[PS]Experimental Workflow Applied to Marine Source Rocks Sampled in the Montney-Doig Formations of the Western Canada Sedimentary Basin*

William Sassi[1], Elisabeth Bemer[1], Marc Fleury[1], Guillaume Berthe[1], Maria-Fernanda Romero-Sarmiento[1], and Tristan Euzen[2]

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Abstract

Oil and gas in the Montney-Doig succession in the Western Canada Sedimentary Basin have been produced conventionally for decades from proximal deposits and turbiditic reservoirs. However, in recent years, tight organic-lean and organic-rich fine-grained sediments from the distal part of the basin have become the most active unconventional play in Canada. The present-day distribution of hydrocarbons within the Montney-Doig system results from the interplay of the stratigraphic architecture that controls the spatial distribution of facies heterogeneity and organic matter, with the structural evolution of the basin that controls the burial history and timing of fluid migrations. Integrating these different elements at basin scale would help better define play concepts and reduce the exploration risk of this complex petroleum system. This integration is performed in a specific workflow designed for low permeability formations and must include some important characterization such as pore size distribution as well as hydromechanical properties. In this presentation, we show a series of source-rock sampled in the Montney-Doig source rock intervals that have been characterised in the laboratory in terms of porosity content, mechanical, petrophysical and geochemical properties. Such characterization is not trivial in low permeability formations due the small pore sizes ranging from nano-meters up to micrometers. Experimental techniques require various samples sizes and can be destructive; therefore an appropriate sequence must be chosen. For the various characterization, we used the most appropriate and up to date methods: NMR for porosity, NMR cryoporometry and mercury injection for pore size distribution, fast gas and water permeability steady state measurement including confinement effects, pressure dependant petroacoustic tests, tensile strength measurements (Brazilian tests), geochemical tests (RockEval) and mineral composition analysis. The findings are discussed in terms of their impacts on the storage capacity and the transport of hydrocarbons fluids in this unconventional reservoir.

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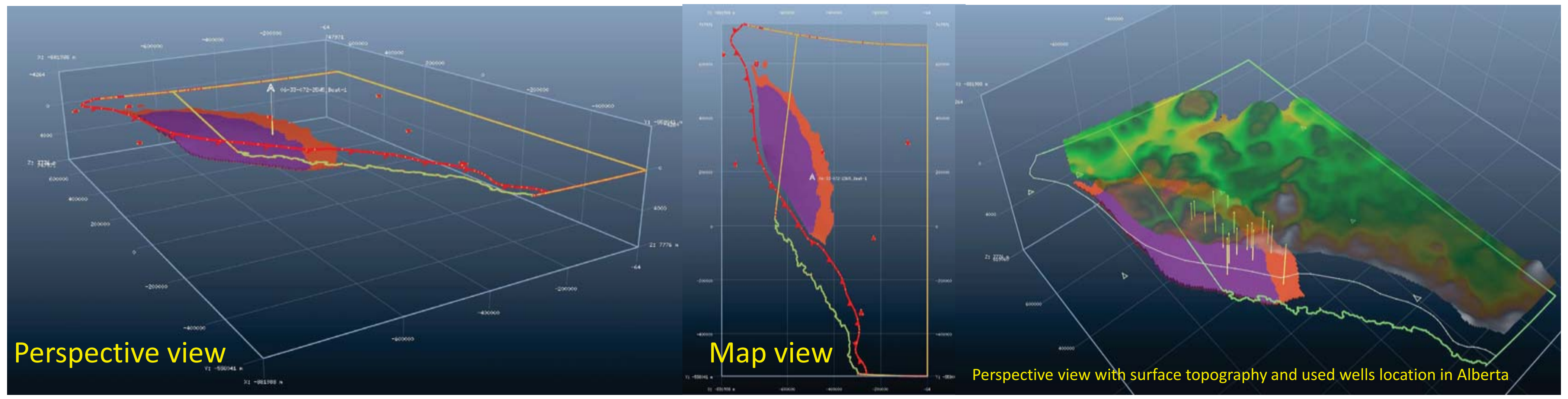
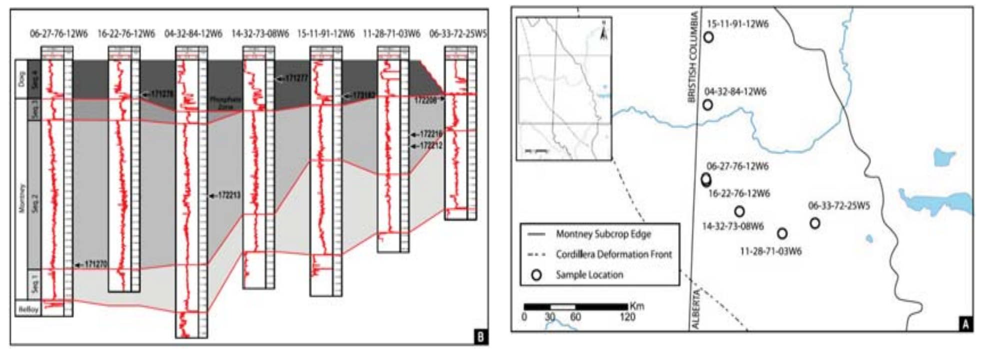
In this presentation, we show a series of source-rock sampled in the Montney-Doig source rock intervals, that have been characterized in the laboratory in terms of porosity content, mechanical, petrophysical and geochemical properties. Such characterization are not trivial in low permeability formations due the small pore sizes ranging from nano-meters up to micro-meters. Experimental techniques require various samples sizes and can be destructive, therefore an appropriate sequence must be chosen. For the various rock characterization parameters, we used the most appropriate and up to date methods : NMR for porosity, NMR cryoporometry and mercury injection for pore size distribution, fast gas and water permeability steady state measurement including confinement effects, pressure dependent petroacoustic tests, tensile strength measurements (Brazilian tests), geochemical tests (RockEval) and mineral composition analysis. The findings are discussed in terms of their impacts on the storage capacity and the transport of hydrocarbons fluids in this unconventional reservoir.

