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REDUCTION OF FORMATION DAMAGE DUE TO DRILLING MUDS

Prof. Dr. Akram H. Al-Hitti **Prof. Dr. Samir A. Al-Assaf** **Mr. Dhorgham S. Abrahim**
Baghdad University
Engineering College
Petroleum Engineering Department

ABSTRACT

An experimental study has been carried out to investigate the possible reduction of formation damage that is result from drilling muds. This was accomplished through making a bridging system with different barite additions 70, 140, 200, 280 lb/bbl to fresh water mud. This bridging system creates an effective sealing of impermeable filter cake, thereby inhibiting continual losses of small solids and mud filtrate into the formation.

The study indicates that all the muds, which were used, have the ability to damage the petrophysical properties of formation, but some additives to mud reduce the damage in petrophysical properties. In addition, it is found that minimum permeability damage can be obtained when the particles of drilling mud are larger than the pore size of formation because no internal mud cake is created. Finally, the relationship between the pore size distribution of the core samples and particle size distribution of drilling muds becomes better and the impairment is reduced, when the particle size distribution in the mud is matched to the pore entry size distribution within the rock; so that each pore entry could be bridged as permitted by the particular fluid flow rate involved.

الخلاصة

أجريت دراسة مختبرية لبحث إمكانية تقليل ضرر التكوين الناتج عن استخدام أطيان الحفر. تم إنجاز هذا من خلال عمل منظومة تجسير مع مختلف إضافات البرايت (70،140،200،280 رطل/برميل) إلى طين الماء العذب. هذه المنظومة تولد غلق محكم لكعكة الطين القليلة النفاذة ، وبذلك تمنع الفقدان المستمر للقطع الصغيرة وراشح الطين داخل التكوين.

تبين هذه الدراسة أن كل الأطيان التي استخدمت لها القابلية على إلحاق الضرر بالمواصفات البتروفيزياوية للتكوين. لكن بعض الإضافات إلى هذه الأطيان قلل الضرر في هذه المواصفات. إضافة إلى إن اقل ضرر بنفاذية التكوين ممكن الحصول عليه عندما تكون جزيئات طين الحفر اكبر من حجم مسامات التكوين بسبب عدم تكون طبقة كعكة طين داخل هذه المسامات. و أخيراً العلاقة بين توزيع الحجوم المسامية للنماذج الصخرية وتوزيع حجوم الجزيئات لطين الحفر، تصبح افضل والضرر يقل عندما يتطابق التوزيعان، حيث كل فتحة للمسام ستغلق بجزيئة خلال جريان المائع.

KEY WORDS
Drilling muds, formation damage, filter coke, additives

INTRODUCTION

Drilling operations always expose a formation to drilling fluids, which may impair its productive capacity. This reduction in productivity is termed formation damage.

There are several important main functions of drilling muds in oil well drilling engineering. The main disadvantage of using drilling fluids is related to formation damage. The selection of suitable mud type for a given reservoir may be critical. Most investigations proved the effects of drilling muds on rock permeability and formation damage due to the selection of unsuitable mud. This may be due to the interactions between the drilling mud filtrate with the formation minerals in the producing horizons, and the penetration of drilling fluid particles into the formation which cause pore plugging of the porous media.

Drilling mud lays down a highly effective filter cake which, once established, filters out the finest particles, so that only filtrate passes from the hole into the formation. Mud solids, therefore, can only invade the formation before the filter cake is fully formed, (during the mud spurt). Spurt loss is being initiated bridging by solids and filter cake formation. Downhole, therefore, the extent to which mud solids invade a porous formation depends on the amount of mud spurt, and that in turn depends mainly on the amount of primary bridging particles in the mud. This problem can be obviated in many situations by appropriate design of a fluid system. In addition the appropriate size distribution of the granular bridging agents to create an effective sealing of impermeable filter cake, which deposits very rapidly on the face of the formation, thereby inhibiting continual losses of small solids and potentially damaging mud filtrate into the formation. Illustrated in **Fig. (1).**

A bridge may be initiated when two large particles start to move into an opening at the same time and lodge against each other. Other smaller particles may bridge the openings between the larger, previously bridged particles. If the proper particle sizes are present, this process may continue until the openings become too small for any contained solids to penetrate. It is at this time that only the filtrate flows through the filter cake (Ismail, A.R.and J.M. , 1994) Illustrated in

It is possible to minimize solids invasion and formation impairment by adding bridging material to the muds. This bridging material is chooses by matching its size to the formation-rock pore size. Two rules are used for selecting the size of concentration of bridging materials.(Abrams, A., 1977)

1- The median particle size of the bridging additive should be equal to or slightly greater than one-third the median pore size of the formation.
2- The concentration of the bridging size solids must be at least 5 percent by volume of the solids in the final mud mix.

