July 13, 1943. L. HORVITZ ET AL 2,324,085

GEOCHEMICAL WELL LOGGING

Filed Dec. 21, 1939 3 Sheets-Sheet 1

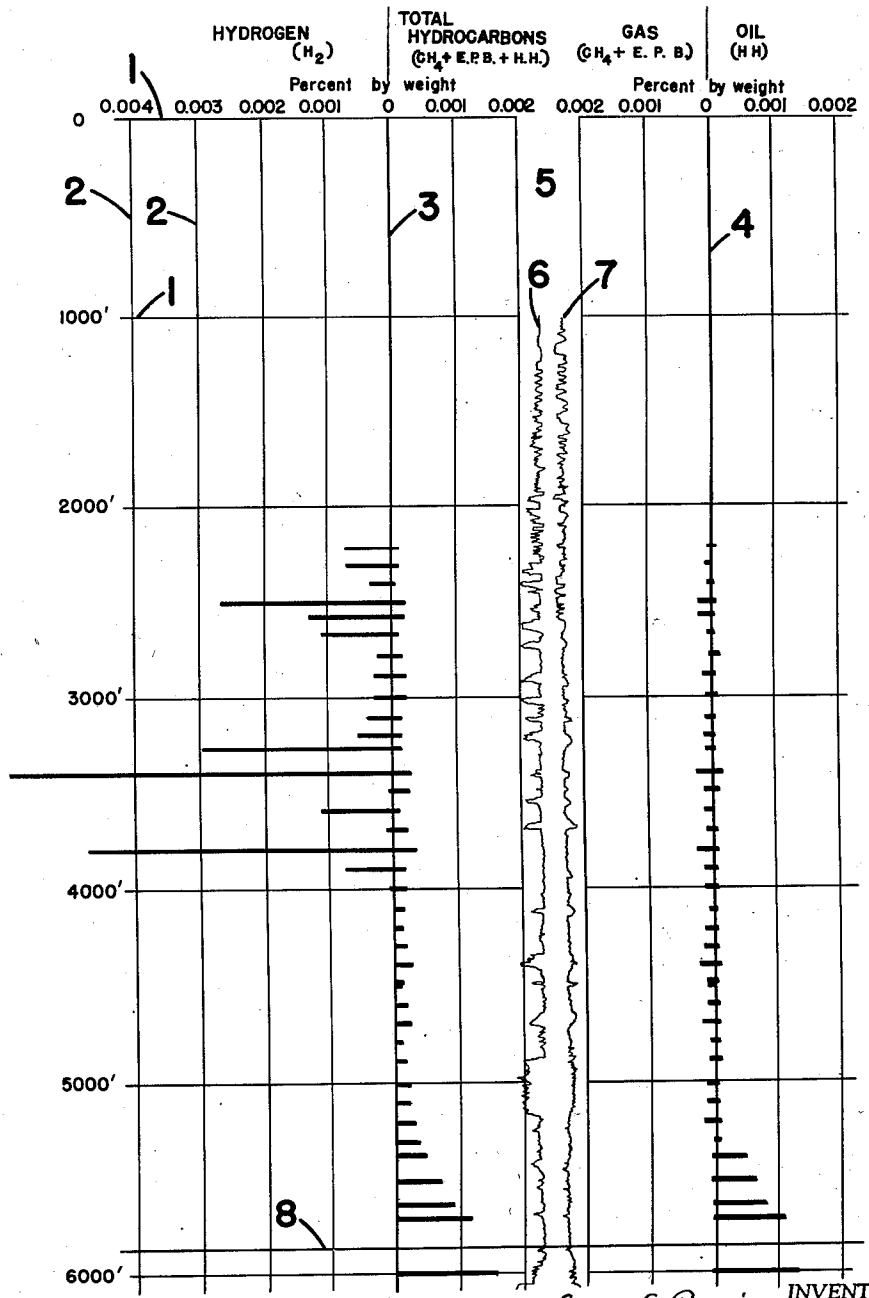


FIG. 1.

Esme E. Rosaire
Leo Horvitz
INVENTOR.

BY G. L. Young
ATTORNEY.

