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Daigle et al.

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[54] **MARINE MUD HYDROCARBON SURVEYING**

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[52] **U.S. Cl.** .....**73/19,** 23/232 EP

[51] **Int. Cl.** **G01n 7/00**

[58] **Field of Search**.....73/19, 23, 23.1, 61, 61.1, 73/152, 153, 154; 23/232 EP; 175/20, 60, 213, 5 X

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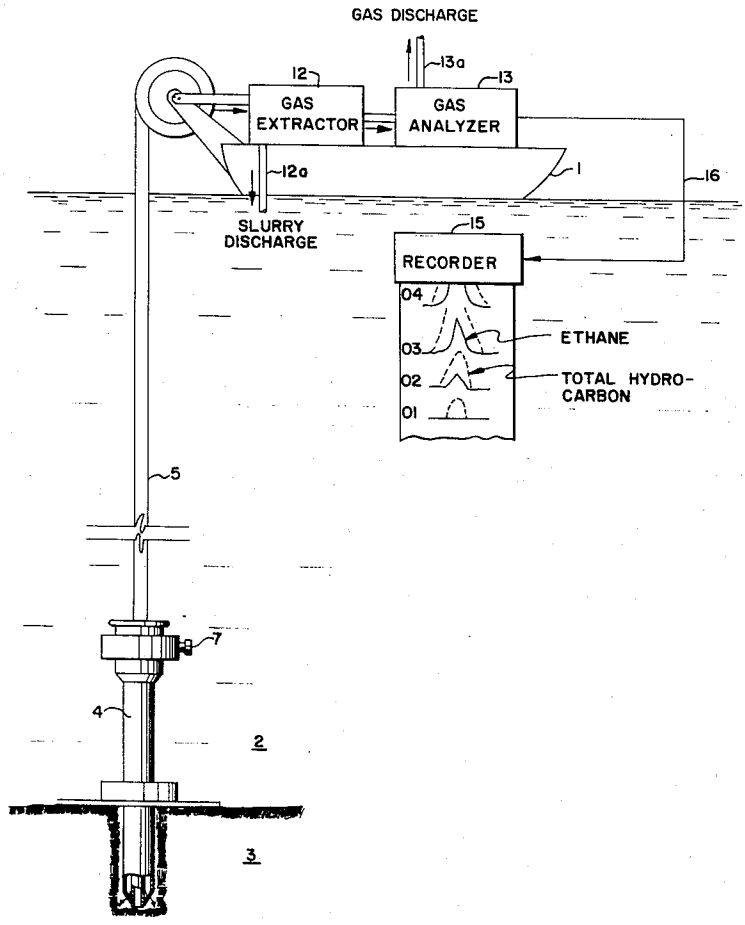
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[57] **ABSTRACT**

A process for exploring a water-covered region is improved by jetting water into soft bottom sediments, forming a slurry of the sediments in water, extracting gas from the slurry and measuring the concentration with location of a mobile reservoir fluid that was entrapped within the bottom sediments.

