

A Sequential Workflow Utilizing Standard Logs for the Robust Petrophysical Evaluations in Formations with Complex Mineralogy. A Southern Alberta Case Study.

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Summary

Technological advancements have led to the development of tools based on nuclear spectroscopy, magnetic resonance and dielectric principles for the efficient and accurate determination of mineralogy, porosity, saturation and permeability in formations with complex mineralogy. However, in most fields or basins, the number of wells in which such measurements are acquired is usually small and the log data in most of the logged wells consists of a subset of the standard quad-combo log data (gamma ray, resistivity, neutron, bulk density and compressional slowness).

The challenge encountered when working with quad-combo logs (or less) for the petrophysical evaluation of formations with complex mineralogy, stems from the fact that there is not enough unique information available on the quad-combo log set. This lack of information makes the use of multi-mineral interpretation software difficult since some of them require a minimum number of input logs to solve for a specified number of mineral and fluid volumes.

This paper presents a sequential workflow that utilizes only basic quad-combo log data for the accurate petrophysical evaluation of complex formations and the workflow is implemented in a multi-mineral solver. In the first step, the mineralogy and porosity are determined and the outputs from this step are the inputs to the second step in which the saturation is determined. Critical to this workflow, is the availability of core data, which is used to both constrain and validate the model results.

Introduction

The petrophysical evaluation of formations with complex mineralogy is made challenging by the fact that there is often not enough unique information contained in basic triple or quad-combo log data sets for accurately resolving the formation into its components. These complex formations are typically comprised of at least two types of clay minerals, quartz, feldspars, micas, calcite, dolomite, heavy minerals such as pyrite and organics (kerogen). The system of linear equations (logs and volumes) that is generated by using only triple or quad-combo logs is often severely under-determined (more outputs than inputs) and no unique mathematical solution exists for such a system. Infact, several multi-mineral software applications will not even initialize when the number of input logs is less than a critical value for a given number of expected output volumes.

The introduction of nuclear spectroscopy, magnetic resonance and dielectric log measurements has greatly improved the ease with which accurate petrophysical evaluations can be performed in formations with complex formations. This is because a dataset that comprises of these log types in addition to quad-combo

data has enough unique information to completely and accurately resolve the formation components as is seen in Figure 1 below. The petrophysical results derived from the use of the advanced log types typically do not require calibration with core data.