July 13, 1943. L. HORVITZ ET AL 2,324,085

GEOCHEMICAL WELL LOGGING

Filed Dec. 21, 1939 3 Sheets-Sheet 2

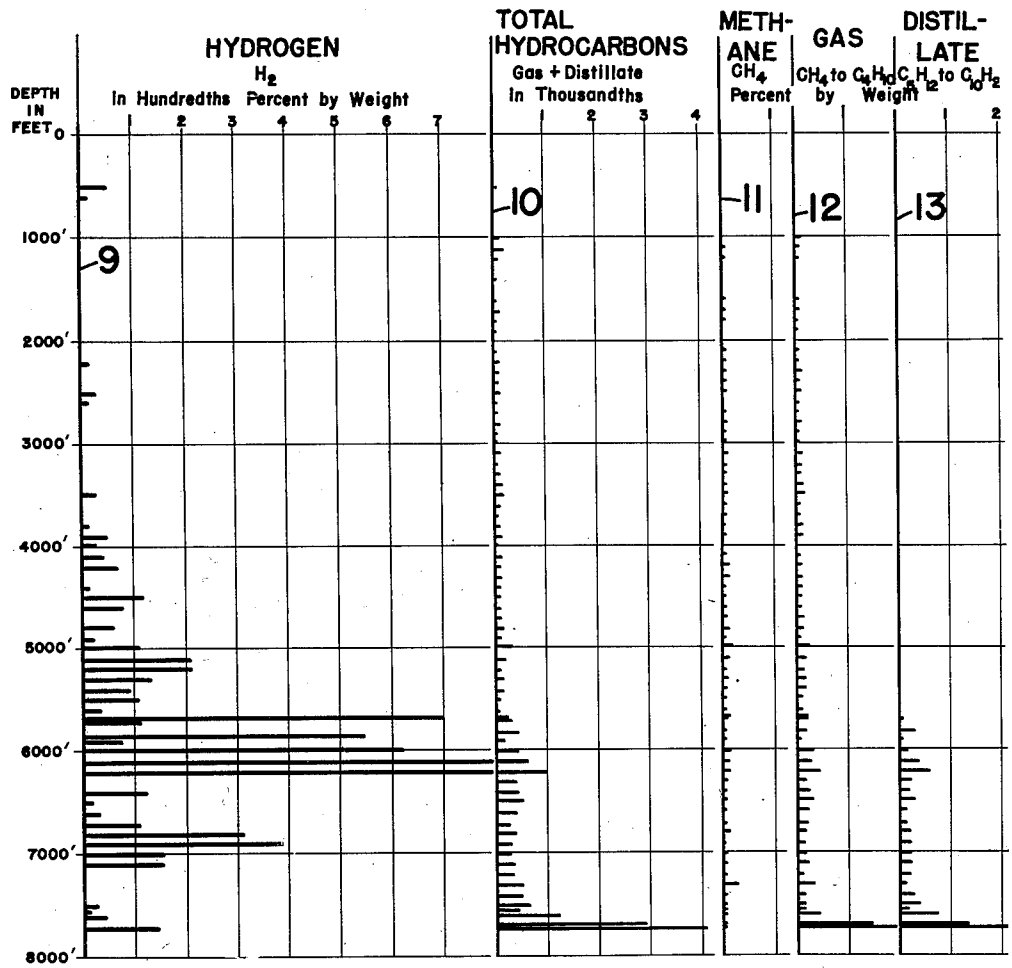


FIG. 2.

Esme E. Rosaire INVENTOR.
Leo Horvitz
BY
G. L. Yaun ATTORNEY.

