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GEOLOGICAL SURVEY

RADIOACTIVITY IN SOME OIL FIELDS OF SOUTHEASTERN KANSAS

By

Garland B. Gott and James W. Hill

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RADIOACTIVITY IN SOME OIL FIELDS OF SOUTHEASTERN KANSAS

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 through the use of gamma-ray and sample logs; by radiometric, chemical petrographic, and spectrographic analyses of the precipitates and drill samples; and through the use of 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, extending 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 dolomite 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 which 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 up to 0.2 parts per million 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 probably was derived from these rocks.

(2) The presence of contact-metamorphic or hydrothermal-type minerals in altered limestones indicates that hydrothermal solutions have penetrated the limestones and suggests that uranium may have been deposited from those solutions.

(3) The amount of radium in the radium-bearing precipitates indicates that appreciable quantities of uranium also must be present.

(4) The association of helium with other uranium-decay products suggests that the helium is radiogenic. So much radiogenic helium would require the presence of 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, was 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 and 121 oil 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 1 _/.

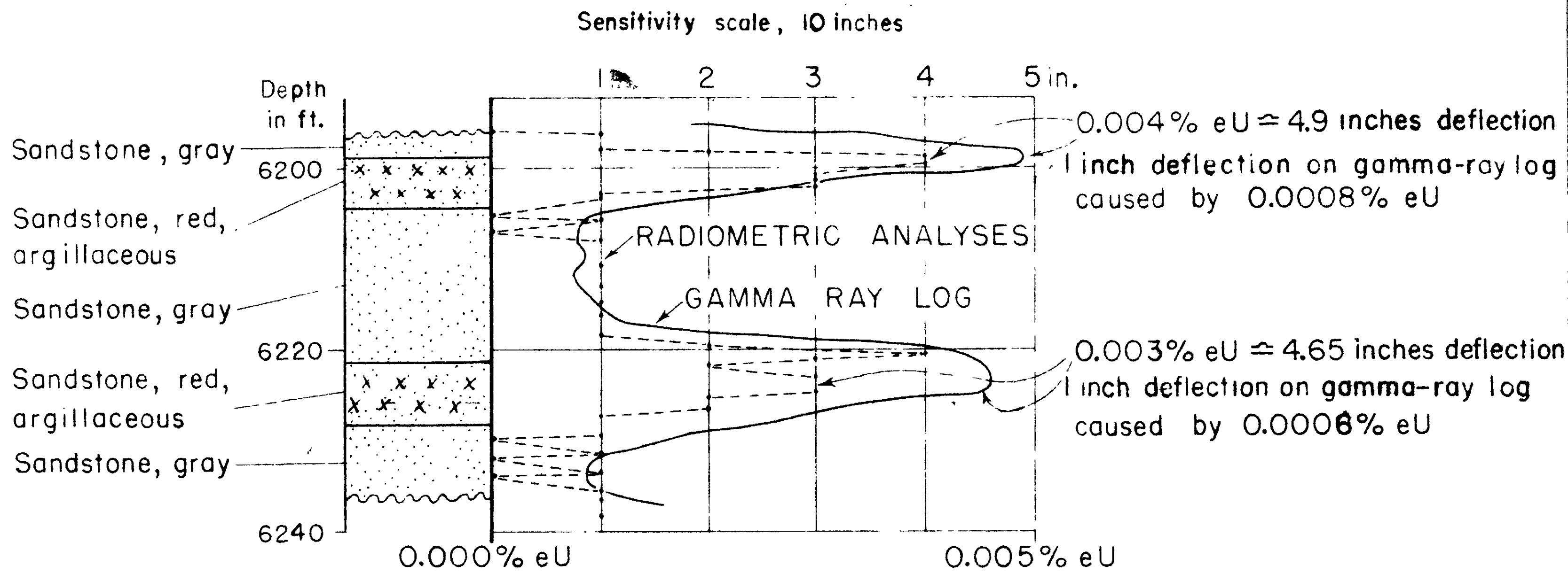
_/ Plate 1. Location of gamma-ray and sample logs of wells in southeastern Kansas.

During the field investigations, uncalibrated Beckman Model MX-5 and El-Tronics Model SM-3 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 Lane-Wells 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, Colo., with the corresponding gamma-ray logs. A one-inch deflection was caused by approximately 0.0007 percent equivalent uranium at a 10-inch sensitivity scale. Part of the calibration data is shown graphically on figure 1. The correlation

Figure 1. Comparison of a Lane-Wells gamma-ray log with radiometric analyses.

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 Lane-Wells 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 well, the shielding effect of casing in cased wells, differences in individual instruments, and the rate of movement of the ionization chamber.



Note: Radiometric analysis of 212 core samples averaged approx. 0.0007% eU per inch of deflection on the gamma-ray log when it was run at a sensitivity scale of 10 inches. The average value has been used in this report.

Figure 1.--Comparison of a Lane-Wells gamma-ray log with radiometric analyses.

Nevertheless, semiquantitative data obtained by the use of the approximate calibration were useful in estimating the order of magnitude of the equivalent uranium in the rocks logged with Lane-Wells instruments.

The radioactivity anomalies represented on gamma-ray logs were thought to indicate that the drill holes had penetrated radioactive host-rocks; therefore, plans were made for exploration in those fields which gamma-ray logs had indicated to be the most promising. 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 was thought advisable to obtain radiometric data of newly drilled wells located adjacent to a radioactive well. The recently completed Rex and Morris - Loomis No. 6 and No. 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 for this purpose, 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 responsible for most of the mineralogic identifications. The Magnolia Petroleum Company, Cities Service Oil Company, Sohio Petroleum Company, and Sinclair-Prairie Oil Company 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 Company, Aikman and Braden, Continental Oil Company, C. R. Colpitt, H. E. Colpitt, Dilworth and Miller, Eagle Picher Mining and Smelting Company, Hammer and McClain Drilling Company, Lane-Wells Company, Rex and Morris Drilling Company, Socony Vacuum Oil Company, Inc., State Geological Survey of Kansas, and the U. S. Bureau of Mines.

GENERAL GEOLOGY

The geologic history of southeastern Kansas from late Cambrian through the Mississippian 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 Arbuckle dolomite of Cambro-Ordovician age; the Simpson-Viola groups and Maquoketa shale of Upper Ordovician age; the dolomites and limestones of Siluro-Devonian age; the Kinderhook shale group (including the Chattanooga shale of questionable Mississippian age) overlain by the cherty limestones of Mississippian age; the interbedded shales, limestones, and sandstones of Pennsylvanian age which are, in ascending order, Cherokee, Marmaton, Pleasanton, Kansas City, Lansing, Douglas, Shawnee, and Wabaunsee groups; and the interbedded shales, limestones and sandstones of lower 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, Siluro-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 of 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 Arbuckle dolomite 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 asymetrical linear uplift. The north end is in southeastern Nebraska and the anticline extends cross 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 _/ through the use of cross-sections.

_/ Lee, Wallace, Structural development of the Forest City basin of Missouri, Kansas, Iowa, and Nebraska: U. S. Geol. Survey Oil and Gas Invs., preliminary map 48, sheet 7, 1946.

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 removed, in part, 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 have indicated that neither uranium nor thorium are 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 _/

_/ Table 1. Radium content of the precipitates.

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 determined by calculations from direct measurements of radon. The calculated percent equivalent uranium was determined from the radium content by calculation.

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 number	Equivalent uranium (percent)	Uranium (percent)	Radium content (1) (gm Ra/gm)	Calculated equivalent uranium (2) (percent)
15539	1.17	0.003	9.4×10^{-9}	1.6
15543	1.14	0.003	7.5×10^{-9}	1.3
18377	1.20	0.000	1.1×10^{-8}	2.0
18446	8.11	0.001	4.6×10^{-8}	7.8
18448	7.10	0.000	3.2×10^{-8}	5.5
18452	4.37	0.001	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} gm/gm. 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 area, sec. 29, T. 26 S., R. 15 E., in Woodson County, Kansas. It contained amphiboles, titaniferous magnetite, sphene (and leucoxene), epidote, and phlogopite. In addition, Knight and Landes _/ have identified galena and sphalerite

_/ Knight, G. L., and Landes, K. K., Kansas laccoliths: Jour. Geology, vol. 40, no. 1, p. 7, 1932.

in well cuttings from this area.

An unusually large number of minerals that may have formed as the result of the introduction of hydrothermal solutions has been identified in Arbuckle dolomite and Kansas City limestone 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 of these minerals, with the exception of 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-Arbuckle contact and in Kansas City limestone. 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 feet 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. The minerals were clintonite, corundophilite, diopside-hedenbergite partly altered to a tremolite-actinolite asbestos, and some orthoclase and calcite.

The sample from 3,230 feet 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 feet 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 1a _/ is a list of these minerals, together with the

_/ Table 1a. Contact metamorphic-type minerals.

Table 1a.--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 feet.
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 feet.
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 feet.

general locality in which they have been found. These minerals may have 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 area _/. The minerals identified in the drill cuttings may be closely associated with similar bodies of intrusive rocks.

_/ Knight, G. L., and Landes, K. K., op. cit.

Introduction of minerals by hydrothermal solutions is strongly indicated, and the presence of radium-bearing celestite in this area indicates that uranium minerals probably were deposited by the same process.

RADIOACTIVITY

General Statement

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 1, and those fields that are located in Cowley, Butler, and Marion Counties also are shown in figures 6, 7, and 8. As shown by these illustrations, the fields in which the radium-bearing precipitates are known to have formed, overlie or are roughly marginal to the Nemaha anticline. However, a few gamma-ray logs of wells located in fields as far as 35 miles from the crest of the anticline indicate that the area in which the radioactive precipitates have formed is greater than that indicated by plate 1.

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 mid-continent 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 a gamma-ray log and the corresponding lithology in figure 2. Some significant exceptions to the general relationship

Figure 2. Typical radioactivity anomalies of different sedimentary rock types as recorded on gamma-ray logs. (Ruled area of gamma-ray curve is telescoped to fit column.)

have been noted, however, and are illustrated by the comparatively high radioactivity of limestones and sandstones shown graphically on plate 6.

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 _/ has shown that the pre-Cambrian rocks of Kansas consist

_/ Landes, K. K., A petrographic study of the pre-Cambrian of Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 11, no. 8, pp. 821-824, 1927.

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

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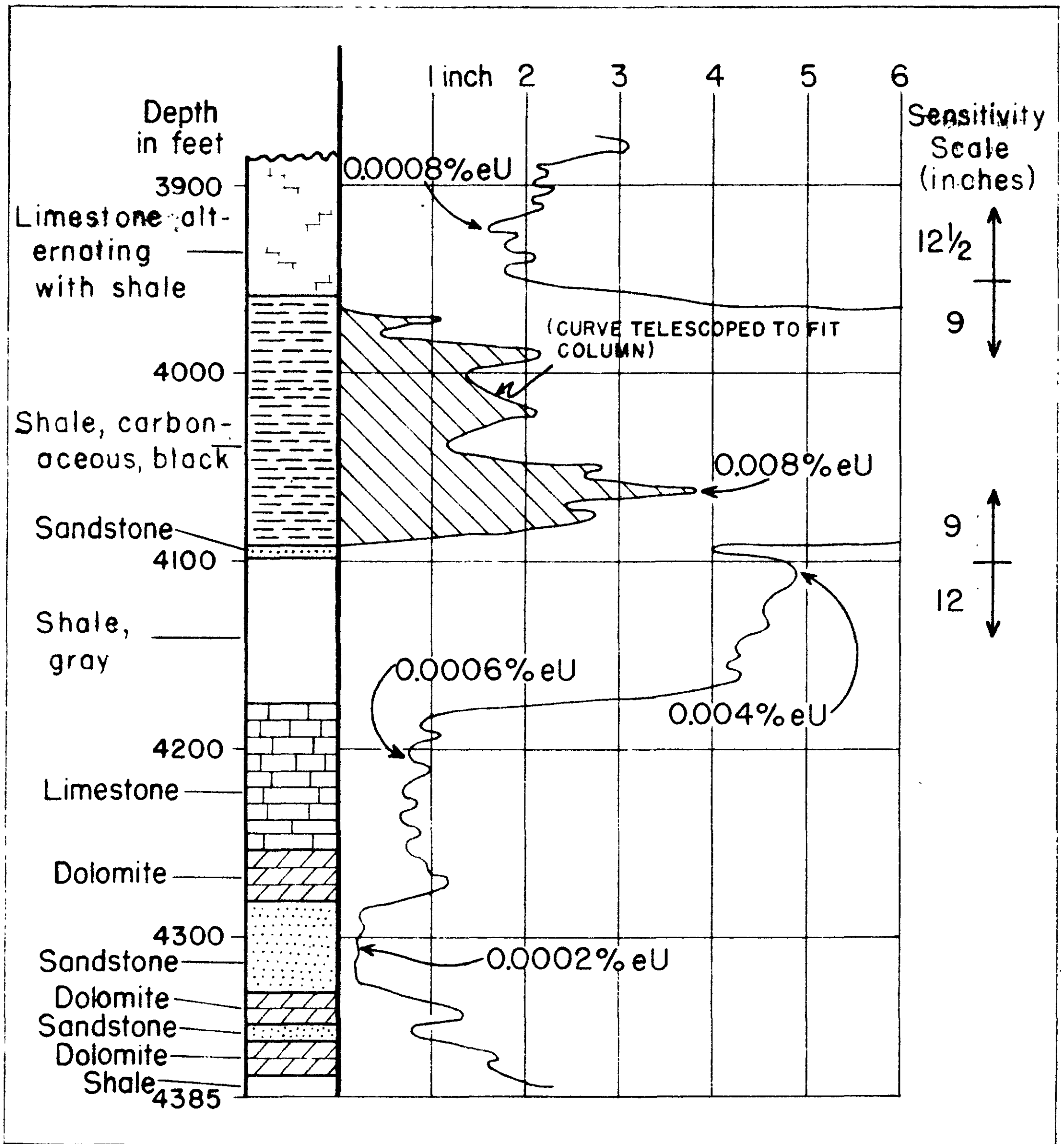

FIGURE 2. — TYPICAL RADIOACTIVITY ANOMALIES OF DIFFERENT SEDIMENTARY ROCK TYPES AS RECORDED ON GAMMA-RAY LOGS.

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 NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 36, T. 31 S., R. 2 E., and from a few fragments of drill cuttings from the Kaufman well in the NW$\frac{1}{4}$NE$\frac{1}{4}$ 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 3

Figure 3. Radioactivity of pre-Cambrian, Cambro-Ordovician, and basal Pennsylvanian rocks.

and illustrates the relative radioactivity of the pre-Cambrian, Cambro-Ordovician and lower Pennsylvanian rocks penetrated by this drill-hole. The drill cuttings from the Kaufman well were fragments of a pre-Cambrian quartz diorite and contained only about 0.001 percent equivalent uranium.

Cambro-Ordovician rocks

Arbuckle dolomite

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

SHELL OIL CO., J. V. TATON NO. 8
C NE 1/4, NW 1/4; SEC 36, T.31 S., R. 2 E.