8 Claims, 4 Drawing Figures



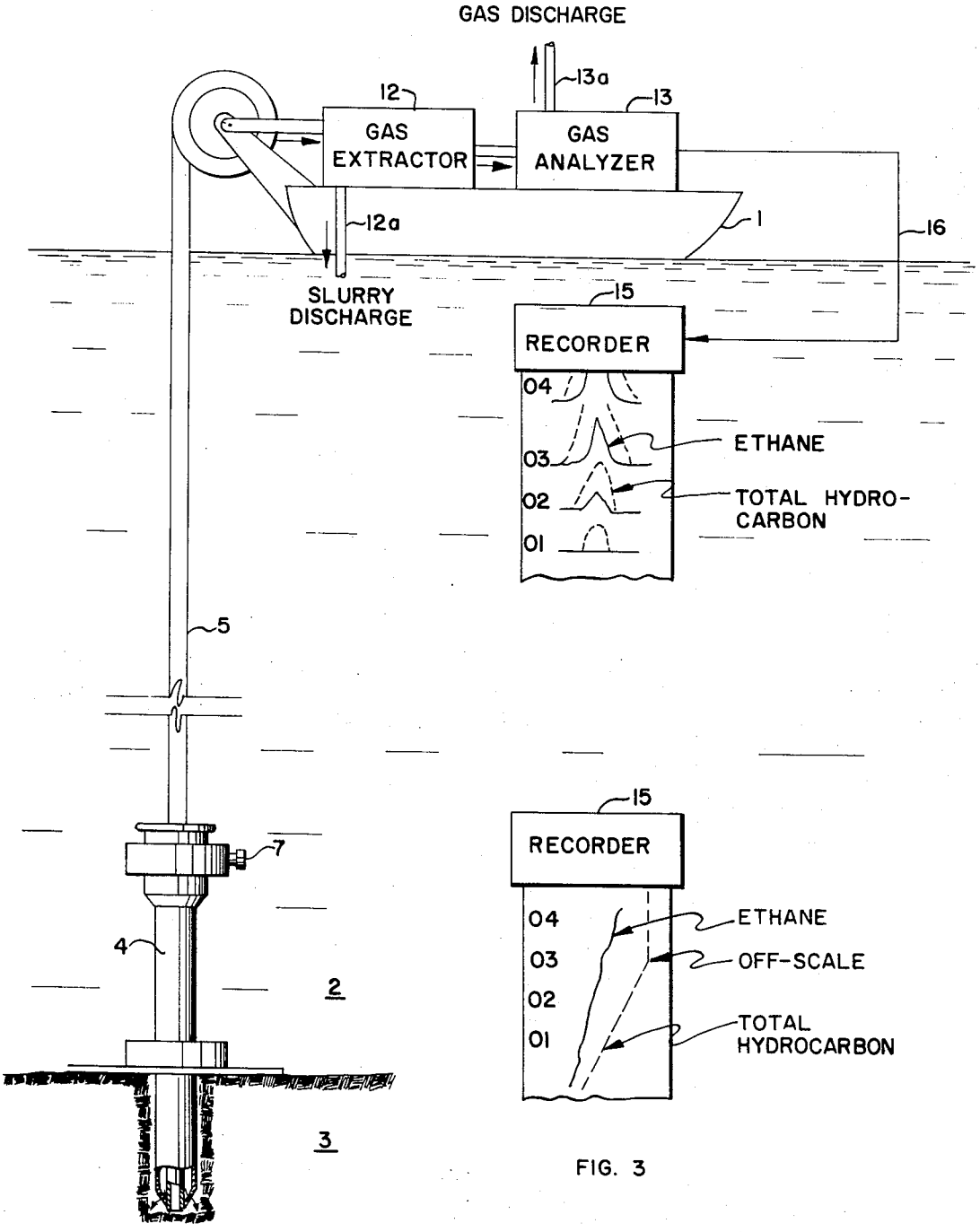
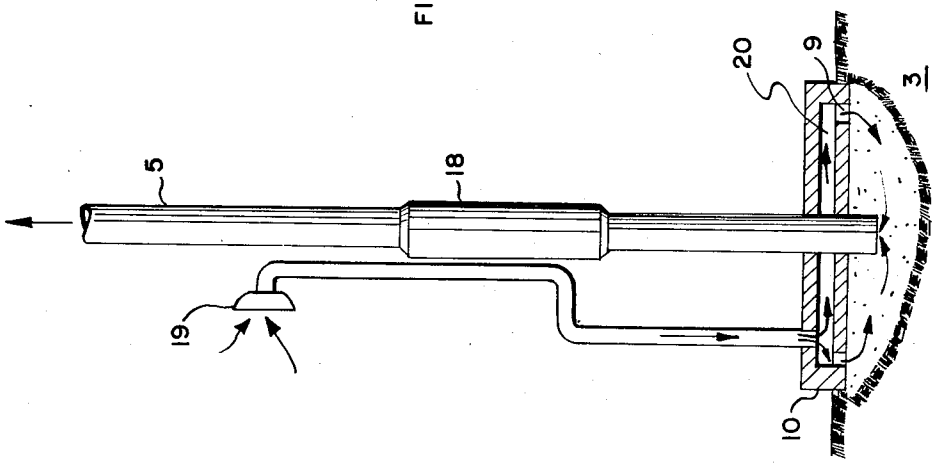


