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APPLICATION OF GAMMA-RAY LOGS OF OIL WELLS TO THE DISCOVERY OF RADIOACTIVE ORE

by

Garland B. Gott

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Application of Gamma-Ray Logs of Oil Wells to the Discovery of Radioactive Ore

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Garland B. Gott

Abstract

A study of 1,000 Gamma-Ray logs of oil wells in the central part of the United States has confirmed the utility of these logs for the detection of radioactive deposits. Radiometric analyses of 200 feet of cores from wells that had been gamma-ray logged indicate that one inch of deflection on a Lane-Wells type of gamma-ray log, made at a sensitivity scale of 10 inches, represents approximately 0.0006 percent equivalent uranium. In normal sedimentary rocks the radioactivity is generally uniform so long as the lithologic characteristics are uniform; the limestones and sandstones cause the smallest deflections, and the black shales, the greatest. In one area, non-marine arkosic sediments are considerably more radioactive than the marine sediments. A cross-section of one oil field shows a correlation between abnormally high radioactive zones and some overlying helium-producing formations.

Introduction

Gamma-ray logs, made by raising a radiation detector through a well bore and continuously measuring and recording the intensity of gamma radiation, were first used by the petroleum industry about ten years ago. Since that time several thousand oil wells within

the United States have been logged in this manner. Such logs are used principally to interpret the stratigraphy in the older wells which have been cased and for which adequate stratigraphic data are lacking. Because they show the amount of gamma radiation, their use for detecting radioactive deposits may be equally as important.

As a great number of logs has been made by the oil companies, and many will be made in the future, and as the area already explored by this technique is large, an investigation has been started by the U. S. Geological Survey for the Atomic Energy Commission to determine the value of these logs in the search for radioactive ore deposits. Approximately one thousand gamma-ray logs, principally of wells in Oklahoma and Kansas, have been collected and studied. Representative cores of gamma-ray logged wells have been analyzed, and an approximate calibration for the Lane-Wells type of gamma-ray log has been established. Although, as was expected, most of the information obtained from these logs has been of a negative nature, selection of three areas of abnormally high radioactivity for further study can be directly attributed to this technique of investigation.

Description of illustrations

Figure 1.--As an initial step in this investigation the relative degree of radioactivity represented by a unit deflection on gamma-ray logs was determined by radiometric and chemical analyses of 200 corresponding core samples. From these data it was determined

empirically that one inch of deflection on a Lane-Wells gamma-ray log, made at a sensitivity scale of 10 inches, represents approximately 0.0008 percent of equivalent uranium. Figure 1 shows graphically a comparison between one short segment of a gamma-ray curve and the curve obtained by plotting the radiometric analysis of the corresponding cores. This calibration is only approximate as many complicating factors have not been taken into account. The most important of these are the thickness versus grade of the bed, the fluid content of the well, the shielding effect of the casing in cased wells, differences in individual instruments, and the rate of movement of the ionization chamber although it is generally raised at the same rate of speed in all wells. Nevertheless, for the purpose of delimiting the most favorable areas an approximate calibration is extremely helpful.

The gamma-ray logging equipment most commonly used records differences as low as a few ten-thousandths of a percent equivalent uranium. The lower limit is dependent upon the sensitivity scale at which the well is logged. Such small differences, however, are of little value for a stratigraphic interpretation of the logs except in so far as the gross pattern may be recognizable from one well to another. On the other hand, differences in deflection large enough to permit identification of individual beds are often yielded by different lithologies where the beds in question are as thick as the length of the ionization chamber. The variation in deflection caused by a change in lithology is particularly pronounced between

shales and the other sedimentary rock types. Nevertheless, a fairly reliable interpretation can commonly be made between sandstones, limestones, and dolomites, by using a neutron log in conjunction with a gamma-ray log. This is particularly true if the stratigraphic section is well known.

Any radical increase in radioactivity over that expected in a normal sequence of rocks indicates an abnormal concentration of radioactive elements and is, therefore, of particular interest.

