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Characterization of organic matter fractions in an unconventional tight gas siltstone reservoir

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ABSTRACT

This paper on core samples collected from the Triassic Montney Formation tight gas reservoir in the Western Canadian Sedimentary Basin (WCSB) illustrates that operationally-defined S1 and S2 hydrocarbon peaks from conventional Rock–Eval analysis may not adequately characterize the organic constituents of unconventional reservoir rocks. Modification of the thermal recipe for Rock–Eval analysis in conjunction with manual peak integration provides important information with significance for the evaluation of reservoir quality. An adapted method of the analysis, herein called the extended slow heating (ESH) cycle, was developed in which the heating rate was slowed to 10 °C per minute over an extended temperature range (from 150 to 650 °C). For Montney core samples within the wet gas window, this method provided quantitative distinctions between major organic matter (OM) components of the rock. We show that the traditional S1 and S2 peaks can now be quantitatively divided into three components: ($S1_{ESH}$) free light oil ($S2a_{ESH}$) fluid-like hydrocarbon residue (FHR), and ($S2b_{ESH}$ + residual carbon) solid bitumen (more refractory, consolidated bitumen/pyrobitumen).

The majority of the total organic carbon (TOC) in the studied Montney core samples consists of solid bitumen that represents a former liquid oil phase which migrated into the larger paleo-intergranular pore spaces. Physicochemical changes to the oil led to the precipitation of asphaltene aggregates. Subsequent diagenetic and thermal cracking processes further consolidated these asphaltene aggregates into "lumps" of solid bitumen (or pyrobitumen at higher thermal maturity). Solid bitumen obstructs porosity and hinders fluid flow, and thus shows strong negative correlations with reservoir qualities such as porosity and pore throat size.

Although the FHR fraction constitutes a small portion of the total rock mass and volume in Montney samples it has important implications for reservoir quality. This fraction represents a thin film of condensed, heavy molecular hydrocarbon residue covering surfaces of the present-time pore spaces and may represent the lighter component of the paleo-oil that migrated into tight interstices in the Montney reservoir. The FHR fraction potentially plays an important role in wettability alteration by creating hydrophobic matrix pore networks in portions of the reservoir that were not already filled with solid bitumen.

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1. Introduction

The total organic carbon (TOC) content of unconventional tight gas and shale gas plays is regarded as an important attribute for assessment of reservoir quality and hydrocarbon productivity. TOC has positive correlations with porosity and permeability in many known self-sourced unconventional plays (Jarvie et al., 2007; Passey et al., 2010). These positive correlations have led to a perception that organic porosity is a dominant control on reservoir quality in many shale formations (*e.g.*, Barnett, Doig and Eagle Ford) and the primary storage mechanism for hydrocarbons in organic-rich mudstones (Jarvie et al., 2006).

The present-day TOC content of rock samples is commonly measured with total carbon analysers (LECO) after removal of mineral carbon (decarbonation by use of HCl) or with thermally programmed Rock–Eval analysis. The bulk measurement of TOC combines various fractions of organic matter (OM) in a given sample. These OM fractions have unique physical and chemical properties and may play different roles in the source and reservoir quality of an unconventional petroleum rock. This study applies a modified Rock–Eval procedure to quantify the amounts of various OM fractions within samples from the Triassic Montney Formation of northeast British Columbia. The new geochemical parameters

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developed in this study are integrated with petrographic observations and various rock property measurements to provide insights into the role of OM on reservoir quality in the Montney tight gas fairway.

2. Study area

The Montney Formation is an Early Triassic tight gas reservoir up to 320 m thick which is located to the northeast of the Cordilleran deformation belt in the Western Canadian Sedimentary Basin (WCSB) (Kuppe et al., 2012; National Energy Board, 2013; Wood, 2013). The Montney Formation is mainly composed of siltstone and was deposited predominantly in lower shore face to offshore environments (Davies et al., 1997; Edwards et al., 1994; Wood, 2013) (Fig. 1a–b).

Core samples for this study were collected from one well in northeastern British Columbia: ECA CRP HZ Sunrise 03-21-080-17 W6. Drill cores were recovered from both the Upper and Lower sections of the Montney Formation at depths between 2126.50 and 2347.28 m. Studied samples vary from medium (mean = 21 μm) to coarse-grained (mean = 48 μm) siltstone in the lower and upper Montney interval, respectively (Table 1).

3. Methodology

3.1. Porosity and pore throat size

Porosity and pore throat size measurements were determined on 18 core samples from the studied well. Porosity was measured on one-inch-diameter plugs at ambient conditions by use of the Boyle's Law method with helium as the gaseous medium. Samples were cleaned with toluene and methanol, and then oven-dried at 100 °C for 24 h prior to porosity measurement. Pore throat size distributions were generated from mercury injection capillary pressure measurements conducted following established methods (Purcell, 1949) and by use of the Washburn equation (Washburn, 1921).