FIG. 1

FIG. 3

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FIG. 4



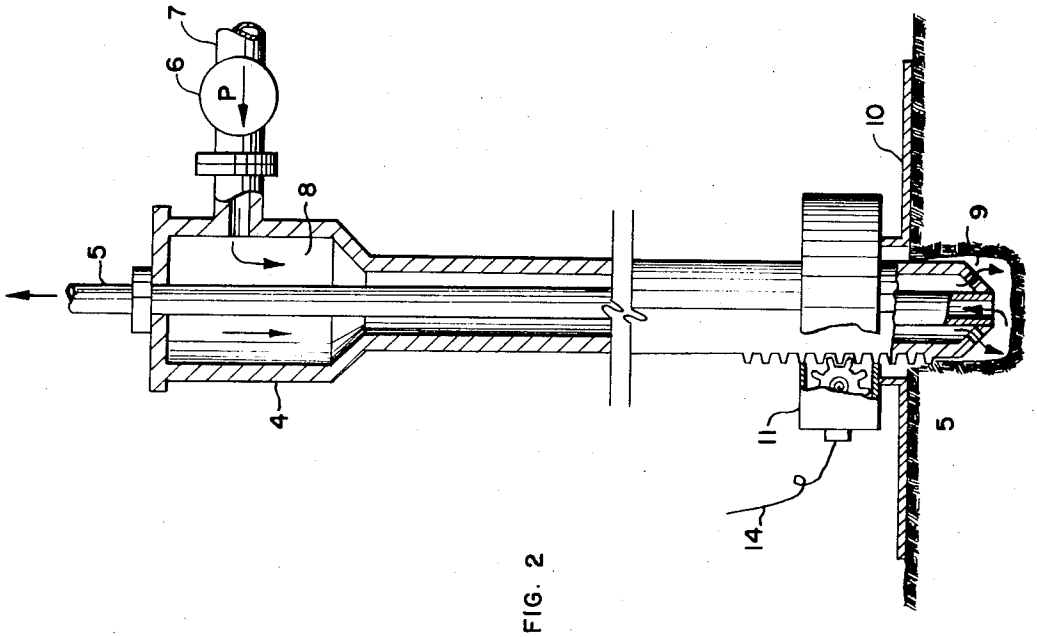


FIG. 2

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MARINE MUD HYDROCARBON SURVEYING

BACKGROUND OF THE INVENTION

The invention relates to a process for investigating earth formations located under a large body of water. More particularly it relates to measuring the concentration with location of a mobile fluid, such as a hydrocarbon, in sediments at the bottom of a body of water, in order to locate an underlying reservoir that contains the mobile fluid,.

Mobile reservoir fluids, such as hydrocarbons and/or inorganic gases, are known to seep from subterranean reservoirs and migrate up through the overlying earth formations. Prior procedures for exploring water-covered regions have utilized various combinations of geophysical techniques, such as seismic or gravity mapping techniques, and measurements of the amounts of hydrocarbon and/or inorganic gases in a body of water or in core samples or bit cuttings of the earth formations underlying the water. The obtaining of core samples or bit cuttings is a relatively expensive operation and is usually employed only in locations that have been selected as the sites for wells, or platforms, or the like.

A survey or map of the amount with location of a mobile reservoir fluid that might be contained within a body of water is not significant unless the bottom sediments have allowed the reservoir fluid to flow through them and enter the water. In a region containing subterranean structures having geophysical properties that may be indicative of a subterranean reservoir, the overlying water may be substantially devoid of any mobile reservoir fluid. Such a situation is common when the bottom sediments are soft and relatively impermeable, such as the clays or muds that cover much of the Gulf of Mexico. An absence of hydrocarbons in the water above a subterranean reservoir structure that might contain hydrocarbons provides substantially no definite information. There may be no hydrocarbons present in the reservoir structure, or none that escape from the reservoir, or none that provide detectable amounts of seepage through the relatively impermeable and hydrocarbon adsorptive layer of mud that underlies the water.

A primary object of the present invention is to provide a relatively economical and reliable procedure for detecting and characterizing any mobile reservoir fluids which have been adsorbed or otherwise trapped or entrained within a layer of unconsolidated sedimentary earth formations underlying a body of water.

SUMMARY OF THE INVENTION

In accordance with this invention measurements are made of the concentration of at least one mobile reservoir fluid in a water-covered unconsolidated sedimentary earth formation. A stream of relatively clean water is jetted into the sedimentary earth formation to form a pumpable slurry of sedimentary material in water. Measurements are made of the locations at which the slurry is formed. And, gaseous fluid is extracted from the slurry and analyzed with respect to its concentration of a mobile reservoir fluid in order to map the concentration with location of the mobile reservoir fluid in the sedimentary earth formation.

The present invention provides an improved method of exploring a water-covered region by: measuring the magnitude with location of at least one geophysical property of subterranean earth formations; measuring the concentration with location within the water of at least one mobile reservoir fluid; and, measuring the concentration with location within an unconsolidated sedimentary earth formation of the mobile reservoir fluid in a region in which a geophysical property is indicative of a subterranean reservoir structure and the overlying water is substantially devoid of the mobile reservoir fluid.

DESCRIPTION OF THE DRAWING

FIG. **1** is a schematic illustration of a suitable system and its use in analyzing an unconsolidated sedimentary earth formation in accordance with the present invention.

FIG. **2** is a more detailed illustration of water-jetting element for use in the system shown in FIG. **1**.

