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MUD LOGGING – A REAL TIME INTERCONNECTION BETWEEN GEOLOGY AND DRILLING

1. INTRODUCTION

The final stage of geological research, which is in fact the essence of the exploration activity for discovering the new hydrocarbons accumulations, is actually represented by designing the new wells. For sure,one of the main condition to achieve the proposed target could be considered the well monitoring

Implementation in Romgaz of the concept known as mud logging wasn't so easy. The beginning is related to the period 1989–1990, when the deepest well from Transylvanian Basin was drilled and the first mud logging unit was rented from the offshore romanian company. After that successful experiment, few appraisal wells were monitored in this way, followed by more and more wells, so nowadays for each well there is a mud logging unit, belonging to different drilling contractors or other services companies. In the last period, Romgaz set up a new department specially designed for mud logging supervising.

2. SOME GENERAL CONSIDERATIONS REGARDING THE MUD LOGGING UNIT

Equipped with specific devices and an experimented geological team, the mud logging unit assures the well supervising and monitoring 24 hours per day (Fig. 1).

The great advantage is represented not only by monitoring the drilling parameters (weight on bit, rate of penetration, rotary torque, pump strokes, fluid level etc.) which allow to create a more accurate image of the well just from the drilling stage and to increase the well security, but also by gathering a lot of geological data such as lithological description, calcimetry analysis, gas indicators and others [1].

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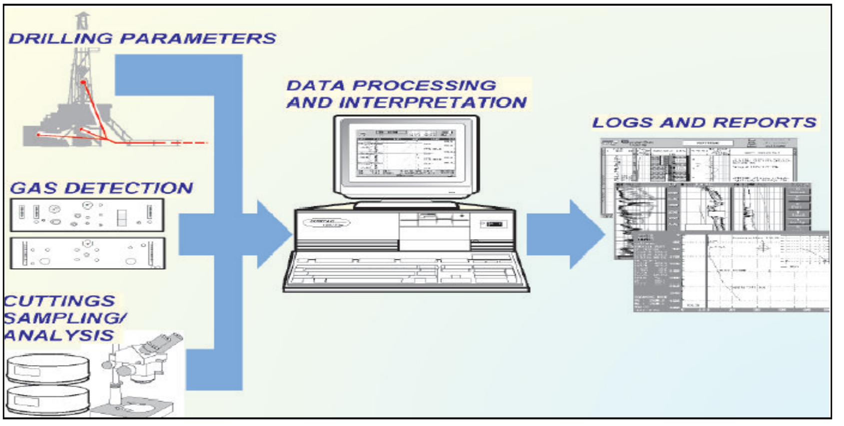

Fig. 1. The mud logging unit components

All these information correlated with the borehole geophysics can predict the production tests and thus the future status of the well.

The main purposes of the mud logging unit can be summarized as follows:

- monitoring and interpretation of the crossed geological formations, gas detection,
- dangerous fractions detection as : H_2S, CO_2, optionally N_2 or He,
- monitoring of drilling parameters,
- primary interpretation in order to avoid technical accidents,
- editing the final well geological reports and specific logs as Litholog, Drilling log and others.

The devices which compose the mud logging unit can be divided in four main categories:

- Gas detection devices,
- Drilling fluid (mud) monitoring,
- Drilling monitoring,
- Several computers for different calculations and editing specific logs.

We describe in this section very briefly each of this component [2].

2.1. Gas detection device

The gas formation detection is essential for a complete evaluation of the formation hydrocarbons potential and for sure, for the well security. The gas is extracted from drilling mud with a degasor, installed on the gas flowing line. The gas/air mixture is then pumped through the gas line to the gas detector (**CROMATOGRAPH**), located inside the geological unit. Here could be analyzed the following hydrocarbons fractions: TG (Total gas), C1 (methane), C2 (ethane), C3 (propane), nC4 (normal butane), iC4 (iso butane), etc., which are displayed in percents and recorded by the Data Terminal computer. There is also an adjustable alarm system, which warns the geologists when a certain gas percent is exceeded. The gas curve is recorded on the final log, called **MASTERLOG** or **LITHOLOG**.

