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The Effect of Proper Selection of Drilling Fluid on Drilling Operation in Janbour Field

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Abstract

Selecting a proper drilling fluid has always been a difficult task to overcome by drilling mud engineers. There are some constraints such as formation lithology encountered, the range of temperature and pressure of the formation, environmental considerations and cost that play a paramount role in the selection of the proper drilling fluid. In this paper, well data from Janbour Oilfield was used and analyzed. The concentration lies on the second section of the well since it shows to be the most problematic one. Salt saturated mud was designed in lab and compared with the mud used to drill the second section of the well. The final result of this paper indicates that the designed salt saturated mud is superior to the mud used to drill the section.

Keywords: Drilling Fluid; Oil Based Mud; Salt Saturated Mud; Drilling Operation; Environmental Considerations.

1. Introduction

Drilling fluid plays an important role in the process of completing a well and its overall cost. Historically, water was the only drilling fluid which was used to facilitate in the drilling operation. The first function done by drilling fluid was to carry the cuttings up to the surface from the bottom of the hole [1]. Many drilling problems such as lost circulation, stuck pipe, shale heaving and many more are influenced by drilling fluid properties and can be prevented eventually. Drilling fluids cover almost one fifth of the overall cost of drilling.

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They must be easy and simple to use, environmentally & ecologically friendly and not too expensive. The drilling fluids are usually designed to do numerous functions at once. They are required to suspend and remove cuttings around the drill bit and well bore, cool and lubricate the drill bit and the drill string, control down-hole pressure, evaluate the formation pressure and seal permeable formation [2,3].

There are some governing agents that affect the proper selection of the drilling fluid. The type of formation encountered, temperature and pressure of the formation, ecological & environmental considerations and cost need to be put into consideration when a proper selection of the drilling fluid is required [4,5]. There are basically three types of drilling fluid that can be used in any mud system. Water base mud (WBM) comprises water as the continuous phase and is the most commonly used drilling fluid. Oil base mud (OBM) consists of oil as the continuous phase and diesel oil is the one used largely. Gas is composed of either air or natural gas and foaming agents are sometimes used [1,6,7]. Resultantly, choosing an appropriate type of drilling fluid can greatly improve the drilling operation. An appropriate selection of the drilling mud has always been a big challenge to the crew working on the rig site. Usually a mud engineer is required to be on the rig site during the drilling operation to prevent any undesired problem and recalculate the properties of the drilling mud [8].

Throughout this paper, collected data related to drilling fluids from Janbour Formation would be analyzed and compared to the designed drilling fluid. It will be indicated that each type of drilling fluids can be properly used for a specific situation. This ultimately results in a safe and successful drilling operation since some drilling hazards can be effectively avoided by selection of proper drilling fluid.

2. Methodology

Various drilling fluids are usually used to drill different formation types. In order to make this paper stronger and more meaningful, real data of a well in Jambour Oil Field Located in Kirkuk (provided by North Oil Company) are going to be used. The focus would be on analyzing the mud which was used to drill the second interval (Lower Fars) and also evaluating the overall mud system used to drill the well.

Moreover, through lab experiment, Salt Saturated Mud would be designed; its properties would be measured and compared with the mud the company has used to drill the second section of the well. The more proper mud between the one used by the company and designed one in the lab would be selected based on the governing factors (Lithology, pressure and temperature, environmental considerations and cost) affecting the proper selection of drilling fluids.

2.1 Study Area

Jambour Oil Field is the study area of this project. The collected data are related to a well drilled in this oil field. Jambour is located in Kirkuk City of Iraq. Its latitude and longitude coordinates are 35.265169 and 44.4314365 respectively.

Figure1: Map of Study Area

2.2 Well X

As explained earlier, this well is one of those wells located in Jambour Oil Field and drilled by North Oil Company back in time. The name and number of the well is to stay confidential. Well X geologically consists of six various intervals.

They are successively Lower Bakhtiary/Upper Fars, Lower Fars, Jeribe Formation, Dhiban Formation, Euphrates/Serikagni Fomration, and Jaddala Fromation. The depth of the well is 2854m.