July 13, 1943. L. HORVITZ ET AL 2,324,085

GEOCHEMICAL WELL LOGGING

Filed Dec. 21, 1939 3 Sheets-Sheet 3

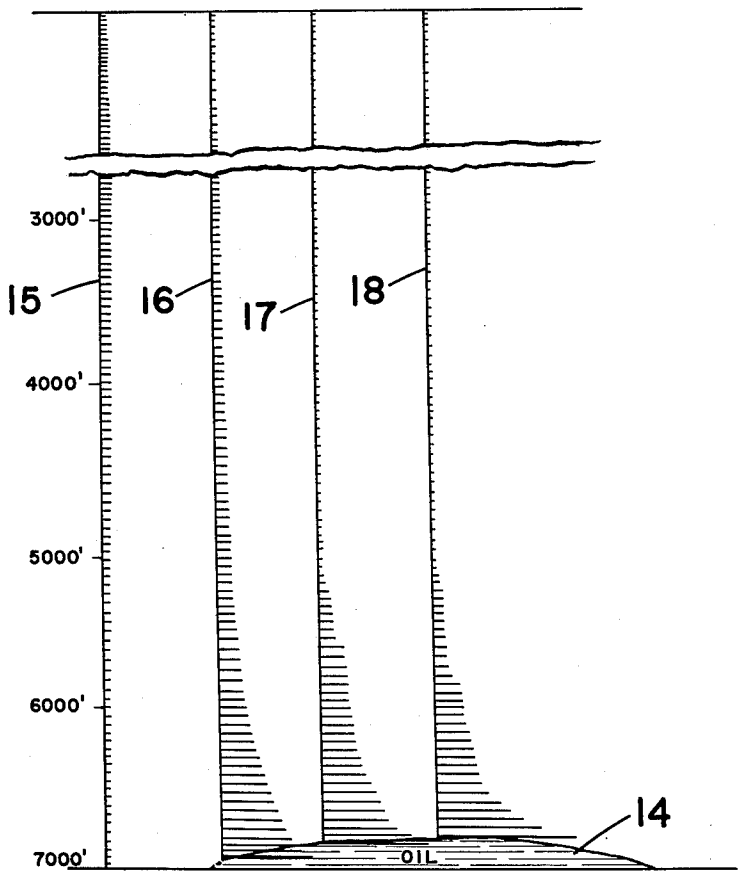


FIG. 3.

Esme E. Rosaire INVENTOR.
Leo Horvitz

BY

G. L. Young ATTORNEY.

Patented July 13, 1943 2,324,085

UNITED STATES PATENT OFFICE

2,324,085

GEOCHEMICAL WELL LOGGING

Leo Horvitz and Esme E. Rosaire, Houston, Tex.;
said Horvitz assignor to said Rosaire

Application December 21, 1939, Serial No. 310,358

16 Claims. (Cl. 23—232)

The present invention is directed to a method of logging wells for the purpose of charting progress and predicting the existence of oil and gas bearing formations before they are encountered by the drill bit.

The desirability of determining the nature of substrata traversed by a drill bit has long been recognized and a multitude of methods have been developed for achieving this end. First came the electrical methods which distinguish strata by electrical conductivity. These methods have serious limitations in that they do not yield reliable logs for discovery purposes. That is to say, water bearing sands and oil bearing sands appear so nearly alike in electrical logs in so many instances that without a knowledge of the subsurface geology the interpreter would be confounded. Furthermore, such logs yield information only with respect to strata which have been traversed and give the driller no information whatsoever as to the advisability of continuing with the drilling operation.

The object of the present invention is the provision of a well logging method which will enable the driller to ascertain that he is approaching an oil or gas producing formation considerably before he reaches it as well as to identify it when it is reached. The practical value of this method is incalculable. Primarily, it enables the driller of a well to decide whether or not drilling should be continued at any given point in its progress. The history of the art has shown that many discovery wells have been abandoned before production was reached because the driller, on the basis of geological information, arrived at the conclusion that oil had to be struck within a certain depth if it was to be found at all. Furthermore, in the development of an oil field the method of the present invention gives information indicating the proximity of a well to the edge of a field and will result in abandonment of the practice of drilling expensive dry holes in order to establish the edge of production. In addition, the method of the present invention yields information concerning the kind of production that can be expected from a producing formation before it is actually reached. That is, it will indicate whether the formation will yield mainly oil or mainly gas.

Further objects and advantages of the present invention will appear from the following detailed description of the accompanying drawings in which

Fig. 1 is a chart showing a well log prepared from evolved hydrogen content, total hydrocarbon content, content of hydrocarbons having 1 to 4 carbon atoms and the content of hydrocarbons having 5 to 10 carbon atoms of samples obtained at selected depths in a bore hole, and also showing an electrical well log of the bore hole;

Fig. 2 is a chart showing a chemical well log based on evolved hydrogen content, total hydrocarbon content, methane content, content of hydrocarbons having 1 to 4 carbon atoms and of hydrocarbons having 5 to 10 carbon atoms of samples taken at selected depths; and

Fig. 3 is a chart showing a plurality of chemical well logs taken in bore holes drilled across a producing structure indicating the manner in which hydrocarbon content varies with the position of the bore hole laterally with respect to the structure.