2.2. Drilling mud monitoring

2.2.1 The mud pit level

It's one of the most frequently monitored parameters, due to the importance in detecting the fluid losses, the influx into the wellbore, or in case of kick – off, because can estimate the magnitude.

2.2.2. The mud temperature

It has a great importance, because can help in detecting the overpressured formations. A higher geothermic gradient than a normal one can be explained based on sealing, which can be physical, chemical or a mixture of them. The other parameters are also correlated with temperature.

2.2.3. The mud density

In order to indicate the influx of different types of fluids (gas, salt water, heavy hydrocarbons, solids), this parameter is very helpful. A decreasing of density means that gas enters in the mud.

2.2.4. Counting the pump strokes

Knowing the wellbore geometry can be computed the circulation time and the lag time, which represents the necessary time for mud in order to arrive to the surface, through the annulus. When the formation fluids enter into the wellbore, the number of pump strokes is increasing and the standpipe pressure has also a light increasing and then decreases.

2.2.5. Mud flowrate out

It is an important tool which can determine the fluid influx in the wellbore. Normally, we have a progressive decreasing of the mud level equal with the volume replaced during the drilling process. When it is noticed an immediately increasing of the out flowrate of the mud, it indicates a fluid influx.

2.2.6.Mud resistivity (conductivity)

When the salt waters enter into the wellbore, the mud conductivity increases (the resistivity decreases) and the amount of chlorides is also higher.

2.3. Drilling monitoring

2.3.1. Rate of penetration (ROP)

Since the change of the bit penetration rate, indicates the change in lithology, this parameter is one of the main important. It's also a very good tool for geological correlation and also for the other analyses, even for detecting the overpressured formations.

2.3.2. Rotation per minute (RPM)

It's a very helpful parameter, because it is mainly used for computing the normalized rate of penetration („d" exponent). The RPM changes have an influence on the rate of penetration, but in normal conditions these changes are not so important as the weight on bit.

2.3.3. Weight on bit (WOB)

Like RPM and weight on hook (WHO), the weight on bit (WOB) is mainly used for computing the normalized rate of penetration, expressed by„ d" exponent, which represents the variation in rate of penetration.

2.3.4. Weight on hook (WOH)

The mud logging system records continuously this parameter,used for computing the drilling string, in different conditions, when it is in the mud, above the well bottom, or on the well bottom.

2.3.5. Torque

The torque increasing can result in wear of bits or stabilizers, bit cone losses, increasing of weight on bit or rate of penetration,lithology change. It can also indicate possible problems like„***key holes***", differential bonding, potential overpressured zones etc.

2.3.6. Standpipe and pumps pressure

Very good tool in detecting the overpressured zones, it also indicates the cleaning on the well bottom, A pressure correctly applied means a proper cleaning on the bottom and transporting the mud and cuttings to the surface.

2.4. Computers

Recording the drilling parameters against depth and also the graphical editing of different logs is realized with several computers inside the mud logging unit.

A lot of computations as„ d" exponent, pore pressures gradients and others are also possible using the available computers.

2.5. Geological assistance service

A proper evaluation of the formations crossed by the well is a result of a sustained work of the geological team, Collecting the cuttings at each meter, they can edit a very accurate geological and stratigraphycal column, which represents the base for well correlation. Beside the geological analyses, they record drilling data, fluid parameters, monitor gas indications, which are correlate in real time with the lithology of cuttings, cores description, open hole logs, in order to detect abnormal values of some parameters and therefore to avoid undesired problems as kick – off, fluid losses, overpressured zones, bit stuck etc. By a real time correlation can also predict the future production tests of the well.

A geological assistance service includes mainly the following issues:

- Lithological description of cuttings and cores, which comprises mainly the following items: name, color, texture (siliciclastic, carbonatic), hardness, type of matrix / cement, cleavage, visual porosity (a percent estimation), accessory components, sedimentary structures, etc.
- Calcimetry/dolometry.
- Fluoroscope analyses.
- Thin sections.
- Different tests for minerals and rocks identification with chemical reagents.

A lot of charts and diagrams are used for a more accurate lithological description for shape (Fig. 2), sphericity (Fig. 3), grains sorting degree (Fig. 4), visual estimation of percentage composition (Fig. 5).

