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Comparing Petrophysical Models for an Unconventional Shale Play: a Case Study of the Lower Jurassic Nordegg/ Gordondale Members in Alberta.

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Summary

A case study is presented to compare results from different methods to estimate key petrophysical properties on an unconventional play located in the Western Canadian Sedimentary Basin. The Nordegg-Gordondale Members, of the Fernie Formation, have been identified as organic rich source rocks, and due to the booming exploration and development of unconventional resources, interest has been placed in these members as potential shale plays.

The basis of this investigation comes from a hydrocarbon prospectivity study performed on the above-mentioned members. My objective as the petrophysicist, consisted of determining which petrophysical methods better matched the core data using a basic well-log data set composed of gamma ray, spectral gamma ray, neutron porosity, formation density, acoustic slowness and photoelectric factor.

The main finding of my investigation was identifying which methodologies best predicted the above petrophysical parameters with the lowest uncertainties. One of the main challenges was accounting for the effect of organic matter on the porosity logs (neutron, density and sonic), since this would affect other property calculations such as clay content, hydrocarbon saturation and permeability.

Method / Workflow

To achieve my objective, 13 methods were applied in 4 wells (containing both well-log and core data for well-log/core calibration) to evaluate the organic richness, maturity and flow capacity of the rocks in the subsurface by calculating the following properties: total organic carbon (TOC), clay content (Vsh), porosity (ϕ), permeability (K), water saturation (Sw) and thermal maturity (Tmax). Subsequently, the methodology that broadly best matched the core data was selected to proceed with the calculations in the remaining wells with well-log data. Finally, calculation outputs were loaded in Petrel® and property maps were generated using the geostatistical methods that best represent the petrophysical and geological data.

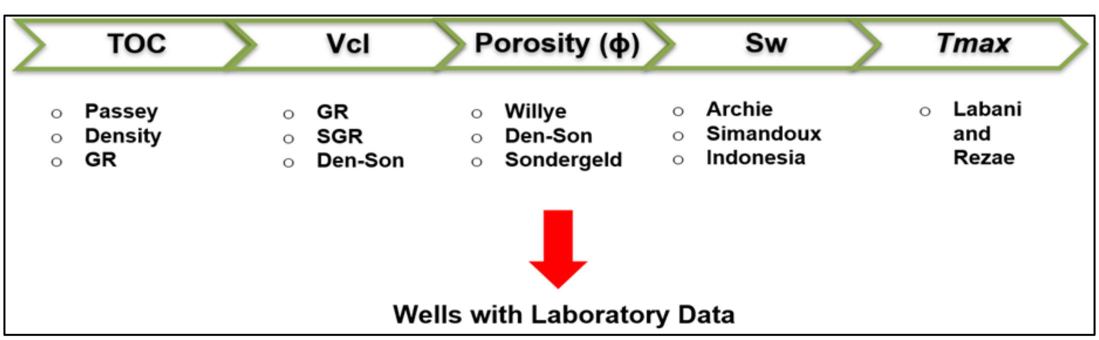

Fig. 1. Work flow applied to find the best matching methodologies between core and well-log data.

Results

Total Organic Carbon

From the three approaches tested (figure 1), the *Delta Log* method by Passey et al (1990) showed to be the most statistical consistent to predict TOC from well-log data. With an average relative error of 31.8% and 28.0% for wells A and B respectively; and correlation coefficients (R^2) of 0.72 for well A and 0.81 for well B (figure 2). The main reason for its accuracy is the fact this method is based in two log responses: porosity log, which is more affected on immature rocks; and resistivity log, which is more affected in mature rocks (LeCompte and Hursan 2010). However, some dispersed points were observed in well A. These outliers giving low predicted TOC values were studied in more detail. It was found high dolomite content at these depths, producing an increase in the acoustic slowness, therefore, causing a decrease in the separation of sonic and resistivity curves (delta Log), obtaining as a final result, lower derived TOC values.

Furthermore, outliers giving higher derived TOC values are likely caused by lamination not resolved by the resistivity tool, where Rt (true resistivity) is lower than RESD (Deep resistivity), resulting in overestimation of TOC content derived from well logs. When these outliers are considered in the regression model, the R^2 in well A is 0.42.

