Reservoir Pressures Suggest Communication between Hugoton and Panoma Fields and Provide Insights on the Nature of the Connections

Martin K. Dubois¹, Alan P. Byrnes¹ and Richard Brownrigg²
¹Kansas Geological Survey, ²EECS Dept., University of Kansas

Midcontinent AAPG, Oklahoma City
September 13, 2005

http://www.kgs.ku.edu/HAMP/index.html
Kansas Development History

1950's
- 4000 wells (Hugoton)
  - Hugoton (Chase)
  - Panoma (Council Grove)
- Thinly layered, alternating carbonate and siltstone reservoir in 13 marine-nonmarine sedimentary cycles

1970's
- 3500 wells (Hugoton infill)
- 2300 wells (Panoma)
- No Hugoton infill wells in Oklahoma

1990's
- 2300 wells (Panoma)
- 550 feet, 13 zones

Map showing Kansas and Oklahoma with key areas labeled (Chase, Council Grove, Panoma).
Stacked reservoir systems are recognized as separate fields and regulated separately. However, several authors have suggested that they at least filled as one reservoir system:

- **Pippin** (1985) shows a common gas/water contact
- **Sorensen** model (2005) implies a common reservoirs system during gas migration

Panoma (below) is only productive in highest portion of field. Gas column is continuous between Chase and Council Grove in Panoma area.

Note: colors are reversed in Pippin x-section.
### Conflicting observations

<table>
<thead>
<tr>
<th>Observations</th>
<th>Suggesting vertical communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hugoton and Panoma pressures generally track one another</td>
<td>Suggesting little or no vertical communication</td>
</tr>
<tr>
<td>Both are layered reservoirs with differential depletion (pressure)</td>
<td></td>
</tr>
<tr>
<td>Rocks separating Chase from Council Grove (Speiser Shale) are same as those separating pay zones within either the two groups</td>
<td>Chase is no more sealed from (or communicated with) Council Grove than is the Towanda sealed from the Ft. Riley, for example.</td>
</tr>
<tr>
<td>DST calculated permeability in science wells approximate core matrix permeability</td>
<td>Rules out pervasive, closely spaced naturally fractured reservoir, at least at locality</td>
</tr>
</tbody>
</table>
Four Basic Permeability Models

Matrix-driven: well performance and field pressure history consistent with matrix properties

Local matrix/Large-scale fractures: well performance consistent with matrix properties, field pressure history indicates large-scale communication

Local matrix/random small-scale fracture/large-scale fractures: well performance consistent with matrix properties in some beds and fracture influence in others, field pressure history indicates large-scale communication

Fracture-driven: well performance and field pressure history inconsistent with matrix properties, field pressure history indicates large-scale communication
Possible conduits *(if in communication)*

1. Naturally occurring, large scale, regional system of large fractures or swarms of smaller fractures
2. Artificial, hydraulic fracture treatments introduced during well completions
3. Both

Another bit of relevant info:
- Permeability of silts between the carbonate and sandstones ~ $10^{-5}$ to $10^{-7}$ md
- Sufficient for gas migration over centuries
- Not for equilibration over years to decades.

*Evidence for communication is strong, but the jury is still out on the nature/cause for communication*
## Pressure data available

<table>
<thead>
<tr>
<th>Main types</th>
<th>Utility</th>
<th>Shortfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 72 hour well head shut in pressure (WHSIP) Extensive in Kansas and Oklahoma.</td>
<td>Connectivity within and “between” reservoirs at various scales</td>
<td>Commingled, equals lowest pressured zone</td>
</tr>
<tr>
<td>2. Long term (equilibrated) buildup Abundant locally, absent otherwise.</td>
<td>Implications on ultimate recovery and field life</td>
<td>Dense data but only in one area</td>
</tr>
<tr>
<td>3. Pressure by zone (layer) through time Modest amount of data.</td>
<td>Critical for estimating remaining GIP and simulation</td>
<td>Minimal scattered data</td>
</tr>
</tbody>
</table>
Similar pressure histories suggest Hugoton and Panoma Fields are connected in Kansas.