Figure 2.--This stratigraphic section shows the normal variation in radioactivity between black and gray shale, limestone, dolomite, and sandstone. The black carbonaceous shale shown near the top of the section is the Chattanooga shale of Upper Devonian and lower Mississippian age that underlies an area of several hundred thousand square miles in the Central United States. The Chattanooga shale penetrated by this well is estimated, from the gamma-ray log, to contain about 0.008 percent equivalent uranium, the approximate average content of both surface and subsurface samples. The radioactivity of this bed is remarkably uniform over wide areas and, as it causes higher deflections than other beds in this part of the stratigraphic section, it can always be recognized on gamma-ray logs.

The gray shale underlying the black Chattanooga shale is indicated on the gamma-ray log by a much shorter deflection. The underlying limestones, dolomites, and sandstones are in turn represented by much shorter deflections than the shales. The type of deflections

seen on this particular log have been duplicated many hundreds of times.

Figure 3.--In comparison with figure 2 this illustration shows a gamma-ray log of sediments containing more than a normal amount of the radioactive elements. It is of interest to note that the non-marine arkoses caused the highest deflections and the marine beds caused the lowest. The most radioactive arkoses were derived from a nearby Pennsylvanian mountain range composed of granitic rocks, and the percentage of radioactive elements in these granitic rocks, so far as is known, is considerably less than that of the arkoses shown on this log. The inference is, therefore, that the radioactive elements were concentrated in the arkoses either through mechanical processes or by leaching of the radioactive minerals and subsequent movement through the medium of ground water.

As no other gamma-ray logs are available from this area, it is not known whether the radioactivity of the arkoses is consistently above normal, but the presence of helium in the same beds, farther to the west, suggests that it may be.

Figure 4.-- Figure 4 compares normal marine sedimentary rocks consisting of limestone, shale, and sandstone in well No. 1 with equivalent, but radioactive, beds of the same lithology in well No. 2 one-quarter of a mile away. The two logs demonstrate the value of using such data whenever they are available. Without a gamma-ray log of well No. 2 the presence of the highly radioactive zone containing an estimated 0.14 percent equivalent uranium would never have been suspected.

Both of these wells were drilled about 30 years ago before the custom of saving samples was started. Consequently, the cause of the radioactivity cannot be determined from samples. Radium-bearing celestite pipe scale found at the surface, however, suggests that a uranium source may be present in the nearby beds through which the fluids have circulated.

Figure 5.--The cross-section shown on figure 5 is of particular interest because of the abnormally high deflections on the gamma-ray logs and because the same wells that have penetrated radioactive horizons have also produced commercial quantities of helium.

The youngest bed shown on figure 5 is from 1,500 to 2,000 feet below the surface. It will be noted that approximately 1,000 feet below this bed there is a pre-Pennsylvanian faulted and truncated anticline. Movement continued, however, throughout Pennsylvanian time, and it is probable that there was some displacement in the lower Pennsylvanian beds. Because surface elevations of the wells plotted on this cross-section were not available the base of the Douglas shale was selected as a datum plane. Consequently, the present structure is not reflected. The presence of the fault shown on the east side of the anticline has been well established, although its exact location and inclination are not known to the writer. The fault drawn along the west side of the anticline is an interpretation from inadequate subsurface data. The fault plane has, therefore, been shown in a vertical position.

Well No. 4 is actually much closer to the western fault than it is to the eastern one. However, in order to get all the information in a small space, the horizontal scale has been distorted. It is possible that the high radioactive zones represented on the gamma-ray logs conform to a fault plane of small displacement or to a fractured zone above a fault plane.

The equivalent uranium content of the radioactive horizons, estimated from the gamma-ray logs, ranges from about 0.05 percent in well No. 3 to 0.2 percent in well No. 1. Appreciable quantities of radium-bearing celestite ($SrSO_4$) pipe coating has formed on the inner surface of the pipes through which the oil and water flow after they are pumped from the wells. This coating contains as much as 1.5 percent equivalent uranium, mostly in the form of radium. Oil and water samples taken from these pipes contained a uranium content ranging up to 0.7 part per million. Abnormally high radioactivity has been found over an area approximately 35 by 100 miles in extent, but the maximum extent has not been determined. So much radium scattered over such a large area may indicate the presence of a very significant quantity of uranium.

Vertical bars are plotted through the position of the beds that have produced helium; however, another helium-producing formation is 800 feet higher than the top of this section. Although in well No. 3 the radioactive zone corresponds to the helium-producing beds, the radioactive beds usually underlie the helium-producing formations.

