Petroleum geochemistry and basin modeling, also known as petroleum systems analysis, are used along the entire subsurface value chain from exploration to production. Traditionally these disciplines have been applied mainly in Regional Exploration and Prospect Evaluation to evaluate source rock properties, charge and fluid property risk. Exploration wells have for decades been a key way to acquire data on source rock properties and thermal maturity, which are used in further evaluation of a basin. Fluid data from discovery wells are used to calibrate basin models, as well as in Appraisal and Development. Geochemistry plays a key role in the assessment of failure in dry holes, which can be critical in evaluation of remaining prospectivity in a basin. A detailed fluid property description across a field from geochemical and PVT fluid data, combined with a thorough filling history from basin modeling, can be used in Appraisal and Development of a field to help assess connectivity and compartmentalization. These data can also help predict the likelihood of compositional grading, tar mats, flow assurance issues (wax, asphaltenes and organic soaps), and biodegradation (heavy oil). Petroleum geochemistry can be used to help address a wide range of Production issues. These include routine monitoring, allocation, casing issues, water injection problems, compartmentalization, H₂S generation or tar mobilization in heavy oil fields. This is probably the main area where geochemistry is currently underutilized. Basin models have been mainly used in the past as a “one way” technology, where the output is the end product, and not used routinely to model at field scales. However, this has slowly changed over the last two decades, as basin modeling has become more integrated into an iterative, full cycle workflow. Rock properties from seismic are fed into basin models, and pore pressure predictions back into seismic until the pressure and rock properties are in agreement. Reservoir quality prediction on a prospect scale uses basin modeling derived pressure and temperature (p-t) histories as inputs to a reservoir quality models, which are used to either predict porosity, or evaluate if the p-t history can explain the measured porosities. An overview of these synergetic technologies and workflows, and their importance in constraining many subsurface uncertainties, will be presented using published and in house examples.
Selected References


The Whys and Wherefores of Geochemistry and Basin Modeling from Exploration to Production

Richard Patience & Friedemann Baur

APT

Chevron
Petroleum System Studies – Why and Where?

**Upstream Value Chain**
- **Exploration**
  - Basin & Play Analysis
  - Prospect Evaluation
  - Drilling
- **Discovery Appraisal & Development**
- **Production**

**Main component**
- Effective source
- Petroleum migration
- Petroleum properties
- Field wide controls on fluid and rock properties
- Fluid composition
- Fluid “issues”

**Geochemistry**
- SR presence, character & maturity data
- Oil-source-correlations
- Analog fluid studies
- Filling history
  - Connectivity
  - Compositional grading
  - Flow assurance
- Monitoring
  - Problem solving

**Basin Modeling**
- SR maturity
- HC migration, entrapment & alteration
- Fluid properties prediction
  - P,T prediction
- Reservoir quality support
  - Integrated filling history
- NA
Outline

Applications of Geochemistry and Basin Modelling in:

1. Exploration (Frontier to Drilling)
2. Appraisal and Development
3. Production
Exploration – Geochemistry and Basin Modeling = HC Charge Evaluation

**Hydrocarbon (HC) Generation**
- Source presence,
- Source properties
- Source maturation & generation

**HC Migration and Accumulation**
- Expulsion efficiency
- Migration
- Entrapment

**HC Properties, Volumes & Sensitivity**
- P,T reservoir conditions
- Timing of migration relative to trap formation, seal competence, alteration (filling history)

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**Vitrinite Reflectance Ro [%]**

**Migration Pathways & Accumulations**

**GOR vs Depth Plot**

**Sensitivity HC Volumes**
- Maturity
- Fetch Area
- SR Thickness
- Timing relative...
- Migration Eff.
- Preservation

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**GOR m3/m3**
Integrated Exploration – Basin Modeling Pressure Prediction

Traditional Approach

**Offset Wells**

- Velocity data
  - Sonic, checkshots
- Pressure data
  - DST, MDT
- Checkshot calibrated velocity cube
- Seismic velocity derived pressure prediction
- Pressure calibrated basin model
- Basin model derived pressure prediction

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Northern Møre Basin, Norway
Prospect located 75 km northwest of Ormen Lange field

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Doyle et al. (2003), SPE/IADC 79848, 1-7

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<table>
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<td>Seismic Velocities</td>
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An unconventional play is not very unconventional geochemically

- TOC
- Pyrolysis (Rock Eval)
- Vitrinite reflectance
- Gas data

Additional unconventional specific data such as...

