Modeling fluid migration and distribution in unconventional reservoirs: an example from the Montney Formation, British Columbia, Canada

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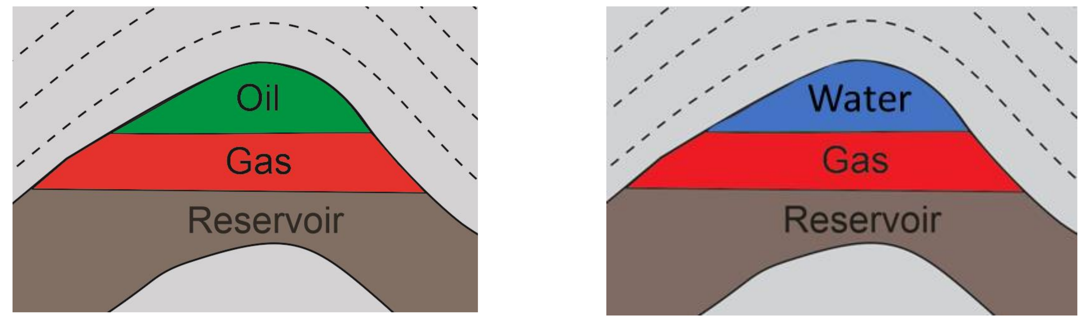
INTRODUCTION

- One defining characteristic of unconventional reservoirs is the unusual fluid distribution.
- Controls exerted by fluid properties and petrophysical properties on fluid distribution are poorly understood.
- We propose to use numerical models for hydrocarbon migration to test the roles of the fluid properties and petrophysical properties on controlling the fluid distribution.

Oil on top of less dense gas



Water on top of less dense gas

Fig.1: Example of unusual fluid distribution in unconventional reservoirs with less dense fluid overlain by denser fluids

BACKGROUND

- Lower Triassic Montney Formation
- Host of both conventional and unconventional systems.
- Dominated by dolomitic-siltstone (Zonneveld and Moslow, 2018; Vaisblat et al., 2021).
- Some fields of the Montney present unusual fluid distributions.
- Gas pools overlain by oil pools (focus of this study).

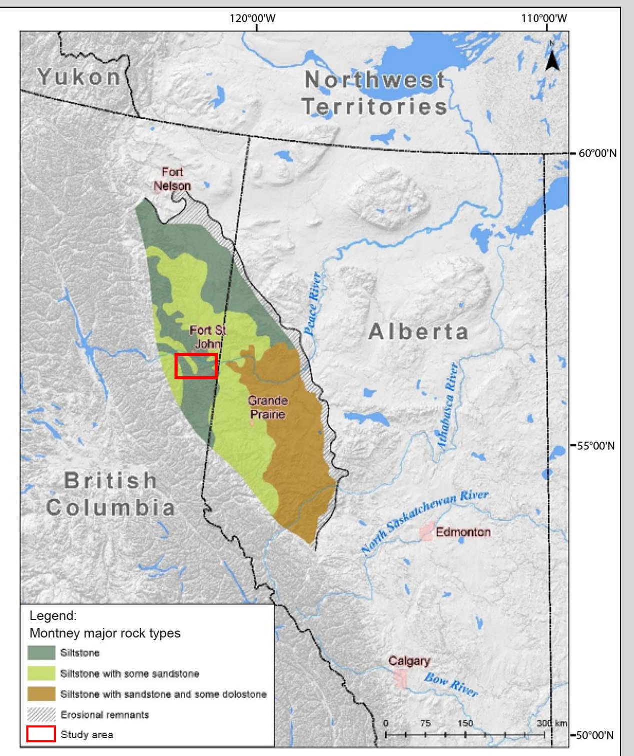


Fig 2: General map of the Montney Formation, with the location of the study area highlighted in the red rectangle. Modified after National Energy Board (2013):