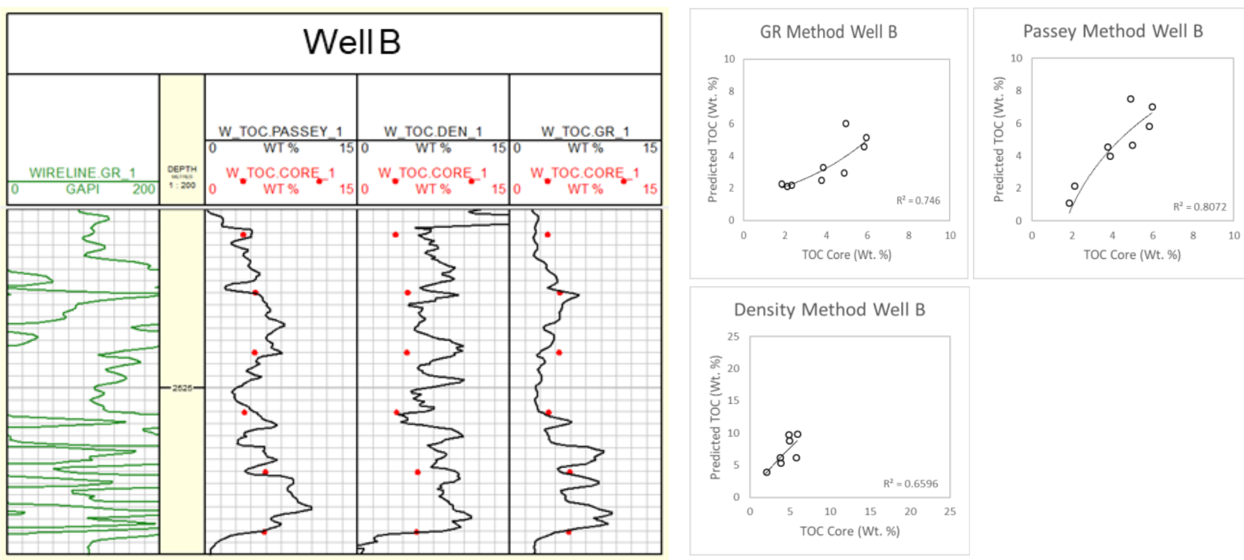

Fig. 2. Well-log / Core calibration results and statistical analysis of TOC methodologies applied on Well B. Track 1: Wireline GR. Track 2: Passey vs Core; Track 3: Density vs Core and Track 4: Gamma Ray method vs Core.

Volume of Clay

The (1) Spectral Gamma Ray (SGR) and *the (2) Density – Porosity* methods best matched the core laboratory data, whereas the (3) *Gamma Ray (GR)* method results did not, showing very high values (up to 65% of average Vsh). The reason for these higher values is that total gamma ray is affected by the organic matter, which increases the uranium reading (Total gamma ray is the sum of Thorium, Potassium and Uranium). Therefore, the *SGR* results, which takes only into consideration the Thorium and Potassium components, matches considerably better the core data. In the other hand, the *Density – Sonic* method showed also very good match with core data, confirming the relationship between the separation of these two curves with the clay and mineral content of the rocks.

Conclusions

- *Delta Log* method (Passey et al, 1990) was the best TOC predictor throughout the study area.
- The high total gamma ray values in the Gordondale Member were found to be caused by the uranium contribution to the GR, which is an effect of the high organic matter content in this stratigraphic units.
- The best Vsh predictors were found to be (1) the *Spectral Gamma Ray* method (using only Thorium and Potassium; and (2) the *Density – Sonic* method.
- The *Density* method (Sondergeld et al, 2010), was the best for predicting porosity. However, although this method corrects for TOC, such a correction was not enough and an additional correction had to be applied.
- The *Indonesia* approach was the best for calculating the water saturation. As an alternative the second best was the Simandoux method (figure 3).
- Conventional permeability predictors did not show accurate results when compared with laboratory data. Furthermore, no good correlations were found between porosity and permeability in the wells studied.

