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Research Article

A STUDY ON THE ROLE OF PRE-GELATINIZED STARCH (PGS) IN THE NON DAMAGING DRILLING FLUID (NDDF) FOR THE TIPAM SAND OF GELEKI OILFIELD OF UPPER ASSAM BASIN

Prasenjit Talukdar* and Subrata Borgohain Gogoi

Department of Petroleum Engineering and Department of Petroleum Technology, Dibrugarh University, Dibrugarh-786004, Assam, India

*Corresponding Author's email: prasenjit.ptech@gmail.com

Abstract

The drilling of the wells from surface to target location with conventional drilling fluids may impair production and ultimate recovery by failing to adequately connect the reservoir with the wellbore by damaging the producing interval. One of the most common ways of damaging a formation is the filtration loss. Non Damaging Drilling Fluid (NDDF) is a clay and barite free environmental friendly polymer mud system mostly used in pay zone sections of development wells and specifically in horizontal drilling to avoid formation damage. Starches [$(C_6H_{10}O_5)$ n] are an environment-friendly drilling mud additive for water-base drilling fluids used to control the filtration loss. This paper reports the effect and optimum composition of Pre-Gelatinized Starch (PGS) as a filtration control component in the NDDF. PGS is a high-quality non-ionic polysaccharide having the Chemical Formula: $C_{27}H_{48}O_{20}$ and Molecular Weight: 692.658020 [g/mol] which controls the filtration loss by sealing the walls of the borehole due to its long chains of monosaccharide. Some clay specifically the montmorillonite a member of the smectite group that generally also found in the payzones of Geleki Oilfield of Upper Assam Basin absorb hydrogen ions into their structure when comes in contact with fresh water and causing swelling of the clay resulting in a reduction of the pore volume and possibly plug in the pore throats. Therefore the filtration loss should be as low as possible by forming high quality low permeable mud cake of as thin as possible. In this work, an attempt has been made to study the effect of varying composition of PGS on the different mud properties of laboratory formulated NDDF and to choose its optimum composition based on the required mud parameters of the study area.

Keywords: Non Damaging Drilling Fluid; Pre-Gelatinized Starch; Filtration Loss; Mud cake: Formation Damage; Geleki Oilfield

Introduction

Drilling fluid or mud is any fluid used in rotary drilling that is circulated or pumped from the surface, down through the drill string, bit, and back to the surface via the annulus to perform various functions required in a drilling operation.

A conventional water-based mud (WBM) may cause wellbore instability, formation damage, torque & drag, stuck pipe, logging and primary cementation failures, borehole washouts etc. in water sensitive clays and shale formations. These problems may become even more serious in directional or horizontal wells. The alternate option of oil-based mud (OBM) is also economically & environmentally unviable (**Dwivedi, 2010**). So, in the current stringent environmental regulations, the oil industries are interested to environmental friendly bio-degradable drilling muds.

Due to the overbalance pressure the mud invades the formation and can cause formation damage. Invading particles which were initially suspended in the drilling fluids can plug the pores and hence reduce rock permeability. Mud filtrate can interact with formation minerals to cause mobilization and subsequent re-deposition of in-situ fines, to swell the pay-zone clay, to alteration of reservoir rock wettability, to development of emulsions leading to reduction of permeability.

Lesser the damage; more is the production of hydrocarbon. Therefore, to diminish the formation damage, the most important points (Mandal, 2006) to keep in mind for the designing of a fruitful mud are:

1. Diminish fluid loss
2. Should not use dispersant and non-degradable fine solids like- bentonite, barite, etc. in the mud,
3. Should minimise drilled fine solids in the mud,
4. Produce inhibitive filtrate which would not swell the clay envelop in the formation particles and should not react with the formation fluid to generate insoluble precipitate

The NDDF is a clay and barite free polymer mud system mostly used in pay zone section to avoid formation damage and to keep pay zone or reservoir intact. It incorporate long-chain, high molecular weight polymers in the systems either to encapsulate drill solids to prevent dispersion or to coat the shales for inhibition as well as to increase viscosity and reduce fluid loss. An extensive range of particle sizes is used which, on de-hydration, fit together into a strongly compacted very low permeable mud cake on the surface of the rocks to quickly seals off the permeable paths of the pay-zone.

Thus the proposed / optimally designed NDDF

- Should minimize formation damage, lower overall well costs and optimize production without neglecting HSE regulations.
- Should retain all relevant drilling fluid characteristics
- Contain specialized sized materials to bridge all exposed pore openings.
- Deposit a non - damaging filter cake that is easily and effectively removed by initial production and / or by treatment of mild reactant / oxidizing agents.

Geleki field was discovered in 1968 and was put to trial production in August, 1970. The commercial production started in August, 1974. The field has been divided into twenty-three blocks by faults. All the twenty-three blocks are oil/gas producers.

In the Upper Assam basin, following producing horizons have been identified (top to bottom): a) Tipam Sand, b) Barail Sand, c) Kopili, d) Sylhet, e) Basal Sandstone, and f) Basement. In Geleki-field, the main horizons are Tipam and Barail main sand. In addition, few wells are producing within Barail coal-shale unit. The geological age of the Barail main sand and Barail coal-shale is Oligocene and that of Tipam is Miocene. The corresponding depth range of Barail main sand and Barail coal-shale is about 3420 - 4070 meters. Tipam main sand, comprising of TS-3A, TS-4B, TS-5A, TS-5B & TS-5C, is at an average total depth of about 2300-3400 meters. The average total thickness of Barail main sand is about 70 - 80 meters, Barail coal-shale unit about 400 - 500 meters, and that of Tipam, TS-3A is about 20 - 30 meters, TS-4B is about 10 - 30 meters, TS-5A is about 10 - 40 meters, & TS-5B is about 10 - 20 meters, of oil bearing rock.