3D Model of present day Montney-Doig Formation



sampling strategy



		N° GEOCHIM	N° PETRA	Name	Well	Nature	Depth (m)	Core No.	Box No.	Latitude	Longitude
Petro & Geomecha	1	171270	2661	Sample 1-1 (bottom)	0/06-27-76-12W6	Core	2447.4	1	10	55 36 48.859 N	119 46 24.096 W
	2	171271	2662	Sample 1-2 (top)	0/06-27-76-12W6	Core	2447.4	1	10	56 36 48.859 N	120 46 24.096 W
	3	171272	2664	Sample 2-1 (bottom)	0/06-09-75-08W6	Core	2139.8	1	2	55 28 52.241 N	119 10 46.448 W
	4	171273	2665	Sample 2-2 (top)	0/06-09-75-08W6	Core	2139.8	1	2	55 28 52.241 N	119 10 46.448 W
	5	171274	2666	Sample 3	2/06-18-75-08W6	Core	2189.4	1	2	55 29 50.240 N	119 13 56.071 W
	6	171275	2667	Sample 4	2/06-18-75-08W6	Core	2189.4	1	2	55 29 50.240 N	119 13 56.071 W
Geochemistry	7	171276		Sample 9	0/14-32-73-08W6	Core	2036.1	1	1	55 22 15.949 N	119 11 53.207 W
	8	171277		Sample 6	0/14-32-73-08W6	Core	2066.65	2	13	55 22 15.949 N	119 11 53.207 W
	9	171278		Sample 7	0/16-22-76-12W6	Core	2187.4	1	1	55 36 12.949 N	119 45 50.911 W
	10	171279		Sample 8	0/01-30-85-23W5	Core	883	1		56 23 46.640 N	117 23 13.880 W
	11	171280		Sample 10	0/15-23-86-01W6	Core	965			56 28 39.390 N	118 57 52.350 W

Context and Objectives

A specific laboratory shale characterization workflow has been designed for the study of low permeability fine grained rocks. Such integrated experimental workflows must produce in near future projects, the fundamental parameters and observations to capture and formulate the principles for the evolution of the key petrophysical parameters of low permeability source-rock facies, at large time scale since source rock deposition.

This work presents a first application of a dedicated laboratory rock characterization workflow, illustrated using the study case of the Montney and Doig Formations of the **WCSB** (West Canada Sedimentary Basin, extending from the Alberta to the British Columbia Provinces). Extensively studied as hydrocarbon bearing reservoirs and as source rock, the present-day distribution of hydrocarbons within the Montney-Doig shows typical distribution tends expected for a foreland flexural basin. The interplay of the stratigraphic architecture with the WCSB structural evolution, Integrated in a 3D basin model, support a rock sampling strategy for a better assessment and understanding of the Montney-Doig petroleum system.

One objective is to gather the key maturity and paleo-temperature and paleo-pressure indicators which will help to calibrate results of basin scale petroleum system modeling as demonstrated by Gasparrini *et al*. (2014) and Ducros *et al*. (2017). Here an other objective is addressed which is to collect the key rock characteristics in terms of porosity (in the mineral matrix , solid organic matter), and permeability and process of fluid transport for a targeted source rock interval at various grade of maturity/burial history.