In this project, the focus would be on Lower Fars interval since the most expensive and reliable drilling mud has been used to drill this section. Lower Fars is also subdivided into four sub-sections which are the followings:

a. Upper Red Beds (1790.5 – 2060m)
b. b. Seepage Beds (2060 – 2095.5m)
c. Saliferous Beds (2095.5 – 2146.5m)
d. d. Transition Beds (2146.5 – 2268m)

Since it was difficult to get the original stratigraphical column of the well from the company, sedlog3.0 software was used to construct the following stratigraphical column.

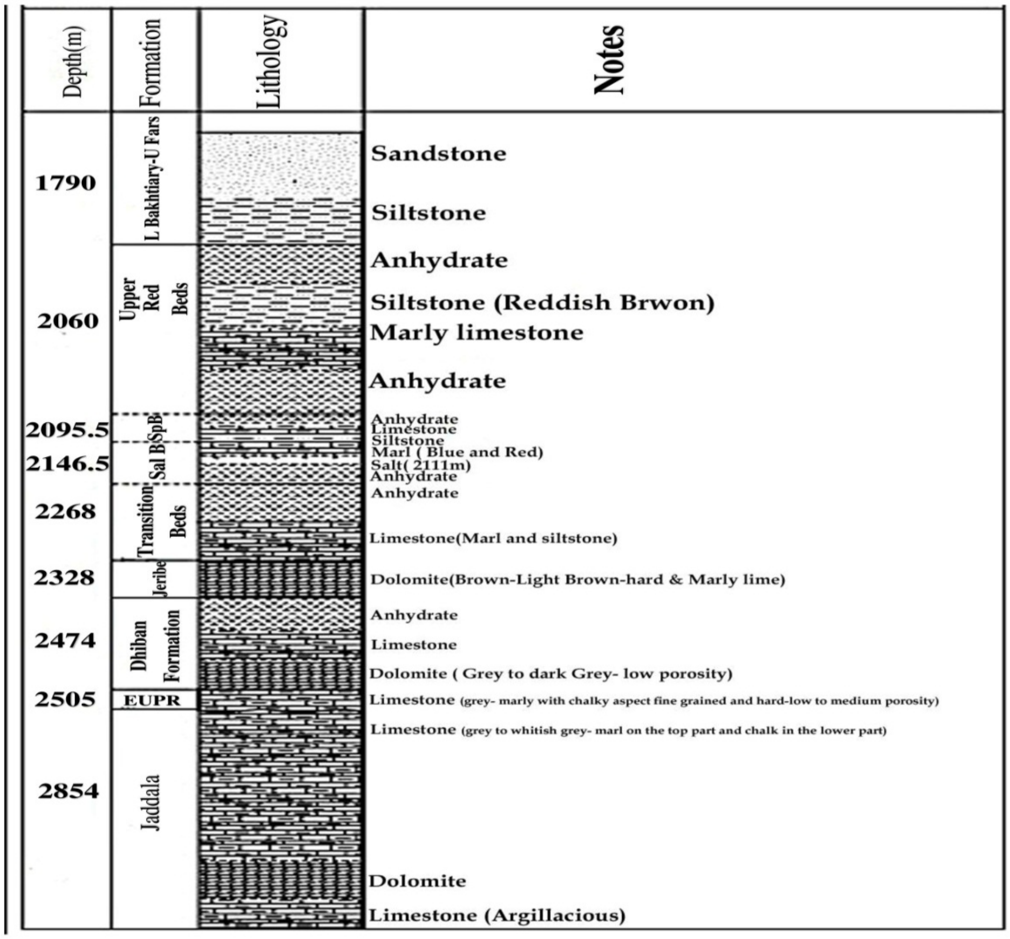

Figure 2: Stratigraphical Column of the Well

2.3 Characteristics of the Drilling Mud Used to Drill Well X

Since the well consists of different intervals and the lithology of the intervals almost varies from one another, various drilling fluids must be used to drill each section. Sometimes, the same drilling fluid could be used to drill two or three intervals considering the lithology of each interval, cost of operation and the environmental considerations. The Characteristics of drilling fluids such as density, viscosity, and filtrate always help the drilling fluid fulfill its functions such as controlling subsurface pressure, carrying and transporting cuttings up to the surface, cooling and lubricating the bit and many more. Moreover, the right choice of drilling fluids is of paramount importance, and it is predominantly governed by the lithology of the interval to be drilled, the cost of operation, and the environmental considerations. Any drilling fluid used to drill any section must abide by these three factors.The following table clarifies the drilling fluids (and their characteristics) used to drill the well. Lithology of each interval (each interval of this well) plays a very significant role in the process of selecting the proper drilling fluid utilized to drill the section. To be more specific, in this project, the mud (and its characteristics) used to drill the second interval (lower fars) would be analyzed and explained thoroughly.

Table 1: The Characteristics of the Drilling Mud

Hole Diameter (mm)	**Depth (m)**	**Type of drilling mud**	**Density (Ib/gal)**	**Unnet viscosity marsh (sec.)**	**Filtrate cm^3/30min-100psi)**	**Alkalinity**	**Salinity (gm/L)**	**%vol/ Solids**	**% vol oil**	**Temp ^{o}c**	Lime	Volts
660.4	**502**	**Fresh water-bentonite**	**8.83-10.41**	**38-45**	**8**	**9.5-10**			**3-5**	**56.67**		
444.5	**1907**	**Fresh water-bentaonte**	**10.83-11.08**	**45-55**	**4-5**	**9-10.5**		**13-14**	**-**	**8.89-55**	2	**1290-1900**
