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## Use of Amine/PHPA System to Drill High Reactive Shales in the Orito Field in Colombia

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### Abstract

The use of water based fluids replacing oil based drilling fluids has been increasingly being applied in the Petroleum Industry in order to mainly accomplish environmental legislation.

A challenge when using water based drilling fluids in highly reactive shales is to overcome problems such as wellbore instability, torque and drag and environmental requirements. This was the case in the Orito oil field in Colombia.

The Orito field is located to the south of the country and has been operated by Petrominerales Colombia Ltd. During years of exploitation, the Orito wells were drilled with oil base muds in order to address wellbore instability problems related to the highly reactive shales of the Villeta formation, which is drilled in the 311 mm (12 1/4") hole and is about 300 m (1000 ft) long.

Some years ago, different water based mud systems have been used in the area; however, it has not achieved the high performance expected by the operator to successfully drill the troublesome Villeta formation. Thus, in order to drill the two last development wells in the Orito field, it was proposed that an Amine/PHPA system to be evaluated. The Amine/PHPA system has been developed by Q'Max Solutions in Canada and has also been used in Ecuador with very good results.

According to own experiences in the field, the Amine/PHPA system was formulated to achieve the right concentration of each mud product to satisfy the necessity of a system that provides at the same time good inhibition, adequate rheology properties and lubrication during the angle build section.

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Capillary Suction Test (CST) were carried out to determine the right concentration of amine and PHPA to provide inhibition for the highly reactive Villeta shales. Historical cases of hydraulics and operational performance were studied to find out xanthan gum concentrations to reach adequate yield point values that secure hole cleaning during the most critical deviated section of the interval and lubricant concentration was also determined to reduce torque and drag in the water based system.

This paper is intended to present the performance of the Amine/PHPA system and environmental achievements in an environmentally sensitive area. Laboratory and field data obtained during the project is also presented.

### Introduction

Drilling operational problems due to borehole instability have led many operators to use of oil-based muds (OBM). However, environmental challenges due to those same OBM's have lead operators and service companies alike to develop water based muds (WBM) with OBM shale stabilizing performance, while significantly reducing environmental impact.

Drilling highly environmental sensitive areas has cost the industry worldwide millions of dollars in disposing of oil-based systems residuals. Indeed, the use of OBM can be such an expensive practice, that the desire for high performance WBM's is forever increasing.

The initial attempts at using alternative WBM's in the Putumayo area (Figure 1) utilized lignosulfonate muds; however the results were not very successful. Acidic lignosulfonates and lignites required high quantities of caustic soda to be used,<sup>1</sup> thereby increasing shale swelling by maximum cations exchange of the sodium present in the caustic soda, and with higher mud costs due to the significant amounts of alkaline materials required. In addition, the lignosulfonate muds increased the high solids in the mud due to over-dispersion. Nevertheless, the most important issue presented with the use of these systems was the negative environmental impact caused by the presence of water dispersible chromium contained within the lignosulfonate.

Tight environmental laws that protect the Putumayo jungle where the Orito field is located, challenged oil companies such as Petrominerales Colombia Ltd. to use the new technology in inhibitive and environmentally friendly water-based mud systems. Chemical and mechanical inhibitors contained within WBM's were then introduced in the Orito field. The well known potassium ion was utilized in the form of potassium nitrate ( $\text{KNO}_3$ ), with the nitrate ( $\text{NO}_3^-$ ) chosen to eliminate the negative environmental impact of the chloride ion ( $\text{Cl}^-$ ) seen with the common use of the potassium chloride (KCl). Acting in synergy with the potassium ion, a low molecular weight glycol was added to the system. The glycol inhibition mechanism is believed to be due to the competition it establishes with water in order to disrupt the hydrogen bonding network of water with the swellable clays of the shale. An apparent hardening of the shale prevents the shale from swelling and dispersing.<sup>2</sup> Partially Hydrolyzed Polyacrylamide (PHPA) was also used in order to improve shale stability.

