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

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Introduction

- 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.
- Almost no federal leases.
- Established infrastructure.
- Landowners and state governments are industry friendly.
- Completed wells cost range $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).
Anadarko Basin

Asymmetrical Basin

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

Stratigraphic Column

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 attractively stacked development opportunities.
- Granite Wash is not one or two reservoirs, rather there are at least fifteen reservoirs, including at least eleven Desmoinesian reservoirs.

Challenges

- Limited published studies
- Subsurface study only, no outcrops
- Over 30,000 wells to correlate; blessing and a curse.
- Eight 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
Mapping Strategy

- Granite Wash divided into 11 zones (does not include Atoka Wash)
  - 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 1500 Hz wells
  - Most Hz wells target the upper zones
  - Shallower drilling
  - More liquid rich in central portion of the play

Opportunity Overview

- One of the Most Attractive North American Resource Plays
- Basin activity supported by superior economics and longevity of the play
- Evolving resource play; several zones in early stages of technological development
- Returns competitive with the best basins in the U.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 over pressured.
- 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.
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
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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 Lower 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

- First GRWS well 1920
- # Verticals 16,307
- First GRWS HZ 2002
- HZ Development Explodes in 2008
- # of HZ Completions 1586
- # Active GRWS HZ Rigs 33

Source: IHS, Inc.
Granite Wash Vertical Completions – Pre 1/1/2006
Granite Wash Vertical Completions – Post 1/1/2006

- Vertical Pre-2006
- Vertical Post 2006

Map showing the distribution of vertical completions in the Granit Wash area post-1/1/2006.
Granite Wash Vertical & Horizontal Completions

- Vertical Pre-2006
- Vertical Post 2006
- Horizontal
Granite Wash Vertical & Horizontal Completions

- Vertical Pre-2006
- Vertical Post 2006
- Horizontal

10 miles
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
1586 GRWS H-wells producers
264 GRWS Permits / H-well spud / WOC
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
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.
  - Eight 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>
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<th>Lithology</th>
<th>Age Connotation</th>
<th>Kansas Shelf Nomenclature</th>
<th>Other</th>
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</tr>
<tr>
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<td></td>
<td>Morrow Wash</td>
<td></td>
</tr>
</tbody>
</table>
Our Nomenclature

- 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
**Mapping Strategy**

- **Granite Wash divided into 11 zones (does not include Atoka Wash)**
  - Strategy was to correlate significant flooding surfaces across area of interest
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**Total Horizontal Granite Wash Wells to Date**
- 1586 GRWS H-wells producers
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Regional Cross-Section Index Map

- Regional grid of 20 X-sections spanning 12,000mi² 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
Section E

West

Datum
CLVD
GRWS
ATOK

East

VE = 28.7x
HZ Scale = 87 mi
Section C

West East

Datum CLVD
GRWS
ATOK

VE = 87x
HZ Scale = 130 mi

5,500 ft
C.I = 20'

Datum: CLVD

Kansas Shelf

Amarillo/Wichita Uplift

Granite Wash

Upper Granite Wash

Lower Granite Wash

Skinner

GWJ

Atoka

GWB

GWC

GWD

GWE

GWF

SKINNER

GWG

GWH

GWI

GWJ

GWJ

GWJ

GWJ

GWJ

GWJ
C.I = 20'
Upper Granite Wash
Lower Granite Wash

Datum: CLVD

Atoka
Skinner

Kansas Shelf

Amarillo/Wichita Uplift

GWH

C.I= 20’
Upper Granite Wash
Lower Granite Wash

Datum: CLVD

Atoka Skimmer
Kansas Shelf

Amarillo/Wichita Uplift

GWF

C.I= 20'

GWF
Granite Wash

75 miles

1000 ft
C.I= 20°

Datum: CLVD

Kansas Shelf

Amarillo/Wichita Uplift

GWE

Net Pay Isopach

75 miles

1000 ft

GRWS
BRITT
GWB
GWC
GWD
GWE
GWG
GWH
GWI
GWF
SKINNER
ATOK

GWE

GWF

GWI

Atoka

Skinner

Upper Granite Wash

Lower Granite Wash

Ochiltree
Lipscomb
Hemphill
Wheeler
Mountain View
Mountain View
Dewey
Dewey
Washita
Custer

GWE

Kansas Shelf

Granite Wash
Upper Granite Wash
Lower Granite Wash

Datum: CLVD

Atoka
Skinner

Kansas Shelf

Amarillo/Wichita Uplift

GWD

C.I. = 20'

75 miles

1000 ft

Granite Wash
Upper Granite Wash
Lower Granite Wash

Datum: CLVD

Atoka
Skinner
Kansas Shelf

GWB
1000 ft
75 miles

C.I= 20'
Datum: CLVD

Atoka
Skinner

Granite Wash

Amarillo/Wichita Uplift

C.I= 20'

Kansas Shelf

Upper Granite Wash

Lower Granite Wash

Ochiltree
Lipscomb
Hemphill
Roger Mills
Mountain View
Beckham
Wheatley

1000 ft

75 miles
Opportunity Overview
One of the Most Attractive North American Resource Plays

- Basin activity supported by superior economics and longevity of the play
- Evolving resource play; several zones in early stages of technological development
- Returns competitive with the best basins in the U.S.

Select Basin Type Curve Parameters

Source: IHS Herold.

1 Source: Jefferies and Co.; May 29, 2014 NYMEX price strip.
2 Includes upper and lower Marmaton Channel and Fan.
3 Includes Britt and Granite Wash B, C, and D.
4 Excludes TNKW Low GOR T2.
Conclusion

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