PS 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

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enhancing our understanding of hydrocarbon generation and migration dynamics as well as reducing exploration risk.

References

Baur, F., R. Littke, H. Wielens, C. Lampe, and T. Fuchs, 2010, Basin Modelling meets rift analysis – A numerical modeling study from the Jeanne d'Arc basin, offshore Newfoundland, Canada: Marine and Petroleum Geology, v. 27, p. 585-599.

Carruthers, D.J., 2003. Modeling of Secondary Petroleum Migration Using Invasion Percolation Techniques, *in* S. Düppenbecker and R. Marzi, (editors) Multidimensional Basin Modeling: AAPG Datapages Discovery Series No. 7, p. 21-37.

Hantschel, T. and A.I. Kauerauf, 2009, Fundamentals of Basin and Petroleum Systems Modeling: Springer Berlin, 476 p.

Magoon, L. B., T.L. Hudson, and K.E. Peters, 2005, Egret-Hibernia(!), a significant petroleum system, northern Grand Banks area, offshore Eastern Canada: AAPG Bulletin, v. 89, p. 1203-1237.

di Primio, R. and B. Horsfield, 2006, From petroleum-type organofacies to hydrocarbon phase prediction: AAPG Bulletin, v. 90/7, p. 1031-1058.

Sinclair, I.K., 1993, Tectonism: The dominant factor in mid-Cretaceous deposition in the Jeanne d'Arc Basin, Grand Banks: Marine and Petroleum Geology, v. 10, p. 530-549.

Wielens, J.B.W., C.D. Jauer, and G.L. Williams, 2006, Is there a viable petroleum system in the Carson and Salar basins, offshore Newfoundland?: Journal of Petroleum Geology, v. 29/4, p. 303-326.

Withjack, M.O. and R.W. Schlische, 2005, A review of tectonic events on the passive margin of eastern North America, *in* P. Post, N.C. Rosen, D.L. Olson, S.K.T. Palmes, and G.B. Newton (editors) Petroleum Systems of Divergent Continental Margin Basins: 25th Bob S. Perkins Research Conference, Gulf Coast Section of SEPM, p. 203–235.

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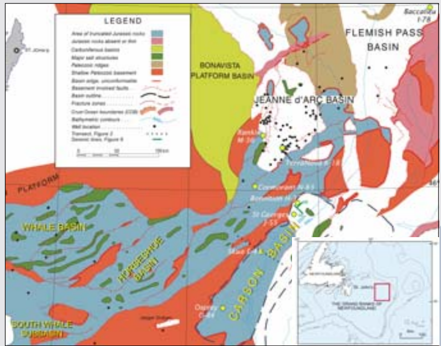
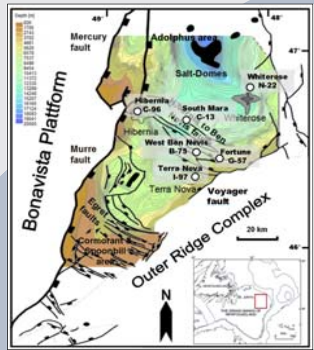
Introduction: The Jeanne d'Arc basin, on the Grand Banks offshore Newfoundland, is a confined, failed-rift basin. Its initial development and burial history were controlled by crustal stretching and thinning (Baur et al. 2010).The Jeanne d'Arc basin contains 3 major accumulations: the Hibernia- and Terra 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.

Geology

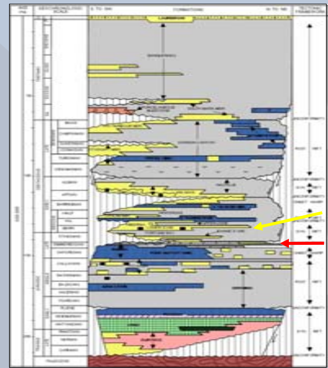
Location
Stratigraphy
Petroleum System



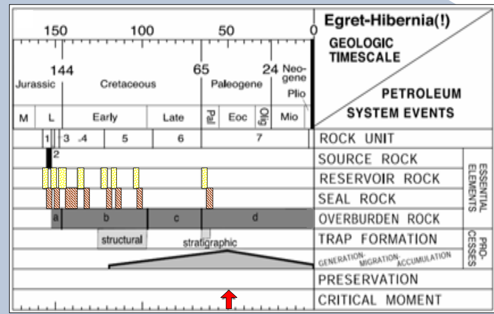
Geologic provinces and prominent basins and tectonic elements around the study area (after Wielens et al., 2006)



Jeanne d'Arc basin (Fault pattern after Withjack & Schlische, 2005)



