Using Sequence Stratigraphy to Optimize Target Selection in Tight Sandstone Reservoirs of the Rockies (and Beyond)*

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Abstract

Sequence stratigraphy is not THE answer in optimizing the selection of horizontal targets in tight sandstone reservoirs. But it is an extremely useful, and oftentimes necessary, tool that should be used to assess potential reservoir intervals and improve geosteering.

Sequence stratigraphy can aid subsurface geologic interpretation and evaluation in numerous ways. It (1) provides an increased understanding of depositional controls on reservoir vs. non-reservoir facies, (2) promotes better well-log correlations, (3) aids in reservoir prediction, (4) offers a framework for data integration, (5) guides sample collection from core, (6) delivers better reservoir flow models and volumetric calculations, (7) helps in choosing and staying within the target zone, and (8) furnishes input for completion design.

This talk focuses on three aspects of optimizing target selection and horizontal drilling in tight sandstone reservoirs based on sequence stratigraphic concepts. First, the importance of establishing accurate correlations based on flooding surfaces and
parasequences when selecting a target and landing the wellbore is demonstrated for the Baxter and Parkman sandstones. Second, the significance of reservoir compartmentalization relative to reservoir modeling and economic evaluation in highstand vs. falling stage systems tracts is described for the Viking, Woodbine, Sussex, and Frontier-Turner systems. Finally, identifying different types of erosional surfaces and their impact on hydrocarbon production and the placement of laterals are highlighted for the Frontier-Turner and Three Forks-Bakken intervals.

References Cited


**Websites Cited**


Using Sequence Stratigraphy to Optimize Target Selection in Tight Sandstone Reservoirs of the Rockies (and Beyond)

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Acknowledgements

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* previously with EOG Resources
Sequence Stratigraphy

- provides another tool in your “tool box”
- promotes better well-log correlations
- offers context for depositional controls on reservoir vs. non-reservoir
- aids facies prediction (exploration)
- guides data collection from core
- provides framework for data integration
- delivers better reservoir flow models & volumetrics (compartmentalization)
- helps select & stay in horizontal target
Targeting Optimization

- parasequence (flooding surface) correlation
  - Parkman
  - Baxter

- HST vs. FSST & compartmentalization
  - Viking
  - Woodbine
  - Sussex
  - Frontier-Turner

- erosional surfaces & HC production
  - Frontier-Turner
  - Three Forks-Bakken
Sea Level Change & Systems Tracts

Early Lowstand Systems Tract

Late Lowstand Systems Tract

Highstand Systems Tract

Falling Stage Systems Tract

Sea Level Change & Systems Tracts

Sea Level

Transgressive Systems Tract

Transgressive surface/sequence boundary

Transgressive Systems Tract

Modified from Kendall, 2006

Sea Level

sequence boundary

sequence boundary

sequence boundary

sequence boundary

regressive surface(s) of marine erosion
Parasequence = Fundamental Correlation Unit

modified from Van Wagoner et al., 1990

Targeting Optimization

• parasequence (flooding surface) correlation
  ➢ Parkman
  ➢ Baxter

• HST vs. FSST & compartmentalization
  ➢ Viking
  ➢ Woodbine
  ➢ Sussex
  ➢ Frontier-Turner

• erosional surfaces & HC production
  ➢ Frontier-Turner
  ➢ Three Forks-Bakken
How Would You Correlate These Parasequences?

Layer Cake

Dipping Clinoforms
How Would You Correlate These Parasequences?

Layer Cake

Dipping Clinoforms
Parkman Targeting

Wet Facies
Reservoir Facies

Savegeton Fld
House Creek Fld

frac barrier

PS5
PS4
PS3
PS2

W highstand progradation

PS5
PS4
PS3
PS2
PS1

from Wheeler, 2010
Parkman Targeting

Wet Facies

Reservoir Facies

Savegeton Fld

House Creek Fld

frac barrier

from Wheeler, 2010

highstand progradation
Baxter Compartmentalization

landward

basinward
Baxter Core Observations

“normal” parasequence capped by flooding surface

tight flooding surface between parasequences

5088'
5111.3'
4541'
4562.7'
4562.7'
4938'
4960'

FS
shelf
middle shoreface
lower shoreface
middle shoreface
lower shoreface
middle shoreface
lower shoreface

Tight carbonate-cemented zone (resistivity & density spike)
Baxter Compartmentalization

landward

basinward

ENRON OIL & GAS CO
BNG
200-20
T28.0N R113.0W S20.0
8/19/1992

EOG RESOURCES INC
BX
20-20
T28N R113W S20
3/13/2001

MOBIL OIL CORP
TIP TOP UNIT
T34X-22G
T28N R113W S22
7/19/1994

ENRON OIL & GAS CO
NEW FORK MESA
1-15
T28.0N R113.0W S15.0
6/30/1990

EOG RESOURCES INC
MERLIN
1-13D
T28N R113W S13
9/20/2000

top Baxter

PS1

PS2

PS3
Targeting Optimization

• parasequence (flooding surface) correlation
  ➢ Parkman
  ➢ Baxter

• HST vs. FSST & compartmentalization
  ➢ Viking
  ➢ Woodbine
  ➢ Sussex
  ➢ Frontier-Turner