As discussed earlier, the formation damage basically depends upon the type and properties of the mud and formation properties. Table 01 shows that the average Porosity and Permeability of the Tipam Sands of Geleki

Table 1: Reservoir Properties of Geleki Oilfield

SAND	Average Depth in MSL (m)	Average Porosity (%)	Permeability (md)	Temp. (ºC)
Gurujan Clay	2100-2270	22		
TS-1A	2401-2340	22	30	70-75
TS-2A	2470-2530	22	25	70-75
TS-3A	2350-2700	22	30-50	70-75
TS-3B	2420-2750	22		
TS-3C	2550-2950	18-22		
TS-4B	2700-3000	18-20	10-20	70-75
TS-5A1	2770-3000	18-20	10-30	70-75
TS-5A2	2800-3075	17-20		
TS-5B	2820-3200	18-22		70-78
TS-5C	2860-3200	20-23		
TS-6	3000-3400	15-18	18-30	78-80
BCS-VI	3420	15		
BCS-V	3400-3500	15-20		
BCS-IV	3500-3670	12-18		
BCS-III	3600-3670	15-18		90-92
BCS-II	3700-3800	15		
BCS-I	3740-3760	15		
BMS UP	3820-3920	15-20	5-45	98-105
BMS-LO	3855-3965	10	5-45	
BMS-I	3940-4010	10-14		
BMS-II	3900-3960	10		
BMS-III	3900-4070	10-13	5-45	
KSU-I	390-4080	13		
KSU-II	4060-4100	10-15		
KSU-III	4080-4160	10-11		
KSU-IV	4100	10		
KSU-V	4100-4230	10	5-45	100-108
KSU-VI	4130-4190	12-15		
KSU-VII	4265	10		
KSU-VIII	4270	12		
KSU-IX	4310	12		
KSU-X	4330-4380	12		
KSU-XII	4400-4535	10-14		

(ONGC, unpublished report)

field are about 21% and 26 md which are very much susceptible for spurt as well as filtration loss. With the conventional WBM, the spurts loss during drilling is tremendously high and continuous in this formation. So, the loss cannot be arrested without using the NDDF.

Particles less than 2 micron is known to bridge rock permeability less than 100 md, 10 micron to bridge consolidated rocks permeability between 100-1000 md and 74 micron (200 mesh) upto 10 darcies. Particles up to 74 micron size will bridge and forms filter cake on all formations except macro openings or open fractures (**Sharma, 2010**).

Materials and Methods

Materials

The general components used for formulation of NDDF are:

1. Base fluid - fresh water
2. Viscosifier- XC polymer
3. Fluid loss control / coating agent - Starch e.g. PGS (Pre Gelatinized Starch), PAC (LVG) & PAC (RG)
4. Lubricity- Linseed oil
5. Formation clay/shale inhibitor-Potassium Chloride
6. Weighing and bridging materials: Limestone, MCC (Micronized Calcium Carbonate)
7. Other additives- Caustic soda, Bactericide

To study the effect of PGS, the NDDF is prepared by properly mixing of XC-Polymer: 0.4%, PAC (LVG): 0.5%, PAC (RG): 0.3%, Biocide: 0.1%, NaOH: 0.025%, KCl: 5%, Limestone powder: 3.5%, MCC: 6%, and varying composition of PGS in gm /100ml basis (Rao, 2010 and Chattopadhyay, 2010).

As discussed earlier, the formation damage also depends upon the formation properties. So, to study in detail, some data of reservoir rock properties as well as some mud policy & well cards for NDDF of drilled wells, mud chemicals, etc. are collected from Assam Asset, ONGCL.

Methods

According to proper measuring manual instructions different muds samples are formulated by varying the composition of PGS, keeping the other components as constant using the following equipments:

a) Mettler Electronic Precision balance to measure the mass of different chemicals for proper composition.
b) 1000 ml measurable stainless steel cup for measuring the water volume.
c) Hamilton Beach Mixer for proper stirring/mixing water and the mud component for generation of proper mud properties.
d) 15 ml pipette to measure small liquid volume.

Then the effect of varying composition of PGS on mud properties with change in time are investigated to see the role of PGS in NDDF and to select optimum composition of PGS which gives proper / suitable parameters (i.e. the parameters which will not create any mud related drilling complications and will not damage the payzone accomplishing the other mud functions properly) of NDDF for the study area of Upper Assam Basin. The suitable parameters of NDDF for the study area have been selected from the well cards collected from ONGC and optimum composition of PGS was selected by interpreting the parameters with the generated graphs.

To investigate the effect of varying composition with increasing time in days on the various mud properties, the following equipments have used:

a) OFITE 4 scale plastic model Mud Balance to measure the density of formulated mud.
b) OFITE plastic Marsh Funnel Viscometer to measure the Funnel Viscosity of formulated mud.
c) OFITE model 800 Viscometer to measure/determine Gel_0, Gel_{10}, Apparent Viscosity, Plastic Viscosity, Yield Point of formulated mud.
d) Filter Press for measuring the Fluid Loss and Mud Cake Thickness of formulated mud.
e) pH Meter for measuring the pH of water used for formulating mud and the formulated mud.
f) Conductivity Meter to measure Salinity of water used for formulating mud and the formulated mud.

