Bitumen Evaluation in the Grosmont Carbonate Reservoir: A Case Study of Wireline Technology Applications*

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Abstract

In this case study, magnetic resonance, dielectric dispersion, gamma ray spectroscopy, and cased hole pulsed neutron tools are used in conjunction with conventional porosity logs to calculate weight-percent bitumen in the Grosmont formation. These results are compared to weight-percent bitumen obtained using Dean Stark analysis of core samples.

Introduction

The Grosmont is a vuggy, fractured, and karsted dolomite reservoir resulting in porosities reaching the 20- to 25-pu range with 7–9 API bitumen. The principle reservoir units in the Saleski area exceed 50 m in thickness. Acquisition of fluid saturation data through coring is time consuming and expensive over the Grosmont C and Grosmont D reservoir units. Further, to attempt to achieve a vertical resolution for core data comparable to wireline logs through core analysis would be impractical at a project scale (Figure 1). Obtaining consistent hydrocarbon saturation results using an Archie-based analysis with resistivity and porosity logs is difficult owing to extremely high resistivity values in the oil-bearing intervals, and changing textural properties of the rock related to fracturing and mixed wettability. Given this situation, Laricina Energy Ltd. explored several alternatives to supplement or support core data with wireline data and compared various wireline technologies.

Theory and/or Method

To facilitate a direct comparison of bitumen content from log data with bitumen content from Dean Stark core measurements, it is necessary to calculate weight-percent bitumen from log data, which is the ratio of the mass of oil to the total formation mass. Expressing this in terms of variables from log data gives the following equation:

$$Wt\%_{bitumen} = \frac{(volume_{bitument})\rho_{bitumen}}{\rho_{formation}} = \frac{(\phi_{total} - \phi_{water\ filled})\rho_{bitumen}}{\rho_{formation}}$$

Total porosity is determined from analysis of conventional neutron-density porosity logs and formation density is obtained directly from the bulk density log. Oil density is a constant value that is appropriate for the bitumen in a particular reservoir and usually ranges from 1,005 to 1,015 kg/m^3.

Water-filled porosity can be determined from

- Archie analysis using formation resistivity and porosity logs with input values for formation water resistivity, cementation exponent, and saturation exponent.
- Calculation from magnetic resonance logs by determination of a cutoff on the T_2 distribution that allows differentiation of oil and water.
- Direct output from dielectric dispersion tools.

Gamma spectroscopy measurements use a high-output pulsed neutron generator and a high-performance gamma ray detector to measure both inelastic and capture gamma ray spectra. From these spectral measurements as inputs, total organic carbon (TOC) is computed by subtracting the amount of inorganic carbon (IC) associated with the rock matrix from the total carbon (TC) measurement. This stand-alone TOC is used to output weight-percent bitumen that is independent of formation porosity, resistivity, and formation water salinity by accounting for the carbon density in the oil.

Example

Figure 2 shows the dry-weight lithology from spectroscopy measurements in track 1, with conventional resistivity and porosity logs presented in track 2 and track 3, respectively. The overall agreement between log and core porosity is good considering the heterogeneous nature of the reservoir and the difference in vertical resolution of the measurements, which increases the scatter in the fit in the data. Tracks 4 through 7 show a comparison of weight-percent bitumen obtained from Dean Stark core measurements compared with the calculated weight-percent bitumen from log data for each of the different logging tools. An overlay of data from two logging passes shows the repeatability of the results. Overall, the core data shows very good agreement to the log data, and the log results from each of the different logging tools are consistent with each other.

Conclusions

Magnetic resonance, dielectric dispersion, gamma spectroscopy, and cased hole pulsed neutron tools used in conjunction with conventional porosity logs provide an accurate calculation of weight-percent bitumen that shows excellent agreement to core data in the Grosmont formation.

Bitumen volume computed from magnetic resonance measurements and neutron-density porosity is independent of formation resistivity and formation water salinity and shows very good agreement to core data. However, in shaly sections of the reservoir the bitumen volume computed from magnetic resonance is optimistic compared with core results owing to an overlap of the bitumen and oil signals.

