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Extended Rock Debris Analysis in Oil and Gas Wells Construction and Production

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Abstract

Robust hard rock data to provide successful cases in oil and gas wells construction and production has been more a desire than a reality. Robust is meant as statistically representative within a large enough population of direct physical samples.

When reviewing, the data used to make decisions on where and how a candidate well is selected, dominant parameters are porosity, permeability and fluid saturation. They are basically indirect parameters from petrophysics sources such as seismic and logging tools. Direct measured parameters like mineralogy and associated lithologies, pore body, pore throat and grain or clastic sizes are limited in samples available due to economic restrain related to their collection and laboratory analysis cost.

Conventional rock samples are divided in two main categories: cored fragments and drill cuttings. It is possible to fill the gap in regards of the number and size of samples using an established technology called Variable Pressure Scanning Electron Microscopy and EDS Imaging (VP SEM/EDS). This approach has made available relevant information from collected samples in a wide variety of lithologies found in different reservoir types, in a simple straight fashion, with no sample preparation making it a nondestructive analysis.

Some field cases are presented where decisions to design and select drilling and completion fluids, as well as completion hardware (open hole screen selection) were made using the above-mentioned techniques.

Introduction

After reviewing cases of success after oil or gas wells have been constructed and completed, it is observed there is a random trend about such “success”. Current downturn in the industry made clear that low productivity problems have been present for decades and remain the same today.

Rock-fluid interaction and Formation Damage assessment were introduced many years ago, to help avoid the low productivity problem created by fluid invasion. When the call is made to be more “efficient” it is a recognition that what is done conventionally is not enough and different approaches deserve and opportunity.

Rock-fluid interaction is mentioned when selecting a working fluid, somehow the testing and selection process is biased by measuring only fluid properties at bottom hole conditions of pressure and temperature, using paper or in the best case a ceramic disc to have an idea of invasion control for permeable Payzone. What about the rock part of the system? General answer is: difficult access to representative formation samples because it is expensive to have cored material, and drill cuttings provide little information, especially when drilling with fast PDC bits.

Therefore, there is the acceptance that natural subsurface formations are heterogenous but they are drilled and completed with very few working fluids alternatives. It is like trying to open 200 different locks with 10 keys only.

The subject of this paper is to present a cost effective and fast response alternative to have fit for purpose fluids, enhancing the rock-fluid interaction approach by obtaining important structure and composition information from rock fragments, using Variable Pressure Scanning Electron Microscopy with an attached X Ray Spectroscopy Detector, and Digital Image Processing and Analysis.

These techniques by themselves do not provide automatic answers or problem solutions. Integration of all data found, requires expertise with equipment use and a multidiscipline approach in Geoscience.

Extended Rock Debris Analysis

A Work Flow has been implemented to make possible an **Extended Rock Debris Analysis**. On this exercise, Debris include from drill cuttings to larger fragments coming from cored material (Figure 1).

An interesting technology has been reported[1] in which new generation bits (microcoring), look as a good way to improve fragments analysis in stratigraphic and exploratory wells without affecting ROP.

Size of rock fragments become important based on the information that can be obtained. A size range has been proposed. PDC drilling bits generate about 90 % fragments with 2 mm or less in size, creating an important limitation for analysis under conventional methods.

Good mudlogging practices taking care of lag times to get estimated depths to correlate with logs, can provide a simple and reliable method for lithology reconstruction in stratigraphic and exploratory wells.

There is a need to find more detailed information in regards of mineral composition and structural nature from subsurface rocks. This information will help to recommend better drilling and completion fluid design and eventually stimulation intervals and practices (acidizing/fracking) to improve well productivity.

Techniques involved during the process of analysis include: (1) Scanning Electron Microscopy in Variable Pressure mode, (2) Elemental and Mineral Analysis by X Ray Spectroscopy using Silicon Drift Detector (SSD), and (3) Digital Processing and Analysis of Images of fragments or drill cuttings.

They are well established techniques for rock analysis including polished drill cutting samples[2], but new technology trends[,3] has put them forward with smaller footprint instruments, easy to use, less dependable on facilities like water cooling, electrical outlets, liquid nitrogen and dark rooms.

Another interesting feature is fast and efficient pump system inside the scope that allows to have low vacuum condition to receive and observe either wet and oily samples without preparation steps like drying or conductive coating.

This really simplifies time of analysis keeping sample intact for any other test. Most important, their affordable cost makes these instruments compete with conventional techniques such as XRD, Petrographic Analysis and Mercury Injection Capillary Pressure (MICP).