Referring to Fig. 1 in detail, the chart is made up of horizontal lines 1 indicating depth and vertical lines 2 indicating percent by weight. Numeral 3 designates a zero line to the left of which is indicated hydrogen content of samples at the depths indicated and to the right of which is indicated total hydrocarbon content of the samples at the depths indicated. Numeral 4 designates another zero line to the left of which is indicated the hydrocarbons having from 1 to 4 carbon atoms contained in the samples at the depths indicated, and to the right of which is indicated the hydrocarbons having 5 or more carbon atoms contained in the samples taken at the depths indicated. In the electrical log which occupies the space indicated by numeral 5, the left hand line 6 designates resistivity measurements correlated with depth, and the line designated by numeral 7 indicates potential measurements correlated with depth.

It will be seen that the hydrogen content of samples taken at successive depths became significant at a depth below two thousand feet and reached a maximum at a depth between three and four thousand feet, dropping off to zero above four thousand feet. The hydrocarbon content of the samples was appreciable at starting depth and remained substantially constant to a depth of five thousand feet and then continuously increased to six thousand feet. In this particular case, the upper side of the producing horizon is indicated by the line 8 at 5941 feet. By reason of the fact that the hydrogen reached a maximum and then decreased to zero, the driller could recognize that he was approaching a producing horizon. At just below five thousand feet, when a distinct rise in hydrocarbon content became noticeable and persisted in successive samples, the operator then knew with certainty that he was not far from a producing horizon. A reference to the electrical well log shows that at a depth of about five thousand two hundred feet and from there to the producing horizon, there was no indication given that there was any producing horizon below. As a matter of fact, the electrical log could not have been produced

until after the drilling was completed. This demonstates the vital difference between the well logging method of the present invention and the well known electrical well logging method.

In addition to indicating to the driller that he was approaching a producing formation, the well log also indicated to him that the formation would mainly produce oil. This appears from the gas oil ratio shown on either side of line 4. As can be seen, the gas-oil ratio was high until a depth just below five thousand feet was reached when it abruptly changed to a high oil-gas ratio. Thus, the driller was not only acquainted with the fact that continuous drilling would lead to a productive sand, but he was also given a clear idea as to what sort of production he could expect from the sand. In this particular instance the driller did not have to take precautions that would be dictated by his approach to a sand having an extremely high gas-oil ratio. If the sand he was approaching were of such a character, the gas-oil ratio shown in line 4 would increase as the formation was approached and he would be given timely warning so that he could take the necessary precaution, such as adjustment of the weight of his drilling mud and the like, to avoid a blowout.

Before proceeding to a discussion of Fig. 2 it is deemed advisable to offer a general discussion of the methods employed in procuring samples for well logging purposes and analyzing them. The samples employed for this purpose may be obtained in a number of ways. For example, they may be obtained by coring in the known manner, either longitudinally or from the side wall of the bore hole. For speed in operation, however, it is desirable to take cuttings from the drill bit as samples. These cuttings, when the rate of drilling is taken into consideration, can be correlated with depth in the bore hole. A convenient method for correlating cuttings with depth is described at pages 107 et seq. of Bulletin No. 201 of the Bureau of Mines, entitled Prospecting and Testing for Oil and Gas, by R. E. Collom, published in 1922. The use of cuttings offers the additional advantage that continuous sampling is thereby made possible. Furthermore, by using cuttings it is possible to take average samples covering any desired length of the bore hole. For example, cuttings taken during the drilling of ten feet can be formed into a composite sample, and in this manner changes in the contents of the subsoil can be more accurately located with respect to depth. A desirable procedure is to take composite cuttings of samples for about fifty feet of drilling made up of 25 feet of drilling from which cuttings went into a previous composite sample and 25 feet of new drilling. By overlapping the composite samples in this manner, it is possible to judge more accurately the changes in concentration of the constituent sought for with depth.