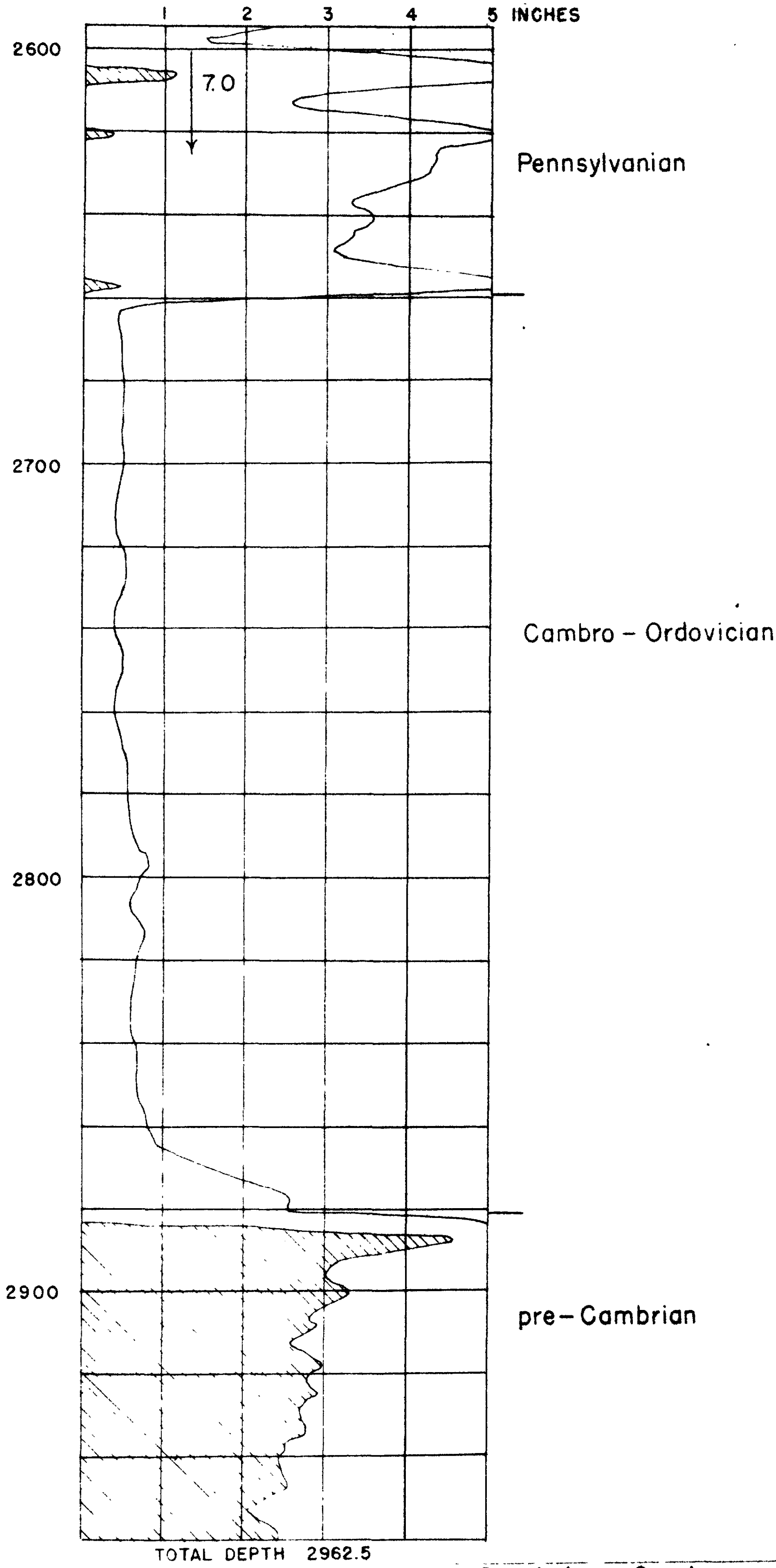

FIGURE 3.— Radioactivity of pre–Cambrian, Cambro-

Drill samples of the Arbuckle from several places along the Nemaha anticline are radioactive. These samples were examined microscopically and they contain minerals that probably were formed by the introduction of hydrothermal solutions into the sediments. An example of this is a radioactive, black, vuggy limestone sample from between 2529 and 2530 feet deep in the Magnolia-South Anderson No. 7 well in sec. 15 T. 27 S., R. 4 E., in the North Augusta field, (plates 5 and 6, Index No. 344). This limestone is several feet below the top of the Arbuckle dolomite and in the bottom six feet 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 of 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 contaminatedwith a high percentage of shale caved from higher 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 lime-

stone contained approximately 0.1 percent equivalent uranium oxide, and more nearly represent the degree of radioactivity in this zone.

An Arbuckel dolomite sample from between depths of 2513 and 2514 feet 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 6, Index No. 29.

Although the samples were significantly radioactive, chemical analyses have shown that uranium is not present. As 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 years, the presence of uranium decay products 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.

Upper Ordovician rocks

Little data have been obtained relative to the radioactivity of the Viola group or the Moquoketa shale of Upper 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 6 (Index Numbers 70, 72-76, and 310-312).

Mississippian Rocks

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

Shales

As the Chattanooga shale has been removed by pre-Pennsylvanian erosion in most of the fields in which wells have been gamma-ray logged, only scanty 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.

Limestones

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. Colpétt - 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 reason to believe 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 4. It

Figure 4. Radioactivity of Dilworth, No. 2 Fee, well.

shows a marked radioactivity anomaly between depths of 2,685 and 2,710 feet, an interval which should represent part of the Cherokee group of lower Pennsylvanian age. A smaller radicactivity anomaly at depths correlative with the "Mississippi" limestone is represented on the log between 2,815 and 2,856 feet. Radiometric measurements of samples from 2,700 to 2,706 feet, in the zone of greatest deflection, and of other samples from that part of the adjacent Olds No. 1 well represented in figure 4, indicate that the sediments are only normally radioactive. Inasmuch as a radium-bearing precipitate was collected from the tubing which had been removed from the bottom of the Dilworth well, it is believed that all of the abnormal radioactivity recorded on the gamma-ray log had a similar source.

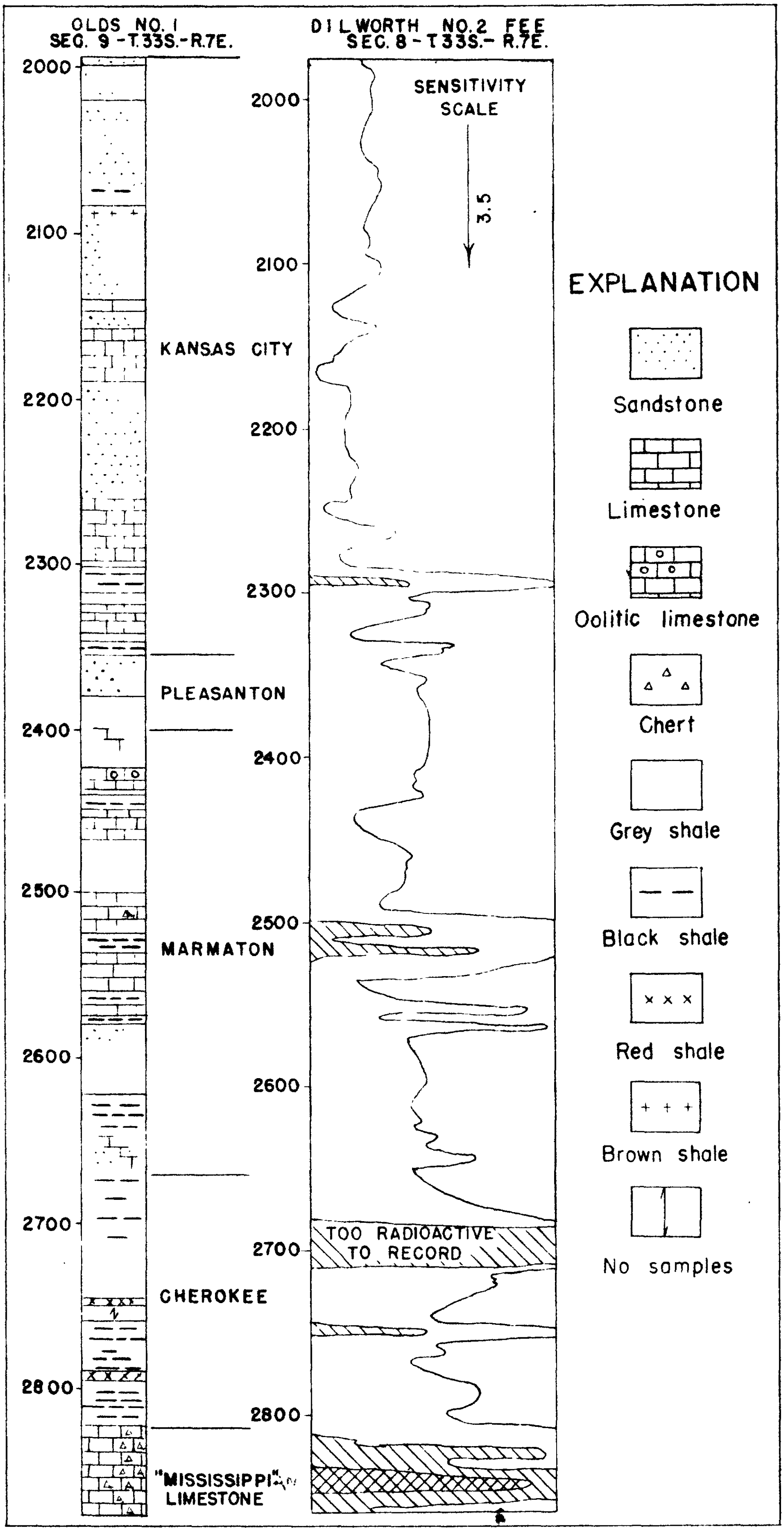

Figure 4 .— Radioactivity of Dilworth, No. 2, Fee Well

A gamma-ray log of the C. R. Colpitt - Spier No. 1 well (pl. 2) located in the Peabody field, in sec. 8, T. 22 S., R. 4 E.,

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Plate 2. Cross section A-A'; Comparison of sample and gamma-ray logs, Marion County, Kansas.

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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 feet also is caused by a radium-bearing precipitate.

Pennsylvanian rocks

Shales

The radioactivity of the exposed Pennsylvanian black shales was investigated by Slaughter _/. He found that phosphatic nodules

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_/ Slaughter, A. L., Radioactivity of Pennsylvanian black shales and coals in Kansas and Oklahoma: U. S. Geol. Survey Trace Elements Investigations Rept. 18, September 1945.

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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 feet and usually are represented on the gamma-ray logs by large deflections. In degree of radioactivity, most of these shales are comparable to 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 relative radioactivity of the black shales compared to most other Pennsylvanian rocks is illustrated on plates 2, 3, 4, and 6.

Plate 3. Cross section B-B'; Comparison of sample and gamma-ray logs, Sedgwick and Butler Counties, Kansas.

Plate 4. Radioactivity and lithology in the North Augusta field, Butler County, Kansas.

The gray Pennsylvanian shales contain a smaller proportion of radioactive elements than the black shales. However, the gamma-ray log that is partially reproduced on figure 5 indicates that one of

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Figure 5. Part of the gamma-ray log of the C. V. Stewart, Brown No. 2 well, showing abnormal radioactivity in Wabaunsee group.

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the upper gray shale 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.

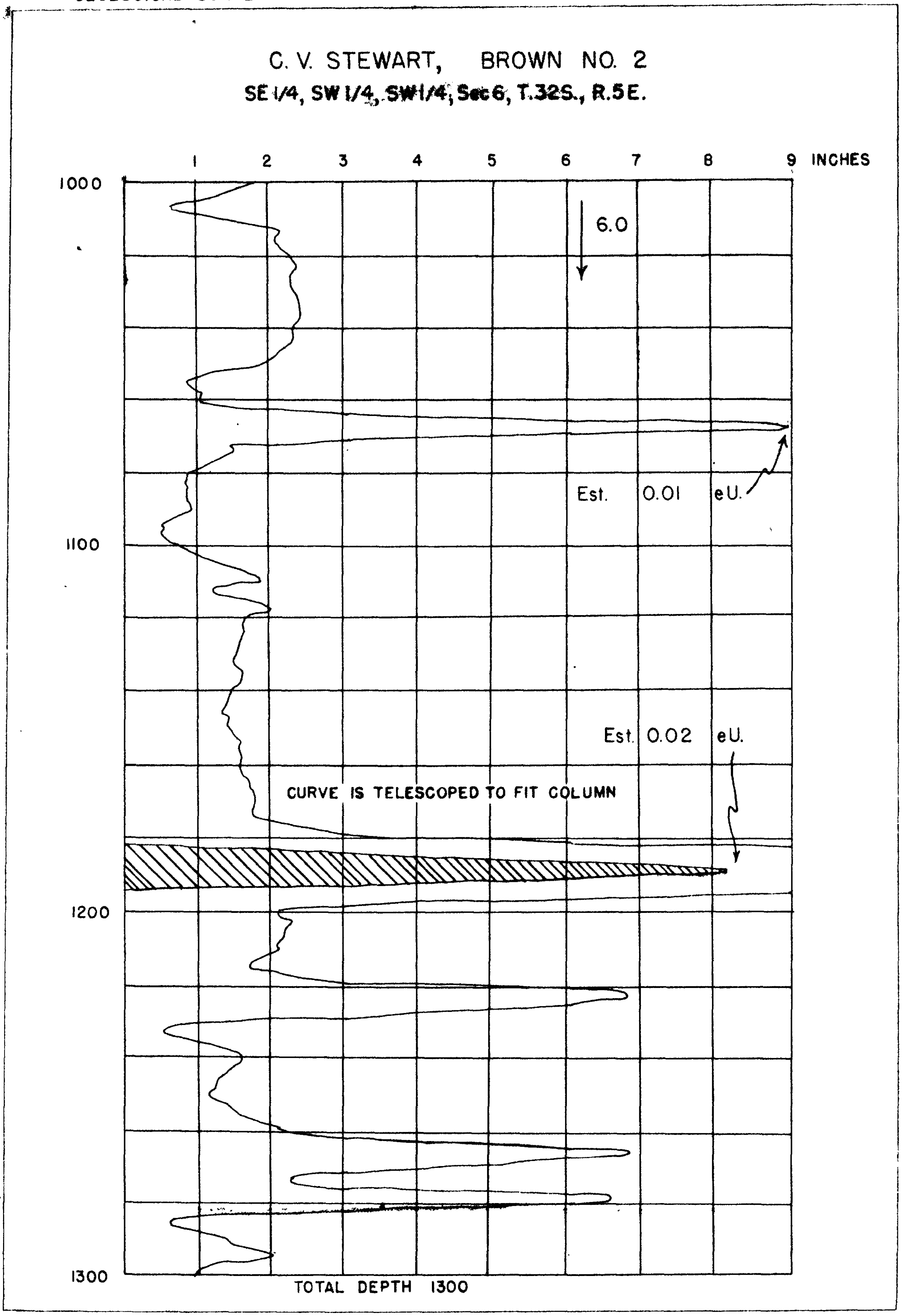

Figure 5. — Part of the C.V. Stewart, Brown No. 2 well, showing abnormal radioactivity in Wabaunsee group.

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 6. The

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Plate 6. Columnar sections and radiometric measurements of drill samples, Marion, Butler, Sedgwick, Cowley, and Elk Counties, Kansas.

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most radioactive limestone sample detected in this manner was from the Kansas City limestone 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 feet 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 plates 5 and 6, Index Number 22). 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 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 very likely one or more uranium minerals 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 2 indicate that their uranium content is uniformly

Table 2. Radiometric analyses of Pennsylvanian coals from southeastern Kansas and adjacent areas.

