WOLFCAMP HORIZONTAL PLAY
MIDLAND BASIN, WEST TEXAS

IHS Geoscience Webinar Series

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Agenda

- Introduction
- Play History
- Data Summary
- Geologic Characteristics
- Source Rock Characteristics
- Sweet Spot
- Play Particulars
- Summary
- Question & Answer
Play History – Santa Rita No. 1

• 1923 – Drilled and completed. It was one of the first producing oil wells in the Permian Basin. Santa Rita is the patron saint of impossible dreams.

• 1958 - The original production equipment was restored and moved to the Univ Texas - Austin campus, corner of San Jacinto Blvd and Trinity Street.

• 1990 - Marathon plugged the well after 67 years of production.
Play History – Santa Rita No. 1

- The Santa Rita No. 1 played a role in the 2002 film, “The Rookie”, starring Dennis Quaid.
Data Summary

- Enerdeq – Greater Permian Basin
  571,119 wells
- GDS Interpreted Formation Tops
  284,945 wells
- Enerdeq – Midland Basin
  116,302 wells
- Wolfcamp Shale Bench Correlations
  6,200 wells
Midland Basin Summary

- 116,302 Total wells drilled
- 96,894 Wells produced oil & gas
- Success Rate = 83%
- South & Central portions of Basin are the most productive
- 5114 Total HZ wells drilled (all reservoirs included)

Using a geology-based assessment methodology, the U.S. Geological Survey assessed technically recoverable mean resources of 20 billion barrels of oil and 16 trillion cubic feet of gas in the Wolfcamp shale in the Midland Basin part of the Permian Basin Province, Texas.
Play Map – Greater Permian Basin

Wolfcamp+ Wells Spud by Year

Data from Enerdeq; thru August 2016
Play History

• 1950-1990  -  Vertical play +Spraberry; 27,114 wells drilled
• 1990-2001  -  12 HZ wells drilled
• 2002-2006  -  No HZ wells drilled
• 2007-2010  -  6 HZ wells drilled
• 2011       -  57 HZ wells drilled
• 2012       -  164 HZ wells drilled
• 2013       -  485 HZ wells drilled
• 2014       -  1020 HZ wells drilled
• 2015       -  942 HZ wells drilled
• 2016       -  262 HZ wells drilled (thru May)

Data from Enerdeq
Wolfcamp HZ Wells Drilled by Year

Data from Enerdeq, thru August 2016
Regional Stratigraphy

- Stratigraphy of Midland Basin consists of thick Permian & Pennsylvanian sections
- Several productive plays; focus here is on the Wolfcamp
- Wolfcamp has been an active vertical play in the Midland Basin since the 1950’s
- Wolfcamp now an unconventional play

From Roberts (1989) and GDS
Wolfcamp Shale Benches - Type Log

- Type log for the Wolfcamp Section in the Midland Basin
- Clinton Oil #2 O. L. Greer API# 42-383-10575
- These 6 Wolfcamp Benches correlated in 6,200 wells in Wolfberry Trend in Midland, Glasscock, Reagan and Upton Counties
- These correlations also tied to over 2,800 HZ wells
Stratigraphy

- Lithology: Mostly shale and argillaceous carbonates
- Some sand and sandy intervals near basin edges
- Facies exhibit abrupt lateral changes
- 6 shale horizons or benches
Geologic Characteristics

- Depths: 4,000 – 10,000 ft
- Thickness: 185 - 4,600 ft
  > Average thickness: 2,029 ft
- Porosity: 4% - 12%
  > Average porosity: 7%
- Permeability: as low as 10mD
- Type locality at Wolfcamp Hills in Glass Mountains, west of Marathon, Texas (Udden, 1917; King, 1937)
Permian Basin 3D Wolfcamp Structure

Note: Generated from 110,000 Wolfcamp tops; view is to the north
Midland Basin Block Diagram

Facies of Wolfcamp A & B; View is to the Southeast.

From Figure by Reed in paper by Deen, et al (2013)
Wolfcampian Paleogeography of the Midland Basin

From Blakey (2014)

From Fu (2011)
Paleogeography – Late Wolfcampian in Permian Basin Region

From Fu (2011)
Greater Permian Basin Cross Section
Midland Basin Sequence Boundaries

- Sequence boundaries are related to transgressive and regressive seas.
- 2nd Order Sequence boundaries present during Wolfcampian time.
- TOC & Source Rock Quality patterns are related to flooding surfaces.
- Creaney and Passey (1993) showed that patterns in vertical distribution of TOC can be explained using sequence stratigraphic concepts.
- The maximum TOC in a vertical profile correlates to the maximum flooding surface in a marine sequence.

