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[54] **GEOPRESSURE DETECTION DURING DRILLING OF A WELL**

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[52] **U.S. Cl.** **175/50,** 73/153

[51] **Int. Cl.** **E21b 47/00**

[58] **Field of Search** 175/40, 50; 73/153

[56] **References Cited**

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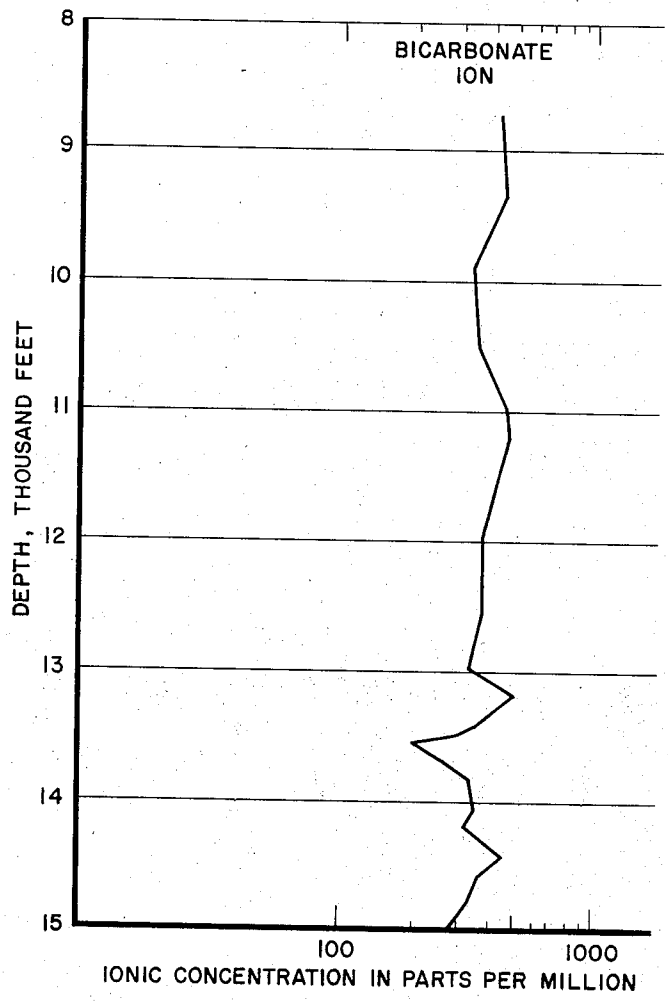
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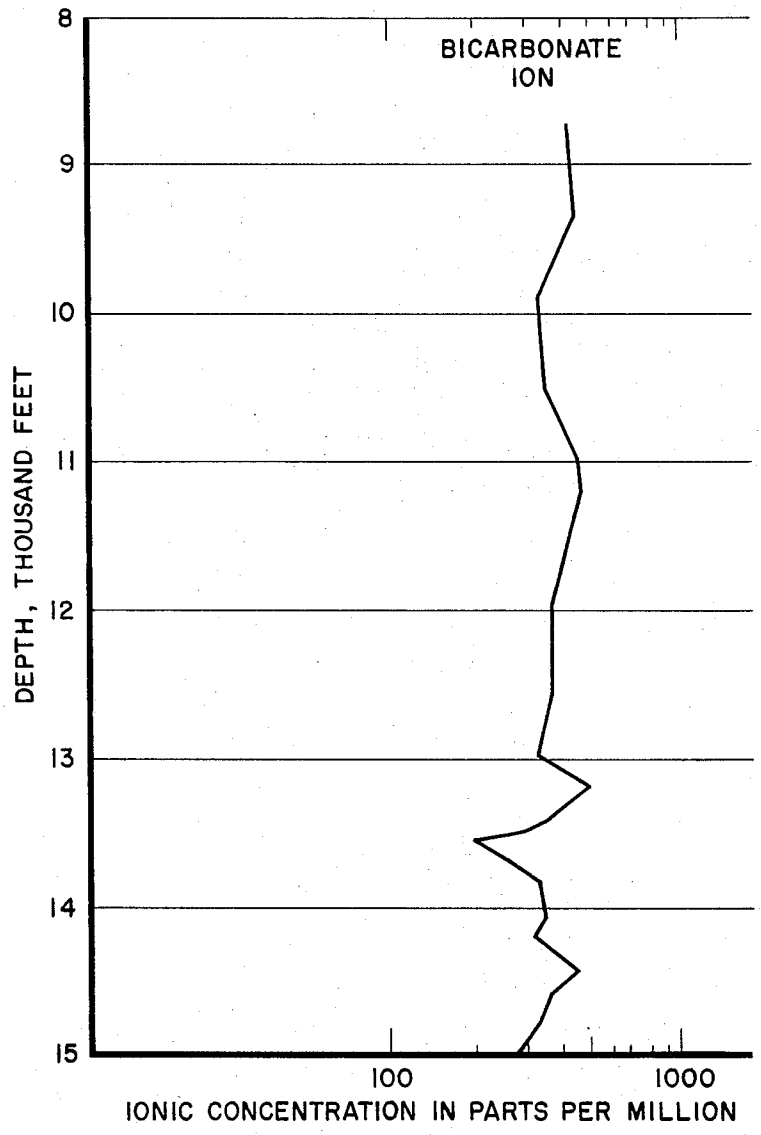
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[57] **ABSTRACT**