Work Flow Time Comparison

Work flow used on this experience is set to compare time of response between VP SEM/EDS Imaging technique versus conventional Petrographic thin section analysis and MICP (Table 1). Parameters generated by the different techniques are those needed to design water based drilling fluids, on this case pore throat size distribution for bridging material selection, and clay type for reactivity (Illite/Smectite and Smectite), and structure (massive/fractured).

Field Example 1

A subsurface sequence with clastics on top evolving to carbonates at the bottom has been drilled by means of a PDC bit, collecting drill cuttings with a mudlogging unit at 10 feet intervals. Well logs were run and they directed the horizons of interest and from there visual inspection with X30 magnifier to get size selection and put together those samples to analyze without long times on random picking. A brief but significant sequence reconstruction was made (Figure 3).

Each selected sample is described in terms of associated lithology from mineral composition, abundance and structural features on each case (Figures 4-5). Pore throat size distribution obtained included as a demonstration example in a sandstone fragment of about 4 mm, shows the potential of this analysis approach. One correlated sample of shale indicates Illitic composition showing characteristic microfractured structures (Figures 6-7), that in general make flakes to disperse in contact with fluids, not a matter of hydration due to cation exchange but lack of seal for microfractures. In other words, if there is a more extended presence of similar shales, using an inhibitor won't stop the washout problem.

Additional fragments of evaporitic sandstone (Figure 8) have been related historically to high salinity formation waters and in most cases, all over the field, they were associated to light crude oil Payzone, acting as indicator or tracer lithology. Limestones show a massive structure very simple and direct features (Figures 9).

Field Example 2

A poorly consolidated heavy oil sandstone was facing problems during the selection of correct premium screens for open hole completions. Plugging of current screens has not been solved putting an economic burden on the field production. Clastics granulometry using laser diffraction generates distribution curves that support calculation for screens apertures.

Sidewall samples were used. Due to impregnation of crude oil, solvent cleaning an oven drying are used to prepare samples for laser diffraction. On this process clays that could be present are dispersed and washed away. Also, there is a population of crushed grains and grain clusters. Laser diffraction doesn't differentiate and counts all grains as individual grains, so results may be biased or not representative.

VP SEM/EDS imaging was tested to get grain size distribution using preserved impregnated plugs. This type of sample was placed directly on the scope chamber with no treatment or preparation (Figure 10). In minutes a granulometric curve was obtained from individual grains (Figure 11).

Conclusions

VP SEM/EDS Imaging is presented as a cost effective, simple, fast response, reliable, and versatile technique. Many different attributes can be determined as direct measurement or by indirect generation of hard rock data.

From the examples discussed on this paper, drilling and completion fluids design is possible on a fit for purpose approach increasing the importance of rock-fluid interaction studies, even with very small rock samples.

A more extended used of VP SEM/EDS imaging in the Oil and Gas industry is not happening because of prejudice and misinformation among the Oil & Gas community, considering it expensive and sophisticated (It is not). In other areas, it is widely known from elementary to high schools, in Colleges, small labs and factories.

Acknowledgments

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References

1. Shotwell, D.” Drill bit designed to return microcore samples to surface”. Hart Energy E & P Magazine, Feb. 1, 2013.
2. Guzman, J: “Formation Characterization in a Different Perspective: Drill Cuttings Analysis Revisited”. AADE-03-NTCE-25, AADE National Technical Conference, Houston April 1-3, 2003.
3. Guzman, B; Walls, J.; McLean, R.; Whitman, N.:” Understanding Variability along a Lateral Wellbore in the Eagle Ford using Drill Cuttings and LWD Data”, AAPG, ACE 2015.

Table 1. Work Flow Time Comparison

Technique	Sample Depth Log Correlation	Sample Collection Cutting/Breaking	Sample Preparation	Sample Analysis	Report Elaboration	Sample Integrity
Thin Section Analysis	20 min	30 min	3-5 days	1-2 hours	1-2 hours	Destroyed
Hg Intrusion Porosimetry	20 min	30 min	3-5 days	2-4 hours	1-2 hours	Destroyed
VP SEM/EDS Imaging	20 min	30 min	None	1 hour*	1-2 hours	Kept
VP SEM Imaging	20 min	30 min	None	15 min	1-2 hours	Kept

