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SUCCESSFULLY PLANNING AND DRILLING THE REACTIVE SHALES IN THE CENTRAL NORTH SEA WITH A WATER BASED DRILLING FLUID

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Abstract

The Britannia platform is located in Block 16/26 of the U.K. Central North Sea. Historically, mineral oil and ester based muds have been used to drill the intermediate hole interval through the Tertiary claystones. The intermediate interval is drilled through the Hordaland Group which is among the most reactive claystone formations encountered anywhere in the world. The current utilization of mineral oil-based muds is dependent upon shipping all cuttings back to shore for processing and subsequent disposal. The supplemental costs involved with cuttings containment are very high and there is also a high risk of additional costs due to adverse weather conditions preventing the transfer of cuttings from the platform to a supply vessel thus curtailing the drilling operation. It therefore became apparent that significant savings to the current overall well costs can be realized if water based mud systems can successfully be used to drill this intermediate hole interval.

Introduction

The drilling program for the Britannia development well B-17 called for the intermediate hole interval to be drilled from the 20” casing shoe at ± 3,500 ft MD (± 3,400 ft TVD) to a TD of ± 8,900 ft MD (± 7,600 ft TVD) with a final hole angle of 63 degrees. Selection of the proper drilling fluid system has been predicated on the use of mineral oil-based and ester based muds which provides the most efficient means of drilling through some of the most chemically reactive shales anywhere in the world. The subject of this paper is to discuss the planning, preparation and drilling of the intermediate hole interval on Well B-17 with a water based mud. As a result of changing U.K government environmental legislation, the utilization of mineral oil-based muds is dependent upon shipping all cuttings back to shore for processing and subsequent disposal. Because of this change, there was an immediate need for a suitable water based mud for drilling this interval. Several types of water based systems such as lime-based muds, high salinity polymer muds and even potassium chloride muds have been used with little success. The need to develop a water-based mud system was necessary since there would be a large quantity of cuttings generated. Mineral oil muds usage would require containment of the cuttings however the containment facilities on this platform were considered inadequate for this large diameter hole size. Due to the specific well plan, the success of achieving the objective would be dependent upon setting the 13 3/8" casing at the end of the build section. This would allow for the target productive zone to be drilled at the optimum angle of attack.

Well Planning

The choice of a suitable water-based system must be based on the following criteria: shale inhibition, correct mud weight and good hole cleaning design. Mineral oil-based muds have always provided the most inhibitive drilling fluid in this area where chemically reactive shales are the rule. The challenge was to design a water-based mud system that has the ability to have near performance of the mineral oil-based mud. An accurate understanding of the nature of shales that will be encountered is critical to the success of designing a high performance water-based mud system. It was determined that a drilling window of no more than 10 days would be allotted to this interval because of the reactive nature of the formations. Any time spent beyond this would probably result in deterioration of the hole and resulting in a high risk of ultimately loosing the hole.

Shale Analysis

The shales encountered in the central Graben area of the North Sea are some of the most chemically reactive found in any drilling area. These shales are found to contain high percentages of smectite clays, which are prone to swelling and dispersion. These shales disperse into the mud system and promote difficulty in controlling the rheological properties of the mud system.

Shale analysis consisting of X-ray analysis, cation exchange capacity (CEC) and exchangeable cations were conducted on cuttings from a nearby well in the same block. The results are found in Table 1. The shales contain a very high concentration of mixed layer illite/smectite. The DCM (Dielectric Constant Measurement) was also used to identify and quantify the risk associated with hydratable and reactive formations as encountered in Hordaland Group. The DCM technique was developed by P. K. Leung and R. P. Steiger of Exxon[1]. A DCM analysis was performed on (unwashed) cuttings from the 17 ½" hole interval of Well B-15 previously drilled with mineral oil-based mud. The DCM provides a quantitative determination of rock properties by measuring the specific surface area, in square meters per gram, thus representing the total hydratable surface area of a cuttings sample. The DCM is dominated by the presence of smectite and also strongly influenced by the presence of other hydratable clays, the presence of which can be correlated with specific surface areas as shown in the Table 2. The measured DCM versus depth for this hole interval clearly indicates the DCM increasing from 250 m^2/g at the 20" casing shoe to a maximum of 580 m^2/g at 7,500 ft TVD in the Alba and Lothian formations as shown in Figure 1. The DCM was used during both the planning and drilling phases and proved to be an invaluable tool. The DCM showed where the most reactive shales would be encountered and at what point changes in the mud system should be made.