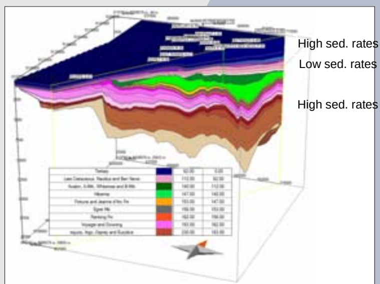
Stratigraphy (after Sinclair, 1993)



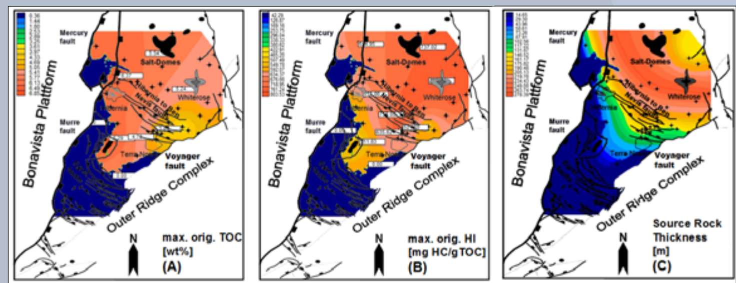
Petroleum System Event Chart (Magoon et al., 2005)

Input

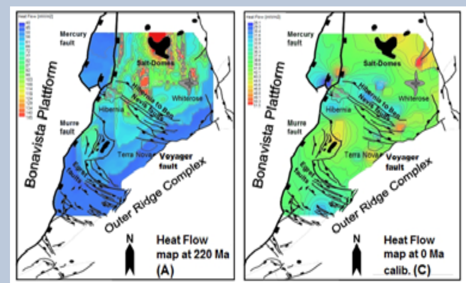
Basic Input Data



Geometry of layers with facies assignment



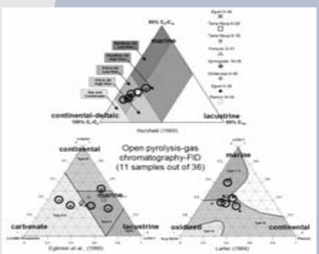
Source rock related input parameters like original TOC, original HI and thickness



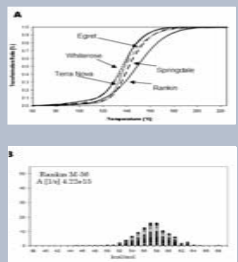
Heat flow definition for the models boundary

Input

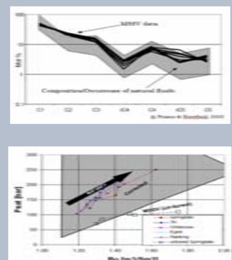
Geochemical Data



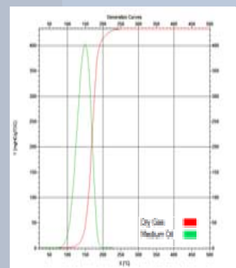
Geochemical composition of Egret SR samples



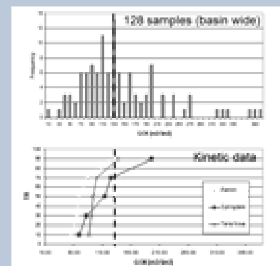
Egret SR kinetics



Tuning gas and liquid composition to better reproduce the phase behavior (after di Primio & Horsfield, 2006)



Secondary Cracking



MSSV Predicted vs. measured GOR data

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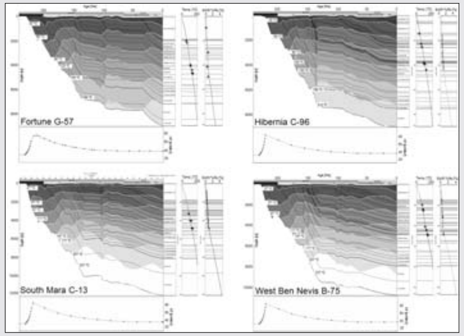
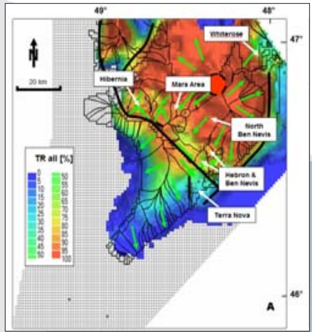
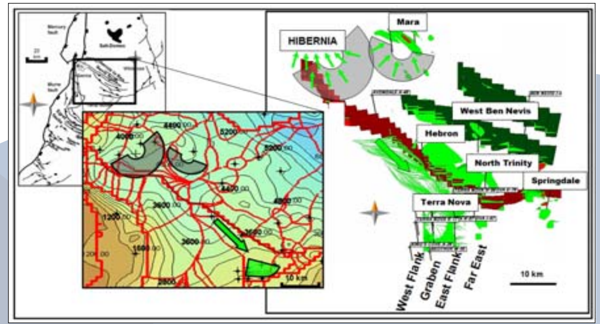
Numerical Model
Calibration