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 2.--Radiometric analyses of Pennsylvanian coals from southeastern Kansas and adjacent areas

Sample Number	Location	Percent eU_3O_8	Name of Coal	Group	Remarks
18383	SE$\frac{1}{4}$SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 16, T. 16 S., R. 15 E.	0.001	Nodaway	Wabaunsee	Strip pit
18384	SW$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 27, T. 17 S., R. 17 E.	0.000	Upper Williamsburg	Douglas	Outcrop, slacked, wet.
18385	SW$\frac{1}{4}$ sec. 14, T. 17 S., R. 19 E.	0.001	Ottawa	Douglas	Outcrop.
18386	SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 29, T. 16 S., R. 18 E.	0.000	Lower Williamsburg	Douglas	Outcrop.
18387	Center sec. 11, T. 23 S., R. 25 E.	0.000	Mulberry	Marmaton	Strip pit.
18388	NE$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 17, T. 27 S., R. 25 E.	0.000	Bevier	Cherokee	Strip pit.
18390	NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 5, T. 26 S., R. 25 E.	0.004	Mulky	Cherokee	Outcrop.
18391	SE$\frac{1}{4}$ sec. 19, T. 31 N., R. 33 W.	0.000	Weir-Pittsburgh	Cherokee	Strip pit. 1 mile south of Munden, Mo.
18392	NW$\frac{1}{4}$ sec. 13, T. 29 S., R. 25 E.	0.000	Mineral	Cherokee	Strip pit.
18393	SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 34, T. 28 S., R. 25 E.	0.000	Croweburg	Cherokee	Abandoned strip pit.
18394	SW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 16, T. 28 S., R. 25 E.	0.001	Bevier	Cherokee	Abandoned strip pit; slacked
18395	SW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 16, T. 28 S., R. 25 E.	0.000	Bevier	Cherokee	Slacked.
18396	Center W $\frac{1}{2}$ sec. 32, T. 31 S., R. 25 E.	0.000	Rowe	Cherokee	Strip pit.
18397	NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 7, T. 33 S., R. 24 E.	0.000	Columbus	Cherokee	Abandoned strip pit
18398	SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 23, T. 31 S., R. 16 E.	0.000	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 2 and 3. The number 2 and 3 gamma-ray logs shown on plate 3 are unusual in that abnormal radioactivity is recorded at depths less than 500 feet. It is of considerable interest that part of the abnormal radioactivity recorded on the log of the number 2 well may have been caused by marine evaporites. It is uncertain, however, whether the radioactivity anomalies recorded on these two logs represent radioactive elements in the sediments or radioactive precipitates on the casing. The radioactivity anomalies shown on the number 5 log on plate 2 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 in 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 sediments, 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 1. 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 figures 6, 7, and 8. Some disagreement is shown by comparison of the relative

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Figure 6. Location of radium-bearing precipitates, Cowley County, Kansas.

Figure 7. Location of radium-bearing precipitates, Butler, County, Kansas.

Figure 8. Location of radium-bearing precipitates, Marion County, Kansas.

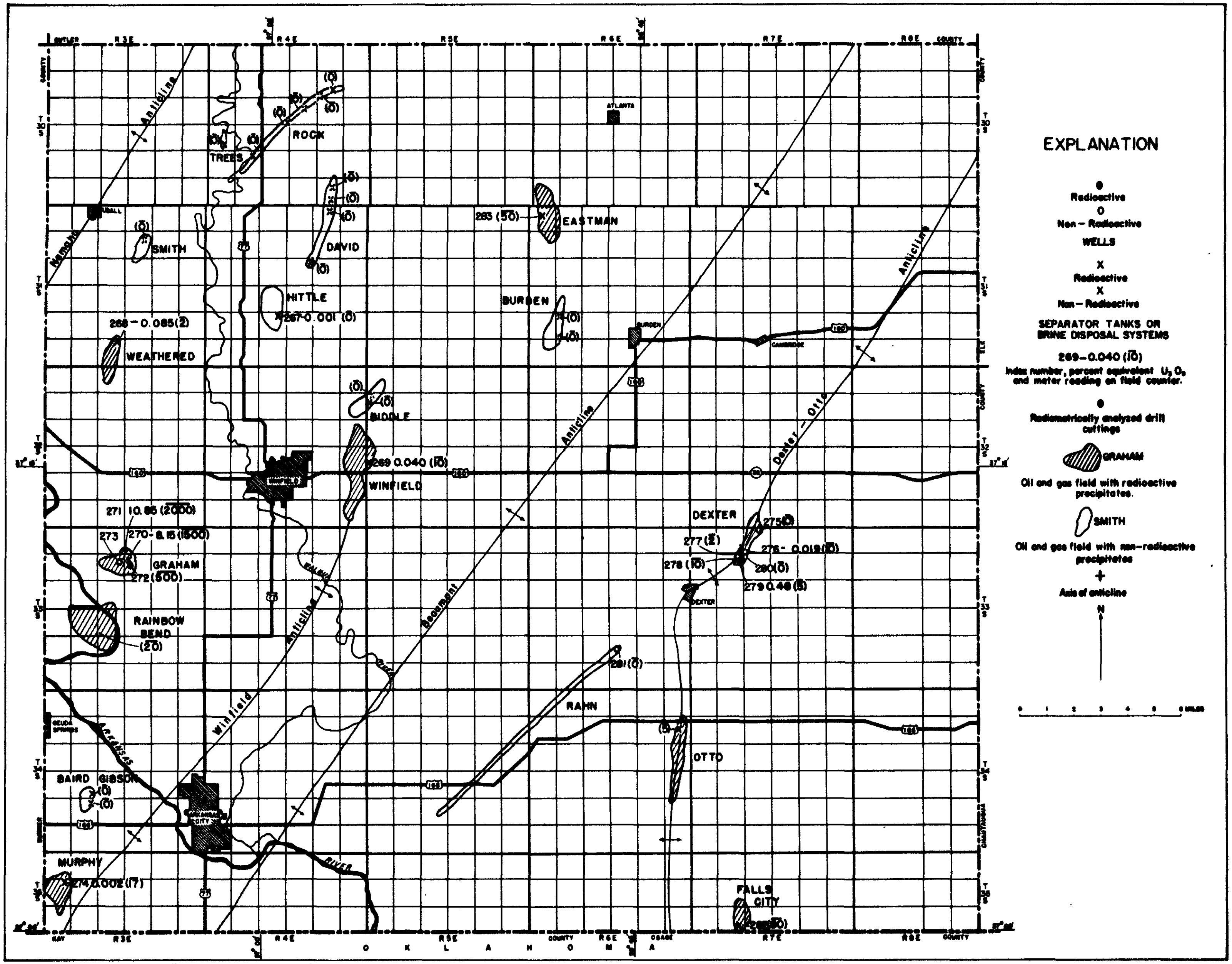

FIGURE 6.--LOCATION OF RADIUM-BEARING PRECIPITATES, COWLEY COUNTY, KANSAS.

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GEOLOGICAL SURVEY

TRACE ELEMENTS INVESTIGATIONS
REPORT No. 161

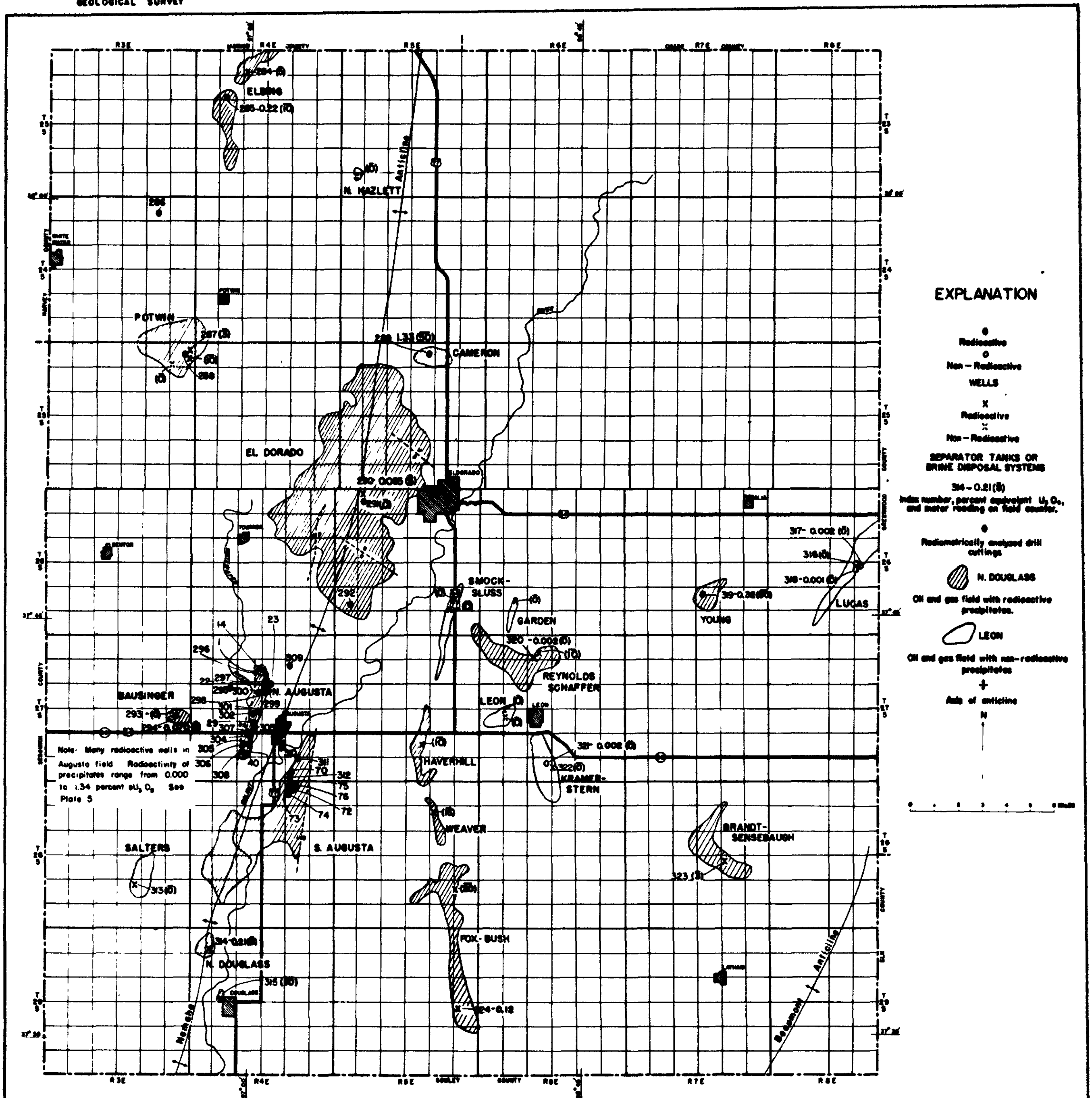

FIGURE 7 -- LOCATION OF RADIUM-BEARING PRECIPITATES, BUTLER COUNTY, KANSAS.

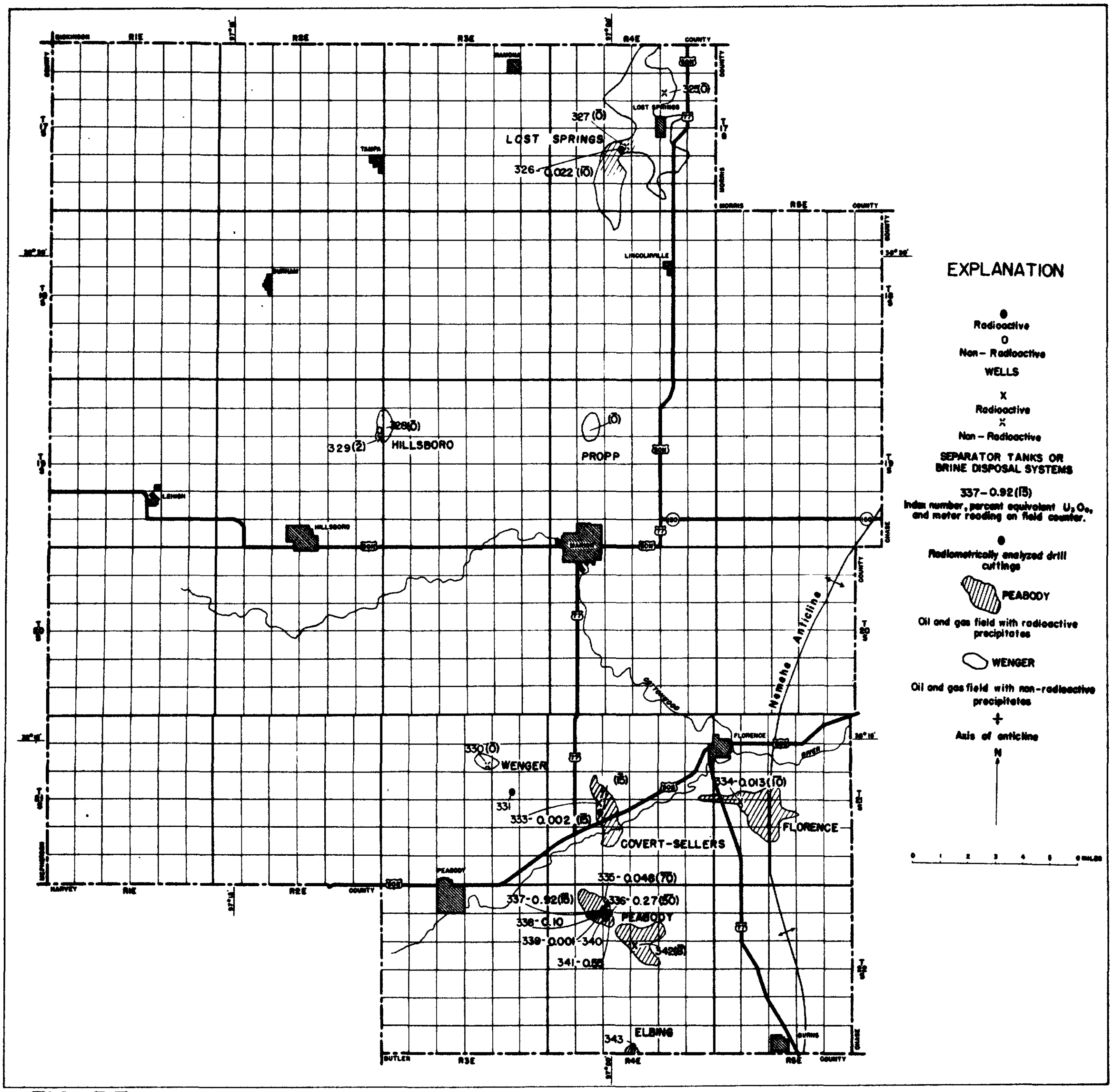

FIGURE 8.-- LOCATION OF RADIUM-BEARING PRECIPITATES, MARION COUNTY, KANSAS.

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 5 and on plate 5, 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 El-Tronics and Beckman instruments 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. As discussed under "mineralogy", radiometric measurements have shown 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 3.

Table 3. Description of radium-bearing precipitates.

Table 3.--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 re-cemented 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 quartz sand."
18448	8.15	0.000	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."
15558	0.24	0.005	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."

Serial No.	Percent eU_3O_8	Percent U_3O_8	Description
15548	0.38	0.000	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. R. S. Jones, Geological Survey laboratory, has described the sample as follows: "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. *** "
13165	0.029	0.000	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."

Serial No.	Percent eU_3O_8	Percent U_3O_8	Description
13167	0.043	0.000	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."
13169	0.12	0.000	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	0.24	0.000	The sample was collected from the inside of a pipe at 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."
13171	0.39	0.000	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 is present.

Spectrographic analyses (table 4) _/ have been made of several

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_/ Table 4. Spectrographic, radiometric, and chemical analyses of radium-bearing precipitates.

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samples, and show that the principal elements in the radium-bearing precipitates 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 4, 5, 6, 7, 8, and 9. These data show a range from no detectable

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Table 5. Sample data: Augusta field, Butler County, Kansas.