Figure 1. Conventional and Extended Rock Debris Samples

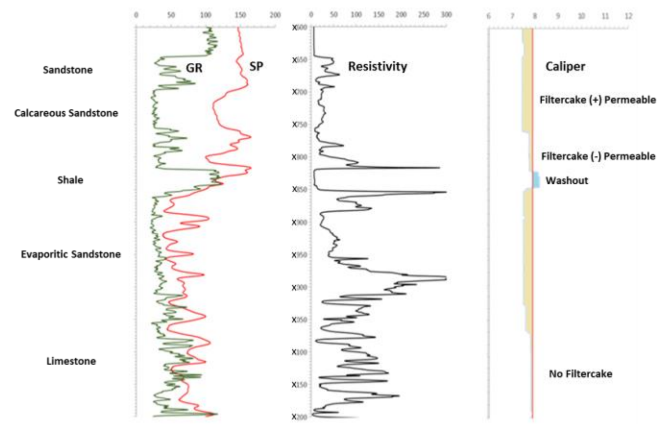

Figure 2. Fragment lithology correlation with Well Logs

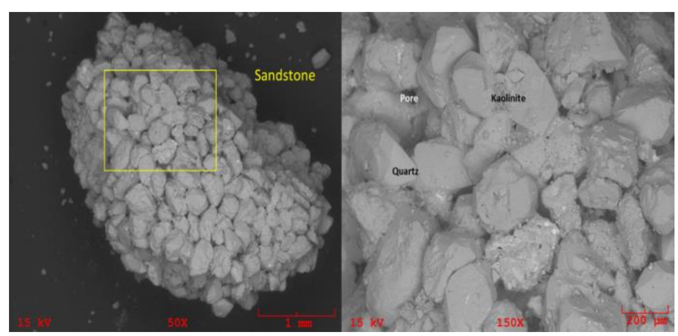

Figure 3. Sandstone Digital Image from lithology correlation

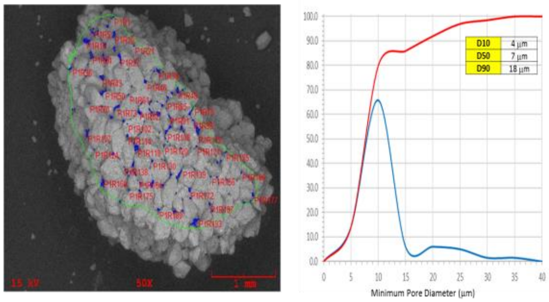

Figure 4. Sandstone fragment Pore Throat Size distribution

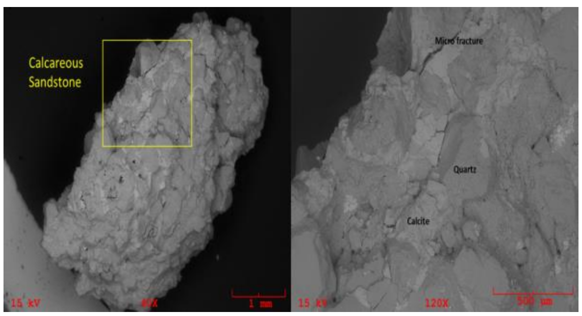

Figure 5 Calcareous Sandstone from lithology correlation

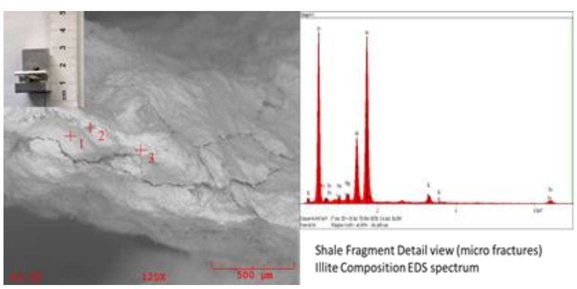

Figure 6. Shale fragment from lithology correlation. Microfractures and EDS spectrum (Illite)

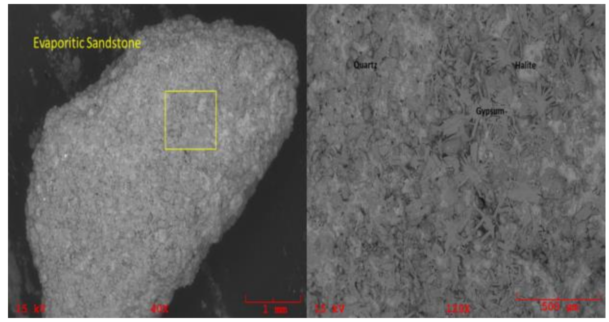

Figure 7 Evaporitic Sandstone fragment from lithology correlation.