Drilling Fluid Selection

Various types of water based muds have been tried in this interval and generally have had little success in achieving good hole stability. The shales are very reactive and poor performance from these fluids has resulted in stuck pipe, poor drilling performance and on some wells, loosing the hole. On occasion, sidetracks had to be performed in order to drill this interval and were drilled with mineral oil muds or ester-based muds. Since the platform does not have a large capacity for storing cuttings while drilling a large diameter hole with a mineral oil-based mud, the need for a water based mud to drill this interval became even more important. A review of various water-based muds was conducted to determine which system would be the best fluid choice for drilling these chemically reactive shales. It was determined that the drilling fluid would be an integral component for success but other factors such as hole cleaning, proper mud weight and solids control would also play a major role in the success. These factors were considered important enough that a major part of the planning phase also included these factors.

Based on the review of various drilling fluid candidates, it was determined that a KCl/Polymer system was the best choice. The other mud systems considered was a silicate system, KOH/Lime, calcium chloride and sodium chloride based muds systems. These other systems had limitations that disqualified them for further consideration. The silicate mud system had been used by another operator on a nearby well in a similar interval and had numerous problems with this system and ultimately displaced to a mineral oil-based mud. Calcium chloride muds have been used in the Gulf of Mexico but not in the North Sea. Also, the calcium chloride mud system has been known to have problems controlling the fluid loss and rheological properties. Chevron had used a KOH/Lime system on a nearby well with less than desired results. Sodium chloride based systems have been used in the North Sea with mixed results but because of the high swelling content of the shales present, this system was not considered as being very successful.

Mud Weight Prediction

A mud weight schedule with an initial mud weight of 11.5 lb/gal and a final mud weight of 12.5 lb/gal was developed as a result of wellbore stability studies and offset data. The predicted mud weights were based upon the anticipated hole angle with depth. The collapse and breakdown predictions are depicted graphically in Figure 2. Increases in mud weight higher than those above will be based on the hole conditions and will be confined by the fracture gradient and LOT achieved at the 20" casing shoe (> 14.0 lb/gal expected). If the mud weight is increased above 12.5 lb/gal care must be taken to avoid differential sticking across any permeable zones encountered while drilling the section. The mud weight schedule was altered just prior to spud for an initial mud weight of 11.0 lb/gal and a minimum mud weight of 11.5 lb/gal prior to drilling into the Alba formation.

Hole Cleaning

The commonly used 17 ½" hole size was scaled back to 16" as it was apparent that the smaller hole diameter would result in higher annular velocities thus improving hole cleaning which was considered to be a critical factor in the success of drilling this interval. Moreover, it was assumed that the 16" hole would be washed out somewhat due to the dispersive nature of the formation when drilled with a water-based mud system. Hole cleaning will be a major factor to the success in drilling the large diameter hole section. A series of hole cleaning simulations were performed and the following conclusions were made:

1. The higher the deviation, the more difficult the hole cleaning even when the cuttings are small for the 17 ½" hole. A 16" hole is somewhat easier to clean and improvements in hole cleaning are seen with large drill pipe and higher pipe rotation compared to a 17 ½" hole.
2. The larger the cutting, the less efficient will be the

hole cleaning.

3. More viscous mud does not improve the hole cleaning.
4. A 16” hole at 40 deg and 63 deg is easier to clean than a 17 ½" hole at the same deviations.

Penetration rates were to be controlled to ensure that the hole is not loading up with cuttings. Torque and drag measurements would be made to determine if hole cleaning problems may be occurring. To successfully drill and clean the 16” hole section, several drilling / fluids issues must be adequately addressed. The rheological properties of the mud are an important aspect of hole cleaning but other factors such as pipe movement, hole size, rate of penetration, cuttings size, hole geometry and annular velocity all influence hole cleaning.