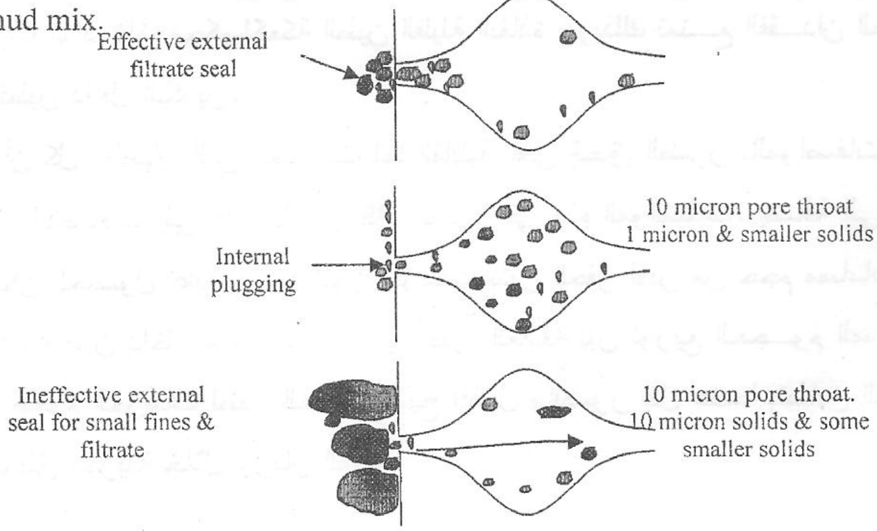

Fig. (1) Solids invasion into a homogenous pore system.

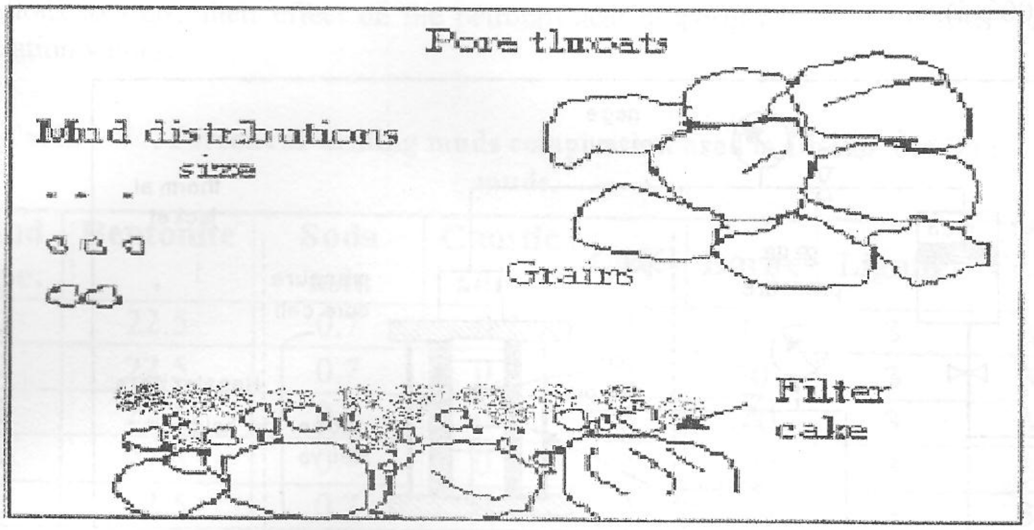

Fig. (2) Representation of how filter cake is formed on a porous rock. The larger particles are lodged first; the smaller particles fill in the spaces

EXPERIMENTAL WORK

In this study, the core samples were provided for Zubair formation southern and northern Rumaila and Zubair fields. A study was carried out to treat cores for seven wells with different drilling muds, which are prepared, so that it approximately similar to that used in the fields when were drilled. The reservoir conditions for these cores were prepared as close as possible to the actual borehole condition; namely, hydrostatic pressure, formation pressure, and hole temperature.

About 100 core plugs were prepared from seven wells and for three fields of the Zubair formation from depths of over (3000) meters. The core plugs were cut in size to about one inch (2.54 centimeters) diameter and three centimeters length. They were cleaned, dried, then subjected to petrophysical tests, which were (porosity, permeability, saturation, and pore size distribution by the capillary pressure).

The prepared drilling muds were subjected to several tests as follows: - mud density test, sand content test, yield point, plastic viscosity, filter pressure, mud cake thickness, and particle size distribution by soil hydrometer. Several treatments for used drilling mud by barite additions were made to improve their properties and give maximum return oil permeability.