In treating the samples recovered for analyses according to the present invention, each sample may be weighed and then subjected to suction and moderate heat for the recovery therefrom of a gas which is analyzed for hydrocarbons, especially those heavier than methane, or hydrogen or carbon monoxide, or any other significant constituent, the analysis being conducted in the manner described in copending application Serial No. 183,960, filed January 8, 1938. The preferred method of handling the samples is to place them in a container connected with a gas receiver and to treat them with a chemical, such as a mineral acid or an organic acid capable of decomposing carbonates. This treatment results in the evolution of gases which, after being treated for the removal of carbon dioxide, are analyzed for the quantitative determination therein of significant hydrocarbons. During this analysis the total hydrocarbons may be determined as well as the separate fractions thereof, such as the normally liquid fractions and the normally gaseous fractions. Methane can be determined individually as well as together with other gaseous hydrocarbons. Ordinarily, the amount of hydrocarbons found is expressed in terms of unit weight of sample.

In the case of samples which have been in storage for a considerable length of time, they are usually available in the form of dried material, the drying having been resorted to in order to preserve them for paleontological purposes. Generally, the acid treatment is necessary in such cases. When samples are to be kept in storage for a few weeks, or even several days, before the analysis, it is deemed desirable to dry them for purposes of preservation and then to utilize a treatment to decompose the carbonates and release the occluded constituents.

Referring to Fig. 2, the vertical axes represent depth and the horizontal axes represent percent by weight of constituent. Vertical axis number 9 is the zero line for hydrogen content, which is plotted to the right of this line. The numbers over the vertical lines to the right of line 9 designate hundredths of a percent by weight of the sample. Vertical line 10 is the zero line for total hydrocarbons, the content of which is plotted to the right of this line. The numbers at the top of the vertical lines in this log designate thousandths of a percent by weight of a sample. The same is true of the numbers above the vertical lines of the logs to the right of vertical axes 11, 12 and 13 which, respectively, are the vertical axes for methane content, C_1–C_4 hydrocarbon content and C_5–C_{10} hydrocarbon content.

In preparing the log shown in Fig. 2, the samples collected were cuttings. These cuttings were collected for approximately every ninety feet of drilling and used to make a composite sample. These samples were washed free of drilling mud and were taken to the laboratory. Here a water determination was made on one portion of the sample so as to determine the dry weight of the sample. Another portion of the sample was then subjected to treatment for the recovery therefrom of a gas sample which was analyzed for hydrogen and hydrocarbons.

The hydrogen did not begin to appear consistently in the samples until a depth of about 3800 feet was reached. From this point on it increased steadily to a maximum at about 6200 feet. It then dropped off consistently to a low value at production depth, which was 7736 feet. This log indicates that the well was an edge well which in fact it was.

The log having zero line 10 recording total hydrocarbons began to show appreciable amounts of hydrocarbons at 1000 feet, this amount remaining substantially constant until a depth of about 5700 feet was reached at which point it began to increase to a first maximum at about 6200 feet. This increase indicated an oil deposit, but it was possible to predict in advance that it would not be a producing well at this point because of the high hydrogen found at this level. Such was actually the case. This indication

would lead one to believe that at another location laterally the sand indicated at 6200 feet might be a producer. Below 6200 feet the hydrocarbon concentration again dropped. Its new level, however, was greater than the normal level above 5800 feet indicating that a deposit of greater consequence than that at 6200 feet was being approached. A gradual increase in the hydrocarbon content of the samples began at about 7000 feet and continued to a maximum at the producing level at 7736 feet. Before the producing level was reached, however, the continuous increase in the hydrocarbon content together with the dropping of the hydrogen content of the samples constituted clear evidence that a producing sand was being approached. In this connection it is important to note that below the 6200 feet level the hydrogen content dropped off to a low and came back to a new peak at 6800 feet, and then dropped off again, the new peak offering concrete evidence of an approaching producing horizon. Here again, it may be noted that the fact that the hydrocarbons were not present in greater quantities at higher levels above the producing horizon indicates that the well was being drilled along the edge of the producing horizon.

As previously indicated, the gas samples were also examined for methane content as well as for C_1–C_4 hydrocarbons and C_5–C_{10} hydrocarbons. The methane content was negligible as indicated in the log having zero line 11. The hydrocarbon content at depths at which it began to increase was divided almost equally between C_1–C_4 hydrocarbons and C_5–C_{10} hydrocarbons with the latter predominating as the producing horizon was approached. This indicated that the producing formation would yield considerable amounts of liquid hydrocarbons, and this information was available from the logs at a distance of more than 1000 feet above the producing horizon.

