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[54] **DETECTING GEOPRESSURED SUBTERRANEAN FORMATIONS DURING DRILLING OF A WELL**

[75] Inventors: **Edward B. Reynolds**, Spring, Tex.; **Donald M. Pert**, New Orleans, La.; **Aldo M. Zanier**, Port Harcourt, Nigeria

[73] Assignee: **Continental Oil Company**, Ponca City, Okla.

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[51] **Int. Cl.**[2] **E21B 47/06**

[58] **Field of Search** 175/41, 50, 48, 49, 46; 73/152, 153

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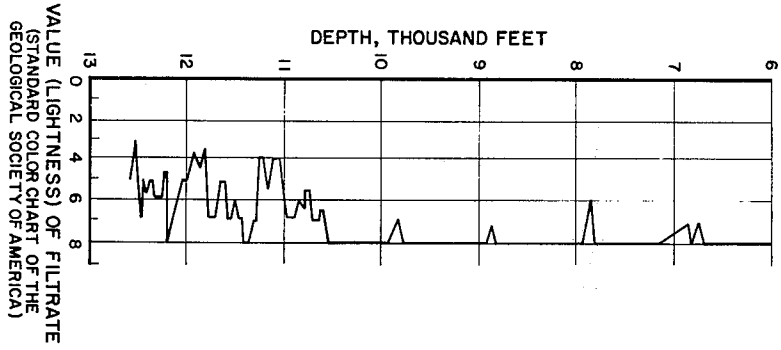
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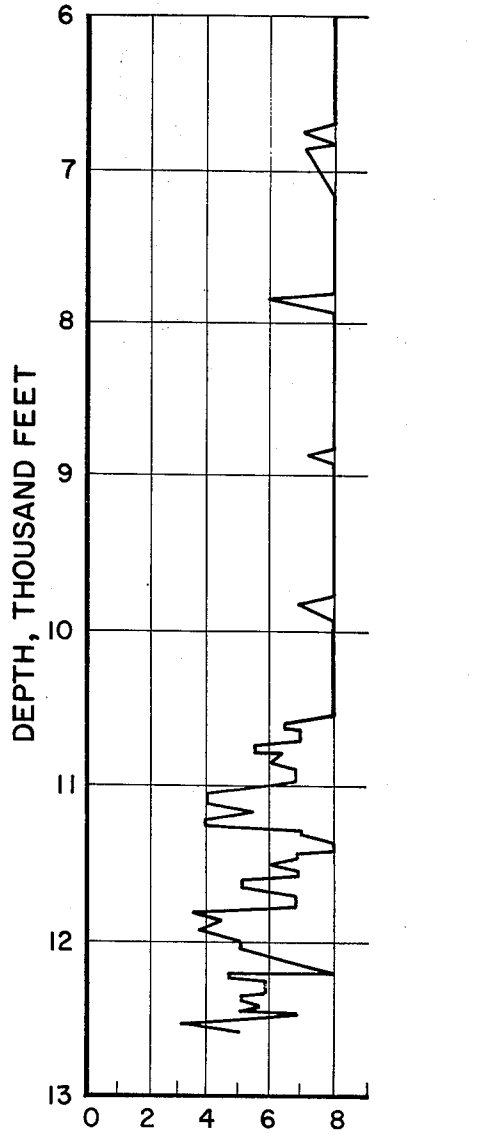
Primary Examiner—Ernest R. Purser
Assistant Examiner—Richard E. Favreau
Attorney, Agent, or Firm—Richard W. Collins

[57] **ABSTRACT**

A method of determining lithology changes in a well during drilling operations. Abnormal formation pressure, generally geopressure, and hydrocarbon-containing environments in subterranean rock strata can be detected before drilling into the same by making aqueous slurries of samples of the formation being drilled and observing and comparing the color characteristics of the liquid recovered from the filtration of such slurries.

6 Claims, 1 Drawing Figure




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7
8
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12
13
DEPTH, THOUSAND FEET
0 2 4 6 8
VALUE (LIGHTNESS) OF FILTRATE
(STANDARD COLOR CHART OF THE
GEOLOGICAL SOCIETY OF AMERICA)

DETECTING GEOPRESSURED SUBTERRANEAN FORMATIONS DURING DRILLING OF A WELL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention involves a method of detecting changes in formation properties and characteristics as a well is being drilled through subterranean rock formations containing zones having normal and abnormal formation fluid pressure as well as hydrocarbon-containing zones and nonhydrocarbon-containing zones. More particularly, the invention involves the detection and prediction of impending hydrocarboncontaining formations and pressure changes well ahead of the drill bit, i.e., 200 to 1,500 feet prior to actually drilling into such formations. This forewarning of impending pressure changes is vital so that engineering preparations can be altered for successfully drilling the well safely and efficiently through the pressure change or to the desired depth. Other pressure detection systems presently in use in the drilling industry do not permit a guaranteed prediction of formation pressure changes not yet drilled.