Dielectric dispersion measurements combined with neutron-density porosity measurements provide an accurate bitumen volume calculation independent of formation resistivity and formation water salinity. With 1-in. vertical resolution, the dielectric measurement has the best vertical resolution of the tools run in this comparison. In addition, textural analysis of the dielectric dispersion data shows variable wettability, which is problematic for estimating bitumen volume with resistivity-based analysis.

Neutron-induced gamma spectroscopy measurements yield a weight-percent bitumen output independent of formation porosity, formation resistivity, and formation water salinity. Once again, the results show excellent agreement to bitumen obtained from core analysis. In addition, the dry-weight elements provide data necessary for accurate analysis of formation lithology.

Weight-percent bitumen obtained from cased hole pulsed neutron data in conjunction with the open hole porosity logs also shows excellent agreement to the core data. There is an application here for time-lapse monitoring of bitumen volume to evaluate production efficiency.

All of the advanced technology measurements applied here provide excellent results for the evaluation of bitumen volume in comparison with core data. Selection of the exact combination of logging tools to be used for evaluation depends on potential additional value that can come from each of the measurements. For example, dielectric dispersion measurements can provide reservoir textural information, whereas neutron-induced gamma spectroscopy measurements provide data that enables the accurate evaluation of lithology, resulting in an improved porosity analysis.

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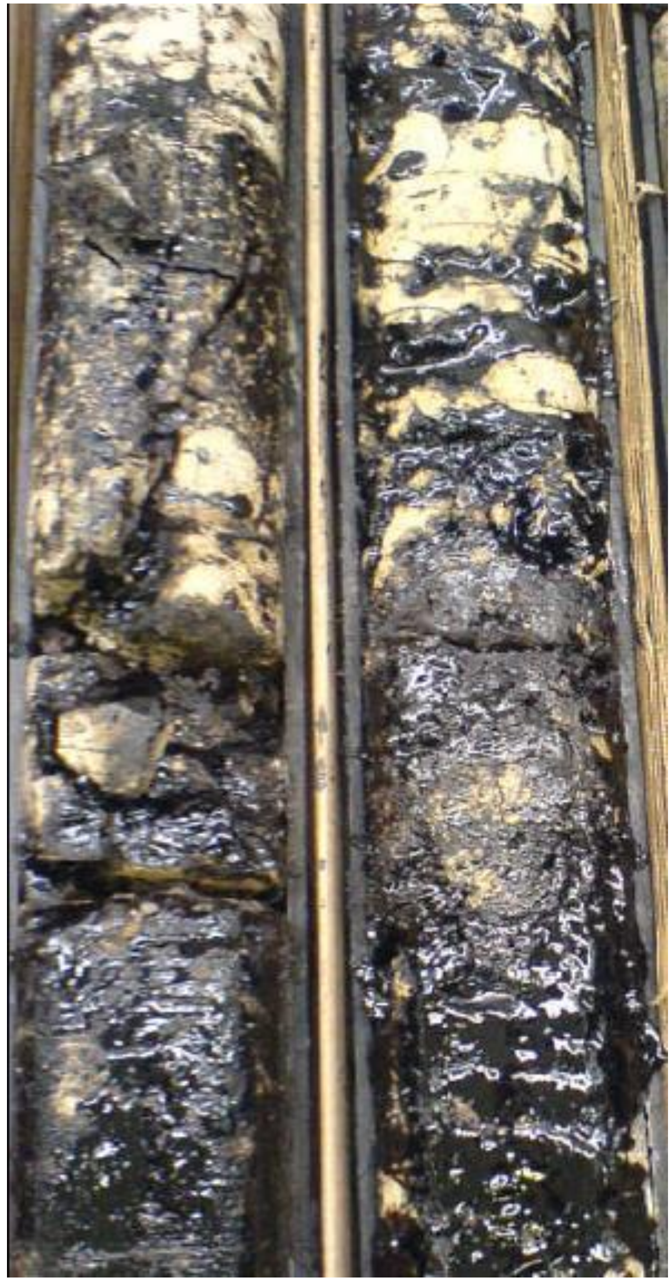

Figure 1. Photograph of Grosmont reservoir core.