Repeated logs of the type shown in Fig. 2 on bore holes arranged across a producing horizon made possible the development of a picture of the type of logs that can be expected from bore holes depending upon their lateral position with respect to the producing horizon. This picture is shown in Fig. 3 which is a vertical section through the earth including an oil deposit 14. Vertical line 15 indicates a log of a well about a half mile from the edge of deposit 14. This line carries depth marks which are applicable to the other logs shown. The horizontal marks on the line indicate hydrocarbon content of samples at depths indicated, these contents being expressed in percent by weight of the sample. The scale employed is two thousandths of a percent by weight per inch.

Vertical line 16 is the zero axis of the log of a well at the edge of the deposit 14. Vertical lines 17 and 18 are logs of wells in the locations shown.

From these logs it can be seen that off the deposit and at some distance therefrom some hydrocarbon shows can be found in bore hole samples. The quantities found, however, are usually small, decreasing with the lateral distance of the well from the deposit. In the particular case shown, well 15 is in the "halo" region, showing greater concentrations of hydrocarbons at the surface than wells over the deposit.

Values of hydrocarbons found in an edge well tend to increase gradually with depth from whatever values were found at the surface. Nearer the center of production, near surface hydrocarbon values tend to be lower than in wells located at the edge or just outside production, and the low value tends to persist to considerable depth before any increase is noted. Then, instead of a gradual increase, the hydrocarbons appear to increase in a step or a series of steps. The first step of increase occurs at greater depth as the center of production is approached, and the step becomes more abrupt.

In general, it may be said that for wells closer to the center than to the edge of the deposit, the increase in hydrocarbon content of bore hole samples begins to appear several hundred feet above the producing horizon.

In the foregoing description, analyses for hydrocarbons and hydrogen have been generally discussed. It will be understood that the present invention contemplates the analysis of the bore hole samples for any constituents, the concentration of which varies with depth in a manner significant of the presence or absence of a subterranean deposit of carboniferous material. As previously indicated, logs showing hydrocarbon and hydrogen concentrations are of great value in predicting the final outcome of a drilling operation. A more complete picture can be secured by analyzing the bore hole samples for inorganic constituents as well as for gaseous constituents.

This application is a continuation in part of applications Serial Nos. 107,497, filed October 24, 1936, and 296,556, filed September 26, 1939, now Patent 2,192,525.

The nature and objects of the present invention having been thus described and illustrated, what is claimed as new and useful and is desired to be secured by Letters Patent is:

1. A method for logging a bore hole drilled for the production of petroleum which comprises securing samples of earth at selected points along the bore hole for a considerable portion of its length including a substantial portion traversing non-petroleum producing formations, quantitatively analyzing each sample for its content of at least one constituent significant of the proximity of a petroleum deposit, the constituent determined being the same for all the samples and being one which is normally present in most of the formations traversed in minor amounts and which may be normally foreign to some of the formations traversed, and correlating with depth the concentrations of the constituent so determined.

2. A method for logging a bore hole drilled for the production of petroleum which comprises securing samples of earth at spaced points along the bore hole for a considerable portion of its length including a substantial portion traversing non-productive formations, subjecting each sample to a treatment suitable for the recovery therefrom of a hydrocarbon gas, quantitatively analyzing the gas so recovered from each sample for its content of at least one selected hydrocarbon which is the same for all the samples, and correlating the contents so determined with sample depth.

3. A method for logging a bore hole drilled for the production of petroleum which comprises periodically collecting cuttings from the bore hole along a considerable portion of the length thereof including a substantial portion traversing non-productive formations in such a way that the cuttings may be associated with bore hole depth, quantitatively analyzing the cuttings so obtained for their content of at least one constituent significant of the proximity of a petroleum deposit, the constituent determined being the same for all

cuttings, and being one which is normally present in most of the formations traversed in minor amounts and which may be normally foreign to some of the formations traversed, and correlating with depth the concentrations of the constituent so determined.

4. A method for logging a bore hole drilled for the production of petroleum which comprises collecting cuttings from the bore hole over a given period of drilling, whereby the cuttings represent a selected length of bore hole, preparing a composite sample from said cuttings, quantitatively analyzing said sample for its content of at least one constituent significant of the proximity of a petroleum deposit, said constituent being one which is normally present in most of the formations traversed in minor amounts and which may be normally foreign to some of the formations traversed, correlating with depth the concentration of the constituent so determined, and repeating said operations for successive periods of drilling.

