, 1949b.)
13167	.043	.000	An oil-impregnated sample from the ground surface in the North Augusta field near a well located in the SE¼SW¼NE¼ sec. 21, T. 27 S., R. 4 E. "It is composed predominantly of iron oxide and gypsum with minor amounts of clay and quartz." (Mineralogy by Berman, Joseph, 1949b.)
13169	.12	.000	The sample is composed of surface debris collected from near a well in the SE¼ sec. 9, T. 27 S., R. 4 E. It is partially oil-impregnated with residual oil and is composed predominantly of iron oxide, small prisms of celestite, and gypsum. Minor amounts of clay and fine quartz silt are present.
13170	.24	.000	The sample was collected from the inside of a pipe at a well in sec. 9, T. 27 S., R. 4 E. It is partially oil-impregnated with residual oil and "is composed predominantly of iron oxide, small prisms of celestite, and gypsum. Minor amounts of clay and fine quartz silt are present." (Mineralogy by Berman, Joseph, 1949b.)
13171	.39	.000	The sample was collected near the center of sec. 21, T. 27 S., R. 4 E., in the North Augusta field. It was formed as an encrustation on the ground surface and mineralogically is similar to sample no. 13170. However, a greater amount of gypsum and a correspondingly lesser amount of celestite are present.

itates are strontium, barium, calcium, iron, silicon, and aluminum. Nineteen minor elements seem consistently to be present in the five samples that were analyzed.

SAMPLE DATA

Both radiometric and chemical data for the samples collected in Cowley, Butler, and Marion Counties are tabulated in tables 5, 6, 7, 8, 9, and 10. These data show a range from no detectable radioactivity to a maximum of 10.85 percent equivalent uranium oxide in one of the samples collected from Cowley County. The most uranium oxide found in any of these samples was 0.006 percent in a sample from the Molk-Loomis well in the North Augusta field in Butler County. (See table 6, index no. 244.) Several samples collected from wells in Marion County (see table 9) contained as much as 0.003 percent uranium oxide, but all these samples were composed of surface debris in which fine-grained fragments of radium-bearing precipitates had become disseminated. As the samples that are contaminated with surface debris seem to contain more uranium than do the uncontaminated samples, some uranium may have been concentrated in the surface material from fluids that had leaked or overflowed.

TABLE 5.—*Spectrographic, radiometric, and chemical analyses of radium-bearing precipitates*

[The values are visual estimates]

Serial no.	Radiometric	Chemical	Spectrographic analyses									
	Percent eU_3O_8	Percent U_3O_8	Sr	Ba	Ca	Fe	Al	Si	Cu	Mn	Ti	Mg
13170 [1]	0.24	0.000	xx	------	xx	xx	x	x	0.0x	0.0x	0.0x	------
13171 [1]	.39	.000	xx	------	xx	xx	x	x	0.0x	0.0x	0.0x	------
15526 [1]	.64	.006	xx	------	x	xx	x	x	0.0x	0.0x	0.0x	0.0x
15555 [1]	.83	.000	xx	------	x	xx	x	x	0.0x	0.0x	0.0x	0.0x
15539 [1]	1.31	.003	xx	------	x	xx	xx	x	0.0x	0.0x	0.0x	0.0x
18451 [2]	.12	.000	0.x	0.x	x	x	------	0.x	------	------	------	------
18450 [2]	.001	.001	0.x	0.x	0.x	xx	------	0.x	------	0.x	------	------
18446 [2]	10.85	.001	xx	xx	x	x	------	0.x	------	------	------	------
18382 [2]	.007	--------	x	x	xx	0.x	x	xx	------	0.x	------	x
18381 [2]	.026	--------	x	x	x	x	x	xx	------	------	------	x
18380 [2]	.002	.000	0.x	0.x	0.x	xx	------	x	------	0.x	------	------
18372 [2]	.000	.000	0.x	0.x	x	xx	------	0.x	------	------	------	------
18369 [2]	.000	.000	0.x	0.x	0.x	xx	------	0.x	------	------	------	------
15529 [1]	.31	.000	xx	------	x	xx	x	x	0.0x	0.0x	0.0x	0.0x
15537 [1]	.49	.001	xx	------	x	xx	x	x	0.0x	0.0x	0.0x	0.0x
15543 [1]	1.34	.003	xx	------	x	xx	x	x	0.0x	0.0x	0.0x	0.0x
15558 [1]	.24	.005	xx	------	x	xx	x	x	0.0x	0.0x	0.0x	0.0x

[1] Analyses by Morris Slaven, U. S. Geological Survey, July 5, 1949. The following elements were found to be present in quantities less than 0.01 percent: Ag, B, Be, Bi, Cb, Cd, Co, Cr, Mo, Ni, Pb, Sn, V, Zn, and Zr.

[2] Analyses by Paul R. Barnett, U. S. Geological Survey.

NOTE.—0.0x, 0.x, x, and xx mean 0.01 to 0.1, 0.1 to 1, 1 to 10, and 10 to 100 percent, respectively.

TABLE 6.—*Sample data: Augusta field, Butler County*

Index no.	Producing formation or group	Company	Lease name and well no.	Location (Sec.-T.S.-R.E.)	Field radioactivity [1]	Serial no.
	Samples from producing wells					
1	Kansas City	Magnolia	Suits 1	SW¼-10-27-4	(2)	15604
2	Douglas	do	Suits 1½	do	(3)	16311
2	do	do	do	do	(3)	16412
2	do	do	do	do	(3)	15599
3	Arbuckle, plugged back to Kansas City	do	Suits 3	do	(2)	15602
4	Simpson	do	Suits 7	do	(2)	15539
4	do	do	do	do	(2)	18444
5	Arbuckle	Sinclair	Scully 1	NE¼-9-27-4	(2)	15543
6	do	do	Scully 2	NE¼-16-27-4	(2)	15548
7	do	do	Scully 3	NE¼-9-27-4	(3)	15544
8	Kansas City	do	Scully 5	NE¼-16-27-4	(0)	
9	Arbuckle	do	Scully 6	do	(5)	15550
10	do	do	Scully 15	NE¼-9-27-4	(3)	
11	Kansas City	do	Scully 23	NE¼-16-27-4	(0)	
12	Arbuckle	do	Scully 25	do	(10)	15551
13	Kansas City	do	Scully 28	do	(0)	
14	Arbuckle	do	Scully 29	NE¼-9-27-4	(2)	
15	Kansas City	Magnolia	Anderson 1	SE¼-9-27-4	(2)	15546
15	do	do	do	do	(2)	15609
15	do	do	do	do	(2)	15610
16	do	do	Anderson 2	do	(0)	15617
16	do	do	do	do	(0)	15618
17	Arbuckle, plugged back to Kansas City	do	Anderson 4	do	(15)	15613
17	do	do	do	do	(15)	15614
18	Arbuckle	do	Anderson 7	do	(2)	
19	do	do	Anderson 9	do	(3)	15545
19	do	do	do	do	(3)	15611
19	do	do	do	do	(3)	15612
20	Douglas	United		do	(15)	
21	Arbuckle	Hammer and Maclean	Bates 2A	SW¼-10-27-4	(0)	
22	do	Aikman and Braden	South Anderson 1	NW¼-15-27-4	(0)	
23	do	do	South Anderson 2	do	(0)	
24	do	Magnolia	Robertson 1	NW¼-10-27-4	(5)	
25	do	Rex and Morris	Loomis 7	do	(0)	
26	do	Magnolia	Foster 1	SE¼-21-27-4	(15)	15632
27	Arbuckle, plugged back to Kansas City	do	Foster 3	do	(10)	

See footnote at end of table.

TABLE 6.—*Sample data: Augusta field, Butler County*—Continued

Index no.	Producing formation or group	Company	Lease name and well no.	Location (Sec.-T.S.-R.E.)	Field radioactivity [1]	Serial no.
	Samples from producing wells—Continued					
28	Kansas City	Magnolia	Foster 9	SE¼-21-27-4	(0)	
29	Arbuckle, plugged back to Kansas City	do	Foster 14	do	(0)	5809
30	Arbuckle	do	Foster 16	do	(20)	15555
30	do	do	do	do	(20)	15625
31	Kansas City	do	Foster 24	NE¼-21-27-4	(2)	
32	do	do	Foster 25	SE¼-21-27-4	(0)	
33	do	do	Foster 26	NE¼-21-27-4	(2)	15629
34	do	do	Foster 31	do	(0)	15627
35	do	do	Foster 32	do	(0)	15628
36	do	do	Foster 36	SE¼-21-27-4	(0)	15631
37	do	do	Carter 3	NE¼-28-27-4	(0)	
38	do	do	Kramer 15	SW¼-28-27-4	(0)	
39	Arbuckle	do	Kramer 16	NW¼-28-27-4	(0)	15634
40	do	do	Kramer 17	SW¼-28-27-4	(0)	
41	Kansas City		Safford 4	SE¼-26-27-4	(0)	
42	do		Safford 5	do	(0)	
43	Douglas?		Safford 7	do	(5)	16232
44	Kansas City		Safford 8	do	(0)	
45	do	Sinclair—Cities Service	Skaer 1	NE¼-35-27-4	(0)	
46	do	do	Skaer 2	do	(0)	16265
47	Simpson	do	Skaer 5	do	(0)	16262
47	do	do	do	do	(0)	16261
48	Kansas City	do	Skaer 10	do	(0)	
49	Arbuckle	do	Skaer 12	do	(0)	
50	Arbuckle, plugged back to Kansas City	do	Skaer 14	do	(2)	
51	Kansas City	do	Skaer 15	do	(0)	16235
52	Arbuckle, plugged back to Kansas City	do	Skaer 16	do	(10)	16268
52	do	do	do	do	(10)	16267
53	Simpson	do	Skaer 17	do	(0)	16266
54	do	do	Skaer 18	do	(0)	16236
55	do	do	Skaer 19	do	(3)	
56	Arbuckle, plugged back to Kansas City	do	Starkey 1	SE¼-35-27-4	(0)	16272
57	Kansas City	do	Starkey 3	do	(0)	
58	do	do	Starkey 4	do	(0)	16270
58	do	do	do	do	(0)	16269
59	do	do	Starkey 5	do	(0)	16275
60	Arbuckle	do	Starkey 7	do	(0)	16276
61	do	do	Starkey 8	do	(0)	
62	Arbuckle, plugged back to Kansas City	do	Starkey 9	do	(0)	