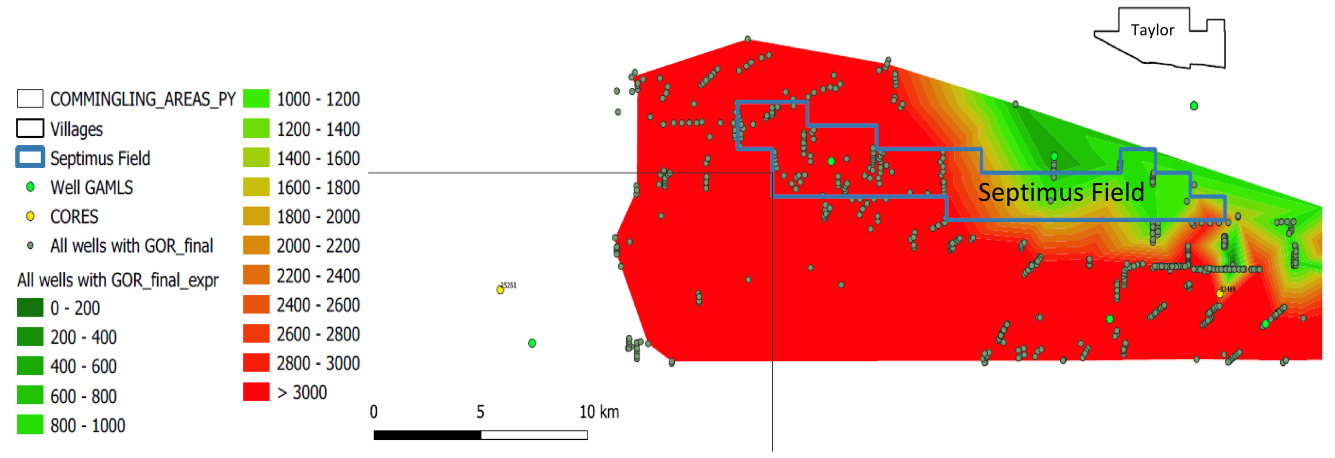


Fig.3: Map of the gas/oil ratio at the Septimus Field. Hernandez, 2021

MIGRATION

- Buoyancy forces > capillary pressure ➔ Migration
- Capillary pressure > Buoyancy forces ➔ Seal
- Capillary pressure is the main constrain to migration:

$$Pc = \frac{2\sigma \cos\theta}{r} \quad (1)$$

With σ the interfacial tension (IFT), θ the contact angle, and *r* the pore throat radius.

- **Pc is directly related to the rock fabric and petrophysical properties**

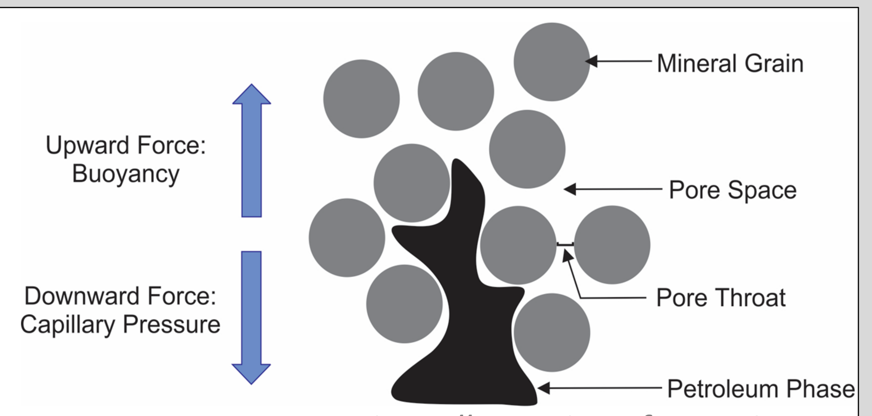


Fig.4: Illustration of opposing forces involved during the migration of hydrocarbons

MODELLING

- Permedia® software, a petroleum systems modeling toolkit developed by Halliburton.
- Applies the invasion-percolation theory (Carruthers, 2003) to the simulation of complex fluid-migration processes under the influence of both capillary and buoyancy forces.
- Petrophysical and fluid properties are both accounted for in the modeling.

