Geologic model for the giant Hugoton and Panoma Fields

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Midcontinent AAPG, Oklahoma City
September 13, 2005
Objectives of modeling project

**Objective:** Build 3D cellular model populated with lithofacies and petrophysical properties

**Purpose:**

1. Identify and quantify remaining gas in order to develop best field practices for efficient recovery.
2. Study sedimentary response to rapid glacio-eustatic sea level fluctuations on an extremely gently sloped ramp (shelf).

More specifically, and in conjunction with simulations studies:

- Estimate *original gas in place* at well, region and field scales
- *Reservoir connectivity* at pore, flow unit, well, inter-well, region and field scales
- *Differential depletion* in stratigraphically separate reservoirs
- *Production decline rates and EUR* at ultra low pressures
Status and outline

Modeling project status:
- Township scale models have been built and tested by numerical simulation
- Components are in place for building field-wide cellular model and work is underway

To be covered today:
- Model workflow
- Major lithofacies and depositional model
- Large scale geometry of Hugoton and Panoma
- Lithofacies in maps and cross sections

(Field 3D model not yet complete but plenty to see)
Hugoton and Panoma Stratigraphy

Thinly layered, alternating carbonate and siltstone reservoir in 13 marine-nonmarine sedimentary cycles

Chase Group (Hugoton)

Council Grove Group (Panoma)

L. Permian

Harrington
Kriger
Winfield
Towanda
Ft Riley
Florence
Wreford
Funston
Crouse
Middleburg
Eiss
Morrill
Cottonwood
Neva
Geomodel Workflow (static model)

**Gather data**
- CORE & ELog Var.

**Neural Net** → **NODE WELLS** → **Stochastic Methods** → **3D MODEL**

1400 “Node” Wells

Train Neural network and predict lithofacies in non cored wells (nodes)

Lithofacies in core tied to log and geologic constraining variables

Fill volume between node wells using stochastic methods
Develop dynamic model through empirical relationships


Dubois, Byrnes et al., 2003
Lithofacies from Core to “Node” Wells

Training set for neural network lithofacies prediction

<table>
<thead>
<tr>
<th>Well count</th>
<th>1/2 foot intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>3952 Chase</td>
</tr>
<tr>
<td>10</td>
<td>4593 Council Grove</td>
</tr>
</tbody>
</table>

8545 ½-foot intervals with lithofacies tied to log and core properties

Some wells have both Chase and Council Grove core

Lithofacies predicted at 1369 “node wells”
Neural Network Training and Predictions

Distribution of lithofacies predicted in 1369 wells is similar to that in training set.

<table>
<thead>
<tr>
<th>Facies</th>
<th>Council Grove</th>
<th>Chase</th>
<th>All</th>
<th>1369 Wells Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Continental</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandstone</td>
<td>8%</td>
<td>4%</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>Coarse Silt</td>
<td>28%</td>
<td>23%</td>
<td>23%</td>
<td>20%</td>
</tr>
<tr>
<td>Fine Silt</td>
<td>24%</td>
<td>4%</td>
<td>13%</td>
<td>8%</td>
</tr>
<tr>
<td><strong>Marine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siltstone</td>
<td>9%</td>
<td>7%</td>
<td>8%</td>
<td>10%</td>
</tr>
<tr>
<td>Carb Mdst</td>
<td>7%</td>
<td>5%</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>Wackestone</td>
<td>18%</td>
<td>13%</td>
<td>14%</td>
<td>19%</td>
</tr>
<tr>
<td>Fxln Dol.</td>
<td>4%</td>
<td>2%</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Packstone</td>
<td>15%</td>
<td>17%</td>
<td>15%</td>
<td>23%</td>
</tr>
<tr>
<td>Grainstone</td>
<td>4%</td>
<td>1%</td>
<td>2%</td>
<td>0%</td>
</tr>
<tr>
<td>M-Cxln Dol.</td>
<td>0%*</td>
<td>12%</td>
<td>6%</td>
<td>4%</td>
</tr>
<tr>
<td>Sandstone</td>
<td>0%**</td>
<td>12%</td>
<td>5%</td>
<td>6%</td>
</tr>
</tbody>
</table>

* Insufficient training sample. Combined with Fxln Dolomite
** Insufficient training sample. Combined with Siltstone.

**Distribution of eleven lithofacies in training set**

- M-Cxln Dol: 6%
- MM SS: 5%
- Cont SS: 6%
- Cont Crs Slt: 23%
- Cont Fn Slt: 13%
- Mar Slt: 8%
- Wkst: 14%
- Mdst: 5%
- Fxln Dol: 4%
- Grnst: 2%
- Pkst: 15%
- Cont Slt: 13%

**Training vs Predicted**

- Training: 42% Sandstone, 30% Coarse Silt, 27% Fine Silt, 31% Marine Siltstone, 37% Carb Mdst, 27% Wackestone, 33% Fxln Dol, 23% Packstone, 4% Grainstone, 4% M-Cxln Dol, 6% Sandstone.
- Predicted: 30% Sandstone, 20% Coarse Silt, 19% Fine Silt, 33% Marine Siltstone, 33% Carb Mdst, 33% Wackestone, 37% Fxln Dol, 23% Packstone, 4% Grainstone, 4% M-Cxln Dol, 6% Sandstone.
Unique Chase Lithofacies

Two additional lithofacies plus same nine as in Council Grove but in different proportions. No phylloid algal facies.

