Organic content variations and links to sequence stratigraphy in the Montney and Doig Formations (Alberta / British columbia)

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Summary

The integration of core and outcrop description in a sequence stratigraphy framework provides a well constrained sedimentary architecture of the Montney and Doig Formations, whereas the use of CARBOLOG method (Carpentier *et al.,* 1989) gives an estimation of the TOC content along a 2D section.

The aim of the present work is to study the relationship between sequence stratigraphy and TOC content in organic-rich deposits. A better understanding of this relationship can provide a tool to better predict the spatial distribution of the organic matter and the occurrence of sweet spot for production.

Introduction

In the last decade, the World's hydrocarbon demand increased significantly. Potential supply sources to the demand are hydrocarbon accumulations in or closely associated with organic rich fine-grained sediments. These new types of plays are very different from conventional resources in many aspects, because hydrocarbons are trapped in the organic matter or in very fine-grained low permeability sediments inter-bedded with organic rich deposits. Understanding the spatial distribution of organic rich deposits and their relationship with other sedimentary facies within a sequence stratigraphic framework is paramount to better define prospective areas in these unconventional plays.

Conventional reservoirs of the Montney and Doig Formations have been producing for decades (Armitage, 1962), but it is only in the last five years that the industry started focusing on the unconventional part of this depositional system. Most recent estimates by the Canadian National Energy Board suggest marketable resources of 449 Tcf of gas, 14.5 Gbbl of NGLs and 1.1 Gbbl of oil (NEB, 2013). These outsized resources make Western Canada's Lower Triassic one of the most promising unconventional play in the world.

The Montney and Doig Formations

The studied formations are located in the Western Canada sedimentary basin (WCSB), in the subcrop of the Alberta basin (Montney and Doig Formations) and in the fold and thrust belt of the Canadian Cordillera (Sulfur Mountain Formation).

The silty and sandy Montney and Doig Formations were deposited on the western margin of Pangea during Lower and Middle Triassic. At that time, Western Canada was located between the Equator and 30°N and had a climate similar to present-day Western Morocco. Numerous studies intended to constrain the stratigraphic settings of the Lower Triassic formations (Gibson and Barclay, 1989; Davies *et al.,* 1997…), of the "*Montney Turbidites*" (Moslow and Davies, 1997…) or of the Doig Formation (Evoy, 1997). As stratigraphy, organic content of the Lower and Middle Triassic Formations is the focus

of ongoing researches (Jarvie, 2012; Chalmers and Bustin 2012…) and is studied since the 90's (Riediger *et al.,* 1990; Zonneveld *et al.,* 2010)

Even if organic geochemistry and stratigraphy are the lead of scientific effervescence, there is not at our knowledge any public studies establishing a relationship between sequence stratigraphy and the organic matter distribution in the Lower and Middle Triassic formations of the WCSB. Due to the rich petroleum history of the Western Canada, numerous data (well logs, cores, drill cuttings, public studies…) are available on Lower and Middle Triassic formations. According to the high unconventional potential of this interval, this data availability makes the Montney and Doig Formations a good analogue for the study of the relationships between organic matter and sequence stratigraphy.

Material and Method

The aim of this work is to study relationships between organic matter content, sedimentary facies and sequence stratigraphy at lower orders (II^{nd} and III^{rd}) in the Montney and Doig Formations.

This study is based on a 2D section of 450 km, with 39 wells, numerous cores and outcrops description had been studied.

This NW-SE section encompass the distal and proximal parts of the basin in British Columbia and Alberta, including the “G-Sand”, the Doig “Phosphate Zone”, the coquina beds and the turbidites.

According to principles of sequence stratigraphy exposed by Mitchum *et al.* (1977) the Montney and Doig Formations had been divided into several sequences.

In the basin a total of 330 drill cuttings sampled on 9 wells (Figure 1.a), 150 core samples and 40 outcrop samples had been analyzed with a Rock-Eval VI (Behar *et al.* 2001).

The Rock-Eval analyses were used to calibrate CARBOLOG (Carpentier *et al.,* 1989), a method for quantifying TOC from well logs.

As Passey's method (Passey *et al.,* 1990), the CARBOLOG method is based on resistivity and sonic logs. The parameterization of this method stands in the definition of 3 pure poles: 100% organic matter, 100% matrix, 100% shale.

The values of the poles were defined using the 9 wells with Rock-Eval data and the TOC was then quantified with CARBOLOG along the entire 2D section.

Results and Conclusions

This study sheds new light on the Montney and Doig sedimentary architecture. The Montney and Doig Formations show 6 III^{rd} order-like sequences corresponding approximately to 10-15 Ma. The first transgressive system tract show multiple backstepping shorefaces, including the "*G-Sand*". The study also suggests the preservation of tidal facies during these transgressive phases. In the proposed stratigraphic architecture the "*Mid-Montney Turbidites*" occured during the first lowstand and multiple "*Phosphates zones*" occured within the transgressive to maximum flooding surfaces (Figure 1.b.).

According to previous works the first phosphate zone corresponds to the base of the Doig Formation. In our study, it is related to the third transgressive surface above the Permian unconformity (Figure 1b).

The TOC analysis on hundreds of drill cutting shows a mean value around 1.5% with HI between 100 and 400 mgHC/gTOC (Figure 1a) and rare analysis with a TOC higher than 3%. The HI range is typical of a mix between type II and type III.