- **Initial Hugoton WHSIP**: 435 psia
- **Early Panoma initial well pressure**: low and ~ to Hugoton
- **Later Panoma initial well pressure parallels Hugoton

<table>
<thead>
<tr>
<th>Field</th>
<th>Disc. Yr</th>
<th>Prod. Yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hugoton</td>
<td>1928</td>
<td>1944</td>
</tr>
<tr>
<td>Panoma</td>
<td>1958</td>
<td>1970</td>
</tr>
</tbody>
</table>
Hugoton & Panoma Composite WHSIP
Grant County, Kansas

Hug-Parent WHSIP
Hug-Infill WHSIP
Panoma WHSIP

Hug-Parent Data Count
Hug-Infill Data Count
Panoma Data Count

Pressure Data Counts

2004 Well Count
562 Hugoton Parent Wells
573 Panoma Wells
587 Hugoton Infill or Replacement Wells
Interference with Panoma by Hugoton Infill wells?

Change in slope in the P/Z vs. cumulative gas indicates a possibility of interference after 1992, roughly coincident with the addition of nine Hugoton infill wells.

Data is from wells in 9 contiguous units
Hugoton & Panoma Composite WHSIP vs. Cum Gas
Grant County, Kansas

\[ y = -61.67x + 411.84 \]
\[ R^2 = 0.9927 \]

(Annual data from 1969)

Change in slopes probably indicates interference by successive generations of wells added.

Impact of Hug-infill
Impact of Hug-infill & Panoma
Combined

Hug-Parent + Panoma + Hug-Infill
Hug-Parent + Panoma
Hug-Parent
WHSIP vs. Cumulative Gas
(same 9 section area as before)

\[ y = -4.6087x + 382.69 \]
\[ R^2 = 0.9723 \]

Pattern of interference observed at many scales (well, multiwell, and county)
WHSIP does not accurately reflect BHP for all layers, but may to be proportional to overall depletion.

WHSIP does not equilibrate

72 Hour WHSIP is readily available but is misleading
- Pressure \( \approx \) that of highest permeability zone (lowest pressure)
- Insufficient time to equilibrate

72 hour WHSIP \( \sim 30 \text{ psi (2004)} \)

Cross-flow during SI
It is probably a stretch, but Chase wells in data set project to 89 psi in 100 years vs. 30 psi in 72 hours.

Though it is certain that 72 hour WHSIP cannot be used to project remaining GIP, it remains a useful metric in evaluating communication and relative depletion.

First 100 days: 11 Hugoton and 32 Panoma wells
101-260 days: 7 Hugoton and 24 Panoma wells
### Foam drilled well (1994)

<table>
<thead>
<tr>
<th>CHASE</th>
<th>SIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herrington</td>
<td>120</td>
</tr>
<tr>
<td>Krider</td>
<td>88</td>
</tr>
<tr>
<td>Winfield SS</td>
<td>105</td>
</tr>
<tr>
<td>Winfield LS</td>
<td>121</td>
</tr>
<tr>
<td>Towanda</td>
<td>187</td>
</tr>
<tr>
<td>U. Fort Riley</td>
<td>230</td>
</tr>
<tr>
<td>L. Fort Riley</td>
<td>&gt;400</td>
</tr>
<tr>
<td>Florence</td>
<td>398</td>
</tr>
<tr>
<td>Wreford</td>
<td>372</td>
</tr>
</tbody>
</table>

### New Well (2005)

- **Herrington**: 19, 21, 30
- **Krider SS**: 141, 217, 265
- **Krider DOL**: 165, 192
- **Winfield SS**: 179, 180, 199, 187, 193
- **Winfield LS**: 179, 180, 199, 187, 193
- **Towanda**: 179, 180, 199, 187, 193
- **U. Fort Riley**: 179, 180, 199, 187, 193
- **L. Fort Riley**: 179, 180, 199, 187, 193