63	Simpson	do	Starkey 12	do	(0)	16277
64	Kansas City	do	Starkey 13	do	(0)	
65	Simpson	do	Starkey 15	do	(0)	
66	Arbuckle	do	Starkey 16	do	(0)	
67	do	Shawver Graham	King 7	SW¼-36-27-4	(2)	16242
68	do	do	King 12	do	(0)	16243
69	do	do	King 14	NW¼-36-27-4	(0)	----------
70	do	Hammer and Maclean	Moyle 2	SW¼-35-27-4	(0)	16278
71	do	do	Moyle 3	do	(0)	----------
72	do	do	Ambler 1	NW¼-2-28-4	(0)	16284
73	do	do	Ambler 2	do	(0)	----------
74	do	do	Ambler 3	do	(0)	16245
75	do	do	Ambler 4	do	(0)	16285
76	do	do	Ambler 5	do	(0)	----------
77	do	Cities Service	Brant 3	SE¼-2-28-4	(0)	16260
78	do	do	Brant 7	do	(4)	16256
79	Kansas City	do	Brant 9	do	(0)	----------
80	Arbuckle	do	Brant 10	do	(0)	----------
81	do	do	Brant 11	do	(10)	16258
81	do	do	do	do	(10)	16259
82	do	do	Brant 13	do	(0)	----------
83	do	do	Brant 14	do	(0)	----------
84	Kansas City	do	Hazlett 3	NE¼-11-28-4	(0)	----------
85	do	do	Hazlett 4	do	(0)	----------
86	Arbuckle	do	Hazlett 5	do	(10)	16250
87	do	do	Hazlett 6	do	(0)	----------
88	do	do	Hazlett 7	do	(0)	----------
89	do	do	Wallace 4	NW¼-11-28-4	(3)	16288
90	do	do	Wallace 7	do	(0)	----------
91	do	do	Wallace 8	do	(0)	----------
92	do	do	Wallace 10	do	(0)	----------
93	do	do	Wallace 12	do	(0)	----------
94	Kansas City	do	Wallace 18	do	(0)	----------
95	do	do	Wallace 19	do	(0)	16253
96	do	do	Wallace 20	do	(0)	16287
97	do	do	Moyle 1	SE¼-10-28-4	(0)	----------
98	do	do	Moyle 10	SW¼-10-28-4	(0)	----------
99	do	do	Moyle 11	do	(0)	----------
100	Arbuckle	do	Moyle 27	NE¼-15-28-4	(0)	----------
101	do	do	Moyle 29	SW¼-10-28-4	(0)	----------
102	do	do	Moyle 30	SE¼-10-28-4	(0)	----------
103	do	do	Moyle 33	SW¼-11-28-4	(3)	16291
104	do	do	Moyle 34	NE¼-15-28-4	(0)	----------
105	(?)	do	Moyle 43	SE¼-10-28-4	(0)	----------
106	Arbuckle	do	Moyle 44	do	(10)	16289
106	do	do	do	do	(10)	16292

See footnote at end of table.

TABLE 6.—*Sample data: Augusta field, Butler County*—Continued

Index no.	Producing formation or group	Company	Lease name and well no.	Location (Sec.-T.S.-R.E.)	Field radio-activity[1]	Serial no.
	Samples from producing wells—Continued					
107	Kansas City	Cities Service	Moyle 45	SW¼-11-28-4	(0)	
108	Arbuckle	do	Moyle 46	SE¼-10-28-4	(0)	
109	Kansas City	do	Moyle 47	NW¼-14-28-4	(0)	
110	Arbuckle	do	Moyle 48	SW¼-11-28-4	(0)	
111	Douglas	Hammer and Maclean	Walker ? 1	NE¼-3-28-4	(0)	16244
112	Arbuckle	do	Walker? 5	do	(0)	
113	Kansas City	Cities Service	Miller 15	SW¼-2-28-4	(0)	16247
114	Arbuckle	Adair	Moyle 1	NW¼-10-28-4	(0)	
115	do	do	Moyle 2	do	(0)	
116	do	do	Moyle 3	do	(0)	
117	do	do	Moyle 4	do	(0)	
118	do	do	Moyle 5	do	(0)	
119	do	Adair (west)	Feltham 1	NW¼-9-28-4	(0)	
120	do	do	Feltham 1-B	NE¼-9-28-4	(0)	
121	do	do	Feltham 2	do	(0)	
122	do	Cities Service	Scully 4	SE¼-9-28-4	(5)	16301
123	do	do	Scully 8	do	(0)	
124	do	do	Scully 9	do	(3)	
125	do	do	Scully 11	do	(0)	
126	do	do	Scully 12	do	(0)	
127	do	do	Brown 6	NE¼-16-28-4	(3)	
128	do	do	Brown 7	do	(0)	
129	do	do	Brown 16	do	(0)	
130	do	Aikman and Braden	Blood 2	SW¼-21-28-4	(0)	
131	do	do	Blood 3	do	(0)	
132	do	do	Blood 20	do	(0)	
133	do	Cities Service	Varner 6	NE¼-17-28-4	(0)	
134	do	do	Varner 12	do	(0)	
135	do	do	Varner 13	SE¼-8-28-4	(15)	
136	Kansas City	do	Varner 17	do	(0)	
137	do	do	Varner 18	do	(0)	
138	Arbuckle	do	Varner 19	do	(15)	16297
138	do	do	do	do	(15)	16296
139	do	do	Varner 21	NE¼-17-28-4	(0)	
140	do	do	Varner 23	do	(0)	
141	do	do	Varner 25	SE¼-8-28-4	(0)	
142	do	do	Varner 26	NE¼-17-28-4	(15)	
143	do	do	Varner 28	do	(0)	
144	Kansas City	do	Varner 32	do	(0)	
145	do	do	Varner 33	do	(0)	
146	do	do	Varner 34	do	(0)	

147	Arbuckle	do	Kirkpatrick 6	SE¼-17-28-4	(75)	16316
147	do	do	do	do	(75)	16317
148	Kansas City	do	Kirkpatrick 10	do	(0)	----------
149	Arbuckle	do	Haskins 5	NW¼-17-28-4	(3)	16320
150	do	do	Haskins 9	NW¼-20-28-4	(10)	----------
151	do	do	Haskins 20	do	(15)	----------
152	do	do	Haskins 22	SW¼-17-28-4	(0)	----------
153	do	do	Smith 25	NW¼-20-28-4	(50)	16323
153	do	do	do	do	(50)	16322
154	do	do	Smith 26	do	(0)	----------
155	do	do	Smith 31	NE¼-20-28-4	(5)	16314
156	do	do	Smith 32	SE¼-17-28-4	(0)	16315
157	do	do	Smith 44	NW¼-20-28-4	(0)	----------
158	do	do	Love 22	SE¼-20-28-4	(0)	----------
159	do	do	Love 23	SW¼-20-28-4	(0)	----------
160	do	do	Love 26	do	(0)	----------
161	do	do	Love 33	NW¼-29-28-4	(3)	16327
162	Lansing	do	Love 34	SW¼-20-28-4	(0)	----------
163	Arbuckle	do	Kirkpatrick 14	NE¼-20-28-4	(0)	----------
164	do	Thrifty	Haskins 2	NE¼-19-28-4	(0)	----------
165	do	Black	Chance 1	SE¼-19-28-4	(0)	----------
166	do	do	Chance 2	do	(0)	----------
167	do	do	Chance 3	do	(0)	----------
168	do	Thrifty	Vinyard 2	do	(0)	----------
169	do	do	Vinyard 3	do	(0)	----------
170	do	----------	Blakeslee 1	NW¼17-28-4	(0)	----------
171	Arbuckle	Magnolia	Robertson	NW¼-10-27-4	(30)	15540
172	(?)	Hammer and Maclean	Suits	do	(10)	15606
173	Douglas and Kansas City	Magnolia	do	SW¼-10-27-4	(5)	15538
173	do	do	do	do	(5)	15603
174	Arbuckle	Aikman and Braden	Bates	do	(2)	15619
175	do	do	Anderson	NW¼-15-27-4	(10)	15621
176	(?)	Molk	Loomis	do	(10)	15528
176	(?)	do	do	do	(10)	15623
177	Arbuckle	Sinclair	Scully	NE¼-9-27-4	(40)	15608
178	Kansas City and Arbuckle	Magnolia	Anderson	SE¼-9-27-4	(40)	15615
179	(?)	United	----------	do	(0)	----------
180	Kansas City and Arbuckle	Sinclair	Scully	NE¼-16-27-4	(50)	15552
180	do	do	do	do	(50)	15622
181	(?)	Aikman and others	Parry	SE¼-16-27-4	(0)	15624
182	(?)	Aikman and Braden	Brown	do	(0)	----------
183	(?)	Rex and Morris	Loomis	NE¼-21-27-4	(0)	----------
184	(?)	do	do	NW¼-21-27-4	(5)	----------
185	Kansas City and Arbuckle	Magnolia	Foster	SW¼-21-27-4	(50)	15630
186	do	Cities Service	Scully	NW¼-28-27-4	(20)	15633
187	Kansas City?	Magnolia	Carter	NE¼-28-27-4	(0)	----------
188	do	do	do	do	(5)	15556

See footnote at end of table.