The system provided good inhibition and the environmental impact was considerably reduced. However, the high concentrations of potassium nitrate required to successfully inhibiting the problematic shales in the Villeta and the Rumiyaco formations led to new requirements in water treatment in order to meet the Colombian legislation in regards to water disposal. Cuttings were easily treated with native soil and used as land farming. The challenge to improve drilling fluids in order to achieve a High Performance Water Based Drilling Fluid (HPWBF), encouraged researchers to develop a new system that not only efficiently inhibits the troublesome shales found in the Orito field, but also minimizes the environmental impact seen with previous WBM's. Other common drilling parameters such as adequate rheological and lubricity to drill the critical deviated section of the wells needed to be met

The amine/PHPA system was developed in Canada and has been used in more than 100 wells in western Canada, Ecuador and India. This paper describes the development of the system in Colombia to drill the two last development wells in the Orito Field.

### **Amine/PHPA Inhibition Mechanisms**

In the search for a replacement to oil-based muds, the development of inhibitive water-based drilling muds has focused on either altering the chemistry of the aqueous phase by including active cations (e.g. potassium or calcium). Mechanical inhibitions have also been introduced by using high molecular weight materials (e.g. PHPA) in order to physically block the capillary network on the shale surface.<sup>3</sup>

The Amine/PHPA system used to drill the two last development wells in the Orito field combines the chemical inhibition and encapsulation mechanisms provided by the use of an organic amine and a high molecular weight PHPA. Cationic<sup>4</sup> mud components found within the amine efficiently inhibit troublesome shales by absorbing onto the negatively charged mineral surface. The mechanism by which the reaction occurs is believed to be a cation exchange reaction,

where cations contained in the mud component replace the exchangeable cations of the shale surface. The resulting exchange ties up the shale platelets reducing the separation potential of shale matrix.<sup>5</sup> For years, potassium, usually as a chloride salt (KCl), has been considered a very effective inhibitor for clay swelling<sup>6</sup>. However, because of the high salt concentration required to successfully obtain the required levels of inhibition, the industry searched for another cation that promised to be as effective as the potassium. Amines have proven to be effective inhibitors of shale swelling, with their abilities rivaling those of a potassium based salts. Therefore, It was then introduced nitrogen-centered derivatives, which include, among others, amines.

The combined inhibition mechanism of the Amine/PHPA system can be described as absorption of exchangeable cations in two stages: The low molecular weight of the amine used in the system penetrates the clay layers as efficiently as the potassium ion. Amines are effective at relatively low concentrations, thus desorbing exchangeable cations and water molecules associated with the cations in order to maintain charge balance. The second stage of the process is due to the high molecular weight of the PHPA, which produces a superficial adsorption on the surface of the shales, acting as an encapsulating coating. Because of the large molecular size of a PHPA, it cannot penetrate the clay layers as effectively as the amine. Without polymer encapsulation, the already inhibited and brittle surface of the shale may tend to crumble as drilling fluid passes through the annular space. Thus, the known synergetic effect between amine (chemical inhibition) and PHPA (mechanical inhibition) is obtained.

The organic amine chosen for the drilling fluid system is water soluble, has very low toxicity, is biodegradable and therefore creates minimal environmental impact.

### **Orito Field Description**

The Orito field is located Southern Colombia in the high environmentally sensitive Putumayo basin (Figure 1). The Orito oil wells have been drilled in three and four sections. Figure 2 shows a well schematic of the two last development wells drilled during 2005 and early 2006. The intermediate section of the well is drilled deviated with a 311 mm bit within the unstable Rumiyaco and Villeta formations over 1600 meters.

The Rumiyaco and Villeta formations are 300 meters thick and mainly composed of kaolinite, illite and smectite (Figure 3). Mixed-layer illite-smectite is a randomly interstratified type with approximately 70-80% smectite interlayers. Chlorite-smectite is an ordered type with approximately 75-80% chlorite interlayers. Because of the highly reactive minerals present in the drilled formations, the use of water based systems often face problems such as wellbore instability, shale swelling, high torque and drag, and stuck pipe.

## Laboratory Data

In order to establish the correct amine and PHPA concentrations for each mud additive required in the system, Capillary Suction Tests (CST), shale dispersion, rheologic and lubricity tests were carried out on Villeta cuttings obtained from a close geological offset.

