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AIR DRILLING SHALE CONTROL

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The present invention is directed to a method of preventing shales from caving into gas-filled boreholes. More particularly, the invention is directed to preventing shales from caving into a borehole during the drilling thereof with a gaseous circulating fluid. In the latter respect, the invention proves particularly effective to protect shales from the action of water encountered during gas-drilling operations. The term "gas-drilling" as used herein refers to drilling operations wherein a gaseous circulating fluid is used. In such operations the circulated fluid is generally air or natural gas.

During the drilling of wells, the boreholes often encounter geological formations known as "heaving shale formations" or, more simply, "heaving shale" or sometimes "caving shale." The term "heaving shale" or the like denotes shale strata which do not remain consolidated during drilling operations. It is commonly observed that, in gas-drilling operations, such shales start to cave into the borehole after a water-producing formation has been encountered. After the shales have been contacted with water, usually in the form of droplets or foam entrained in the gas returns, the shales are apt to cave in at any time. Where this heaving or caving occurs during drilling, circulation of cuttings from the borehole will be impeded, if not prevented, and the shale may bind or pinch the drill stem, thus preventing its rotation and possibly resulting in its failure. In cases where the caving occurs after the termination of drilling, the caved shale may prevent the removal of the drill string or, if the string has already been removed, will necessitate the redrilling of the borehole to remove the caved shale.

In the case of "mud-drilling," or any drilling operation in which a liquid circulating fluid is used, water flow from porous formations such as limestones, or sandstones, can be avoided by maintaining a hydrostatic head within the borehole that is higher than the fluid pressure in the formation. Furthermore, chemical sealing means are sometimes used to protect shaley formations encountered by the borehole from the action of water-base muds. In addition, caving is less significant in mud-drilling operations because of the ability of the flow of mud to carry the cavings out of the hole, and thus keep the hole clean and the drill pipe free.

Drilling procedures utilizing gaseous circulating fluids are becoming increasingly popular in the well drilling art. The popularity of this drilling method results largely from the increased drilling rates that are attained. However, the advantages of gas-drilling operations are accompanied by difficulties not encountered in drilling operations utilizing liquid circulating fluids. Namely, when drilling with a gaseous circulating fluid it often is impossible, as a practical matter, to maintain a high hydrostatic head to prevent the influx of formation waters into the borehole. Such waters are, therefore, adsorbed by shales exposed along the borehole, causing them to hydrate or fracture, thus initiating caving. It is noted, however, that unless water-producing formations are encountered, the washing of the borehole by gaseous circulating fluids pre-

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sents no serious problem since the relatively dry circulating gases have no appreciable effect on formations, such as shale, encountered by the borehole.

Thus, the primary cause of shale caving during gas-drilling operations is the influx of formation water into the void created by the borehole. This results from the fact that it is generally impracticable, if not impossible, to maintain the borehole under a sufficient hydrostatic head to prevent such an influx. The influx of water and the resultant caving of shale are particularly damaging in gas-drilling operations because of the low carrying capacity of a gas which makes it difficult to carry the cavings out of the hole. Thus, the cavings may accumulate in the hole and bind or pinch the drill stem, preventing its rotation and possibly resulting in its failure.

Therefore, it can be seen that the caving of shale and the influx of water into boreholes during gas-drilling operations presents new problems neither present nor solved by the expedients used in the previously described drilling operations utilizing liquid circulating fluids. An object of the present invention is effectively to prevent shale formations from caving into boreholes formed by gas-drilling operations. A further object of the invention is to protect the walls of a gas-filled borehole from the action of formation waters which enter the borehole with a minimum of expense. In the latter respect, it is an object of the invention to protect the walls of a gas-filled borehole without utilizing casing strings for this purpose. Yet another object of the invention is to provide a means of protecting the borehole from the action of formation waters and resultant caving of shale during gas-drilling operations with a minimum of interruptions and/or interference with the drilling operations.

Basically, the present invention provides a method of preventing shale from caving into a borehole filled with a gaseous fluid, such as the circulating fluid used in gas- or air-drilling operations. The method comprises introducing a solution of an alkali metal silicate into the borehole and contacting the walls of the borehole with said solution to deposit the alkali metal silicate on said walls. As will be developed subsequently, the solution of an alkali metal silicate, such as sodium silicate, may be introduced into the borehole in various forms and, accordingly, the manipulative steps used to contact the walls with said solution also vary. The exact nature of the invention and the enumerated and other objects will become apparent from the following detailed description.

