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Lithofacies, Organic Carbon and Petrophysical Evaluation of the Montney and Doig Formations (Western Canada): Contribution of Quantitative Cuttings Analysis and Electrofacies Classification.

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Introduction

The Western Canadian Montney-Doig Formations forms an overall prograding wedge that was deposited along the western margin of the Pangea during the Lower Triassic (Davies *et al.*, 1997; Zonneveld *et al.,* 2011). This depositional system contains a large spectrum of play types, including conventional, dry and liquid-rich tight gas as well as source rock reservoirs. Conventional reservoirs are associated with shallow marine coquina beds and more distal sandy turbidites and have been producing oil and gas for several decades. However, it is only recently, and thanks to the rapid development of horizontal drilling and multistage fracturing technologies, that the industry has started to focus on the unconventional part of the Montney-Doig petroleum system.

Unconventional reservoirs of the Montney-Doig Formations mainly consist of storm and flood-related thin-bedded fine-grained sediments, deposited in lower shoreface, offshore transition and offshore environments. Optimizing the development of these resources depends on our ability to understand and map the spatial distribution of reservoir quality, organic richness, fluid saturations as well as mechanical properties. However, quantifying these parameters from well log data is challenging because of their combined effects on the log response and the non-unique solution associated with them. For instance, the total organic carbon (TOC) is commonly quantified by methods that strongly depend on the deep resistivity log (Passey 1990; Nieto *et al.*, 2013), while the same log may be used to quantify the bulk volume of water (Wood 2012). Integrating well log data with various other sources of information is key to address non-uniqueness and to reduce the uncertainty in quantitative well log analysis of these unconventional reservoirs.

Reservoir characterisation challenges

The arid climate and associated lack of chemical weathering that prevailed at the time of deposition of the Montney-Doig Formations resulted in a narrow range of grain size variations across most of the basin (mainly siltstone to very-fine grained sandstone), and an overall low proportion of clays. In the study area, the mineralogy of the Montney-Doig Formations dominantly consists of quartz, dolomite, clays, feldspar, calcite, pyrite, micas, anhydrite (Doig) and apatite (Doig). Mineralogical variations are associated with facies changes that may occur from the scale of the laminae (microfacies, Playter 2013) to the scale of the system tract. TOC data also suggest cyclic variations of organic richness at the scale of a few tens of meters (Crombez *et al.*, 2013). These compositional changes may have a strong impact on log-derived effective porosity by affecting among other signals, the Gamma Ray log (mica, K-feldspar, kerogen) or the Density log (dolomite, pyrite, kerogen etc). Facies changes are also associated with variations in pore size distribution, which potentially impacts the porosity/permeability relationships, capillary pressure, relative permeability and fluid saturations.

Detailed analysis of the relationships between petrofacies and reservoir properties in the Montney Formation has been published (Pedersen *et al.*, 2011; Derder, 2012; Vaisblat *et al.*, 2013), but extrapolating these relationships to the entire Montney-Doig succession through quantitative well log analysis remains challenging, because cores provide only very localized information. Quantitative analysis of cuttings may provide very useful information in order to fill this gap between core and well log data.

Concept and method

This study aims at integrating well log interpretation with core and cuttings data, including newly acquired TOC (Rock Eval) and quantitative mineralogical (QEMSCAN) analyses (Figure 1), as well as publically available petrophysical measurements and production data, within a well-defined sequence stratigraphic framework (Crombez *et al.*, 2013). The data was integrated using a 1D log processing software (Easytrace) that combines multivariate cluster analysis (Euzen *et al.*, 2010; Euzen and Power 2012) and CARBOLOG, a TOC quantification method developed by Carpentier *et al.*, (1991). The study focuses on Pouce-Coupe area in West-central Alberta.

