Status Report on Petroleum System Analysis Study of the Triassic Doig Formation, Western Canada Sedimentary Basin, Northeastern British Columbia

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Introduction

The Triassic section of the Western Canada Sedimentary Basin (WCSB) is the richest interval in terms of volume of oil per volume of rock in the basin (Marshall et al., 1987). An important part of the succession is the Lower and Middle Triassic Doig Formation, which historically has been known for limited production from its conventional reservoirs in British Columbia (BC) and Alberta. More recently, the Doig has been recognized as an important unconventional reservoir for gas and natural-gas liquids (NGL), with estimates of total gas-in-place ranging from 1.1 to 5.6 trillion m^3 (Walsh et al., 2006). Little is currently known, however, about the unconventional portion of the Doig succession: the spatial and stratigraphic distribution of litho- and reservoir facies is poorly constrained and measurements of petrophysical properties are sparse and limited in scope. The distribution of unconventional reservoir properties within the Doig succession and the geological controls on these properties and their distribution are therefore unknown. Furthermore, there is an uncertainty in the distribution of hydrocarbon phase and composition, due to variations in thermal maturity, depth of burial and organic-matter type. The purpose of the ongoing research project reported herein is to determine the unconventional hydrocarbon potential of the Doig Formation through a petroleum system analysis (PSA). The principal goal of the study is to delineate the distribution of producible liquids from tight reservoirs in northeastern BC.

The PSA approach used in this study consists of three interrelated elements (Figure 1):

- Source rock evaluation: thorough quantification and mapping of the source-rock properties across the basin, such as thermal-maturity levels and organic-matter abundance and type
- Basin modelling: modelling of the Doig petroleum system on a basin scale, incorporating structural, lithological, geochemical and burial-history data, in order to determine the timing of thermogenic hydrocarbon generation and retention
- Reservoir properties: characterizing the reservoir potential of the Doig Formation in terms of storage capacity, producibility and response to hydraulic stimulation

Geological Background

The Doig Formation consists of mudstone, siltstone and subordinate sandstone, bioclastic packstone and grainstone, deposited under marine conditions in environments ranging from shoreface through offshore (Evoy and Moslow, 1995). It has long been recognized that the Doig can be broadly subdivided into a lower, more organic-rich and phosphatic zone, known as the Doig Phosphate Zone (DPZ); and an upper, relatively organic-lean siltstone interval. A more detailed subdivision has been proposed by Chalmers and Bustin (2012), who recognized three units: a basal Doig A, composed mainly of interbedded dark argillaceous and calcareous siltstones, corresponding to the DPZ and distinguishable in well logs by a gamma-ray signature; an intermediate section, named Doig B, corresponding to medium to dark grey argillaceous siltstone containing localized sand beds; and an upper Doig C, composed of siltstone and argillaceous fine sandstone.

Ongoing Work

To date, 470 m of core from fifteen wells in BC and 190 m from seven wells in Alberta (Table 1) have been logged for lithology, sedimentary structures, bioturbation, diagenetic features and structural features. These wells comprise three strike and six dip cross-sections (Figure 2), covering the entire lateral extent of the Doig Formation in BC and Alberta. The primary selection criterion was availability and length of core in the Doig, in an attempt to adequately represent its stratigraphic and spatial variability. Another factor taken into consideration when selecting wells was the availability of a complete well-log suite over the Doig interval. The minimum requirement for this study is a quad-combo

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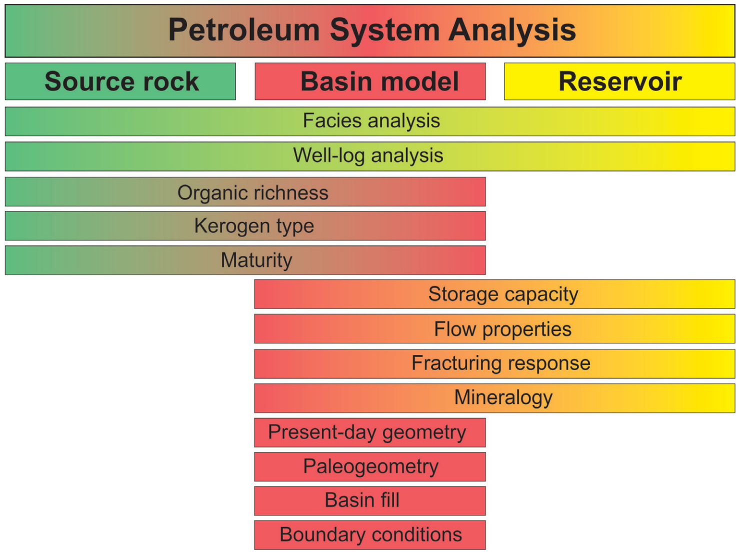

Figure 1. Elements of the petroleum system analysis approach to reservoir evaluation and their respective inputs as implemented in this study.