Advanced Experimental Workflow

Laboratory measurement techniques for rock characterization in terms of porosity content, mechanical, petrophysical and geochemical organic matter content and properties are not trivial in low permeability formations. This is due to the small pore sizes ranging from nano-meters up to micro-meters and the practical difficulties to identify the hydrocarbon fluids phases and the residual kerogen in the cored material (preservation, contamination, aging effects…). Provided early acces to cored rocks, the complete laboratory experimental techniques of self-sourced reservoir rocks, shown here for plugs taken in the Montney S2 and Doig S4 intervals, requires various samples sizes and can be destructive. Therefore it is essential to conduct an appropriate measurement sequence in the logical sequence of tasks, for a full rock sample characterization to be optimized.

For the various physical parameters, we used the most appropriate and up to date methods : NMR for porosity, NMR cryoporometry and mercury injection for pore size distribution, fast gas and water permeability steady state measurement including confinement effects, pressure dependent petroacoustic tests, tensile strength measurements (Brazilian tests), geochemical tests (RockEval, including the Shale Play Method) and DXR for mineral composition as well as 3D imaging techniques.

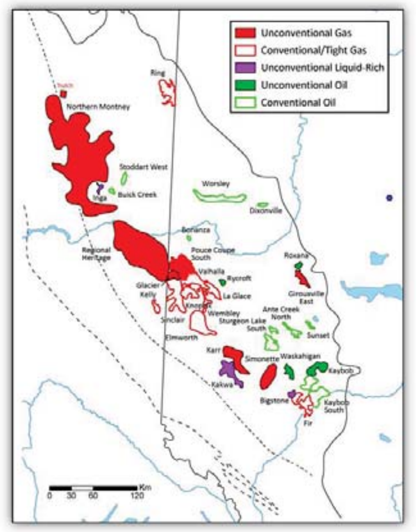
Details on each of the techniques can be found in the following publications (see reference list in the panel 3 of this poster (on the right) : Romero-Sarmiento *et al*. (2012; 2013; 2015; 2016), Fleury and Romero-Sarmiento (2016), Fleury and Kohler (2016).

Background framework for Rock Sampling

A strategy of core sample selection has been applied to AER's core materials. Here we present the selected rocks taken in the sequence S2 (Montney: and S4 (Doig Fm). This is guided by the main stratigraphic members of the Montney-Doig Formations in the Western Canada Sedimentary Basin as identified by Crombez (2016) and described by Euzen *et al*., (2016).

On the S2 rock samples we could gather plugs of reasonable sizes to conduct the full rock measurements workflow : the poromechanical, petroacoustic and geochemical characteristics have been performed (see reported measures in figures of the central poster) and this workflow , now validated and optimized, can be further conducted for any other sample selection campaign.

Rocks samples from the Doig (S3 interval) are richer in organic matter content, but first sampling did not provide large plugs. Thus only the geochemical characterization could be made and these results were fully reported in Romero et al. (2016) of which central poster displays the histograms of vitrinite maturity grade, FID graphs and Kerogen's distribution of activation Energy (displaid near the corresponding Gamma Ray logs).

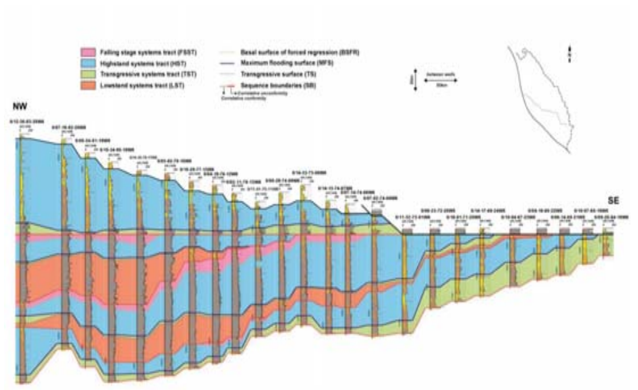


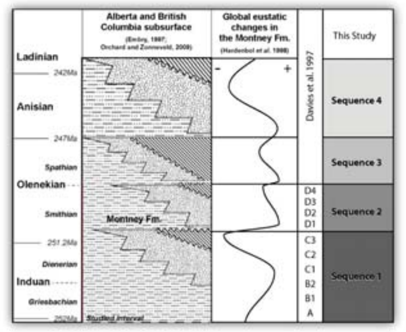
Oil and Gas producing fields from the Montney and Doig Formations in Western Canada

Hydrocarbon Type	In-Place			Marketable		
	Low	Expected	High	Low	Expected	High
Natural Gas – billion m^3 (trillion cubic feet)	90,559 (3,197)	121,080 (4,274)	153,103 (5,405)	8,952 (316)	12,719 (449)	18,257 (645)
NGLs – million m^3 (million barrels)	13,884 (87,360)	20,173 (126,931)	28,096 (176,783)	1,540 (9,689)	2,308 (14,521)	3,344 (21,040)
Oil – million m^3 (million barrels)	12,865 (80,949)	22,484 (141,469)	36,113 (227,221)	72 (452)	179 (1,125)	386 (2,430)