An early warning detection method for predicting abnormal formation pressure, generally geopressure, in subterranean rock strata before it is drilled. The technique is to measure the concentration of the bicarbonate ion in the formation being drilled, while the well is being drilled in the normally pressured rock strata existing above the abnormally pressured formations. When variations are observed in the degree of change of the amount bicarbonate ion present with depth, drilling procedures are altered to meet the requirements of the formation which is about to be penetrated by the drill bit.

5 Claims, 1 Drawing Figure




BICARBONATE
ION
8
9
10
11
12
13
14
15
DEPTH, THOUSAND FEET
100
1000
IONIC CONCENTRATION IN PARTS PER MILLION

GEOPRESSURE DETECTION DURING DRILLING OF A WELL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention involves a method of detecting abnormally pressured formations as a well is drilling through subsurface rock formations containing zones having normal and abnormal formation fluid pressures. More particularly, the invention involves the detection and prediction of impending pressure changes well ahead of the drill bit, i.e., 200 to 1,500 feet prior to actually drilling the pressure changes. 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 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

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 is approximately 0.465 pounds 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 these 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 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 lead 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. This is only about 0.5 pound/gal. 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/gal. excess mud weight at 10,000 to 12,000 feet 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, 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 pressure, 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 pressure changes before drilling them. 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 at some unknown depth. The normally pressured (hydrostatic pressure) 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 the concentration of the bicarbonate ion contained in the formation is systematically and periodically or continuously determined. This is done by measuring at the surface the activity or concentration of the bicarbonate ion in the drilling mud, cores or shale drill cuttings removed from the well at various depth intervals. In the normally pressured formations the concentration of the bicarbonate ion changes only slightly with increasing depth. However, several hundred feet above a geopressured interval the concentration of the bicarbonate ion begins to either increase or decrease rapidly. When this change in activity occurs, it is a signal that a geopressured zone lies somewhat below the drill bit in yet undrilled rock strata. Thus, this early warning of impending geopressure 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 the geopressure is reached since the penetration rate will begin to increase under these controlled procedures at this time and the geopressures will not be masked by uncontrolled conditions. The weight of drilling fluid can then be adjusted to compensate for the change in formation pressure. 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 makes their use throughout the entire drilling operation technically difficult and uneconomical.

BRIEF DESCRIPTION OF THE DRAWINGS

The FIGURE is a graphical representation of the concentration of bicarbonate ion in formation samples at 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.

Formation fluids contain a wide variety of water soluble ions. Among such ions is the bicarbonate ion. In normally pressured formations the concentration or activity of the bicarbonate ion is relatively constant with increasing depth. This invention is based on the discovery that, formations immediately above geopressured zones are an exception to the general rule in that they contain a lower than expected concentration or activity of bicarbonate ion. The reason for this phenomenon is not known with certainty. It has been postulated that water is squeezed out of shales as they compact due to the weight of overlying sediments. However, the shales act as a filtration membrane and the water that is squeezed out is fresh leaving the ions behind in the shale and therefore increasing the shale ion concentration or activity. Since overpressured shales are undercompacted for their depths they still contain considerably more water and the soluble ion concentration or activity is less than in highly compacted shales. When compacted shales with the high ion concentration or activity overlie the undercompacted shales with low soluble ion concentration, or activity, the shales tend to try to come to ionic equilibrium by ion diffusion from the concentrated solution to the dilute solution (normal pressure interval to the abnormal pressure interval) in opposition to the membrane filtration effect. This in theory creates the interval of 200 to 1,500 feet above the geopressure zone where diffusion of ions has caused a freshening of formations waters. This invention therefore has developed a procedure to detect this zone of freshening waters above the abnormal pressure.

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 bicarbonate ion concentration may be measured on any or all of these materials either separately or in combination.

Any of the well known analytical methods for determining bicarbonate ion concentration may be used. If drilling fluid is used for the determination, a representative sample is collected as the drilling fluid is circulated out of the well. The sample is then filtered to remove the solid particles and the bicarbonate ion concentration of the filtrate determined. If cuttings, cores or sidewall samples of the formation are to be used for the determination the samples are removed from the well, washed to remove drilling fluid, ground to a fine particle size, mixed with water, blended for a short time to achieve good mixing and filtered to remove the solid particles. The bicarbonate ion concentration of the filtrate is determined. Alternatively bicarbonate ion concentration may be continuously determined on fluids or slurries circulated out of the borehole.