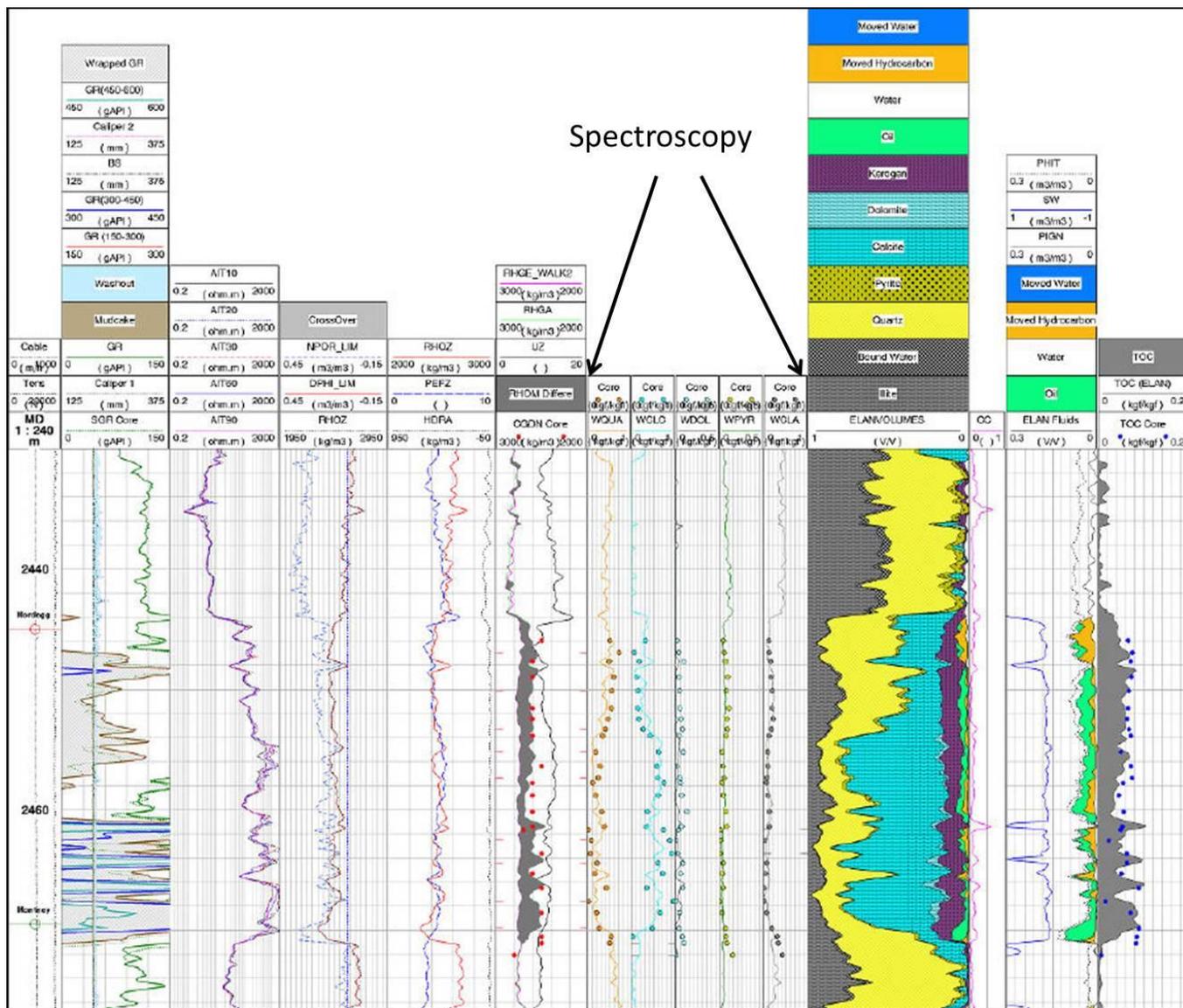


Figure 1 : The use of spectroscopy data together with triple combo logs resulted in the accurate determination of mineralogy, porosity and saturation over this formation with complex mineralogy.

Unfortunately, in most wells only a subset of the quad-combo logs were acquired and accurately resolving the formation components is challenging for the reasons outlined earlier. However, a workflow has been successfully implemented, which successfully determines the mineralogy, porosity and saturation in formations with complex mineralogy.

Theory and/or Method

The workflow consists of two stages. In the first stage, the matrix components and porosity are determined. This stage only focuses on the invaded zone and as such the pore space is assumed to be completely filled with filtrate. The only inputs to this stage of the workflow, are the porosity and lithology logs (no resistivity logs are used) and the invasion factors are set to reflect the fact that all the log response is due

to the invaded zone. The core data is crucial to this stage because it is used to both constrain and validate solution. Without applying appropriate bounds (constrains) to the solution space, the derived result could be both mathematically sound and geologically incorrect.

The volumes obtained from the first stage (mineral volumes and pore volume) and the resistivity log(s) form the inputs to the second stage. In this stage, the fluid volumes are determined by applying the appropriate saturation equation.

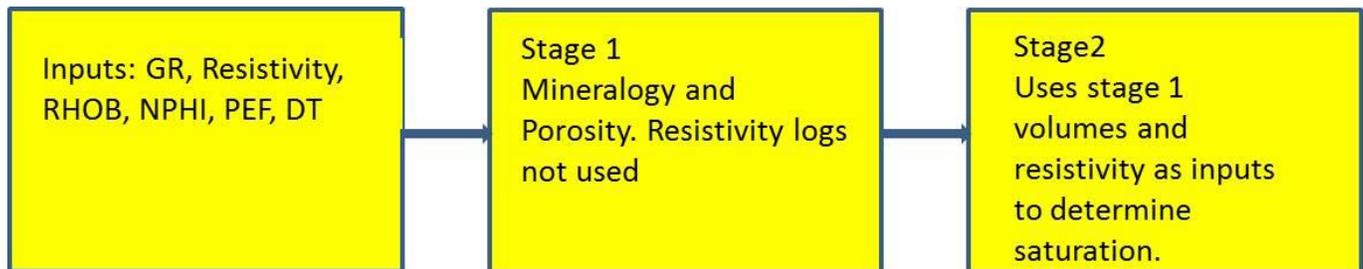


Figure 2: Sequential Workflow.

Examples

This workflow was successfully implemented in the evaluation of the complex mineralogy found in the Montney, Doig and Nordegg formations encountered in the oil fields of southern Alberta.