The circulating rate was considered to be critical with respect to hole cleaning and to minimize bit-balling and/or the formation of mud rings. In the event of mud pump failures, it was decided that drilling would be suspended if the circulating rate fell below 1000 gpm and only be continued when 1000 gpm could be re-established. Adequate and constant rotation of the drillstring was considered to be critical with respect to hole cleaning, particularly in the tangent section. Therefore, in order to optimize hole cleaning the drillstring would be constantly rotated at a minimum of 120 rpm with the only exception being sliding during the two build sections.

Drilling Fluid Formulation

The formulation for the whole mud dilution volume was divided into two sections based on the DCM results. This volume was built by blending premix, brine and drillwater with the required products in order to achieve the desired formulation. Prior to use, all dilution volume was weighted with barite to within ±0.3 lb/gal of the active mud weight. The most important aspect regarding the use of water-based muds is the judicious use of whole mud dilution. Additionally, active mud volume should be dumped as required to maintain continuous and adequate whole mud dilution. The plan was to minimize the requirement for adding products directly to the active system. The formulations of the dilution volume were based on the results of the DCM analysis. As depicted by the DCM, the mud system would be formulated initially with a KCl concentration of 30 - 50 lb/bbl KCl. A fully soluble glycol was also programmed at a concentration of 3-4 % by volume. This system was planned to drill down to top of the Alba formation, which was at 6500' TVD. The formulation for this section is found in Table 3. At this depth, there was a substantial increase in the DCM surface area indicating a more chemically reactive formation would be encountered to the total depth of the interval. The mud system was then modified to have a higher concentration of KCl (50 - 60 lb/bbl), maintain the same glycol concentration as before and begin additions of Clayseal ®, a shale stabilizing surfactant. The formulation for the interval below the Alba formation is found in Table 4.

The Clayseal has been used by Chevron on some wells in the Gulf of Mexico with good results. The shales in this section are very reactive and it was concluded that the mud system should be formulated with all required additives that would provide the most inhibition that could be attained in the water-based mud system. The additives should be included in the active mud system rather than adding after the reactive interval had already been encountered.

Logistics

Pit space requirements were reviewed prior to drilling this section to ensure that there would be space available to mix and store the required mud and to carry out the necessary dilution of the premix with drillwater.

On Britannia the available space allows for adequate volumes:

Active volume = 700 bbl
Reserve volume = 2,000 bbl
Sand traps = 150 bbl
Mix and slug = 400 bbl
Total available space = 3,250 bbl

A total volume of 2800 bbls of concentrated KCl brine (70 lb/bbl) was prepared and shipped to the rig. The concentrated brine would be cut back as required with drillwater. Drillwater is preferable to seawater, since the latter will require pre-treatment to remove divalent ions before blending with premix. If drillwater stocks were depleted, it was planned to use pre-treated seawater to blend with the premix.

At least 3,000 bbl of KCl polymer premix was predicted to be required for this interval; 2,000 bbl of which could be shipped to the rig before the beginning of the section with a second batch of premix being shipped out at a later date, when required. Due to logistical and surface pit constraints it was not considered possible to offload all the KCl polymer premix prior to displacing the well to KCl polymer water based mud. All premixes were to be agitated on a regular basis to ensure homogeneity of the batch.

Drilling Parameters and Guidelines

It was determined that the rate of penetration would be limited in order that an annular cuttings load of 4% by volume would not be exceeded. This essentially limited the ROP to a maximum of 150 ft/hr at the minimum circulating rate of 1000 gpm. Frequent wiper trips were considered to be essential in order to determine the hole condition. The overpull required for tripping out of the hole is one of the most accurate indicator on the rig with which to determine the inhibition. Moreover, it was decided that the hole would be circulated clean based on visual confirmation at the shakers prior to wiper trips - without any arbitrary time limits on the time taken for the shakers to clean up. Back-reaming while tripping was considered to be ill advised due to the high risk of; 1) inducing hole instability and; 2) packing-off as cuttings beds were disturbed. In the event that backreaming was considered necessary as a result of poor hole condition, it would be performed with the same circulating rate as used for drilling and a minimum of 120 rpm drillstring rotation. Back-reaming prior to connections was considered to be prudent, especially after sliding during the two build sections. In any event, back-reaming would be performed with the same circulating rate as used for drilling and a minimum of 120 rpm drillstring rotation.

