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Utilizing well logs to define and characterize rock types (flow units) in the Montney Formation, Western Canada.

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Summary

Prediction of fluid distribution is a critical problem in field development in the Montney Formation, affecting economic decisions and completion strategies. Mineralogy is probably a significant factor in controlling fluid distribution because of its connection to petrophysical properties, including pore size, connectivity and wettability; mineralogy also affects geomechanical properties. Mineralogy in the case of the Montney reflects both detrital composition and subsequent diagenetic alteration; hence it is necessary to build reliable petrophysical models and optimize the production at this reservoir. In this study, we demonstrate an effective methodology to classify discriminate rock types and build field-scale petrophysical models, based fundamentally on well logs with calibration to core data.

Four modes – endmember rock types – were classified through a probabilistic cluster analysis of well logs (Gamma-ray, neutron porosity, and density) in the vicinity of Septimus field. Each mode was initially defined by a unique log signature, but comparison to mineralogical data indicates that each mode is also characterized by unique rock composition and fabric. We then further show modes can be related to petrophysical properties (porosity, permeability, pore and pore throat size). Because rock modes are originally based on well logs, we can therefore create 3D field-scale renditions of petrophysical properties.

Introduction

The identification and characterization of flow units is as significant in unconventional reservoirs as it is in conventional reservoirs. In both reservoir types, this designation guides production designs by identifying high and low flow reservoir intervals. But in unconventional reservoirs – unlike conventional reservoirs – flow units may also predict the distribution of fluid type, related to the size and connectivity of the pore structures pores (Vishkaj et al. 2017).

Our study focuses on the Septimus field of the Montney Formation in British Columbia (Fig. 1). Septimus field is unique because it contains both oil (updip) and gas (downdip). We define and characterize modes (rock type endmembers) based initially on well logs. We then characterize the mineralogy, petrophysical parameters, and rock fabric of each mode and then examine modes in comparison to reservoir fluids to better understand which properties affect hydrocarbon distribution.

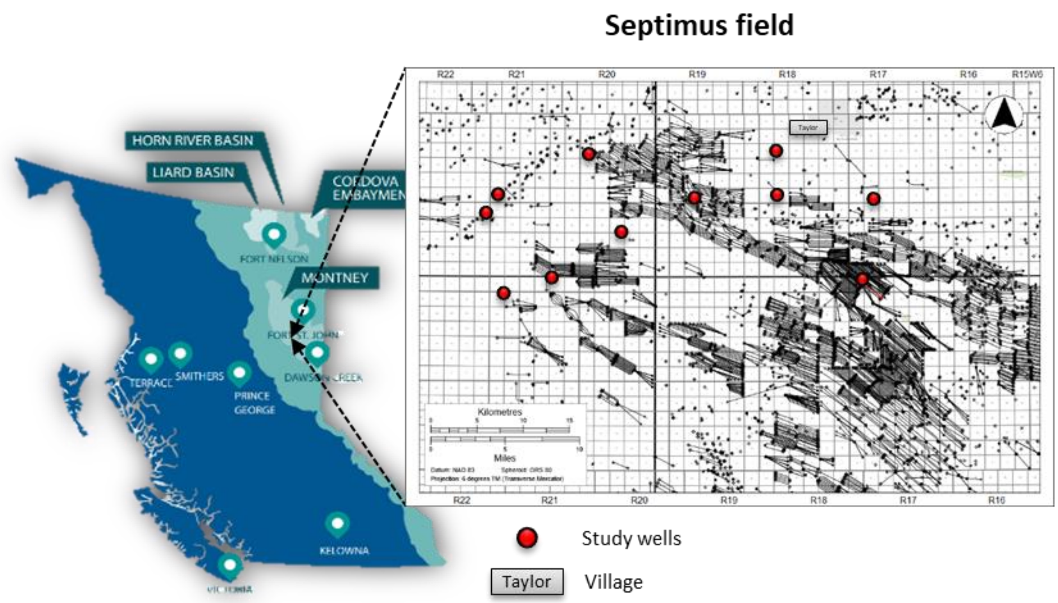

Figure. 1: Basins in British Columbia (Oil and Gas Commission, 2015) and location map of Septimus field with cross-section model.

Geological Background

The Montney Formation is a west-dipping mixed siliciclastic and carbonates siltstone wedge of Early Triassic age, deposited in the Western Canada Sedimentary Basin (Crombez, 2014). The Montney Formation is subdivided into several stratigraphic sequences separated by regionally extensive erosional surfaces in more proximal settings. (Zonneveld, Golding and Moslow, 2011).