Montney and lowermost Doig unconventional in-place oil and gas resources in Western Canada published by federal and provincial governemental agencies (NEB, AER, BCOGC and BCMNGD, 2013)

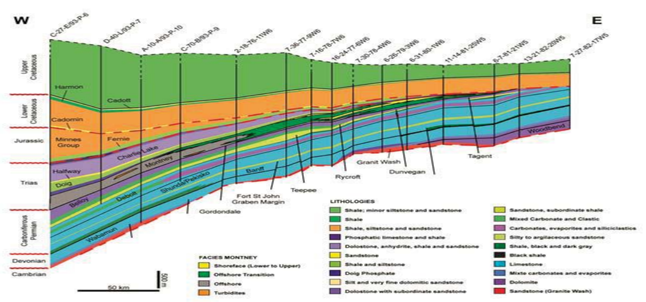
Montney-Doig Stratigraphic Architecture



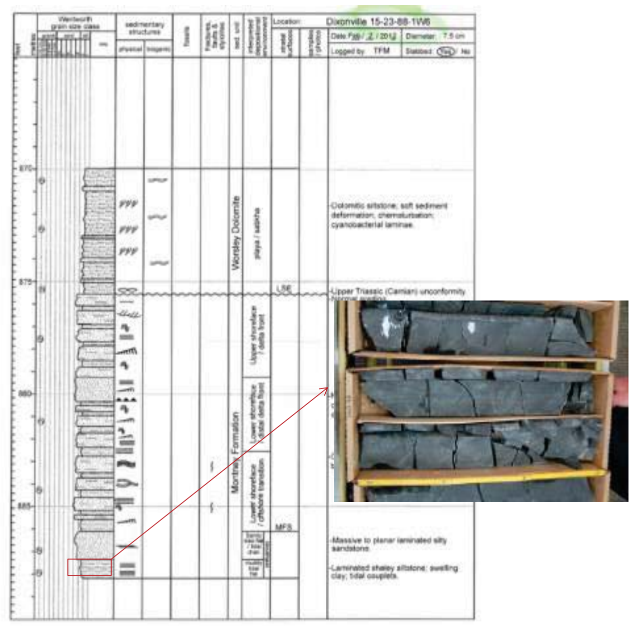


This chart summarizes the stratigraphy of the Lower/Middle Triassic in Alberta and BC.

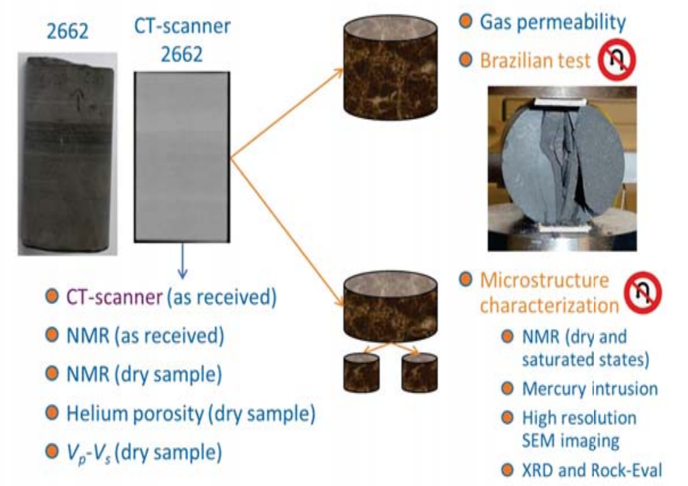
Basin Scale Structural Architecture



Core Sample Selection

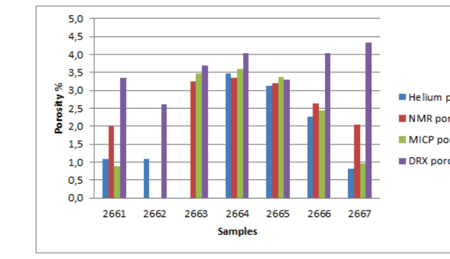


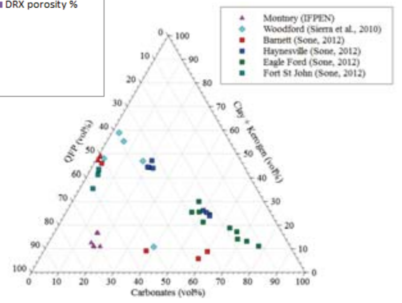
Validation of an experimental workflow structured around non destructive petroacoustic tests: study carried out on six samples from the Montney formation