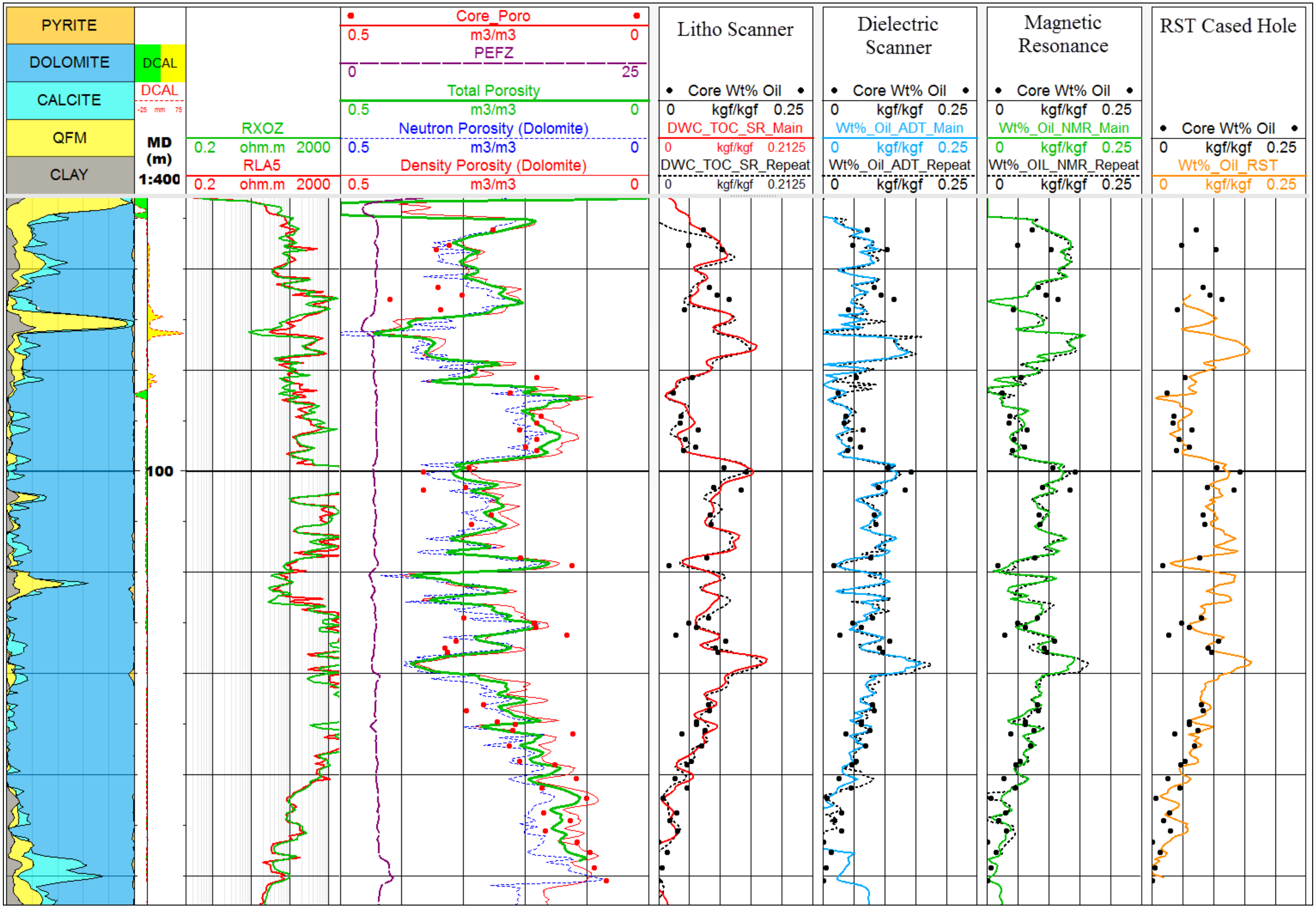

Figure 2. Comparison of weight-percent bitumen from core measurements to results obtained from different wireline logging technologies.