TABLE 6.—*Sample data: Augusta field, Butler County*—Continued

Index no.	Producing formation or group	Company	Lease name and well no.	Location (Sec.-T.S.-R.E.)	Field radio-activity[1]	Serial no.
	Samples from producing wells—Continued					
189	Kansas City and Arbuckle	Magnolia	Kramer	SW¼-28-27-4	(5)	
190	Kansas City	(?)		SE¼-26-27-4	(0)	
191	Kansas City, Simpson, and Arbuckle	Sinclair-Cities Service	Skear	NE¼-35-27-4	(7)	16263
192	(?)	Magnolia	Palmer	NW¼-35-27-4	(3)	
193	Arbuckle	Hammer and Maclean	Moyle	SW¼-35-27-4	(10)	16231
194	Kansas City, Simpson, and Arbuckle	Sinclair-Cities Service	Starkey	SE¼-35-27-4	(5)	16271
195	Arbuckle	Shawver Graham	King	SW¼-36-27-4	(0)	16241
196	do	Hammer and Maclean	Ambler	NW¼-2-28-4	(0)	
197	(?)	B and R	Collins	NE¼-2-28-4	(0)	
198	Kansas City and Arbuckle	Cities Service	Brant	SE¼-2-28-4	(5)	16255
198	do	do	do	do	(5)	16257
199	Kansas City	do	Miller	SW¼-2-28-4	(5)	16248
200	Kansas City and Arbuckle	do	Wallace	NW¼-11-28-4	(35)	16252
201	do	Sinclair-Cities Service	Hazlett	NE¼-11-28-4	(10)	
202	do	Cities Service	Moyle	SW¼-11-28-4	(10)	
203	Arbuckle	Hammer and Maclean	Walker?	NE¼-3-28-4	(0)	
204	(?)	Adair	Moyle	NE¼-10-28-4	(4)	
205	(?)	do	do	do	(0)	16290
206	Kansas City and Arbuckle	Cities Service	do	SE¼-10-28-4	(5)	16293
207	do	do	do	SW¼-10-28-4	(10)	
208	(?)	Adair	Feltham	NW¼-10-28-4	(0)	
209	(?)	Adair (west)	do	NE¼-9-28-4	(0)	
210	Kansas City and Arbuckle	Cities Service	Scully	SE¼-9-28-4	(10)	16302
211	Arbuckle	do	Brown	NE¼-16-28-4	(5)	
212	do	do	do	do	(5)	
213	Kansas City and Arbuckle	do	Varner	NE¼-17-28-4	(10)	
214	do	do	do	do	(10)	16298
215	do	do	Kirkpatrick	SE¼-17-28-4	(15)	16318
216	(?)		Blakeslee	NW¼-17-28-4	(0)	
217	Arbuckle	Cities Service	Haskins	SW¼-17-28-4	(5)	16321
218	Kansas City and Arbuckle	do	do	NW¼-20-28-4	(20)	16307
218	do	do	do	do	(20)	16306
219	do	do	Smith	do	(10)	16305
219	do	do	do	do	(10)	16304
220	do	do	do	NE¼-20-28-4	(20)	16313
220	do	do	do	do	(20)	16312
221	Lansing and Arbuckle	do	Kirkpatrick	SE¼-20-28-4	(40)	16295
221	do	do	do	do	(40)	16294
222	do	do	Love	do	(10)	16326
223	Arbuckle	Aikman and Braden	Blood	SW¼-21-28-4	(0)	16303
224	do	Thrifty	Haskins	NE¼-19-28-4	(3)	16324

235	do	do	Vinyard	SE¼-19-28-4	(0)	
226	do	do	do	do	(0)	
227	do	Black	Chance	do	(0)	16325
228	(?)		MacKay	NE¼-30-28-4	(5)	
229	(?)	Pure Oil		SW¼-29-28-4	(5)	

Index no.	Producing formation or group	Company	Lease name and well no.	Location (Sec.-T.S.-R.E)		Serial no.
			Samples from miscellaneous localities [2]			
230	Kansas City and Arbuckle	Magnolia	Anderson	SE¼-9-27-4		13165
230	do	do	do	do		13166
230	do	do	do	do		13169
230	do	do	do	do		13170
230	do	do	do	do		13171
231	Arbuckle?	Citron?	Anderson 8	NE¼-SE¼-SE¼-9-27-4		15547
232	(?)	do	Anderson	do		15620
233	(?)		Suits	SW¼-SW¼-NW¼-10-27-4		15541
233	(?)		do	do		15542
234	(?)		Suits (?)	do		15607
235	Kansas City?	Magnolia	Suits 4	SE¼-NW¼-SW¼-10-27-4		15600
236	(?)	do	Suits	W½-NW¼-SW¼-10-27-4		15536
236	(?)	do	do	do		15537
237	(?)		Bates	SW¼-SW¼-SW¼-10-27-4		15533
238	(?)		do	NW¼-SW¼-SW¼-10-27-4		15534
239	(?)		Bates 1?	do		15535
240	(?)		South Anderson 2	SW¼-NW¼-NW¼-15-27-4		15529
241	(?)		South Anderson 6	C-NW¼-15-27-4		15530
242	(?)		South Anderson 7	NW¼-NW¼-NW¼-15-27-4		15531
243	(?)		South Anderson	N½-NW¼-NW¼-15-27-4		15532
244	(?)	Molk	Loomis	SW¼-SW¼-NW¼-15-27-4		15526

See footnotes at end of table.

TABLE 6.—*Sample data: Augusta field, Butler County*—Continued

Index no.	Producing formation or group	Company	Lease name and well no.	Location (Sec.-T.S.-R.E)	Serial no.
	Samples from miscellaneous localities [2]—Continued				
245	(?)	Molk	Loomis	N½-SW¼-NW¼-15-27-4	15527
245	(?)	do	do	do	15528
246	(?)	do	Loomis 7	S½-NW¼-SW¼-15-27-4	15553
247	(?)	Sinclair	Scully 16	NE¼-NE¼-16-27-4	15549
248	(?)	Magnolia	Foster (?)	SE¼-21-27-4	13167
248	(?)	do	do	do	13168
249	(?)	do	Foster 7	SW¼-SW¼-NE¼-21-27-4	15554
250	(?)	do	Kramer 13	C-SE¼-NW¼-28-27-4	15557
251	Douglas?		Safford(?)	SE¼-NW¼-SE¼-26-27-4	16233
252	(?)		Safford	SW¼-SW¼-SE¼-26-27-4	16234
253	(?)	Magnolia	Safford 2	NE¼-SE¼-NW¼-35-27-4	16281
254	Kansas City	do	Safford 3	SW¼-SE¼-NW¼-35-27-4	16283
255	do	do	Safford 6	SE¼-NE¼-NW¼-35-27-4	16282
256	(?)	do	Safford 8	NE¼-NE¼-NW¼-35-27-4	16239
257	(?)	Sinclair-Cities Service	Skaer 3	NW¼-NW¼-NE¼-35-27-4	16238
258	Kansas City	do	Skaer 6	NW¼-SW¼-NE¼-35-27-4	16264
259	Arbuckle	do	Skaer 9	N½-NW¼-NE¼-35-27-4	16237
260	do	do	Starkey 2	NW¼-NW¼-SE¼-35-27-4	16274
261	(?)	do	Starkey 14	SW¼-NE¼-SE¼-35-27-4	16240
262	(?)	United		SE¼-NE¼-SE¼-3-28-4	16246
263	(?)	do		E½-SW¼-SE¼-3-28-4	16251
264		Cities Service		NW¼-NE¼-NE¼-16-28-4	16299
265		do		do	16300
266	(?)	do	Smith 20	NW¼-NE¼-NW¼-20-28-4	16308