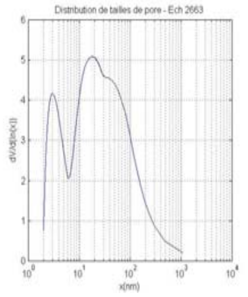


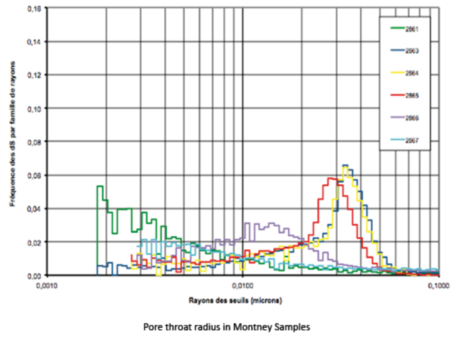
Num Petra	Helium porosity %	NMR porosity %	MICP porosity %	DRX porosity %
2261	1,1	2,0	0,9	3,4
2662	1,1	-	-	2,6*
2663	-	3,2	3,5	3,7*
2664	3,5	3,3	3,6	4,0
2665	3,1	3,2	3,4	3,3
2666	2,3	2,6	2,4	4,0
2667	0,8	2,1	1,0	4,3

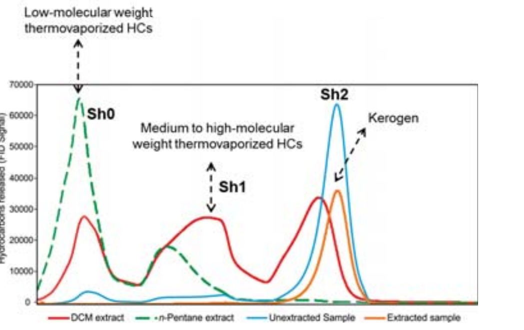
Results: Porosity, Permeability and Pore throat distribution