Results

The 20” casing shoe at 3,750 ft was drilled and a 16" hole was drilled to a TD of 8,843 ft and the 13 3/8” casing was run and landed well within time limit of 10 days. The frequent wiper trips and extended circulation accounted for a significant portion of the total time for the interval. However, this was the first attempt to drill this hole interval with a water-based mud so a very conservative approach was taken with respect to the overall drilling operation. There is no doubt that the total time required for similar hole intervals drilled with this water-based mud in the future can be significantly reduced as a result of the experience and confidence gained during drilling this well. The products consumed for the mud system used in this interval is shown in Table 5. The total mud materials cost for the hole interval was £290,000, which could be considered as acceptable for this first effort. Moreover, it is likely that incorporating the lessons learned from this hole interval for future wells can reduce this cost. However, the opportunity for significant cost reductions is relevant to improving the drilling performance where approximately 2 days are likely to be saved. Therefore, it is essential that the mud system is not compromised as the potential cost reductions of improved drilling performance far outweigh the limited potential of mud cost reductions.

The easily defined results achieved were:

- Two critical build sections were drilled without any sliding problems
- An estimated near gauge hole with an average hole diameter of 16.3” at TD being based upon carbide lags
- Hole conditions were excellent throughout the entire hole interval
- Mud properties were very stable throughout the entire hole interval
- Cuttings integrity was excellent throughout the entire hole interval
- Shaker efficiency and performance was excellent throughout the entire hole interval
- No overpull of greater than 50 K lbs on trips
- No wiper trip required at TD prior to running the 13 3/8” casing
- No down time to mud related incidents: bit balling, stabilizer balling, mud rings etc.

The overall mud system performance was considered as exceptionally good, based upon hole condition and mud properties throughout the entire hole interval. The mud properties recorded during this interval are shown in Table 6. The MBT was one of the key parameters monitored and controlled through dilution and solids control equipment. The MBT value was generally maintained below 25-lb/bbl equivalent and was achieved with dilution through the more reactive formations. The mud system was extremely tolerant of solids, as reflected by the acceptable rheological properties at a mud weight of 12.0 lb/gal with an MBT of 25.0 lb/bbl. The accurately specified KCl and glycol concentrations are undoubtedly instrumental in providing the solids tolerance and the PHPA and Clayseal treatments also appear to have made a significant contribution.

The dilution rate is critical as it has a significant effect upon costs, a higher than anticipated dilution rate resulting in increased material consumption and costs. This well was programmed and costed at an assumed average dilution rate of 1.0 barrels per foot whereas the actual dilution rate averaged 1.32 barrels per foot. Nevertheless, the average dilution rate of 1.32 barrels per foot for this hole interval was considered as acceptable considering the formation drilled and solids control equipment on the rig. It would be very difficult to significantly reduce the dilution rate of this hole interval without further improving the overall solids removal efficiency.

The KCl concentration was programmed at 30 – 50 lb/bbl in the upper part and 50 – 60 lb/bbl in the lower part. The KCl concentration was maintained at 30.0 –

40.0 lb/bbl for the upper part of the hole interval and increased, as per the program, in the lower part. However, it was not possible to increase the KCl content to 60.0 lb/bbl due to severe depletion of the product and a maximum of 54 lb/bbl was only achieved. The KCl depletion over one circulation while drilling (from suction pit to shakers) was measured at ±8.0 lb/bbl on several occasions in the lower part of the hole interval. The KCl concentration was well programmed and was instrumental in the mud system performance and resultant excellent hole condition.

The programmed glycol was one that is fully miscible in water. There was no attempt to employ any cloud point technology with this fluid formulation and the glycol is assumed to have partially formed a micro-emulsion and to be partially in solution within the water phase of the fluid. The glycol content was maintained at 3 – 4% with the exception of the last day when the concentration was increased to 4.6% at TD. The glycol concentration (% by volume) was determined by use of a hand held refractometer that proved to be easy to use, accurate and reliable.

An initial 4.0-lb/bbl Clayseal treatment was the principal exception to direct product addition to the active mud system. The treatment was added while drilling prior to entering the Alba formation. There was a noticeable improvement in the cuttings integrity and also cuttings travel on the screens after the initial treatment and it was decided to maintain a product concentration of ± 4.0 lb/bbl thereafter. Moreover, there was no increase in the rheological properties, which is desirable for an inhibition product. It is somewhat difficult to quantify the value of Clayseal as this is the only use to date in the region and offset comparative data is not available. However, Clayseal was considered as an essential component for any similar hole intervals drilled with KCl polymer water-based muds in the future.