Results and Discussion

As discussed earlier, reservoir minerals have a great role in the formation damage mechanism when they come in contact with the filtrate from water base mud (WBM). The minerals of the study area have studied and identified with the help of X-ray diffraction analysis. The major minerals in most of the rock samples found to present are Smectite, Kaolinite, Quartz, and Feldspar as shown in Figure 01-02. The study reveals that in all the portion of TS-5A sand of Geleki field contains both the swelling (Smectite) and non-swelling (Kaolinite) clay and the swelling is always more than the non-swelling clay. Smectites can swell with changing ionic conditions and eventually disperse and migrate with the flowing fluid. Swelling alone reduces the effective area for flow and causes reduction in permeability. Kaolinite is non-swelling clay that tends to detach from the rock surface and migrate when the colloidal conditions are conducive for release. The migrating particles can get trapped in pore throats, thus causing a reduction in permeability. High pH (e.g. 10.5) causes the kaolinites to develop sufficiently high potentials to cause them to detach from the surface, migrate and be in the pore constrictions (Mohan, 1993).

Upon contact with the invasion water from WBM, the smectite group of clay minerals is hydrated. The hydration of this smectite group originates as a result of short range attractive forces developed on the negatively charged clay particles and interlayer surfaces due to hydrogen bonding, charged surface-dipole attraction or a combination of both. Therefore, the Tipam Sand of Geleki field is a very good candidate for the implementation of NDDF.

The mud properties were start to measure at the day of formulation (Zero-day) after 2-3 hours of proper mixing in the Hamilton Beach mud mixer. Then the measured / determined values of mud properties are tabulated and the effects on these properties of varying composition of PGS are investigated as shown in Fig. 3.

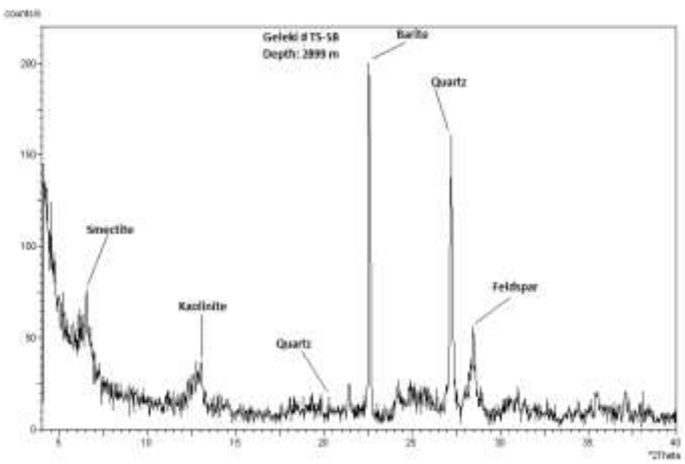

Fig. 1: X-Ray Diffractogram (XRD) of Core Sample (Depth: 2899m) of Geleki oilfield showing Smectite, Kaolinite, Quartz, Feldspar and Barite (impurity)

All the mud parameters must be optimum for smooth successful drilling without any complications. A low value of Viscosity and Yield Point can results in low cuttings carrying capacity of mud; high values can results in high pumping pressure which may results in formation fracture, lost circulation, may demands high capacity rig, etc. A low value of Gel strength and Yield Point may results in low - capacity to suspend the solids of mud at rest; high values can results in high pumping pressure. Low density can results in well kick and blow out; high density can results in lost circulation and low drilling rate. Both the low and high value of pH is unfavourable for the mud and the equipments. Low pH results in corrosion and low crude oil recovery related problems; high pH causes the Kaolinite clays to -develop sufficiently high potentials to cause them to detach from the surface, migrate and be captured in the pore constrictions, although it has positive role in oil recovery. Low salinity results in decrease in permeability due to clay swelling, increase in the value of pH although it has positive role in oil recovery; high salinity results in corrosion related problem due to decrease in the value of pH.

From the Figure 03-10, we can investigate that the PGS has negligible effect on Specific Gravity, pH and salinity of mud, and has small effect on the Mud Cake thickness and on rheological properties of mud, e.g. Viscosity, Yield point and Gel Strength, but it has great effect on the Fluid Loss characteristics of mud.

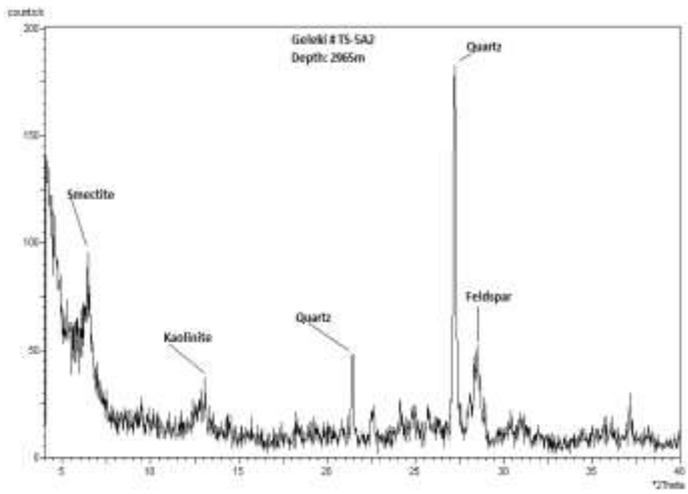

Fig. 2: X-Ray Diffractogram (XRD) of Core Sample (Depth: 2965m) of Geleki oilfield showing Smectite, Kaolinite, Quartz, and Feldspar

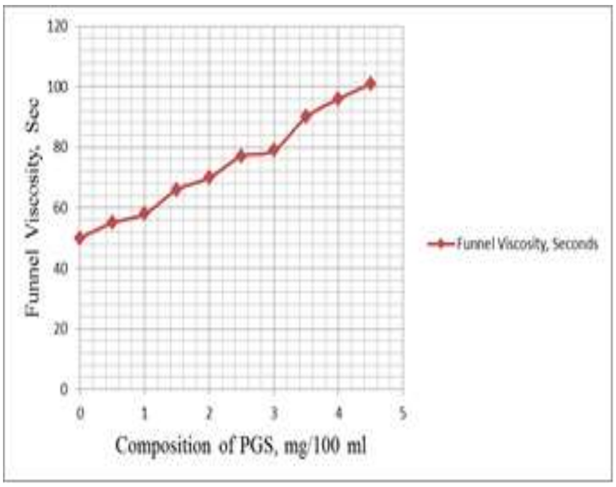

Fig. 3: Funnel Viscosity vs. Composition of PGS

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Table 2: Properties of the formulated mud at the day of formulation (Zero-day) with change in PGS composition.