The equation for calculating percent of permeability damage is: (Keelan, D.K and Koepf, E.H., 1977)

$$\% \text{ Permeability damage} = \frac{ka - kd}{ka} * 100 \qquad \dots(1)$$

Experimental Rig

A laboratory rig is prepared for filtration test. It consists of a core holder similar to Hassler core holder, which can accommodate a core plug of 1-inch diameter .The core holder tolerates high pressure and temperature. The core is placed inside a rubber sleeve and the two sealed together by means of overburden pressure applied by hydraulic pump. Nitrogen gas pressure is used to push the mud through the core at constant pressure for one hour. This pressure is considered as the differential pressure between hydrostatic and formation pressures. Filtration is collected in a micro cylinder to compute the cumulative mass volume of filtrate with time record. **Fig. (3)** shows a schematic diagram of the Hassler core holder. The parameters that were kept constant in this study are the differential pressure (300-psi), the formation temperature (200 °F), and the confining pressure (5000 psi).

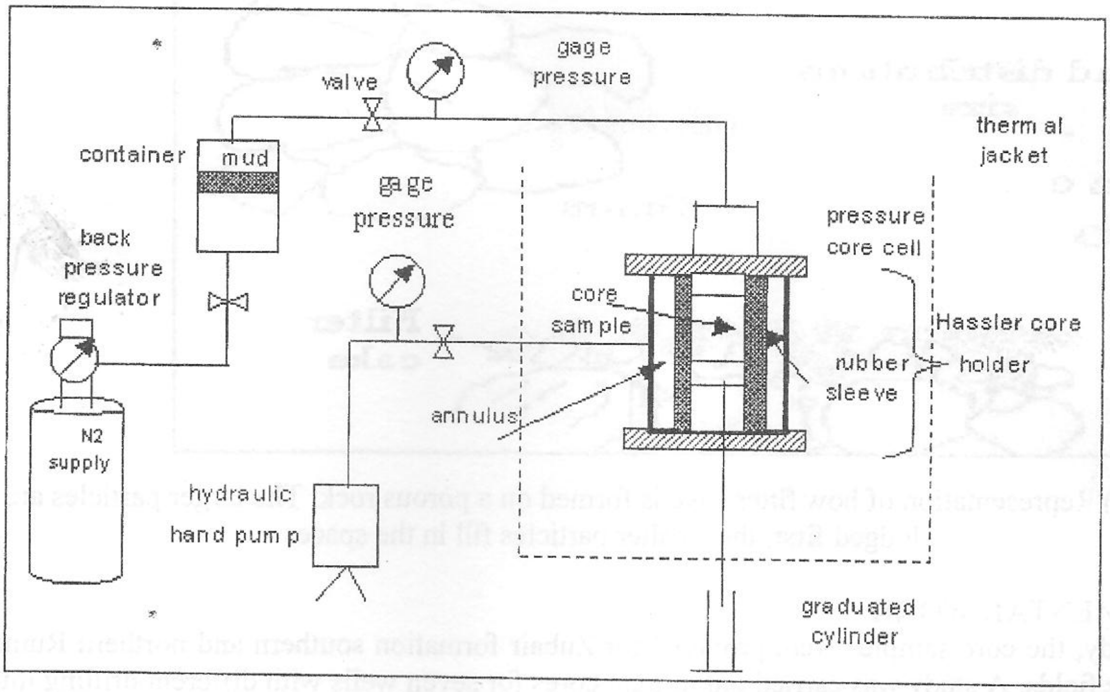

Fig. (3) Schematic diagram of the experimental apparatus

Experimental Procedure

All essential calibrations for pumps, pressure gauges and other devices are carried out before starting up any experiment. The system is also evacuated completely from air before any run. The core is evacuated over a period of 12 hours, to a vacuum of about atmospheric pressure. The core is then saturated with NaCl solution (formation water).

The experiments were carried out as follows:

1- The absolute permeability is measured by Ruska liquid permeameter with formation water.
2- Effective permeability of the core to gas oil is determined by flowing it at constant pressure before the mud was exposed.
3- The plug is mounted in the Hassler core holder and the pressure is raised to the confining pressure (5000-psi). This represents the net overburden pressure.
4- The Hassler core holder is covered with thermal jacket to raise the temperature to reservoir formation temperature 200 °F.
5- The core is damaged by mud penetrating across its face at a constant differential pressure of 300 psi, using nitrogen gas pressure, for duration of one hour.
6- The sample left for one day to backflow with gas oil following a pressure as that used in the gas oil drive step until no further recovery in permeability is obtained.
7- By comparison between the effective permeability before and after mud exposed the percent of permeability damage may be determined.

DISSCUSION OF THE EXPIRIMENTAL RESULTS

Several experiments have been carried out to investigate the major controlling factors of formation damage by drilling muds. Different mud treatments are used to examine the possibility of reducing its damaging effect.

Barite plays an important role on the physical properties of muds. It addition increases mud filtrate because of its ability to bridge filter paper and formation; also it increases mud density, mud viscosity, mud cake thickness, and percent of sand content. This may be noticed in

Tables (1 and 2). The core samples are exposed to various combinations of muds with different additions to study their effect on the petrophysical properties such as effective permeability and saturation values.