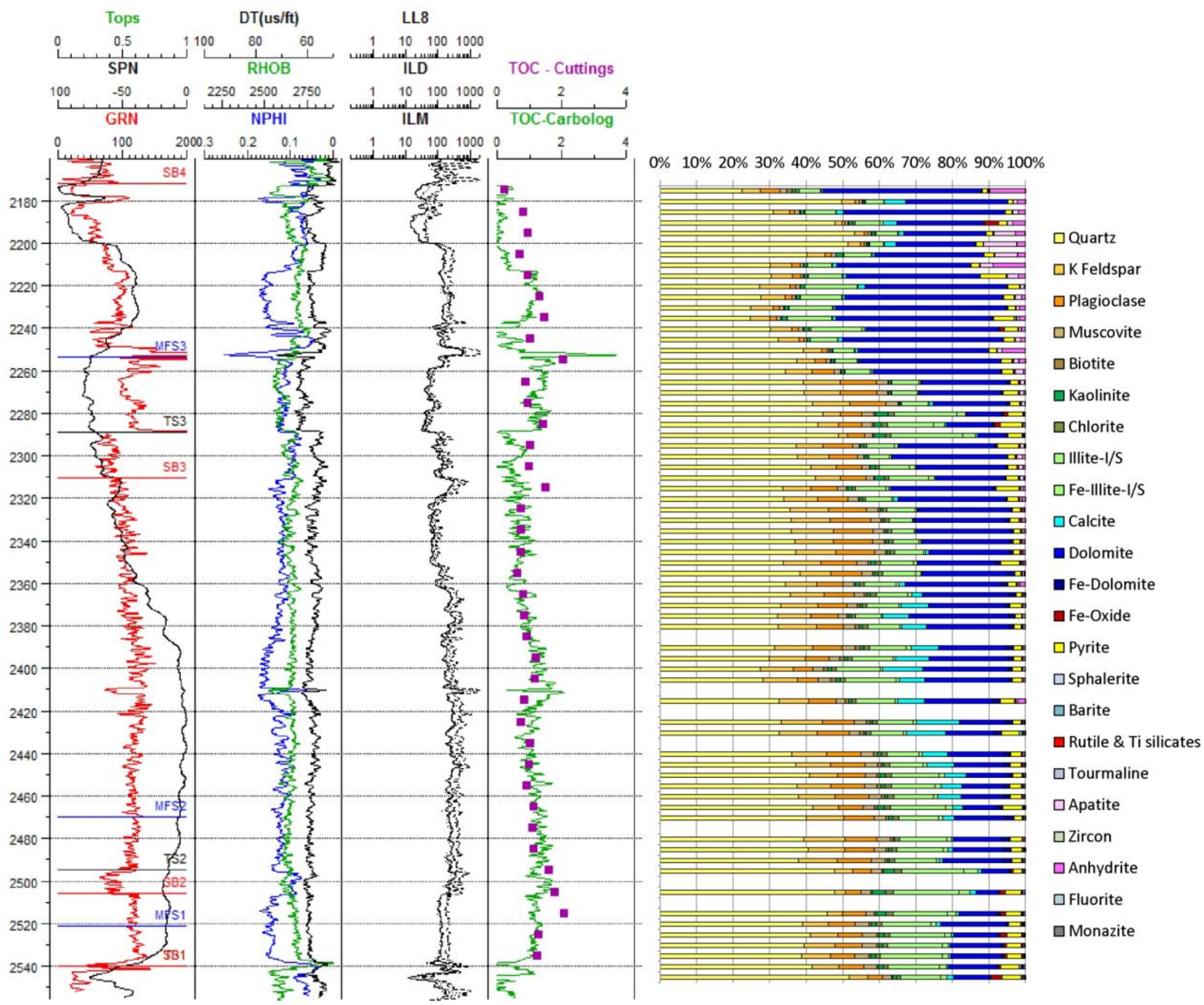

Figure 1: Composite log with TOC Rock Eval data and CARBOLOG estimation as well as bulk mineralogical composition from cutting samples.