0(Zero)-Day														
Composition of PGS, gm/100ml	Mud Properties													
	Funnel Viscosity, Seconds	θ600	θ300	Apparent Viscosity, CP	Plastic Viscosity, CP	Gel Strength, lb/100ft^2		Yield Point, lb/100ft^2	Density of mud, kg/m^3	pH (Hydrogen Ion Concentration)	Salinity, psu	Fluid Loss, ml	Mud Cake Thickness, mm	Temperature, °C
						Gel_o	Gel_{10}							
0	50	64	47	32	17	11.9	17	30	1070	9.5	0.01	8.4	0.29	29
0.5	55	68.5	50	34.3	18.5	12.8	17.5	31.5	1068	9.46	0.01	7.5	0.29	31
1	58	75	54	37.5	21	13.6	17.9	33	1067	9.43	0.01	6.9	0.3	31
1.5	66	78	56	39	22	13.8	18.2	34	1064	9.4	0.01	6.6	0.3	30
2	70	81	58	40.5	23	14.9	18.6	35	1061	9.35	0.01	6.4	0.31	29.5
2.5	77	85	61	42.5	24	15.2	19.3	37	1059	9.31	0.01	6.3	0.31	31
3	79	92	67	46	25	15.5	20.5	42	1058	9.25	0.01	6.25	0.32	29
3.5	90	104	77	52	27	16.5	22	50	1056	9.23	0.01	6.2	0.33	30
4	96	110	82	55	28	16.7	22	54	1055	9.19	0.01	6.2	0.33	30.5
4.5	101	114	85	57	29	17.5	23	56	1054	9.19	0.01	6.1	0.34	29