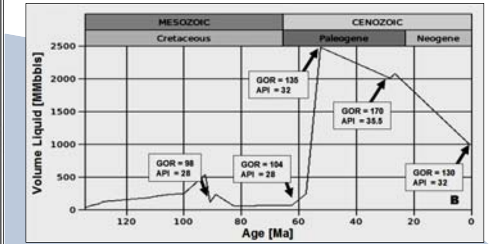
Burial history with maturity and temperature calibration data



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

Migration Methods
Darcy, Flowptah
IP and Hybrid

DARCY

$$Q = A\frac{k}{\eta}\frac{\partial p}{\partial x} = A\frac{k}{\eta}\frac{u^p}{L}$$

Q = Darcy velocity [m/s], [$m^2/m^2/s$]
A = Area [m]
k = permeability [Darcy]
η = viscosity [Pa*s]
dp/dx= gradient [Pa/m]
u^p = pressure potential

$$u^p = u^w + (\rho^w - \rho^p)\cdot g \cdot h + p^c$$

Overpressure — Buoyancy for multi-phase. flow — Capillary Pressure for multi-phase flow

Pressure driven
influenced by viscosity and permeability
(after Hantschel & Kauerauf 2009)

FLOWPATH

$$u^p = (\rho^w - \rho^p)\cdot g \cdot h$$

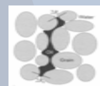
u^p = pressure potential
g = acceleration caused by gravity
h = column height
ρ_w = water density
ρ_o = oil density

Buoyancy driven
influenced by the seal geometry
(after Hantschel & Kauerauf 2009)

INVASION PERCOLATION

$$Z_c = \frac{2\gamma\left(\frac{1}{r_t} - \frac{1}{r_p}\right)}{g(\rho_w - \rho_o)}$$

Z_c = Critical column height
γ = interfacial tension
r_t = pore throat radius in the caprock
r_p = pore throat radius in the reservoir
g = acceleration caused by gravity
ρ_w = water density
ρ_o = oil density



Capillary forces driven
influenced by the density and interfacial tension
(after Carruthers, 2003)

HYBRID MIGRATION

Domain Subdivision
Darcy at low permeabuility
Flowpath at high permeability

Pressure driven in low permeable rocks &
buoyancy driven in high permeable rock
(after Hantschel & Kauerauf 2009)

Mass Balance Calculation
For different migration techniques

Darcy simulation 67.8	mass %
Egret SR Sum Generated	100.00
Accumulated in Egret SR	1.49
Egret SR Expelled	98.51
Accumulated in Reservoirs	40.93
Migration Losses	6.78
Sec. Cracking Losses	0.06
Outflow Top	12.53
Outflow Side	38.21
HC Losses total	58.45
Accumulation Efficiency	41.55

Flowpath simulation 67.4	mass %
Egret SR Sum Generated	100.00
Accumulated in Egret SR	0.93
Egret SR Expelled	99.07
Accumulated in Reservoirs	4.69
Migration Losses	0.18
Sec. Cracking Losses	1.50
Outflow Top	51.87
Outflow Side	40.83
HC Losses total	95.27
Accumulation Efficiency	4.73

IP simulation 67.0 (6x6_333)	mass %
Egret SR Sum Generated	100.00
Accumulated in Egret SR	0.67
Egret SR Expelled	99.33
Accumulated in Reservoirs	7.08
Migration Losses	0.74
Sec. Cracking Losses	0.00
Outflow Top	60.11
Outflow Side	31.40
HC Losses total	92.87
Accumulation Efficiency	7.13

Hybrid simulation 67.6	mass %
Egret SR Sum Generated	100.00
Accumulated in Egret SR	1.12
Egret SR Expelled	98.88
Accumulated in Reservoirs	4.84
Migration Losses	0.30
Sec. Cracking Losses	1.66
Outflow Top	49.44
Outflow Side	42.63
HC Losses total	95.10
Accumulation Efficiency	4.90

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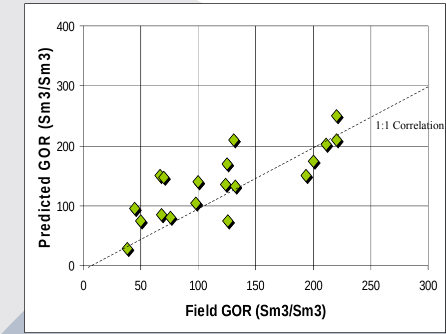
GOR Prediction

