**The Jeanne d'Arc Basin Offshore Canada: Testing the Predictive Capacity of PhaseKinetic Models Using 3-D Basin Modeling**

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Abstract

Kinetic models of petroleum generation have become the standard tool for the prediction of hydrocarbon distribution and properties using basin modeling. Such models rely on laboratory analysis of hydrocarbon generation and extrapolation of the reactions characterized to geologic heating rates. Bulk kinetic models describe the primary generation of hydrocarbons using open-system pyrolysis, whereas compositional kinetic models capable of predicting composition, gas vs. oil proportions etc. require either multiple open or closed system pyrolysis experiments.

The compositional kinetic models developed at GFZ, termed PhaseKinetics, are based on a combination of bulk kinetics and closed system pyrolysis experiments to describe the compositional evolution of generated fluids as a function of increasing maturity. Due to the compositional resolution used, which is based on that of PVT data formats, the prediction of petroleum phase properties is possible. Here we demonstrate for the Jeanne d'Arc Basin offshore eastern Canada that such compositional predictions are accurate.

In the Jeanne d'Arc Basin offshore Canada the Late Jurassic Ranking Formation is the main source rock and is also characterized by significant facies variability. 5 samples with petroleum type organofacies ranging from paraffinic-napthenic-aromatic sulfur-rich to paraffinic high-wax were studied in detail and compositional kinetic predictions compared to production data from over 100 well tests. In this case 3-D basin modeling including the simulation of petroleum generation and migration taking hydrocarbon phase behaviour into account was performed. The basin model predictions correctly reproduced observed distribution, phase state and GORs of the known accumulations in the area and allowed a clear characterization of the principle drainage areas of the known accumulations.

The application of PhaseKinetic models in petroleum exploration via 3-D basin modeling provides thus a significant step forward in
enhancing our understanding of hydrocarbon generation and migration dynamics as well as reducing exploration risk.

References


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Introduction: The Jeanne d’Arc basin, on the Grand Banks offshore Newfoundland, is a confined, failed-rift basin. Its initial development and burial history were controlled by crustal stretching and thinning (Baur et al. 2010). The Jeanne d’Arc basin contains 3 major accumulations: the Hibernia- and Terra Nova oil fields and the Whiterose- oil and gas field. Due to the presence of only a single active source rock, this basin is ideal to test and quantify our compositional kinetic phase-predictive approach in combination with different migration simulation methods in a 4D petroleum basin model. The aims are to assess the potential of this methodology to reduce exploration risk and provide a reasonable resource assessment in frontier basins.
Burial history with maturity and temperature calibration data

Transformation Ratio for Egret SR with Drainage Areas and Migration Pathways for the Jeanne d’Arc reservoir

Terra Nova Oil Field... the calibrated reference system for each migration model

Filling History of the Terra Nova Oil Field

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**Numerical Model Calibration**

**Migration Methods**
- Darcy
- Flowpath
- IP and Hybrid

**Mass Balance Calculation**
- For different migration techniques

**Mass Balance Calculation**
- Darcy SR Sum Generated 100.00%
- Accumulated in Egret SR 99.37%
- Accumulated in Reservoirs 98.31%
- Migration Losses 1.69%
- Sec. Cracking Losses 0.08%
- Outflow Top 59.44%
- Outflow Side 21.43%
- HC Losses total 58.40%
- Accumulation Efficiency 41.56%

**Flowpath simulation 67.4**
- Egret SR Sum Generated 100.00%
- Accumulated in Egret SR 99.37%
- Accumulated in Reservoirs 98.31%
- Migration Losses 1.69%
- Sec. Cracking Losses 0.08%
- Outflow Top 59.44%
- Outflow Side 21.43%
- HC Losses total 58.40%
- Accumulation Efficiency 41.56%

**IP simulation 67.6 (R10_333)**
- Egret SR Sum Generated 100.00%
- Accumulated in Egret SR 99.37%
- Accumulated in Reservoirs 98.31%
- Migration Losses 1.69%
- Sec. Cracking Losses 0.08%
- Outflow Top 59.44%
- Outflow Side 21.43%
- HC Losses total 58.40%
- Accumulation Efficiency 41.56%

**HYBRID MIGRATION**
- Domain Subdivision
- Darcy at low permeability
- Flowpath at high permeability

**DARCY**
- \[ Q = A k \frac{\partial p}{\partial x} = A \frac{k u}{\eta} \]
- \( Q \) = Darcy velocity [m/s], [m²/m²/s]
- \( A \) = Area [m²]
- \( k \) = permeability [Darcy]
- \( \eta \) = viscosity [Pa·s]
- \( p \) = pressure potential

**FLOWPATH**
- \[ u^p = (\rho_w - \rho_o) \cdot g \cdot h \]
- \( u^p \) = pressure potential
- \( \rho_w \) = water density
- \( \rho_o \) = oil density
- \( g \) = acceleration caused by gravity
- \( h \) = column height

**INVASION PERCOLATION**
- \[ Zc = \frac{2 \gamma}{g (\rho_w - \rho_o)} \]
- \( Zc \) = critical column height
- \( \gamma \) = interfacial tension
- \( g \) = acceleration caused by gravity
- \( \rho_w \) = water density
- \( \rho_o \) = oil density

**Buoyancy driven influenced by the density and interfacial tension**
- (after Carruthers, 2003)

**Pressure driven influenced by the seal geometry**
- (after Hantschel & Kauerauf 2006)
A 4D JEANNE D'ARC BASIN MODEL WAS BUILT AND CALIBRATED. Different methods of simulating petroleum migration were tested with respect to the amount and type of impact on the mass balance calculation and accumulated fluids in the reservoir.

- The choice of the technique used for petroleum migration simulation can have a major impact on
  - calculated migration losses
  - accumulation efficiency
  - fluid distribution in the model

- Pure Darcy flow predictions show largest difference to alternative migration methods

- Flowpath, Invasion Percolation and Hybrid migration techniques show similar results

- Application of PhaseKinetic models of hydrocarbon generation and cracking allowed good reproduction of natural fluid GOR and phase state
  - Best results obtained with Hybrid migration