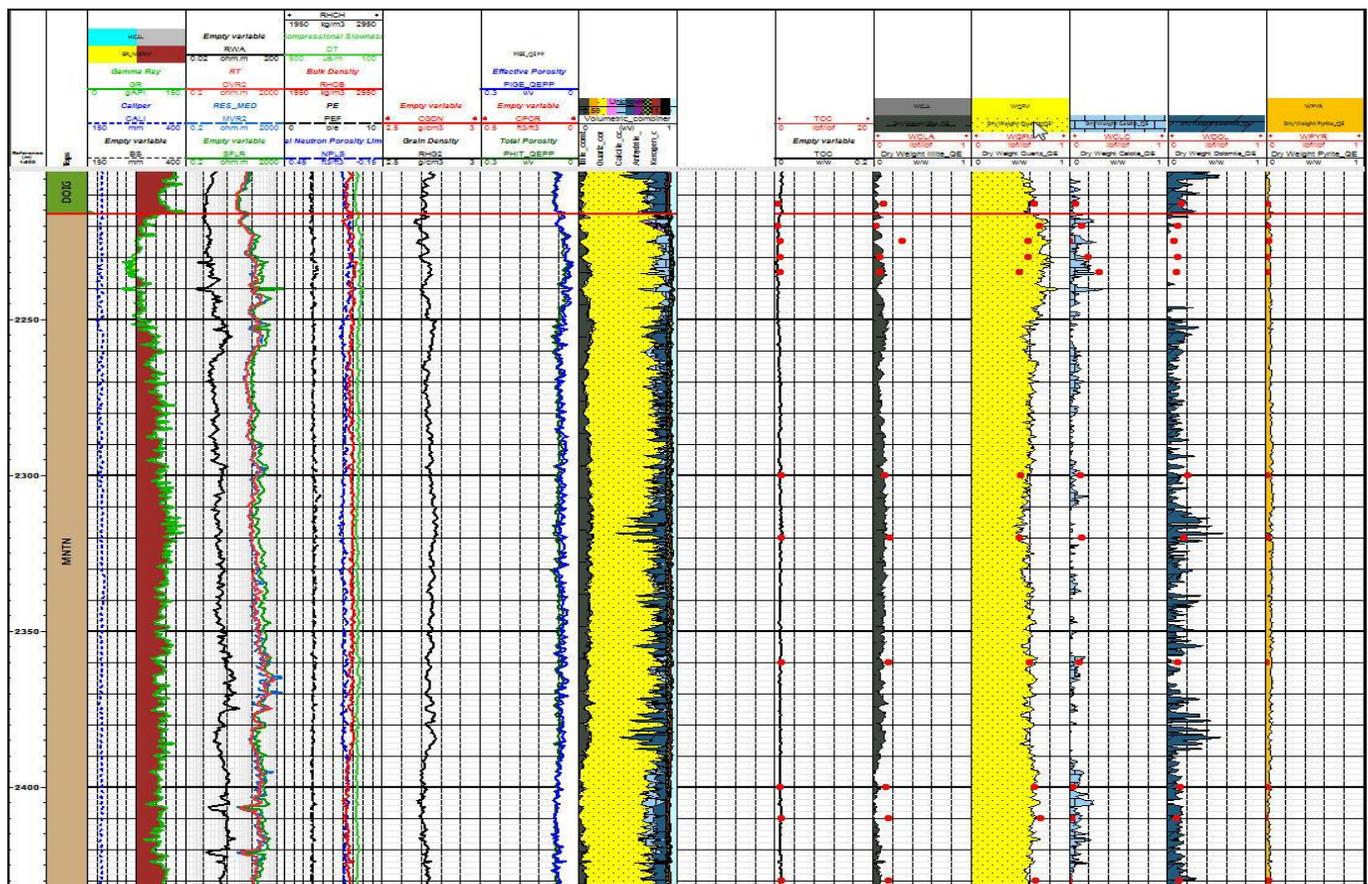


Figure 3 : A good match is seen between the log and core derived mineralogy and TOC.

Figure 3 shows the good match obtained between the log derived mineralogy and TOC and the core derived values. In Figure 4, we see the very good match between the log and core derived grain density, porosity and water saturation over the Doig and Montney formations.