Conclusions

There were several accomplishments during this first attempt to drill the chemically reactive interval with a water based mud system. The accomplishments were as follows:

- Two build sections - one at 40 deg and the other at 63 deg were drilled successfully and there were no reported sliding problems.
- There was minimal overpull on trips which was attributed to good hole cleaning in the highly deviated interval.
- 13 3/8" casing was successfully run with minimal problems to the programmed depth.
- No wiper trip was required prior to running the 13 3/8" casing.
- No down time related to mud related incidents and the interval was drilled within the prescribed time frame.
- Hole conditions and cuttings integrity were excellent throughout the interval.
- There was no downtime related to dilution volume handling on the rig.
- The DCM was considered as a valuable tool for distinguishing the reactive shale intervals and used to dictate what mud treatments were required.

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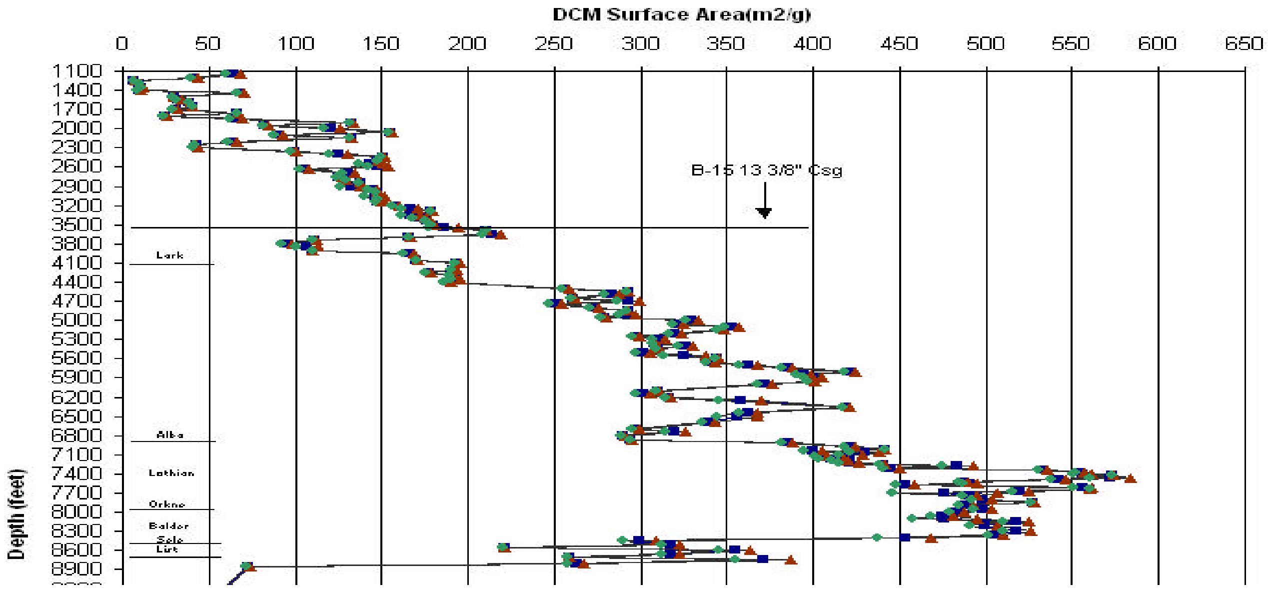
Nomenclature

KCl - Potassium Chloride
KOH - Potassium Hydroxde
CEC - Cation Exchange Capacity
DCM - Dielectric Constant Measurement
MBT - Methylene Blue Test

References

1. Leung, P. K. and Steiger, R.P: "Dielectric Constant Measurement: A New, Rapid Method To Characterize Shale at the Wellsite," SPE 23887, 1992 IADC/SPE Conference, February 18-21, 1992, New Orleans.