Table 6. Sample data: Cowley County.

Table 7. Sample data: Butler County.

Table 8. Sample data: Marion County.

Table 9. Drill samples radiometrically analyzed: Southeastern Kansas.

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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 5, Index No. 244). Several samples collected

from wells in Marion County (see table 8) contained as much as 0.003 percent uranium oxide but all of 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.

Samples Nos. 16328 and 16310 from Butler County (see table 7, 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.

Table 4.--Spectrographic, radiometric, and chemical analyses of radium-bearing precipitates

	Radiometric	Chemical	Spectrographic Analyses									
Serial Number	Percent eU_3O_8	Percent U_3O_8	Sr	Ba	Ca	Fe	Al	Si	Cu	Mn	Ti	Mg
1/ 13170	0.24	0.000	xx		xx	xx	x	x	0.0x	0.0x	0.0x	
1/ 13171	0.39	0.000	xx		xx	xx	x	x	0.0x	0.0x	0.0x	
1/ 15526	0.64	0.006	xx		x	xx	x	x	0.0x	0.0x	0.0x	0.0x
1/ 15555	0.83	0.000	xx		x	xx	x	x	0.0x	0.0x	0.0x	0.0x
1/ 15539	1.31	0.003	xx		x	xx	xx	x	0.0x	0.0x	0.0x	0.0x
2/ 18451	0.12	0.000	0.x	0.x	x	x		0.x				
2/ 18450	0.001	0.001	0.x	0.x	0.x	xx		0.x		0.x		
2/ 18446	10.85	0.001	xx	xx	x	x		0.x				
2/ 18382	0.007		x	x	xx	0.x	x	xx		0.x		x
2/ 18381	0.026		x	x	x	x	x	xx				x
2/ 18380	0.002	0.000	0.x	0.x	0.x	xx		x		0.x		
2/ 18372	0.000	0.000	0.x	0.x	x	xx		0.x				
2/ 18369	0.000	0.000	0.x	0.x	0.x	xx		0.x				
1/ 15529	0.31	0.000	xx		x	xx	x	x	0.0x	0.0x	0.0x	0.0x
1/ 15537	0.49	0.001	xx		x	xx	x	x	0.0x	0.0x	0.0x	0.0x
1/ 15543	1.34	0.003	xx		x	xx	x	x	0.0x	0.0x	0.0x	0.0x
1/ 15558	0.24	0.005	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 values are visual estimates. 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. The values are visual estimates.

Note: 0.0x, 0.x, x, and xx means 0.01 to 0.1, 0.1 to 1, 1 to 10, and 10 to 100 percent respectively.

Table 5.--Sample data

Augusta Field, Butler County, Kansas

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field 1/ radio-activity	Serial number	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	Kansas City.	Magnolia.	Suits - 1.	SW 1/4-10-27-4	($\bar{2}$)	15604					0.1	81	115,100	-	27	-	-	-	-	-	-	-	6.4	
2	Douglas.	do.	Suits - 1½.	do.	($\bar{3}$)	16311	0.34	0.00																Collected from gas well. Some brine is also pumped.
2	do.	do.	do.	do.	($\bar{3}$)	16412	0.67	0.001																Do., encrusted fibre cup from insert pump.
2	do.	do.	do.	do.	($\bar{3}$)	15599					0.0	1,387	80,400	-	9	-	-	-	-	-	-	-	6.1	Collected from gas well.
3	Arbuckle, plugged back to Kansas City.	do.	Suits - 3.	do.	($\bar{2}$)	15602					0.0	63	116,000	-	14	-	-	-	-	-	-	-	6.5	
4	Simpson.	do.	Suits - 7.	do.	($\bar{2}$)	15539	1.31	0.003																Also spectrographically analyzed.
4	do.	do.	do.	do.	($\bar{2}$)	18444	0.000	0.001																Evaporite.
5	Arbuckle .	Sinclair.	Scully - 1.	NE 1/4- 9-27-4	($\bar{2}$)	15543	1.34	0.003																
6	do.	do.	Scully - 2 .	NE 1/4-16-27-4	($\bar{2}$)	15548	0.38	0.000																
7	do.	do.	Scully - 3.	NE 1/4- 9-27-4	($\bar{3}$)	15544	0.15	0.000																
8	Kansas City.	do.	Scully - 5.	NE 1/4-16-27-4	($\bar{0}$)																			No samples.
9	Arbuckle.	do.	Scully - 6.	do.	($\bar{5}$)	15550	0.61	0.000																
10	do.	do.	Scully - 15.	NE 1/4- 9-27-4	($\bar{3}$)																			No samples.
11	Kansas City.	do.	Scully - 23.	NE 1/4-16-27-4	($\bar{8}$)																			Do.
12	Arbuckle.	do.	Scully - 25.	do.	($\bar{10}$)	15551			0.075	0.000														
13	Kansas City.	do.	Scully - 28.	do.	($\bar{0}$)																			No samples.
14	Arbuckle.	do.	Scully - 29.	NE 1/4- 9-27-4	($\bar{2}$)																			Cable tool drill cuttings, see Table 9 .
15	Kansas City.	Magnolia.	Anderson - 1.	SE 1/4- 9-27-4	($\bar{2}$)	15546	0.012	0.000																Evaporite.
15	do.	do.	do.	do.	($\bar{2}$)	15609					0.0	82	116,700	-	26	-	-	-	-	-	-	-	5.8	
15	do.	do.	do.	do.	($\bar{2}$)	15610					0.0	182	115,700	-	28	-	-	-	-	-	-	-	6.3	
16	do.	do.	Anderson - 2.	do.	($\bar{0}$)	15617					0.0	85	117,400	-	32	-	-	-	-	-	-	-	6.8	
16	do.	do.	do.	do.	($\bar{0}$)	15618					0.0	75	118,900	-	29	-	-	-	-	-	-	-	6.8	
17	Arbuckle, plugged back to Kansas City.	do.	Anderson - 4.	do.	($\bar{13}$)	15613					0.0	1,759	34,000	-	200	99	127	2,880	923	-	17,710	-	7.2	
17	do.	do.	do.	do.	($\bar{13}$)	15614					0.0	1,735	34,000	-	167	47	228	2,670	477	-	19,140	-	7.6	
18	Arbuckle.	do.	Anderson - 7.	do.	($\bar{2}$)																			No samples.
19	do.	do.	Anderson - 9.	do.	($\bar{3}$)	15545	0.006	0.000																

1/ Approximate radioactivity determined in the field with Beckman model MX-5 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.

Table 5.—Sample data

Augusta Field, Butler County, Kansas—Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	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																							
19	Arbuckle.	Magnolia.	Anderson - 9.	SE 1/4- 9-27-4	(3̄)	15611					0.0	2,834	20,100	-	239	9	29	1,725	455	-	11,100	38,000	7.9	
19	do.	do.	do.	do.	(3̄)	15612					0.0	2,380	20,700	-	232	59	25	1,950	417	-	11,450	38,100	7.8	
20	Douglas.	United.	-	do.	(1̄5)																			Gas well; no samples. Radio-activity possibly caused by radon.
21	Arbuckle.	Hammer and McLain.	Bates 2A.	SW 1/4-10-27-4	(0̄)																			Cable tool drill cuttings, see Table 9.
22	do.	Aikman and Braden.	So. Anderson-1.	NW 1/4-15-27-4	(0̄)																			Do.
23	do.	do.	So. Anderson-2.	do.	(0̄)																			Do.
24	do.	Magnolia.	Robertson - 1.	NW 1/4-10-27-4	(5̄)																			No samples.
25	do.	Rex and Morris.	Loomis - 7.	do.	(0̄)																			Cable tool drill cuttings, see Table 9.
26	do.	Magnolia.	Foster - 1.	SE 1/4-21-27-4	(1̄5)	15632					0.0	-	-	-	-	-	-	-	-	-	-	-	7.8	
27	Arbuckle, plugged back to Kansas City.	do.	Foster - 3.	do.	(1̄0)																			No samples.
28	Kansas City.	do.	Foster - 9.	do.	(0̄)																			Do.
29	Arbuckle, plugged back to Kansas City.	do.	Foster - 14.	do.	(0̄)	5809			0.001															
30	Arbuckle.	do.	Foster - 16.	do.	(2̄0)	15555	0.83	0.000																Also spectrographically analyzed.
30	do.	do.	do.	do.	(2̄0)	15625					0.0	712	81,800	-	112	-	-	-	-	-	-	-	6.9	
31	Kansas City.	do.	Foster - 24.	NE 1/4-21-27-4	(2̄)																			No samples.
32	do.	do.	Foster - 25.	SE 1/4-21-27-4	(0̄)																			Do.
33	do.	do.	Foster - 26.	NE 1/4-21-27-4	(2̄)	15629					0.1	32	115,200	-	28	-	-	-	-	-	-	-	6.3	
34	do.	do.	Foster - 31.	do.	(0̄)	15627					0.0	56	114,500	-	34	-	-	-	-	-	-	-	7.0	
35	do.	do.	Foster - 32.	do.	(0̄)	15628					0.0	52	115,200	-	30	-	-	-	-	-	-	-	6.9	
36	do.	do.	Foster - 36.	SE 1/4-21-27-4	(0̄)	15631					0.0	-	-	-	-	-	-	-	-	-	-	-	5.4	
37	do.	do.	Carter - 3.	NE 1/4-28-27-4	(0̄)																			No samples.
38	do.	do.	Kramer - 15.	SW 1/4-28-27-4	(0̄)																			Do.
39	Arbuckle.	do.	Kramer - 16.	NW 1/4-28-27-4	(0̄)	15634					0.0	-	-	-	-	-	-	-	-	-	-	-	4.9	
40	do.	do.	Kramer - 17.	SW 1/4-28-27-4	(0̄)																			Cable tool drill cuttings, see Table 9.
41	Kansas City.	-	Safford - 4.	SE 1/4-26-27-4	(0̄)																			No samples.

Table 5.—Sample data

Augusta Field, Butler County, Kansas—Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	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															
42	Kansas City.	-	Safford - 5.	SE 1/4-26-27-4	$(\bar{0})$																			No samples.
43	Douglas ?	-	Safford - 7.	do.	$(\bar{5})$	16232	0.008	0.000																Collected from gas well. Field measurement mass of precipitate.
44	Kansas City.	-	Safford - 8.	do.	$(\bar{0})$																			No samples.
45	do.	Sinclair - Cities Service.	Skaer - 1.	NE 1/4-35-27-4	$(\bar{0})$																			Do.
46	do.	do.	Skaer - 2.	do.	$(\bar{0})$	16265					0.0	204	98,300	-	64	-	-	-	-	-	-	-	-	
47	Simpson.	do.	Skaer - 5.	do.	$(\bar{0})$	16262	0.000	0.000																
47	do.	do.	do.	do.	$(\bar{0})$	16261					0.0	1,595	17,910	-	320	-	-	-	-	-	-	-	-	
48	Kansas City.	do.	Skaer - 10.	do.	$(\bar{0})$																			No samples.
49	Arbuckle.	do.	Skaer - 12.	do.	$(\bar{0})$																			Do.
50	Arbuckle, plugged back to Kansas City.	do.	Skaer - 14.	do.	$(\bar{2})$																			Do.
51	Kansas City.	do.	Skaer - 15.	do.	$(\bar{0})$	16235					0.0	74	108,300	-	38	-	-	-	-	-	-	-	-	
52	Arbuckle, plugged back to Kansas City.	do.	Skaer - 16.	do.	$(\bar{10})$	16268	0.17	0.000																
52	do.	do.	do.	do.	$(\bar{10})$	16267					0.0	76	111,000	-	41	-	-	-	-	-	-	-	-	
53	Simpson.	do.	Skaer - 17.	do.	$(\bar{0})$	16266					0.0	-	27,200	-	380	-	-	-	-	-	-	-	-	
54	do.	do.	Skaer - 18.	do.	$(\bar{0})$	16236					0.0	2,084	20,400	-	360	38	68	1,782	464	146	11,560	38,800	-	
55	do.	do.	Skaer - 19.	do.	$(\bar{3})$																			No samples.
56	Arbuckle, plugged back to Kansas City.	do.	Starkey - 1.	SE 1/4-35-27-4	$(\bar{0})$	16272					0.0	-	49,600	-	-	-	-	-	-	-	-	-	-	
57	Kansas City.	do.	Starkey - 3.	do.	$(\bar{0})$																			No samples.
58	do.	do.	Starkey - 4.	do.	$(\bar{0})$	16270	0.001	0.000																
58	do.	do.	do.	do.	$(\bar{0})$	16269					0.0	31	109,900	-	28	-	-	-	-	-	-	-	-	
59	do.	do.	Starkey - 5.	do.	$(\bar{0})$	16275					0.0	2,740	24,300	-	332	-	-	-	-	-	-	-	-	
60	Arbuckle.	do.	Starkey - 7.	do.	$(\bar{0})$	16276					0.0	1,992	16,900	-	268	8	34	1,644	418	-	9,640	33,300	-	
61	do.	do.	Starkey - 8.	do.	$(\bar{0})$																			No samples.
62	Arbuckle, plugged back to Kansas City.	do.	Starkey - 9.	do.	$(\bar{0})$																			Do.

Table 5.--Sample data

Augusta Field, Butler County, Kansas--Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	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															
63	Simpson.	Sinclair - Cities Service.	Starkey - 12.	SE 1/4-35-27-4	($\bar{0}$)	16277					0.0	1,546	39,400	-	187	41	182	2,900	1,038	-	21,740	72,300	-	
64	Kansas City.	do.	Starkey - 13.	do.	($\bar{0}$)																			No samples.
65	Simpson.	do.	Starkey - 15.	do.	($\bar{0}$)																			Do.
66	Arbuckle.	do.	Starkey - 16.	do.	($\bar{0}$)																			Do.
67	do.	Shawver Graham.	King - 7.	SW 1/4-36-27-4	($\bar{2}$)	16242					0.0	2,274	18,100	-	343	13	36	1,804	599	-	10,410	35,200	-	
68	do.	do.	King - 12.	do.	($\bar{0}$)	16243					0.0	2,570	20,800	-	320	8	30	1,994	495	-	11,790	40,400	-	
69	do.	do.	King - 14.	NW 1/4-36-27-4	($\bar{0}$)																			No samples.
70	do.	Hammer and McLain.	Moyle - 2.	SW 1/4-35-27-4	($\bar{0}$)	16278					0.0	1,744	18,330	-	294	-	-	-	-	-	-	-	-	Also cable tool drill cuttings, see Table 9.
71	do.	do.	Moyle - 3.	do.	($\bar{0}$)																			No samples.
72	do.	do.	Ambler - 1.	NW 1/4- 2-28-4	($\bar{0}$)	16284					0.0	2,610	19,640	-	298	-	-	-	-	-	-	-	-	Also cable tool drill cuttings, see Table 9.
73	do.	do.	Ambler - 2.	do.	($\bar{0}$)																			Cable tool drill cuttings, see Table 9.
74	do.	do.	Ambler - 3.	do.	($\bar{0}$)	16245					0.0	2,780	22,700	-	224	-	-	-	-	-	-	-	-	Also cable tool drill cuttings, see Table 9.
75	do.	do.	Ambler - 4.	do.	($\bar{0}$)	16285					0.0	-	21,000	-	-	-	-	-	-	-	-	-	-	Do.
76	do.	do.	Ambler - 5.	do.	($\bar{0}$)																			Cable tool drill cuttings, see Table 9.
77	do.	Cities Service.	Brant - 3.	SE 1/4- 2-28-4	($\bar{0}$)	16260					0.0	2,395	17,900	-	264	59	25	1,857	473	-	10,210	35,100	-	
78	do.	do.	Brant - 7.	do.	($\bar{4}$)	16256					0.0	2,670	23,860	-	251	-	-	-	-	-	-	-	-	
79	Kansas City.	do.	Brant - 9.	do.	($\bar{0}$)																			No samples.
80	Arbuckle.	do.	Brant - 10.	do.	($\bar{0}$)																			Do.
81	do.	do.	Brant - 11.	do.	($\bar{10}$)	16258	0.081	0.001																
81	do.	do.	do.	do.	($\bar{10}$)	16259					0.0	931	17,900	-	266	-	-	-	-	-	-	-	-	
82	do.	do.	Brant - 13.	do.	($\bar{0}$)																			No samples.
83	do.	do.	Brant - 14.	do.	($\bar{0}$)																			Do.
84	Kansas City.	do.	Haslett - 3.	NE 1/4-11-28-4	($\bar{0}$)																			Do.
85	do.	do.	Haslett - 4.	do.	($\bar{0}$)																			Do.