Table 1 . Percent of drilling muds composition used in Lb./bbl for (FcLs) muds.

Mud type.	Bentonite .	Soda ash.	Caustic soda.	*CMC*	Barite	Lignite	FcLs
1	22.5	0.7	0.7	2	0	3	3
2	22.5	0.7	0.7	2	70	3	3
3	22.5	0.7	0.7	2	140	3	3
4	22.5	0.7	0.7	2	200	3	3
5	22.5	0.7	0.7	2	280	3	3

Table 2 Characteristics and Composition of drilling muds studied for (FcLs) muds.

Barite add in lb/bbl	Sand content in %	θ300 (rpm)	θ600 (rpm)	Yp (lb/100ft^2)	M.cake thick. (mm)	PV (cp)	Density in ppg	Mud filtrate in (cc).
0	0.5	17	29	5	<0.5	12	8.6	14
70	2	24	38	10	1	14	9.6	9.6
140	2.6	28	45	11	2	17	10.6	10.5
200	2.75	29.5	47.5	11.5	2.7	18	11.4	11.5
280	3	33	52	14	4	19	12.2	11.8

Bridging of Fresh Water Mud

Bridging systems are one of the most conventional methods used in drilling fluids to minimize formation damage due to invasion of mud solids and filtrates. Five combinations of muds consisting of 0, 70, 140, 200, and 280 lb/bbl of barite were used. It was used to reduce permeability damage and to know the best concentration of barite that has the ability to reduce the damage. **Table (1)** gives the composition of these combinations of muds.

Several conditions are necessary to be studied to investigate the factors affecting the success of this test.

Mud Cake Thickness Test

This factor also was examined to study the effect of barite addition on the mud cake thickness, keeping in mind that any increase in this factor may cause pipe-sticking problem. **Table (2)** and **Fig. (4)** indicates that with the increase of barite additions, the mud cake thickness increases.

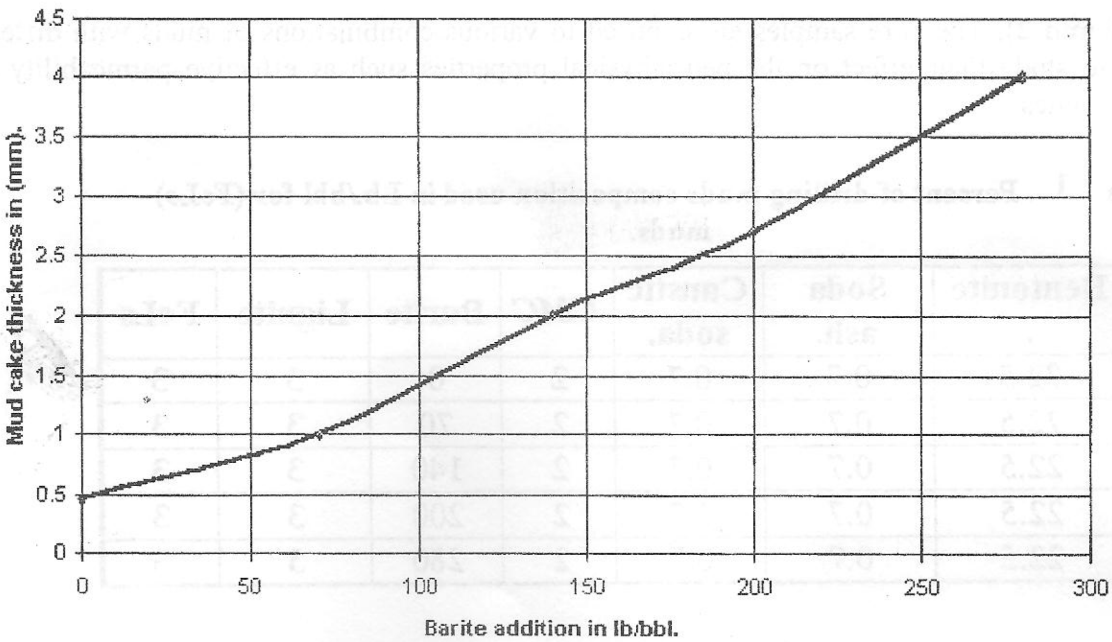

Fig. (4) Mud cake thickness and barite additions

Effect of Particle Size Distribution of the Muds

One of the important relationships that must be studied, is the relationship between the pore size distribution of the core samples, which was measured by capillary pressure method, and particle size distribution of drilling muds, which was measured by a soil hydrometer.
Figs. (5) through (9) show these relationships for different core samples permeabilities and for a various barite additions. **Fig. (5)** shows that the relationship between the pore and particle size distribution, seems weak because there is no barite added. The particle size distributions of colloidal particles have a large percent and reach to 77%; namely high range of mud particle size distribution compared with the pore size distribution for different core permeabilities. The colloidal particles caused high permeability impairment because of their ability to pass through the core pores openings. **Figs. (8, and 9)** show sufficient overlap and give a good relationship because of the distribution of particles in mud attends with pore size of core. Also narrow range of particle distributions of mud from (1-80) microns. **Figs. (6 and 7)** show moderate effect.