Bicarbonate ion concentration may conveniently be determined by titrating the sample solution with an acid such as a hydrochloric acid solution to a pH of 4 using methyl orange as an indicator. Any other suitable analytical method may also be used.

EXAMPLE

A well was drilled on the Louisiana Gulf Coast in an area where geopressures are often encountered at a depth somewhere below 8,000 feet. The well was drilled to 8,000 feet using known techniques of balancing drilling mud pressure against formation pressure. At depths below 8,000 feet the concentration of bicarbonate ions in well cuttings was determined. The drilling mud stream circulated out of the borehole was passed over a shale shaker. At every 30 foot interval of increased depth a quart of cuttings passing through a 10 mesh screen (U.S. Standard Sieve Series) and retained on a 40 mesh screen were removed from the shale shaker. A knowledge of the depth at which the

well was drilling when the samples were taken, the annular mud velocity and the penetration rate allowed calculation of the depth from which the cuttings originated. Drilling mud was washed from the cuttings with fresh water and excess water blotted from the cuttings with a towel. The cuttings were then dried on a hot plate at 230°F for 20 minutes. A 10 gram sample of dry cuttings was cooled, mixed with 100 milliliters of distilled water and blended for 5 minutes in an electric micro-blender cell. The concentration of bicarbonate ion in the resulting slurry was determined by titrating to pH 4 with a hydrochloric acid solution using methyl orange as an indicator.

The FIGURE is a plot of the concentration of bicarbonate ion in the slurry at various depths. It can be seen that the concentration was relatively constant from just below 8,000 feet to about 13,000 feet. From 13,000 feet to about 13,200 feet the concentration increased sharply. From about 13,200 feet to about 13,500 feet the concentration decreased sharply. This indicated the approach of a high pressure zone. The well had been drilled from 9,000 feet with a drilling mud having a weight of 10 pounds per gallon. When the approach of a high pressure zone was indicated by the changes in bicarbonate ion concentration controlled drilling procedures were instigated. A constant rotary speed and weight on the drill bit was maintained while the penetration rate was monitored. When the penetration rate began to increase at a depth of about 13,500 feet, the weight of the drilling mud was increased to 17 pounds per gallon. The well was then drilled to the total desired depth of about 15,000 feet without difficulty.

The foregoing discussion and description have been made in connection with preferred specific emobdiments of the process for detecting geopressure zones 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. For example in addition to making measurements of the concentration of bicarbonate ions in a slurry made from shale cuttings, such measurements may be made on slurries made using formation samples taken with a sidewall cutting apparatus or on the filtrate of such slurries. Further measurements may be made on samples of the drilling fluid stream being circulated into or out of the borehole.

Measurements may be made by periodically sampling the material being circulated out of the borehole, or, as in the case of testing the drilling fluid, continuously with the results conveniently being plotted on a strip chart recorder connected to the measuring apparatus.

We claim:

1. A method for detecting the approach of an underlying abnormally pressured zone while drilling a well in normally pressured zones of a subterranean strata comprising:

a. drilling the normally pressured zones with a drilling fluid whose pressure is balanced against the subterranean strata pressure,

b. monitoring the concentration of the bicarbonate ion in the subterranean strata being drilled,

c. when the rate of change of concentration of the bicarbonate ion with depth begins to change, instituting controlled drilling procedures, and

d. when the abnormally pressured zone is penetrated, adjusting the drilling fluid pressure to balance the same against the pressure in the abnormally pressured zone.

2. The method of claim **1** wherein the controlled drilling procedures instituted comprise keeping a constant rotary speed and weight on the bit while monitoring the penetration rate.

3. The method of claim **1** wherein the concentration of the bicarbonate ion is measured continually on samples of formation circulated from the well.

4. A method for detecting the approach of an underlying geopressure zone while drilling normally pressured subterranean strata comprising:

a. drilling the normally pressured subterranean strata with a drilling fluid whose pressure against the subterranean strata is balanced against pressure in the subterranean strata,

b. monitoring the concentration of the bicarbonate ion in the subterranean strata being drilled,

c. when the concentration of the bicarbonate ion in the subterranean strata begins to change rapidly with change in depth, instituting controlled drilling procedures, and

d. when the controlled drilling procedures indicate that a geopressured zone has been penetrated, increasing the drilling fluid pressure to balance the same against the pressure in the geopressured zone.

5. The method of claim **4** wherein the controlled drilling procedures instituted comprise keeping a constant rotary speed and weight on the bit while monitoring the penetration rate.

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