To determine the effect of the deposited material on shale formations, laboratory tests were conducted wherein shale was treated with various concentrations of sodium silicate. In these tests, pieces of shale 1½ inches in diameter and ½ inch thick were maintained under a constant vertical intergranular load by means of a hydraulically actuated piston. The annulus surrounding the specimen was then, alternatively, filled with sodium chloride brine and sodium silicate to contact the specimen with either of the solutions. When sodium chloride brine was first introduced into the annulus surrounding the specimen, failure occurred in a comparatively short time. However, when sodium silicate was introduced first and then replaced by brine, the failure times in the brine were much longer. Some typical results of the laboratory tests are set forward in the following table. The ratio of sodium oxide to silicon dioxide in the various sodium silicates specified in the table are set forth therebelow.

INFLUENCE OF SODIUM SILICATE ON FAILING TIME OF SHALES IMMERSSED IN BRINE

Shale identification: (1) depth at which specimen was taken (2) failing-load in air	Specimen No.	Load pressure, p.s.i.	Pretreatment under load (1 hour duration)	Failing time, mins. after introduction of 5.8% Brine
(1) 4,846 feet. (2) 6,200 p.s.i.	1	4,700	None.....	1
	2	4,700	66% Na Silicate D (plus) 34% of 5.8% Brine.....	180
	3	4,700	do.....	5
	4	4,700	Waterglass (40° Bé.).....	24
	5	2,600	None.....	64
	6	2,600	85% Waterglass plus 15% of 5.8% Brine.....	5,347
(1) 9,188 feet. (2) 8,000 p.s.i.	7	4,700	None.....	8
	8	4,700	85% Waterglass plus 15% of 5.8% Brine.....	56
	9	3,500	None.....	12
	10	3,500	Waterglass (40° Bé.).....	8
	11	3,500	92% Waterglass plus 8% of 12% Brine.....	4,297
	12	3,500	85% Waterglass plus 15% of 12% Brine.....	126
	13	3,500	66% Waterglass plus 34% of 12% Brine.....	86
	14	3,500	66% Na Silicate D plus 34% of 12% Brine.....	23
(1) 9,208 feet. (2) 15,000 p.s.i.	15	10,000	None.....	12
	16	10,000	92% Waterglass plus 8% of 12% Brine.....	1,330
	17	10,000	85% Waterglass plus 15% of 12% Brine.....	174
(1) 2,031 feet. (2) 6,200 p.s.i.	18	4,700	None.....	1
	19	4,700	85% Waterglass plus 14% of 12% Brine.....	249

1 This specimen was exposed to brine foam instead of liquid brine.
Na Silicate D—Na₂O·2SiO₂.
Waterglass—Na₂O·3.22SiO₂.
Waterglass (40° Baumé)—Na₂O·3.22SiO₂.

The brine used in the laboratory test was a solution of sodium chloride in water. However, the invention is not limited in its effectiveness to any particular brine. Furthermore, the particular alkali metal silicate solutions used in the laboratory test are not intended to be limiting on the invention. In general, the alkali metal silicate solution can include any liquid solution containing from about 10 to 95 percent by weight of silicates of the formula M₂O·SiO₂, where M is an alkali metal and the ratios of the oxides range from about 2M₂O·SiO₂ to M₂O·4SiO₂. Suitable sodium and potassium silicates are commercially available both as solids and liquids in proportions such as 2.0Na₂O·SiO₂ to Na₂O·3.75SiO₂ and K₂O·2.1SiO₂ to K₂O·2.5SiO₂. Water solutions of the alkali metal silicates are particularly suitable.

The significance of most of the information in the foregoing table is evident from the headings. One point which perhaps needs some clarification is the second item listed under the shale identification column. The failing-load in air for each type of shale was measured by loading it in the manner described previously. The particular procedure used to determine the load causing failure was to increase the pressure applied to the sample in increments of 400 p.s.i. As the ultimate strength was approached, the load was held constant for 10 minutes. If failure had not occurred in this time period, the load was increased by another 400 p.s.i. with the cycle repeated until the specimen shattered.

From the information presented in the table, it is clear that, in all but two cases, treatment of the loaded specimen with silicate solution before exposure to brine produced large increases in the failing time. The two cases for which significant improvement did not result were specimens 10 and 14, in which 100% waterglass and 66% sodium silicate D, respectively, were used. The other results obtained with varying concentrations of waterglass or sodium silicate indicate that a composition close to 90% waterglass may be optimum. Other tests of a similar nature showed that effectiveness of the sodium silicate decreased at concentrations less than 50% and solutions containing less than 10% sodium silicate were quite ineffective.

The actual failing time was greatly dependent upon the load applied (compare samples 8 and 12), the time decreasing sharply as the load approached that causing failure in air. For all samples and loading conditions studied (up to 75% of the load which would cause failure in air), a one hour treatment using the optimum

composition of silicate produced large increases in the failure time.

At this point it is again noted that the present invention is directed to a method of preventing shale from caving into boreholes being formed by gas drilling operations. Although the subsequent disclosure will develop alternative applications of the invention, in the form of procedures, it is not intended that the invention be limited to these specific alternatives.