2. Description of the Prior Art

In subterranean formations the physical characteristics of the rock or lithology varies with depth. A multitude of such characteristics have long been observed while drilling wells through such formations either by examining samples of materials removed from the well during drilling or by logging the well. Among the lithological changes of high interest are the presence of hydrocarbons in the formation, the object of drilling most wells, and abnormally pressured formations which present certain difficulties to the drilling operation.

Present methods of detecting hydrocarbon-containing formations during drilling are largely directed to detection of such formations only after they have been penetrated by the drill bit. It would be highly desirable to be able to predict the occurrence of such formations while drilling through the overlying formations. This prediction would allow instigation of carefully controlled drilling procedures while drilling into and through hydrocarbon-containing formations so as to minimize formation damage to the potential producing interval and to prevent the formation fluids from entering the well bore, hence avoiding the danger of blowouts.

When a well is drilled, normal pressures, i.e., hydrostatic pressures, exist to some unknown depth where transition to abnormal pressures might be encountered. In the normally pressured zones, formation pressure increases at a constant rate with increasing depth. This rate of increase in the Gulf Coast of the United States is approximately 0.465 pound per square inch per foot of depth and is the equivalent to the pressure exerted at the base of a column of water containing 80,000 ppm total solids. Abnormal pressures either are less than (underpressured) or greater than (geopressured) this pressure gradient increase of 0.465 psi/ft.

In many geographical areas, such as the Gulf Coast of the United States, abnormal pressures are encountered. Of particular importance are geopressures since they are very common and can cause very severe drilling problems. When geopressures are encountered, they must be drilled with a weighted drilling fluid that exerts a pressure exceeding or equal to that of the geopressured zone or else the shale and fluids in the abnormal

pressured zone, i.e., oil, gas, and/or water, will flow into the well bore and possibly cause a catastrophic "blowout" or drill string sticking. Numerous causes for geopressures have been postulated. One such cause is that shales and sands that are being buried deeper because of additional deposition on top must compact to stay at normal pressure. These shales and sands can only compact, however, if the associated water is allowed to leak off. If this water cannot bleed off, the formations will exhibit geopressures, i.e., high fluid pressures.

Underpressures, although much less frequently encountered compared to geopressures, have been found in areas of oil and/or gas production where pressure in the formations is depleted through the years by production.

Drilling wells in any formation pressure environment requires the weight of the drilling mud to be balanced against the pressure of the formation being drilled. The fastest and most efficient drilling rates are obtained when an overbalance of mud to formation pressure is held to a minimum. The penetration rate begins to decrease dramatically when overbalances exceed about 300 psi more than formation pressures at 10,000 to 12,000 feet of depth. This is only about 0.5 pound/gallon excess mud weight. Further, it is dangerous to drill with mud weight pressures that exceed formation pressures by about 1,000 psi, which is about 2.0 pounds/gallon excess mud weight at 10,000 to 12,000 feet of depth, since this high a differential pressure can cause the formations to fracture or break down with loss of the mud column into the formation. When mud is lost in one zone, the entire mud column drops decreasing the hydrostatic mud head and overbalance across other zones and even probably getting into an underbalanced condition across these other zones. When this happens, the differential pressure of higher formation pressure than mud pressure will allow flow of formation fluid into the well bore. This can literally cause the entire mud column to be blown out of the hole resulting in a catastrophic "blowout" and loss of the hole, drilling rig, and endangering the lives of the rig personnel.

Also when mud weight pressure to formation pressure is excessive as when overbalance exceeds about 1,000 psi, there is a tendency for the drill pipe to stick, due to this differential pressure. To get unstuck sometimes can be very expensive or even impossible with present technology; thus, the well has to be abandoned with great financial loss.

It can be seen that the drilling of wells through abnormal pressures requires great engineering skill. The knowledge of impending abnormal pressures enables the drilling engineer to prepare and perform the drilling in a safe and efficient engineering manner, since he is aware of the impending difficulties and problems.