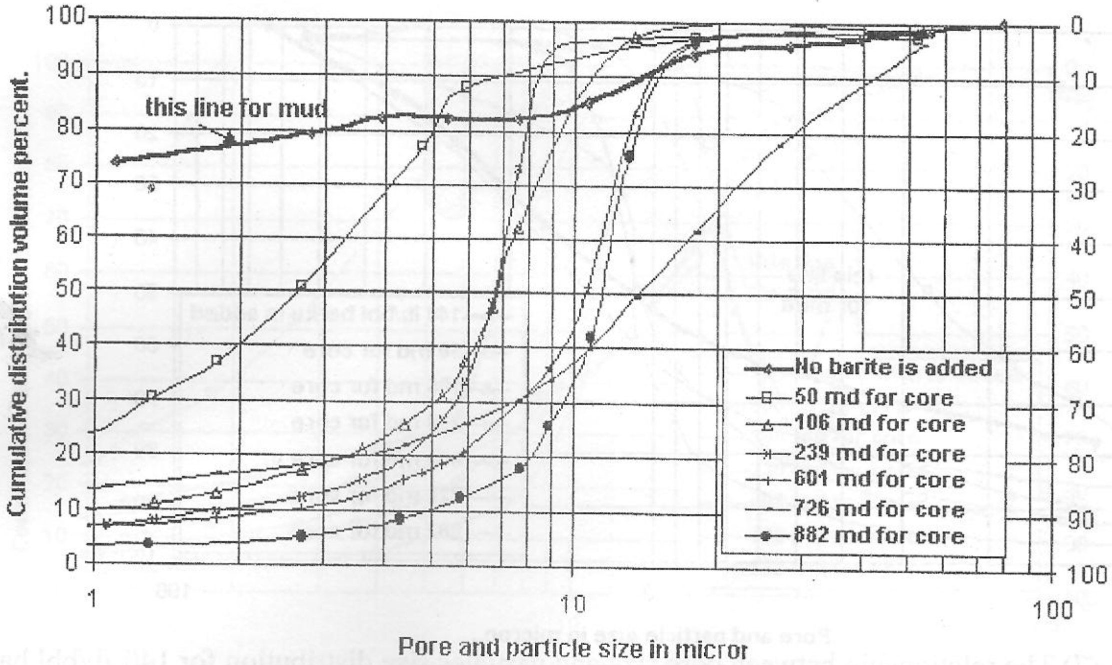

Fig. (5) The relationship between pore size and particles size distribution for no barite addition

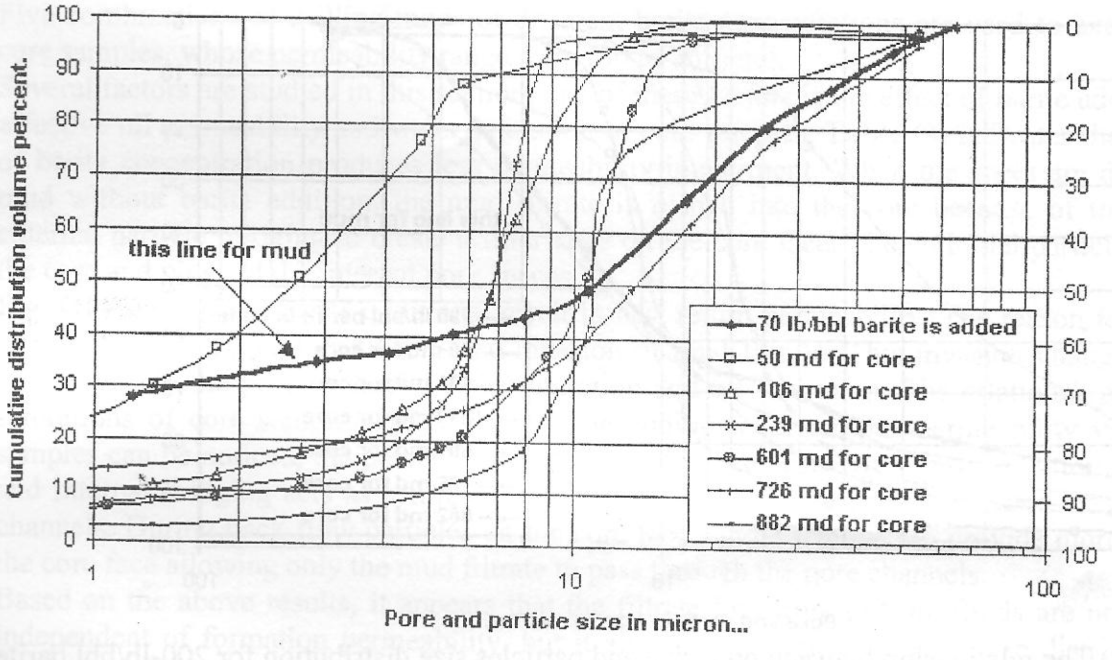

Fig. (6) The relationship between pore size and particles size distribution for 70-lb/bbl barite addition

