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APPLICATION OF ADDITIVES IN COMPLEX DRILLING CONDITIONS

Dinka Pašić-Škripić¹, Edin Šehić², Amir Jahić³

ABSTRACT

Exploration drilling represents one of the fastest and most efficient methods for recovering data regarding the geological structure of the terrain. One of the important factors in exploration drilling is the use of additives during drilling otherwise known as drilling mud. The additive is used to improve and enable continuous removal of drilled material from the bottom of the well as it can stop the circulation of the water and in turn, bring the stability of the well into question. It can also increase the pressure of the rotation, make it harder to extract the pipes as well as slow down progress. Drilling additives must be carefully chosen and dosed while doing permanent control and adjusting characteristics during drilling.

At the Vareš exploration area (Rupica), several drilling mud materials were used in very complex drilling conditions. The additives were based on water, oil, and synthetics and their use, function, and choice will be elaborated on in this paper.

Keywords: additives, types of additives and application, exploration drilling, hydrogeological conditions of the environment, ecological aspects of protection.

INTRODUCTION

The drilling plan for the Rupica location included a 160-meter well with a 90-degree drilling angle and an adequate azimuth for a vertical well. To drill the well, preparation work such as determining the position of the well, the coordinates, and the elements of the well needed to be done. Drill site preparation was the next step. A key factor for a successful drilling operation is carefully preparing the drilling mud or additive. To create adequate drilling mud a calculation of the pipe volume must be conducted to get the proper amount of water or drilling mud required for the pipe to be full. During that process, additives are chosen and properly dosed while being constantly controlled during drilling and their characteristics being changed if needed. When additives are applied during drilling, their viscosity must be checked two to three times a day using the Marsh funnel. During the Rupica exploration drilling, several types of additives have been used and their characteristics, advantages, flaws, and functionalities have been noted. Another thing that was noted was their negative impact on the soil and water as well as their general impact on the environment which was reduced to a minimum while providing the necessary tasks during drilling.

¹ PdD., professor at the Faculty of Mining, Geology, and Civil Engineering

² BA in Geology Engineering

³ Ph.D., Tuzla Canton Regional Roads Directorate

1. GEOLOGICAL CHARACTERISTICS

The Vareš area – Rupica and Juraševac-Brestić – is in the southwest part of the Borovica-Vareš-Čevljanovići (Image 1) mining area. Around a dozen discoveries of complex lead ore as well as zinc and barite were made in this 20-kilometer mining zone. Those discoveries had differing contents of silver, gold, copper, and antimony as well. The terrain around Rupica and Juraševac-Brestić consists of Lower Triassic, Middle Triassic, and Jurassic-Cretaceous sediments.

According to data from previous exploration, Sediments of the Lower Triassic in the Borovica-Vareš-Čevljanovići mining zone are split into two: sandy limestones, marls, clays with interlayers of sandstones, and quartz sandstones while the other is sandy clays.

Middle Triassic sediments hold the bulk of the ores, so their analysis was done in detail. Several levels of the Middle Triassic are rich in fauna – mostly mollusks – so the age of those sediments is reliable. At a wider area, those sediments consist of Anisian calcareous limestones, dolomites, dolomitic limestones, and limestones; Anisian-Ladinian Fe-Mn alumina, and cherts; spilites, Ladinian red cherts, and tuffites; Ladinian red limestones, cherts, and Jurassic-Cretaceous turbidite sediments.

Jurassic-Cretaceous turbidite sediments form the northeastern rim of the Rupica exploration area. They consist of marl, limestones, clays, and breccias which are in tectonic contact with Middle Triassic formations. At Rupica, Calpionella alpina Loremz and Tintinopsella point to an Upper Jurassic to Lower Cretaceous age.



Image 1. Geological map of the wider Rupice-Juraševac Brestić area

2. HYDROGEOLOGICAL RELATIONS IN THE EXPLORATION AREA

The aquifer within the Middle Triassic dolomites and dolomitic limestones (T21) at Rupica has a very complex structure with multiple erosions and depositions so separate blocks can be seen which are in direct or indirect contact. In the southeast part of the Brestić-Juraševac area, this aquifer takes up a larger space than in the Rupica area and is separated by a thick layer of Lower Triassic clastites (T1) and Middle Triassic layered cherts (1T2), with manganese schists, tuffites, and tuffitic sandstones. This layer of waterproof rocks makes a hydrogeological barrier between the Rupica and Brestić-Juraševac areas so a conditional conclusion can be made that there are two separate accumulations of underground waters in the same aquifer layer and formed independent fields of groundwater filtration within them. Geological mapping has clearly shown a more complex structure in the Rupica area. This is conditioned by erosion and deposition and confirmed with explorational drilling in the vertical profile. But, hydrogeologically speaking, this complex structure does not cause fragmentation of the groundwater filtration field since there are several direct and indirect links between the blocks of the aquifer. Also, erosion and deposition zones have an important role in groundwater communication. Another conclusion is that erosion and deposition zones as a limitation of certain aquifer blocks do not necessarily mean that the function of the aquifer or the field of groundwater filtration will stop. The way some blocks make contact is especially important for creating a field of groundwater filtration and attention must be directed toward that in future hydrogeological exploration.