` Figure 1 - Well 16/26-B15, Measured Depth versus DCM Surface Area

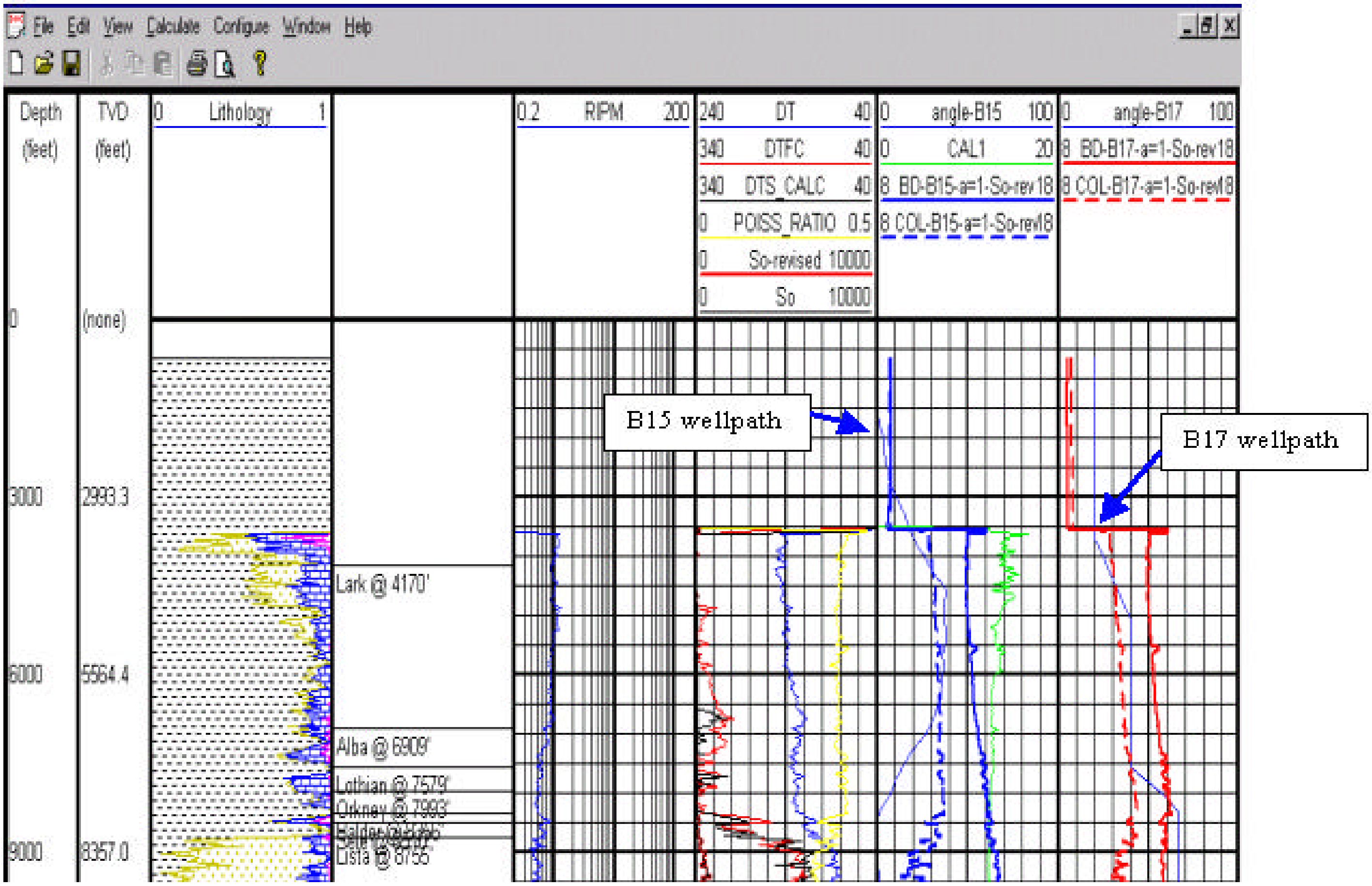


Figure 2. Hole stability forecast B15 deviation & B17 proposed deviation.