TABLE 6.—*Sample data: Augusta field, Butler County*—Continued

Index no.	Precipitates: Collected from pipes, Percent eU_3O_8	Precipitates: Collected from pipes, Percent U_3O_8	Precipitates: Contaminated with surface debris, Percent eU_3O_8	Precipitates: Contaminated with surface debris, Percent U_3O_8	Brines (Milligrams per liter): U_3O_8	SO_4	Cl	CO_3	HCO_3	Ba	Sr	Ca	Mg	K	Na	Total solids	pH	Remarks
Samples from producing wells																		
1					0.1	81	115,100		27								6.4	
2	0.34	0.00																Collected from gas well. Some brine is also pumped.
2	.67	.001																Encrusted fiber cup from insert pump.
2					.0	1,387	80,400		9								6.1	Collected from gas well.
3					.0	63	116,000		14								6.5	
4	1.31	.003																Also spectrographically analyzed.
4	.000	.001																Evaporite.
5	1.34	.003																
6	.38	.000																
7	.15	.000																
8																		No samples.
9	.61	.000																
10																		Do.
11																		Do.
12			0.075	0.000														
13																		Do.
14																		Cable-tool drill cuttings, see table 10.
15	.012	.000																Evaporite.
15					.0	82	116,700		26								5.8	
15					.0	182	115,700		28								6.3	
16					.0	85	117,400		32								6.8	
16					.0	75	118,900		29								6.8	
17					.0	1,759	34,000		200	99	127	2,880	923		17,710		7.2	
17					.0	1,735	34,000		167	47	228	2,670	477		19,140		7.6	
18																		No samples.
19	.006	.000																
19					.0	2,834	20,100		239	9	29	1,725	455		11,100	38,000	7.9	
19					.0	2,380	20,700		232	59	25	1,950	417		11,450	38,100	7.8	

TABLE 6.—*Sample data: Augusta field, Butler County*—Continued

Index no.	Precipitates: Collected from pipes, Percent eU_3O_8	Precipitates: Collected from pipes, Percent U_3O_8	Precipitates: Contaminated with surface debris, Percent eU_3O_8	Precipitates: Contaminated with surface debris, Percent U_3O_8	Brines, Milligrams per liter: U_3O_8	SO_4	Cl	CO_3	HCO_3	Ba	Sr	Ca	Mg	K	Na	Total solids	pH	Remarks
Samples from producing wells—Continued																		
20																		Gas well; no samples. Radio activity possibly caused by radon.
21																		Cable-tool drill cuttings, see table 10.
22																		Do.
23																		Do.
24																		No samples.
25																		Cable-tool drill cuttings, see table 10.
26					0.0												7.8	
27																		No samples.
28																		Do.
29			0.001															
30	0.83	0.000																Also spectrographically analyzed.
30					.0	712	81,800		112								6.9	
31																		No samples.
32																		Do.
33					.1	32	115,200		28								6.3	
34					.0	56	114,500		34								7.0	
35					.0	52	115,200		30								6.9	
36					.0												5.4	
37																		Do.
38																		Do.
39					.0												4.9	
40																		Cable-tool drill cuttings, see table 10.
41																		No samples.
42																		Do.
43	0.008	0.000																Collected from gas well. Field measurement made of precipitate.

44																		No samples.
45																		Do.
46					.0	204	98,300		64									
47	.000	.000																
47					.0	1,595	17,910		320									
48																		Do.
49																		Do.
50																		Do.
51					.0	74	108,300		38									
52	.17	.000																
52					.0	76	111,000		41									
53					.0		27,200		380									
54					.0	2,084	20,400		360	38	68	1,782	464	146	11,560	38,800		
55																		Do.
56					.0		49,600											
57																		Do.
58	.001	.000																
58					.0	31	109,900		28									
59					.0	2,740	24,300		332									
60					.0	1,992	16,900		268	8	34	1,644	418		9,640	33,300		
61																		Do.
62																		Do.
63					.0	1,546	39,400		187	41	182	2,900	1,038		21,740	72,300		
64																		Do.
65																		Do.
66																		Do.
67					.0	2,274	18,100		343	13	36	1,804	859		10,410	35,200		
68					.0	2,570	20,800		320	8	30	1,994	495		11,790	40,400		
69																		Do.
70					.0	1,744	18,330		294									Also cable-tool drill cuttings, see table 10.
71																		No samples.
72					.0	2,610	19,640		298									Also cable-tool drill cuttings, see table 10.
73																		Cable-tool drill cuttings, see table 10.
74					.0	2,780	22,700		224									Also cable-tool drill cuttings, see table 10.
75					.0		21,000											Do.
76																		Cable-tool drill cuttings, see table 10.
77					.0	2,395	17,900		264	59	25	1,857	473		10,210	35,100		
78					.0	2,670	23,860		251									
79																		No samples.
80																		Do.
81	.081	.001																
81					.0	931	17,900		268									
82																		Do.
83																		Do.
84																		Do.
85																		Do.
86	.26	.000																
87																		Do.

TABLE 6.—*Sample data: Augusta field, Butler County*—Continued

Index no.	Precipitates: Collected from pipes, Percent eU_3O_8	Precipitates: Collected from pipes, Percent U_3O_8	Precipitates: Contaminated with surface debris, Percent eU_3O_8	Precipitates: Contaminated with surface debris, Percent U_3O_8	Brines, Milligrams per liter: U_3O_8	SO_4	Cl	CO_3	HCO_3	Ba	Sr	Ca	Mg	K	Na	Total solids	Brines: pH	Remarks
Samples from producing wells—Continued																		
88																		No samples.
89	0.17	0.000																
90																		Do.
91																		Do.
92																		Do.
93																		Do.
94																		Do.
95					0.0		103,900		34									
96					.0	11	101,900		37									
97																		Do.
98																		Do.
99																		Do.
100																		Do.
101																		Do.
102																		Do.
103					.0	2,700	18,560		332		24	1,872			17,710	37,700		
104																		Do.
105																		Do.
106	.22	.000																
106					.0		26,900		383									
107																		Do.
108																		Do.
109																		Do.
110																		Do.
111					.0	83	99,000		26									
112																		Do.
113					.0	35	101,600		30									
114																		Do.
115																		Do.
116																		Do.
116																		Do.
118																		Do.
119																		Do.
120																		Do.

121																		Do.
122	.42	.001																
123																		Do.
124																		Do.
125																		Do.
126																		Do.
127																		Do.
128																		Do.
129																		Do.
130																		Do.
131																		Do.
132																		Do.
133																		Do.
134																		Do.
135																		Do.
136																		Do.
137																		Do.
138	.064	.000																
138					.0	2,340	22,990		283	12	46	2,335	598		12,980	45,500		
139																		Do.
140																		Do.
141																		Do.
142																		Do.
143																		Do.
144																		Do.
145																		Do.
146																		Do.
147	.42	.000																
147					.0	2,285	19,000		345	11	34	1,975	488	158	11,000	37,900		
148																		Do.
149	.052	.000																
150																		Do.
151																		Do.
152																		Do.
153	.58	.000																
153					.0	638	71,900		164									
154																		Do.
155	.28	.000																
156					.0	2,670	20,400		307	47	52	2,106	477	160	11,830	39,900		
157																		Do.
158																		Do.
159																		Do.
160																		Do.
161	.018	.000																
162																		Do.
163																		Do.
164																		Do.
165																		Do.
166																		Do.
167																		Do.
168																		Do.
169																		Do.
170																		Do.

TABLE 6.—*Sample data: Augusta field, Butler County*—Continued

Index no.	Precipitates				Brines													Remarks
	Collected from pipes		Contaminated with surface debris		Milligrams per liter												pH	
	Percent eU_3O_8	Percent U_3O_8	Percent eU_3O_8	Percent U_3O_8	U_3O_8	SO_4	Cl	CO_3	HCO_3	Ba	Sr	Ca	Mg	K	Na	Total solids		
	Samples from brine-disposal systems																	
171	0.004	0.000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Wood collected from separator tank, radioactivity caused precipitates.
172	-----	-----	-----	-----	0.0	91	113,700	-----	33	-----	-----	-----	-----	-----	-----	-----	6.9	
173	.002	.000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Do.
173	-----	-----	-----	-----	.0	29	118,500	-----	22	68	2,332	8,080	3,550	207	57,800	201,600	6.9	
174	-----	-----	-----	-----	.0	46	108,800	-----	26	52	2,003	7,810	3,620	193	51,600	184,000	6.9	
175	-----	-----	-----	-----	.0	363	87,800	-----	34	-----	-----	-----	-----	-----	-----	-----	6.5	
176	-----	-----	0.014	0.000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Collected from area near separator tank.
176	-----	-----	-----	-----	.0	457	19,220	-----	63	-----	-----	-----	-----	-----	-----	-----	7.0	
177	-----	-----	-----	-----	.0	219	109,800	-----	57	-----	-----	-----	-----	-----	-----	-----	6.8	
178	-----	-----	-----	-----	.0	172	88,800	-----	26	20	1,282	6,640	2,720	184	43,900	152,400	7.0	
179	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	No samples.
180	.28	.000	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Collected from separator tank.
180	-----	-----	-----	-----	.0	536	78,300	-----	115	-----	-----	-----	-----	-----	-----	-----	7.2	
181	-----	-----	-----	-----	.0	2,720	28,000	-----	103	20	19	2,153	697	152	17,200	51,200	7.9	
182	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	No samples.
183	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Do.
184	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Do.
185	-----	-----	-----	-----	.0	741	81,700	-----	87	-----	-----	-----	-----	-----	-----	-----	6.9	
186	-----	-----	-----	-----	.0	1,627	38,770	-----	113	13	281	3,040	1,056	155	20,050	68,200	7.2	
187	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Do.
188	-----	-----	.060	.002	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Collected from area near separator tank.
189	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	No samples.
190	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Do.
191	-----	-----	-----	-----	.0	1,263	34,250	-----	195	50	356	2,950	1,046	138	18,200	60,700	-----	
192	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Do.