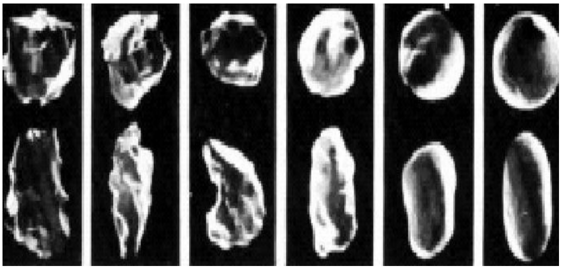

Fig. 2. Shape determination

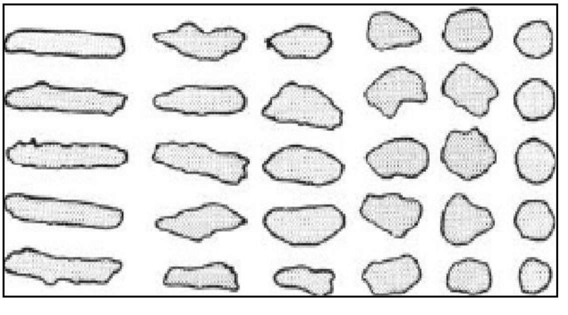

Fig. 3. Sphericity determination

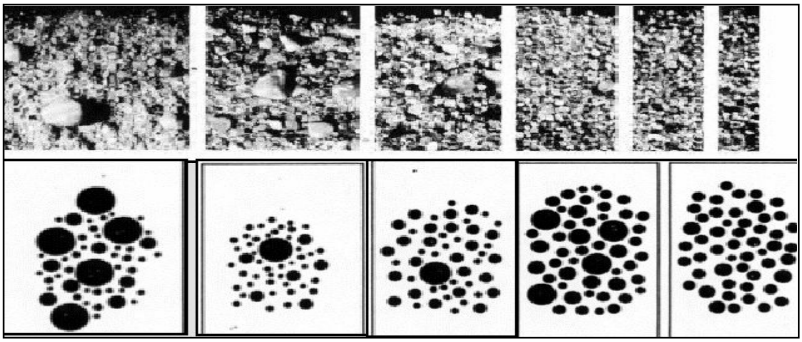

Fig. 4. Grains sorting degree

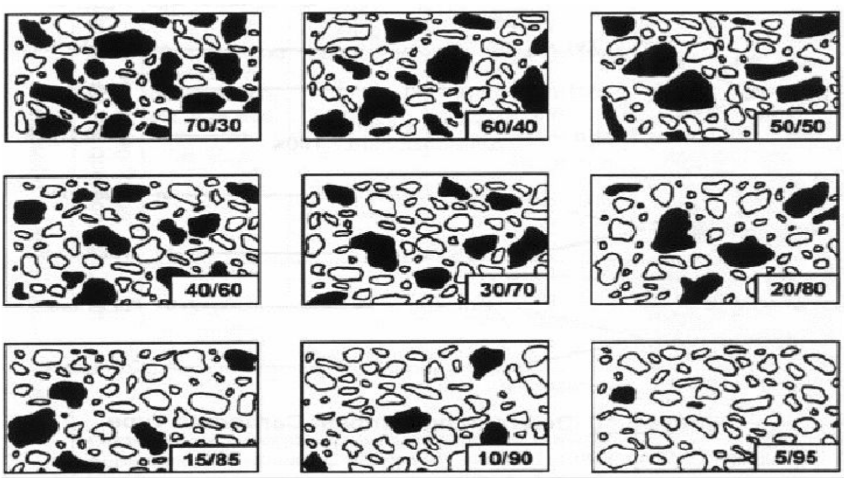

Fig. 5. Comparison diagram for visual estimation of percentage composition

The most important output of the mud logging team activity is a synthetic diagram, called **LITHOLOG**, which actually represents the interface between geology and drilling, being in fact a link between geological data,drilling and mud parameters.

3. CASE STUDY

Beside the short description of the main recorded drilling parameters and some aspects regarding the geological assistance,the case study presented in the paper highlights a very good correspondence between geological and drilling parameters, open hole logs and the production tests.

We present here a fragment of **Litholog** (Fig. 6), recorded in one well located in Moldavian Platform, in one block $\mathbf{A_1}$ belonging to a major gas field **A**, which indicates a zone of interest in the interval depth between **1487 and 1500 m**.