Table 1 - X-Ray Analysis, CEC and Exchangable Ions

	Mineral Composition							Total	**% of Total Sample**			Mixed	Mixed Layer		**% of clay fraction**			Mixed	Total	**CEC**	Exchangeable Cations			
Depth	Quartz	Felds	Calcite	Dolo	Pyrite	Side	Clay	Kaol	Chlor	Illite	Layer	Illite	Smec	Kaol	Chlor	Illite	Layer	Illite	Smec	Total	Na	K	Ca	Mg
3300	30	3	4		1	1	61	18	0	17	26	45	55	30		28	42	40	14	19.3	13.7	3.5	6.3	2.5
3380	33	3	14	3	1	1	45	11	0	14	20	47	53	25	1	30	44	39	10	20.5	16.9	54.5	7.5	2.6
3635	38	4	7	1		1	49	13	0	16	20	48	52	27		32	41	42	10	17.6	12.1	3.1	8.1	2.5
3695	25	3	5		2		65	21	0	23	21	42	58	32		35	33	44	12	19.9	14.6	2.8	10.8	2.9
3900	16	1	15		1		67	21	0	21	25	46	54	31		32	37	43	13	23.1	15.8	2.8	12	3.3
4006	14	3	11	1	1	2	68	22	0	19	27	36	64	32		28	40	38	17	29.8	25.1	3.6	11.5	4.3
4100	17	2	19	1	1	1	59	21	0	18	21	37	63	35		30	35	38	13	22.3	16.2	2.3	10.1	3.1
4200	13	1	11		2	1	72	22	0	22	28	46	54	31		30	39	43	15	29.6	20.8	3.5	12.4	3.5
4416	18	4	4		1	1	72	16	0	19	37	41	59	22		26	52	41	22	32.8	19.4	2.7	5.7	4.8
4530	24	5	6	1	3	1	60	14	0	14	32	33	67	24		23	53	33	21	30.6	19.4	1.8	6.6	4.7
4540	53	4	11	1	2	3	24	8	2	4	10	42	58	33	9	17	41	21	6	13.5	4.3	0.6	10.4	0.8
4760	20	3	4			1	71	11	0	17	43	33	67	16		24	60	38	29	38.6	23.1	4.1	6	3.6
5210	25	4	3	1			67	13	0	11	43	30	70	19		17	64	30	30	29.8	21.9	1.3	6.6	2.2
5485	16	3	3				77	18	1	12	47	36	64	23	1	15	61	32	30	33.4	27.1	1.3	8.3	2.2
5650	10	3	6	1	2	3	75	17	1	13	45	32	68	22	1	17	60	31	31	36.8	27.6	1.5	8.7	2.2
5750	9	3	4		1	1	82	31	1	13	37	40	60	38	1	16	45	31	22	33.2	25.2	1.3	9.1	2.1
5810	8	3	2	1	1	1	84	31	1	15	37	37	63	37	1	18	44	32	23	33.7	23.8	1.2	7.5	2
5850	7	3	4	1	2	2	81	21	0	17	43	33	67	26		21	53	35	29	38.7	28.1	1.5	7.9	2
6150	9	5	5	1	2	2	76	11	1	12	52	32	68	15	1	16	68	33	35	42.2	33.9	1.1	9.3	1.6
6195	7	3	5	1	1	1	82	25	1	13	43	34	66	31	1	16	52	30	28	41.1	28.5	1.2	8.4	2
6304	9	3	3	2	3		80	10	1	13	57	31	69	12	1	16	71	34	39	41.6	35.6	1.4	10.4	1.5
6338	9	4	4	1	2	2	78	16	0	12	49	35	65	21		16	63	33	32	43.8	33.2	1.1	9.1	1.7
6510	8	3	2	1	1	1	84	22	0	13	49	33	67	26		16	58	32	33	40	30.5	1.2	12	1.2
6700	7	4	3	1	2	2	81	23	1	11	46	32	68	28	1	14	57	29	31	40.6	30	1.1	11.5	1.6
6900	7	3	3	1	2	1	83	21	0	12	50	35	65	25		15	60	32	32	40.4	31.6	0.9	8	1.3
7000	9	4	3		1	1	82	19	1	11	51	27	73	23	1	14	62	28	37	40.1	31.2	1.2	11.1	1.1
7250	6	3	4	1	3	2	81	19	1	16	45	46	54	23	1	20	56	41	24	39	29.9	1.5	12.6	1
7500	23	3	2	1	5	2	64	6	1	16	42	21	79	9	1	25	65	34	33	28.9	25	1.1	11	1
7600	22	3	3		3	2	67	7	0	17	44	23	77	10		25	65	35	34	33.1	26.1	1.3	10.5	1.5
7650	32	2	2		3	2	59	12	0	21	25	25	75	21		36	43	42	19	24	19.7	0.6	11.6	2.5
7667	16	3	5	1	7	2	66	7	1	13	46	18	82	10	1	20	69	28	37	38.5	30.3	1.5	10.2	2.6
8000	20	4	4	1		1	70	5	1	14	50	24	76	7	1	20	72	32	38	37.9	30.2	1.7	11.3	0.9
8705	6	4	4	1		1	84	23	3	24	35	55	45	27	3	28	42	47	16	27.8	22.7	2.2	7.3	1.1