Table 5.--Sample data

Augusta Field, Butler County, Kansas--Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	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														
86	Arbuckle.	Cities Service.	Haslett - 5.	NE 1/4-11-28-4	(1̄0)	16250	0.26	0.000																
87	do.	do.	Haslett - 6.	do.	(8̄)																			No samples.
88	do.	do.	Haslett - 7.	do.	(8̄)																			Do.
89	do.	do.	Wallace - 4.	NW 1/4-11-28-4	(3̄)	16288	0.17	0.000																
90	do.	do.	Wallace - 7.	do.	(8̄)																			No samples.
91	do.	do.	Wallace - 8.	do.	(8̄)																			Do.
92	do.	do.	Wallace - 10.	do.	(8̄)																			Do.
93	do.	do.	Wallace - 12.	do.	(8̄)																			Do.
94	Kansas City.	do.	Wallace - 18.	do.	(8̄)																			Do.
95	do.	do.	Wallace - 19.	do.	(8̄)	16253					0.0	-	103,900	-	34	-	-	-	-	-	-	-	-	
96	do.	do.	Wallace - 20.	do.	(8̄)	16287					0.0	11	101,900	-	37	-	-	-	-	-	-	-	-	
97	do.	do.	Moyle - 1.	SE 1/4-10-28-4	(8̄)																			No samples.
98	do.	do.	Moyle - 10.	SW 1/4-10-28-4	(8̄)																			Do.
99	do.	do.	Moyle - 11.	do.	(8̄)																			Do.
100	Arbuckle.	do.	Moyle - 27.	NE 1/4-15-28-4	(8̄)																			Do.
101	do.	do.	Moyle - 29.	SW 1/4-10-28-4	(8̄)																			Do.
102	do.	do.	Moyle - 30.	SE 1/4-10-28-4	(8̄)																			Do.
103	do.	do.	Moyle - 33.	SW 1/4-11-28-4	(3̄)	16291					0.0	2,700	18,560	-	332	-	24	1,872	-	-	17,710	37,700	-	
104	do.	do.	Moyle - 34.	NE 1/4-15-28-4	(8̄)																			No samples.
105	?	do.	Moyle - 43.	SE 1/4-10-28-4	(8̄)																			Do.
106	Arbuckle.	do.	Moyle - 44.	do.	(1̄0)	16289	0.22	0.000																
106	do.	do.	do.	do.	(1̄0)	16292					0.0	-	26,900	-	383	-	-	-	-	-	-	-	-	
107	Kansas City.	do.	Moyle - 45.	SW 1/4-11-28-4	(8̄)																			No samples.
108	Arbuckle.	do.	Moyle - 46.	SE 1/4-10-28-4	(8̄)																			Do.
109	Kansas City.	do.	Moyle - 47.	NW 1/4-14-28-4	(8̄)																			Do.
110	Arbuckle.	do.	Moyle - 48.	SW 1/4-11-28-4	(8̄)																			Do.
111	Douglas.	Hammer and McLain.	Walker ? - 1.	NE 1/4- 3-28-4	(8̄)	16244					0.0	83	99,000	-	26	-	-	-	-	-	-	-	-	

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Table 5.--Sample data

Augusta Field, Butler County, Kansas--Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	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																
112	Arbuckle.	Hammer and McLain.	Walker ? - 5.	NE 1/4- 3-28-4	($\bar{0}$)																			No samples.
113	Kansas City.	Cities Service.	Miller - 15.	SW 1/4- 2-28-4	($\bar{0}$)	16247					0.0	35	101,600	-	30	-	-	-	-	-	-	-	-	
114	Arbuckle	Adair.	Hoyle - 1.	NW 1/4-10-28-4	($\bar{0}$)																			No samples.
115	do.	do.	Moyle - 2.	do.	($\bar{0}$)																			Do.
116	do.	do.	Moyle - 3.	do.	($\bar{0}$)																			Do.
117	do.	do.	Moyle - 4.	do.	($\bar{0}$)																			Do.
118	do.	do.	Moyle - 5.	do.	($\bar{0}$)																			Do.
119	do.	Adair (west).	Feltham - 1.	NW 1/4- 9-28-4	($\bar{0}$)																			Do.
120	do.	do.	Feltham -1-B.	NE 1/4- 9-28-4	($\bar{0}$)																			Do.
121	do.	do.	Feltham - 2.	do.	($\bar{0}$)																			Do.
122	do.	Cities Service.	Scully - 4.	SE 1/4- 9-28-4	($\bar{5}$)	16301	0.42	0.001																
123	do.	do.	Scully - 8.	do.	($\bar{0}$)																			No samples.
124	do.	do.	Scully - 9.	do.	($\bar{3}$)																			Do.
125	do.	do.	Scully - 11.	do.	($\bar{0}$)																			Do.
126	do.	do.	Scully - 12.	do.	($\bar{0}$)																			Do.
127	do.	do.	Brown - 6.	NE 1/4-16-28-4	($\bar{3}$)																			Do.
128	do.	do.	Brown - 7.	do.	($\bar{0}$)																			Do.
129	do.	do.	Brown - 16.	do.	($\bar{0}$)																			Do.
130	do.	Aikman and Braden.	Blood - 2.	SW 1/4-21-28-4	($\bar{0}$)																			Do.
131	do.	do.	Blood - 3.	do.	($\bar{0}$)																			Do.
132	do.	do.	Blood - 20.	do.	($\bar{0}$)																			Do.
133	do.	Cities Service.	Varner - 6.	NE 1/4-17-28-4	($\bar{0}$)																			Do.
134	do.	do.	Varner - 12.	do.	($\bar{0}$)																			Do.
135	do.	do.	Varner - 13.	SE 1/4- 8-28-4	($\bar{15}$)																			Do.
136	Kansas City.	do.	Varner - 17.	do.	($\bar{0}$)																			Do.
137	do.	do.	Varner - 18.	do.	($\bar{0}$)																			Do.
138	Arbuckle.	do.	Varner - 19.	do.	($\bar{15}$)	16297	0.064	0.000																

Table 5.--Sample data

Augusta Field, Butler County, Kansas--Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	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													
138	Arbuckle.	Cities Service.	Varner - 19.	SE 1/4- 8-28-4	(15)	16296					0.0	2,340	22,990	-	283	12	46	2,335	598	-	12,980	45,500	-	
139	do.	do.	Varner - 21.	NE 1/4-17-28-4	(5)																			No samples.
140	do.	do.	Varner - 23.	do.	(5)																			Do.
141	do.	do.	Varner - 25.	SE 1/4- 8-28-4	(5)																			Do.
142	do.	do.	Varner - 26.	NE 1/4-17-28-4	(15)																			Do.
143	do.	do.	Varner - 28.	do.	(5)																			Do.
144	Kansas City.	do.	Varner - 32.	do.	(5)																			Do.
145	do.	do.	Varner - 33.	do.	(5)																			Do.
146	do.	do.	Varner - 34.	do.	(5)																			Do.
147	Arbuckle.	do.	Kirkpatrick - 6	SE 1/4-17-28- 4	(75)	16316	0.42	0.000																
147	do.	do.	do.	do.	(75)	16317					0.0	2,285	19,000	-	345	11	34	1,975	488	158	11,000	37,900	-	
148	Kansas City.	do.	Kirkpatrick-10.	do.	(5)																			No samples.
149	Arbuckle.	do.	Haskins - 5.	NW 1/4-17-28-4	(3)	16320	0.052	0.000																
150	do.	do.	Haskins - 9.	NW 1/4-20-28-4	(10)																			No samples.
151	do.	do.	Haskins - 20.	do.	(15)																			Do.
152	do.	do.	Haskins - 22.	SW 1/4-17-28-4	(5)																			Do.
153	do.	do.	Smith - 25.	NW 1/4-20-28-4	(50)	16323	0.58	0.000																
153	do.	do.	do.	do.	(50)	16322					0.0	638	71,900	-	164	-	-	-	-	-	-	-	-	
154	do.	do.	Smith - 26.	do.	(5)																			No samples.
155	do.	do.	Smith - 31.	NE 1/4-20-28-4	(5)	16314	0.28	0.000																
156	do.	do.	Smith - 32.	SE 1/4-17-28-4	(5)	16315					0.0	2,670	20,400	-	307	47	52	2,106	477	160	11,830	39,900	-	
157	do.	do.	Smith - 44.	NW 1/4-20-28-4	(5)																			No samples.
158	do.	do.	Love - 22.	SE 1/4-20-28-4	(5)																			Do.
159	do.	do.	Love - 23.	SW 1/4-20-28-4	(5)																			Do.
160	do.	do.	Love - 26.	do.	(5)																			Do.
161	do.	do.	Love - 33.	NW 1/4-29-28-4	(3)	16327	0.018	0.000																
162	Lansing.	do.	Love - 34.	SW 1/4-20-28-4	(5)																			No samples.
163	Arbuckle.	do.	Kirkpatrick-14.	NE 1/4-20-28-4	(5)																			Do.

Table 5.--Sample data

Augusta Field, Butler County, Kansas--Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	Precipitates: Collected from pipes		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		
							Samples from producing wells																	
164	Arbuckle.	Thrifty.	Haskins - 2.	NE 1/4-19-28-4	($\bar{0}$)																			No samples.
165	do.	Black.	Chance - 1.	SE 1/4-19-28-4	($\bar{0}$)																			Do.
166	do.	do.	Chance - 2.	do.	($\bar{0}$)																			Do.
167	do.	do.	Chance - 3.	do.	($\bar{0}$)																			Do.
168	do.	Thrifty.	Vinyard - 2.	do.	($\bar{0}$)																			Do.
169	do.	do.	Vinyard - 3.	do.	($\bar{0}$)																			Do.
170	do.	-	Blakeslee - 1.	NW 1/4-17-28-4	($\bar{0}$)																			Do.

Table 5.--Sample data

Augusta Field, Butler County, Kansas--Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	Precipitates: Collected from pipes or tanks: Percent eU3O8	Precipitates: Collected from pipes or tanks: Percent U3O8	Precipitates: Contaminated with surface debris: Percent eU3O8	Precipitates: Contaminated with surface debris: Percent U3O8	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 brine disposal systems																	
171	Arbuckle.	Magnolia.	Robertson.	NW 1/4-10-27-4	(30)	15540	0.004	0.000																Wood collected from separator tank, radioactivity caused by precipitates.
172	?	Hammer and McLain.	Suits.	do.	(10)	15606					0.0	91	113,700	-	33	-	-	-	-	-	-	-	6.9	
173	Douglas and Kansas City.	Magnolia.	do.	SW 1/4-10-27-4	(5)	15538	0.002	0.000																Wood collected from separator tank, radioactivity caused by precipitates.
173	do.	do.	do.	do.	(5)	15603					0.0	29	118,500	-	22	68	2,332	8,080	3,550	207	57,800	201,600	6.9	
174	Arbuckle.	Aikman and Braden.	Bates.	do.	(2)	15619					0.0	46	108,800	-	26	52	2,003	7,810	3,620	193	51,600	184,000	6.9	
175	do.	do.	Anderson.	NW 1/4-15-27-4	(10)	15621					0.0	363	87,800	-	34	-	-	-	-	-	-	-	6.5	
176	?	Holk.	Loomis.	do.	(10)	15528			0.014	0.000														Collected from area near separator tank.
176	?	do.	do.	do.	(10)	15623					0.0	457	19,220	-	63	-	-	-	-	-	-	-	7.0	
177	Arbuckle.	Sinclair.	Scully.	NE 1/4- 9-27-4	(40)	15608					0.0	219	109,800	-	57	-	-	-	-	-	-	-	6.8	
178	Kansas City and Arbuckle.	Magnolia.	Anderson.	SE 1/4- 9-27-4	(40)	15615					0.0	172	88,800	-	26	20	1,282	6,640	2,720	184	43,900	152,400	7.0	
179	?	United.	-	do.	(0)																			No samples.
180	Kansas City and Arbuckle.	Sinclair.	Scully	NE 1/4-16-27-4	(50)	15552	0.28	0.000																Collected from separator tank.
180	do.	do.	do.	do.	(50)	15622					0.0	536	78,300	-	115	-	-	-	-	-	-	-	7.2	
181	?	Aikman, et al	Parry.	SE 1/4-16-27-4	(0)	15624					0.0	2,720	28,000	-	103	20	19	2,153	697	152	17,200	51,200	7.9	
182	?	Aikman and Braden.	Brown.	do.	(0)																			No samples.
183	?	Rex and Morris.	Loomis.	NE 1/4-21-27-4	(0)																			Do.
184	?	do.	do.	NW 1/4-21-27-4	(5)																			Do.
185	Kansas City and Arbuckle.	Magnolia.	Foster.	SW 1/4-21-27-4	(50)	15630					0.0	741	81,700	-	87	-	-	-	-	-	-	-	6.9	
186	do.	Cities Service.	Scully.	NW 1/4-28-27-4	(20)	15633					0.0	1,627	38,770	-	113	13	281	3,040	1,056	155	20,050	68,200	7.2	
187	Kansas City?	Magnolia.	Carter.	NE 1/4-28-27-4	(0)																			No samples.
188	do.	do.	do.	do.	(5)	15556			0.060	0.002														Collected from area near separator tank.
189	Kansas City and Arbuckle.	do.	Kramer.	SW 1/4-28-27-4	(5)																			No samples.
190	Kansas City.	Wichita Ind.	-	SE 1/4-26-27-4	(0)																			Do.
191	Kansas City, Simpson, and Arbuckle.	Sinclair - Cities Service.	Skaer.	NE 1/4-35-27-4	(7)	16263					0.0	1,263	34,250	-	195	50	356	2,950	1,046	138	18,200	60,700	-	
192	?	Magnolia.	Palmer.	NW 1/4-35-27-4	(3)																			No samples.