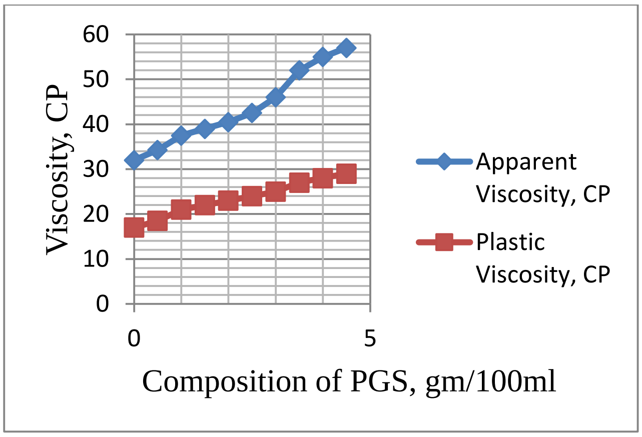

Fig. 4: Apparent Viscosity and Plastic Viscosity vs. Composition of PGS

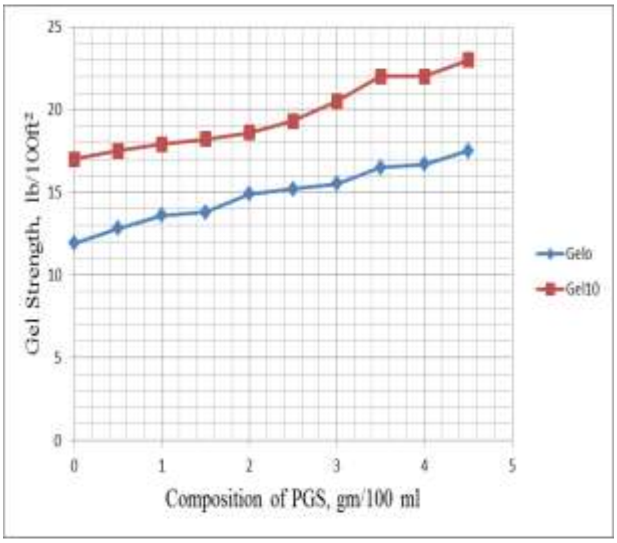

Fig. 5: Gel Strength vs. Composition of PGS

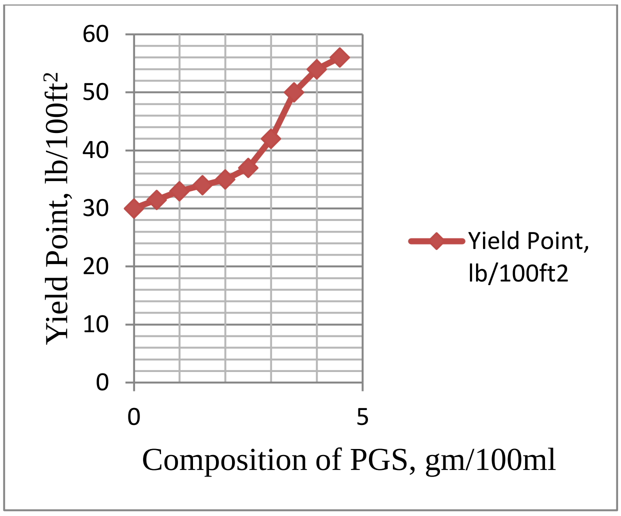

Fig. 6: Yield Point vs. Composition of PGS

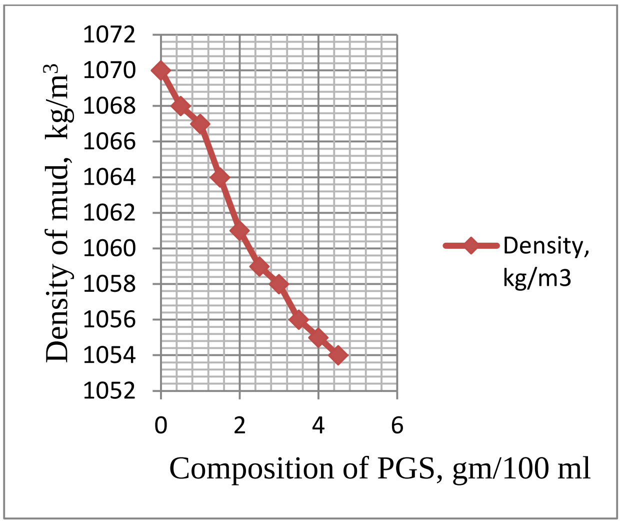

Fig. 7: Density of mud vs. Composition of PGS

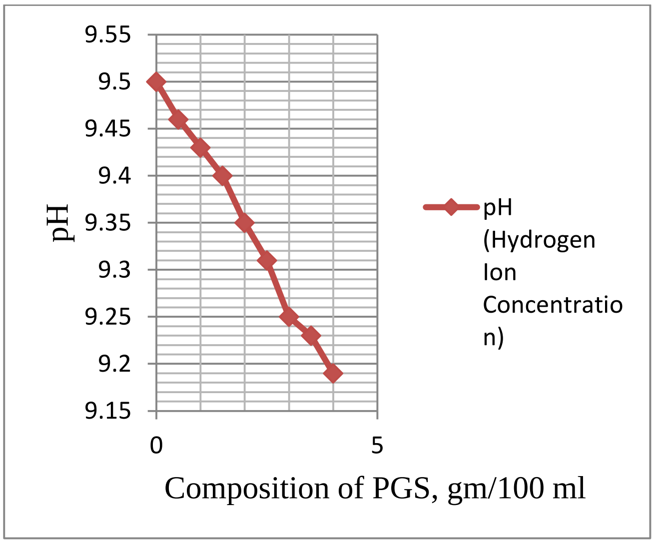

Fig. 8: pH vs. Composition of PGS

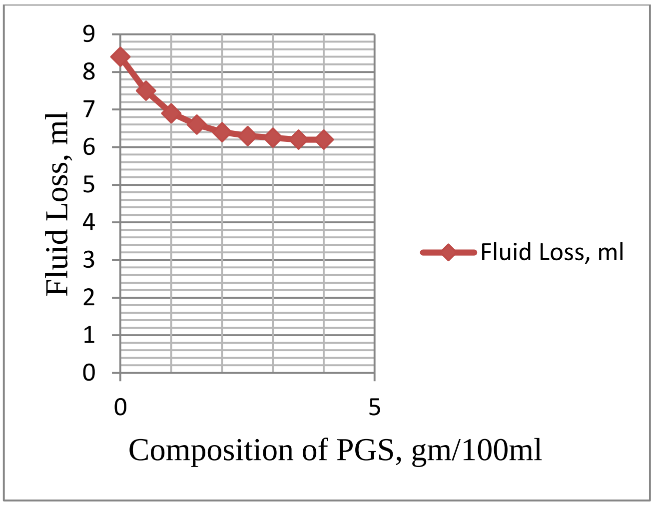

Fig. 9: Fluid Loss vs. Composition of PGS

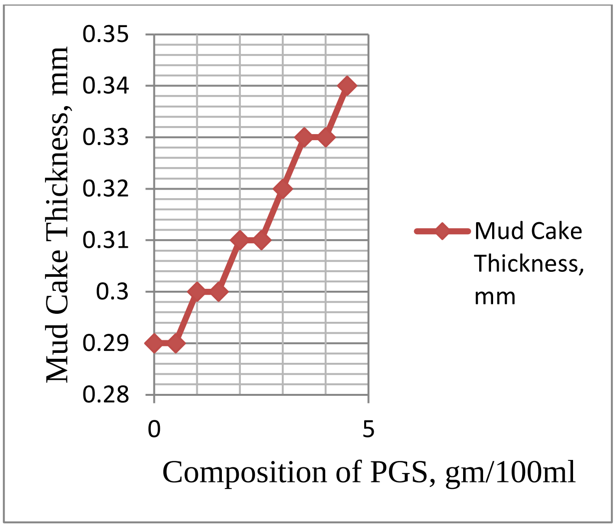

Fig. 10: Mud Cake Thickness vs. Composition of PGS

In the Figure 09, we can notice that the fluid loss decreases with the increasing composition of PGS. But the fluid loss is almost same for the PGS range of 2.5-3.5 gm/100 ml. And, from the Table 03, the actual average API Fluid Loss (FL) for the Tipam Sand of Geleki field 6.34. In the Figure 09, we can see that the composition of PGS against FL 6.34 ml is about 2.52 gm/100 ml. But, the average time period required for drilling of the pay-zone using NDDF in the Tipam Sand of Geleki field is about 15-20 days. And from the Figure 17, we can see that the FL rapidly decreases with the increase in time due to highly bio degradable nature of PGS. After 10-15 days from formulation the FL increases almost 30%. So, we have to choose the range of FL as about 6.14-6.53 ml which will be suitable for successful drilling in the study area. Against this range the PGS composition range is about 1.5-3.5 gm/100 ml. So, by considering the laboratory result and field experience we can choose the optimum composition range of PGS for the successful drilling of Tipam Sand as 2.5-3.5 gm/100 ml. Higher compositions of PGS can decreases the fluid loss, but which may have the detrimental effect on Viscosity, Gel strength, Yield point, Density and pH. From the Figure (03-06), we can investigate that the Viscosity, Gel strength and Yield point increases with increasing the composition of PGS. We should start the formulation of NDDF with the composition of PGS as 2.5 gm/100 ml and gradually increase the percentage upto 3.5 gm/100 ml for the compensation of bio-degradation of PGS.