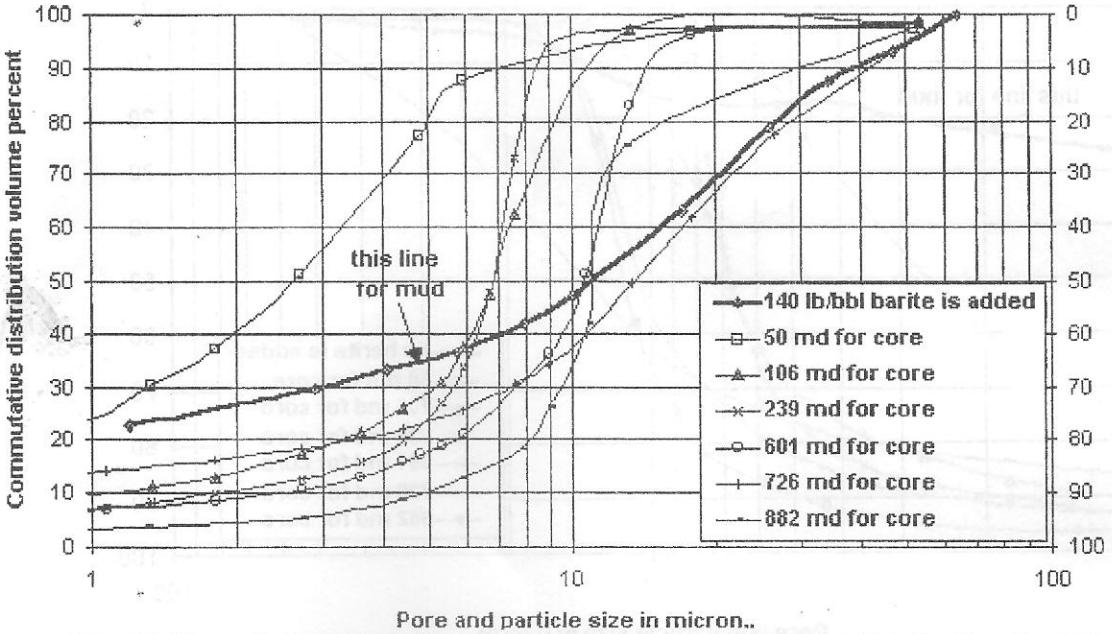

Fig. (7) The relationship between pore size and particles size distribution for 140-lb/bbl barite addition

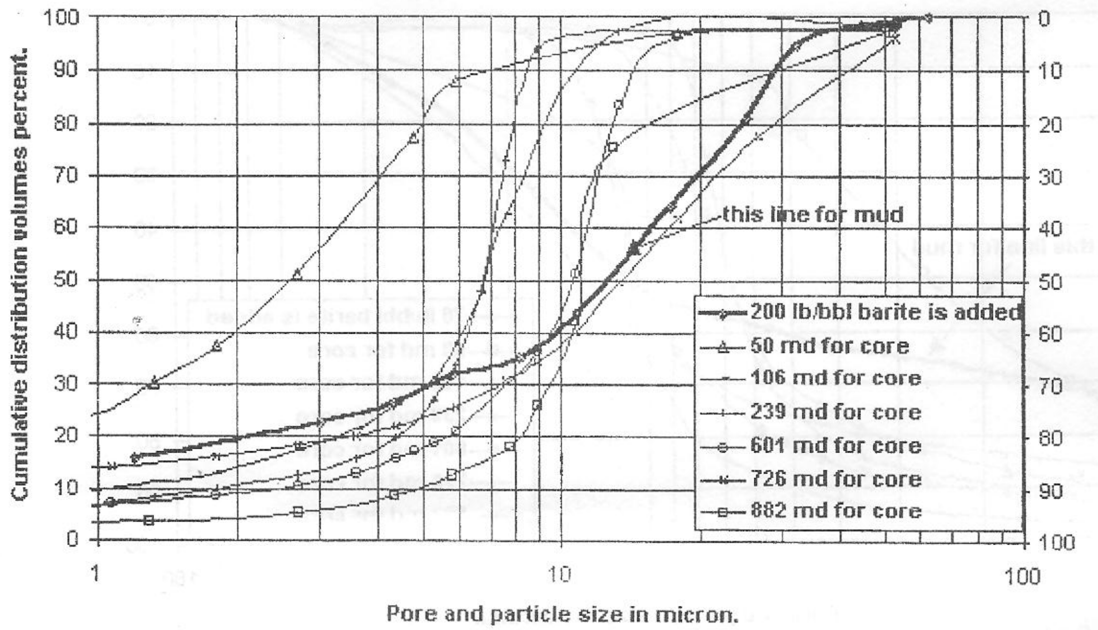

Fig. (8) The relationship between pore size and particles size distribution for 200-lb/bbl barite addition