A dolomite-limestone aquifer is in a complex relationship with accompanying lithostratigraphic members that are waterproof hydrogeological insulators (aquitards). Generally, aquifer floors (1T22) are made of marl, clay, and quartz sandstone sediments (T1) when in a normal stratigraphic sequence. They can also create an aquifer cover as a result of deposition. It is not rare that these sediments (T1) simultaneously create the floor and the cover of the aquifer.

In a normal stratigraphic sequence, alumina and cherts (1T22) also represent the cover of the aquifer and with tectonic movements have been brought to the floor. Although erosion and deposition have made the situation more complex, this kind of status of the aquifer with the waterproof cover and floor has stayed the same in the entire Rupica area.

Replenishment of this aquifer is done via precipitation at the surface level while drainage occurs on the peripheral areas of the massif in streams in the form of diffuse discharge because no significant spring or concentrated discharge phenomena were observed. The infiltration of rainwater is immediate, so there is an oscillation of the underground water level depending on the hydrological conditions.

It can be considered that it is the filtration of underground water under sub-artesian pressure and artesian pressure is also possible locally. The distribution of pressures at groundwater levels in the area of the deposit has been determined in a small number of locations and in a limited area and shows the expected directionality of the underground flow from the center to the periphery of the massif.

3. EXPLORATION DRILLING

Exploration drilling is the most accurate method for geological and hydrogeological data gathering. It also enables gathering data on lithostratigraphic relationships, and tectonic disturbances while proper core mapping enables the creation of vertical and horizontal profiles.

There are several methods of drilling:

- Rotational exploratory drilling
- Percussive exploratory drilling
- Combined exploratory drilling

Drilling wells is most frequently conducted via rotational drilling done by drilling rigs. Exploration well depths can go from just a few meters up to several kilometers depending on the drilling rig type and the drilling target.



Image 2. Mustang 13 Atlas Copco Drilling Rig (Rig Teh East Sarajevo)

4. ADDITIVES FOR EXPLORATION DRILLING

The success of exploration drilling is dependent on properly choosing drilling additives. Without drilling mud drilling would be much more difficult and planned results could not be reached. The purpose of the additives is to improve and enable the continuous removal of drilled material from the bottom of the well. If the drilled material from the bottom of the well is not removed, it can stop the circulation of the water and in turn, bring the stability of the well into question. It can also increase the pressure of the rotation, make it harder to extract the pipes as well as slow down progress. The most important aspect of the additives is the cooling of the diamond crown drill bit and the lubrication of the drill pipe which enable better progress during drilling. Drilling additives have gone a long way from the simple mix of clay and water – today's additives must be considered. They are also continuously controlled while their characteristics are adjusted during drilling. The most important additive characteristics are density and viscosity. Liquids or additives for drilling are created for a large array of functions.

At the Rupica exploration site, several additives have been used in very complex drilling conditions. Their characteristics, dosage, reason for use, and how they assisted during drilling can be seen below.

PLUG

It is a granulated polymer that absorbs up to 500 times its volume in water. Plug is ideal for sealing zones where circulation has been lost and can also be used for reducing pipe vibrations in wells.

Plug needs to be partially hydrated in sweet water before pumping it into the well. It will quickly swell up to assist with sealing cracks and porous formations. Drilling can be continued after 30 minutes. If salinity and hardness are present, drilling should be resumed after 1 hour. This procedure can be repeated until

circulation resumes. Where the water level is low or there is a complete loss of water Plug can be poured into the well ring to reduce vibrations.

Plug is in the form of white liquid crystals and its typical physical characteristics are a volume density of 510 ± 50 , a particle size of 2 to 4 millimeters, quick swell-up upon contact, and a pH of 7.0 - 8.0. Plug can be used individually or in combination with other additives for circulation control.



Image 3. Schematic of Plug application

BORE SEAL

This is an additive used to improve the stability of the well as well as for a better core recovery which improves and returns proper circulation of drilling mud. Bore Seal is ideal for the stabilization of formations like micro-fractured shale, coal, unconsolidated sand, and limestone. It is most efficient to seal medium to fine fractures and porous zones. It can be used with most drill bits.

Bore Seal is a light-brown or brown powder that can't be dissolved in water. It is used between 3 and 15 kilograms per cubic meter (1 - 5 lbs/bbl) depending on the drilling mud and the formation being drilled. Medium and coarse types are applied as concentrated pills which are most frequently used between 40 and 115 kilograms per cubic meter (14 - 40 lbs/bbl) depending on the severity of the losses.