The parameterization of the CARBOLOG method tends to show the link between poles position and depth of the estimated interval. The uses of CARBOLOG on the cross section's wells show the same distribution of TOC values than those obtained with Rock-Eval analysis: a mean value around 1.5% TOC and few points higher than 3% TOC (Figure 1.b.).

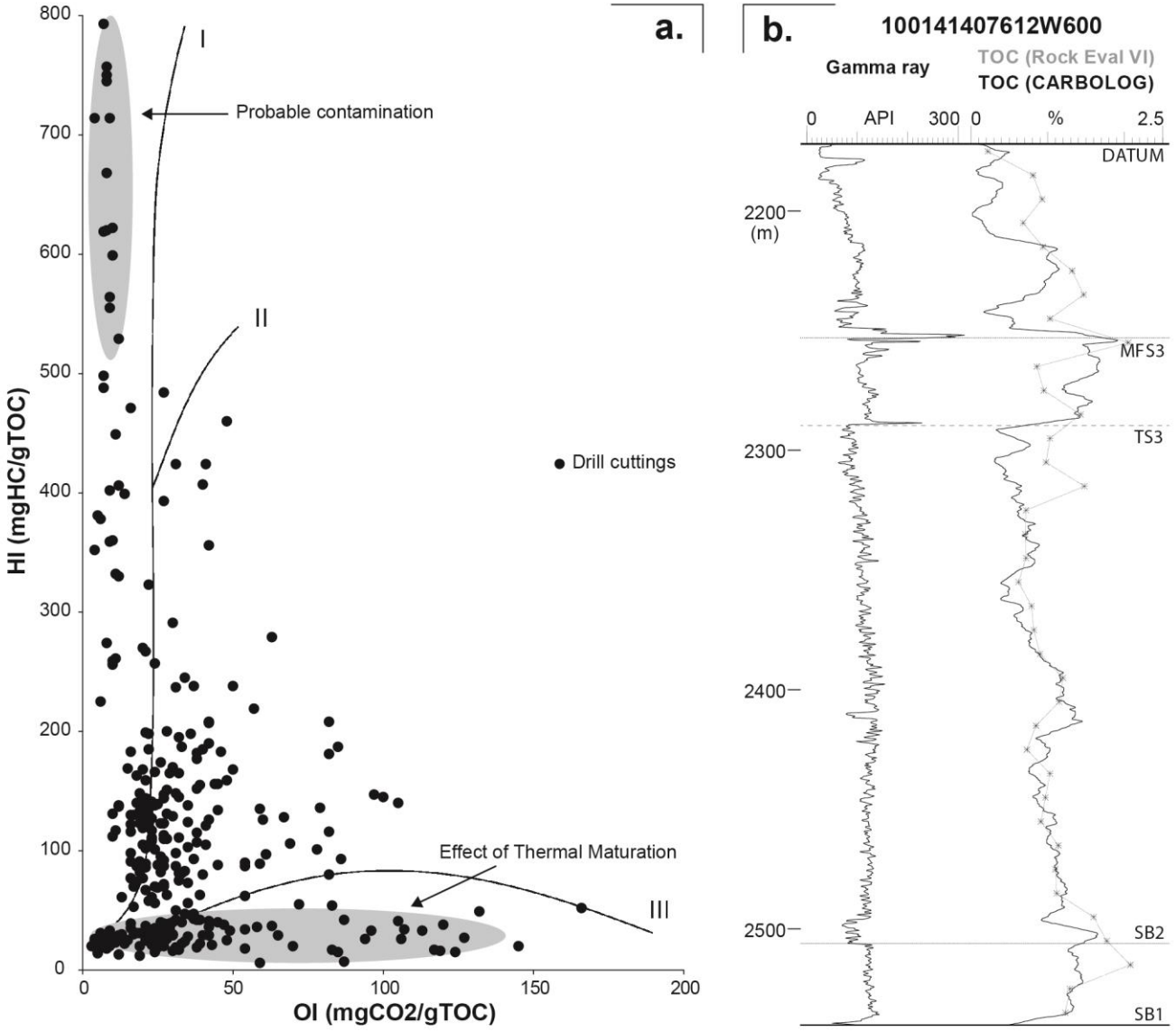

Figure 1: a. Van Krevelen diagram on drill cuttings. b. TOC Estimation with CARBOLOG.

The comparative study of Rock-Eval analysis on drill cuttings and CARBOLOG estimation shows the probable contamination (Figure1.a.) of samples by the Nordegg Formation (Jurassic) when Montney and Doig Formation are located immediately below. This would explain the anomalous TOC (up to 10% HI higher than 800 mgHC/gTOC).

The measured and estimated TOC values in this study tends to be lower than those already published, this may be linked to the measurement of drill cutting that tends to smooth geochemical results, or on the other hand this may be linked to an oversampling of rich intervals in previous work to study organic composition of the Montney and Doig Formations.

Rock-Eval analysis and CARBOLOG estimations provide a good overview of the Montney and Doig organic content variations. By combining the new stratigraphic interpretation and the TOC estimation on

each well, this study shows relations between sequences, system tracts and organic content in the Montney and Doig Formations.

The ultimate goal of this PhD thesis is to provide a detailed sequence stratigraphy analysis of the basin along multiple sections in order to establish a 3D model of organic content in the Montney and Doig Formations.

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