Detrital minerals are quartz, feldspars, plagioclase, dolomite, micas and clays. Diagenetic phases are significant to rock composition and include calcite, dolomite, feldspars and quartz cements. Pyrite also has been reported throughout the Montney as well as authigenic clays like illite, and illitized smectite (Vaisblat et al., 2017).

Workflow

We used the GAMLS software to perform a probabilistic cluster analysis on multiple wells, in order to identify 4 modes (rock type endmembers) in the Montney Formation interval of the Septimus field. Input parameters were gamma ray, neutron porosity, and density logs from 15 wells in the area. GAMLS software uses an algorithm that identifies similar patterns in well logs response; through a multivariate (multidimensional) cluster analysis in which each sample (depth step) is assigned to one or more modes.

To authenticate identification of these 4 different modes, core samples were selected from intervals where the presence of each mode was ≥70% for further analysis, in order to confirm each rock type behavior.

Sets of 3 samples from 2 cores, were subjected to a suit of analyses: quantitative analysis of minerals with QEMSCAN, SEM/EDS images (surface topography and composition), major and minor trace elements analysis by ICP/ICP-MS, total organic carbon content by LECO analysis, pore throat size from mercury injection capillary pressure (MICP) analysis, pore size analysis by nitrogen adsorption/desorption, porosity, and permeability analysis. In addition, pseudo cuttings (samples crushed to a size fraction similar of a drill cuttings) were sampled at one-meter intervals throughout the entire length of each core for mineralogical analysis (QEMSCAN).

Results and discussion

1) Log interpretation

Our clustering (GAMLS) analysis identifies 4 modes. Mode 2 the most abundant (50-80%), followed by mode 1 (20-30%), mode 3 (10-15%), and mode 4 (5-10%).

2) Mineralogical and geochemical analyses

QEMSCAN analysis of modes samples, supported by SEM/EDS images and petrographic analysis of thin sections show that log-defined modes can be differentiated in terms of rock composition. Fig. 2 shows the mineralogical composition for each one of the four modes. Mode 1 is characterized by the highest carbonate content and the lowest clay content of all modes. Modes 2 and 4 have similar compositional trends, although mode 2 has slightly lower content of micas, clays, and quartz, and slightly higher carbonate content in relationship to mode 4. Mode 3 has the highest clay content and the lowest content of micas, K Feldspar + plagioclase, and quartz.

Mineralogical differences between modes were tested by comparison to whole rock geochemical data. From major elements distribution agree with mineralogical distribution (i.e. high carbonates = high Mg, Ca). In addition to inorganic geochemistry, LECO %TOC was calculated and although there are slight variations between sets of each mode, mode 3 represents the mode with highest values of %TOC (2 to 4%), while mode 1 represents the mode with the lowest TOC (1%).

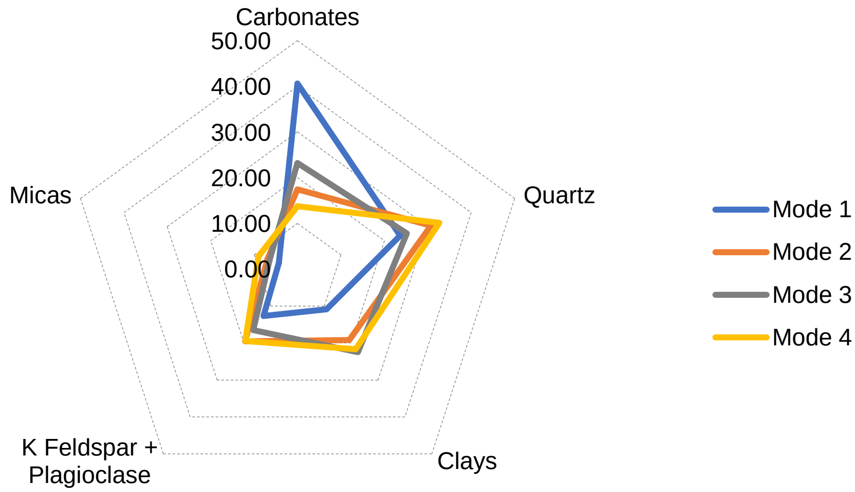

Figure 2: Diagram representing the main mineralogy identify by QEMSCAN analysis. Values are in (%). As observed, each mode has a very unique configuration. Carbonate minerals include (calcite + dolomite), clays minerals include [(Illite and Illite-smectite) + (Fe + Illite and Illite-smectite)], and micas include (Muscovite + Biotite + Kaolinite + Chlorite).