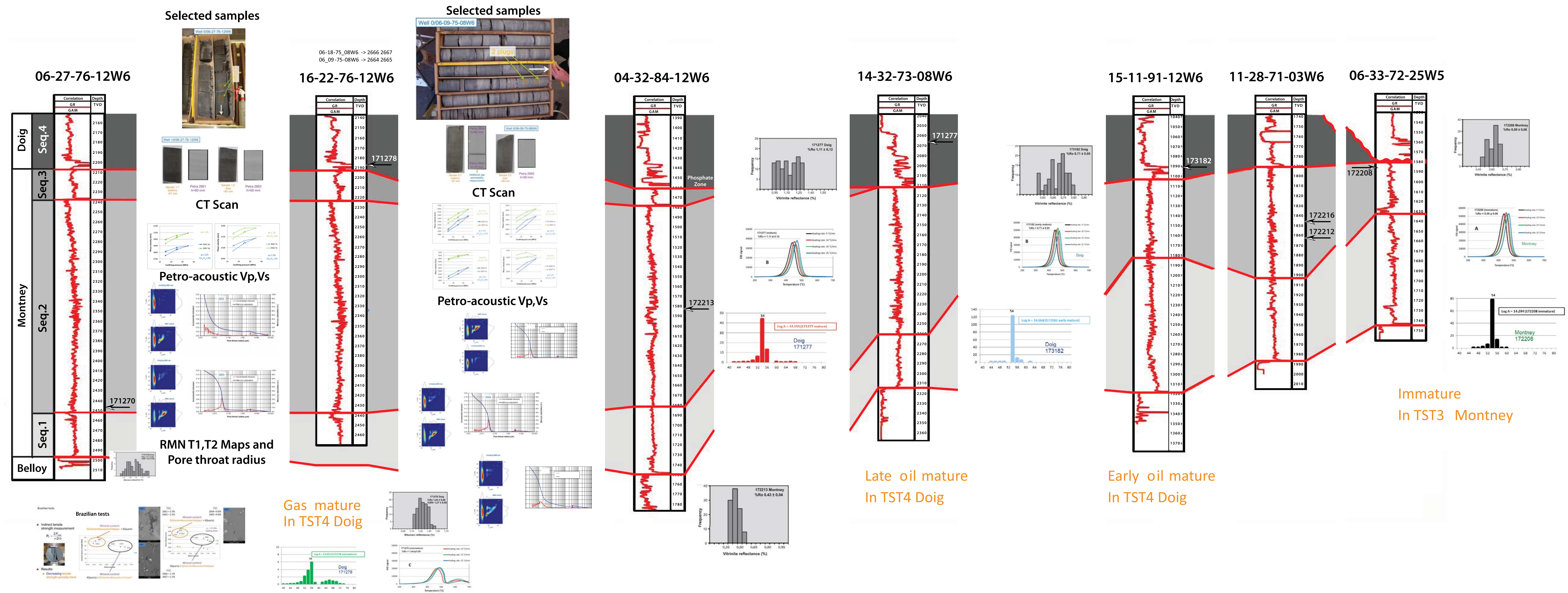




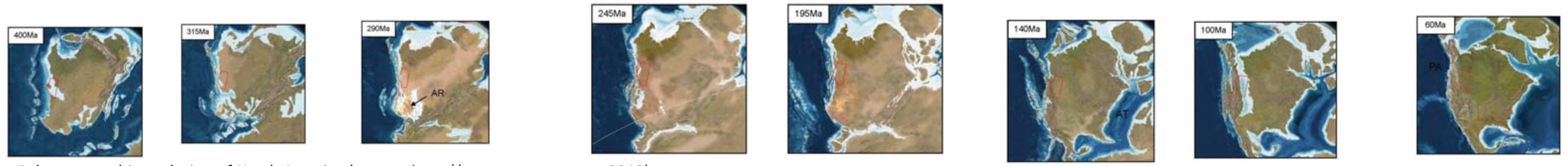




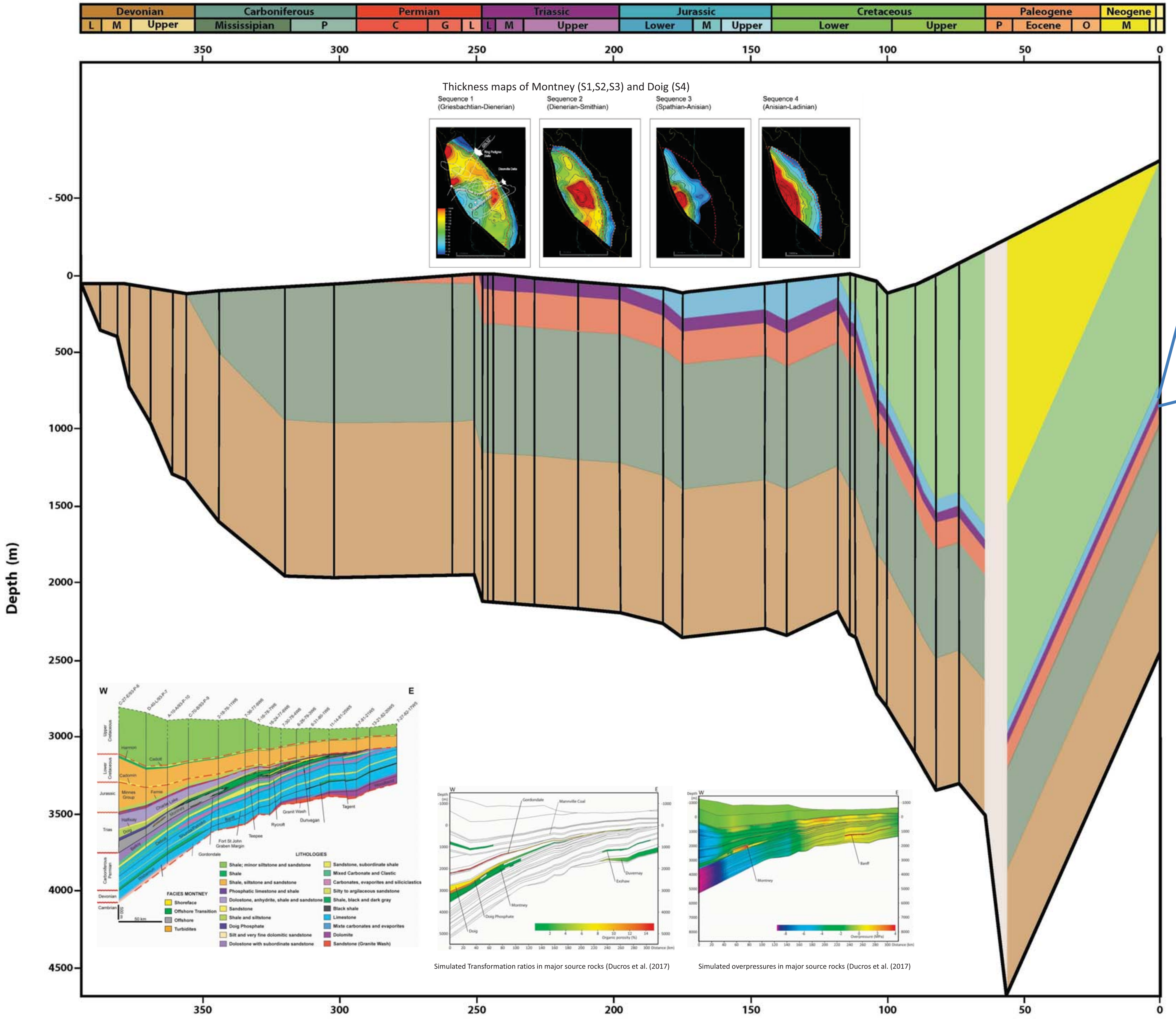




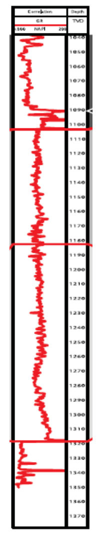
Selected samples
Selected samples
06-27-76-12W6
16-22-76-12W6
04-32-84-12W6
14-32-73-08W6
15-11-91-12W6
11-28-71-03W6
06-33-72-25W5
06-18-75_08W6 -> 2666 2667
06_09-75-08W6 -> 2664 2665
Doig
Montney
Belloy
Seq.4
Seq.3
Seq.2
Seq.1
171270
171278
171277