In application of the invention, gas-drilling is commenced in a conventional manner, typically with the use of a rotary drill being driven by a drill string. Drilling may be continued in this manner until the borehole has encountered a shale formation. The presence of shale formations may be determined in any of the ways well known to those skilled in the drilling arts. For example, the determination could be made through a knowledge of the geology of the area being drilled or through conventional logging means. It is also possible that shale encountered by the borehole might be detected by the drill cuttings carried to the surface by the circulating gas being used in the drilling operation.

After a borehole has encountered a shale formation, the present invention is applied, either before or after the borehole has encountered a formation from which water flows into the hole. In applying the present invention, the shale-containing portion of the borehole wall is contacted with an alkali metal silicate solution, such as an aqueous solution of sodium silicate. This contacting can be effected by any feasible procedure for wetting that portion of the wall with the silicate solution. Preferably, contacting is effected before water has started to flow into the borehole. It can be effected by simply adding sufficient silicate solution to the circulating gas stream. Ideally, the drilling is interrupted as soon as the shale has been drilled through, sufficient silicate solution is introduced to coat the sides of the borehole up to the top of the shale, and then the excess silicate solution is removed from the borehole by the resumption of the gas circulation.

A preferred practical procedure involves the following steps:

(1) Drilling is suspended and the hole is blown free of solids and water.

(2) Gas-circulation is terminated and aqueous sodium silicate is poured into the well, either through the drill string or through the annulus. The amount used is based on the area of borehole wall to be wetted by the solu-

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tion. For example, in a hole cut smoothly to gage, the wall would be wetted by 0.08 pound of 90-percent aqueous waterglass per square foot of the circumferential surface on a cylinder of the hole diameter. It is usually preferable to use an excess.

(3) Gas-circulation is resumed at a rate adjusted to lift the silicate solution from the bottom and distribute it along the wall. Most of the excess silicate solution will be carried out of the hole and discharged, but it may be desirable to use water and foaming agent along with the input gas to assist in the removal of the excess liquid.

In numerous situations it may be desirable to simply fill the hole with sodium silicate solution, or at least to use a large slug, such as a 50-barrel slug, and then recover the unadsorbed solution when it is gas-lifted to the surface by the resumed circulation of gas. Since a coating of alkali metal silicate will be gradually worn away or washed off during a drilling operation, the treatment should be repeated at intervals such as one treatment per day or one per hour.

Example of field application

In drilling a well, using air as the circulating fluid, to an objective depth below 5500 feet, the upper portion of the borehole was cased to a depth of 1028 feet. A shale formation was encountered in the course of extending the hole to 4450 feet, where a water-producing formation was encountered. At this depth, drilling was interrupted and the hole was blown free of solids and water. The air circulation was temporarily interrupted while a 10-barrel slug of aqueous 90 percent waterglass was dumped into the drill string. The air-circulation was resumed and built up to its full rate over a period of about 15 minutes. In about 20 minutes, the well was blown substantially free of excess silicate solution. Drilling was continued to the objective depth with the above type of silicate solution treatment (using 2-barrel slugs of the silicate solution) being repeated daily. In contrast to most drilling experiences in similar formation, no caving was experienced. The well was drilled at a rate significantly greater than could have been obtained by drilling through the same interval with a liquid circulating fluid.

To summarize, the present invention provides a means whereby boreholes may be formed with gas-drilling operations even though they traverse water-laden formations. Thus, the invention provides a means whereby gas drilling proves practical under situations which heretofore seemed unfeasible. The invention is not, however, intended to be limited to the specific examples set forth in the description. For example, the amount and

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the concentrations of the alkali metal silicate solution used are merely intended for purpose of explanation and should not be considered limiting. Therefore, various changes in the details of the described methods may be made, within the scope of the appended claims, without departing from the spirit of the invention.

I claim as my invention:

1. A method of preventing subterranean shale formation from caving into boreholes penetrating the same when drilling with a gaseous circulating fluid comprising:
 - (a) interrupting drilling operations in said borehole when a shale formation has been penetrated and prior to encountering a formation from which water flows into said borehole;
 - (b) blowing said borehole free of water and solid particles;
 - (c) introducing an aqueous solution of an alkali metal silica into said borehole whereby said shale formation exposed in the borehole is contacted by said solution; and
 - (d) subsequently blowing said borehole free of remaining aqueous solution prior to resuming drilling operations.
2. A method according to claim 1 in which the treatment is repeated prior to resuming drilling.
3. A method according to claim 1 wherein the alkali metal silicate is sodium silicate.
4. A method according to claim 1 wherein the solution of alkali metal silicate is introduced into the borehole in the form of a slug.
5. A method according to claim 4 wherein the walls of the borehole are contacted with alkali metal silicate by circulating the slug through the borehole.
6. A method according to claim 4 wherein the slug substantially fills the area of the borehole that is subject to caving.

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