Granite Wash Play Overview, Anadarko Basin: Stratigraphic Framework and Controls on Pennsylvanian Granite Wash Production, Anadarko Basin, Texas and Oklahoma

Ed LoCricchio

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Introduction and Play Highlights

- Granite Wash play extends over 130 miles across 7 counties in the Anadarko Basin covering 2.5 million acres.
- Multi-stacked resource play concentrates value with potential of 40 Hz wells/section in Granite Wash.
- There are almost no federal leases.
- Established infrastructure is present.
- Landowners and state governments are industry-friendly.
- Range of cost of completed wells is $6-9MM.
- IP Range 50-3,500 BO and 3,000-30,000 MCFGPD.
- EUR Range 3-17 BCFE.
- Total Recoverable resources potential of 500 TCFE, (114 BBOE including NGL’s).

Conclusion

- Desmoinesian Granite Wash Play in the Anadarko Basin is one of the most active plays in the Continental United States.
- Clastics shed from the Wichita Mountain-Amarillo Uplift were deposited in the Anadarko Basin by sediment gravity flows, creating a massive submarine sand complex.
- Anomalously pressured hydrocarbon system, both under- and overpressured.
- Produces both oil and gas, ratios vary laterally and vertically.
- Minimum of fifteen separate reservoirs.
- Advent of horizontal drilling technology and isolated multi-stage fracture stimulation has revolutionized play.
- New technology has enabled development of a giant field within a mature basin.
- As mapped today this field will take decades to develop, with new isolated reservoirs still being discovered.

References


Granite Wash Play Overview, Anadarko Basin
Stratigraphic Framework and Controls on Pennsylvanian Granite Wash Production, Anadarko Basin, Texas and Oklahoma

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  School of Mines
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Discussion Outline

- Location Map and Stratigraphic Column
- Play extents and expansion through time
- Depositional model and hydrocarbon system
- Challenges and hurdles to Granite Wash study
- Nomenclature issues and type log
- Regional cross-sections
- Net sand isopachs
- Conclusion
Anadarko Basin

- Asymmetrical Basin
- >35,000’ Cambrian – Permian Sediments
- Burial history suggests greatest subsidence in Early Pennsylvanian
- Thermal history indicates pre-GRWS source rocks entered oil generation window in Early Pennsylvanian, dry gas phase by Early Permian
Key Points

- The Granite Wash and associated plays are among the most attractive domestic opportunities due to liquids-rich production, stacked pay zones and high rates of return.
- Horizontal drilling technology, combined with advancements in multi-stage fracture stimulation, has caused a massive expansion of the resource potential with numerous attractive stacked development opportunities.

Map of Western Anadarko Basin

Note: Granite Wash spans from the Early Permian to the Pennsylvanian in age. Areas marked with an oil, gas or liquids symbol represent zones present in the Western Anadarko Basin.
## Anadarko Basin Goes Horizontal

<table>
<thead>
<tr>
<th></th>
<th>Cleveland</th>
<th>Granite Wash</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Well</td>
<td>1951</td>
<td>1920</td>
</tr>
<tr>
<td># Verticals</td>
<td>2,660</td>
<td>16,307</td>
</tr>
<tr>
<td>First Horizontal</td>
<td>2002</td>
<td>2002</td>
</tr>
<tr>
<td># of Horiz Completions</td>
<td>880</td>
<td>415</td>
</tr>
<tr>
<td># of Horiz Rigs</td>
<td>22</td>
<td>60</td>
</tr>
<tr>
<td># of Horiz Permits</td>
<td>153</td>
<td>165</td>
</tr>
</tbody>
</table>

HZ Development **Explodes in 2008**

### Granite Wash Wells Completed

- **Vertical Wells**
- **Horizontal Wells**

Source: IHS, Inc. – reflects YE 2010 data
Granite Wash Vertical Completions – Pre 1/1/2006

• Vertical Pre-2006
Granite Wash Vertical & Horizontal Completions

- Vertical Pre-2006
- Vertical Post 2006
- Horizontal
Eleven Stacked Horizons

Upper Granite Wash
- AVG. BTU – 1,280
- 116 Bbls NGLs / MMcf

Lower Granite Wash
- AVG. BTU – 1,080
- 40 Bbls NGLs / MMcf

Total Horizontal Granite Wash Wells to Date
872 GRWS H-wells producers
388 GRWS Permits / H-well spud / WOC

Britt: 57
B: 233
C: 277
D: 87
E: 5
F: 26
G: 27
H: 26
I: 45
J: 62
Granite Wash Depositional Model

- Massive sand deposits shed off the Amarillo uplift and Wichita Mtn. to SW, >15,000 ft of GRWS deposits preserved in the rock record
- Sediments spread laterally and stacked vertically to create a submarine sand complex
- GRWS records cyclic sandstone and siltstone deposition that corresponds to submarine fan growth and abandonment
- Focus on DSMS GRWS