Table 2 - Clay Minerals & DCM Equivalent

Clay Mineral	DCM m2/g
Smectite	600 – 800
Illite / Smectite	200 – 250
Kaolinite	80 – 120
Chlorite	20 – 40
Limestone	<1
Quartz	<1

Table 3 - Upper Hole Interval: 20” Casing Shoe (3,750 ft) - Top Of Alba Formation (6,500 ft)

KCl	30.0 – 40.0 ppb
Glycol	3.0 – 4.0 %vol
Starch	4.0 lb/bbl
PAC LV	1.0 – 2.0 lb/bbl
Biopolymer	1.0 lb/bbl
Biocide	as required
Caustic	0.2 - 0.25 ppb for pH of 8.5 – 8.8
Oxygen Scavanger	as required
PHPA	0.0 – 0.5 ppb (calculated, not tested)
Barite	as required for 11.0 – 11.5 lb/gal

Table 4 - Lower Hole Interval: Top Of Alba Formation (6,500 ft) -TD (8,843 ft)

KCl	40.0 – 55.0 ppb
Glycol	3.0 – 4.0 %vol
Clayseal	3.0 – 4.0 ppb
Starch	4.0 ppb
PAC LV	1.5 – 2.0 ppb
Biopolymer	1.0 – 1.5 ppb
Biocide	as required
Oxygen Scavanger	as required
PHPA	0.5 – 0.8 ppb (calculated, not tested)
Caustic	0.2 – 0.25 ppb for pH 8.5 – 8.8)
Barite	as required for 11.5 – 12.2 ppg
Bentonite Equivalent	16.0 – 25.0 ppb (MBT)

Table 5 - Interval Drilling Fluid Consumption

Interval #	02	16 in. Hole Section	Top of Interval	3,750 ft
			Bottom of Interval	8,843 ft

Material	Unit size	Quantity
Oxygen Scavenger	5 GAL. CAN	15
Biopolymer	25 KG. BAG	145
Barite	1000 KG. TON	582.9
Defoamer	25 KG. CAN	24
Caustic soda	25 KG. BAG	44
CLAYSEAL	55 GAL. DRUM	40
Starch	25 KG. BAG	79
PHPA	5 GAL. PAIL	94
KCl/Glycol Premix	42 GAL. BBL	5,154
PAC-L	25 KG. BAG	160
Potassium chloride brine	42 GAL. BBL	2,792

Table 6 - Drilling Fluid Properties

Report Date	MD	Mud Weight	Viscosity	PV	YP	Gels Sec	Gels Min	API WL	Mud pH	Chlorides	Calcium	MBT	LG Solids, %
18-May-00	3951	11.0	60	17	25	8	11	4.6	9.4	57200	280	1.5	0.3
19-May-00	5114	11.3	52	18	26	10	16	4.2	8.6	55000	380	13.7	2.3
20-May-00	5494	11.3	69	14	25	11	20	4.5	9.3	58000	600	16	2.1
21-May-00	6784	11.5	58	22	25	9	18	4.0	8.6	72200	560	22.5	2.9
22-May-00	6916	11.7	68	22	24	9	16	4.4	8.5	78000	560	22.5	
23-May-00	8078	12.0	89	25	32	11	23	3.2	8.5	81000	480	25	3.8
24-May-00	8654	12.0	68	26	36	11	19	2.8	8.5	85500	480	25	5.7
25-May-00	8843	12.2	83	25	28	9	16	2.8	8.6	86500	480	27	5.1