Abstract

As the demand for fossil fuels continues to grow and fields mature, hydrocarbon resource characterization has become increasingly important. Optimal valuation and exploitation of a field requires a realistic description of the reservoir, which in turn requires integrated reservoir characterization and modeling using all the available data and rigorous quantification of the uncertainty. Based on our research and experience with worldwide hydrocarbon resource characterization projects, we present a historical review of various phases of petroleum geology and reservoir characterization, which illustrates how the challenges were met in the past and what new technologies will be emerging in the future. Important past developments include the transition from general petroleum geology to reservoir geology, from disciplinary-focused reservoir description to integrated reservoir characterization, from 2-D subsurface mapping to 3-D reservoir modeling, and from reservoir deterministic analysis to uncertainty analysis. With emergence of unconventional resources and the maturation of many of the world's conventional fields, an integrated, multidisciplinary approach using new innovative technologies, including all the geoscience and engineering disciplines, is even more critical to meet the challenges posed in developing these fields.

References Cited


Hydrocarbon Resource Characterization and Modeling: Past, Present and Future

Y. Zee Ma, Ernie Gomez, Barbara Luneau, William Clark,* Mike Du

Schlumberger – PTS, Denver, CO 80202
Outline

• Previous methods of interpretation

• Present methods
  – Example: Rocky Mountain tight sand reservoir

• What’s next
  – Unconventional reservoirs

• Summary
Where have we been?

**Last 30 years**

E&P technology and business cycles

- 2D, 3D Seismic, seismic stratigraphy
- Sequence stratigraphy
- Geostatistics
- Reservoir simulation
- Drilling and logging breakthroughs
- Rapid changes in computing

**Last 5 years**

Integrated Reservoir Modeling

- PC based modeling packages
- From seismic to reservoir simulation

Seismic stratigraphy, interpretation ...

Geostatistics, stochastic reservoir modeling

Reservoir Simulation
What are we doing?

Integrated Reservoir Modeling

- Integrating multiple disciplines
- Integrating various data sources
- Integrated reservoir modeling platform

Geologic modeling and reservoir simulation in one platform

Reservoir Characterization/Modeling as a core facilitator in field development

- Reservoir model is a basis for field planning.
- Living model as resource repository
- An example is now presented

Yu et al., 2001
Rocky Mountain Tight Gas Sand Example

Tertiary

Cretaceous

Cell size: 100 x 100 x 5 ft
Model size: 6 million cells

Ma et al., 2011
Predicted Log Facies versus Core Facies

- Use GR and Resistivity logs to predict facies
- Prediction versus reality
- Log response matches well with logs
Fluvial Object-based Modeling Workflow

Parameter specification

Trend maps

Seismic attributes

Facies fraction is honored
Facies Model Stacking Patterns
Petrophysical Property Relationships Based on Well Logs

\[ R = -0.86 \]

\[ R = 0.87 \]

\[ R = -0.91 \]
Petrophysical Property Modeling Workflow

OBM Fluvial Facies by Unit

PHI: SGS by Unit & Facies

SW: CoCoSim with PHI by Facies & Units

Kbp: CoCoSim with PHI by Facies & Units

Geostatistical Methods Used

- SGS: Sequential Gaussian Simulation
- CoCoSim: Collocated Co-Simulation
Porosity Modeling

Facies Model

Porosity

SGS

NW  SE

SW  NE

Major: 1000ft
Minor: 700ft
20ft
Permeability Modeling

Porosity

CoCoSim

Permeability

R = 0.87
Where are we heading?

• Unconventional reservoirs demand greater integration, earlier
  - Reservoir and completion quality
• Broader deployment of modeling in production and completion design (hydraulic fracturing)
• Fast track reservoir modeling in field development
• Quantify impact of uncertainty on performance predictions
• Real time reservoir management with reservoir modeling a core facilitator
• Every field has a living model (conventional and unconventional)
• No boundary between geoscience and engineering models
# Shale Resource Assessment

## Characterizing Controls on Reservoir Productivity

### Defining Reservoir Quality
- Hydrocarbon in place
- Porosity/Permeability
- Organic content and Maturation
- Pore Pressure

### Defining Completion Quality
- Fracture Containment (anisotropy, in-situ stress)
- Rock mechanics (surface area per reservoir volume)
- Ability to retain surface area
- Fracture conductivity
- Fluid sensitivity

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**Reservoir Quality + Completion Quality = Economic Success**
# Production Drivers and Well Measurements: Assessing Data Gaps

<table>
<thead>
<tr>
<th>Production Driver</th>
<th>Why is it important</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir quality (porosity, permeability, saturation)</td>
<td>Hydrocarbon storage, oil-in-place, and matric contribution to flow</td>
<td>Triple combo, NMR, lithology and mineralogy logs, core calibration, seismic inversion</td>
</tr>
<tr>
<td>Structure (fractures and structural complexity)</td>
<td>Fractures provide system permeability and reservoir connectivity, structure impacts ability to stay in zone</td>
<td>Conventional and LWD image logs, dipole sonic anisotropy, 3-D seismic and attributes</td>
</tr>
<tr>
<td>Charge access</td>
<td>Thermal maturation impacts fluid properties and pore pressure</td>
<td>Lithology and mineralogy logs</td>
</tr>
<tr>
<td>Fluid properties and pressure</td>
<td>Downhole pressure, oil properties</td>
<td>PVT and in-situ pressure sampling</td>
</tr>
<tr>
<td>Geomechanics</td>
<td>Stress orientation and magnitude for fracture containment, achieving transverse hydraulic fractures, wellbore stability</td>
<td>3-D sonic measurements, mechanical earth modeling, microseismic monitoring, seismic inversion</td>
</tr>
<tr>
<td>Well Placement</td>
<td>Intercept best quality reservoir for production, optimal stimulation, avoiding near-wellbore pinch-off</td>
<td>Vertical and lateral well placement from high-end depth imaging, real-time geosteering with image logs</td>
</tr>
<tr>
<td>Well performance</td>
<td>Validation of hydraulic fracturing success and need for well placement</td>
<td>Production logging (vertical and horizontal), correlation of seismic attributes with production</td>
</tr>
</tbody>
</table>
Unconventional Resource Assessment Workflow

Production Drivers

1. Structure
   - Seismic Grid

2. Reservoir Quality
   - Petrophysics Rock Classes

3. Charge
   - Maturity Temperature

4. Completion Quality
   - Pressure Stress

3-D Data Integration

- Rock Quality
- Rock Properties
- Completion Quality

Ranking/Pilot Selection

Lateral Target ID and Rank
Delineating “Sweet-Spots” with Seismic Attributes

Integration of petrophysical log data, completions and seismic to select drilling locations and explain production

Kaufman, et.al., 2013
SPE 164345
Completion and Development Workflow

Stress State and Completion Strategy

- How to complete
- Number stages
- Fluid and proppant

Development Strategy

- Spacing
- Timing

Production Mechanism
Summary

• Modeling is being used throughout the life cycle of the field
  - Resource assessment (appraisal)
  - Field development
  - Completions

• Unconventional reservoirs demand greater integration, earlier

• Broader deployment of modeling in production and completion design (hydraulic fracturing)

• Understanding of reservoir and completion quality critical in economic success of unconventionals