304.8	**2230**	**Oil – base mud**	**11.83-19.33**	**60-65**	**1-5 Under P and high T.**			**36-46**	**47-60**	**48.89-93.33**		
215.9	**2387**	**Fresh water bentonite**	**15.83-18.74**	**52-63**	**5**	**10-10.5**	**3.0-43**	**33-40**	**3-6**	**54.44-56.11**		
215.9	**2700**	**Salt–saturated mud**	**17.24-17.66**	**54-90**	**2-7**	**11-12**	**300-310**	**31-38**	**2-6**	**43.33-65.56**		

2.4 Experimental Work

The main purpose of this experimental work was to design a mud which could drill the Lower Fars Interval with less cost and fewer environmental considerations compared to the oil based mud used by the company. Since the lithology of lower Fars interval is highly composed of limestone, anhydrite, some small salt sections, and blue/red marl, salt saturated mud would be a good choice to drill through this section. The experiment was carried out in IDEC (International Drilling Fluid and Engineering Services Company) lab. In this experimental work, salt saturated mud was designed and its properties were measured. This mud was lab tested and it came out to give positive results.

Table 2: Salt Saturated Mud Formulation

Component	Component Description	Concentration – lb/bbl
Water	Drill water	
WEL-GEL	Bentonite to provide initial particle size for filter cake	Contingency
WEL-ZAN	Polymeric Viscosifier	0.5 – 1
Salt (NaCl)	Salinity and Saturation	71 (per finished bbl)
WEL-PAC L	Fluid Loss Control	6-8
Caustic Soda	Alkalinity Control & treat out Mg^{++} ions	0.5 – 1.0
Soda Ash	Sodium Carbonate to treat out Ca^{++} ions	0.5
WEL-BAR	Weight Material	540
WEL-STAB	Sulphonated Asphalt	3 – 5 if required to stabilise shales/blue and red marl
WEL-SPERSE™	Dispersant	2 – 5 if required

Moreover, the measured properties of the salt saturated mud came out to be the followings:

2.5 Procedure

The procedure used to design a drilling mud is usually according to the following: The first step of designing the mud would be adding the salt (NaCl) to the water used. Then Soda ash and Caustic Soda are added to the mixture to reduce hardness and keep the pH in a desired range. In addition, polymer viscosifier and fluid lose control would be added to the mixture. The polymer would provide a good viscosity, and the fluid loss control keeps the fluid loss at minimum. Finally, barite is added to the mixture so that desired mud weight can be obtained. The designed mud then would be mixed for 30 minutes by a mixer. The indispensible instruments (mud balance, fann V-G meter and filter press) are used to measure the most important properties (density, viscosity and filtration) respectively.