CR 650

CR 650 is a high molecular weight polymer powder developed to improve the removal of drilled material as well as help stabilize the formation. It forms a protective polymer layer on the drill pipe and the drill bit as well as on the wall of the well and helps with lubrication during drilling in problematic formations. CR 650 is ideal for use in horizontal drilling, ordinary wells, mining, and tunnel drilling.

It can be used as an individual product or in combination with gels or other clay and shale stabilizers like potassium chloride.

CR 650 is white-colored and can be dissolved in water. The pH of a 0,5% solution is 7 - 8. It is ecologically acceptable and is not toxic.

| Application | kg/m ³ | Lbs/bbl |
|--|-------------------|------------|
| Add to fresh water during drilling | 0.5 - 0.75 | 0.15 - 0.3 |
| For stabilizing swelling clays and shale | 0.5 - 1.0 | 0.15 - 0.4 |
| To improve core recovery in | | |
| problematic formations and | 1.0 - 3.0 | 0.4 - 1.0 |
| increasing well stability | | |





Image 4. CR 650

COREWELL

Corewell is a multifunctional additive created for coring drilling activities as it provides good core protection and stability to the side walls. Corewell assists with preserving the original state of the core sample which enables better data acquisition from the core. It is used to stabilize unconsolidated soils and broken parts, to prevent additional crushing.

Water is recommended for this additive to work to its best, with a pH between 8.5 and 9.5. Between 1.5 and 3 kilograms per cubic meter (0,5 - 1,05 lbs/bbl) is mixed with water and mixed for 20 to 30 minutes. The viscosity of the product will vary depending on the dosage, so a test is recommended before use. Corewell is an off-white crystalline grainy product without a smell that can be dissolved.

LIQUI POL (POLYMER)

This is a polymer that is most frequently used during deep exploration drilling in Bosnia and Herzegovina due to its several positive characteristics. It is a high molecular-weight polymer that is added quickly because of its liquid form which ensures viscosity. It can also be combined with other polymers and additives, so it is used often by all drilling companies in Bosnia and Herzegovina since it enables material savings.

The polymer is easily mixed, controls sticky clay and prevents swelling up, and decreases vibration and drill pipe resistance while at the same time being an economical choice. Liqui pol is a white viscous solvable liquid with a specific weight of 1.00 - 1.10.

BENTONITE

Sodium bentonite is most frequently used during exploration drilling. It creates drilling mud of high viscosity. It is suitable for the preparation of water-based drilling mud for all types of drilling operations. It combines well with polymers and other additives. Bentonite's advantages include the cooling and lubricating of the drill bit, reducing the loss of mud through well walls, bringing drilled material to the surface, keeping drilled material in suspension during drill pipe stoppage, stabilizing the well, creating an impermeable layer on the well walls, enabling the application of other materials in the mud.

Bentonite is prepared by slowly adding it to water and mixing the solution intensely. It is prepared with clean water, quickly and efficiently. For the best results, sodium is added to the water (before the bentonite is put in the mix). The pH of the water is adjusted to an 8.5 to 9.5 interval when preparing the drilling fluid. Water purity affects the results of bentonite application.



Image 5. Mixing bentonite in a 1000-liter container

Table 2. How to add bentonite depending on the soil is shown in

| Soil characteristics | Bentonite dosage |
|--|-------------------------|
| High permeability soil: gravel, sharp sand | 60-70 kg/m ³ |
| Non-cohesive soil of medium permeability: sand formation | 50-60 kg/m ³ |
| Cohesive soil of medium permeability: silty sand | 40-50 kg/m ³ |
| Cohesive soil with low permeability: limestone, clay | 35-40 kg/m ³ |

CONCLUSION

The main goal of exploration drilling via a complex 160-meter well in central Bosnia on the territory of the Vareš municipality near Rupica is to analyze in detail the geological and hydrogeological characteristics of the area with a special focus on the use of adequate additives during drilling and their ecological impact. Drilling success greatly depends on the correct choice and proper dosage of additives during drilling operations. Without drilling mud, drilling would be difficult and planned results could not be achieved. Also, important geological data couldn't be acquired. The purpose of the additives is to improve and enable continuous removal of drilling material from the bottom of the well. Continuous removal of the drilling material is essential as it can block the circulation of water, bring the stability of the well into question, create complications for drill pipe extraction, decrease the rate of progress, and increase pressure on the rotation. The most important thing the additives do is serve as a coolant for the diamond drill bit and as a lubricant for the drill pipe which in turn reduces wear and tear and enhances progress during drilling. There is another goal in all drilling operations. Namely, it relates to the safety and ecological aspects of drilling while maintaining a high level of performance. Drilling and service companies use adequate measures to decrease the potential danger of accidents and enable safe working conditions while simultaneously protecting the geological and work environment. Ecological policy (HSE) of many companies is stricter than those requested by national governments and agencies which supervise drilling

operations. Packing, transport, and storage of additives for drilling fluids are carefully tested regarding protecting the environment.

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