193	.21	.000																Collected from separator tank.
194			.046	.002														Collected from abandoned separator tank site.
195					.19	2,354	20,200		328	44	19	1,800	455	144	11,280	38,000		
196																		No samples.
197																		Do.
198			.055	.000														Collected from area near separator tank.
198					.0	2,107	25,600		222	73	194	2,185	642	153	14,050	47,300		
199					.0	32	104,900		41									
200					.0	243	106,700		37									
201																		No samples.
202																		Do.
203																		Do.
204																		Do.
205					.0	1,694	18,240		147	13	22	1,627	449	150	10,370	35,100		
206			.036	.000														Collected from area near separator tank.
207																		No samples.
208																		Do.
209																		Do.
210					.0	1,487	51,200		132									
211																		Do.
212																		Do.
213																		Do.
214					.14	1,322	51,400		179									
215					.0	2,140	24,440		258	34	127	2,238	618	166	13,450	45,900		
216																		Do.
217					.0	1,087	20,010		177									
218			.051	.000														Collected from area near separator tank.
218					.0	790	70,800		128									
219			.093	.001														Do.
219					.0	2,368	36,750		291	14	369	3,340	1,096	173	20,050	67,400		
220			.021	.000														Do.
220					.0	356	63,300		199									
221	.33	.005																Collected from separator tank.
221					.0	2,610	21,300		168	43	33	2,010	499	166	12,300	41,900		
222					.0	1,651	33,400		136									
223					.2	2,209	19,430		232									
224					.2	371	19,820		272									
225																		No samples.
226																		Do.
227					.0	634	19,820		488									
228																		Do.
229																		Do.

TABLE 6.—*Sample data: Augusta field, Butler County*—Continued

Index no.	Precipitates: Collected from pipes or tanks		Precipitates: Contaminated with surface debris		Brines: Milligrams per liter												Brines: pH	Remarks
	Percent eU_3O_8	Percent U_3O_8	Percent eU_3O_8	Percent U_3O_8	U_3O_8	SO_4	Cl	CO_3	HCO_3	Ba	Sr	Ca	Mg	K	Na	Total solids		
230			0.029	0.000														Collected from area near separator tank.
230			.008	.000														Do.
230	0.12	0.000																Collected from separator tank.
230	.24	.000																Collected from separator tank; also spectrographically analyzed.
230			.39	.000														Collected from area near separator tank.
231	.001	.000																Evaporite, collected from well.
232					0.0	99	111,600		38								6.7	Collected from separator tank.
233	.16	.000																Collected from abandoned separator tank site.
233	.22	.000																Do.
234					.1	95	113,600	18									7.0	Collected from well.
235					.0												6.5	Do.
236	.056	.002																Collected from scrap pipe.
236	.49	.001																Collected from scrap pipe; also spectrographically analyzed.
237	.006	.000																Collected from scrap pipe.
238	.42	.000																Do.
239	.33	.000																Collected from well.
240	.31	.000																Collected from abandoned well site.
241	.38	.000																Do.

242			.007	.000														Collected from abandoned well site, cable-tool drill cuttings, see table 10.
243			.011	.000														Collected from abandoned separator tank site.
244	.64	.006																Collected from area near separator tank; also spectrographically analyzed.
245			.003	.000														Collected from area near separator tank.
245			.14	.000														Do.
246			.001	.000														Collected from area near well.
247	.025	.001																Collected from abandoned well site.
248			.043	.000														Do.
248	.092	.000																Do.
249	.004	.000																Do.
250	.28	.000																Do.
251	.001	.000																Collected from well.
252					.0	2,213	98,400		1									Collected from disposal pond.
253	.003	.000																Collected from abandoned well site.
254					.0	48	112,700		31									Collected from well.
255					.0	9	111,700		53									Do.
256			.000	.000														Collected from abandoned well site.
257			.000	.000														Do.
258			.044	.000														Do.
259	.000	.000																Do.
260	.003	.000																Do.
261			.049	.000														Do.
262	.16	.000																Do.
263			.002	.000														Do.
264	.001	.000																Fresh water precipitate collected from power plant.
265					.0	123	1		130									Fresh water from 4-mile creek.
266	.085	.000																Collected from abandoned well site.

[1] Approximate radioactivity determined in the field with a standard portable gamma-beta survey meter. Figures listed are meter divisions (excluding average background of 2–3 divisions). Figures between 0 and 20, 21 and 200, 201 and 2,000, were observed on the 0.2, the 2.0, and the 20.0 sensitivity scales, respectively, and were converted to the comparable number of units on the 0.2 scale. The conversion is not exact because the instrument was uncalibrated.

[2] These miscellaneous sample localities are not shown on the Augusta field map because of poor information relative to location or to fluid source.

TABLE 7.—*Sample Data: Cowley County*

Index no.	Producing formation or group	Company	Lease name and well no.	Location (Sec.-T.S.-R.E.)	Serial no.
267	Arbuckle		Lewis	NE¼-28-31-4	18450
268	do	Bennett and others	Weathered	SE¼-28-31-3	18429
268	do		do	do	18430
269	Cherokee (Bartlesville)		Boyd	SW¼-19-32-5	15585
269	do		do	do	15643
270	Arbuckle and Kansas City	Continental	Bower	NW¼-10-33-3	18447
270	do	do	do	do	18448
270	do	do	do	do	18449
270	do	do	do	do	18452
271	(?)	do	Bower or Graham	9 or 10-33-3	18446
270	Arbuckle and Kansas City	do	Bower	NW¼-10-33-3	17918
272	Arbuckle	do	Bower 6	do	17923
272	do	do	do	do	17924
273	do	do	Graham 3	NE¼-9-33-3	17919
273	do	do	do	do	17920
274	Kansas City and Cherokee (Bartlesville)	Hill	Finch	NE¼-7-35-3	18427
275			Marker(?)	NE¼-4-33-7	15635
276			Radcliffe	SE¼-5-33-7	15584
276			do	do	15597
276			do	do	15636
277	Mississippian	Dilworth and Miller	Dilworth Fee 1	NE¼-8-33-7	
278	do	do	Dilworth	do	15637
279	do	do	Dilworth Fee 2	do	15558
279	do	do	do	do	15598
279	do	do	do	do	15638
279	do	do	do	do	15639
280	do		Olds 1	NW¼-9-33-7	15641
280	do		do	do	15642
281	Cherokee (Bartlesville)	Fleet		W½-27-33-6	
282	Simpson		Bauman	SE¼-17-35-7	18344
283	Cherokee (Bartlesville)	Texas	Eastman	NE¼-6-31-6	17921

Index no.	Precipitates				Brines														Remarks
	Collected from pipes or tanks		Contaminated with surface debris		Milligrams per liter												pH		
	Percent eU_3O_8	Percent U_3O_8	Percent eU_3O_8	Percent U_3O_8	U_3O_8	SO_4	Cl	CO_3	HCO_3	Ba	Sr	Ca	Mg	K	Na	Total solids			
267	0.001	0.001																	Collected from separator tank.

268			0.085	0.000														Do.
268			.027	.001														Collected from separator tank; gypsum, and celestite.
269			.040	.001														Collected from separator tank.
269					0.0												6.5	Do.
270			.32	.001														Do.
270	8.15	.000																Collected from brine-disposal line.
270	.048	.001																Collected from top of separator tank.
270	5.16	.001																Collected form separator tank
271	10.85	.001																Collected from scrap pipe used on the Bower or Graham lease.
270					.0	1,137	68,000	0	71	18	403	5,600	1,367	179	33,100	112,500		Collected from separator tank.
272					.0	1,296	61,100	0	83	0	109	5,070	1,187	171	31,500	99,800		Collected from well.
272					.0	1,301	58,100	0	98	16	248	4,920	1,172	170	30,400	99,800		Do.
273					.0	1,450	50,400	0	75	11	56	3,090	1,006	234	27,000	88,600		Do.
273					.0	1,441	52,100	4	79	11	31	4,490	1,015	192	27,400	88,900		Do.
274			.002	.002														Evaporite on brine-disposal pump.
275					.0												7.5	Collected from well.
276			.019	.001														Collected from brine-disposal pond.
276			.001	.000														Collected from brine-disposal pond; evaporite.
276					.0	716	56,000		55	16	259	5,090	1,150	374	29,960	99,100	7.0	Collected from brine-disposal pond.
277																		Drill cuttings, see table 10.
278					.0												6.5	Collected from separator tank.
279	.24	.005																Also drill cuttings, see table 10.
279	.48	.002																Collected from well.
279					.0													Do.
279					.0												5.5	Do.
280					.0													Do.
280					.0	1,658	50,800		80	59	144	4,530	784		27,000	91,800	6.5	Do.
281																		Core samples, see table 10.
282					.05		137											Collected from separator tank.
283					.0	9	82,600	0	11	441	719	6,740	1,813	66	44,000	139,100		Do.