172213
173182
172216
172212
172208
Phosphate Zone
CT Scan
CT Scan
Petro-acoustic Vp,Vs
Petro-acoustic Vp,Vs
RMN T1,T2 Maps and
Pore throat radius
Brazilian tests
Gas mature
In TST4 Doig
Late oil mature
In TST4 Doig
Early oil mature
In TST4 Doig
Immature
In TST3 Montney
Vitrinite reflectance (%)
Frequency



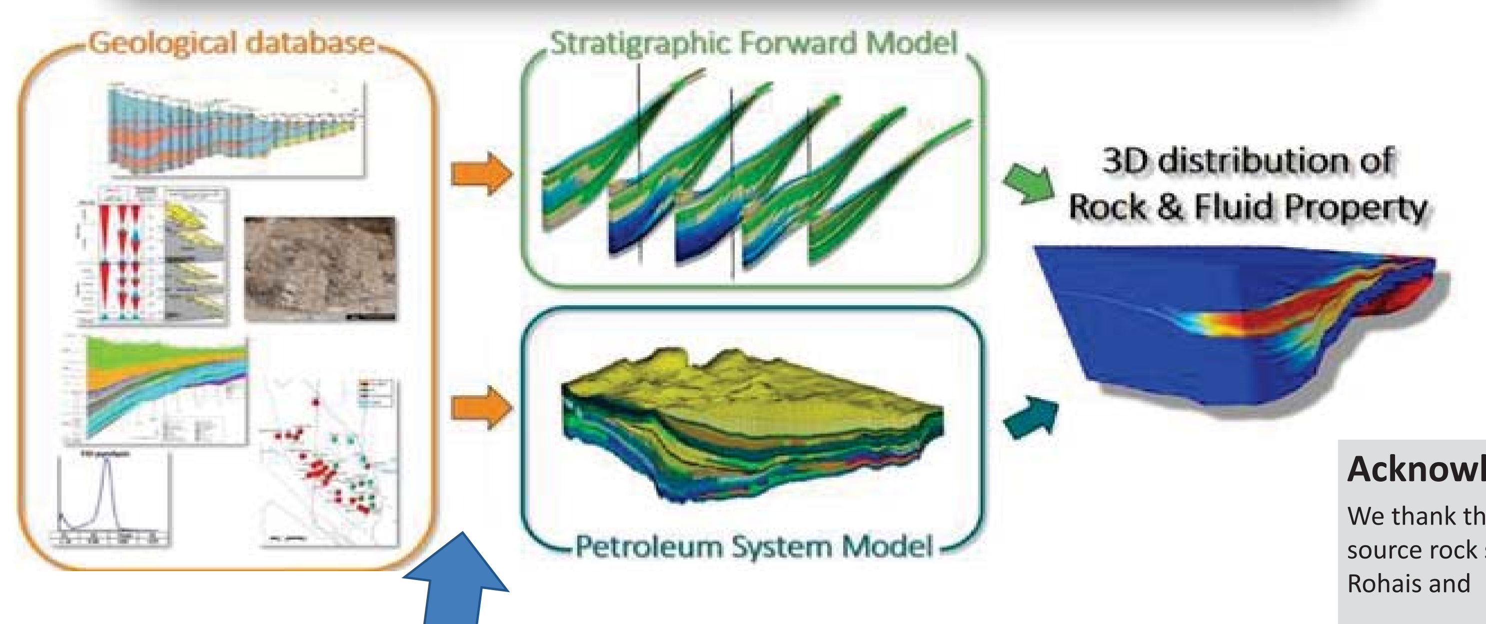
Paleogeographic evolution of North America (source: http://cpgeosystems.com, 2013)

