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SOIL GAS PROSPECTING

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The present invention resides in a geochemical method for prospecting for petroliferous deposits.

Various methods have been devised for prospecting for oil by a chemical examination of soil and soil gases for the measurement therein of constituents considered diagnostic. The most directly diagnostic constituents are, of course, hydrocarbon gases, especially those heavier than methane which are normally associated with petroleum. For this purpose, a soil gas sample is collected, either by direct suction from a hole in the ground or by evacuation of a soil sample, and subjected to analysis for the selected hydrocarbons.

In the prospecting methods which are based on the analyses of soil gases it has been recognized that certain factors may have an important bearing on results. In the method according to which soil samples are collected and subjected to a treatment for the liberation of gas contained therein, it has been suggested that the hydrocarbons determined in the gas be corrected for the adsorbitivity of the soil as, for example, by the application of a correction factor based on the sand-clay ratio of the soil sample. In the alternative technique of sucking a gas sample directly from the earth, this correction factor is normally not relevant.

The present invention is predicated on the recognition of a factor hitherto overlooked, which influences the values determined for hydrocarbon concentration in soil gas, either by the so-called Laubmeyer method or by the soil sample method. This factor is the permeability of the soil between the point of sampling and the surface. The rate of hydrocarbon gas flow from a reservoir to the surface is determined by the nature and pressure of gases in the reservoir and the flow resistance of the whole section of earth between the reservoir and the surface. This section may be several thousand feet thick, so the flow rate will be in the ordinary case only slightly affected by that part of the section, which may be only a few feet thick, above the sampling zone. The partial pressure of the gas in the soil air in the sampling zone, or the amount adsorbed on soil for this zone, will, however, be directly affected by the flow resistance of this thin upper layer. For example, it may be postulated that if soil gas samples are collected at a depth of ten feet and there is a given rate of flow of hydrocarbons upwardly, the concentration in which these hydrocarbons are found will be greater if the top ten feet of earth is composed of clay of low per-

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meability than if it is composed of a permeable sand.

The actual mechanism of gas movement may be by diffusion rather than actual flow, since at normal sampling depths the soil air contains only a few parts per million of these gases; in any case this mechanism is not relevant to the basic idea of this invention. It should be noted that it is an essential object of geochemical measurements on hydrocarbon gases to arrive at the rate of flow without error due to purely local surface factors. Consequently, a correction for the above described effects is necessary.

As is well known in the practice of soil gas prospecting methods, sampling holes of various depths may be employed, whether the gas is obtained directly or by treatment of a soil sample. Generally the depth of sampling is at least five feet, and is preferably greater if drilling can be performed with sufficient economy. The actual sampling depth is usually dictated by drilling conditions and it is generally believed that the greater the sampling depth, within limits, the better. Thus, in all cases there is a substantial layer of earth above the sampling zone, and the factor discussed above is one of consequence.

In the practical application of the correction factor of the present invention, the problem is to determine some function of the permeability of the surface covering layer which will serve as a fairly reliable index. This can be done by a number of methods, among the more obvious of which is, of course, the measurement of the rate of flow of a gas through this covering layer. This can be done by examining separate increments of the covering layer and integrating the results, or by making a flow test on the whole layer. The former method gives more accurate results, but in most instances the latter may be made sufficiently accurate at least for reconnaissance purposes.

One way of examining several increments of the covering layer is to take sidewall cores of the sampling bore hole at successive depths and run an actual permeability test on such cores under standardized conditions. In this way an average permeability figure can be calculated which can be used as a permeability correction factor. Another way is to make permeability tests of successive increments in situ.

A simple method for obtaining an indication or function of the permeability of the covering layer as a whole is to introduce into the bottom of the sample bore hole a gas carrying a known concentration of an indicator or a tracer which

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lends itself readily to quantitative determination, cause the gas to flow through the covering layer, and determine the amount of indicator or tracer agent which has passed through the covering layer. In the practice of this method it is necessary to introduce the same amount of gas contained in the indicator into the sample holes under the same pressure, so as to make the results comparable.

The nature of the present invention may be better understood from the following detailed description of the accompanying drawing, in which Figure 1 is a diagrammatic representation of one method for practicing the present invention; and

Figure 2 is a similar view of an alternative method.

Referring to Figure 1, numeral 1 designates a bore hole extending from the surface to a level indicated by numeral 2, which may be termed the sampling zone. The earth between the sampling zone and the surface may be referred to as the covering layer or surface layer.

In the practice of this embodiment, after the soil sample or gas sample, as the case may be, is collected, there is lowered into the bore hole a unit composed of two spaced packers 3, through which is inserted a pipe 4. A pipe 5 connects the space between the packers to a flow meter 6, which in turn is connected to a suction device 7 adapted to exert a constant suction on the system. The packers may be inflatable rubber sleeves which are made of thin sheet rubber and lend themselves readily to effective sealing against the earth wall of the bore hole.