Dolomitized medium to coarse-grained ooid and bioclastic grainstone are the dominant reservoir facies in Chase.
Reservoirs of Hugoton and Panoma Fields were deposited on a very gently dipping shelf. Relief was much less than it is today.
Carbonate thins toward updip field margin
Redbeds thin basinward
Eolian sands at west margin
Council Grove thinnest at mid-shelf
Similar sedimentation patterns in Chase and Council Grove

<table>
<thead>
<tr>
<th>Chase</th>
<th>Gross interval</th>
<th>“Continental”</th>
<th>Net Marine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>220'</td>
<td>150'</td>
<td>70'</td>
</tr>
<tr>
<td></td>
<td>400'</td>
<td>30'</td>
<td>370'</td>
</tr>
<tr>
<td></td>
<td>210'</td>
<td>170'</td>
<td>40'</td>
</tr>
<tr>
<td></td>
<td>Thinnest Midshelf</td>
<td>250'</td>
<td>220'</td>
</tr>
<tr>
<td>Council Grove (thru B5_LM)</td>
<td>210'</td>
<td>170'</td>
<td>40'</td>
</tr>
</tbody>
</table>

Series of slides based on facies predicted by Nnet in 1369 wells
Mean Lithofacies in Marine Intervals

**Facies 3-10**
Mean $F = 6.7$ SD = 0.9
F10 dominates west margin

**Facies 3-9**
Mean $F = 5.8$ SD = 0.6

**Facies 3-9**
Mean $F = 5.8$ SD = 0.9
F9 dominates south

**Facies 3-9**
Mean $F = 5.4$ SD = 0.4
F6 dominates to NE
F7 dominates to SE

Shown are the mean code value for lithofacies predicted by neural network models in 1350 wells.
Main “Pay” Lithofacies in Chase (F7-9)

Herrington
Krider
Winfield
Towanda

(Herrington through Gage)

Net thickness
Facies 7 thru 9

Net / Gross
Facies 7 thru 9

Krider only PhiH for F9

Phi x H for Facies 9
Cutoff phi >15%

Accumulation of coarse-grained bioclastic-ooid sand associated with bathymetry of embayment near the shelf margin
Krider Ooid shoal facies in Stevens County

10 foot divisions

Close-up Core Slab

Thin Section

Crs XLN Dolomite (CG oo-grnst)

22.3%

275 md

2 cm

1 Coarse Silt

3 Siltstone

4-5 Mdst-Wackestone

7 Pack-Grainstone

9 M-Cxln Dol.

10 Sandstone
Cottonwood (B5_LM) Phylloid Algal Mounds

Phylloid Algal Bafflestone

Core Slab

L8

20.6%

1141 md

Net H, F7-8, Phi >10%

0 Sandstone
1 Coarse Silt
2 Fine Silt
3 Siltstone
4-5 Mdst-Wackestone
6 Fxln Dol.
7-8 Pack-Grainstone
Crouse (B1_LM) fine-crystalline dolomite lithofacies

F6-8, phi > 8%, Net/Gross

Dolomite
13.9%
1.1 md

Core

0 Sandstone
1 Coarse Silt
2 Fine Silt
3 Siltstone
4-5 Mdst-Wackestone
6 Fxln Dol.
7-8 Pack-Grainstone
Net thickness, phi >15%

Fine-grained sandstone in lower Council Grove is pay in Texas County
Eolian sandstone Council Grove

Continental sandstone thickness

Cum. Prod. 1.5 BCF

Dubois and Goldstein, 2005
Summary

- **Township scale models** have been built and tested by numerical simulation.
- **Components** are in place for building **field-wide cellular model** (underway).
- **Neural network models** are proving effective in facies predictions and building an accurate geomodel.
- We anticipate being able to successfully delineate remaining gas in place in the Hugoton and Panoma Fields.
Acknowledgements

We thank our industry partners for their support of the Hugoton Asset Management Project and their permission to share the results of the study.

Anadarko Petroleum Corporation
BP America Production Company
Cimarex Energy Co.
ConocoPhillips Company
E.O.G. Resources Inc.
Medicine Bow Energy Corporation
Osborn Heirs Company
OXY USA, Inc.
Pioneer Natural Resources USA, Inc.

also geoPlus (Petra) and Schlumberger (Petrel)