In the proposed workflow, the first step consists in defining electrofacies and selecting training samples. The choice of the training sample is based on the identification of high density clusters in the multivariate space of logs (cluster analysis), as well as quantitative mineralogical and TOC data from cuttings and cores, complemented by available core descriptions and petrophysical measurements. Then, each data point along the wellbore is assigned an electrofacies and a probability of good assignment, based on the well log responses and on the probability law of each electrofacies. A quantitative log analysis is then performed by defining a specific set of input parameters for each electrofacies, based on their average mineralogical composition (matrix density and velocity…) and petrophysical characteristic (porosity/permeability relationship, electrical properties…).

This approach aims to optimize the integration of data with various spatial resolutions and sampling frequencies, while capturing subtle lithofacies variations in the quantitative log analysis.

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References

Carpentier B., Huc A.Y., B. G. (1991). Wireline Logging and Source Rocks - Estimation of Organic Carbon Content by the CARBOLBG Method. The Log Analyst, 32(3), 279–297.

Crombez, V.; Rohais, S., Baudin, F., Euzen, T. & Petrovic M. (2013). Relation Entre Stratigraphie Séquentielle, Faciès Sédimentaires et Matière Organique : Exemple des Formation Montney et Doig, Trias, Bassin Ouest Canadien (Canada). *14e Congrès Français de Sédimentologie, Associations des Sédimentologistes Français,* 5-7 Novembre 2013.

Davies, G.; Moslow, T. & Sherwin, M., (1997). The lower Triassic Montney Formation, west-central Alberta. *Bulletin of Canadian Petroleum Geology, Canadian Society of Petroleum Geologists, 45*, 474-505.

Derder, O. (2012). Rock Typing and Definition of F low Units, Montney Formation (Unit C), West-Central Alberta. *In Site*, Canadian Well Log Socity, Fall 2012, 16-21.

Euzen, T., Delamaide, E., Feuchtwanger, T., & and Kingsmith, K. D. (2010). Well Log Cluster Analysis : An Innovative Tool for Unconventional Exploration. *Canadian Unconventional Resources & International Petroleum Conference*. Calgary, Alberta, Canada, 19–21 October 2010.

Euzen, T. & Power, M. (2012). Well log cluster analysis and electrofacies classification : a probabilistic approach for integrating log with mineralogical data . *2012 CSPG CSEG CWLS Convention*, Calgary, Alberta, Canada, 14-16 May 2012.

Nieto, J.; Batlai, B. & Delbecq, F. (1997). Seismic Lithology Prediction: A Montney Shale Gas Cas Study. *CSEG Recorder, February 2013*, 35-42.

Passey, Q.; Creaney, S.; Kulla, J.; Moretti, F. & Stroud, J. (1990). A practical model for organic richness from porosity and resistivity logs. *AAPG Bulletin, American Association of Petroleum Geologists, 74*, 1777-1794.

Playter, T.; 2013, Petrographic and X-ray Microtomographic Analysis of the Upper Montney Formation, Northeastern British Columbia, Canada. *Master of Science,* Department of Earth and Atmospheric Sciences*,* University of Alberta.

Pedersen, P. K., Clarkson, C., Jensen, J., Derder, O., & Freeman, M. (2011). Innovative Methods for Flow Unit and Pore Structure Analysis in a Tight Gas Reservoir , Montney Formation, NE, BC, Canada. *Annual Convention and Exhibition*, Houston, Texas, USA, April 10-13, 2011.

Vaisblat, N. (2013). Lower Triassic Montney Formation Petrophysics and Paragenesis. *2013 CSPG CSEG CWLS Convention.* Calgary, Alberta, Canada, 6-10 May 2013

Zonneveld, J.; Golding, M.; Moslow, T. F.; Orchard, M. J.; Playter, T. & Wilson, N. (2011). Depositional Framework of the Lower Triassic Montey Formation, West-central Alberta and Northeastern British Columbia. *2011 CSPG CSEG CWLS Convention*, Calgary, Alberta, Canada, 9-11 May 2011.

Wood, J. M. (2012). Water Distribution in the Montney Tight Gas Play of the Western Canadian Sedimentary Basin: Significance for Resource Evaluation. *SPE Canadian Unconventional Resources Conference,* Calgary, Alberta, Canada, 30 October-1 November 2012.