From Fu (2011)
Wolfcamp Structure

- Asymmetric basin geometry
- Contoured top of Wolfcamp Fm
- Contour Interval = 500 ft
- Tops from GDS correlated tops data (260,000+ correlated wells in Permian Basin)
Wolfcamp Structure

Contour Interval = 25 feet
Cross Section with Wolfcamp Shale Benches
Wolfcamp Isopach

- Top of Wolfcamp A to top of Strawn
- Contour Interval = 500 ft
- Wolfcamp is 185 - 4600 ft thick
- Thickens to the south and east
- Tops from GDS correlated tops data (260,000+ correlated wells in Permian Basin)
Source Rock Characteristics

• Several thick shales: A, B, C upper, C lower, D upper, and D lower

• TOC Range: 1% - 7%
  Good to Excellent Source Rock

• TOC highest in siliceous mudrocks and is diluted by carbonates; therefore, TOC is facies dependent

• Zones most drilled: A and B

• Shales respond well to fracture stimulation due to calcite content

Core of Wolfcamp B - siliceous mudrock
  Good to Excellent source rock
Source Rock

Samples from PanAmerican #1 O.L. Greer, Depth=8356 ft

- Wolfcamp B
- Siliceous mudrock – Source Rock; TOC of 3.7%

Natural Fractures

- Map of Southern Midland Basin
- 2712 Wolfcamp HZ wells this view
- Pattern of laterals suggests the direction of dominant fracture set
- Present day $S_{\text{max}}$ is E-W and is consistent with drilling induced fractures (Nelson, et al, 2013)
Sweet Spot - Definition

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The geoscientist defines the sweet spot as early as possible so as to be first to the right play, to be first to the sweet spot, and to assist in optimally developing the resource.

Adapted from Fairhurst and Reid (2016).
Sweet Spot Factors

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• Reservoir Pressure
• Oil Viscosity

Horizontal Play Particulars

• 5,114 HZ wells drilled in Midland Basin
• 3,017 HZ wells Wolfcamp;
  - drilled by 61 operators
  - 20% ops drilled 80% of wells
• Top 3 operators are:
  Pioneer Natural Resources
  Apache Corp
  Laredo Petroleum
Play Particulars

- 5,114 total HZ wells drilled in Midland Basin
Play Particulars

• 3,017 total HZ wells drilled in Wolfcamp Formation
Wolfcamp HZ Wells by Operator

Data from Enerdeq thru May 2016
Top 15 Wolfcamp HZ Operators - Midland Basin

- Map of Southern Midland Basin
- The top 15 Wolfcamp HZ Operators have 2,510 wells in the southern Midland Basin
Top 3 Wolfcamp HZ Operators - Midland Basin

- The top 3 Wolfcamp HZ Operators have 1,080 wells in the southern Midland Basin
- These include:
  > Pioneer Natural Resources
  > Apache Corporation
  > Laredo Petroleum
Play Particulars – Lateral Lengths

• Total Wolfcamp HZ = 3,017 wells
• Average Lateral Length = 7,107 ft
• 122 wells with laterals > 10,000 ft
• Laterals now being drilled > 13,000 ft
  • i.e. by Pioneer
Wolfcamp Play

Drilling deeper and adding fracture stimulation stages have added production and improved recoveries.

From Pioneer Natural Resources (2013)
**MIDLAND BASIN HORIZONTAL RESOURCE POTENTIAL**

75 BBOE Recoverable Resource Potential

- Wolfcamp C 2 BBOE
- Wolfcamp D 13 BBOE
- Spraberry Shales 14 BBOE
- Wolfcamp A 19 BBOE
- Wolfcamp B 27 BBOE

- 75 BBOE recoverable resource potential in shale intervals where successful horizontal wells have been drilled
- Assumes 140-acre spacing on 75% of acreage and downspacing to 100-acres on 25% of acreage; additional down-spacing potential exists
- Additional horizontal potential from other intervals (e.g. Clearfork, Middle Spraberry Shale, Atoka, Woodford)

Source: Pioneer Natl Resources Dec 2016 Investors Presentation
Summary

• Based upon areal extent, abundant and thick source rocks, and stacked pay zones, the Wolfcamp Play is one of the largest resource plays in the world.

• When Wolfcamp and the overlying Spraberry Formation are combined, i.e. The Wolfberry Play, this may be the largest resource play in the world.

• Total Recoverable Reserves for the Wolfcamp Play may exceed 20 billion barrels oil. Estimates range from 20 – 75 billion barrels of oil.
Questions?