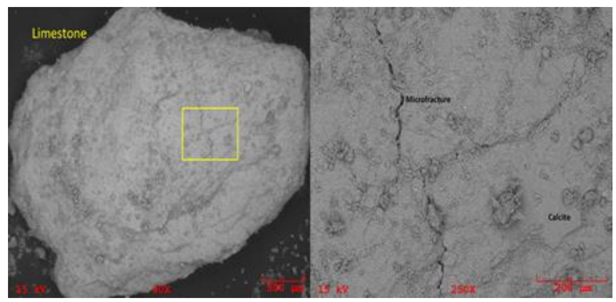

Figure 8. Limestone fragment from lithology correlation.

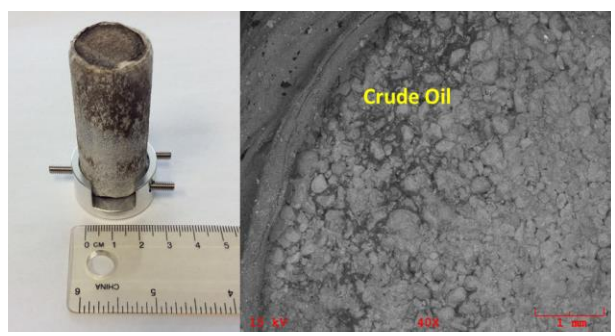

Figure 9 Crude Oil impregnated plug for granulometric analysis.

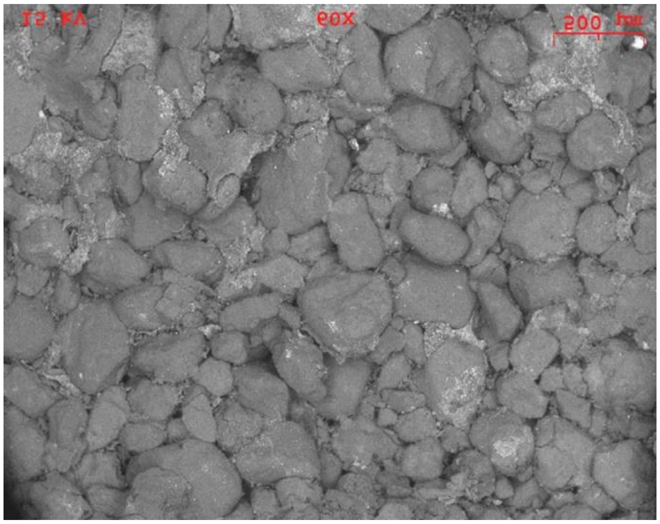

Figure 10. Detailed image from poorly consolidate sandstone impregnated with crude oil. Mud contamination is visible.

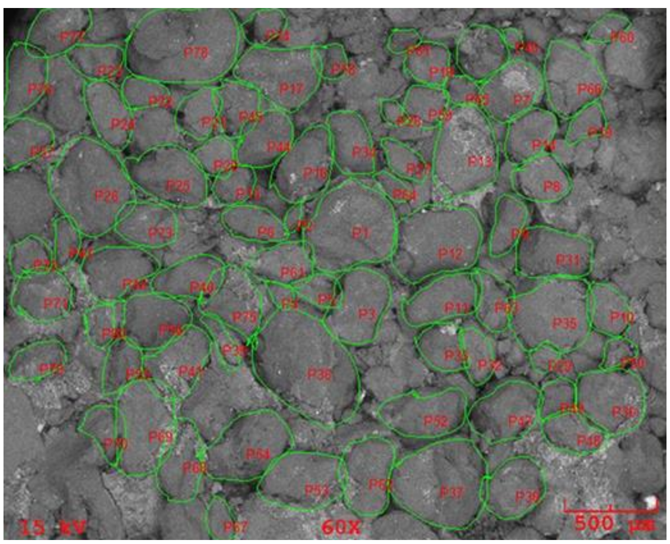

Figure 11. Image analysis of individual grains in impregnated sandstone

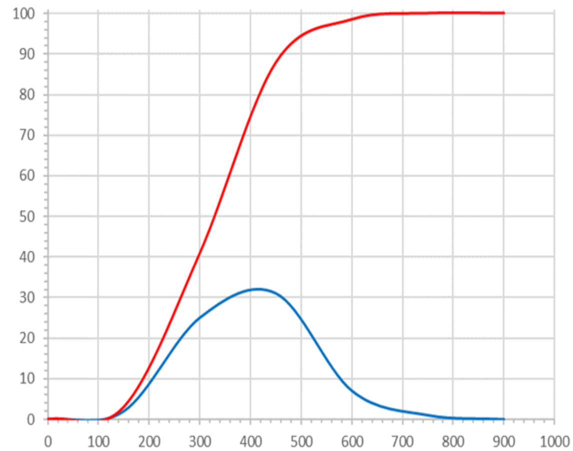

Figure 12. Granulometric Size distribution from figure 11