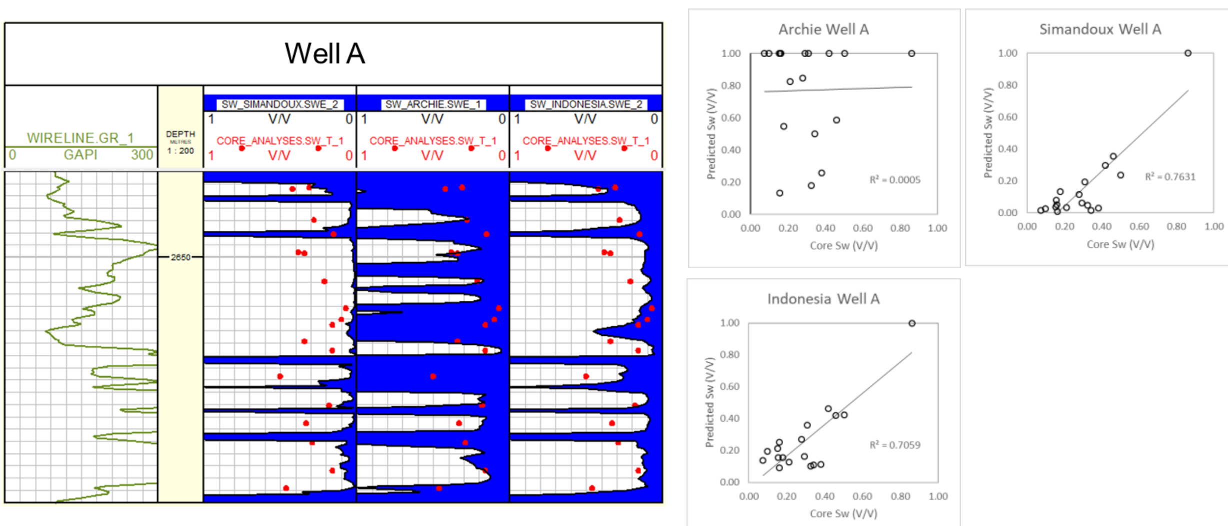

Fig. 3. Well-log / Core calibration results and statistical analysis of Water Saturation (Sw) methodologies applied on Well A. Track 1: Wireline GR. Track 2: Simandoux vs Core; Track 3: Archie vs Core and Track 4: Indonesia vs Core.

Novel/Additive Information

As an additional outcome, two zones possessing satisfactory petrophysical properties and high hydrocarbon prospectivity were identified and will be presented based on the results of this study (50 wells in total). The data was compared with actual production data in order to show the feasibility of the approaches selected.

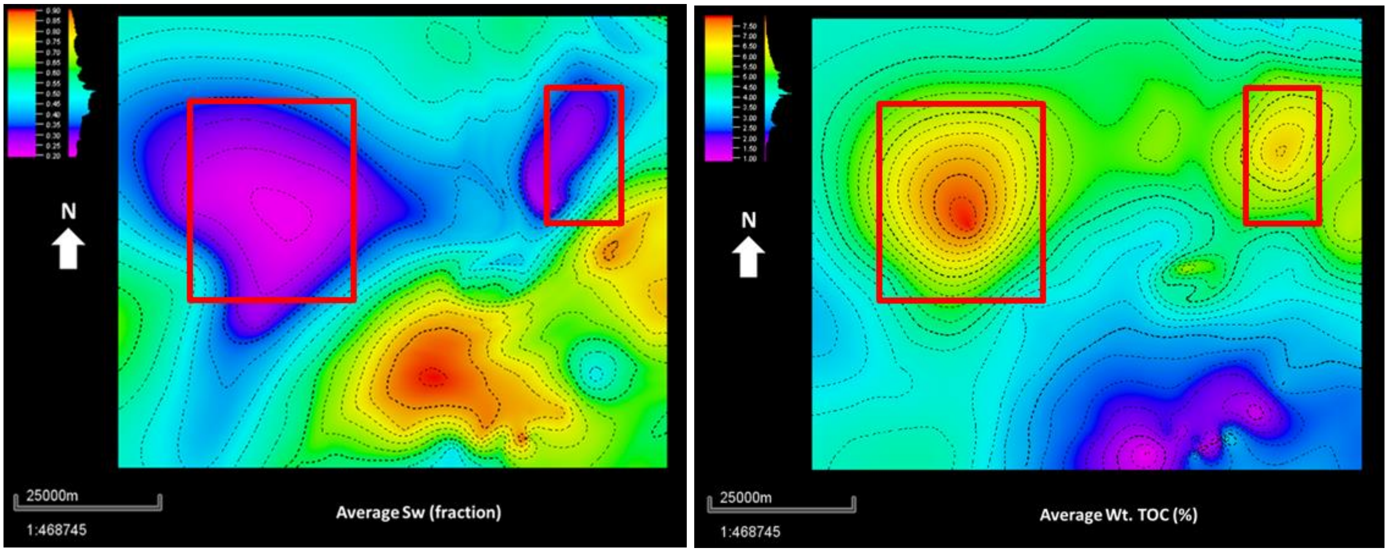

Fig. 4. Average Sw and TOC map (in weight percent) for the study area highlighting two prospective zones with los Sw and high TOC concentrations (Purple/Pink = low values. Red/Yellow = high values).

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