(gamma ray, density/neutron, resistivity and compressional slowness), and preference was given to wells with shear slowness, nuclear magnetic resonance, elemental capture spectroscopy and spectral gamma ray. These logs, although not available for all wells in the study, will aid in the development of neural-network models and in the extrapolation of petrophysical and organic geochemical properties measured on core and on cuttings to non-cored sections and wells.

Analytical work in progress includes X-ray diffraction for quantitative mineralogy, Rock-Eval pyrolysis for organic geochemical properties, helium pycnometry and mercury intrusion for porosity and pore size distribution, pressure pulse-decay permeameter measurements of permeability, and triaxial cell tests for geomechanical properties. These properties will be extrapolated to non-cored intervals and wells using quad-combo well logs through multiresolution graph-based clustering and neural-network techniques.

Table 1. Wells from which core of the Doig Formation was logged. See Figure 2 for location.

UWI	Well Name	Length (m)	Interval
100/01-10-082-23W6/00	ADU MONIAS 01-10-082-23	37	Upper Doig, DPZ
100/01-32-083-25W6/00	PROGRESS ET AL HZ ALTARES A01-32-083-25	81	DPZ
100/08-36-081-14W6/00	HUSKY MICA 08-36-081-14	10	Upper Doig
100/04-09-084-22W6/00	ARCRES ATTACHIE 04-09-084-22	29	DPZ
100/05-04-088-14W6/00	CHINOOK N BOUNDARY 05-04-088-14	22	Upper Doig
100/09-33-079-21W6/00	TALISMAN GROUNDBIRCH 09-33-079-21	83	Upper Doig
100/12-04-086-20W6/00	CNRL ET AL W STODDART 12-04-086-20	18	Upper Doig
100/15-34-080-18W6/00	SHELL SUNSET 15-34-080-18	26	DPZ
200/a-063-A 093-P-09/00	MURPHY HERITAGE A 063-A/093-P-09	25	Upper Doig
200/a-070-A 093-P-10/00	ARCRES SUNDOWN A-B 070-A/093-P-10	37	Upper Doig
200/b-008-L 094-H-07/00	CNRL ET AL ZAREMBA B 008-L/094-H-07	18	Upper Doig
200/b-046-E 094-A-15/00	TALISMAN ET AL BEAVERTAIL B 046-E/094-A-15	18	Upper Doig
200/c-073-J 094-A-12/00	ARCRES INGA C 073-J/094-A-12	19	Upper Doig
200/c-075-A 094-G-16/00	CNRL TOMMY C 075-A/094-G-16	17	Upper Doig
200/c-082-F 094-H-01/00	CNRL DRAKE C 082-F/094-H-01	30	Upper Doig
100/03-22-078-10W6/00	CNRL PROGRESS 3-22-78-10	33	Upper Doig
100/04-10-079-05W6/00	CNRL ET AL HOWARD 4-10-79-5	18	Upper Doig
100/06-22-074-10W6/00	NORTHROCK KNOPCIK 6-22-74-10	48	Upper Doig
100/15-01-074-04W6/00	CNRL TEEPEE 15-1-74-4	19	Upper Doig
100/06-03-070-04W6/00	GULF GOLD CREEK 6-3-70-4	18	Upper Doig
100/08-28-071-07W6/00	RANCHWEST DIMSD 8-28-71-7	23	Upper Doig
102/15-05-071-12W6/00	HUSKY 102 ELM 15-5-71-12	36	Upper Doig