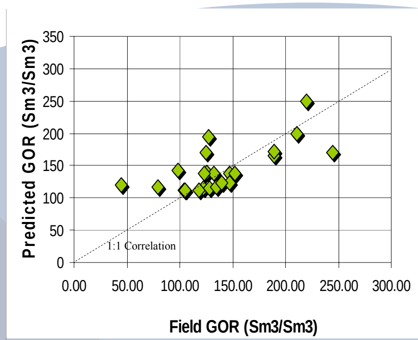
DARCY

very few but large accum.
not representative

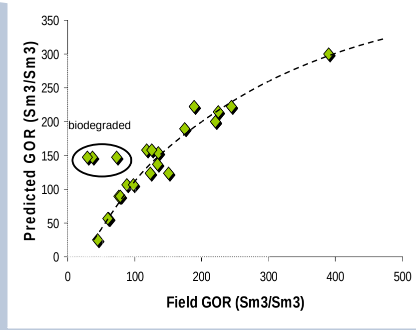
FLOWPATH



INVASION PERCOLATION

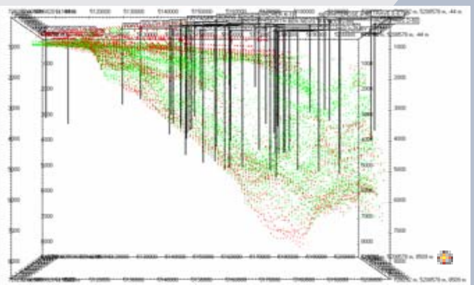


HYBRID MIGRATION

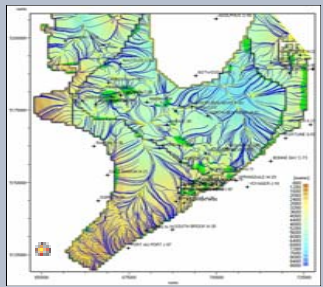


Migration Results

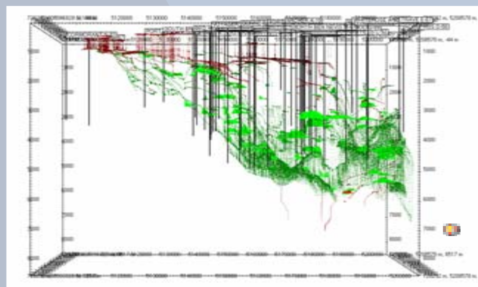
Migration Pattern



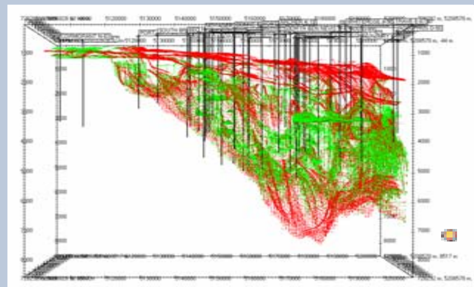
Darcy analysis for the JdA basin



Flowpath analysis for the JdA reservoir



Invasion percolation migration analysis



Hybrid migration analysis

Conclusions

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

References & Acknowledgements

Baur, F., Littke, R., Wielens, H., Lampe, C., Fuchs, T. 2010. Basin Modelling meets rift analysis – A numerical modeling study from the Jeanne dÁrc basin, offshore Newfoundland, Canada. Marine and Petroleum Geology, v. 27, p. 585-599
Carruthers, D.J. (2003): Modeling of Secondary Petroleum Migration Using Invasion Percolation Techniques, in S. Düppenbecker and R. Marzi, eds., Multidimensional Basin modeling, AAPG/Datapages Discovery Series No. 7, p. 21-37.
Hantschel, T., Kauerauf, A. I. (2009): Fundamentals of Basin and Petroleum Systems Modeling, Springer Berlin, pp. 476.
Magoon, L. B., T. L. Hudson, and K. E. Peters, 2005, Egret-Hibernia(!), a significant petroleum system, northern Grand Banks area, offshore Eastern Canada: AAPG Bulletin, v. 89, p. 1203-1237.
di Primio, R., and B. Horsfield, 2006, From petroleum-type organofacies to hydrocarbon phase prediction: AAPG Bulletin, v. 90, no. 7, p. 1031-1058.
Sinclair, I.K. 1993. Tectonism: the dominant factor in mid-Cretaceous deposition in the Jeanne d'Arc Basin, Grand Banks. Marine and Petroleum Geology, v. 10, p. 530-549.
Wielens, J.B.W., Jauer, C.D. and Williams, G.L. 2006: Is there a viable petroleum system in the Carson and Salar basins, offshore Newfoundland? – Journal of Petroleum Geology, V. 29, No. 4, pp. 303-326.
Withjack, M.O., Schlische, R.W, 2005. A review of tectonic events on the passive margin of eastern North America. In: Post, P. (Ed.), Petroleum Systems of Divergent Continental Margin Basins. 25th Bob S. Perkins Research Conference, Gulf Coast Section of SEPM, pp. 203–235.

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