What is important to see in this section are the following items:

a. **low values of rate of penetration** (***minimum 6 min/m***) which means that a porous permeable formation (sandstone) was passed,

b. **gas indicators**: The maximum total gas recorded = **10,79 %** (***Formation gas***),
Note: During circulation, at 1490 m depth, the fluid density has also decreased for 10 minutes, from 1.25 kg/cdm to 1.20 kg/cdm, The mud was treated and density increased to 1.28 kg/cdm, which was the fluid density until the final depth. The mud temperature has also decreased, which confirms that we have gas. (Fig. 7 –**Drilling log**),

c. **lithology description** – quartz lithic sandstone with good visual porosity,with thin layers of clay (see the description of core collected from the interval: 1490–1498 m – Fig. 6 – right side).

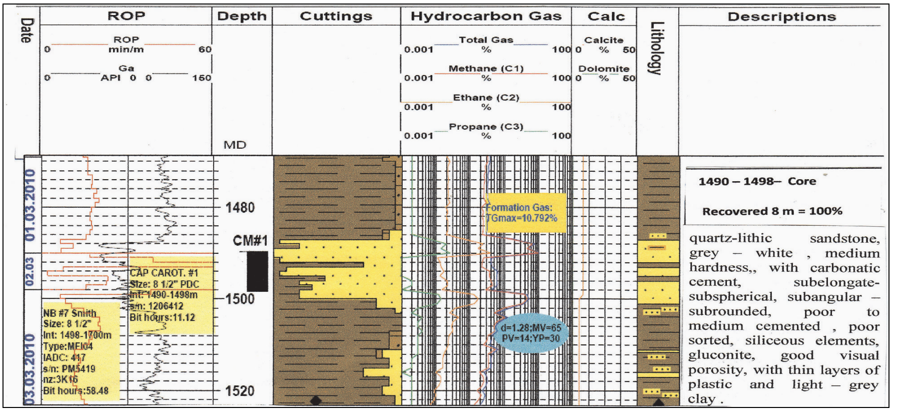

Fig. 6. Litholog

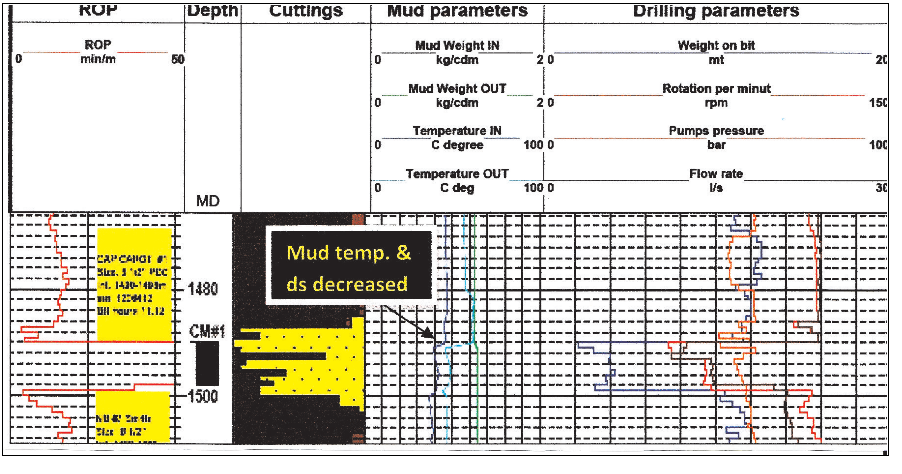

Fig. 7. Drilling log

The special open hole logs (Fig. 8 – **Composite log**) recorded in this zone allow the following qualitative interpretation:

a. So, on this depth range, the recorded values of GR are low (around 50 API units), which indicates a cleaner formation (track 1).

b. The values of resistivity curves on DLL log are high (up to 10 ohmm) (track 3).

c. Separation between density and neutronic curve indicates a classical „***gas effect***” zone (track 4).

