Digital Rock Analysis and Petrophysical Integration for Improved Characterization in the Wolfcamp Formation

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Introduction

The well analyzed for this project was drilled in 2014 and had a full diameter core sample of 247ft in length. Imaging and digital rock properties were obtained from the core where sample selection was managed utilizing a statistical method based on whole core dual energy CT. Porosity (SEM) and geochemical values (FTIR/SEM) were collected and compared with GRI crushed porosity and LECO TOC data at the same depths. A porosity permeability trend was generated and propagated along the length of the core. Wireline log data was integrated with digital rock property data from the core to yield a more robust petrophysical model.

Problem Statement and Objectives

In the Wolfcamp, porosity associated with organic matter (PAOM) is interbedded with inter-granular porosity and most of the hydrocarbon resource is likely to be stored in the PAOM. A major goal of this poster it to show how total porosity (PhiT), effective porosity (PhiE), and porosity associated with organic matter (PAOM) were quantified and used to aid in the interpretation of high resolution Dual Energy CT and wireline log data.

Building a Geological and Petrophysical Framework

Whole core was collected at the well site and immediately shipped to Ingrain's facility where cores were scanned within their aluminum tubes to obtain early visibility into the critical properties of whole core. DE-CT derived RHOB and PEF curves helped discriminate lithology, rock facies, and depositional sequences. We combined spectral gamma logging to compute other petrophysical information such as mineralogy and organic matter.

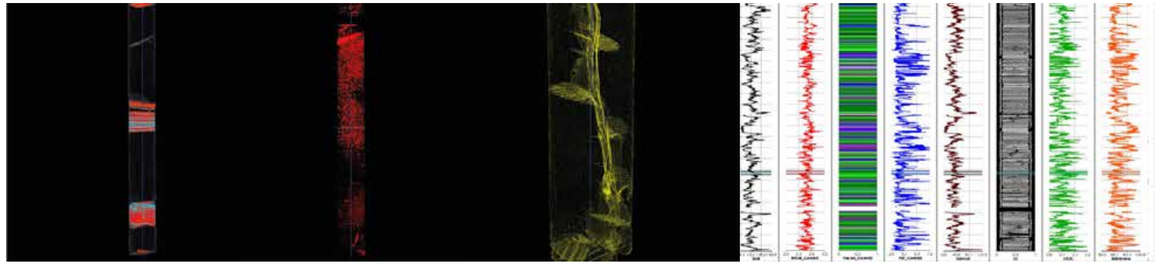

Figure 1. Visualization generated from whole core CT showing geologic features captured within the digital record (left). All data is managed in Lithovision ™ where loading of all volumes based on petrophysical data is simple (right).

Statistical Sampling Method & SEM Imaging Program

In order to ensure adequate sampling of zones with greatest reservoir potential, data was divided into classes based on RHOB and PEF threshold values. *(Figure 2)*

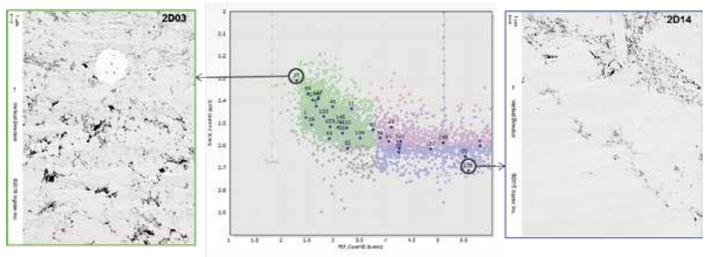

Figure 2: Core CT based cutoffs and sample recommendation.

Porosity associated with organic matter (PAOM, and inter/intra-granular porosity can be measured directly from the SEM images.

The sets of high resolution images were combined and segmented to quantify volume fractions.