Present methods used in pressure detection such as wire line logs, i.e., electric, acoustic, density, etc, all require temporarily suspending drilling operations to acquire the logs. Further, wire line logs must be considered as after-the-fact since they have the inherent drawback that the abnormal pressures can only be detected after the zone has been drilled. In many instances, getting pressure information at this time is too late as drilling problems such as pipe sticking and well blowouts occur when the abnormal pressure zones are being penetrated.

Other methods of abnormal pressure detection while drilling include bulk density measurements of the

drilled shale cuttings, drill penetration rate, torque or drag on the drill pipe, mud pump pressures, mud pit level changes, measurement of gas in mud system and clay mineral changes. These methods for pressure detection are generally faster than the wire line logging techniques, but they all have the same drawback in that none of these guarantee the ahead-of-bit prediction in all cases. The drilling industry is in need of a method for predicting and detecting abnormal pressure zones prior to drilling into them.

It is an object of this invention to provide a method of predicting and detecting lithological changes while drilling a well into such changes. It is also an object during the drilling of a well to predict underlying hydrocarbon-containing formations and abnormally pressured formations. It is another object to drill geopressured formations without danger of a blowout. It is also an object of this invention to keep mud weights at a safe minimum during drilling so that loss of circulation does not occur. It is a further object to drill abnormal pressured formations at a high penetration rate without ceasing drilling operations to detect such abnormal pressures. Other objects, advantages, and features of this invention will become obvious from the following specification and appended claims.

SUMMARY OF THE INVENTION

This invention involves a method of drilling a well through subsurface rock strata containing abnormal formation pressures and/or hydrocarbon-containing formations at some unknown kepth. The normally pressured (hydrostatic pressured) and nonhydrocarbon-containing portions of the strata are drilled according to well-known techniques in which a drilling fluid is circulated in the borehole. While drilling the normally pressured rock, the drilling fluid is maintained at a relatively low weight, i.e., balanced against or slightly above hydrostatic pressure, so that fast and economic drilling can be accomplished. During this drilling operation, samples of formation particles, e.g., cuttings, being circulated out of the borehole along with the drilling fluid are periodically collected, cleaned to remove drilling fluid therefrom, ground to a fine-particle size, and added to water to form a slurry or suspension. The slurried or suspended particles are then removed from the supernatant liquid, such as by filtering, centrifuging, or decanting, and the color of the liquid which is obtained is observed. When the color of this liquid changes, a change in properties and characteristics of the formation underlying the drill bit, i.e, presence of an abnormally pressured zone and/or a hydrocarbon-bearing zone, is indicated. Thus, this early warning of impending changes permits the drilling engineers to start controlled drilling procedures. These procedures, such as keeping a constant rotary speed and weight on the bit while monitoring penetration rate, will alert the driller when these changes have occurred, since the penetration rate will begin to increase under these controlled procedures at this time, and the change in properties and characteristics, or lithology, will not be masked by uncontrolled conditions. The weight and/or character of drilling fluid can then be adjusted to compensate for the above-mentioned changes. Drilling a well in the above-described method provides the fastest and most efficient drilling, but most important, permits the safest drilling. Controlled drilling procedures require special precautions which make their use throughout the entire drilling operation technically difficult and uneconomical.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE is a graphical representation of the color of the slurry filtrate made using formation samples from various depths.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The drilling fluid used in this process may be an aqueous or oil base drilling mud, air, or mist. Where a drilling mud is used, the pressure of the column of drilling mud against the formation is increased by increasing the density of the drilling mud as by adding to the mud barium sulfate or some other weighting agent. If air or mist drilling is being employed, the pressure is increased by increasing the amount of air being compressed. In most subterranean formations, the color of the slurry filtrate of finely particulated samples of the formation is about constant. The invention is based on the discovery that formations immediately above hydrocarbon-bearing formations and/or abnormally pressured formations are an exception to the general rule, in that the color of such slurry filtrate becomes relatively dark. The reason for this phenomenon is not known with certainty. It has been postulated that the darker color is due to the formation overlying the anomalous formation being a more oxidized environment.

During drilling operations a drilling fluid is pumped into the borehole and circulated past the drill bit. Cuttings and possibly formation fluids are picked up by the drilling fluid and circulated to the surface. Thus, the material coming out of the borehole consists of a mixture of drilling fluid, formation fluids, and cuttings. Sometimes a coring or sidewall sampling apparatus is lowered downhole and a formation core or sidewall sample removed. The process of this invention may be carried out on any or all of the solid formation materials either separately or in combination.