Conclusions

One company alone has made gamma-ray logs of oil wells at the rate of about 2,000 per year over large areas within the Mid-continent, Gulf Coast, Rocky Mountain, and Pacific Coast regions. As they show positive anomalies, the more promising areas are set apart from the thousands of square miles of barren rocks. Several of these logs have pointed the way toward areas of abnormally radioactive rocks where there is reason to hope that uranium ore deposits will be found.

Results obtained from the study of 1,000 gamma-ray logs distributed through two states indicate that these logs are a useful means of determining semi-quantitatively the amount of radioactivity in subsurface rocks and indicate as well that they should be used whenever they are available for regional reconnaissance investigations of radioactive deposits.

COMPARISON OF GAMMA-RAY LOG WITH RADIOMETRIC ANALYSES

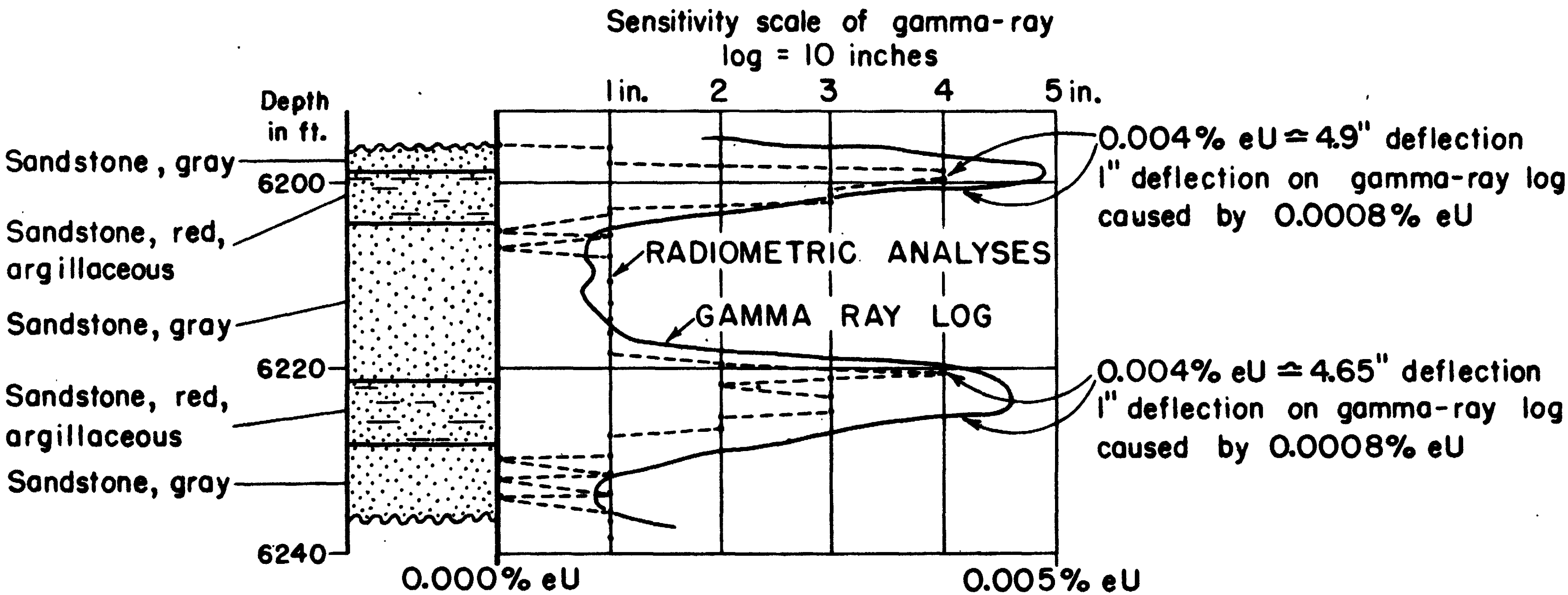
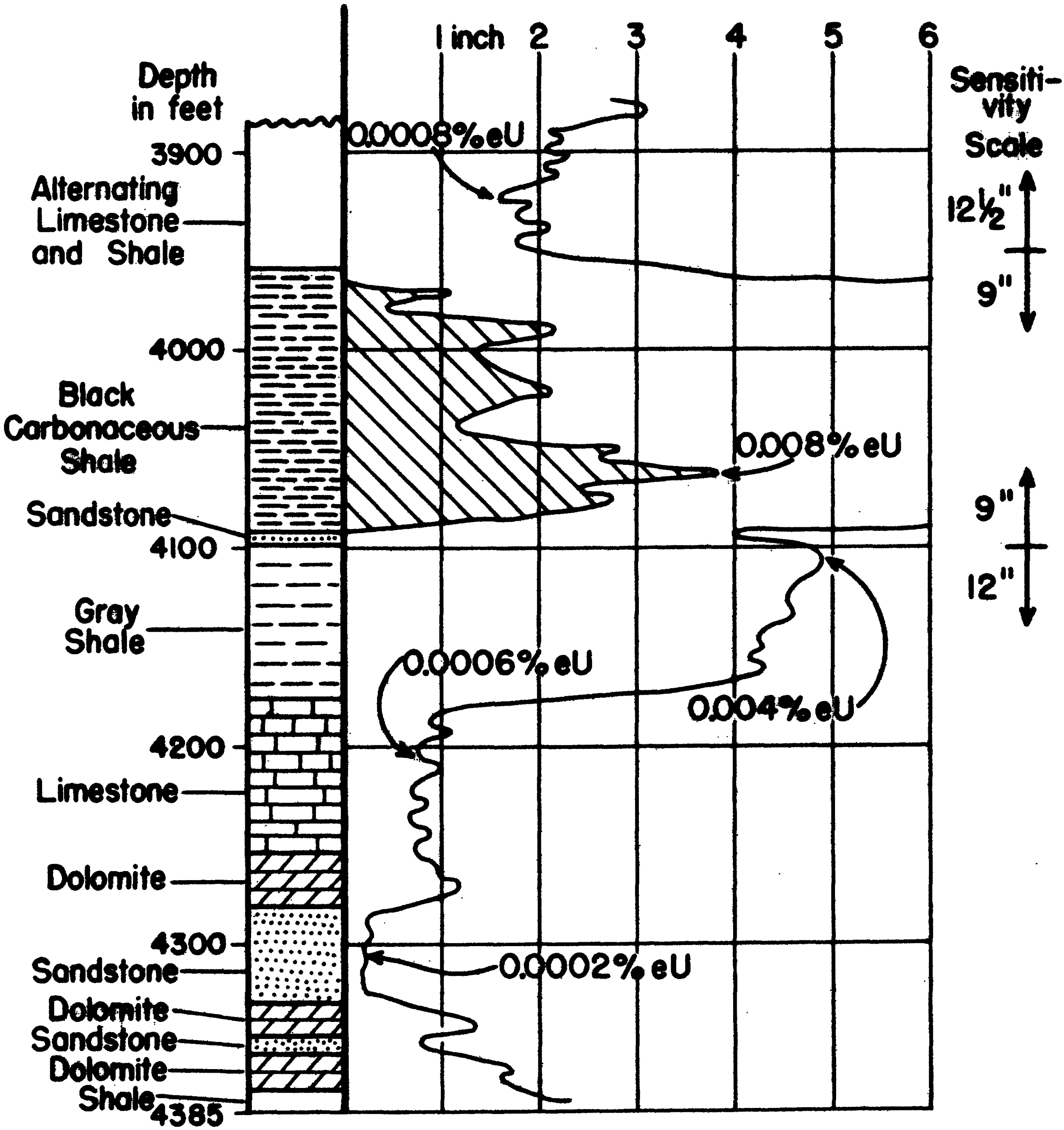