PROBLEMS AND OBJECTIVE

- Complexity in the pore system and petrophysical properties.
- Unpredictable fluid distribution.
- Critical to develop reliable petrophysical models to predict fluid distribution and improve productivity.

➔ Build a suite of numerical models to test the role of petrophysical and fluid properties in controlling fluid distribution in the Septimus field.

DATASET

- 13 wells from the Septimus field; some are gas producers, some are oil producers
- Identification of 4 rock types (Hernandez 2021)
- Each rock type has different: mineralogical composition, TOC, petrophysical properties
- Different petrophysical properties between the samples from the oil and gas wells

FIRST MODELS

- The main goal is to test the effect of different fluid compositions by varying IFT and density, using simple reservoir mesh with only 2 lithologies: Rock Type 2 and Rock Type 3.
- The petrophysical properties of the rocks are based on Hernandez (2021).
- Density and IFT are defined at reservoirs conditions based on Schowalter (1979).

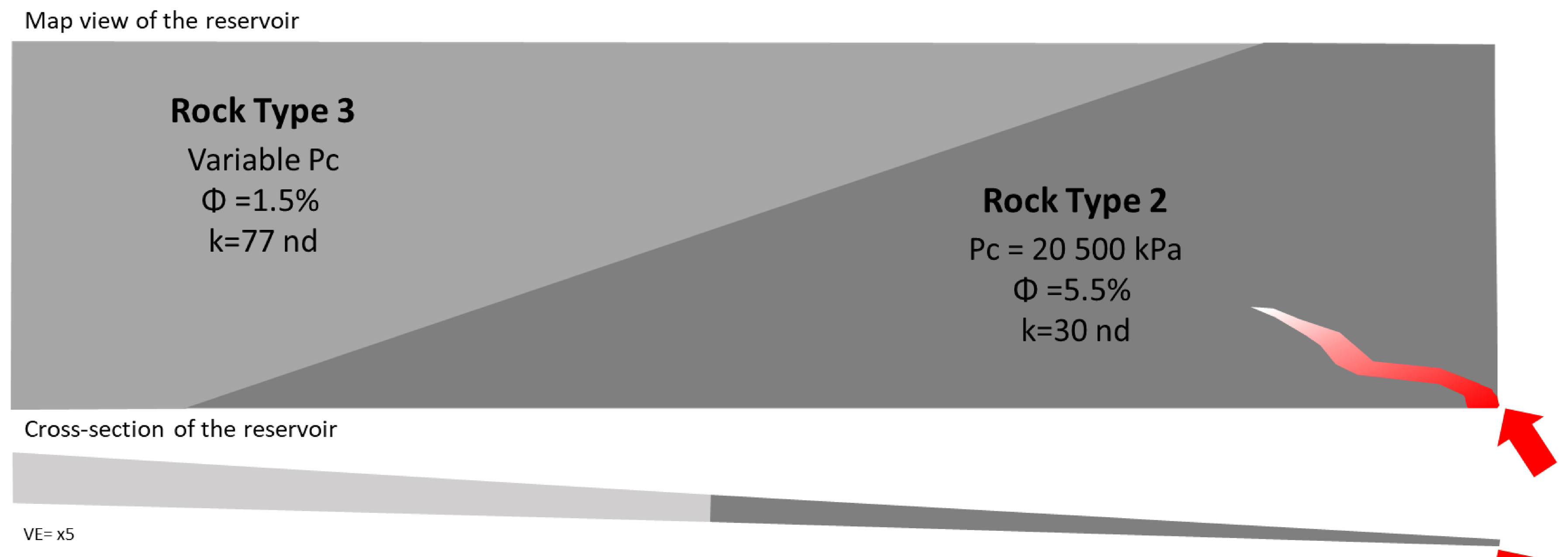


Fig.5: Input reservoir mesh with 2 lithologies RT 2 and RT 3, the red arrow represents the injection point in the model.