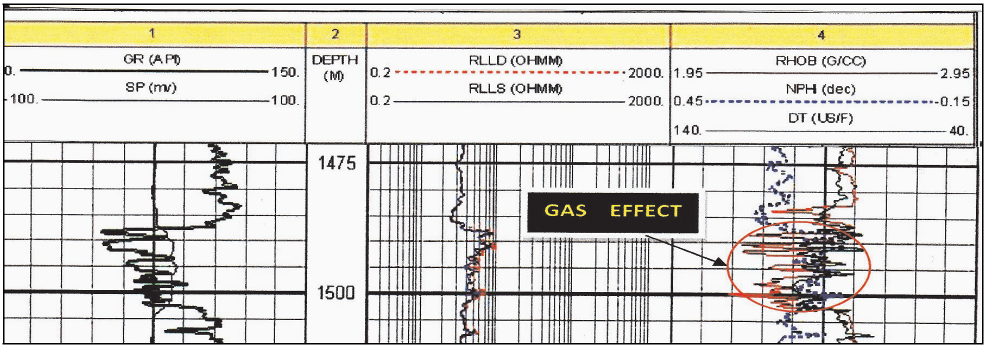

Fig. 8. Composite log

These qualitative information were then confirmed by the quantitative petrophysical interpretation, performed with the ELAN software. The result was gas saturation of max 80% and an effective porosity of around 20%, which confirms the visual porosity estimation from the core description (Fig. 9).

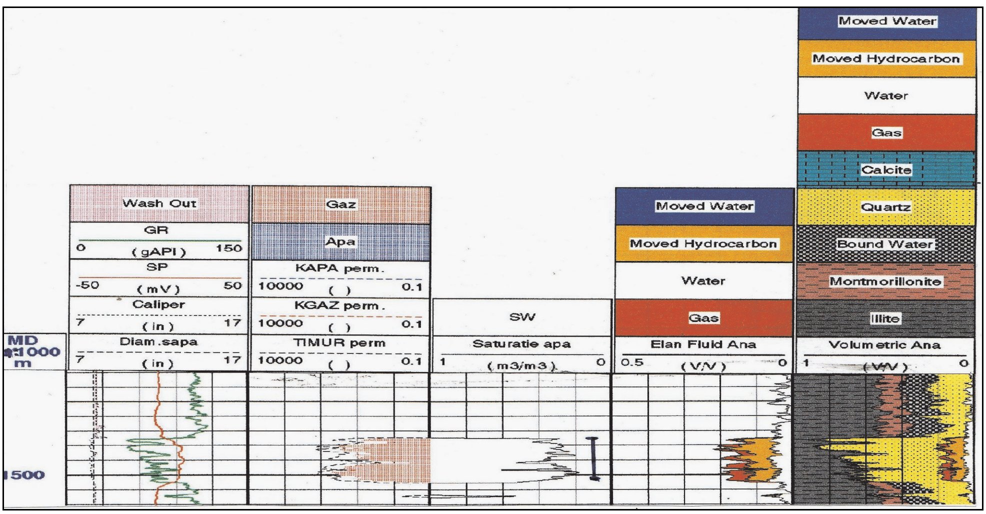

Fig. 9. Petrophysical interpretation

The final step was the production test, which confirms all the previous evaluations, because the well was perforated on the interval **1487.5–1501 m** and the flow rate obtained was ***300.000 stcm/day on 14 mm choke – gas and condensate***.

4. CONCLUSIONS

It's very obvious that mud logging activity has a lot of benefits, which could be summarized briefly in some main issues as below:

- detecting the gas influx or other fluids (salt waters, CO_2, H_2S,etc.) overpressured zones. monitoring the fluid losses, predicting the unexpected kick – off, bit stuck, etc.;
- identifying just while drilling process the possible zones of interest for hydrocarbons accumulations, based on a real time correlation between geology, drilling and borehole geophysics;
- assuring a maximum well security during drilling;
- the several diagrams (litholog, drilling log, composite log) provided by mud – logging services, including specialized devices and a competitive team, represent an accurate data base not only for the current well evaluation, but also for a better approach of the risk analyses in designing the new wells;
- predicting production well tests, being therefore a real help in designing the well testing program.

All these above considerations justify in fact the reason for which the mud logging service became a real necessity, representing today in Romgaz a constant requirement for each new well.

REFERENCES

[1] Halliburton, "Basic logging manual", May, 1989
[2] **** Romgaz Archive