3) Petrophysical analysis

Mercury injection analysis provides information about pore size distribution. Figure 3 shows that mode 3 has the highest pore volume than mode 2. Figure 4 demonstrates that mode 3 has smaller pore throat diameter than mode 2. These trends are explained by the higher clay content and higher TOC content of mode 3 with respect to mode 2.

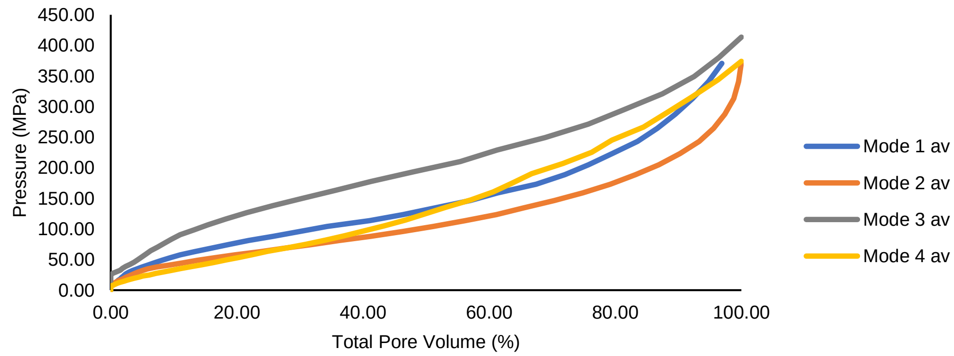

Figure 3: Total Pore Volume versus pressure relationship for each mode. Each mode is represented by the average result from the 3 sets of samples per mode.

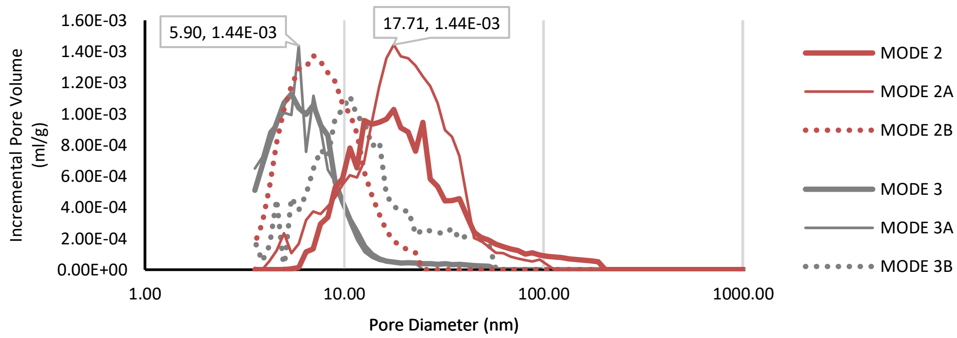

Figure 4: Example of pore throat diameter distribution vs IPV of samples for modes 2 and 3, mode 3 representing the smallest pore diameter distribution.

Conclusions

We have demonstrated an effective workflow to define and map flow units in the Montney Formation. Our analysis shows that the Montney reservoir in Septimus field can be effectively classified from well logs as a combination of four modes (rock type endmembers). We have also demonstrated that these modes distinctly differ in their mineralogical composition, organic carbon content, rock fabric and, in turn, their petrophysical properties.

References

Euzen, T., Power, M., Crombez, V., Rohais, S., Petrovic, M., Carpentier, B.; "Lithofacies, Organic Carbon and Petrophysical Evaluation of the Montney and Doig Formations (Western Canada): Contribution of Quantitative Cuttings Analysis and Electrofacies Classification". GeoConvention, 2014.

Vaisblat, N., Harris, N.B., DeBuhr, C., Euzen, T., Gasparrini, M., Crombez, V., Rohais, S., Krause, F. and Ayranci, K., 2017, "Diagenetic model for the deep Montney Formation, northeastern British Columbia"; in Geoscience BC Summary of Activities 2016, Geoscience BC, Report 2017-1, p. 37–48.

Vishkai, M., Wang, J., Wong, C.K.R., Clarkson, R.C., Gates D.I.; 2017; "Modeling geomechanical properties in the Montney formation, Alberta, Canada"; International Journal of Rock Mechanics & Mining Sciences; 96 (2017) 94-105.

Zonneveld, J.P., Golding, M., Moslow, T.F., Orchard, M.J., Playter, T., Wilson, N.; "Depositional Framework of the Lower Triassic Montney Formation, West-central Alberta and Northeastern British Columbia"; AAPG Search and Discovery Article; GeoConvention, Calgary, Alberta, 2011.