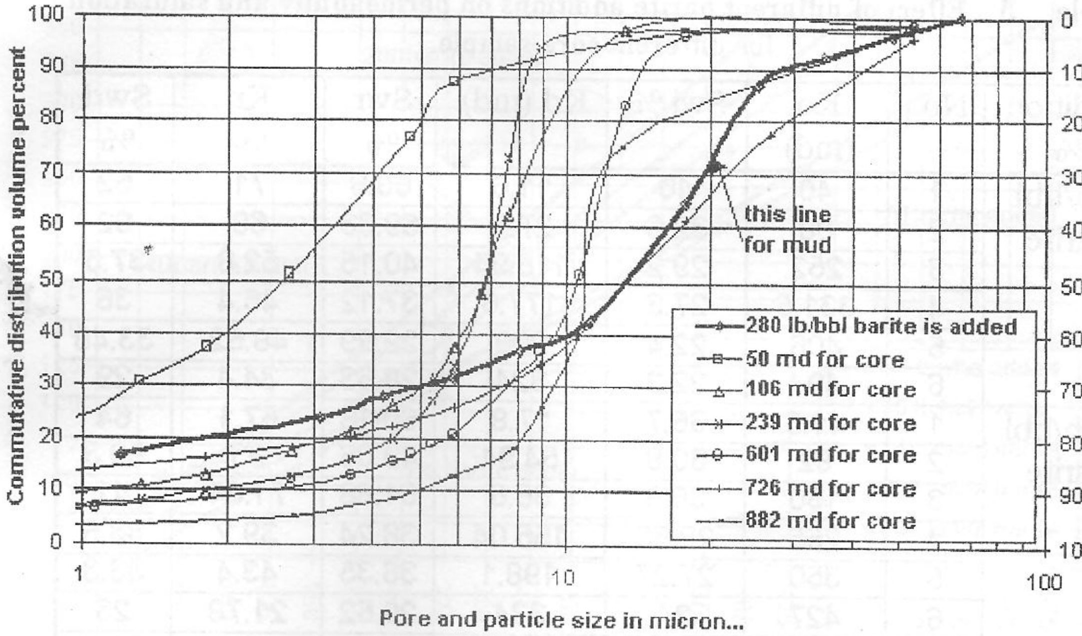

Fig. (9) The relationship between pore size and particles size distribution for 280-lb/bbl barite addition

Barite Bridging Core Samples.

Five combinations of drilling muds of different barite concentrations are used to examine several core samples, whose permeability range from (36 to 568) md.

Several factors are studied in this section; one of these factors is the effect of barite additions on the effective oil permeability and water saturation of core samples. **Table (3)** indicates that an increase of barite concentration produces less permeability impairment. When the cores are damaged with mud without barite addition, the mud filtrate is rushed into the core because of the absence of external particle bridging to create a filter cake on the core face. The colloidal particles penetrated the core and plugged the internal pore spaces.

Fig. (10) shows how barite additions, result in best return permeability. The reason for the change in the effective oil permeability is the invasion of mud filtrate. This invasion changed the liquid percent inside the pores, namely water saturation and oil saturation. The relationship between the saturations of core samples and various barite additions for various permeability values of core samples can be noticed, the percent of water saturation decreased with barite addition. The external and internal bridging acts as a filter to reduce the amount of colloidal materials to enter the pore channels. During back flow particles on the core face can be removed to provide more openings in the core face allowing only the mud filtrate to pass through the pore channels.

Based on the above results, it appears that the filtrate loss from drilling fluids are not completely independent of formation permeability, but it also depends upon the pore size distribution of the medium and the size distribution of the particles in the drilling fluid as well. According to 'Nowak' (Nowak, T.J. and Krueger, R.F., 1951) if the particle size distribution in the mud is such that good bridging occurs on formations of all permeabilities, the filtrate loss will be essentially independent of rock permeability.

Table 3 . Effect of different barite additions on permeability and saturation for different core sample.