TABLE 8.—*Sample data: Butler County* [1]

Index no.	Producing formation or group	Company	Lease name and well no.	Location (Sec.-T.S.-R.E.)	Serial no.
284	Kansas City and Hunton		Hawk	SE¼-4-23-4	16328
284	do.		do.	do.	16329
285	Kansas City		McLaughlin 1	SW¼-8-23-4	18376
286		Palmer	Thompson 1	2-24-3	
287	Mississippian?		Houston	NE¼-1-25-3	17915
288			Augustine 1	do.	
289	Viola	Deep Rock	Robinson 1	3-25-5	18377
289	do.	do.	do.	do.	18342
290	Abruckle?		Starkey	NW¼-5-26-5	16309
290	do.		do.	do.	16310
291		Colpitt	Linn 1A	do.	
292		Magnolia	Koogler 71	SE¼-30-26-5	
293	Kansas City		Klinger	NW¼-24-27-3	18332
294	Simpson		Klinger 1	do.	18367
295			Taylor 1	NE¼-17-27-4	
14	Arbuckle	Sinclair	Scully 29	NE¼-9-27-4	
1	Kansas City	Magnolia?	Suits 1	SW¼-10-27-4	
296	do.	Magnolia	Suits 9	do.	
297	Arbuckle	Hammer and Maclean	Bates 2	do.	
22	do.	Aikman and Braden	South Anderson 1	NW¼-15-27-4	
23	do.	do.	South Anderson 2	do.	
298	Kansas City	Cosmic	Loomis 10	15-27-4	
299	Arbuckle	Magnolia	South Anderson 9	NW¼-15-27-4	
300			Perry 1	16-27-4	
301			Loomis 3	NE¼-21-27-4	
302			Loomis 7	do.	
29	Arbuckle, plugged back to Kansas City	Magnolia	Foster 14	SE¼-21-27-4	
303	Arbuckle	do.	Foster 21	do.	

304		Blakeslee	Wilson 1½	NE¼-28-27-4	
305	Arbuckle	Magnolia	Kramer 14	NW¼-28-27-4	
40	do	do	Kramer 17	SW¼-28-27-4	
306	do	do	Kramer 18	NW¼-28-27-4	
307	do	Cities Service	Scully 120	SE¼-21-27-4	
308		Richmond and Riegle	West (?)	SW¼-28-27-4	
309		Palmer	Lychlyter (?)	NW¼-11-27-4	
310		Alter and Brackensiek	Sanford 1	SE¼-27-27-4	
311		Magnolia	Palmer 7A	NW¼-35-27-4	
70	Arbuckle	Hammer and Maclean	Moyle 2	SW¼-35-27-4	
312	do	do	Moyle 4	do	
72	do	do	Ambler 1	NW¼-2-28-4	
73	do	do	Ambler 2	do	
74	do	do	Ambler 3	do	
75	do	do	Ambler 4	do	
76	do	do	Ambler 5	do	
313	Simpson?		Hawks	NE¼-27-38-3	18346
314			Darter(?)	SE¼-6-29-4	18426
315	Arbuckle?		Creed	SW¼-17-29-4	17909
316	Cherokee (Bartlesville)	Sohio	Liggett-W-14	16-26-8	
317	do	do	Liggett 6	do	15514
318	Douglas	do	Liggett-S-1	do	15583
319	Mississippian		Young 4A	NW¼-27-26-7	18379
320	Arbuckle		Beadles	SW¼-4-27-6	18378
320	do		do	do	18343
321	Viola		Stern 1	NE¼-33-27-6	18380
322	do		Patterson	NW¼-34-27-6	18347
323	do		Ramp	NW¼-23-28-7	18348
324	Arbuckle	Morrison	Bush	NW¼-24-29-5	18451
324	do	do	do	do	17922
324	do	do	do	do	18366

[1] Sample data pertaining to the Augusta field in Butler County are listed separately in table 6.

TABLE 8.—*Sample data: Butler County*[1]—Continued

Index no.	Precipitates				Brines													Remarks
	Collected from pipes or tanks		Contaminated with surface debris		Milligrams per liter												pH	
	Percent eU_3O_8	Percent U_3O_8	Percent eU_3O_8	Percent U_3O_8	U_3O_8	SO_4	Cl	CO_2	HCO_3	Ba	Sr	Ca	Mg	K	Na	Total solids		
284			0.001	0.002														Collected from separator tank.
284					0.0	1,588	13,240		192									Do.
285	0.22	0.001																Collected from well.
286																		Cable-tool drill cuttings, see table 10.
287					.0	1,407	110,800	0	0	82	112	280	2,960	64	67,100	199,300		Collected from separator tank.
288																		Cable-tool drill cuttings, see table 10.
289	1.33	.000																Collected from well.
289					.0		18,360											Do.
290			.085	.000														Collected from separator tank.
290			.004	.003														Do.
291																		Rotary-drill cuttings, see table 10.
292																		Cable-tool drill cuttings, see table 10.
293					.04		122,400											Collected from separator tank.
294	.070	.000																Collected from well.
295																		Cable-tool drill cuttings, see table 10.
14																		Do.
1																		Do.
296																		Do.
297																		Do.
22																		Do.
23																		Do.
298																		Do.
299																		Do.
300																		Do.
301																		Do.
302																		Do.
29																		Do.
303																		Do.

304																		Do.
305																		Do.
40																		Do.
306																		Do.
307																		Do.
308																		Do.
309																		Do.
310																		Do.
311																		Do.
70																		Do.
312																		Do.
72																		Do.
73																		Do.
74																		Do.
75																		Do.
76																		Do.
313					.0		19, 530											Collected from separator tank.
314	.21	.001																Collected from well.
315					.0	21	124, 700	0	10	153	1, 897	6, 590	3, 430	151	67, 100	205, 500		Collected from separator tank.
316																		Core samples, see table 10.
317	.002	.000																Collected from well.
318	.001	.000																Do.
319	.32	.000																Do.
320			.002	.001														Collected from separator tank.
320					.0		20, 310											Do.
321	.002	.000																Collected from well.
322					.0		19, 590											Collected from separator tank.
323					.0		68, 500											Do.
324	.12	.000																Collected from water-flood system (precipitate from brine before filtering).
324					.0	2, 248	27, 300		87	0	74	2, 500	582	302	15, 080	48, 200		Collected from water-flood system (brine before filtering).
324					.09													Collected from water-flood system (brine residue from filtering).

[1] Sample data pertaining to the Augusta field in Butler County are listed separately in table 6.

TABLE 9.—*Sample data: Marion County*

Index no.	Producing formation or group	Company	Lease name and well no.	Location (Sec.-T.S.-R.E.)	Serial no.
325	Mississippian		Cowman	SW¼-11-17-4	18333
326	do		Bevins 4	SE¼-21-17-4	18368
326	do		do	do	18334
327	do		Bevins	do	18335
328	Viola	Aladdin	Rempel 1	SE¼-12-19-2	18369
329	do	Sohio	Rempel	NE¼-13-19-2	18336
330	Hunton?		Mott	SE¼-10-21-3	18338
331			Wenger 1	SE¼-14-21-3	
332	Viola	Coop. Refinery Assoc	Reamy 10	NE¼-20-21-4	18372
333	Kansas City and Viola	do	Reamy	do	18371
333	do	do	do	do	18337
334	Viola		Greeley	NE¼-19-21-5	18370
335	do	Faylor?	Joliffe	SE¼-4-22-4	18374
335	do	do	do	do	18339
336			Joliffe(?)	do	18375
336			do	do	3660
336			do	do	18340
337	Mississippian	Colpitt	Spier 1	NW¼-8-22-4	18373
337	do	do	do	do	3662
337	do	do	do	do	5803
337	do	do	do	do	5804
337	do	do	do	do	5805
337	do	do	do	do	5793
338			Spier(?)	NE¼-8-22-4	3659
338			do	do	5807
339		Berry and Eells	Spier 1A	NE¼-8-22-4	5798
340	Viola	do	Joliffe 1	NW¼-9-22-4	
341			Joliffe(?)	do	3661
341			do	do	3663
341			do	do	5799
341			do	do	5802
341			do	do	5808
342	Mississippian		B. Alvin	NW¼-15-22-4	18341
343	Viola	Progressive	Nonken 1	34-22-4	

Index no.	Precipitates: Collected from pipes or tanks: Percent eU_3O_8	Precipitates: Collected from pipes or tanks: Percent U_3O_8	Precipitates: Contaminated with surface debris: Percent eU_3O_8	Precipitates: Contaminated with surface debris: Percent U_3O_8	Brines, milligrams per liter: U_3O_8	SO_4	Cl	CO_3	HCO_3	Ba	Sr	Ca	Mg	K	Na	Total solids	pH	Remarks
325					0.0		31,900											Collected from separator tank.
326	0.022	0.000																Collected from well.
326					.0		75,400											Do.
327					.0		30,500											Collected from separator tank.
328	.000	.000																Collected from well.
329					.0		18,950											Collected from separator tank.
330					.0		19,920											Do.
331																		Rotary-drill cuttings, see table 10.
332	.000	.000																Collected from well.
333			0.002	0.001														Collected from separator tank.
333					.0		22,070											Do.
334	.013	.001																Do.
335			.048	.001														Do.
335					.0		104,700											Do.
336	.27	.001																Collected from well.
336			.083	.003														Do.
336					.0		102,900											Do.
337	.92	.001																Do.
337			.088	.003														Do.
337			.091	.001														Do.
337			.63	.000														Do.
337			.077	.001														Do.
337					.0													Do.
338			.088	.003														Do.
338			.10	.000														Do.
339			.001															Do.
340																		Rotary-drill cuttings, see table 10.
341			.103	.001														Collected from area near separator tank.
341			.059	.003														Do.
341			.023															Do.
341			.20	.000														Do.
341			.55	.001														Do.
342					.0		9,380											Collected from separator tank.
343																		Cable-tool drill cuttings, see table 10.

