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Abstract

Petroleum system modeling has long been used to model generation, migration and entrapment of yet-to-be-discovered hydrocarbons in conventional plays. The same software has been modified to give improved prediction of the hydrocarbons remaining in the source rock that constitute unconventional plays. This methodology provides predictions of secondary porosity, fluid type, pressure, adsorbed vs. free gas and geomechanical properties. Play chance mapping of these parameters, combined with other elements of the play, may be used to identify sweet spots early in the life of an unconventional play prior to extensive drilling.

Selected References


Decker, P.L., 2011, Source-reservoired oil resources, Alaskan North Slope: Alaska Department of Natural Resources, Division of Oil and Gas, 52 p.


**Website**

http://www.adn.com/2012/09/22/2636242/great-bear-wants-to-speed-up-shale.html#storylink=cpy
Systematic evaluation of unconventional resource plays using petroleum system modeling combined with play chance mapping

Ian Bryant
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AAPG GTW, Houston, 2012
Agenda

- Introduction
  - Understanding geology **and** technology is key
- Petroleum System Modeling
- Play chance mapping
- Case Studies - getting the right acreage early in play
  - Data-poor example: Haynesville gas play
  - Data-rich example: Alaska oil play
- Conclusions
Shale in Perspective: Permeability

- Arab-D Carbonate
- Berea Sand
- Brick
- Jonah Lance Fm.
- Organic Shale
- Cement
- Salt

Permeability values: 1000, 100, 10, 1.0, 0.1, 0.01, 0.001, 0.0001, 0.00001, 1e-06

mD
Porosity in Kerogen

Shale 3: Gas/oil window. Producer

Calcite

Kerogen: 10.61%
Pore: 8.24%
Connected porosity: 0%
K = 0

From nano-volume:
Pore + Kerogen: 5%

Diaz., 2010

Shale 4: Oil window. Producer

Kerogen: 24%
Pore: 5%
Connected porosity_Z: 1.6%
Kz = 0.002 mD

From nano-volume:
Pore + Kerogen: 11.2%
Shale Plays: Variations in Bulk Mineralogy

- Barnett
- Marcellus
- Haynesville
- Fayetteville
- Eagle Ford
- Wolfcamp
TOC and In Situ Stress - Marcellus Example

<table>
<thead>
<tr>
<th>Reference (ft)</th>
<th>Initial Tops</th>
<th>OPEN - HOLE DATA</th>
<th>INTERPRETED DATA</th>
<th>CORE PHOTOS</th>
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</tbody>
</table>

- **OPEN - HOLE DATA**
  - Sand - Shale (RD)
  - RHOM
  - DTS
  - PGN
  - TOC

- **INTERPRETED DATA**
  - Min/Max Stress
  - Core Photos

- **CORE PHOTOS**
  - Zoom factor: 20.00
Keys for Success in Unconventional Reservoirs

Understand the geology

Understand the technology

Use models to leverage the appropriate technology and create value
Keys for Exploration Economic Success

Rich resource in place

- Maturity of source rocks
  - Oil, wet gas or dry gas?
- Porous and permeable
  Good quality reservoir filled with the desired hydrocarbon fluids

Economically recoverable with current technology

- Drillablity
- Fracability
  - Geomechanical properties
  - Stress distribution

Ability to create high quality completions at the right price
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- **Petroleum System Modeling**
- **Play chance mapping**
- **Case Studies - getting the right acreage early in play**
  - Data-poor example: Haynesville gas play
  - Data-rich example: Alaska oil play
- **Conclusions**
## Role of Petroleum System Modeling

<table>
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<th>Property</th>
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<td>Fluid type</td>
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<td>Pore pressure</td>
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<tr>
<td>In situ stress</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Modified from: Moumen Bouhel & Bryant, 2012. SPE 152455
Conventional vs. Unconventional Resource Petroleum Systems Modeling

**Conventional**
- HC has migrated to reservoir
- Secondary cracking of oil to gas in reservoir is not important
- Porosity is modeled in reservoir
- Model free gas in reservoir

**Unconventional**
- HC is still in source rock
- Secondary cracking of oil to gas is important
- Conversion of kerogen creates porosity in source rock
- Adsorption is an important parameter (vs. free gas)
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Play Chance Mapping

- Transform maps of physical properties to chance of success maps for each of the elements of exploration risk
- Combine maps to map overall chance of success for the play and define “sweet spots”

Gas in Place
scft/ton
Gas in Place
0 - 1

From Neber et al., 2012. SPE 158571
Play Chance Mapping

From Neber et al., 2012. SPE 158571
Calculation of Total Play Risk

From Neber et al., 2012. SPE 158571
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Data-poor Environment – Proof of Concept

Exploration in new shale gas plays offer E&P companies a first mover advantage, namely to acquire acreage in sweet spots before license costs escalate

How to find those sweet spots prior to extensive drilling in the play?