Addition %	No.	Ko (md)	Swi %	Kd (md)	Swr %	Kr %	Swd %
0 lb/bbl barite	1	40	40	11.6	60.8	71	52
	2	88	32.6	27.5	59.33	68	82
	3	252	29.2	118.94	40.15	52.8	37.5
	4	331.5	27.3	177.6	37.12	46.4	36
	5	406	22.4	209	29.89	48.52	33.48
	6	494	22.2	324	28.63	34.4	29
70 lb/bbl barite	1	41.5	36.7	17.8	60.18	57.1	64
	2	82	30.8	54.94	49.06	33	59.3
	3	130	36.8	36.6	51.88	71.84	41
	4	255	28.65	155.04	38.24	39.2	33.5
	5	350	27.27	198.1	36.35	43.4	33.3
	6	427	24	334	29.52	21.78	23
	7	568	18.9	329	22.9	42	21.2
140 lb/bbl barite	1	50	33	15	47	70	42.42
	2	84.5	32	53	42.75	37.3	33.6
	3	189.5	27.3	98	35.92	48.28	31.6
	4	288.2	28	218	38.5	24.35	37.5
	5	389.4	25.2	273.6	32.5	29.7	29
	6	448	23.1	343.4	27.58	23.3	19.4
200 lb/bbl barite	1	36	37.6	16.82	51.13	53.27	36
	2	80.6	34	64.48	43.27	20	27.27
	3	149.3	30	143	39	4.2	30
	4	276	28	177.98	36.68	35.5	31
	5	382	29.3	278.77	36.99	27	26.26
	6	480	23.8	356.64	28.79	25.7	21
280 lb/bbl barite	1	41.2	36	22.66	46.8	45	30
	2	63	36	54	44.74	14.28	24.3
	3	100	32	71	38.26	29	19.56
	4	229.6	26	177.9	31.33	22.5	20.5
	5	303.8	27.1	277	30.97	8.82	14.3
	6	402.6	26.3	326.4	31	18.92	17.93

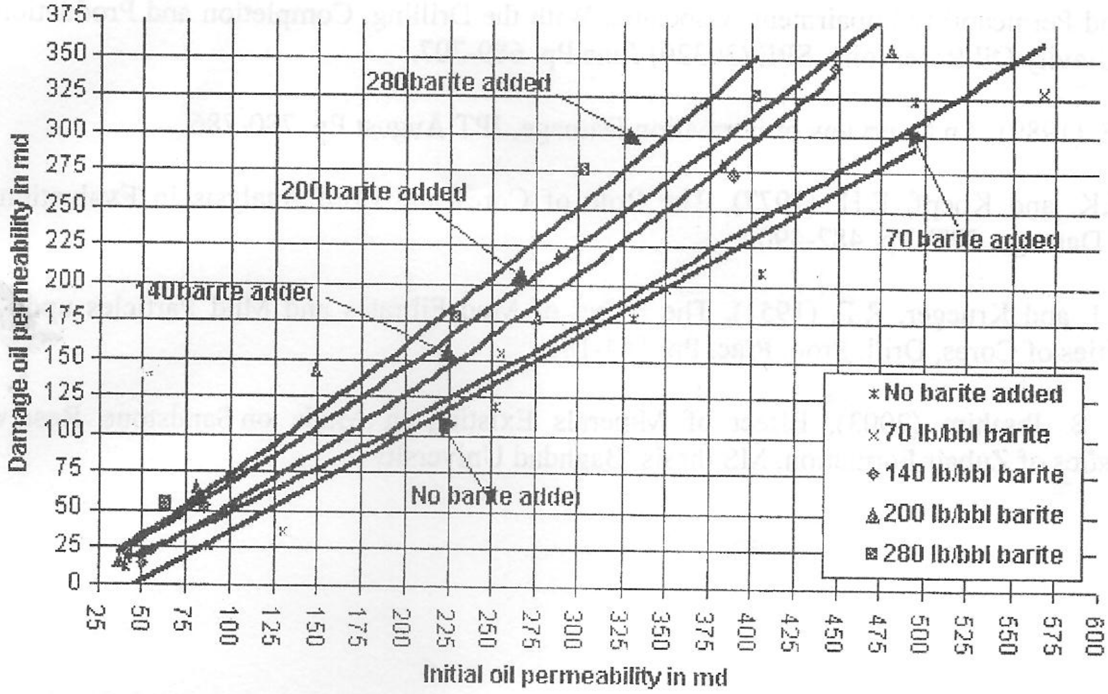

Fig. (10) The relationship between initial oil permeability and damage oil permeability for different barite concentrations.

CONCLUSIONS

1- Minimum permeability damage can be obtained when the particles of drilling mud are larger than the pore size of formation because no internal mud cake is created.
2- All the muds, which were used, have the ability to damage the petrophysical properties of formation, but some additives to the mud may reduce the petrophysical properties.
3- The relationship between the pore size distribution of the core samples and particle size distribution of drilling muds becomes better and the impairment is reduced when the particle size distribution in the mud is matched to the pore entry size distribution within the rock.

NOMENCLATURE

Ka= Permeability before mud damage, md.
Kd= Permeability after mud damage, md.
Yp= Yield point, lb/100 ft^2
PV= Plastic viscosity, cp.
Θ_{300}= Dial reading at a speed 300 rpm
Θ_{600}= Dial reading at a speed 600 rpm

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