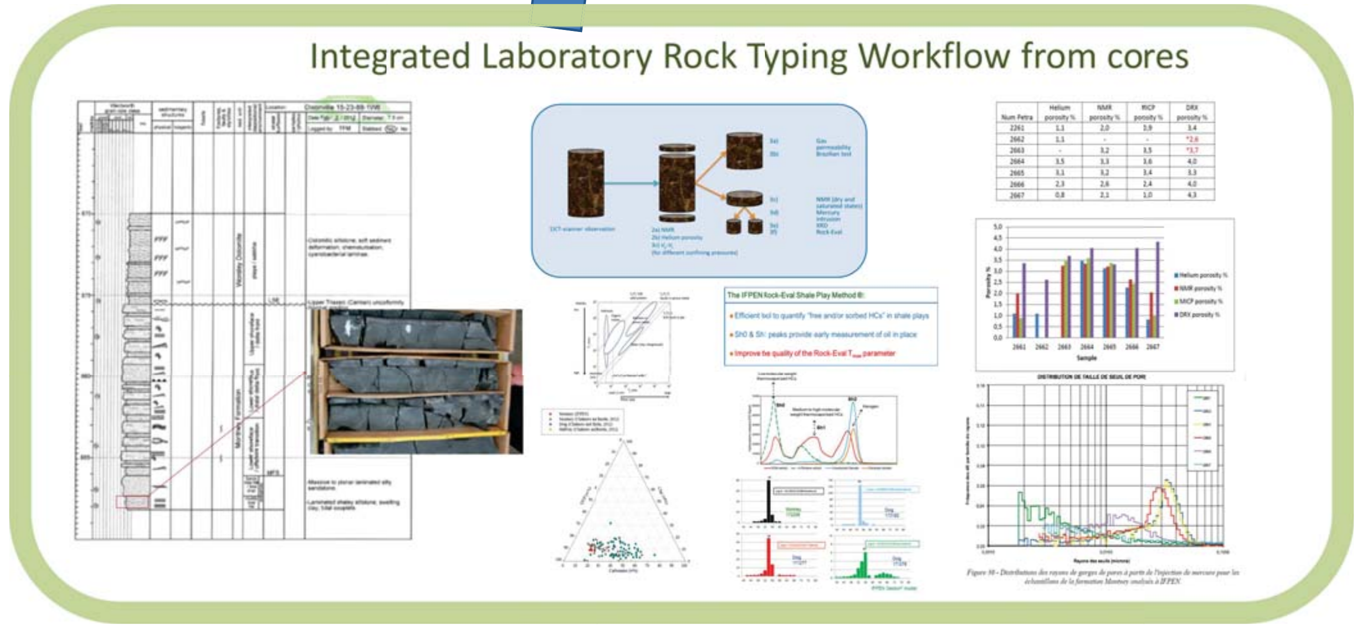


Burial History along well W06-33-72-25W5



Toward a Process-Based Integrated Workflow





Conclusion and Perspectives

An Integrated Laboratory Rock Typing Measurements has been developed to improve the characterization of organic–rich low permeability fine grained rocks. These workflows have been applied on selected cores sampled in two stratigraphic intervals of the Montney-Doig formation from the Alberta sector of the West Canada Sedimentary Basin. Essentially 5 cored intervals belong to the Asnian (Sequence 2) and 3 cored intervals belong to the Doig Phosphate(Sequence 4), results as shown in the central panel of this poster. The whole rock typing characterization workflow involves the utilization of recent patented IFPEn's techniques, stemming from the less to the most destructive ones of cored rock samples. The objective ifs to integrate measurements of petroacoustic, geomechanics, petrophysics and geochemical rock properties. In this work special emphasis is put on porosity determination using direct and indirect methods and steady state gas permeability laboratory measurements. The complete set of parameters could be obtained for the rocks plugs of the Gas mature intervals of the Sequence 2 (Smithian) in well 06-27-76_12W6 and the Sequence 4 (Doig) in Well 16-22-76-12W6 intervals. In the meantime rock samples were collected, the Laboratory rock typing workflows have been optimized and improved. Additional observation and measurement results are expected in the near future to be carried out to other series of rock samples collected in the wells of the less mature zone of the same sequences.

Applying the proposed workflow to organic-rich shale sampled in various maturity grades will bring new insights to found new evolution rules to link with mathematical formulations, the evolution of the rock permeability as a function of pore size distribution and improve quantification and prediction of the range and heterogeneity of fluids pressure, fracturing and timing of hydrocarbons migration.

Acknowledgements

We thank the AER Core Research Centre for providing the Canadian source rock samples. We also thank Vincent Crombez, Sebastien Rohais and Eric Kohler for interesting technical discussions.

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