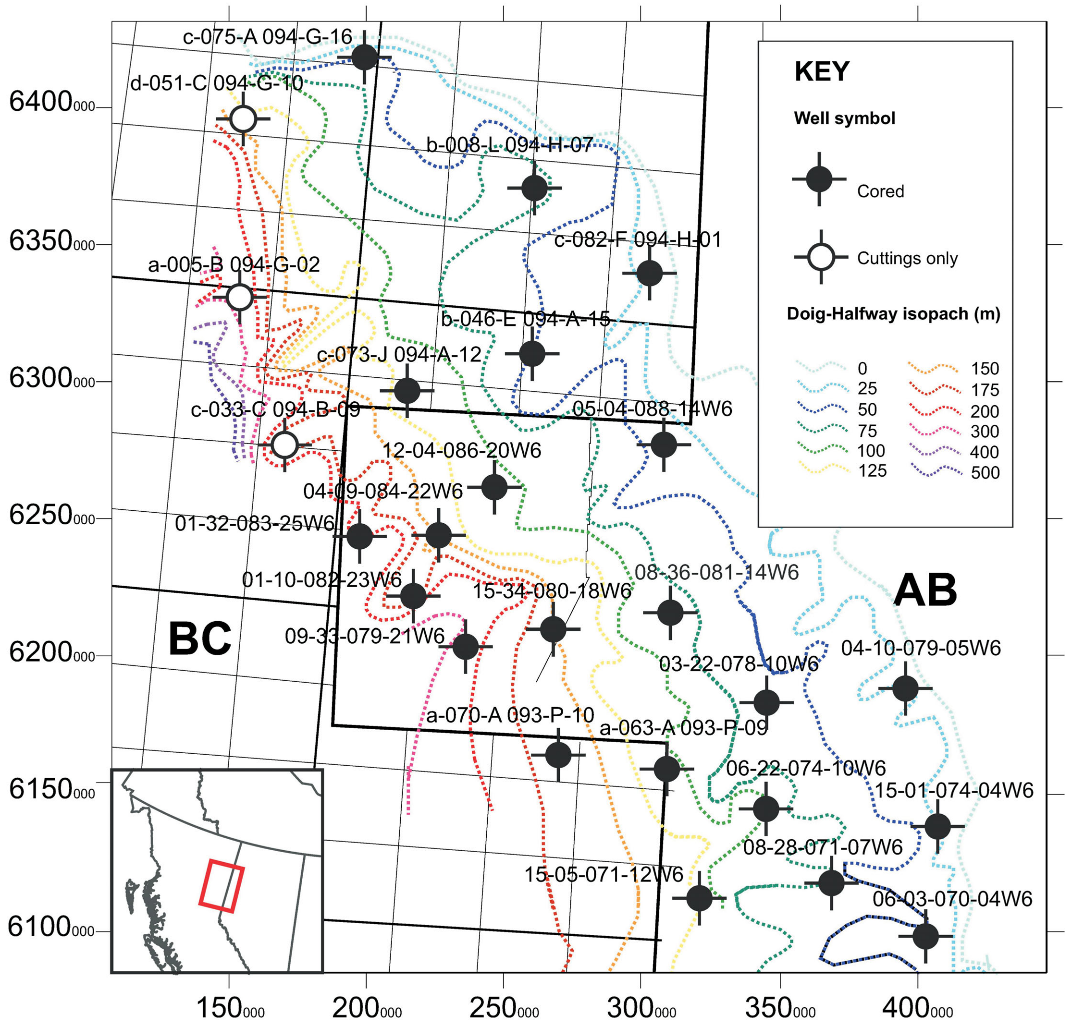

Figure 2. Location of the wells used in this study overlain on the isopach map of the Doig Formation–Halfway Formation interval.

Thermal maturity from pyrolysis will be used in a basin-modelling platform to constrain the maturity of the Doig Formation across the basin. The maps of kerogen type and total organic carbon, also derived from pyrolysis, will constrain the spatial distribution and timing of thermal hydrocarbon generation.

Preliminary core logging reveals a wide variety of lithofacies and complex stacking patterns that confer a high degree of heterogeneity on the succession. Preliminary work has identified ten lithofacies, defined based on colour, lithology and fabric. Diagenetic and structural features add another layer of heterogeneity within individual lithofacies. These facies have distinctly different reservoir properties, such as porosity, distribution of pore-throat size, permeability, elastic moduli and organic content. It has been shown that petrophysical properties vary significantly between the different Doig lithofacies, with median pore-throat size spanning one order of magnitude and permeability spanning four orders of magnitude, despite a narrow range in grain size (Chalmers and Bustin, 2012; Chalmers et al., 2012). It is further anticipated that the degree of bioturbation, which changes the fabric of the sediments, may also control porosity and permeability (Pemberton and Gingras, 2005; Baniak et al., 2015).

There are currently no publicly available regional studies with a systematic petrophysical characterization of the lithofacies found in the Doig Formation. This study aims to fill this gap and will serve as the foundation for a full petrophysical and organic-geochemical characterization of these facies and their spatial and stratigraphic distribution across the WCSB. Ultimately, the lithofacies will be grouped into facies associations to enable work at the log scale, and the facies associations with their petrophysical properties keyed to cored wells will be extrapolated through logs to adjacent wells.

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