- Leverage data from exploration for conventional targets
- Build integrated petroleum systems models to predict resource richness and guide exploration drilling

We simulated a data-poor environment by modeling the Haynesville shale gas play calibrated by only one well
The Haynesville Shale Gas Play

**PetroMod Modeling**
- Multi-component Generation
- Secondary Cracking
- Langmuir Adsorption
- Gas Generation Pressure
- Secondary Porosity
- Seal Quality: Fracturing Model

Model has uniform layer properties and is calibrated with one well

3D petroleum systems model: area ~ 270 x 180 km

From Mavidou, 2010
Here: modified 4 component Behar et al. (1997) TII kinetics:

- HI: 300 mgHC/gTOC: inert kerogen ~ 3.5 x generative kerogen
- Secondary cracking of all components to methane, $E_a = 58$ kcal/mol
Calibration of Temperature
Temperature and Maturity

Temperature

Vitrinite Reflection (Maturity)

present
Calibration of Porosities

Data from Petrel Project
Secondary porosity due to conversion of kerogen to hydrocarbons and pressure build-up due to corresponding volume expansion is incorporated.

Calibration of Pressures

Pressure [MPa]

Depth [m]

lithostatic

hydrostatic pore

Pressure [MPa]

Depth [m]

hydrostatic pore lithostatic
Gas Resource in Place
Validation

Measured gas content
Average 200 scf/ton
Maximum 275 scf/ton

Modeled gas content
Average 220 scf/ton
Maximum 280 scf/ton
Summary – Haynesville Shale Play

• In-place resource estimates are similar to those established after extensive drilling in the Haynesville shale play
• Valid approach for exploration early in the life of unconventional resource plays
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Alaska North Slope Model
Geological History: Reconstructed Brookian sequence
Alaska North Slope - 3D Petroleum Systems Model

Geological History:  

Reconstructed Brookian sequence
Alaska North Slope - 3D Petroleum Systems Model

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Geological History: Reconstructed Brookian sequence
Geological History:  

*Reconstructed Brookian sequence*
Alaska North Slope - 3D Petroleum Systems Model

Geological History: 

Reconstructed Brookian sequence
Alaska North Slope - 3D Petroleum Systems Model

Geological History: Reconstructed Brookian sequence
Alaska North Slope - 3D Petroleum Systems Model

Geological History: Reconstructed Brookian sequence
Geological History:  

Reconstructed Brookian sequence
Geological History:  

Reconstructed Brookian sequence
Alaska North Slope - 3D Petroleum Systems Model

Geological History: Reconstructed Brookian sequence

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041
055
060
065
075
085
097
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110
115
120
Alaska North Slope - 3D Petroleum Systems Model

Geological History:  

Reconstructed Brookian sequence
After first Tertiary uplift
After second Tertiary uplift
After third Tertiary uplift
Play Chance Mapping – COS Depth

*Depth map from 3D petroleum systems model; simple transform of depth values to COS*
Maturation (%Ro) map from 3D petroleum systems model; transform function to COS.
Shublick Shale Oil Play, Alaska
Shublick Maturity and Hydrogen Index

(overlay figure from Peters and others, 2006)

From Decker, 2011
Great Bear – Initial Drilling Results

“Duncan said he determined what leases to purchase and where to drill test wells using a model of the North Slope petroleum system developed by Schlumberger … based on science done by the U.S. Geological Survey and Stanford University. The model had proved successful in explaining the mix of oils found in North Slope fields. The model had predicted the locations of "liquids fairways" in the source rocks, and the drilling results so far have substantiated those predictions, Duncan said.”

http://www.adn.com/2012/09/22/2636242/great-bear-wants-to-speed-up-shale.html#storylink=cpy
Agenda

- Introduction
  - Understanding geology and technology is key

- Exploration tools
  - Wellbore characterization
  - Emerging seismic methods
  - Petroleum system modeling

- Models to improve success
  - Exploration phase – getting the right acreage early in play
    - Data-poor example: Haynesville gas play
    - Data-rich example: Alaska oil play

- Conclusions
Conclusions

- Shale plays rely on finding areas where conventional source rocks may be directly exploited as unconventional reservoirs.
- Economic exploitation of shale resource plays requires an understanding of both geology and technology.
- Petroleum systems modeling provides an integrated framework to estimate resource richness early in the life of unconventional plays.
- More work required to investigate stratigraphic variation within and adjacent to source rocks.