FIG. **3** illustrates an alternative form of record.

FIG. **4** illustrates an alternative form of water-jetting element for use in the system shown in FIG. **1**.

DESCRIPTION OF THE INVENTION

In the equipment shown in FIGS. **1** and **2**, a vessel **1** is shown on a body of water **2**, above a layer of unconsolidated sedimentary earth formation or mud **3**. A mud-sampling device **4** forms a slurry of sediment in water that is pumped to a surface location through conduit **5**. The mud-sampling device contains a pumping means **6** having an intake port **7**, and a pump-discharge conduit **8**. The pump-discharge conduit is connected to jet nozzles **9** which are arranged to jet water into the mud to form a stream of slurry which flows into conduit **5** as shown by the arrows. The mud-sampling device **4** is mounted on a base structure **10**. As the mud-sampling device advances to increasing depths within the mud **3**, a measuring means, such as a rack and pinion arrangement **11**, responds to the extent of such advance and telemeters an electrical signal relating to the depth of penetration by means of electrical conduit **14**.

In a near surface location, the slurry of sedimentary solids in water is pumped through gas extractor **12** and discharged, as indicated at **12***a*. The extracted gas is passed through a gas analyzer **13**, and discharged, as indicated at **13***a*. An electrical signal from the gas analyzer is conveyed to recorder **15** by electrical conduit **16**. The recorder may indicate, for example, measurements made at each of a series of depths within the sediments **3** of the concentration of ethane and the concentration to total hydrocarbon. As indicated in FIG. **3**, such measurements can be utilized to plot the concentration with depth of such components of the sedimentary earth formation.

In the arrangement shown in FIG. **4**, a slurry of sedimentary particles in water is formed by a self-anchoring type of mud-sampling device. Pump **18** is preferably a positive displacement pump, such as a Moyno pump that is adapted to pump a slurry into conduit **5** at a rate exceeding the rate of water inflow through intake port **19**. In such an operation, the pressure is reduced below base structure **10** and conduit **20** while water is jetted from the nozzles **9** into the mud **3** and the sampling device is urged toward the mud by the hydrostatic pressure of the body of water. This sampling arrangement can be operated, for a selected time, such as at least

several minutes at each of a series of locations, so that, at each location, a substantially steady state flow of slurry of substantially uniform concentration is obtained. The maximum concentration during a selected time, or the average concentration during such a time, or the like, is thus representative of the concentration of the mobile reservoir fluid being sampled at each location at which the sampling device is applied to the mud. Alternatively, such a sampling device can be operated substantially continuously while being towed along the bottom of the body of water to measure a quantity such as concentration with distance along the line of tow.

In this invention the mobile subterranean reservoir fluid to be detected can comprise one or more of substantially any kind of mobile fluid that is apt to seep out of a subterranean reservoir and migrate toward the surface of the earth. Such fluids often comprise gaseous or relatively volatile hydrocarbons such as those containing from about one to ten carbon atoms, and/or one or more inorganic gases which are apt to be copresent with hydrocarbons in hydrocarbon containing reservoirs, such as carbon dioxide, nitrogen, oxygen, hydrogen sulfide, etc.

The water which is jetted into the sedimentary earth formation to form a slurry of the sedimentary solids can be obtained from the body of water or from substantially any convenient source of a "clean" water which is substantially free of the mobile reservoir fluid for which the sediment is being analyzed. Where desirable, water from the body of water can be preprocessed to remove contaminants and/or clean water can be transported from a supply source other than the body of water.

The pumping means for jetting the water into the mud and flowing the resulting slurry of sediments in water, or watery mixture of suspended particles, to a surface location can comprise one or more surface or subsurface pumps and pump-driving devices. The rates of jetting the water into contact with the mud, flowing the resultant slurry to surface location, and advancing the stream of jetted water into the mud, are preferably coordinated in order to maintain a relatively constant slurry consistency with respect to the number of parts of suspended solid per part of water.

In measuring the concentration of a mobile reservoir fluid with depth within the bottom sediments, a stream of jetted water is preferably advanced into the sediments by advancing a nozzle-supporting means downward past a base structure that rests on the top of a layer of sediments while measurements are made of the magnitude with time of that advance.

At a convenient location near the surface of the body water, gas is preferably extracted from the slurry by subjecting the slurry to a flashing or vaporizing action under a relatively strong vacuum. Such a gas extraction operation can be accomplished by means of known and available equipment and techniques such as those described in U.S. Pat. Nos. 2,918,579, 3,116,133, 3,296,776, 3,455,144, etc.