Figure 1

A COMPARISON OF RADIOACTIVITY CAUSED BY DIFFERENT ROCK TYPES

SOUTH CENTRAL OKLAHOMA

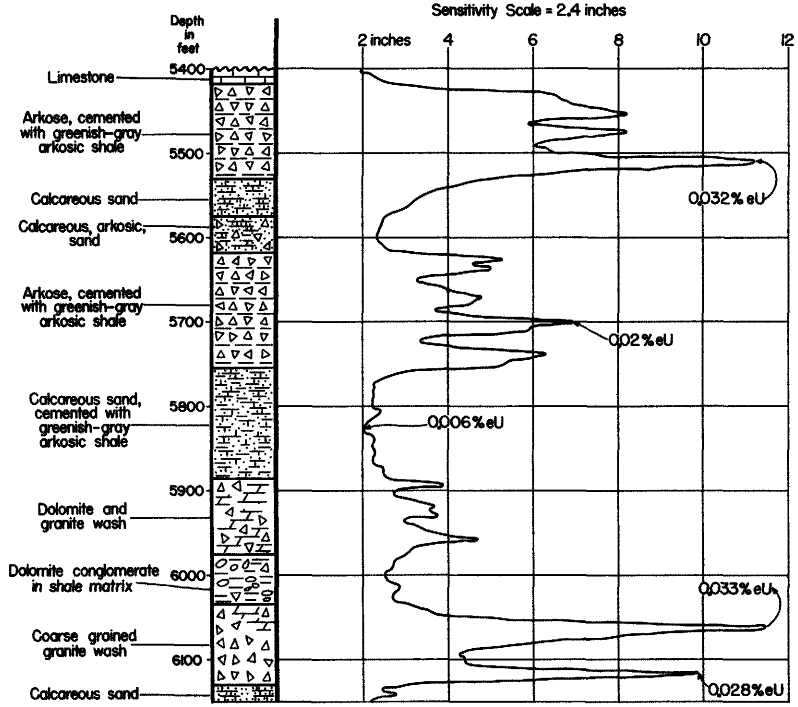


MID-CONTINENT—SMITH NO. 3

Figure 2

RADIOACTIVITY OF NON-MARINE ARKOSES AND MARINE SEDIMENTS

SOUTHWESTERN OKLAHOMA



GULF OIL CORP.—DURLAND NO. 1 WELL

Figure 3

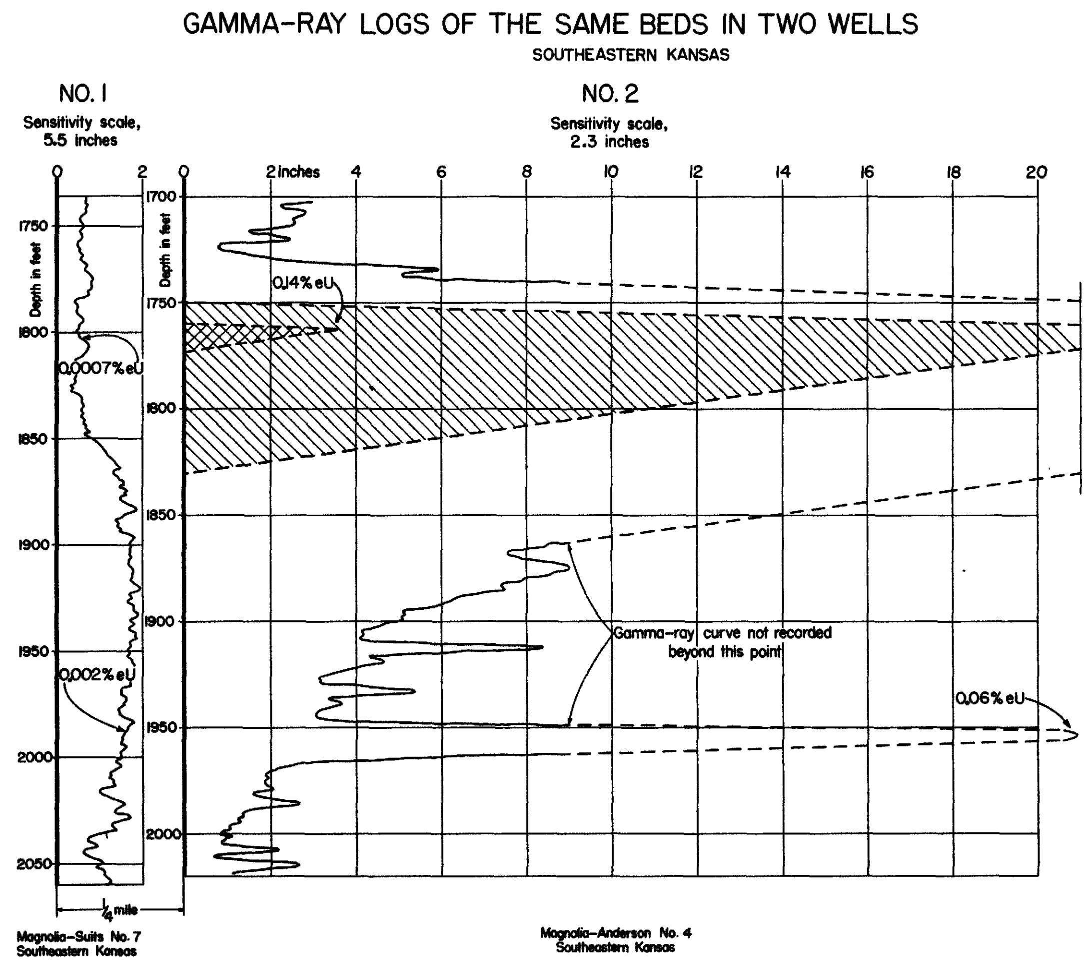

GAMMA-RAY LOGS OF THE SAME BEDS IN TWO WELLS
SOUTHEASTERN KANSAS
NO. 1
Sensitivity scale, 5.5 inches
NO. 2
Sensitivity scale, 2.3 inches