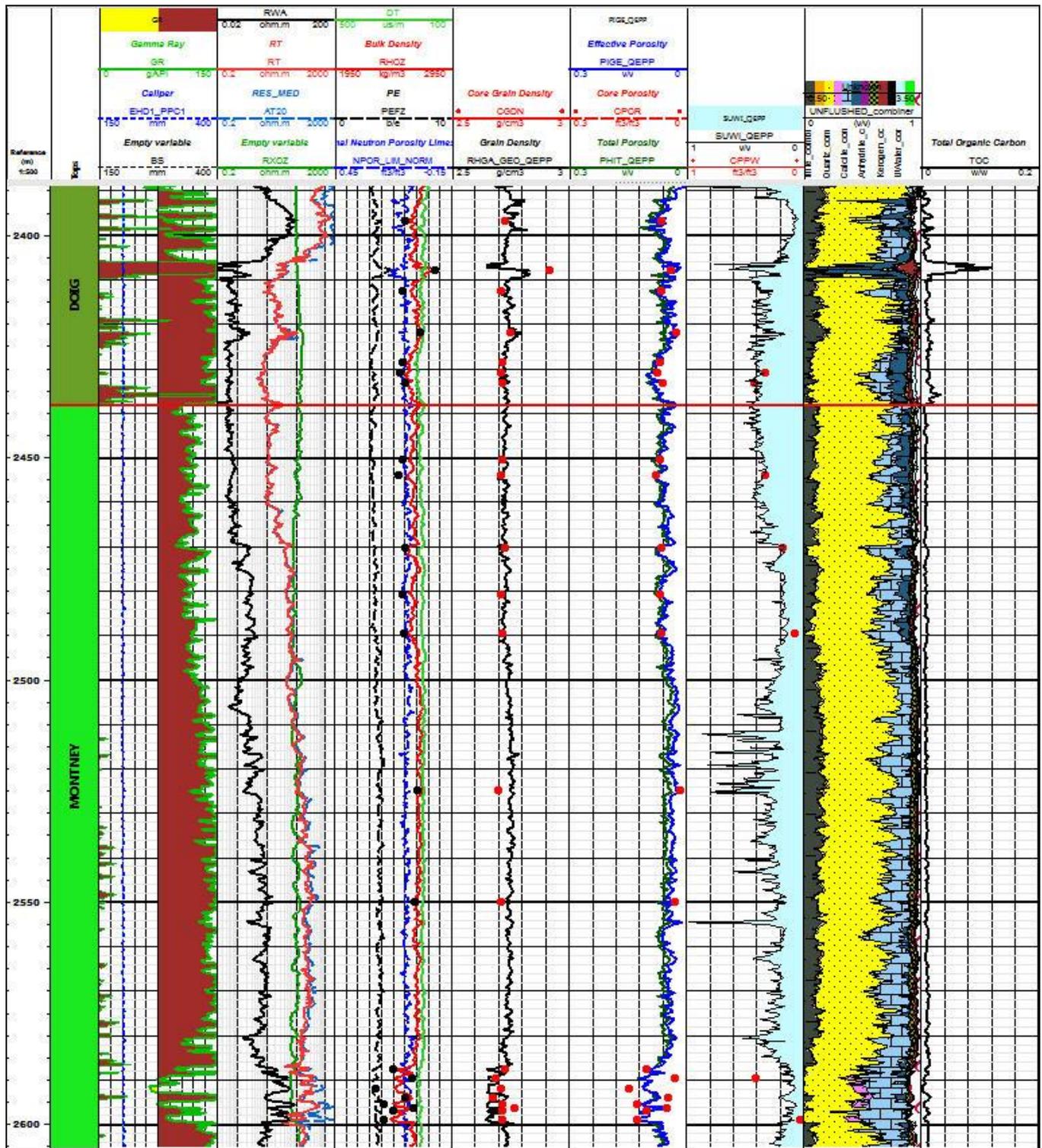


Figure 4 : Excellent comparison between the log and core derived grain density, porosity and saturation in the Doig and Montney.

Conclusions

A robust sequential workflow that uses only quad-combo logs was implemented for the accurate petrophysical evaluation of complex mineralogy formations in Southern Alberta. This work has been implemented in a multi-mineral solver and relies on core data as a critical input to both constrain and validate it. It can be successfully applied in wells where spectroscopy, magnetic resonance or dielectric measurements do not exist for the non-core data dependent petrophysical evaluation of complex formations.