From Figure10, we can investigate that with the increasing composition of PGS, the mud cake thickness also directly increases. But we know that for the smooth or problem free drilling operation, optimum mud cake thickness is necessary. Low mud thickness can results in high fluid loss and in turn high formation damage; high mud thickness results in sloughing or breaking and dropping of the cake which again results unstable hole, high fluid loss and formation damage. Our objective is to forming high quality low permeable thin Mud Cake which can resist the further fluid and particle invasion into the formation without rupturing and dropping into the hole. Since the Cake thickness increases with increasing composition of PGS, the higher composition of PGS than the optimum will be detrimental for drilling.

So, from these studies, we can recommend that we will start the formulation of mud in the drilling rig with the PGS composition of 2.5 gm/100 ml and we will investigate the functions of the mud while drilling. We will investigate whether the cuttings are properly carrying out of the hole or not; drilling rate is satisfactory or not; mud solids are properly suspended or not at the rest of the mud, solid control equipments are properly working or not, etc. as well as continuous testing of the mud parameters e.g. Density, Rheological properties, Fluid Loss, Mud Cake, pH, Salinity, etc. If we have the problem free drilling operations are going on, we will continue the drilling with the same composition and otherwise we may slightly increase the composition of PGS up to 3.5 gm/100 ml investigating the functions.

Then we have kept the same mud samples for two months in the laboratory in the ambient temperature & atmospheric pressure condition and the effect of mud properties with change in time periods are investigated. We have done the experiments for measuring the properties as an order of 0-day, 1-day, 2-days, 5-days, 10-days, 15-days, 20-days, 30-days, 45-days and 60-days and choose a fixed composition of PGS (2.5 gm/100 ml) for making the graphs of various mud properties verses change in time for studying the properties as follows:

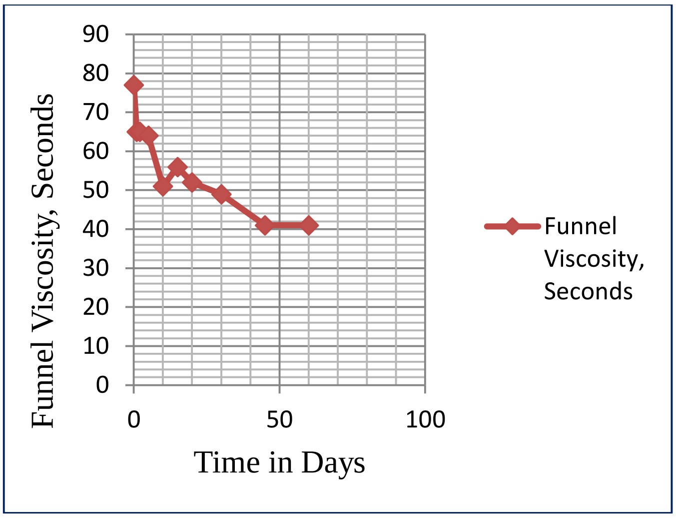

Fig. 11: Funnel Viscosity vs. Time

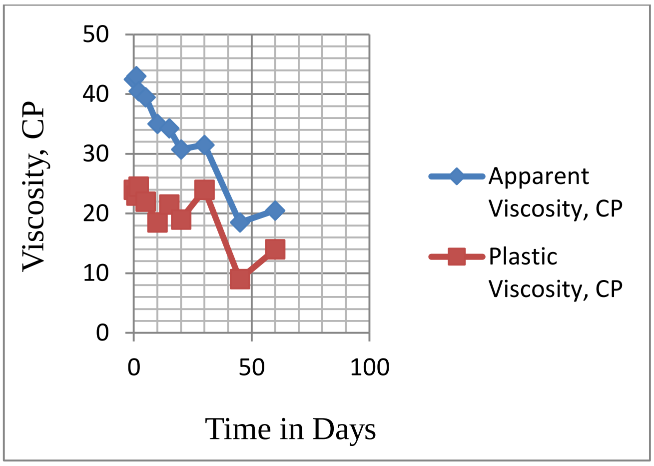

Fig. 12: Apparent and Plastic Viscosity vs. Time

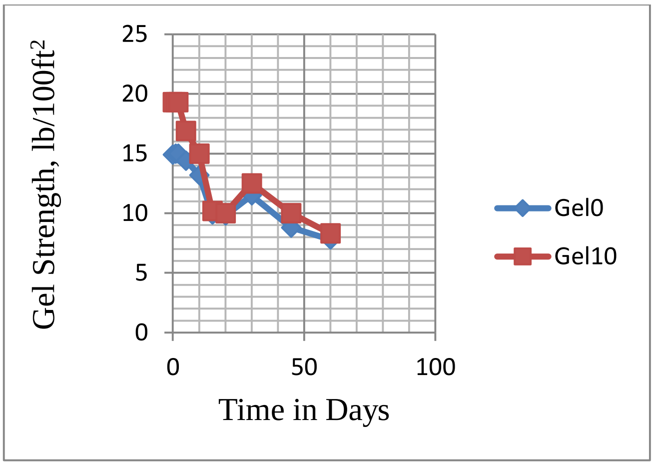

Fig. 13: Gel Strength vs. Time

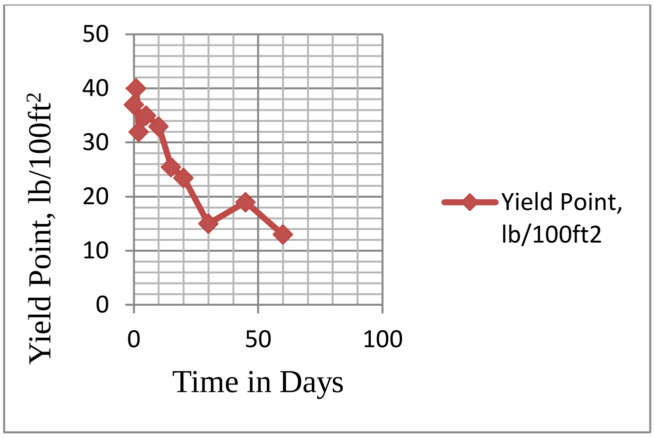

Fig. 14: Yield Point vs. Time

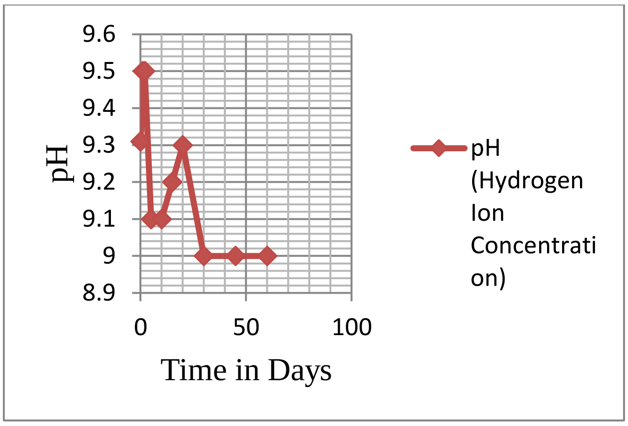

Fig. 16: pH vs. Time

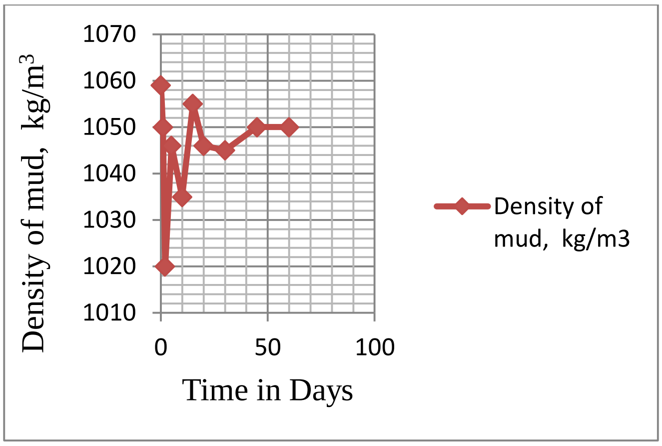

Fig. 15: Density vs. Time

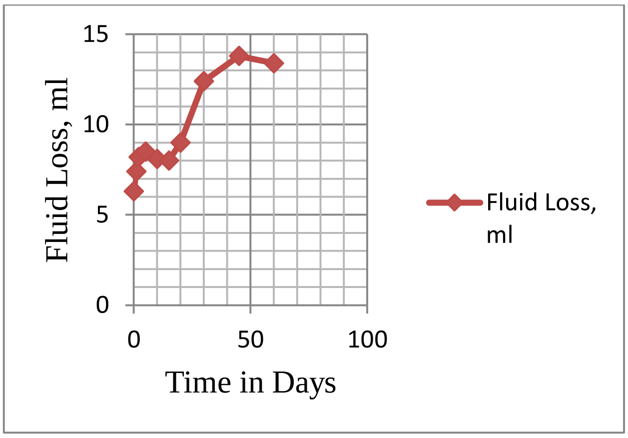

Fig. 17: Fluid Loss vs. Time

It can be noticed from the Figure (11-18) that all the mud properties are degrading with increasing time span. The investigated trends are as follows:

- Funnel Viscosity: Decreases with increasing time.
- Apparent Viscosity: Decreases with increasing time.
- Plastic Viscosity: Decreases with increasing time.
- Gel Strength: Decreases with increasing time.
- Yield Point: Decreases with increasing time.
- Density of mud: Negligibly changes.
- pH (Hydrogen Ion Concentration): Negligibly decreases.
- Salinity: Negligibly changes.
- Fluid Loss: Increases with increasing time.
- Mud Cake Thickness: Slightly decreases with increasing time.

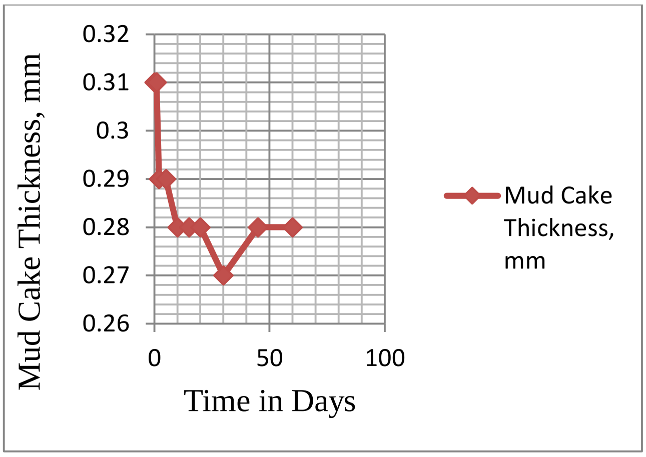

Fig. 18: Mud Cake Thickness Vs Time

Table 3: NDDF parameters of ten(10) successfully drilled wells in Tipam Sand of Geleki field of Upper Assam Basin

