ADVANCED RCA - Bridging the Gap between Routine and Special Core Analysis.

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ABSTRACT

In this paper, we advocate an extension/expansion of the traditional RCA program by implementing some relatively simple and quick analyses, normally associated with SCAL, at the early stages of a core analysis program. The main purpose is to bridge the gap between routine and special core analysis in order to provide essential core data for reservoir description concurrent with the traditional RCA data.

We suggest that samples are taken at the well site or along with the standard RCA samples, at regular interval (non-biased). Mud invasion should be checked by extracting fluids from the samples. If the samples are not contaminated, fresh state wettability may be attempted, otherwise not. Mineralogy and CEC are essential parameters. These may be measured on samples used for simplified rock strength tests or run on separate samples. MICP should preferably be run on plug samples. Some samples should be saturated with synthetic formation water to measure permeability and NMR T_2 to check for water - and rate sensitivity and have estimates of clay bound water and Qv values.

Several wettability tests should be included. Any test results should be judge against what could be expected based on the properties of the oil, formation water and matrix.

Mud properties and records of the core handling must be documented.

INTRODUCTION

Coring lengthens the drilling operation and core analysis, particularly SCAL, is in most cases expensive and time consuming. Therefore, the objectives of coring should be well defined and the planning thorough as it also may influence the choice of mud and imply mobilization of extra crew and equipment at the well site.

In the following, we will assume that the coring is performed in an exploration or appraisal well and that the main purpose of the core acquisition program is to obtain information for geological modelling, petrophysical interpretation and reservoir engineering. We will assume that the standard method for low invasion coring is applied. Special coring tools and the selection of the most suitable type of mud, even if paramount for a successful execution of the coring program, are outside the scope of this paper.

Evaluation of a new prospect starts immediately after a discovery. Preliminary development plans and production prognosis are often made very early. A full SCAL program may take one or two years to finalize. Sometimes SCAL results arrives too late to have impact on development plans, in other cases plans are put on hold while waiting for SCAL data to be reported. When results arrive, they may not be according to expectation and/or of low quality. While core description, geochemistry and PVT/chemical analysis are carried out as soon as the well is drilled and the fluids are sampled, it often takes quite a long time and much effort to establish a SCAL program.

In the following, we will outline the methodology required to obtain valuable and robust core analysis data much faster than what has been customary. While no new technology is introduced, a change of mind-set in approaching the core analysis program is required.

We will mainly focus on consolidated cores. Griffin et al. had discussed some of these aspects related to unconsolidated cores [1]. Horizontal and vertical plug samples are in this context relative to the lithological bedding plan orientation.

AT THE WELL SITE

In an ideal case, one would like to retrieve a core with all its in-situ properties unaltered. Unfortunately, this is not possible in practice. Despite all attempts to avoid invasion of mud filtrate, the outer rim of the core has been in contact with mud. Unless special pressured coring equipment is used, the core will experience loss of pressure and temperature while tripping out of hole. This will in most cases result in phase change of the fluids and possibly drop out of asphaltenes and appearance of wax in the pore space.

After the core is retrieved, it is common practice to keep the core in the inner liner and cut the liner in 1 m length pieces. In order to have the best possible quality of the core material, any further contamination by mud, loss of fluids and oxidation should be strenuously avoided. Therefore, drilling and preserving of plugs and draining of mud from the liner should be done at this stage, before it is capped and sent to laboratory.

The plugging should be done by drilling 1,5“ diameter and approx. 2 “ long plugs axially from one end of each 1 m section of the core. Some extra companion plugs from the other end of the 1 m core should also be taken (these could be drilled horizontally). These plugs must be properly preserved and transported to the laboratory for analysis. The importance of drilling plugs as early as possible to avoid further contamination of the core by diffusion of mud components into the core has been documented by Ringen et al [2].

It is essential that samples of mud used during coring are collected. Information of mud properties and timing of the operations (core retrieved, samples drilling, sample shipment) should be recorded and included in the core report.

IN THE LABORATORY

The plugs sampled at the well site will normally arrive at the laboratory before the whole cores. Analysis for water saturation, by for example Dean-Stark method (D-S) [3], starts immediately.

It is recommended to use some of the 1,5“ plugs for the following:

1. Extract fluid by ultracentrifuge or by geochemical methods [4].
2. Extract salts after hydrocarbons and water has been removed by toluene in the D-S test [5].

In this way, it is possible to obtain valuable information on mud invasion and/or fluid composition at an early stage in the process. These data are very valuable when planning further analysis or evaluating the results of SCAL tests. In cases where fluids sampling/well-testing is not performed or possible, this may be the only source of information of the fluid properties. These extra SCAL size plugs can be used for several different "Advanced RCA" analyses as discussed below.

It is essential that the properties of the mud, used during coring, is available to everyone involved in the core analysis program. If tracer is used, correction of D-S data is normally straightforward; otherwise, components of mud may be used as "tracers". In oil based mud, the base oil may be used for that purpose. The water phase also contains some salts which may be detected. Glycols are often added to water based mud. They dissolve both in hydrocarbons and in water. It is fairly easy to detect glycols in oil phase. This type of mud normally also has large quantities of some salts (usually KCl) which could be analysed.