Table 3: Salt Saturated Mud Properties

Property		Specification
Mud Density	(lb/gal)	18.0 – 18.8
Plastic Viscosity	(cP)	40-45
Yield Point	($lb/100ft^2$) @ 50°C	30-47
6 rpm reading	dial units	8+
Gels		Low and non-progressive
API Fluid Loss		< 4
NaCl – mg/l Cl^-(saturation)		192,000
pH		9.0-9.5

3. Results and Discussion

The main discussion of this paper emanates from the main constraints such as the type of lithology, temperature and pressure of the formation, environmental consideration and cost of operation. Since the overall lithology of the well is not much problematic, a simple fresh water bentonite mud was used to drill through Lower Bakhtyari/Upper Fars, Jeribe formation and a small part of Dhiban Formation as it can be seen in table (1). The cost and environmental considerations of fresh water- bentonite mud make it favorable in most cases. The encountered lithology during drilling these sections has almost been a combination of anhydrite, limestone and siltstone. In addition, salt saturated mud was used to drill Dhiban Formation, Euphrates/serikagni formation and Jaddala formation since the dominating lithology was anhydrite and limestone.

Moreover, the rate of mud loss faced when fresh water-bentonite mud was used is almost normal and not much cost-problematic since the mud is simple and cheap table (2). Both partial and total loss circulation have occurred but controlled easily by using fiber lost circulation materials. For the sections drilled by salt saturated mud, some mud losses could also be seen table (2). Total mud loss of 71m^3 at the depth of 2605 occurred and efficiently controlled by sealing materials (lost circulation materials).

As clarified earlier, the focus here would be on Lower Fars Interval of the well where blue and red marl along with limestone, anhydrite and small sub-sections of salt exist. Not any drilling fluid could be used to drill through blue and red marl due to sloughing, hydration and collapsing problems. As a result, when this kind of lithology is concerned, all factors should be taken into consideration so that a safe and cost effective drilling operation can easily be maintained. Oil-based mud was used in this case to drill this section since it can effectively control well collapse and thwart shale sloughing/heaving as it does not react with the blue and red marl.

The problems faced while oil based mud is used would be cost and environmental considerations. The cost of OBM is very expensive, and it is not environmentally friendly [9]. Moreover, through complete analysis of this interval's lithology, it could be observed that oil based mud has not been the best option to be used. In this interval, there are not very long sub-sections of blue/red marl, and this shows that other drilling fluids could have been used instead of expensive oil based mud. Additionally, they could have added filtration reducers, have increased density of the previous mud used (the one used before converting to OBM) for greater pressure support, or have increased circulation rate for faster removal of solid particles.

As it can be seen from table (2), some mud losses can be observed through this section too. These losses were due to fishing of the drilling pipe when stuck pipe occurred and partially because of running in casing and its successive cementation.

Furthermore, the properties (density, viscosity and filtration) of the oil based mud used to drill Lower Fars Interval assisted the mud fulfill its functions quite properly. As it (the highlighted part) can be observed in table (1), the density of the mud ranges from (11.83 – 19.33 lb/gal). This provides enough hydrostatic pressure to support and control subsurface pressure. As a result, there would be no consequent well problems. The viscosity of the mud is 60-65 seconds (marsh funnel measurement), and this is even more than sufficient to remove and transport the cuttings upward through the annulus to the surface. Apparently, the filtrate ranges from 1-5 cm^3/ 30min-100psi, and this shows how efficient the mud would control and avoid fluid loss to the formation.

However oil based mud could drill this interval efficiently by providing good fluid loss control; outstanding red/blue marl inhibition and avoiding well collapse, its consequent cost and environmental considerations would make it unfavorable.

3.1 The Designed Salt Saturated Mud

Salt saturated mud was designed to see whether or not it could be used to drill Lower Fars section (since the section consists of blue/red marl, and salt saturated mud could be a good choice) instead of the oil based mud used. After the mud was lab tested, it appeared that it could be used to drill the section. It could inhibit and control blue/red marl sloughing and consequently gives no reaction. Moreover, the pressure and temperature conditions further proved that the mud could be efficiently used to drill the section. In addition, since salt and anhydrite sub-sections are present, this designed salt-saturated mud would be a very functioning mud to be used.