The system described is first fixed at the lowest level of the bore hole, the suction is applied, and the flow meter is read. Where the height of each packer is not greater than the diameter of the bore hole and the space between the packers is of a similar dimension, and where the suction is maintained constant, the flow rate is approximately proportional to the effective permeability to vertical gas flow of the section of soil around the space between the packers. Thus, by repeating this procedure at various depths, data may be secured from which a correction factor can be derived. By plotting the flow rate against depth, a curve can be obtained which will be very similar to a curve of effective permeability plotted against depth, except for a constant factor. This factor will depend on the geometry of the assembly, the degree of suction applied, etc. It can be shown, therefore, that the effective permeability to the vertical flow of gas from the sampling zone to the surface is proportional to

$$\left(\int_0^h \frac{dh}{k}\right)^{-1}$$

or to

$$\left(\int_0^h \frac{dh}{R}\right)^{-1} (=Q)$$

In these equations h equals depth of hole, k equals specific permeability, and R equals flow rate.

Since the concentration C of hydrocarbon gases in soil air or on the soil sample from the sampling zone may be expected to decrease as the near-surface permeability increases, a first approximation would be to assume that C corrected equals MCQ , where M is an arbitrary constant factor which may be chosen to make the average value of MCQ close to unity in any given area being surveyed.

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In the embodiment shown in Figure 2, there is introduced into the sampling bore hole a somewhat different assembly which, in the illustration shown, includes a long tube 8 which carries for a considerable portion of its length an expansible rubber sheath 9 provided with a suitable valve 10 for inflating. Above this sheath there is fixed to the tube a block 11 which is of a smaller diameter than the bore hole and which carries a second tube 12 which terminates in a collection chamber 13, which may be connected, if desired, to a suction pump 14 by a line 15 supplied with a valve 16. Tube 12 also has a valve 17. The block 11 carries around its periphery an expansible rubber sheath 18 provided with a valve 19. The upper end of tube 8 is connected to a cylinder 20, which may be of any desired dimensions and may be provided with a piston 21, or in the alternative may be connected to a pump. The cylinder is provided with a gas inlet tube 22 provided with a valve 23.

The assembly is lowered into the bore hole with the rubber sheaths collapsed. When in place the rubber sheath 9 is inflated to sealing position. Then the rubber sheath 18 is inflated. Then valves 16 and 17 are opened and suction is applied to the space between the sealing members. After a predetermined length of time, which may be five minutes or greater, a valve 24 in tube 8 is opened and a gas mixture containing an indicator or tracer which has previously been introduced into cylinder 20 is pumped into the bore hole. The suction pump 14 is kept in operation for several minutes after the opening of valve 24 and then, after a given interval, valves 16 and 17 are closed and the gas contained in chamber 13 is analyzed for its content of indicator or tracer. The latter may be any gaseous agent which lends itself readily to detection and measurement. For example, hydrogen sulphide may be employed, and may be determined by any of the many known methods for quantitatively analyzing gases for this constituent. It is, of course, necessary to use a constituent which is not normally found in the atmosphere.

It will be understood that in the latter embodiment it is necessary to follow the same procedure in all sampling holes; that is to say, the same suction must be applied by the pump 14 for the same periods of time, and the same amount of tracer gas must be admitted, either by adding it in under a constant pressure for a constant period of time, or by displacing a constant volume of it. Likewise, it is important that the space between the sealing packers be maintained as nearly uniform as possible by using the same degree of inflation of the sealing members for all of the holes. It will naturally be necessary in any case to inflate these members sufficiently to effect a good seal.

As has previously been indicated in this embodiment, the significant factor is the concentration of indicator or tracer found in the cylinder 13 when a tracer is employed which is easily measured. This procedure can be followed with a minimum consumption of time. It will be understood that if desired in this embodiment the entire borehole can be sealed up and a sample of the indicator gas collected in a shallow hole drilled for this purpose adjacent the main sampling hole. It will be understood the pumping times indicated above are not necessarily limiting, but will manifestly vary from area to area.

Other methods for determining a correction factor which will be a function of the permeability of the covering or surface layer may occur to those

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skilled in the art. It is not the purpose of this specification to describe all possible methods, but rather to suggest representative methods which may be followed for the realization of the desired objective.

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. In a method for prospecting for subterranean petroliferous deposits in which sampling holes are drilled to a depth of several feet at spaced intervals over the area to be investigated and soil gas samples are recovered from a point adjacent the bottom of said holes and analyzed for their content of a significant constituent, the steps which comprise passing a fluid through portions of the earth surrounding the hole, representative of the layer overlying the sampling point, measuring the rate of travel of said fluid through said portions under a known pressure whereby values are obtained from which the average permeability of the layer over the sampling

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point may be determined and variations of this permeability over the area may be applied to the determinations of the significant constituent as a correction factor.

2. A method according to claim 1 in which the value determined is that obtained by sealing off the sampling hole at two points spaced from each other a substantial portion of the length of the hole, admitting air into the hole above and below said sealing points, connecting the space between the sealing points to a collection apparatus, and determining the amount of air collected in said apparatus from said space which has entered the latter from above and below the sealing points in a given period of time.

3. A method according to claim 1 in which the value determined is that obtained by collecting samples of soil at successive points along the sampling hole, measuring the effective permeability of the several samples and averaging the values so obtained.

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