If the chemical analysis of fluids/salts from fresh samples clearly shows that there has been no significant mud invasion, wettability tests may be attempted on the fresh samples. This may give results that are representative for the in-situ reservoir condition, assuming that oil properties are such that no permanent changes have occurred. If this is not confirmed, fresh state wettability analysis (or other fresh state analysis) is most likely a waste of time and money.

End trims of the plugs mentioned above should be used for pore structure evaluation and mineralogy/petrology using MICP, XRD/ XRF, CEC, grain size distribution, THS and SEM analysis. It is critical that any minerals (e.g. clays) that may be altered during the subsequent core handling and preparation phase (cleaning and drying) are identified as early as possible. MICP should preferable be run on plug samples in order to have permeability measured and to have a greater pore volume, i.e. improved accuracy.

Samples for a simplified rock strength test should be taken along with sampling for RCA plugs. The test is run on vertical plugs by increasing the axial stress while maintaining a radial stress until mechanical failure occurs. The main purpose of this test is to identify possible mechanically fragile/unstable zones to be avoided during well testing. After the sample is crushed, it can be used for further analyses such as grain size analysis, CEC and rock mineralogy.

If the petrophysical logs or mineralogy analyses indicate fragile or reactive clays, a test of drying procedures should be run on end trims. SEM analysis will reveal if drying has caused any changes or damage to the pore network structure or minerals.

Some RCA samples should be saturated with Synthetic Formation Water (SFW). Comparison of permeability to water and to air will reveal if the SFW is in equilibrium with the minerals in the matrix. This may result in a decision to keep the SCAL samples fully saturated (not dried to measure K and Ø) until the end of the analysis program. Water saturated samples may be used to test critical flow rate and brine sensitivity. This is very useful when designing measurements of relative permeability and to evaluate if injection of non-formation water may impair the formation permeability.

Once saturated, formation resistivity factor and NMR T_2 should be measured. Besides being useful for calibration of petrophysical logs, these data can be applied for rock characterization. From the NMR data, an estimate of clay bound water and CEC can be made.

Wettability is probably the single most important parameter in core analysis as it governs the distribution of fluids within the pores. Traditionally, wettability tests have been part of elaborated SCAL program and usually based on the Amott/USBM methods. Sometimes wettability is inferred from other tests like formation resistivity index or relative permeability experiments. Usually the results are not available until the end of the SCAL program.

We advocate a change of mind-set:

1. Wettability should be determined as part of the Advanced RCA program

2. More than one wettability method should be used.

Ad 1: If wettability is known, it will limit the possible variation of parameters to use in log interpretation (n-exponent) and reservoir engineering (relative permeability) in the early reservoir evaluation.

Ad 2: The traditional methods for wettability determination (Amott and USBM, including combinations) are time consuming and prone to errors. By recording the rate of spontaneous imbibition as part of the Amott A cycle, a good estimate of wettability can be made by comparison with published data [6]. Adhesion tests [7] and measurements of contact angle are valuable additional laboratory tests that could be initiated at this stage.

In addition to these tests, one should apply the COBR approach [8]. This methodology requires that the properties of the Crude Oil (CO), brine (B) and rock (R) be evaluated to estimate the probability of having oil adsorbed to the pore surface. This will help to delineate the possible wetting conditions or at least eliminate some extreme wettability cases.

EXAMPLES

In an exploration well drilled on Norwegian Continental Shelf (NCS) autumn 2012, part of the "Advanced RCA" program was implemented. Plugs for D-S were sampled as one per meter. Plugs for simplified rock strength test, grain size analysis, Kw, MICP and XRD were sampled as one per five meter in the reservoir section. These tests were carried out along with the traditional RCA analysis. As a prelude to the SCAL program a critical flow rate test was also performed.

In another exploration scenario on NCS, traditional SCAL was postponed while waiting for an appraisal well. In the meantime, some advanced RCA analyses, including wettability testing, were performed on samples from the discovery well. A Seal Peel (wax-preserved whole core section) was selected for the wettability test. This test also gave some valuable endpoints for relative permeability. The results were in accordance with expectations based on the COBR approach.

In order to have some reasonable input data for relative permeability, pore scale modelling was done based on five RCA samples from the discovery well. Data gathered during Advanced RCA was used for calibration (K, Ø and MICP) and results from wettability test as input to the modelling.

CONCLUSION

We have illustrated a new approach to obtain valuable and robust core data at an early stage by extended the scope of the traditional RCA, i.e. Advanced RCA. The main concept is to sample at the well site or in conjunction with the standard RCA sampling in order to provide the relevant reservoir data at the same time as the RCA data becomes available. The additional samples proposed should be collected at regular intervals and subjected to the following analysis/investigation:

1. Extract fluid from core to estimate fluid properties and/or contamination by mud
2. Mineralogy (XRD, SEM) and CEC. If sensitive or friable minerals (i.e. clays) are identified, a drying test is performed.
3. Water permeability, formation factor and NMR T_2.
4. Critical flow rate and brine sensitivity test.
5. Rock strength tests (remains from the test may be used for the analysis in item 2 above)
6. Drainage capillary pressure and pore throat size distribution by MICP.
7. Wettability test and evaluation (may be done on fresh samples if proved uncontaminated).

Mud properties and records of the core handling/sampling must be documented.

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