The gas which is extracted from the slurry is preferably supplied to a chromatographic analyzer containing a chromatographic column adapted to isolate at least one individual component from the other components of the extracted gas. A flame ionization detector that is adapted to provide an electrical signal related to the concentration of such a gas is preferably utilized to measure the concentration of the isolated component. Such gas analyzing devices are known and suitable types of such equipment and techniques are described in the patents referred to above.

In a preferred procedure: a slurry of the bottom sediments is formed and pumped at coordinated rates, as mentioned above; gas is extracted substantially continuously from the slurry; and, aliquot portions of the extracted gas are supplied periodically to a gas analyzer. Such a procedure facilitates the provision of a record of the type shown in FIGS. 1 and 3 which indicates the concentration with depth within the mud. The extracted gas can advantageously comprise the vapors of at least one hydrocarbon that contains at least four carbon atoms and may be a liquid at normal atmospheric pressure and temperature. The measurements of the gas are preferably indicative of the concentrations of at least one individual hydrocarbon higher than methane.

In a particularly preferred embodiment, such hydrocarbon measurements are supplemented by measurements of at least one inorganic gas. The copresence of at least one hydrocarbon and at least one inorganic gas in significant proportions provides a particularly significant indication of the presence of an underlying reservoir that contains valuable petroleum material.

The present invention is particularly useful in conjunction with other geophysical and geochemical exploration processes that are applicable to a water-covered region. In an exploration process, it is generally too expensive to undertake all of the sampling and analyzing operations which would be needed to resolve all, or even most, of the questions concerning what might be contained in reservoirs below a large water-covered region such as the Gulf of Mexico. Marine seismic and/or gravity measurements may indicate the presence of numerous anomalies indicative of subterranean structures that might contain petroleum material. An analysis of water samples is apt to indicate that no hydrocarbon and/or inorganic gases indicative of seepage from subterranean reservoirs are present in the water in a region containing such an anomaly.

The present invention is at least in part premised on a discovery that, in the above-type of situation such inconsistent measurements may be due to the low permeability and/or high fluid adsorptive properties of unconsolidate sedimentary earth formation material underlying that portion of the body of water. For example, in at least one region in the Gulf of Mexico it was found that seismic anomalies and other geological information were indicative of subterranean reservoirs that were apt to contain hydrocarbons, but no hydrocarbons could be detected in samples of the water in measurements made in a manner that was adapted to detect less than one part per million. In the same region, when the underlying bottom sediments were analyzed in accordance with the present reservoir they were found to contain significant concentrations of total hydrocarbons and ethane. In the same region it was established that the subterranean reservoir which was responsible for the appearance of the seismic anomaly was an oil-containing reservoir.

We claim as our invention:

1. In a process for surveying a water-covered region by measuring concentrations of at least one mobile reservoir fluid in water-covered unconsolidated sedimentary earth formations at known areal locations, an improved procedure that provides a measurement of the concentrations with depth within the formations, comprising:

jetting a stream of water into contact with a water-covered unconsolidated sedimentary earth formation at increasingly deeper depths within the formation to form a pumpable slurry of the sedimentary material in water;

flowing said slurry to a surface location;

coordinating the rate at which said water is jetted, the rate at which the depth at which said slurry is formed is advanced deeper within the earth formation and the rate at which said slurry is flowed to a surface location in order to maintain a substantially constant slurry consistency;

measuring a quantity related to the depth within said sedimentary earth formation at which said slurry is formed; and

extracting gas from said slurry and measuring a quantity related to the concentration with depth within said sedimentary earth formation of at least one mobile subterranean reservoir fluid.

2. The process of claim 1 including:

measuring the magnitude with areal location of (a) at least one geophysical property responsive to subterranean earth formations and (b) the concentration of said at least one mobile subterranean reservoir fluid; with said measurements being conducted in a region in which the water is substantially devoid of said mobile subterranean reservoir fluid but said measured geophysical properties of the subterranean earth formations are indicative of the presence of a subterranean adapted to be a reservoir.

3. The process of claim 2 in which said geophysical property is the reflection of seismic energy.

4. The process of claim 3 in which said mobile subterranean reservoir fluid is a hydrocarbon higher than methane.

5. The process of claim 1 including measuring the concentration of at least one hydrocarbon higher than methane and at least one inorganic gas.

6. The process of claim 1 including measuring maximum concentration of said mobile fluid that is extracted within a selected depth interval within said sedimentary earth formation.

7. The process of claim 1 including measuring the average concentration of said mobile fluid that is extracted within a selected depth interval in said sedimentary earth formation.

8. The process of claim 1 including measuring the concentration of said mobile fluid with location along the upper boundary of said sedimentary earth formation.

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