Table 5.--Sample data

Augusta Field, Butler County, Kansas--Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	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
							Samples from brine disposal systems																	
193	Arbuckle.	Harmer and McLain.	Hoyle.	SW 1/4-35-27-4	($\bar{10}$)	16231	0.21	0.000																Collected from separator tank.
194	Kansas City, Simpson, and Arbuckle.	Sinclair - Cities Service.	Starkey.	SE 1/4-35-27-4	($\bar{5}$)	16271			0.046	0.002														Collected from abandoned separator tank site.
195	Arbuckle.	Sharver Graham.	King.	SW 1/4-36-27-4	($\bar{6}$)	16241					0.19	2,354	20,200	-	328	44	19	1,800	455	144	11,280	38,000	-	
196	do.	Harmer and McLain.	Ambler.	NW 1/4- 2-28-4	($\bar{0}$)																			No samples.
197	?	B and R.	Collins.	NE 1/4- 2-28-4	($\bar{0}$)																			Do.
198	Kansas City and Arbuckle.	Cities Service.	Brant.	SE 1/4- 2-28-4	($\bar{5}$)	16255			0.055	0.000														Collected from area near separator tank.
198	do.	do.	do.	do.	($\bar{5}$)	16257					0.0	2,107	25,600	-	222	73	194	2,185	642	153	14,050	47,300	-	
199	Kansas City.	do.	Miller.	SW 1/4- 2-28-4	($\bar{5}$)	16248					0.0	32	104,900	-	41	-	-	-	-	-	-	-	-	
200	Kansas City and Arbuckle.	do.	Wallace.	NW 1/4-11-28-4	($\bar{35}$)	16252					0.0	243	106,700	-	37	-	-	-	-	-	-	-	-	
201	do.	Sinclair - Cities Service.	Hazlett.	NE 1/4-11-28-4	($\bar{10}$)																			No samples.
202	do.	Cities Service.	Hoyle.	SW 1/4-11-28-4	($\bar{10}$)																			Do.
203	Arbuckle.	Harmer and McLain (?).	Walker?	NE 1/4- 3-28-4	($\bar{0}$)																			Do.
204	?	Adair.	Hoyle.	NE 1/4-10-28-4	($\bar{4}$)																			Do.
205	?	do.	do.	do.	($\bar{0}$)	16290					0.0	1,694	18,240	-	147	13	22	1,627	449	150	10,370	35,100	-	
206	Kansas City and Arbuckle.	Cities Service.	do.	SE 1/4-10-28-4	($\bar{5}$)	16293			0.036	0.000														Collected from area near separator tank.
207	do.	do.	do.	SW 1/4-10-28-4	($\bar{10}$)																			No samples.
208	?	Adair.	Feltham.	NW 1/4-10-28-4	($\bar{0}$)																			Do.
209	?	Adair (west).	do.	NE 1/4- 9-28-4	($\bar{0}$)																			Do.
210	Kansas City and Arbuckle.	Cities Service.	Scully.	SE 1/4- 9-28-4	($\bar{10}$)	16302					0.0	1,487	51,200	-	132	-	-	-	-	-	-	-	-	
211	Arbuckle.	do.	Brown.	NE 1/4-16-28-4	($\bar{5}$)																			No samples.
212	do.	do.	do.	do.	($\bar{5}$)																			Do.
213	Kansas City and Arbuckle.	do.	Varner.	NE 1/4-17-28-4	($\bar{10}$)																			Do.
214	do.	do.	do.	do.	($\bar{10}$)	16298					0.14	1,322	51,400	-	179	-	-	-	-	-	-	-	-	

Table 5.--Sample data

Augusta Field, Butler County, Kansas--Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Field radio-activity	Serial number	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: U_3O_8	Brines: SO_4	Brines: Cl	Brines: CO_3	Brines: HCO_3	Brines: Ba	Brines: Sr	Brines: Ca	Brines: Mg	Brines: K	Brines: Na	Brines: Total solids	pH	Remarks
	Samples from brine disposal systems																							
215	Arbuckle.	Cities Service.	Kirkpatrick.	SE 1/4-17-28-4	(15)	16318					0.0	2,140	24,440	-	258	34	127	2,238	618	166	13,450	45,900	-	
216	?	-	Blakeslee.	NW 1/4-17-28-4	(0)																			No samples.
217	Arbuckle.	Cities Service.	Haskins.	SW 1/4-17-28-4	(5)	16321					0.0	1,087	20,010	-	177	-	-	-	-	-	-	-	-	
218	Kansas City and Arbuckle.	do.	do.	NW 1/4-20-28-4	(20)	16307			0.051	0.000														Collected from area near separator tank.
218	do.	do.	do.	do.	(20)	16306					0.0	790	70,800	-	128	-	-	-	-	-	-	-	-	
219	do.	do.	Smith.	do.	(10)	16305			0.093	0.001														Collected from area near separator tank.
219	do.	do.	do.	do.	(10)	16304					0.0	2,368	36,750	-	291	14	369	3,340	1,096	173	20,050	67,400	-	
220	do.	do.	do.	NE 1/4-20-28-4	(20)	16313			0.021	0.000														Collected from area near separator tank.
220	do.	do.	do.	do.	(20)	16312					0.0	356	63,300	-	199	-	-	-	-	-	-	-	-	
221	Lansing and Arbuckle.	do.	Kirkpatrick.	SE 1/4-20-28-4	(40)	16295	0.33	0.005																Collected from separator tank.
221	do.	do.	do.	do.	(40)	16294					0.0	2,610	21,300	-	168	43	33	2,010	499	166	12,300	41,900	-	
222	do.	do.	Love.	do.	(10)	16326					0.0	1,651	33,400	-	136	-	-	-	-	-	-	-	-	
223	Arbuckle.	Aikman and Braden.	Blood.	SW 1/4-21-28-4	(0)	16303					0.2	2,209	19,430	-	232	-	-	-	-	-	-	-	-	
224	do.	Thrifty.	Haskins.	NE 1/4-19-28-4	(3)	16324					0.2	371	19,820	-	272	-	-	-	-	-	-	-	-	
225	do.	do.	Vinyard.	SE 1/4-19-28-4	(0)																			No samples.
226	do.	do.	do.	do.	(0)																			Do.
227	do.	Black.	Chance.	do.	(0)	16325					0.0	634	19,820	-	488	-	-	-	-	-	-	-	-	
228	?	-	Mackey.	NE 1/4-30-28-4	(5)																			No samples.
229	?	Pure Oil.	-	SW 1/4-29-28-4	(5)																			Do.

Table 5.—Sample data

Augusta Field, Butler County, Kansas—Continued

Locality number 2/	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Serial number	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
						Samples from miscellaneous localities 2/.																	
230	Kansas City and Arbuckle.	Magnolia.	Anderson.	SE 1/4- 9-27-4	13165			0.029	0.000														Collected from area near separator tank.
230	do.	do.	do.	do.	13166			0.008	0.000														Do.
230	do.	do.	do.	do.	13169	0.12	0.000																Collected from separator tank.
230	do.	do.	do.	do.	13170	0.24	0.000																Do., also spectrographically analyzed.
230	do.	do.	do.	do.	13171			0.39	0.000														Collected from area near separator tank.
231	Arbuckle ?	Citron ?	Anderson - 8.	NE 1/4-SE 1/4-SE 1/4- 9-27-4	15547	0.001	0.000																Evaporite, collected from well.
232	?	do.	Anderson.	do.	15620					0.0	99	111,600	-	38	-	-	-	-	-	-	-	6.7	Collected from separator tank.
233	?	-	Suits.	SW 1/4-SW 1/4-NW 1/4-10-27-4	15541	0.16	0.000																Collected from abandoned separator tank site.
233	?	-	do.	do.	15542	0.22	0.000																Do.
234	?	-	Suits - ?	do.	15607					0.1	95	113,600	18	-	-	-	-	-	-	-	-	7.0	Collected from well.
235	Kansas City ?	Magnolia.	Suits - 4.	SE 1/4-NW 1/4-SW 1/4-10-27-4	15600					0.0	-	-	-	-	-	-	-	-	-	-	-	6.5	Do.
236	?	do.	Suits.	W 1/2-NW 1/4-SW 1/4-10-27-4	15536	0.056	0.002																Collected from scrap pipe.
236	?	do.	do.	do.	15537	0.49	0.001																Do., also spectrographically analyzed.
237	?	-	Bates	SW 1/4-SW 1/4-SW 1/4-10-27-4	15533	0.006	0.000																Collected from scrap pipe.
238	?	-	do.	NW 1/4-SW 1/4- SW 1/4-10-27-4	15534	0.42	0.000																Do.
239	?	-	Bates - 1?	do.	15535	0.33	0.000																Collected from well.
240	?	-	So. Anderson-2.	SW 1/4-NW 1/4-NW 1/4-15-27-4	15529	0.31	0.000																Collected from abandoned well site.
241	?	-	So. Anderson-6.	C-NW 1/4-15-27-4	15530	0.38	0.000																Do.
242	?	-	So. Anderson-7.	NW 1/4-NW 1/4- NW 1/4-15-27-4	15531			0.007	0.000														Do., cable tool drill cuttings, see Table 9.
243	?	-	So. Anderson.	N 1/2-NW 1/4- NW 1/4-15-27-4	15532			0.011	0.000														Collected from abandoned separator tank site.
244	?	Molk.	Loomis.	SW 1/4-SW 1/4- NW 1/4-15-27-4	15526	0.64	0.006																Collected from area near separator tank; also spectrographically analyzed.
245	?	do.	do.	N 1/2-SW 1/4- NW 1/4-15-27-4	15527			0.003	0.000														Collected from area near separator tank.
245	?	do.	do.	do.	15528			0.14	0.000														Do.
246	?	do.	Loomis - 7.	S 1/2-NW 1/4- SW 1/4-15-27-4	15553			0.001	0.000														Collected from area near well.
247	?	Sinclair.	Scully - 16.	NE 1/4- NE 1/4-15-27-4	15549	0.025	0.001																Collected from abandoned well site.
248	?	Magnolia.	Foster - ?	SE 1/4-21-27-4	13167			0.043	0.000														Do.
248	?	do.	do.	do.	13168	0.092	0.000																Do.
249	?	do.	Foster - 7.	SW 1/4-SW 1/4- NE 1/4-21-27-4	15554	0.004	0.000																Do.

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 5.--Sample data

Augusta Field, Butler County, Kansas--Continued

Locality number 2/	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Serial number	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
					Samples from miscellaneous localities.																		
250	?	Magnolia.	Kramer - 13.	C-SE 1/4-NW 1/4-28-27-4	15557	0.28	0.000																Collected from abandoned well site.
251	Douglas?	-	Safford - ?	SE 1/4-NW 1/4-SE 1/4-26-27-4	16233	0.001	0.000																Collected from well.
252	?	-	Safford.	SW 1/4-SW 1/4-SE 1/4-26-27-4	16234					0.0	2,213	98,400	-	1	-	-	-	-	-	-	-	-	Collected from disposal pond.
253	?	Magnolia.	Safford - 2.	NE 1/4-SE 1/4-NW 1/4-35-27-4	16281	0.003	0.000																Collected from abandoned well site.
254	Kansas City.	do.	Safford - 3.	SW 1/4-SE 1/4-NW 1/4-35-27-4	16283					0.0	48	112,700	-	31	-	-	-	-	-	-	-	-	Collected from well.
255	do.	do.	Safford - 6.	SE 1/4-NE 1/4-NW 1/4-35-27-4	16282					0.0	9	111,700	-	53	-	-	-	-	-	-	-	-	Do.
256	?	do.	Safford - 8.	NE 1/4-NE 1/4-NW 1/4-35-27-4	16239			0.000	0.000														Collected from abandoned well site.
257	?	Sinclair-Cities. Service.	Skaer - 3.	NW 1/4-NW 1/4-NE 1/4-35-27-4	16238			0.000	0.000														Do.
258	Kansas City.	do.	Skaer - 6.	NW 1/4-SW 1/4-NE 1/4-35-27-4	16264			0.044	0.000														Do.
259	Arbuckle.	do.	Skaer - 9.	N 1/2-NW 1/4-NE 1/4-35-27-4	16237	0.000	0.000																Do.
260	do.	do.	Starkey - 2.	NW 1/4-NW 1/4-SE 1/4-35-27-4	16274	0.003	0.000																Do.
261	?	do.	Starkey - 14.	SW 1/4-NE 1/4- SE 1/4-35-27-4	16240			0.049	0.000														Do.
262	?	United.	-	SE 1/4-NE 1/4-SE 1/4- 3-28-4	16246	0.16	0.000																Do.
263	?	do.	-	E 1/2-SW 1/4-SE 1/4- 3-28-4	16251			0.002	0.000														Do.
264	-	Cities Service.	-	NW 1/4-NE 1/4-NE 1/4-16-28-4	16299	0.001	0.000																Fresh water precipitate collected from power plant.
265	-	do.	-	do.	16300					0.0	123	1	-	130	-	-	-	-	-	-	-	-	Fresh water from 4-mile creek.
266	?	do.	Smith - 20.	NW 1/4-NE 1/4-NW 1/4-20-28-4	16308	0.085	0.000																Collected from abandoned well site.

Table 6.—Sample data

Cowley County

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Serial number	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
267	Arbuckle.	-	Lewis.	NE 1/4-28-31-4	18450	0.001	0.001																Collected from separator tank.
268	do.	Bennett et al.	Weathered.	SE 1/4-28-31-3	18429			0.085	0.000														Do.
268	do.	-	do.	do.	18430			0.027	0.001														Do., gypsum, and celestite.
269	Bartlesville.	-	Boyd.	SW 1/4-19-32-5	15585			0.040	0.001														Collected from separator tank.
269	do.	-	do.	do.	15643					0.0	-	-	-	-	-	-	-	-	-	-	-	6.5	Do.
270	Arbuckle and Kansas City.	Continental.	Bower.	NW 1/4-10-33-3	18447			0.32	0.001														Do.
270	do.	do.	do.	do.	18448	8.15	0.000																Collected from brine disposal line.
270	do.	do.	do.	do.	18449	0.048	0.001																Collected from top of separator tank.
270	do.	do.	do.	do.	18452	5.16	0.001																Collected from separator tank.
271	?	do.	Bower or Graham.	9 or 10-33-3	18446	10.85	0.001																Collected from scrap pipe used on the Bower or Graham lease.
270	Arbuckle and Kansas City.	do.	Bower.	NW 1/4-10-33-3	17918					0.0	1,137	68,000	0	71	18	403	5,600	1,367	179	33,100	112,500	-	Collected from separator tank.
272	Arbuckle.	do.	Bower - 6.	do.	17923					0.0	1,296	61,100	0	83	0	109	5,070	1,187	171	31,500	99,800	-	Collected from well.
272	do.	do.	do.	do.	17924					0.0	1,301	58,100	0	98	16	248	4,920	1,172	170	30,400	99,800	-	Do.
273	do.	do.	Graham - 3.	NE 1/4- 9-33-3	17919					0.0	1,450	50,400	0	75	11	56	3,090	1,006	234	27,000	88,600	-	Do.
273	do.	do.	do.	do.	17920					0.0	1,441	52,100	4	79	11	31	4,490	1,015	192	27,400	88,900	-	Do.
274	Kansas City and Bartlesville.	Hill.	Finch.	NE 1/4- 7-35-3	18427			0.002	0.002														Evaporite on brine disposal pump.
275	-	-	Marker - ?	NE 1/4- 4-33-7	15635					0.0	-	-	-	-	-	-	-	-	-	-	-	7.5	Collected from well.
276	-	-	Radcliffe.	SE 1/4- 5-33-7	15584			0.019	0.001														Collected from brine disposal pond.
276	-	-	do.	do.	15597			0.001	0.000														Do., evaporite.
276	-	-	do.	do.	15636					0.0	716	56,000	-	55	16	259	5,090	1,150	374	29,960	99,100	7.0	Collected from brine disposal pond.
277	Mississippian.	Dilworth and Miller.	Dilworth Fee - 1.	NE 1/4- 8-33-7																			Drill cuttings, see Table 9.
278	do.	do.	Dilworth.	do.	15637					0.0	-	-	-	-	-	-	-	-	-	-	-	6.5	Collected from separator tank.
279	do.	do.	Dilworth Fee - 2.	do.	15558	0.24	0.005																Also drill cuttings, see Table 9.
279	do.	do.	do.	do.	15598	0.48	0.002																Collected from well.
279	do.	do.	do.	do.	15638					0.0	-	-	-	-	-	-	-	-	-	-	-	-	Do.
279	do.	do.	do.	do.	15639					0.0	-	-	-	-	-	-	-	-	-	-	-	5.5	Do.
280	do.	-	Olds - 1.	NW 1/4- 9-33-7	15641					0.0	-	-	-	-	-	-	-	-	-	-	-	-	Do.
280	do.	-	do.	do.	15642					0.0	1,658	50,800	-	80	59	144	4,530	784	-	27,000	91,800	6.5	Do.
281	Bartlesville.	Fleet.	-	W 1/2-27-33-6																			Core samples, see Table 9.
282	Simpson.	-	Bauman.	SE 1/4-17-35-7	18344					0.05	-	137	-	-	-	-	-	-	-	-	-	-	Collected from separator tank.
283	Bartlesville.	Texas.	Eastman.	NE 1/4- 6-31-6	17921					0.0	9	82,600	0	11	441	719	6,740	1,813	66	44,000	139,100	-	Do.