3.2. Rock–Eval analysis

Dry samples weighing 50 to 70 mg were finely ground and their TOC contents measured using the standard cycle of Rock–Eval 6® (Vinci Technologies, France) analysis (Lafargue et al., 1998). The pyrolysis portion of the standard cycle used an iso-temperature of 300 °C for 3 min followed by increasing temperature at a rate of 25 °C per minute up to 650 °C. The amount of hydrocarbon (mg HC/g Rock) released during

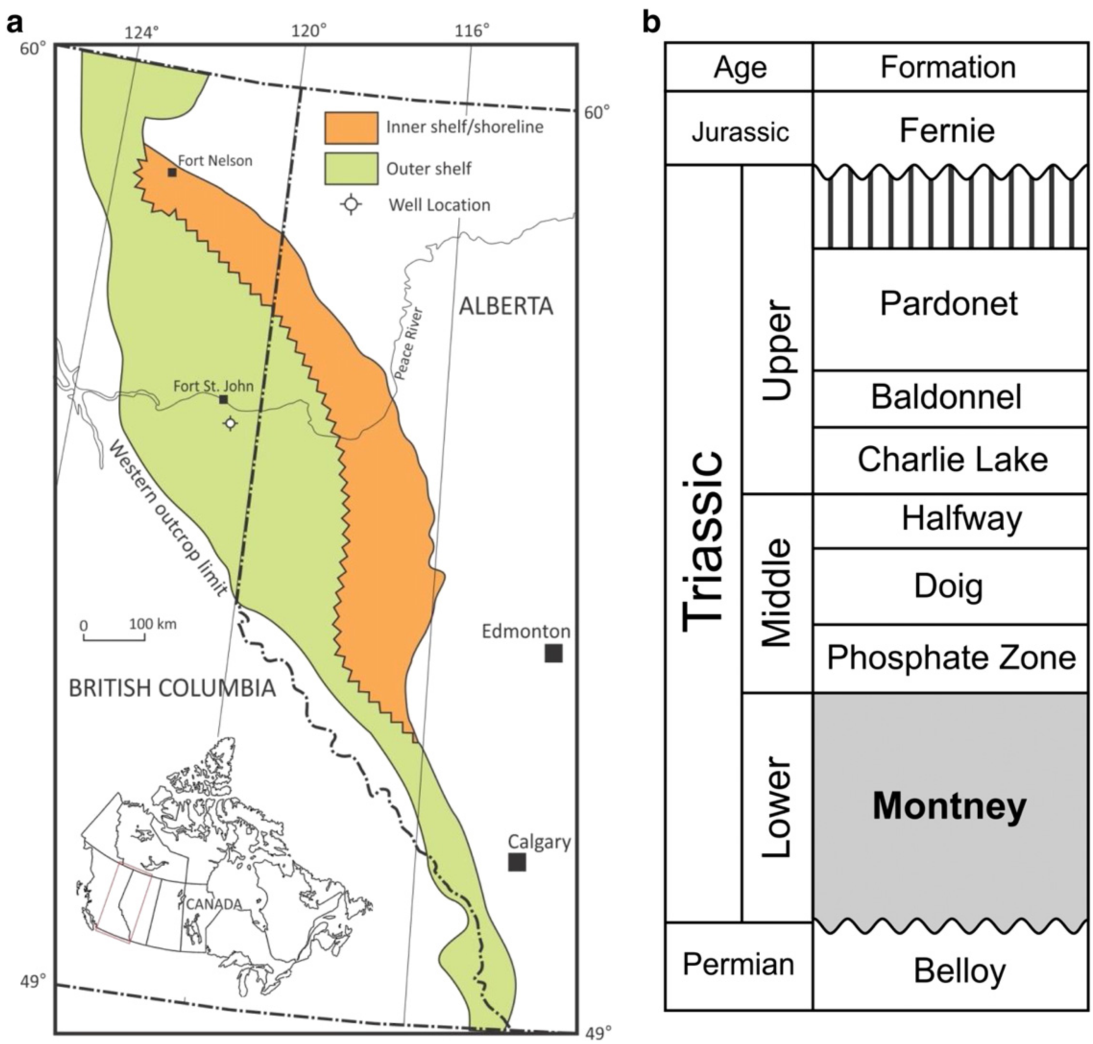

Fig. 1. (a) Map of distribution of preserved Triassic strata in the subsurface of western Canada and approximate location of the studied well. (b) Stratigraphic column of Permian, Triassic and Jurassic strata in the WCSB (modified after Davies, 1997).

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