Figure 4 shows the CST results for the cuttings described in Figure 3. Four different concentrations of amine were used to test the amine/PHPA system and inhibition efficiency was compared to the inhibition achieved with a previously used potassium/glycol/PHPA system. Note that the CST test is a good screening tool to estimate effective concentrations of salts or amines to achieve better wellbore stability.

Amine concentration was increased until the best CST time was obtained. Notice that the system has a very similar and even slightly better overall performance compared to the potassium/glycol system. PHPA concentration was maintained as used in the former system, since it was experienced to be enough to provide excellent mechanical inhibition. Adequate amine concentration observed in the tests is between 14 – 19 L/m<sup>3</sup>.

According to the results obtained from the CST test, a shale dispersion test was performed in order to verify efficiency of inhibition in a more rigorous heated environment. The dispersion test basically consists of introducing a known weight of sized formation solids/shales into complete drilling fluids to be tested. For this test, the samples were hot rolled for 16 hours at 65°C. Upon test completion, the sized cuttings are recovered, dried and weighed in order to establish the loss of weight due to hydration and disintegration.

Figure 5 shows the good performance of the amine/PHPA system achieved in the dispersion test. Recovery percentage of the sample is very high, as mentioned above; overall performance is a little better than the potassium/PHPA system.

According to past experiences, rheological properties were measured in the laboratory in order to obtain efficient hole cleaning. Xanthan gum was used to provide adequate values of rheology while modified starch controlled mud filtrate as required. Caustic potash was used to maintain pH. Table 1 shows the mud properties measured in the laboratory for the amine/PHPA system.

## Field Results

Once laboratory data were obtained and analyzed, the amine/PHPA system was used to drill the O-117 and O-118 wells. Both wells were successfully drilled. The intermediate section used the amine/PHPA system and did not show any evidence of wellbore instability. Cuttings over the shakers screens were observed to be normal with little evidence of long splinters or large blocks of wellbore material commonly associated with instability of the formation. Initial density was 1115 kg/m<sup>3</sup> and it was increased up to 1220 kg/m<sup>3</sup> in order to control typical gas presence in the Villeta formation. A water-dispersible lubricant was used in the two wells to minimize torque and drag concerns. No evidence of torque

and drag was observed, due to both the good wellbore conditions and the presence of the lubricant.

Table 2 shows the maximum, minimum and typical properties of the amine/PHPA system as it was run in the field. Properties were maintained as proposed in the laboratory analysis, therefore, reducing hole cleaning problems, good lubricity values to reduce torque and drag in the critical deviated section of the interval and, as expected, successful inhibition of the troublesome Villeta and Rumiyaco shales.

Overall costs of the project decreased because of low dilution rates, water treatment efficiencies. The high performance of the system was evidenced by the good results in productive time during the drilling operations.

Solids control equipment has been a very important partner in the high drilling fluids performance. Efficient solids separation from the mud resulted in drilling fluid rheological properties maintenance as well as proper low gravity solids content in the system. Shakers screen sizes were planned according to previous experiences and continuous monitoring was carried out by the Total Fluids Management (TFM) engineer. Two centrifuges of high and low speeds were used in order to provide higher solids cleaning.

Cuttings generated from drilling process were collected in a catch tank. Once cuttings are collected, they are transported to the disposal area (Figure 6). In the disposal area, cuttings were dried out and mixed with native soil. No lime was used in order to avoid pH increase and excessive toxic dust generated by this material. Once the mixing was accomplished according to regulatory guidelines, no further environmental treatment was needed.

## Conclusions

- The system used to drill the section of the troublesome Villeta and Rumiyaco formation consisted on amine additive, PHPA and rheology and filtrate controllers. Also a lubricant was used because of the deviation angle to prevent torque and drag. This formulation provided the required inhibition to achieve wellbore stability and general good operational performance.
- The system proved to be environmentally friendly since its components are easily disposed according to environmental regulations for the sensitive Orito field area.
- Results obtained with CST and dispersion tests were determinant in designing the system for its specific application in the Orito field in Colombia.
- The amine/PHPA system is designed to combine the chemical inhibition obtained through the amine cationic characteristics and by the mechanical inhibition provided by the high molecular weight PHPA. The synergy between these products is achieved by mixing them in the adequate concentrations.