Table 7.—Sample data

Butler County, Kansas 1/

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Serial number	Precipitates: Collected from pipes or tanks, Percent eU3O8	Precipitates: Collected from pipes or tanks, Percent U3O8	Precipitates: Contaminated with surface debris, Percent eU3O8	Precipitates: Contaminated with surface debris, Percent U3O8	Brines, Milligrams per liter: U3O8	SO4	Cl	CO3	HCO3	Ba	Sr	Ca	Mg	K	Na	Total solids	pH	Remarks
284	Kansas City and Hunton.	-	Mack.	SE 1/4- 4-23-4	16328			0.001	0.002														Collected from separator tank.
284	do.	-	do.	do.	16329					0.0	1,588	13,240	-	192	-	-	-	-	-	-	-	-	Do.
285	Kansas City.	-	McLaughlin - 1.	SW 1/4- 8-23-4	18376	0.22	0.001																Collected from well.
286	-	Palmer.	Thompson - 1.	2-24-3																			Cable tool drill cuttings, see Table 9.
287	Mississippian ?	-	Houston.	NE 1/4- 1-25-3	17915					0.0	1,407	110,800	0	0	82	112	280	2,960	64	67,100	199,300	-	Collected from separator tank.
288	-	-	Augustine - 1.	do.																			Cable tool drill cuttings, see Table 9.
289	Viola.	Deep Rock.	Robinson - 1.	3-25-5	18377	1.33	0.000																Collected from well.
289	do.	do.	do.	do.	18342					0.0	-	18,360	-	-	-	-	-	-	-	-	-	-	Do.
290	Arbuckle ?	-	Starkey.	NW 1/4- 5-26-5	16309			0.085	0.000														Collected from separator tank.
290	do.	-	do.	do.	16310			0.004	0.003														Do.
291	-	Colpitt.	Linn - 1A.	do.																			Rotary drill cuttings, see Table 9.
292	-	Magnolia.	Koogler - 71.	SE 1/4-30-26-5																			Cable tool drill cuttings, see Table 9.
293	Kansas City.	-	Klinger.	NW 1/4-24-27-3	18332					0.04	-	122,400	-	-	-	-	-	-	-	-	-	-	Collected from separator tank.
294	Simpson.	-	Klinger - 1.	do.	18367	0.070	0.000																Collected from well.
295	-	-	Taylor - 1.	NE 1/4-17-27-4																			Cable tool drill cuttings, see Table 9.
14	Arbuckle.	Sinclair.	Scully - 29.	NE 1/4- 9-27-4																			Do.
1	Kansas City.	Magnolia ?	Suits - 1.	SW 1/4-10-27-4																			Do.
296	do.	Magnolia.	Suits - 9.	do.																			Do.
297	Arbuckle.	Hammer and McLain.	Bates - 2.	do.																			Do.
22	do.	Aikman and Braden.	So. Anderson - 1.	NW 1/4-15-27-4																			Do.
23	do.	do.	So. Anderson - 2.	do.																			Do.
298	Kansas City.	Cosmic.	Loomis - 10.	15-27-4																			Do.
299	Arbuckle.	Magnolia.	So. Anderson - 9.	NW 1/4-15-27-4																			Do.
300	-	-	Perry - 1.	16-27-4																			Do.
301	-	-	Loomis - 3.	NE 1/4-21-27-4																			Do.
302	-	-	Loomis - 7	do.																			Do.
29	Arbuckle, plugged back to Kansas City.	Magnolia.	Foster - 14.	SE 1/4-21-27-4																			Do.
303	Arbuckle.	do.	Foster - 21.	do.																			Do.
304	-	Blakeslee.	Wilson - 1B.	NE 1/4-28-27-4																			Do.
305	Arbuckle.	Magnolia.	Kramer - 14.	NW 1/4-28-27-4																			Do.

1/ Sample data pertaining to the Augusta Field in Butler County are listed separately in Table 7.

Table 7.--Sample data

Butler County, Kansas--Continued

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Serial number	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	Brines: pH	Remarks
40	Arbuckle.	Magnolia.	Kramer - 17.	SW 1/4-28-27-4																			Cable tool drill cuttings, see Table 9.
306	do.	do.	Kramer - 18.	NW 1/4-28-27-4																			Do.
307	do.	Cities Service.	Scully - 120.	SE 1/4-21-27-4																			Do.
308	-	Richmond and Riegle.	West - ?	SW 1/4-28-27-4																			Do.
309	-	Palmer.	Lychlyter - ?	NW 1/4-11-27-4																			Do.
310	-	Alter and Brackensiek.	Sanford - 1.	SE 1/4-27-27-4																			Do.
311	-	Magnolia.	Palmer - 7A.	NW 1/4-35-27-4																			Do.
70	Arbuckle.	Hammer and McLain.	Moyle - 2.	SW 1/4-35-27-4																			Do.
312	do.	do.	Moyle - 4.	do.																			Do.
72	do.	do.	Ambler - 1.	NW 1/4- 2-28-4																			Do.
73	do.	do.	Ambler - 2.	do.																			Do.
74	do.	do.	Ambler - 3.	do.																			Do.
75	do.	do.	Ambler - 4.	do.																			Do.
76	do.	do.	Ambler - 5.	do.																			Do.
313	Simpson ?	-	Hawks.	NE 1/4-27-28-3	18346					0.0	-	19,530	-	-	-	-	-	-	-	-	-	-	Collected from separator tank.
314	-	-	Darter - ?	SE 1/4- 6-29-4	18426	0.21	0.001																Collected from well.
315	Arbuckle ?	-	Creed.	SW 1/4-17-29-4	17909					0.0	21	124,700	0	10	153	1,897	6,590	3,430	151	67,100	205,500	-	Collected from separator tank.
316	Bartlesville.	Sohio.	Liggett-W-14.	16-26-8																			Core samples, see Table 9.
317	do.	do.	Liggett - 6.	do.	15514	0.002	0.000																Collected from well.
318	Douglas.	do.	Liggett-S-1.	do.	15583	0.001	0.000																Do.
319	Mississippian.	-	Young - 4A.	NW 1/4-27-26-7	18379	0.32	0.000																Do.
320	Arbuckle.	-	Beadles.	SW 1/4- 4-27-6	18378			0.002	0.001														Collected from separator tank.
320	do.	-	do.	do.	18343					0.0	-	20,310	-	-	-	-	-	-	-	-	-	-	Do.
321	Viola.	-	Stern - 1.	NE 1/4-33-27-6	18380	0.002	0.000																Collected from well.
321	do.	-	Patterson.	NW 1/4-34-27-6	18347					0.0	-	19,590	-	-	-	-	-	-	-	-	-	-	Collected from separator tank.
323	do.	-	Ramp.	NW 1/4-23-28-7	18348					0.0	-	68,500	-	-	-	-	-	-	-	-	-	-	Do.
324	Arbuckle.	Harrison.	Bush.	NW 1/4-24-29-5	18451	0.12	0.000																Collected from water flood system, (precipitate from brine before filtering.)
324	do.	do.	do.	do.	17922					0.0	2,248	27,300	-	87	0	74	2,500	582	302	15,060	48,200	-	Collected from water flood system, (brine before filtering.)
324	do.	do.	do.	do.	18366					0.09	-	-	-	-	-	-	-	-	-	-	-	-	Collected from water flood system, (brine residue from filtering.)

Table 8.—Sample data

Marion County, Kansas

Index number	Producing formation or group	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Serial number	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	Mississippian.	-	Cowman.	SW 1/4-11-17-4	18333					0.0	-	31,900	-	-	-	-	-	-	-	-	-	-	Collected from separator tank.
326	do.	-	Bevins - 4.	SE 1/4-21-17-4	18368	0.022	0.000	-	-														Collected from well.
326	do.	-	do.	do.	18334					0.0	-	75,400	-	-	-	-	-	-	-	-	-	-	Do.
327	do.	-	Bevins.	do.	18335					0.0	-	30,500	-	-	-	-	-	-	-	-	-	-	Collected from separator tank.
328	Viola.	Aladdin.	Rempel - 1.	SE 1/4-12-19-2	18369	0.000	0.000	-	-														Collected from well.
329	do.	Sohio.	Rempel.	NE 1/4-13-19-2	18336					0.0	-	18,950	-	-	-	-	-	-	-	-	-	-	Collected from separator tank.
330	Hunton ?	-	Mott.	SE 1/4-10-21-3	18338					0.0	-	19,920	-	-	-	-	-	-	-	-	-	-	Do.
331	-	-	Wenger - 1.	SE 1/4-14-21-3																			Rotary drill cuttings, see Table 9.
332	Viola.	Coop. Ref. Assn.	Reamy - 10.	NE 1/4-20-21-4	18372	0.000	0.000	-	-														Collected from well.
333	Kansas City and Viola.	do.	Reamy.	do.	18371	-	-	0.002	0.001														Collected from separator tank.
333	do.	do.	do.	do.	18337					0.0	-	22,070	-	-	-	-	-	-	-	-	-	-	Do.
334	Viola.	-	Greeley.	NE 1/4-19-21-5	18370	0.013	0.001	-	-														Do.
335	do.	Taylor ?	Joliffe.	SW 1/4- 4-22-4	18374	-	-	0.048	0.001														Do.
335	do.	do.	do.	do.	18339					0.0	-	104,700	-	-	-	-	-	-	-	-	-	-	Do.
336	-	-	Joliffe - ?	do.	18375	0.27	0.001	-	-														Collected from well.
336	-	-	do.	do.	3660	-	-	0.083	0.003														Do.
336	-	-	do.	do.	18340					0.0	-	102,900	-	-	-	-	-	-	-	-	-	-	Do.
337	Mississippian.	Colpitt.	Spier - 1.	NW 1/4- 8-22-4	18373	0.92	0.001	-	-														Do.
337	do.	do.	do.	do.	3662	-	-	0.088	0.003														Do.
337	do.	do.	do.	do.	5803	-	-	0.091	0.001														Do.
337	do.	do.	do.	do.	5804	-	-	0.63	0.000														Do.
337	do.	do.	do.	do.	5805	-	-	0.077	0.001														Do.
337	do.	do.	do.	do.	5793					0.0	-	-	-	-	-	-	-	-	-	-	-	-	Do.
338	-	-	Spier - ?	NE 1/4- 8-22-4	3659	-	-	0.088	0.003														Do.
338	-	-	do.	do.	5807	-	-	0.10	0.000														Do.
339	-	Berry and Bells.	Spier - 1A.	NE 1/4- 8-22-4	5798	-	-	0.001	-														Do.
340	Viola.	do.	Joliffe - 1.	NW 1/4- 9-22-4																			Rotary drill cuttings, see Table 9.
341	-	-	Joliffe ?	do.	3661	-	-	0.103	0.001														Collected from area near separator tank.
341	-	-	do.	do.	3663	-	-	0.059	0.003														Do.
341	-	-	do.	do.	5799	-	-	0.023	-														Do.
341	-	-	do.	do.	5802	-	-	0.20	0.000														Do.
341	-	-	do.	do.	5808	-	-	0.55	0.001														Do.
342	Mississippian.	-	B. Alvin.	NW 1/4-15-22-4	18341					0.0	-	9,380	-	-	-	-	-	-	-	-	-	-	Collected from separator tank.
343	Viola.	Progressive.	Nonken - 1.	34-22-4																			Cable tool drill cuttings, see Table 8.