Samples of particles of formation circulated out or otherwise removed from the borehole are periodically collected and separated from the drilling fluid, as by removing the solid materials retained by the shale shaker. The solids are then preferably sieved and the 10 mesh to 40 mesh size particles retained. The mesh size refers to U.S. Sieve Series designation by the U.S. Bureau of Standards. Any drilling fluid remaining on the solids is then removed, as by washing with the water used to make up the drilling fluid. The cleaned solids are then dried as by placing the same on a hot plate or in an oven at a temperature of approximately 225°F for a length of time sufficient to volatilize the surficial water but not alter the sample. The dried sample is cooled and disaggregated to a particle size of from 44 to 350 microns, as by grinding with a mortar and pestle. A convenient sized portion of the sample, say 0.5 to 50 grams, is then mixed with water to form a slurry or suspension. Generally, from 1 part by weight sample to from 1 to 5 parts or more by weight water forms a satisfactory slurry. It is preferred that distilled or deionized water be used for uniformity of results. The solid material of the slurry is then separated from the liquid, as by centrifugation or filtration.

The color of the filtrate is then observed and compared with the color of filtrates made from formation samples taken from other depths. This observation of

color can be made visually as by comparing the sample with a color chart or measured by an instrument such as a colorimeter, reflectometer, or spectophotometer. When the color of the filtrate begins to change rapidly with depth, i.e., becomes darker, a change is indicated in the properties, or lithology, of the formation underlying the formation from which the sample was taken. Controlled drilling procedures are then instigated.

WELL EXAMPLE

To demonstrate the effectiveness of the method of this invention, color measurements were made on filtrated fluids from slurries prepared from shale cuttings removed during drilling of offshore Louisiana test well No. 2. The well was drilled to a depth of 6,000 feet using ordinary drilling procedures, as no important changes were expected over this interval. Beginning when the well had reached a depth of 6,000 feet, shale cuttings were periodically removed from the aqueous drilling mud stream circulated out of the well during drilling by collecting the same on a shale shaker. A sample of cuttings was passed through a 40-mesh sieve and washed with water used to make up the drilling mud to remove excess drilling mud therefrom. The sample was then dried for approximately 10 minutes at 225°F on a hot plate. A 10-gram portion of the sample was selected and ground to less than 325 mesh with a mortar and pestle. To this portion was added 20 milliliters of distilled water and the mixture stirred to form a slurry. The slurry was then filtered with an air filter press, using paper as a filtering medium and applying 100 psi of pressure. The color of the filtrate passing through the filter press was determined by visually comparing it to the standard color chart of the Geological Society of America. The color was plotted on graph paper versus depth. The procedure was repeated every ten feet as drilling continued. The results of this procedure are shown in the FIGURE. It can be seen that the color remained relatively constant at about 8 value units from 6,000 feet to about 10,500 feet of depth. Below about 10,500 feet the color of the filtrate became darker. Several hundred feet below 10,500 feet, both hydrocarbon and geopressured zones were encountered.

The foregoing discussion and description have been made in connection with specific preferred embodiments of the process for detecting changes in formation properties and characteristics during drilling of a well. However, it is to be understood that the discussion and description of the invention is only intended to illustrate and teach those skilled in the art how to practice the process and is not to unduly limit the scope of the invention which is defined and claimed hereafter.

We claim:

1. A method for detecting changes in properties and characteristics of a subterranean formation during drilling operations comprising:

a. drilling a well in a subterranean formation utilizing a circulating drilling fluid;

b. periodically collecting formation samples from increasing depths;

c. preparing filtrates of aqueous slurries of said formation samples;

d. determining a color characteristic of said filtrates prepared from aqueous slurries of said formation samples taken from increasing depths; and

e. when said color characteristic of said filtrates begins to change rapidly with depth, instituting controlled drilling procedures.

2. The method of claim **1** where the change in formation properties and characteristics is the change from a nonhydrocarbon-containing formation to a hydrocarbon-containing formation.

3. The method of claim **1** wherein the determination of a color characteristic is carried out visually using a color chart.

4. The method of claim **1** wherein the sample of the formation is made up of cuttings.

5. The method of claim **1** wherein the change in formation properties and characteristics is a change from a normally-pressured formation to an abnormally-pressured formation.

6. The method of claim **5** wherein the abnormally-pressured formation is a geopressured formation.

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