**Individual SIP**

- 19
- 21
- 23
- 30
- 29
- 141
- 240
- 194
- 169
- 180
- 151
- 144
- 179
- 189
- 199
- 187
- 193
- 252
- 277
- 200
- 237
- 386
- 385
- 370
- 340
- 342
- 353
- 343
- 339

#### (DST’s)

- ALM: 400
- B1LM: 350
- B2LM: 131
- B3LM: 368
- B4LM: 215
- B5LM: 160

#### (XPT’s)

- B3_LM: 386
- B5_LM: 348

**Depleted Targets?**
**Pressure by Zone**

Data is from 25 wells taken between 1977-2005, all areas of field (Kansas and Oklahoma).

Variability within zone due to:
- Geographic location (facies & k)
- Below G/W contact
- Time

**Formation**

1. Herrington
2. Kridger
3. Winfield
4. Towanda
5. Ft Riley
6. Florence
7. Wreford
8. A1_LM
9. B1_LM
11. B3_LM
12. B5_LM
13. D_LM
4D View of Panoma WHSIP through time in Kansas

Cloud of Pressure Data Points

X(ew), Y(ns), Z(time) Color(p)

Surface passes through the “cloud” at 141 psi. Peaks are later in years.

Ft Riley Slope (1st derivative of structure)

Panoma  P = 141, T-map =1984

SW Kansas
Ft. Riley dip map at 1981 on time axis

WHSIP isobar surface = 143#

Hugoton and Panoma isobar pressure surfaces are very similar, having similar correlation to the Ft. Riley dip map, however, the Panoma 143# isobar surface lags the Hugoton by approximately two years.
Map view of Panoma 170# isobar surface with Z axis being time. Ft. Riley dip map is placed at T = 1976 and is an opaque plane that slices the 3D Panoma 170# surface. The four images have different opacity settings for the 170# surface (100% to 0% clockwise) allowing one to see the correlation with the Ft. Riley dip map.

Areas with high rates of dip may be areas where joints and fractures provide more effective communication between layers and thus higher WHSIP as gas is fed from higher pressure layers.
Later in life
P = 60, T-map = 1996

Hugoton

Panoma
Ft Riley Structure 1st Derivative
Hugoton-Panoma Area
Lineaments in Ft Riley Structure
1st Derivative Map, Flower Model Area

Possible conduits for vertical communication between layers and between Hugoton and Panoma?
Fractures in Chase and Council Grove

Joint frequency and geometry in core suggest that if regular (square) they may occur in 10-15 foot patterns in SW Kansas
### Trends in pressure through time

<table>
<thead>
<tr>
<th>1. Hugoton and Panoma show similar patterns</th>
<th>1. Behaving as one reservoir system (or separate behaving exactly the same)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Slightly higher pressures correlate well with basement related fractures</td>
<td>2. Recurrent movement could cause higher frequency of open joints (swarms) that provide better communication within low perm zones, thus higher WHSIP</td>
</tr>
<tr>
<td>3. Pressures often times are not inversely proportional to cumulative gas production</td>
<td>3. Better communication of tighter zones may lead to slightly better production</td>
</tr>
</tbody>
</table>

*Additional work may provide better understanding of reservoir communication and guidance on prospective sites for “alternative plumbing”*
Conclusions

Hugoton and Panoma Fields in Kansas appear to have behaved as one large reservoir rather than two separate systems during production, though effects of proration could have had an artificial influence.

Lines of evidence:
- Similar pressure histories, temporally and spatially
- Interference by successive generations of wells

Possible causes:
- Natural large scale fractures or swarms of smaller fractures, possibly coincident with basement
- Hydraulic fractures during well completion
- Both

The conclusions and insights presented are preliminary and are based upon work that is still in progress. They are the opinions of the authors and not necessarily those of the sponsors of the Hugoton project.
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.
Compare Panoma and Hugoton