• erosional surfaces & HC production
  ➢ Frontier-Turner
  ➢ Three Forks-Bakken
Viking Ss Compartmentalization

“Main Sand”

Zone of Maximum Sweep (2.0-3.2 km)

HST

RSME

FSST

after Posamentier & Chamberlain, 1993
Woodbine (Double A Wells Field) Falling Stage Systems Tract

- Lose sandstones landward
- Sharp-based deltaic sandstones
- Variable thicknesses along dip
Woodbine (Double A Wells Field) Compartmentalization

different families of pressure decline

each type of symbol refers to a specific well

cross section wells

Blackstone #C-1 Champion

Blackstone #2 Ala-Coushatta

Blackstone #1 Trostman

seismic separation between wells
Woodbine (Double A Wells Field) Falling Stage Systems Tract

basinward

landward

Blackstone #1 Trostman
Blackstone #2 Alabama-Coushatta
Blackstone #C-2 Champion
Blackstone #C-1 Champion
Shell #2 Southland

rsme

sb/tse

eur 12.7 bcfE
eur 26.9 bcfE
eur 11.4 bcfE
eur 8.4 bcfE

1000 feet
Reworking of Falling Stage Shorelines

Falling Sea Level

Transgressive Removal & Reworking

from Walker & Plint, 1992
Reworking of Falling Stage Shorelines

Falling Sea Level

Transgressive Removal & Reworking

Reworked by waves & tides
Facies Variation In Reworked FSST

East Coast Sand Ridges (palimpsest deposits)

Flow
Steamlines

- Glauconitic
- Cross Bedded
- Thin Bedded
- Bioturbated

from Snedden & Dalrymple, 1999

from Swift & Parsons, 1999
Sussex Falling Stage Systems Tract

after Bottjer et al., 2015

truncation of Steele Shale markers

RSME

updip sand pinchout

outcrops

Hornbuckle-Spearhead

House Creek

RSME

t truncation of Steele Shale markers

after Bottjer et al., 2015
Sussex (House Creek Fld) Facies Variation

Woods Petroleum Mandell-Fed’l #1

Woods Petroleum Gov’t Miles A #1

Woods Petroleum Empire Fed’l C #1

after Bottjer et al., 2015
Sussex (House Creek Fld) Facies Variation

Woods Petroleum Mandell-Fed’l #1

Woods Petroleum Gov’t Miles A #1

Woods Petroleum Empire Fed’l C #1

RSME
## Frontier-Wall Creek/Turner Stratigraphy

<table>
<thead>
<tr>
<th>Stage</th>
<th>West PRB</th>
<th>East PRB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maastrichtian (part)</td>
<td>Fox Hills Fm</td>
<td>Fox Hills Fm</td>
</tr>
<tr>
<td>Campanian</td>
<td>Mesaverde Fm</td>
<td>Pierre Shale</td>
</tr>
<tr>
<td>Santonian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coniacian</td>
<td>Cody Shale</td>
<td></td>
</tr>
<tr>
<td>Turonian</td>
<td></td>
<td>Niobrara</td>
</tr>
<tr>
<td>Cenomanian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albian (part)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Mesaverde Fm:**
  - Lewis Sh
  - Teapot Ss Mbr
  - Parkman Ss Mbr
- **Cody Shale:**
  - Sussex Ss
  - Shannon Ss
  - Steele Sh
- **Frontier Fm:**
  - Wall Ck Mbr
- **Belle Fourche Mbr:**
  - Frontier Sandstones
  - Greenhorn Fm
  - Belle Fourche Sh
- **Mowry Sh:**
  - Mowry Sh

*modified from Anna, 2009*
Wall Creek Member (Turner)

- RSME
- Chert & siderite pebbles

RSME
Frontier-Wall Creek/ Turner Outcrops

Facies
- distal prodelta
- proximal prodelta
- delta front
- (subaqueous) channels
- tidal bars
- accretionary mouth bars
- proximal prodelta
- distal prodelta

Sea Level

from Lee et al., 2007
Targeting Optimization

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  - Viking
  - Woodbine
  - Sussex
  - Frontier-Turner

- erosional surfaces & HC production
  - Frontier-Turner
  - Three Forks-Bakken
Frontier-Turner Correlations & Erosion

SW  Avery/Finley/Powell  Crossbow/Porcupine  NE

Frontier  Turner

SB/TSE  RSME

after E. Kling
Turner Erosional Modification

Mary’s Draw/ Crossbow/ Porcupine area

merged sequence boundary & transgressive surface of erosion

from Martinsen, 2003

after E. Kling
Turner Erosional Modification

Mary’s Draw/
Crossbow/
Porcupine area

merged sequence boundary & transgressive surface of erosion

from Martinsen, 2003

after E. Kling
Three Forks Optimization

from Bottjer et al., 2011
Unconformities & Targeting

Pronghorn present (SW)

Pronghorn Isopach & Three Forks Production

Pronghorn missing (NE)

from Bottjer et al., 2011
Conclusions: Sequence Stratigraphy & Horizontal Targeting

- not “THE” answer, but a useful (necessary?) tool
- increased understanding of depositional controls on reservoir vs. non-reservoir
- framework for data selection and integration
- better correlation and mapping of targets
- aids reservoir modeling & economic evaluation (compartmentalization)
- helps with selection of & staying in best zone