- Active petroleum systems charged by multiple source rocks
- Basin-centered gas system combined with regional stratigraphic pinch-out
- Gross DSMS thickness as much as 3,400 ft
- Subdivided DSMS GRWS into 11 productive benches separated by regionally correlative shales
Two Plays: Conventional and Unconventional

South of Mountain View Fault System: Conventional Traps

North of Mountain View Fault System: Basin-Centered Gas Resource Play
Challenges

- Perception that the Granite Wash is only one or two reservoirs
  - When it is at least fifteen reservoirs
  - At least eleven Desmoinesian-age reservoirs

- Limited published studies

- Subsurface study only, no outcrops
  - Over 30,000 wells to correlate; blessing and a curse.
  - Five years ago when we started this work there were few digital logs available

- Petrophysical challenges
  - Radioactive minerals
  - Variable clay content
  - Low porosity and permeability
  - Overbalanced drilling masked Granite Wash pay

- No established stratigraphic framework

- Nomenclature issues are a major hurdle to overcome
**What’s in a name?**

Numerous different styles for naming individual Granite Wash zones

<table>
<thead>
<tr>
<th><strong>Lithology</strong></th>
<th><strong>Age Connotation</strong></th>
<th><strong>Kansas Shelf Nomenclature</strong></th>
<th><strong>Other</strong></th>
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<tbody>
<tr>
<td><em>Granite Wash</em></td>
<td>Permian Wash</td>
<td>Cottage Grove Wash</td>
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<td>Conglomerate</td>
<td>Pennsylvanian Wash</td>
<td>Hogshooter Wash</td>
<td>Alpha-Numeric</td>
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<td>Missourian Wash</td>
<td>Cleveland Wash</td>
<td>Inverse Alphabetic</td>
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<td>Dolomite Wash</td>
<td><em>Desmoinesian Wash</em></td>
<td>Marmaton Wash</td>
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<tr>
<td></td>
<td>Atokan Wash</td>
<td>Cherokee Wash</td>
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</tr>
<tr>
<td></td>
<td>Morrowan Wash</td>
<td>Skinner Wash</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Red Fork Wash</td>
<td></td>
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</tbody>
</table>

|                               |                              |                               |                        |
Divided the Desmoinesian age Granite Wash into eleven zones

- Separated by regionally correlative flooding surfaces
- Frac barriers
- At least eleven Desmoinesian-age reservoirs

System is a hybrid of Core Lab study members
Granite Wash divided into 11 zones (does not include Atoka Wash)
- Strategy was to correlate significant flooding surfaces across area of interest
- Create structure maps for each surface and project those surfaces into all wells
- Define zones based on projected surfaces to eliminate nomenclature issues and to be able to extract meaningful test, perf, and production data

Net sand maps for each individual zone
- Only wells penetrating that zone
- Highlight wells with perfs in that zone
- Highlight HZ wells in zone
Eleven Stacked Horizons

- All GRWS zones proven productive by 100’s to 1000’s of vertical wells, and over 800 Hz wells
- Most Hz wells target the upper zones
  - Shallower drilling
  - More liquid-rich in central portion of the play

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Granite Wash Structure

C.I. = 25'
Regional Cross-Section Index Map

- Regional grid of 20 X-sections spanning 12,000 mi² and containing 895 wells
- Created consistent nomenclature and correlations
- Regional perspective provided insight to basin history

>24,000 Wells Correlated

>200,000 Proprietary CEP III Tops

>4,500 Wells Containing LAS Digital Curves
Section 4

VE = 40x
HZ Scale = 83 mi

South North
Section 4

VE = 40x
HZ Scale = 83 mi
Section 6

VE = 35x
HZ Scale = 75 mi

Datum: CLVD
GRWS
ATOK
Section E

VE = 28.7x
HZ Scale = 87 mi
Section C
Upper Granite Wash
Lower Granite Wash

Datum: CLVD

Atoka
Skinner

Kansas Shelf

GWE

C.I = 20'

Amarillo/Wichita Uplift

GWE

75 miles

3000 ft
Kansas Shelf

Amarillo/Wichita Uplift

Datum: CLVD

C.I= 20'

75 miles

1000 ft

GRW
BRITT
GWB
GWC
GWD
GWE
GWF
GWH
GWI
GWJ
ATOK

Lower Granite Wash

Upper Granite Wash

Atoka

Skinner

BRITT

Mountain View

Fault System

Ochiltree
Lipscorn
Hemphill
Roger Mills
Reeds
Wheaton
Burling
Elks
Dewey
Custer

Atoka
Skinner
Granite Wash

C.I= 20'

Datum: CLVD

Kansas Shelf

C.I= 20'

Datum: CLVD

Kansas Shelf

Amarillo/Wichita Uplift
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