SPE 139101
Fast Track Reservoir Modeling of Shale Formations in the Appalachian Basin. Application to Lower Huron Shale in Eastern Kentucky

O. Grujic, S.D. Mohaghegh, G. Bromhal

The research was performed in support of the NETL-RUA, Project # 4000.4.650.920.004
Outline

• Introduction
• Lower Huron Shale
• Data Preparation
• Conventional Reservoir Simulation vs. Top Down Reservoir Modeling
• Top Down Reservoir Modeling - Workflow
• Fuzzy Pattern Recognition
• Predictive model development
• Performance prediction of future wells.
• Acknowledgements
Introduction

- 77 Wells, all completed in Lower Huron Shale (Big Sandy Gas Field), were used in this study;

- Production was history matched with Fracgen/Nfflow Simulator;

- Top Down Reservoir Modeling was performed on the studied area.

- Predictive models were developed.
Location of the Study Area

- Producing localities
- Distribution of thick and deep shale
- Thickness $\geq 100$ and Depth $\geq 1000$
- Shale is present in subsurface

Big Sandy Gas Field
Lower Huron Shale

- Highly organically rich, dark, fine laminated, naturally fractured shale;

- Porosity (core measurements) is from 1 to 5%;

- Permeability (core measurements) is in the range of $10^{-7}$ to $10^{-9}$ md;

- Natural fracture occurrences:
  - North – South fracture set (dominant);
  - East – West fracture set (secondary).

- Well logging (typically GR, and RHOB curves are recorded)
Data Preparation

- Well log interpretation (thickness and porosity estimates);
- Single Well History Matching with Fracgen/Nflow Simulator;
  - Fracture Networks were generated for 40, 60, 80, 120, 160, 240 Acres.
  - Two fracture sets: N-S, E-W, matrix properties were changed within the range found in the literature.
Conventional Res. Simulation vs. Top Down RM
# Modeling - History Matching - Forecasting

<table>
<thead>
<tr>
<th>INPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
</tr>
<tr>
<td>Well X/Longitude</td>
</tr>
<tr>
<td>Well Y/Latitude</td>
</tr>
<tr>
<td>Well Depth (ft)</td>
</tr>
<tr>
<td>Well GR Response (API)</td>
</tr>
<tr>
<td>Well Type Curve - Permeability</td>
</tr>
<tr>
<td>Well Total Fluid Injected (bbl)</td>
</tr>
<tr>
<td>Well Total Propped Interval</td>
</tr>
<tr>
<td>Well q(t-1)-Gas</td>
</tr>
<tr>
<td>Well q(t-2)-Gas</td>
</tr>
<tr>
<td>Well q(t-3)-Gas</td>
</tr>
<tr>
<td>Offset Producer Well 1 Distance</td>
</tr>
<tr>
<td>Offset Producer Well 1 Depth (ft)</td>
</tr>
<tr>
<td>Offset Producer Well 1 q(t-1)-Gas</td>
</tr>
<tr>
<td>Offset Producer Well 2 q(t-1)-Gas</td>
</tr>
</tbody>
</table>
Modeling - History Matching - Forecasting

![Graph showing gas rate and cumulative production over time with markers for history match and forecast.](image)
Modeling - History Matching - Forecasting

Field Gas Rate

- History Match
- Forecast

- Real Production Rate
- Top Down Model Prediction
- Real - Cumulative Gas
- Top Down Model - Cumulative Gas
- Number of Active Wells
- Fuzzy Pattern Recognition
- Predictive Modeling

- Decline Curve analysis
- Type Curve Matching (Cox et. al)
- Geostatistics
- Fuzzy Pattern Recognition
- Predictive Modeling

$\frac{Q_i}{D_i} = 1812; \quad \frac{b}{D_i} = 0.0168; \quad b = 2.912$

EUR = 317.55

Net Pay (ft)

Porosity - logs

Porosity - HM
Fuzzy Pattern Recognition

- Large Spatio-Temporal database was build in previous steps.
- 2 Dimensional Fuzzy Pattern Recognition is applied on the database (Lat – Long)
- Reservoir is delineated into 5 zones of different quality
- Model is calibrated with the latest drilled wells.
Fuzzy Pattern Recognition
Fuzzy Pattern Recognition - Calibration

- 4 wells were removed from the analysis (last drilled wells).
- FPR was applied to 1st year cumulative production in order to predict average 1st year cumulative production of the removed wells.
- Model was capable of predicting average 1st year cumulative production of the removed wells.

<table>
<thead>
<tr>
<th>RRQI</th>
<th>More Than</th>
<th>Less Than</th>
<th>Average 1 Yr Cum.</th>
<th># of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>39,923.10</td>
<td>39,923.10</td>
<td>33,902.57</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>27,313.98</td>
<td>39,923.10</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>18,750.49</td>
<td>27,313.98</td>
<td>22,018.31</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>16,337.87</td>
<td>18,750.49</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>16,337.87</td>
<td>16,337.87</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
Predictive Model Development

- Artificial neural networks were trained with:
  - Reservoir properties (from well logs, type curve matching)
  - Decline curve parameters
  - Properties of the offset wells
Performance of Future Wells

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Qi (MCF/m)</th>
<th>Di</th>
<th>b</th>
<th>EUR (MMCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Well 1</td>
<td>2384.65</td>
<td>0.02</td>
<td>3.77</td>
<td>457</td>
</tr>
<tr>
<td>New Well 2</td>
<td>2723.24</td>
<td>0.02</td>
<td>2.15</td>
<td>412</td>
</tr>
<tr>
<td>New Well 3</td>
<td>2996.23</td>
<td>0.03</td>
<td>3.48</td>
<td>504</td>
</tr>
<tr>
<td>New Well 4</td>
<td>2261.67</td>
<td>0.02</td>
<td>3.16</td>
<td>404</td>
</tr>
<tr>
<td>New Well 5</td>
<td>2349.62</td>
<td>0.02</td>
<td>1.99</td>
<td>343</td>
</tr>
</tbody>
</table>
Acknowledgements

The research was performed in support of the NETL-RUA

Authors would like to acknowledge:

• NETL/DOE for financially supporting this project (Project # 4000.4.650.920.004), and providing the Fracgen/NFlow software package;

• Equitable Resources (EQT) for providing the well production data;

• Intelligent Solutions Inc. for providing the IPDA, EPIQ and IDEA software packages.
Questions???