Regarding the properties of this salt saturated mud (density, viscosity and filtration), it could be seen from table

(3) that the density of the mud is about 18.0-18.8 lb/gal. This provides enough subsurface pressure control and avoids the subsequent problems. The starting mud weight would be 18 lb/gal and it might increase to 18.8 lb/gal as the hole conditions require higher weights Moreover, the viscosity measured and tested through marsh funnel was nearly 55-65 seconds which is close to OBM. This indicates good removal and transportation of the cuttings to the surface. To add, the value of mud filtration is quite satisfying since it is less than 4 cm^3/ 30min-100psi, and this shows that the salt saturated mud could efficiently control mud losses to the encountered formation. In this case to control the filtrate, WELL-PAC L is used as a filtration reducer.

3.2 Comparison between the Oil Based Mud and Designed salt Saturated Mud

Even though the mud was designed in lab and confirmed that it could be used to drill the Lower Fars section, it also could be confirmed that it would be applicable since it possess almost close density, viscosity and filtration values to those of the oil based mud used by the company. A comparison between the two muds would show that the designed salt saturated mud would be a more appropriate mud to use. Table (4) shows the properties of both muds.

Table 4: Basic Properties of the Muds

Mud Type	**Mud Properties**		
	Density(lb/gal)	Viscosity (seconds/marsh funnel)	Filtration(cm^3/30min-100psi)
Oil based mud	11.83-19.33	60-65	1-5
Salt saturated mud	18.0-18.8	55-65	Less than 4

It could be clearly viewed that they have very close properties and could be competently used to drill the section. In another word, the properties of the salt saturated mud should be in the range mentioned in table (4) so that they would be almost equivalent to the OBM properties. The very minor differences between these two muds would be summed up in the fact that the designed salt saturated mud would have been a better mud to select. The main differences that would make the salt saturated mud more dominating are the cost and environmental considerations. Oil based mud is a very expensive mud and concurrently environmentally problematic. On the other side, salt saturated mud is less expensive compared to oil based mud and has always shown positive environmental outcomes. This indicates that the usage of salt saturated mud would have definitely resulted in a safer, more environmentally friendly and cost effective drilling operation.

Importantly, the section does not contain very long blue/red marl parts and consequently the OBM is not strictly needed to be used. OBMs are usually used in sections containing large extensions of blue/red marl or shale. The salt saturated mud is the best and most proper mud in this case since two parts of salt and long extensions of anhydrite exist in the interval. This mud would be able to drill these types of lithology very efficiently and in a cost efficient manner.

When selection of the proper mud is concerned, the governing factors such as cost, environmental considerations, encountered formation and pressure/temperature must be proficiently met. In this project, the designed salt saturated mud would be the proper mud to use since it abides by the above four governing factors.

4. Conclusions

The following points are the main conclusive results:

1. The use of OBM is not strictly needed in this case since there are not very long parts of blue/red marl present in the interval.
2. In this paper, the salt saturated mud would be the proper one since it completely complies with the governing factors. The salt saturated mud is more suitable since it costs less and is more environmentally friendly compared to OBM.
3. Sometimes two or three drilling fluid might be applicable to drill a specific interval, but the one proficiently abiding by the four governing factors (the encountered lithology, the pressure and temperature conditions, the environmental considerations and cost of performance) would be the proper one.
4. The experimental work was carried out to measure the most important drilling fluid properties such as density, viscosity and filtration which are responsible to control subsurface pressure, remove and transport cuttings to the surface through annulus, suspend cuttings when circulation has halted, and provide a good mud cake respectively.
5. When designing and dealing with drilling fluids is concerned, professional and experienced people are highly the ones who must be chosen to fulfill the job.

5. Recommendation

It is recommended that the followings should be fulfilled when proper selection of drilling fluid is concerned:

1. Drillbench software must be used to give an idea regarding the applicability of the drilling fluid in hand.
2. Committed and professional personnel must be deployed to deal with the preparation and design of the drilling fluid.
3. The constraints related to drilling fluids should be well understood and practiced.
4. Each drilling fluid to be used must go through pilot test to show its state of applicability.

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