Table 9.—Drill samples radiometrically analyzed

Southeastern Kansas

Index number	Reference map	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Serial numbers	Range in percent eU3O8	Depth in feet	Remarks
286	Figure 7.	Palmer.	Thompson - 1.	NE-1/4-SW-1/4- 2-24-3	14150 to 14205	0.000 to 0.007	2508 to 2913	1/.
288	do.	Sheldon and Wixon.	Augustine - 1.	NE-1/4-NW-1/4-NE-1/4- 1-25-3	13937 to 13939	0.000 to 0.001	2670 to 2681	1/.
291	do.	Colpitt.	Linn - 1A.	NW-1/4- 5-26-5	18609 to 18977	0.000 to 0.004	605 to 2425	Rotary drill cuttings.
292	do.	Magnolia.	Koogler - 71.	SE-1/4-30-26-5	13507 to 13567	0.000 to 0.002	800 to 1410	Do.
295	do.	Adkins.	Taylor - 1.	NW-1/4-NE-1/4-17-27-4	13728 to 13839	0.001 to 0.006	2350 to 2880	Do.
14	do.	Sinclair.	Scully - 29.	SE-1/4-NE-1/4- 9-27-4	13975 to 13982	0.000 to 0.004	2400 to 2453	1/.
1	do.	Hammer and Maclean.	Suits - 1.	NW-1/4-NW-1/4-SW-1/4-10-27-4	13930 to 13933	0.000 to 0.002	1989 to 2013	1/.
296	do.	Magnolia.	Suits - 9.	NW-1/4-SW-1/4-10-27-4	14007 to 14149	0.000 to 0.005	1015 to 2043	1/.
297	do.	Hammer and Maclean.	Bates - 2.	SW-1/4-SW-1/4-SW-1/4-10-27-4	16330 to 16400	0.000 to 0.005	1989 to 2462	1/.
22	do.	Aikman and Braden.	So. Anderson - 1.	NW-1/4-NW-1/4-NW 1/4-15-27-4	18996 to 19022	0.000 to 0.010	2027 to 2471	1/. Radioactive "vesicular" celestite, magnetite, actinolite, and fluorite are present between depths of 2027 and 2031 feet.
23	do.	do.	So. Anderson - 2.	NE-1/4-NW-1/4-NW-1/4-15-27-4	19023 to 19035	0.000 to 0.002	2058 to 2465	1/.
298	do.	Cosmo.	Loomis - 10.	NW-1/4-SW-1/4-NW-1/4-15-27-4	14493B to 14497B	0.000 to 0.002	2004 to 2035	1/.
344	Plate 6.	Magnolia.	So. Anderson.- 7.	NW-1/4-NW-1/4-NW-1/4-15-27-4	15991	0.030	2529 to 2530	1/. Radioactive "vesicular" limestone, in part replaced by magnetite, containing some celestite, and barite is present between depths of 2529 and 2530 feet.
299	Figure 7.	do.	So. Anderson - 9.	SW-1/4-NW-1/4-NW-1/4-15-27-4	13983 to 14006	0.000 to 0.002	1996 to 2075	1/.
300	do.	Aikman et al.	Perry - 1.	16-27-4	13946 to 13949	0.001 to 0.003	2474 to 2481	1/.
345	Plate 6.	Aikman and Bennetts.	Loomis - 1.	NE-1/4-SE-1/4-16-27-4	13940 to 13945	0.001 to 0.006	2475 to 2481	1/.
301	Figure 7.	Rex and Morris.	Loomis - 3.	C-E-1/2-NE-1/4-21-27-4	13845 to 13914	0.000 to 0.006	1919 to 2345-1/2	1/.
302	do.	do.	Loomis - 7.	SE-1/4-NW-1/4-NE-1/4-21-27-4	21356 to 21654	0.000 to 0.007	30 to 2346-1/2	1/.
29	do.	Magnolia.	Foster - 14.	NW-1/4-NW-1/4-SE-1/4-21-27-4	13568 to 13642	0.000 to 0.008	2387 to 2610	1/. Radioactive "vesicular" mineral containing iron, calcium, strontium, and barium is present between depths of 2413 and 2414 feet.
303	do.	do.	Foster - 21.	C-SW-1/4-SE-1/4-21-27-4	13934 to 13936	0.000 and 0.005	2377 and 2431	Black shale, containing 0.005 percent eU3O8 is present at 2431 feet.
304	do.	Blakeslee et al.	Wilson - 1-1/2	NW-1/4-SW-1/4-NE-1/4-28-27-4	13915 to 13929	0.000 to 0.002	1907 to 1934	1/.
305	do.	Magnolia.	Kramer - 14.	NE-1/4-SE-1/4-NW-1/4-28-27-4	14474 to 14493A	0.001 to 0.006	2245 to 2321	1/.
40	do.	do.	Kramer - 17.	NE-1/4-NE-1/4-SW-1/4-28-27-4	13643 to 13727	0.000 to 0.005	1000 to 1815	1/.
306	do.	do.	Kramer - 18.	NW-1/4-SE-1/4-NW-1/4-28-27-4	13364 to 13506	0.000 to 0.006	1000 to 2335	1/.
307	do.	Cities Service.	Scully - 120.	SE-1/4-21-27-4	13190 to 13363	0.000 to 0.004	820 to 2357	Rotary drill cuttings.
308	do.	Richmond and Riegle.	West - 1.	NE-1/4-NW-1/4-SW-1/4-28-27-4	13951 to 13974	0.000 to 0.007	2008 to 2463	1/.
309	do.	Palmer.	Lyohlyter - ?	SE-1/4-NW-1/4-11-27-4	14658 to 14698	0.000 to 0.006	2650 to 2917	1/.
310	do.	Alter and Brackensiek.	Sanford - 1.	SE-1/4-SE-1/4-SE-1/4-27-27-4	14498 to 14534	0.000 to 0.006	2425 to 2629	1/.
311	do.	Magnolia.	Palmer - 7A.	NW-1/4-35-27-4	13840 to 13844	0.001 to 0.006	2553 to 2590	1/.
70	do.	Hammer and Maclean.	Moyle - 2.	NE-1/4-SW-1/4-SW-1/4-35-27-4	19105 to 19135	0.000 to 0.005	2545 to 2610-1/2	1/.
312	do.	do.	Moyle - 4.	SE-1/4-SW-1/4-SW-1/4-35-27-4	19136 to 19171	0.000 to 0.006	2585 to 2640-1/2	1/.
72	do.	do.	Ambler - 1.	SE-1/4-NE-1/4-NW-1/4- 2-28-4	19036 to 19059	0.000 to 0.005	2127 to 2611	1/.
73	do.	do.	Ambler - 2.	SW-1/4-NE-1/4-NW-1/4- 2-28-4	19060 to 19072	0.002 to 0.006	2565 to 2614	1/.

1/ Radiometric and sample logs of this well are plotted on plate 6.

Table 9.—Drill samples radiometrically analyzed

Southeastern Kansas—Continued

Index number	Reference map	Company	Lease name and well number	Location Sec. -T. S.-R. E.	Serial numbers	Range in percent eU_3O_8	Depth in feet	Remarks
74	Figure 7.	Hammer and Maclean	Ambler - 3.	NE-1/4-SW-1/4-NW-1/4- 2-28-4	19073 to 19088	0.000 to 0.005	2058 to 2617	1/.
75	do.	do.	Ambler - 4.	NW-1/4-NE-1/4-NW-1/4- 2-28-4	19089 to 19100	0.000 to 0.004	2609 to 2620	1/.
76	do.	do.	Ambler - 5.	NE-1/4-NE-1/4-NW-1/4- 2-28-4	19101 to 19104	0.001 to 0.003	2618 to 2625	1/.
316	do.	Sohio.	Liggett - W 14.	16-26-8	15578 to 15582	0.003 to 0.004	2514 to 2530	Core.
277	Figure 6.	Dilworth and Miller.	Dilworth Fee - 1.	NE-1/4- 8-33-7	19174 to 19181	0.002 to 0.003	2665 to 2725	1/.
279	do.	do.	Dilworth Fee - 2.	NE-1/4- 8-33-7	19172 and 19173	0.003	2700 and 2706	1/.
281	do.	Fleet.	-	W-1/2-27-33-6	15586 and 15587	0.002 and 0.004	2904 to 2940	Core.
331	Figure 8.	-	Wenger - 1.	SE-1/4-14-21-3	18456 to 18608	0.001 to 0.004	1800 to 2880	Rotary drill cuttings.
340	do.	Berry and Eells.	Jolliffe - 1.	NW-1/4-NW-1/4- 9-22-4	5795	0.007 mg/l U 2/	2275	Drilling mud.
340	do.	do.	do.	NW-1/4-NW-1/4- 9-22-4	5794	0.004 mg/l U 2/	2365	Do.
340	do.	do.	do.	NW-1/4-NW-1/4- 9-22-4	5791	0.003 mg/l U 2/	2374	Do.
340	do.	do.	do.	NW-1/4-NW-1/4- 9-22-4	5797	0.005 mg/l U 2/	2485	Do.
340	do.	do.	do.	NW-1/4-NW-1/4- 9-22-4	5851 to 5990	0.000 to 0.003	1805 to 2485-1/2	1/. Rotary drill cuttings.
343	do.	Progressive.	Honken - 1.	NW-1/4-NW-1/4-34-22-4	7052 to 7172	0.000 to 0.008	1786 to 2517	1/.
346	Plate 6.	James.	Rimel - 1.	SE-1/4-NW-1/4-SW-1/4-20-27-2	14615B to 14634	0.000 to 0.008	3264 to 3309-1/2	1/. Chalcopyrite and covellite (?) are present between depths of 3287 and 3309-1/2 feet.
347	do.	Fisher and Lauck.	Trustee - 8.	19-27-2	14635 to 14644	0.000 to 0.003	3080 to 3252	1/.
348	do.	Shawver et. al.	Soukup - 1.	NW-1/4-NE-1/4-19-27-2	14645 to 14657	0.001 to 0.005	3248 to 3269	1/.
349	do.	Vickers and Hinkle.	Keys - 3.	SW-1/4-NW-1/4-NE-1/4-30-27-2	14699 to 14722	0.000 to 0.005	3228 to 3334	1/. Quartz sand, granite fragments, and bentonite between depths of 3272 and 3285 feet.
350	do.	Derby.	Rimel - 2.	C-NE-1/4-30-27-2	14589 to 14615A	0.000 to 0.007	3230 to 3420	1/. Garnet, actinolite, magnetite, and chlorite (?) are present at a depth of 3230 feet.
351	do.	Bird and Hanley.	Shipley - 1.	NW-1/4-15-30-12	7781 to 7835	0.000 to 0.007	1032 to 1685	1/. Clintonite, corundophyllite (?), a diopside-hedenbergite mineral, and some orthoclase are present between depths of 1388 and 1671 feet.

1/ Radiometric and sample logs of this well are plotted on plate 6.

2/ Milligrams of uranium per liter.

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 5, and the location of all wells from which samples were collected or field determinations made are shown on plate 5. The map of the Augusta field shows that

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Plate 5. Radioactivity and structure of the Augusta field, Butler County, Kansas.

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most of the wells in which radium-bearing precipitates have formed either are producing from, or have been plugged back from, the Arbuckle dolomite.

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 dolomite 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 the celestite.

Plate 4 is a diagram of the North Augusta field compiled from sample and gamma-ray logs and compares lithology with radioactivity.

Gamma-ray logs number 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 more probable that radioactive celestite has been precipitated on the casing. All of the abnormal deflections are opposite shale beds and this suggests that oxidation of pyrite in the shale, over the 25 to 30 years since the wells were drilled, has resulted in acid solutions that reacted with the iron casing and caused holes to be formed in the casing. This would have permitted the deeper brines to come in contact with the brines 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 in figure 9, which show that a radioactive deposit

Figure 9. Comparison of normal with abnormal radioactivity and correlation of abnormal radioactivity with perforated casing.

between depths of about 2,950 feet and 3,000 feet in the Cramm "E" No. 1 well exactly corresponds 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 Arbuckle and Pennsylvanian brines could intermingle and thus bring about the conditions necessary for the pre-

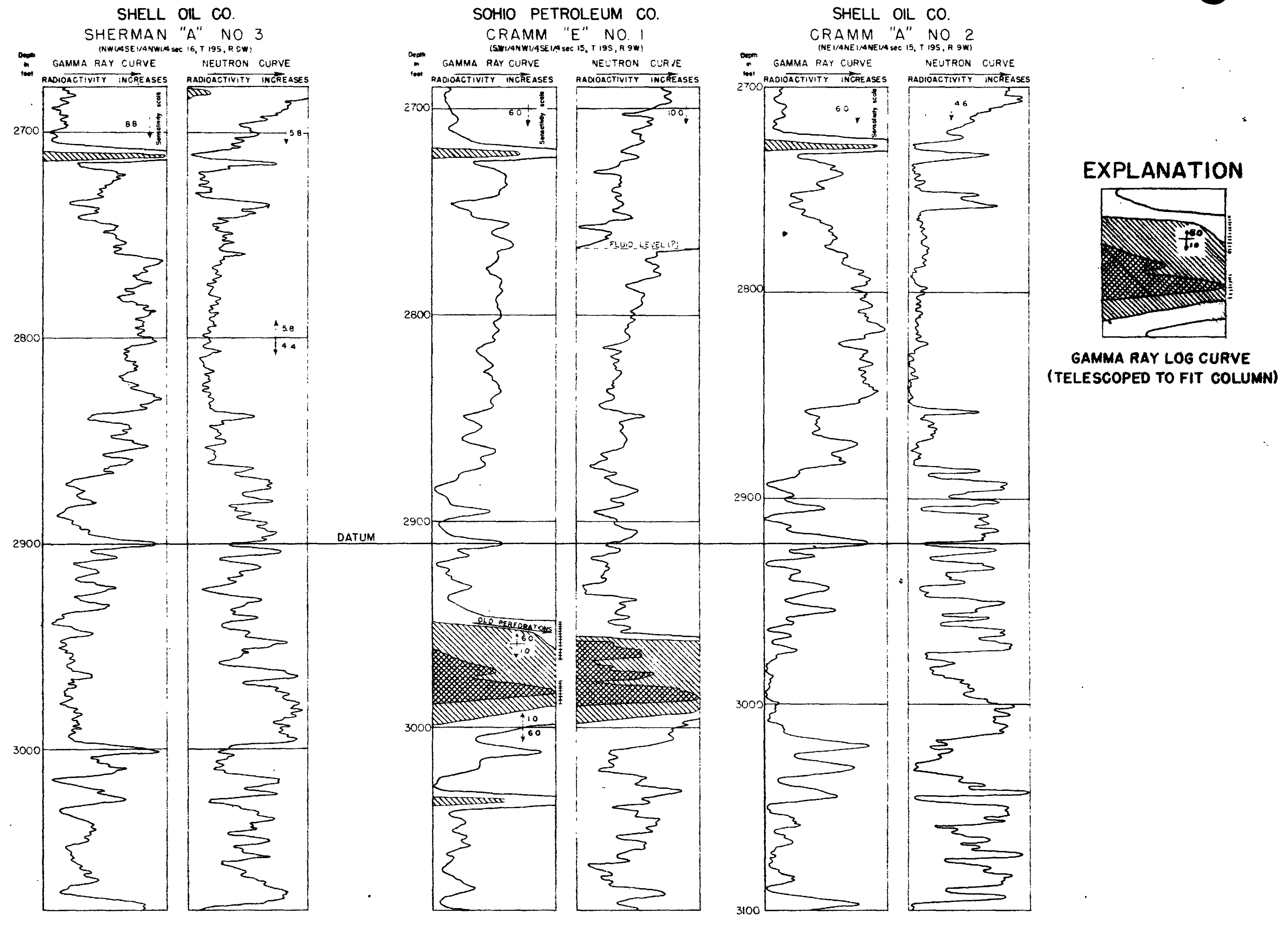

FIGURE 9.-- Comparison of Normal with Abnormal Radioactivity and Correlation of Abnormal Radioactivity with Perforated Casing.

cipitation of celestite. As 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 5, 6, 7, and 8 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 probably is caused by an uneven distribution of uranium in the subsurface rocks. In those samples that have been collected, the range of equivalent uranium oxide is from 0.000 to 10.85 percent. As both the radioactive and nonradioactive precipitates were deposited in similar environments, it is reasonable to assume that radium was not present in the solutions from which the nonradioactive precipitates were deposited. This indicates that the radium was derived from localized sources.

As radium is one of the decay products 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 initial oil production. 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 experi-

mental data _/ indicate that uranium is more soluble in oil than it is in

_/ Petretic, G. J., U. S. Geological Survey, Denver, Colo.: Personal communication.

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 up to 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 _/.

_/ Rogers, G. Sherburne, Helium-bearing natural gas: U. S. Geol. Survey Prof. Paper 121, 1921.

The presence of large volumes of helium, which were not known to be associated with uranium or thorium minerals, has been offered as evidence that the helium is of primary origin. This conclusion was based principally upon the assumption that uranium and thorium deposits large enough 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 satisfactorily explains the presence of large quantities of helium, the following evidence raises grave objections to the idea that all of the helium is from a primary source.

(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 mid-continent 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. As 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 the Amarillo district, 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. The association between radium-bearing precipitates and helium-bearing gas is illustrated on plate 1A.

Plate 1A. Relationship of radioactivity and helium to oil and gas fields in southeastern Kansas.

By a process of elimination, then, it appears that most of the helium in the helium-bearing gases probably is radiogenic. Once it is assumed that the helium is radiogenic, it can also be assumed that the radioactive deposits from which it was derived are of higher grade than is 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

The presence of abnormally high concentrations of radium in precipitates and drill samples from southeastern Kansas, the presence of helium thought to be radiogenic in the oil and gas fields in which radium-bearing precipitates have formed, and the localization of radium concentrates in comparatively small areas, leads to the conclusion that uranium is present in greater-than-normal concentrations in the subsurface rocks. The presence of minerals that probably were formed 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, probably is 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 limestone and in the Arbuckle dolomite, 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, and this leads to the conclusion either 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. This suggests that the leached material was a uranium mineral. The presence of radium, which has a half-life of 1,580 years, precludes the possibility of removal of uranium or the introduction of radium, 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 1100 and 1200 feet below sea level and, 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 over more than a short distance under these conditions.

Examination of gamma-ray logs of oil wells in the southeastern Kansas oil fields has led to the conclusion that the usefulness of these logs, in the search for radioactive materials, is three-fold.

(1) They reflect radioactivity anomalies that are indicative of significant quantities or concentrations of radioactive material.

(2) In places that have been logged adequately, gamma-ray logs provide the best means of delimiting favorable areas in which the possibility of finding radioactive ore deposits is good.

(3) The use of gamma-ray logs provides radioactivity measurements of deposits that have not been affected by surface leaching.