0 2 4 6 8 10 12 14 16 18 20
2 inches
Depth in feet
1700 1750 1800 1850 1900 1950 2000 2050
0.14% eU
0.0007% eU
0.002% eU
0.06% eU
Gamma-ray curve not recorded beyond this point
1/4 mile
Magnolia-Suits No. 7
Southeastern Kansas
Magnolia-Anderson No. 4
Southeastern Kansas

Figure 4

GENERALIZED RELATIONSHIP OF RADIOACTIVITY TO HELIUM, LITHOLOGY, AND PRE-PENNSYLVANIAN STRUCTURE.

NORTH AUGUSTA FIELD, KANSAS

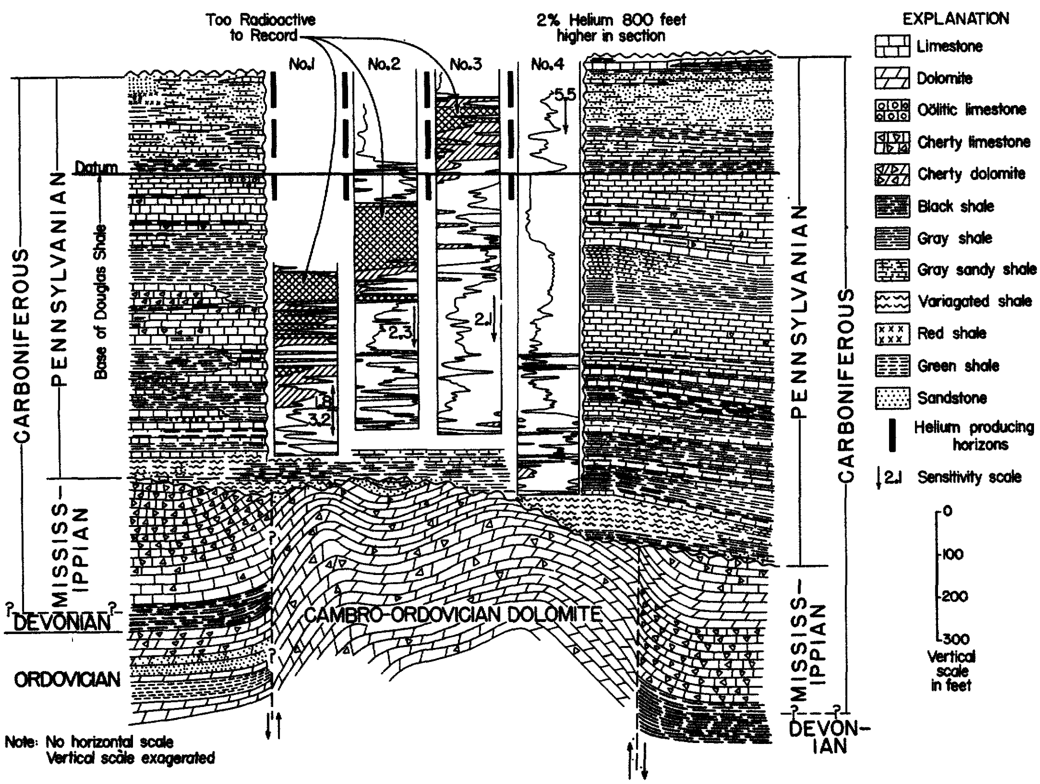


Figure 5