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TABLE 10.—*Drill samples radiometrically analyzed: southeastern Kansas*

[All radiometric and sample logs not marked with an asterisk (*) are plotted on plate 6]

Index no.	Reference map	Company	Lease name and well no.	Location (Sec.-T.S.-R.E.)	Serial nos.	Range in percent eU_3O_8	Depth (feet)	Remarks
286	Plate 14	Palmer	Thompson 1	NE¼SW¼-2-24-3	14150 -14205	0.000-0.007	2,508-2,913	
288	do	Sheldon and Wixon	Augustine 1	NE¼NW¼NE¼-1-25-3	13937 -13939	.000- .001	2,670-2,681	
291	do	Colpitt	Linn 1A	NW¼-5-26-5	18609 -18977	.000- .004	605-2,425	Rotary-drill cuttings.*
292	do	Magnolia	Koogler 71	SE¼-30-26-5	13507 -13567	.000- .002	800-1,410	Rotary-drill cuttings.*
295	do	Adkins	Taylor 1	NW¼NE¼17-27-4	13728 -13839	.001- .006	2,350-2,880	Rotary-drill cuttings.*
14	do	Sinclair	Scully 29	SE¼NE¼-9-27-4	13975 -13982	.000- .004	2,400-2,453	
1	do	Hammer and Maclean	Suits 1	NW¼NW¼SW¼-10-27-4	13930 -13933	.000- .002	1,989-2,013	
296	do	Magnolia	Suits 9	NW¼SW¼-10-27-4	14007 -14149	.000- .005	1,015-2,043	
297	do	Hammer and Maclean	Bates 2	SW¼SW¼SW¼-10-27-4	16330 -16400	.000- .005	1,989-2,462	
22	do	Aikman and Braden	South Anderson 1	NW¼NW¼NW¼-15-27-4	18996 -19022	.000- .010	2,027-2,471	Radioactive "vesicular" celestite, magnetite, actinolite, and fluorite are present between depths of 2,027 and 2,031 ft.
23	do	do	South Anderson 2	NE¼NW¼NW¼-15-27-4	19023 -19035	.000- .002	2,058-2,465	
298	do	Cosmic	Loomis 10	NW¼SW¼NW¼-15-27-4	14493B-14497B	.000- .002	2,004-2,035	
344	Plate 12	Magnolia	South Anderson 7	NW¼NW¼NW¼-15-27-4	15991	.030	2,529-2,530	Radioactive "vesicular" limestone, in part replaced by magnetite, containing some celestite and barite is present between depths of 2,529 and 2,530 ft.
299	Plate 14	do	South Anderson 9	SW¼NW¼NW¼-15-27-4	13983 -14006	.000- .002	1,996-2,075	
300	do	Aikman and others	Perry 1	16-27-4	13946 -13949	.001- .003	2,474-2,481	
345	Plate 12	Aikman and Bennetts	Loomis 1	NE¼SE¼-16-27-4	13940 -13945	.001- .006	2,475-2,481	
301	Plate 14	Rex and Morris	Loomis 3	C-N½NE¼-21-27-4	13845 -13914	.000- .006	1,919-2,345½	
302	do	do	Loomis 7	SE¼NW¼NE¼-21-27-4	21356 -21654	.000- .007	30-2,346½	
29	do	Magnolia	Foster 14	NW¼NW¼SE¼-21-27-4	13568 -13642	.000- .008	2,387-2,610	Radioactive "vesicular" mineral containing iron, calcium, strontium, and barium is present between depths of 2,413 and 2,414 ft.
303	do	do	Foster 21	C-SW¼SE¼-21-27-4	13934 -13936	.000- .005	2,377-2,431	Black shale, containing 0.005 percent eU_3O_8 is present at 2,431 ft.
304	do	Blakeslee and others	Wilson 1½	NW¼SW¼NE¼-28-27-4	13915 -13929	.000- .002	1,907-1,934	
305	do	Magnolia	Kramer 14	NE¼SE¼NW¼-28-27-4	14474 -14493A	.001- .006	2,245-2,321	
40	do	do	Kramer 17	NE¼NE¼SW¼-28-27-4	13643 -13727	.000- .005	1,000-1,815	
306	do	do	Kramer 18	NW¼SE¼NW¼-28-27-4	13364 -13506	.000- .006	1,000-2,335	
307	do	Cities Service	Scully 120	SE¼-21-27-4	13190 -13363	.000- .004	820-2,357	Rotary-drill cuttings.*
308	do	Richmond and Riegle	West 1	NE¼NW¼SW¼-28-27-4	13951 -13974	.000- .007	2,008-2,463	

309	do	Palmer	Lychlyter(?)	SE¼NW¼-11-27-4	14658-14698	.000-.006	2,650-2,917	
310	do	Alter and Brackensiek.	Sanford 1	SE¼SE¼SE¼-27-27-4	14498-14534	.000-.006	2,425-2,629	
311	do	Magnolia	Palmer 7A	NW¼-35-27-4	13840-13844	.001-.006	2,553-2,590	
70	do	Hammer and Maclean	Moyle 2	NE¼SW¼SW¼-35-27-4	19105-19135	.000-.005	2,545-2,610½	
312	do	do	Moyle 4	SE¼SW¼SW¼-35-27-4	19136-19171	.000-.006	2,585-2,640½	
72	do	do	Ambler 1	SE¼NE¼NW¼-2-28-4	19036-19059	.000-.005	2,127-2,611	
73	do	do	Ambler 2	SW¼NE¼NW¼-2-28-4	19060-19072	.002-.006	2,565-2,614	
74	do	do	Ambler 3	NE¼SW¼NW¼-2-28-4	19073-19088	.000-.005	2,058-2,617	
75	do	do	Ambler 4	NW¼NE¼NW¼-2-28-4	19089-19100	.000-.004	2,609-2,620	
76	do	do	Ambler 5	NE¼NE¼NW¼-2-28-4	19101-19104	.001-.003	2,618-2,625	
316	do	Sohio	Liggett W 14	16-26-8	15578-15582	.003-.004	2,514-2,530	Core.*
277	Plate 13	Dilworth and Miller	Dilworth Fee 1	NE¼-8-33-7	19174-19181	.002-.003	2,665-2,725	
279	do	do	Dilworth Fee 2	NE¼-8-33-7	19172-19173	.003	2,700-2,706	
281	do	Fleet		W½-27-33-6	15586-15587	.002-.004	2,904-2,940	Core.*
331	Plate 15		Wenger 1	SE¼-14-21-3	18456-18608	.001-.004	1,800-2,880	Rotary-drill cuttings.*
340	do	Berry and Eells	Jolliffe 1	NW¼NW¼-9-22-4	5795	[1].007 mg	2,275	Drilling mud.*
340	do	do	do	NW¼NW¼-9-22-4	5794	[1].004 mg	2,365	Drilling mud.*
340	do	do	do	NW¼NW¼-9-22-4	5791	[1].003 mg	2,374	Drilling mud.*
340	do	do	do	NW¼NW¼-9-22-4	5797	[1].005 mg	2,485	Drilling mud.*
340	do	do	do	NW¼NW¼-9-22-4	5851 - 5990	0.000-.003	1,805-2,485½	Rotary-drill cuttings.
343	do	Progressive	Nonken 1	NW¼NW¼-34-22-4	7052 - 7172	.000-.008	1,786-2,517	
346	Plate 12	James	Rimel 1	SE¼NW¼SW¼-20-27-2	14615B-14634	.000-.008	3,264-3,309½	Chalcopyrite and covellite(?) are present between depths of 3,287 and 3,309½ ft.
347	do	Fisher and Lauck	Trustee 8	19-27-2	14635-14644	.000-.003	3,080-3,252	
348	do	Shawver and others	Soukup 1	NW¼NE¼-19-27-2	14645-14657	.001-.005	3,248-3,269	
349	do	Vickers and Hinkle	Keys 3	SW¼NW¼NE¼-30-27-2	14699-14722	.000-.005	3,228-3,334	Quartz sand, granite fragments, and bentonite between depths of 3,272 and 3,285 ft.
350	do	Derby	Rimel 2	C-NE¼-30-27-2	14589-14615A	.000-.007	3,230-3,420	Garnet, actinolite, magnetite, and chlorite(?) are present at a depth of 3,230 ft.
351	do	Bird and Hanley	Shipley 1	NW¼15-30-12	7781 - 7835	.000-.007	1,032-1,685	Clintonite, corundophilite(?), a diopside-hedenbergite mineral, and some orthoclase are present between depths of 1,388 and 1,671 ft.

[1] Milligrams of uranium per liter.

Sample nos. 16328 and 16310 from Butler County (see table 8, index nos. 284 and 290) are evaporites formed from brine that had been pumped from the subsurface formations. Although the uranium oxide content of these two samples is only 0.002 and 0.003 percent, it does indicate that some uranium was brought up with the brines.

Because abnormal radioactivity had been recorded on gamma-ray logs of wells in the Augusta field, a radiometric survey was made of all the producing wells to determine whether the radioactivity was evenly distributed throughout the field. The radiometric and chemical data are given in table 6, and the location of all wells from which samples were collected or field determinations made are shown on plate 16. The map of the Augusta field shows that most of the wells in which radium-bearing precipitates have formed either are producing from, or have been plugged back from, the Arbuckle group.