- The success attained by using the amine/PHPA system has been due to the laboratory research carried out in Canada and its application in some fields over there as well as in Ecuador, where shales inhibition is also an issue overcome by this system.
- Rheology properties of the system are well controlled according to the requirements of hole cleaning with the addition of xanthan gum. Density increase to control gas was achieved with calcium carbonate and barite while drilling the Villeta formation. No significant increase in plastic viscosity was observed since the system has low solids content.

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## Tables

Property	Result
Density (kg/m <sup>3</sup> )	1150
Funnel Viscosity (s/L)	45
Plastic Viscosity (mPa.s)	15
Yield Point (Pa)	10
API Fluid Loss (mL)	5.6
pH	9.5
Lubricity Index	0.212

**Table 1 Mud properties measured in the laboratory of the amine/PHPA system**

Property	Min.	Max.	Typical
Density (kg/m <sup>3</sup> )	1080	1222	1198
Funnel Viscosity (s/L)	38	60	50
Plastic Viscosity (mPa.s)	7	18	15
Yield Point (Pa)	8	15	12.5
API Fluid Loss (mL)	7.5	9.8	8.0
pH	9.5	9.5	9.5
MBT (kg/m <sup>3</sup> )	7.1	49.9	42.8

**Table 2 Field properties of the amine/PHPA system**

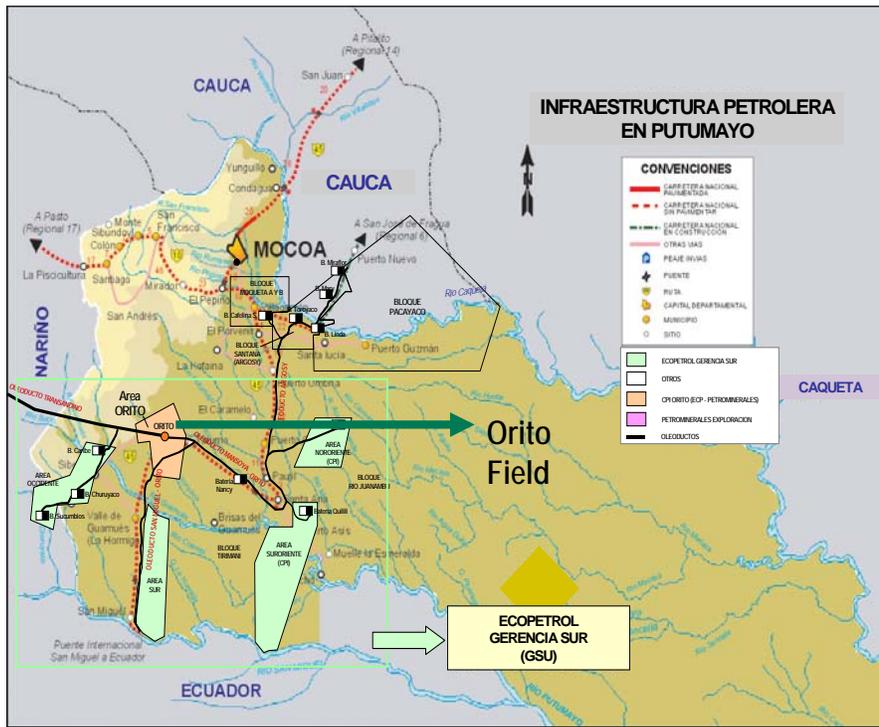


Figure 1: Orito Field Location

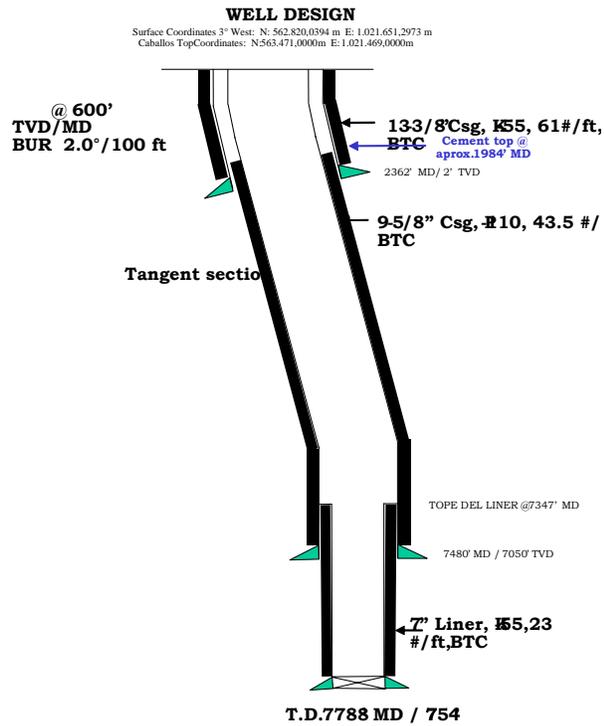


Figure 2: Typical Well Configuration

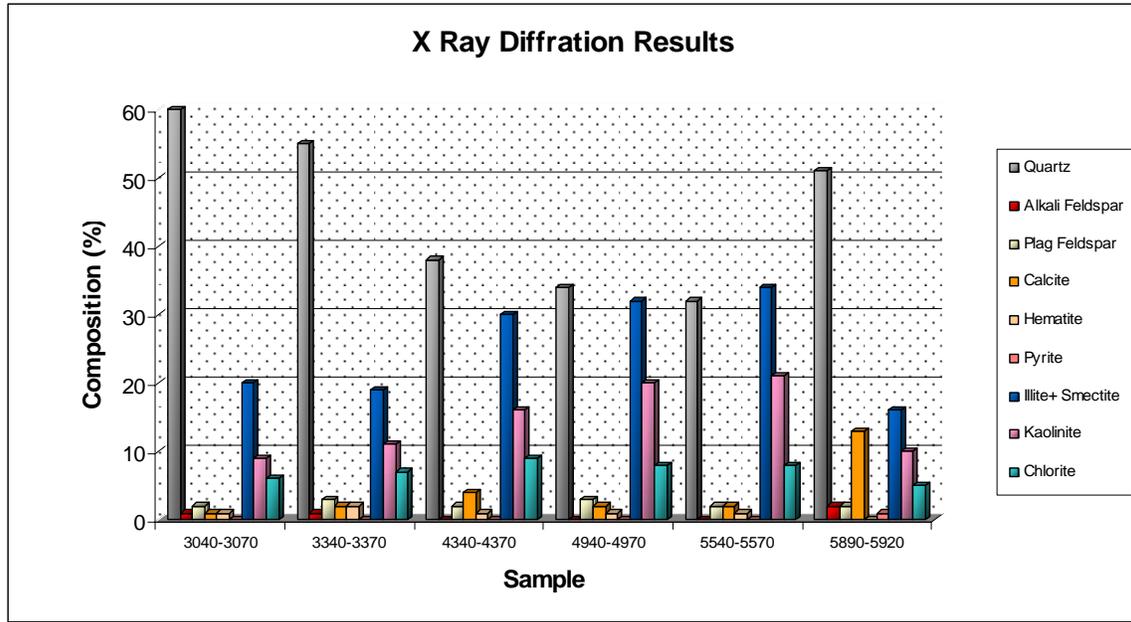


Figure 3. Clay Mineralogy of Villeta Cuttings (<2 microns) as Determined by X-Ray Diffraction.