Porosity (OM
Porosity +Inter-granular
porosity): 5.34%
OM: 3.50%
PaOM (blue): 3.05%
ATR: 47

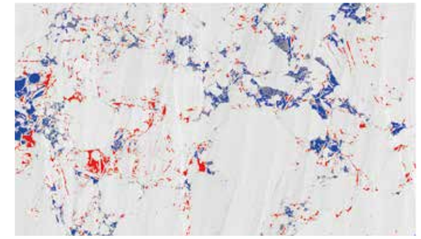

Figure 3: Segmented or classified SEM image and derived computation

Comparison with Traditional Lab Methods

In addition to the data generated by digital rock methods, Fourier Transform Infrared Spectroscopy (FTIR) *(Figure 4)*, LECO TOC lab geochemistry *(Figure 5)* , XRD and GRI *(Figure 6)* experiments were performed. These comparisons show SEM volume fraction analysis is representative of the bulk properties. FIB-SEM analysis was also run to obtain matrix permeability and pore geometry *(Figure 7)*. These permeabilities compare favorably with GRI based method.

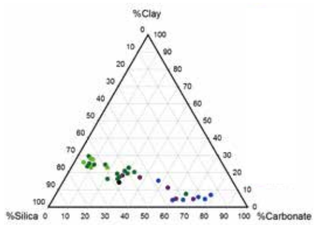

Figure 4: Mineralogy from Fourier transform infrared spectroscopy (FTIR) (FTIR) shows the cored interval ranges from siliceous to calcareous mudstones with low clay content.

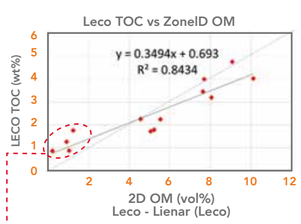

Figure 5: LECO TOC (wt %) versus SEM determined organic matter content (vol. %). Circled high calcite samples probably show too high TOC due to incomplete calcite dissolution before LECO.

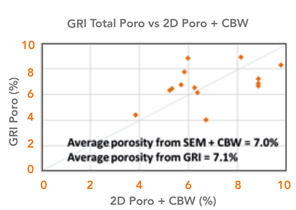

Figure 6: Clay Bound Water (CBW), is captured from the GRI method but not from SEM imaging. Clay speciation data from FTIR was utilized to predict the CBW porosity for each sample. This values were added to each SEM data set to calculate a total porosity.

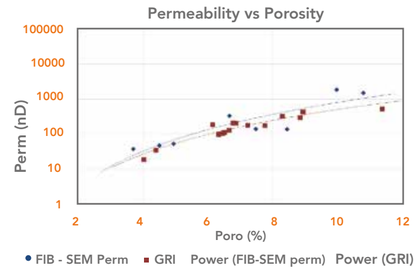

Figure 7: FIB-SEM analysis compared favorably with GRI

Petrophysical Integration

Final high resolution petrophysical interpretation was delivered combining DE-CT scan data, SGR, mineralogy, SEM and FIB-SEM derived computations. *(Figure 8)* Shows how empirical trends were used to upscale the SEM data to PAOM, PHIT, PHIE and permeability for the cored interval. Well log results (red curves) and core computed results agree well over most intervals, but some areas of disagreement need further investigation.

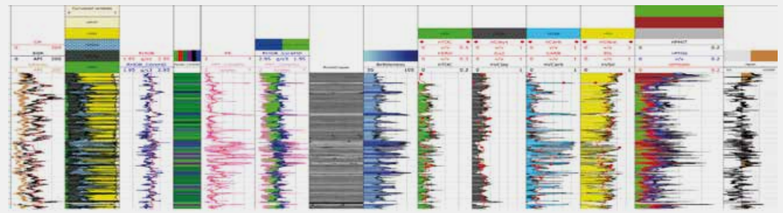

Figure 8: ShalePayTM

Conclusions

- Core CT based petrophysics provides improved vertical resolution. Rock properties are key in the understanding of highly laminated reservoirs.
- CT based petrophysics accurately predicts mineralogy and TOC along the core.
- High resolution log data and statistical facies classification enhances the core plug sample selection and identification of zone of interest.
- Organic matter measured from SEM images and FTIR compared favorably with LECO TOC.
- Ingrain's quantitative SEM analysis provides insights about PAOM by retaining all associated spatial and heterogeneity information. The major difference with GRI is clay-bound water. When comparing GRI based porosity with SEM porosity, you must add clay bound water porosity to the SEM porosity since this kind of porosity is not accounted for in the image.
- The empirical trends developed from SEM and FIB-SEM computations can be used to obtain upscaled PAOM, total porosity, and permeability curves from core scans and wireline logs.
- Overall core vs well log results match well, but there are still a few areas of disagreement that need further investigation.

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References
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Paper: 2461526