The wells in which the radium-bearing precipitates have formed are old, and many of them have leaks in the casing. Such leaks have resulted in the intermingling of high-sulfate brines from the Arbuckle group with comparatively high-strontium brines from the Pennsylvanian formations, particularly those brines from the Kansas City group. Intermingling of these brines apparently has resulted in the precipitation of celestite. Because of the chemical similarity of strontium and radium, radium is intimately associated with celestite.

Plate 11 is a diagram of the Nort Augusta field compiled from sample and gamma-ray logs and compares lithology with radioactivity.

Gamma-ray logs 1, 3, and 4 are normal logs and reflect the differences in lithology that normally would be expected; but logs 2, 5, and 6 show abnormal deflections that could be caused only by a much greater proportion of radioactive elements than normally is present in these rocks. Because radium-bearing precipitates have been found in surface pipes and tanks in this field and because of the intermingling of high-sulfate with high-strontium brines, it seems probable that radioactive celestite has been precipitated on the casing. All the abnormal deflections are opposite shale beds, suggesting that oxidation of pyrite in the shale, during the 25 to 30 yr since the wells were drilled, produced acid solutions that reacted with the iron casing and made holes in the casing. This would have permitted the deeper brines to come in contact with those from the shale beds and under suitable conditions resulted in the deposition of strontium and radium sulfates. This type of deposit probably is illustrated by the gamma-ray logs on plate 17, which show that a radioactive deposit between depths of about 2,950 ft and 3,000 ft in the Cramm "E" no. 1 well corresponds exactly to the perforation in the casing.

It is particularly noticeable that those fields in southeastern Kansas from which the most radioactive samples have been collected are fields in which brines from the Arbuckle group and Pennsylvanian rocks could intermingle and thus bring about the conditions necessary for the precipitation of celestite. Because the chemistry of radium is similar to that of strontium and barium, it would be expected that radium sulfate would be precipitated along with strontium and barium sulfate.

The analytical data presented in tables 6, 7, 8, and 9 show that the radioactivity of the precipitates varies sharply, not only between different oil and gas fields but between different wells in the same field. Most of this variation is caused probably by an uneven distribution of uranium in the subsurface rocks. In the samples collected, the range of equivalent uranium oxide is from 0.000 to 10.85 percent. Because both the radioactive and nonradioactive precipitates were deposited in similar environments, it is probable that radium was present in some solutions and not in others, and that the radium was derived from localized sources.

As radium is a disintegration product of uranium, it would be expected that the brines from which the radium-bearing precipitates were derived also would contain measurable amounts of uranium. Although 0.1 to 0.2 ppm of uranium have been found in a few brine samples, there is no positive correlation between wells that produce these uranium-bearing brines and wells at which radium-bearing precipitates have been deposited. It is possible, however, that the uranium, which is more soluble than radium, was flushed from the reservoir rocks and other rocks surrounding the drill bore, by the first oil produced. During that stage in the history of the well much smaller volumes of brine would have been pumped than during the later stages. Some incomplete and inconclusive experimental data (G. J. Petretic, personal communication) indicate that uranium is more soluble in oil than it is in the type of brines pumped from wells in this area. It might be possible, then, that uranium could be flushed from the subsurface rocks by crude oil and that later the more insoluble radium was brought to the surface in the brine solutions. This would apparently be a satisfactory explanation for the vuggy radium-bearing limestones found in drill samples from the Augusta field in Butler County.

Chemical analyses for uranium have been made of oil samples collected from this area and as much as 0.70 ppm has been indicated; but the analyses could not be consistently duplicated, and the data have not been incorporated into this report. Although the data did indicate that some uranium was present in the oil, their significance cannot be evaluated until other data are available.

RELATIONSHIP OF HELIUM TO RADIOACTIVE MATERIALS

The two principal theories that have been advanced in recent years to account for the large quantities of helium in some natural gases postulate either a primary or a radiogenic origin for helium. Most workers in this field have concluded that the greater part of the helium is of radiogenic origin. This conclusion is based primarily on the accumulation of radiogenic helium in uranium- and thorium-bearing rocks and on the similarity of geologic conditions under which helium-bearing gases have accumulated. A discussion of primary versus radiogenic helium in natural gases is given by Rogers (1921).

The presence of large volumes of helium, which are not known to be associated with uranium or thorium minerals, has been offered as evidence that most of the helium is of primary origin. This conclusion was based principally upon the assumption that uranium and thorium deposits sufficient to supply the helium in the earth and atmosphere do not exist, and, therefore, large volumes of radiogenic helium are improbable. Although the theory of primary origin, as applied to helium-bearing natural gases, could conceivably account for the helium, it apparently could not account for its limited geographic distribution and its association with other products of radioactive decay. Evidence that suggests the probability of radiogenic helium in these deposits is briefly summarized below.

1. If all helium were derived from a primary source, it would be so well disseminated in the earth's crust that it would accumulate in all structural traps that are capped by impervious beds. In the absence of the natural gases, helium would be expected to accumulate by itself. Actually commercial helium-bearing gases have accumulated only in a few places in the world, and helium never has been found except in association with other gases.

2. The important commercial helium reservoirs are located over major structural features, where various types of igneous and metamorphic rocks are closely subjacent to the helium reservoir rocks and are a possible source of radiogenic helium.

3. Most of the helium reservoirs in the midcontinent region are in formations of Pennsylvanian age. Prior to the deposition of these sediments the underlying Paleozoic and, in some places, pre-Cambrian rocks, had been subjected to erosion for long periods of time. In the process any primary helium that had already accumulated in any structure breached by erosion would have been lost to the atmosphere and could not have contributed to the present helium reserves. Because deformation of this region had established the structural outlines by early Pennsylvanian time, any primary accumulations that

escaped destruction would remain entrapped and could not have migrated to the present-day helium fields.

4. Radium-bearing precipitates in the former helium-producing gas fields of southeastern Kansas and radon in the helium-bearing gas of other areas, strongly suggest that the helium is a product of radioactive decay.

5. In general the more radioactive precipitates have been found in those fields that originally produced the most helium (Rogers, pp. 99-103, 1921) and (Anderson and Hinson, pp. 58-66, 1951). The association between radium-bearing precipitates and helium-bearing gas is illustrated on plate 8.

By a process of elimination, then, it appears that most of the helium in the helium-bearing gases probably is radiogenic. If the helium is radiogenic, the deposits from which it was derived are of higher grade than the average rock, for otherwise radiogenic helium deposits would be found in favorable structures everywhere. If the helium and radium had a common source, the radioactive deposit must be relatively close to the rocks that supplied the radium.

CONCLUSIONS

Abnormally high concentrations of radium in precipitates and drill samples from southeastern Kansas, helium thought to be radiogenic in the oil and gas fields in which radium-bearing precipitates have formed, and the concentration of radium in comparatively small areas lead to the conclusion that uranium is present in greater-than-normal concentrations in the subsurface rocks. The presence of minerals that were formed probably as a result of the introduction of hydrothermal solutions suggests that the uranium may be localized in hydrothermal deposits, possibly of the vein type.

Radium-bearing precipitates in the southeastern Kansas oil fields are intimately associated with celestite, gypsum, and barite. This close association, when considered with the fact that strontium, calcium, barium, and radium sulfates are precipitated under the same conditions, strongly suggests that radium, too, is in the form of a sulfate, Radium sulfate, therefore, is probably precipitated and preserved along with the other sulfate minerals. The precipitation of these minerals is probably caused by the intermingling of brines high in sulfate ions with brines containing excess strontium, calcium, barium, and radium ions.

Because radium-bearing rocks are present in the Kansas City and Arbuckle groups, it seems reasonable that the radium-bearing precipitates were derived by solution and redeposition from those rocks. Chemical analyses of the radium-bearing limestones, however, show that they do not contain uranium and radium in equilibrium quantities, which indicates that uranium was removed from these rocks, or that radium was introduced into them within the past few thousand years.

Although the reason for the lack of equilibrium between radium and uranium cannot be determined from finely pulverized cable-tool drill samples, the vuggy nature of the rock fragments strongly suggests that soluble minerals have been removed by leaching. Some samples of vuggy rock fragments, which are thought to have been leached, contain as much radium as would be present with 0.5 percent uranium in equilibrium, suggesting that the leached material was a uranium mineral. The presence of radium, which has a half-life of 1,580 yr, precludes the possibility that uranium was removed or that radium was introduced, except during the last few thousand years.

The alternative to the theory that uranium has been leached from the limestone is to assume that radium has been introduced into it. That radium can be transported by oil-well fluids is demonstrated by the presence of radium-bearing precipitates in surface pipes and tanks, but there is no evidence to suggest that the radium was introduced into the limestones. On the contrary the spherical cavities in these rocks indicate that some material has been removed and not added to them.

The geologic environment of the radium-bearing limestones also suggests that radium was not moved into these rocks from a distant source. The radium-bearing limestones and dolomites are between 1,100 and 1,200 ft below sea level; therefore, circulation of fluids through the rocks probably would have been at a very slow, or even negligible, rate prior to the time that circulation was stimulated artificially by the oil well pumps. It would be difficult to envisage the transportation of radium salts more than a short distance under these conditions.

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