- Inject fluid, to have migration into RT2 and RT3. Run several simulations, increasing the Pc in RT3 until we have a seal.

➔ Define maximum Pc that the fluid can enter.

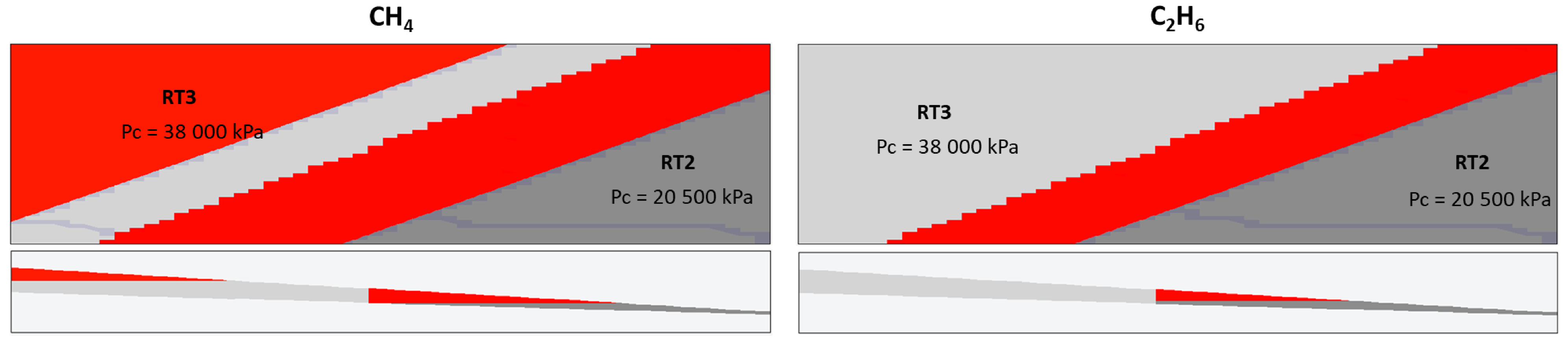


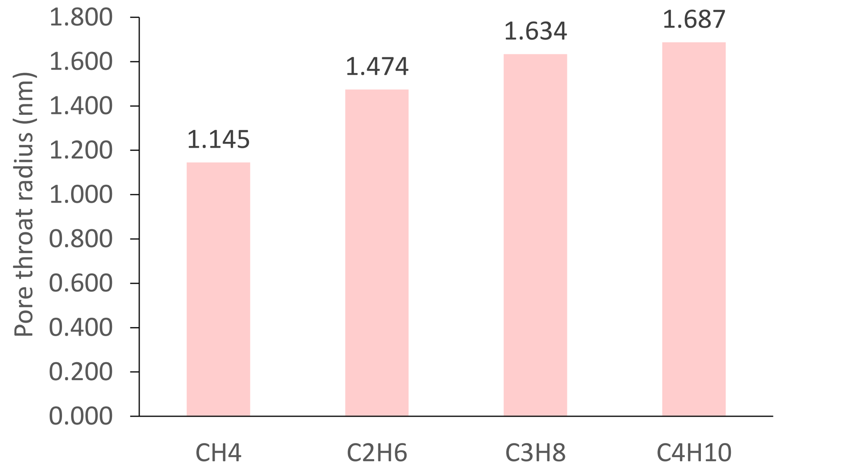
Fig.6: Example where Pc is set at 38 000 kPa in RT3, two different gases (methane and ethane) are injected in the model.