- Organic porosity,
- Adsorption and expulsion

It is analogous to starting a review of a conventional basin or play

Applications of Geochemistry and Basin Modelling in:

1. Exploration (Frontier to Drilling)
2. Appraisal and Development
3. Production
Variations in fluid properties due to:
- Filling history (may = disequilibrium)
- Post-filling mixing (may = equilibrium)
- Alteration (biodegradation)

Reflected in properties such as:
- Asphaltenes
- GOR
- Density
- Viscosity
- GC fingerprints
- Biomarkers
- Gas isotopes
- Etc.

Connected? or Compartmentalized?
Need multiple data points

Ratulowski et al. (2003), SPE84777 Res Eval & Engineering, 168-175
A&D – Effect of Filling and Mixing Processes on Fluid Composition

“Filling history” → Post-Filling mixing → “Equilibrium”

1, 2, 3: Gradual vertical change
- Compositional grading
- Communication

4: Abrupt lateral change
- Barrier

Compositional gradients

Oil leg
Transition zone
Water leg

Bacterial activity

Peace River Oil Sands, Alberta, Canada

Bennett et al. (2013), Organic Geochemistry 56, 94–105
A&D – Effect of Compositional Grading on OWC

Conclusion:
- Wells are in communication (over geological time)
- Fluid has the same density throughout
  - Density = Pressure Gradient/K

Asphaltene gradient in the Tahiti Field, GOM

Freed et al. (2010), Energy & Fuels 24, 3942-3949
• Understand filling, equilibration and alteration history
• Integrate fluid geochemistry and PVT, pressure, rock data

Modified using Slide 18 in:
www.slideshare.net/romance13/practical-wellbore-formation-test-interpretation-120009-2009
Talk by B. Cribbs at AAPG Geoscience Technology Workshop, Houston, 2009
Most fields are charged from kitchens with spatially varying maturities.

When field compartmentalization occurs concurrently with filling, different fluids are expected in different compartments.

Basin models and geochemistry can predict fluid properties in undrilled compartments, including biodegradation risk.

Guthrie et al. (2012), AAPG Hedberg Series no. 4, 159-174
A&D – Basin Modeling Reservoir Quality Support

**Basin Model Effective Stress & Temperature for Well / Prospect**

**Case Study**

**Pre-Drill Prediction**

**Post-Drill Results**

*Predicted Petrography & Paragenesis*

*Touchstone™ (Qz cement kinetics)*

*Final Qz Cement prediction in %*

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Outline

Applications of Geochemistry and Basin Modelling in:

1. Exploration (Frontier to Drilling)
2. Appraisal and Development
3. Production
• Oil fields A, B, C, and D have produced **black oil** and taxed as normal.
• Oil fields E and G now produce **gas/condensate**; tax exempt for the first two years.
• Flow meter only installed on pipeline P5.

Hwang et al. (2000), Organic Geochemistry 31, 1463-1474
• Behind casing pressure due to breaks (authority threatens closure)
• Tar flowing to the surface during steamflooding (lost wells, environmental concern)
• No flow from water injector due to unknown tar mat (waste of time & money)
• Solids problems
  • Unexpected organic soap formation (scale) due to interaction of water and oil
  • Hydrates, Wax, Asphaltenes

Origin of similar tar mat in nearby field discussed in Dahl & Speers (1986), Organic Geochemistry 10, 547-558
Petroleum geochemistry and basin modeling address a wide range of issues from exploration to production. These tools are well established in exploration of both conventional and unconventional plays:

- Source properties and maturity on a basin and play level
- Prediction of likely phase and potential fluid properties for prospects
- Temperature, pressure and effective stress prediction

In appraisal and development, these tools can help explain the reasons for, and make quantified predictions of, variations in fluid and rock properties:

- Filling history, post-filling alteration
- Compositional grading vs. compartmentalization
- Reservoir rock quality

And many production issues can be addressed:

- Routine monitoring
- Solving a wide range of problems