5. A method for logging a bore hole drilled for the production of petroleum which comprises securing samples of earth at spaced points along the bore hole for a considerable portion of its length including a substantial portion traversing non-productive formations, subjecting selected samples individually to a treatment suitable for the recovery therefrom of a gas sample, said treatment being capable of disintegrating any water insoluble carbonates contained in the sample to thereby release from said carbonates any gas entrapped therein, quantitatively analyzing the gas sample so obtained for its content of at least one constituent significant of the proximity of a petroleum deposit, the constituent determined being the same for all the samples and being one which is normally present in most of the formations traversed in minor amounts and which may normally be foreign to some of the formations traversed, and correlating with depth the concentrations of the constituent so determined.

6. A method according to claim 5 in which the gaseous constituent determined is a hydrocarbon heavier than methane.

7. A method according to claim 5 in which the treatment of the sample includes the addition thereto of an acid capable of dissociating water insoluble carbonates to thereby release from said carbonates any gas entrapped therein.

8. A method for logging a bore hole drilled for the production of petroleum which comprises securing samples of earth at selected points along the bore hole for a considerable portion of its length including a substantial portion traversing non-productive formations, treating each sample for the liberation therefrom of a gas containing hydrocarbons, quantitatively determining the concentration in said gas of at least one hydrocarbon per unit weight of sample, the hydrocarbon determined being the same for all the samples, and correlating the concentrations so determined with sample depth.

9. A method according to claim 8 in which the hydrocarbon determined is one heavier than methane.

10. A method for logging a bore hole drilled for the production of petroleum which comprises securing samples of earth at spaced points along the bore hole for a considerable portion of its length including a substantial portion traversing non-productive formations, subjecting each sample to a treatment suitable for the liberation therefrom of hydrocarbons contained therein, quantitatively determining for each unit weight of each sample its content of normally gaseous hydrocarbons and its content of normally liquid hydrocarbons, and correlating these values individually with depth of sample.

11. A method for logging a bore hole drilled for the production of petroleum which comprises securing samples of soil at spaced points along the bore hole for a considerable portion of its length including a substantial portion traversing non-productive formations, subjecting each sample to a treatment suitable for the liberation therefrom of gaseous constituents, quantitatively analyzing the liberated gases for hydrocarbons and free hydrogen, and correlating the values so obtained with sample depth.

12. A method for logging a bore hole drilled for the production of petroleum which comprises systematically identifying cuttings resulting from the drilling operation for a considerable portion of the length of said bore hole, including a substantial portion traversing non-productive formations, with drilling depth, quantitatively determining the hydrocarbon content of said cuttings, and correlating with the depth of said cuttings the hydrocarbon contents so determined.

13. A method for logging a bore hole drilled for the purpose of producing hydrocarbons comprising the steps of quantitatively determining, for a considerable section of the length of the bore hole, including a substantial portion traversing non-productive formations, the variation of the hydrocarbon content of the earth along said section with depth during the drilling operation, and correlating with depth the variations of the hydrocarbon content so determined.

14. A method for logging a bore hole drilled for the production of petroleum which comprises collecting cuttings from spaced points along the bore hole for a considerable portion of its length including a substantial portion traversing non-productive formations during the drilling operation, subjecting cuttings from each point to analysis for the quantitative determination therein of a plurality of constituents significant of the proximity of a petroleum deposit, at least one of said constituents being a hydrocarbon, and the constituents determined being the same for all cuttings and including those which are normally present in most of the formations traversed in minor amounts and which may be normally foreign to some of the formations traversed, and correlating with depth the concentrations of the constituents so determined.

15. A method according to claim 14 in which the analyses include separate determinations of the normally gaseous and normally liquid hydrocarbon constituents of the cuttings.

16. A method for logging during the drilling of a borehole drilled for the purpose of producing hydrocarbons comprising the steps of determining for a considerable portion of the length of the borehole, including a substantial portion traversing non-productive formations, the relative hydrocarbon content at different depths of the earth traversed by the borehole, and correlating said relative values with depths.

LEO HORVITZ.
ESME E. ROSAIRE.