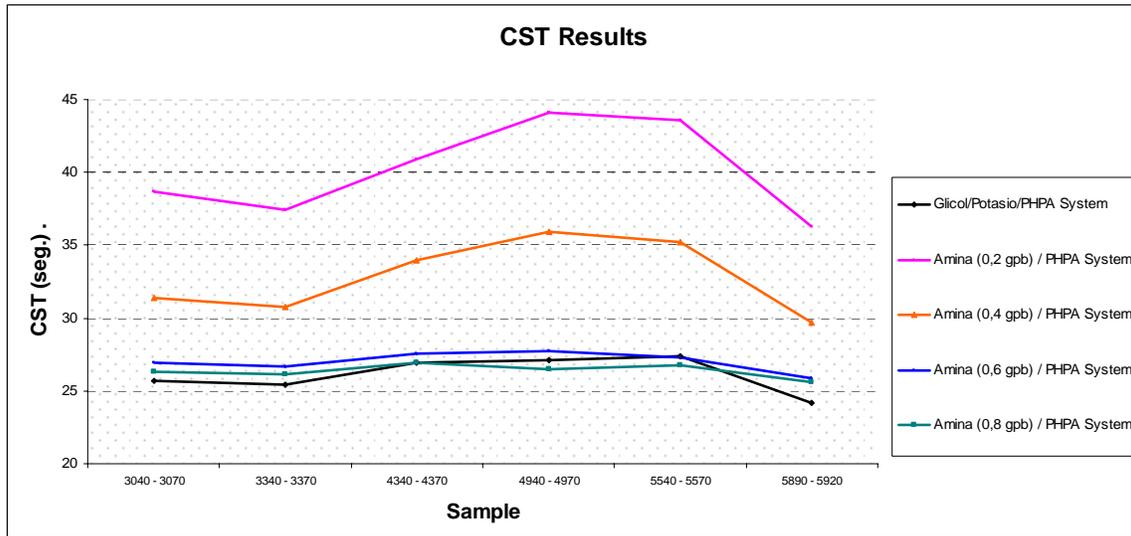


Figure 4. Capillary Suction Timer Results with Amine/PHPA and Potassium/Glycol systems.

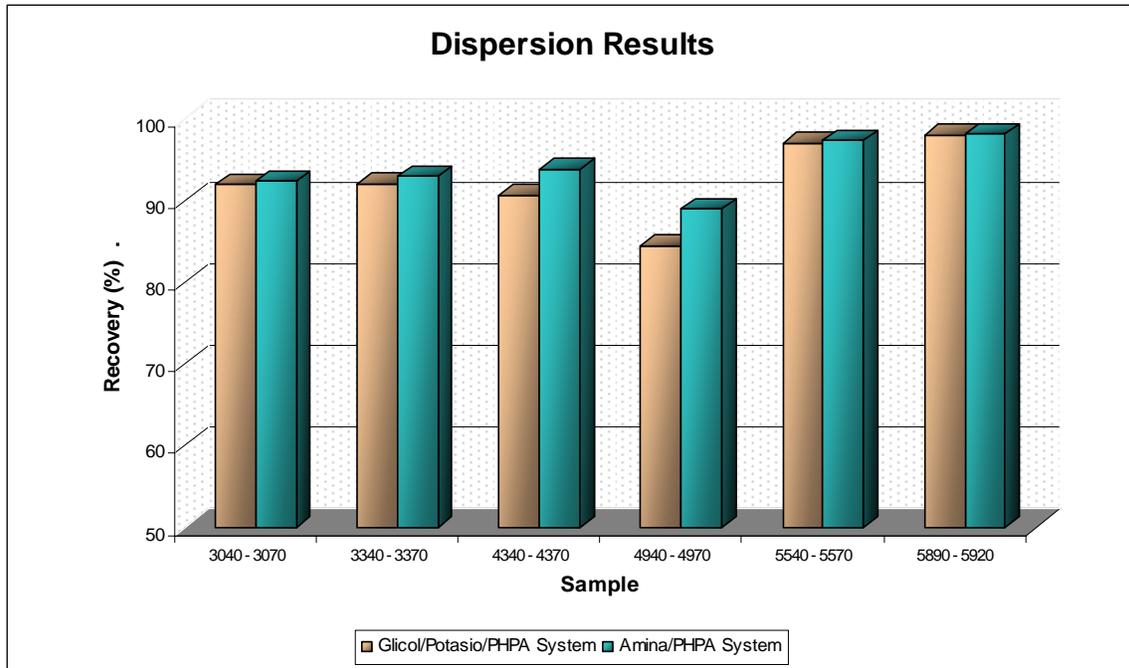


Figure 5. Dispersion Test Results with Amine/PHPA and Potassium/Glycol systems.



Figure 6. Cuttings Disposal Area, Pre- and Post-Remediation