Well Name	**Well's Brief Description**	**NDDF Parameters**									
		Specific Gravity		**Funnal Viscosity**		**Fluid Loss**		**Plastic Viscosity**	**Yield Point**	**Gel Strength**	
		Proposed	**Actual**	**Proposed**	**Actual**	**Proposed**	**Actual**			**Gel$_0$**	**Gel$_{10}$**
Geleki # A	Development well, Inclined (L) profile, TS-2A Pay-zone, 2617m TVD	1.08-1.10	1.07-1.08	50-55	55-59	6-8	5-8	11-16	30-36	8-10	16-18
Geleki # B	Development well, Inclined (L) profile, TS-3A Pay-zone, 2880m TVD	1.05-1.08	1.06-1.07	45-55	42-55	6-8	7-8.5	11-14	16-24	6-8	11-16
Geleki # C	Development well, Inclined (L) profile, TS-3 Pay-zone, 2900m TVD	1.05-1.08	1.08-1.11	55-60	53-60	5-6	5.5-6.2	14-19	25-35	6-7	10-13
Geleki # D	Development well, Inclined (L) profile, TS-3A Pay-zone, 2900m TVD	1.05-1.10	1.08-1.12	50-60	47-57	5-6	4.2-7	10-17	35-38	8-12	15-18
Geleki # E	Development well, Inclined (L) profile, TS-5A1 Pay-zone, 3051m MD	1.07-1.10	1.08-1.12	50-55	43-50	6-8	3.4-7.6	9-18	22-37	8-12	10-17
Geleki # F	Development well, Inclined (L) profile, TS-5A1 & TS-5B Pay-zone, 3010m TVD	1.08-1.2	1.10-1.12(TS-1,2,3,4) & 1.08-1.09(TS-5A,5B)	45-55	45-50(TS-1,2,3,4) & 45-47 (TS-5A,5B)	6-8	4.5-4.8(TS-1,2,3,4) & 5.5-6.5 (TS-5A,5B	15-20(TS-1,2,3,4) & 12-15 (TS-5A,5B	32-36(TS-1,2,3,4) & 23-25 (TS-5A,5B	7-12(TS-1,2,3,4) & 7-8 (TS-5A,5B	14-22(TS-1,2,3,4) & 16-17 (TS-5A,5B
Geleki # G	Development well, Inclined (S) profile, TS-4B Pay-zone, 3150m TVD	1.07-1.10	1.09-1.11	50-55	45-49	4-6	5.5-6.0	11-18	20-28	7-11	14-16
Geleki # H	Development well, Inclined (Horizontal) profile, TS-5A1 & TS-5B Pay-zone, 3258m TVD	1.05-1.08	1.04-1.06	55-60	54-60	6-8	9.0	7-14	26-40	10-15	27-48
Geleki # I	Development well, Inclined (L) profile, TS-3A & TS-6 Pay-zone, 3569 m TVD	1.10-1.12	1.12-1.18	45-55	42-47	6-8	5.7-6.5	10-17	19-25	5-7	11-17
Geleki # J	Development well, Inclined (L) profile, TS-5A1 & TS-6 Pay-zone, 3600m TVD	1.08-1.10	1.08-1.09	55-60	53-58	5-6	6-8	10-12	32-42	10-13	17-20
Actual Average		**1.0923**		**50.7**		**6.34**		**13.64**	**29.36**	**8.95**	**17.4**
Actual Range		**1.04-1.18**		**42-60**		**3.4-9**		**7-20**	**16-40**	**6-15**	**10-48**

(Prepared from Well-Cards of mud services, ONGCL, Assam Asset)

All the rheological properties are decreases and the Fluid Loss increases greatly with duration due to the bio-degradation of PGS. The pH, Salinity and Density are almost same due to the negligible effect of PGS on these- -properties. The Mud Cake Thickness decreases slightly due to the less availability of PGS in mud with increasing time. Therefore, the bactericide has significant role for reducing the degradation rate of PGS.

Conclusion

From the above discussion, the following conclusions are drawn:

- The Tipan sand of Geleki field of Upper Assam Basin is a good candidate for the application of NDDF. This formation having the average Porosity (21%) and Permeability (26 md) is very much susceptible for the formation damage. It contains both the swelling (Smectite) and non-swelling (Kaolinite) clay and the swelling is always more than the non-swelling clay. For the Smectites we must have to decrease the filtration loss and for the Kaolinite we must have to control the pH.

- PGS works excellently as the fluid loss control agent in NDDF (Fig. 9) which also has a moderate role in controlling the rheology of the mud (Figure 03-06). But, the drawback of PGS is that it is highly degradable. After few days of formulation it starts degrading and adversely affects almost all the mud properties (Fig. 11-17). Therefore, the drilling time using NDDF should be as low as possible or the drilling rate in the pay zone should be as high as possible. The biocide must be used to decrease the degradation rate.
- All the reservoirs in the world are heterogeneous. The properties and characteristics are different in different location in the reservoir. Therefore, the composition of any component or the value of any properties of NDDF to serve any function will not be fixed. In this study, from the laboratory experiments and field experience regarding the composition of PGS as Fluid Loss control agent in NDDF used for drilling the payzone without any damage and drilling complicacy, we may start the formulation of NDDF with 2.5 gm/100 ml PGS and may increase upto 3.5 gm/100 ml with the requirements during the drilling.
- Intensive care of the mud and the circulation system is needed during drilling the pay zone section. All the solid control equipments e.g. Shale shaker, De-Sander, De-Silter, Mud Cleaner, etc. should be working properly during the drilling to control the solid particles in mud. Continuous investigation of the properties and functions of the mud, whether they are fulfilling the requirements or not, is necessary and if required we may have to change the composition of the mud during drilling.

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