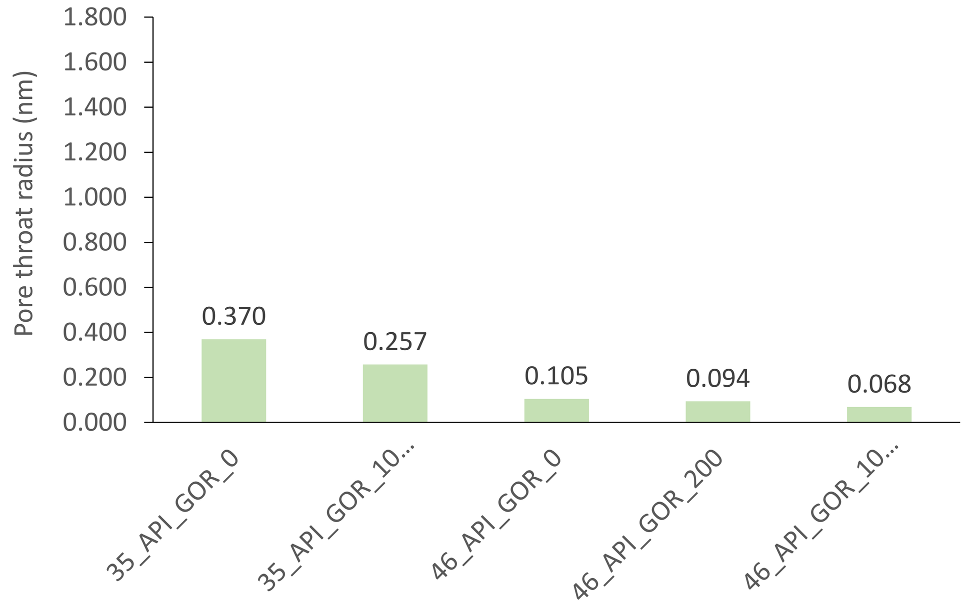
- At same Pc, methane can enter RT3, but ethane cannot.

➔ Fluid composition influences fluid distribution.

RESULTS

The maximum capillary pressure was calculated for different fluids. Assuming a water-wet system we can consider θ to be zero in equation (1), and now we can calculate the pore throat radius: $r=2\sigma/Pc$





Pore throat radius = smallest pore throat that the fluid can enter. If the pore throats are smaller, no migration (it will be a seal).

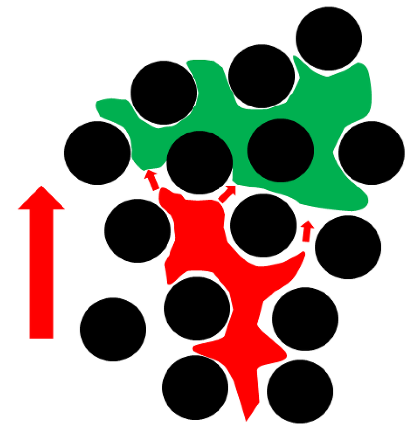
➔ Light gases can enter smaller pore throats than heavy gases.

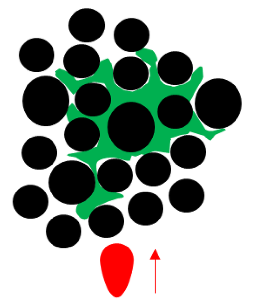
➔Oil can enter smaller pore throat than gas. This is due to very low IFT for oil-water systems.

CONVENTIONAL | UNCONVENTIONAL

Fig.7:Relatioship between rock petrophysical properties and fluid properties in conventional and unconventional reservoirs.

Pore throats big enough ➔ Gas can enter and push the preexisting oil





Smaller pore throats ➔ Gas cannot enter

FUTURE WORK

- Apply the first observations to models reflecting the complexity and heterogeneity of the Montney Formation at Septimus field.
- Test different timing of charging events, and different fluids compositions.
- Consider the dual-wettability of the Montney Formation for pore throats size calculations.
- Some parameters will be varied outside the limits of Septimus field data to explore factors that differentiate conventional from unconventional reservoirs

ACKOWLEDGMENTS

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