Lessons Learned from the KCC #503H Woodford Horizontal Well at Keystone South Field, Winkler County, TX*

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Abstract

The Devonian Woodford Shale is a prolific, world-class source rock in the Permian Basin. Vast amounts of oil and gas have been generated by the Woodford Shale, effectively sourcing nearly every potential reservoir from Early Ordovician through Late Permian. Like so many other source rocks on the heels of Barnett Shale success, the Woodford underwent intense scrutiny as a viable unconventional target. By the mid-2000's, operators yielded some marginally economic gas production in the deep Delaware Basin, while only a few uneconomic vertical oil producers existed throughout the Permian Basin.

Fueled by momentum from Bakken results, Whiting Petroleum Corporation set out to delineate the resource potential of the Woodford. Integration of the previous experiences of some co-authors, the gathering and analysis of geochemical data, and a revised subsurface characterization of Woodford stratigraphy, warranted a test at Whiting's existing acreage at Keystone South Field.

Whiting acquired over 300 feet of conventional core in the upper and middle Woodford, along with an advanced log suite in the vertical pilot hole. To avoid potential water blockage and clay swelling, a synthetic oil-based mud was utilized during the drilling of the lateral. The 3,137 ft horizontal leg consisted of five hydraulic fracture stages using sliding sleeves and an un-
cemented liner with swell-packers. Reservoir modeling was performed, primarily to understand potential contribution from a complex fracture network observed in core. Ultimately, the test was uneconomic.

Several key learnings were made from the test at Keystone South Field. Present-day maturity of the Woodford, at this location, has resulted in insufficient oil-in-place and a low viscosity product that cannot produce from a normally pressured reservoir. Synthetic oil-based mud is not necessary, nor did it add value or contribute to any success in this application. Lastly, insufficient lateral length and subsequently low number of stages, as well as poor execution of most hydraulic fracture stages, resulted in an insignificant stimulated rock volume and an uneconomic test.
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Whiting Petroleum Corporation

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Midland, TX
May 12, 2014
Outline

• History
• Regional Woodford Overview
• Whiting AOI
  • Central Basin Platform
  • Keystone South Field
• KCC #503H
  • Core
  • Well
• Learnings
History

• 2003 — Onset of horizontal drilling in the Barnett
• 2005 — Delaware Basin Woodford/Barnett combo wells
• 2006-2007 — Whiting success in the Bakken
• 2007-2008 — Oklahoma Woodford plays emerge
• 2008 — Whiting Woodford data gathering
• 2nd Qtr. 2009 — Drill and core KCC #503 pilot
• 3rd Qtr. 2009 — Drill and complete KCC #503H
History

Late Devonian
360 Ma
(Blakey, R.)
Regional Woodford Overview

- Whiting area of interest determined by thick section of Woodford (>200’) at “peak oil generation” ($R_o \sim 0.6-1.0\%$)
KCC #503H Type Log

Modified from Dutton et al., 2005
Whiting AOI Woodford Characteristics

What we knew!

- > 500’ thick
- > 5% TOC common – up to 12% TOC or higher?
- Oil-prone type II kerogen
- ~0.6-0.8% $R_o$ – Onset of oil generation
- 8,000-9,000’ vertical depth
- Existing vertical production in the area
  - Kermit Field – 3 miles west
  - Bedford Field – 20 miles north
  - Monahans Field – 18 miles south
Keystone S. Woodford Characteristics

Early observations from core

- Complex oil-stained fracture network
- Excellent TOC – up to over 14%!
- Excellent source rock characteristics from RockEval
- Average 0.7% $R_o$ – low-level conversion
Fracture Network

- E-W drilling induced fracture throughout core
- NW-SE through going fractures
- Bed-limited fractures with multiple orientations

- TOC/tasmanites mudstone
- Quartzitic or dolomitic silt
- Clay-rich mudstone

Left: 100x photomicrograph of tasmanites-rich mudstone; Middle: close-up view of partially cemented bed-limited fracture sets; Right: UV close-up showing partially cemented, oil-stained through going fracture in tasmanites and organic-rich interbeds.
## Pyrolysis Data

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- **TOC**: Total Organic Carbon
- **RE**: Rock Eval
- **S1, S2, S3**: Rock Eval S1, S2, S3
- **Tmax (°C)**: Maximum Temperature
- **HI**: Hydrogen Index
- **OI**: Oxygen Index
- **S2/S3**: Ratio of Rock Eval S2 to S3
- **S1/TOC *100**: Ratio of Rock Eval S1 to Total Organic Carbon (in percentages)
- **PI**: Production Index

### Diagrams:
- **Graph 1**: Scatter plot showing the relationship between total organic carbon (TOC) and maturity.
- **Graph 2**: Production index (PI) vs. maturity (based on Tmax, °C) with maturity zones marked.
- **Graph 3**: Schematic diagram illustrating the conversion and maturity stages of organic matter.
KCC #503 Lateral Design

- **Maximize fracture storage potential**
  - Parallel to N-S fault trend
  - Perpendicular to $S_{\text{h max}}$
- Test away from structural crest to prove larger play potential
- Target upper-middle Woodford
  - High TOC
  - Lower clay
  - Abundant fractures
  - Apparent clay-rich frac barrier in lower-middle Woodford to prevent growth into “wet” Devonian
- Drilled with oil-based mud to ensure hole quality and reduce clay-swelling
- Un-cemented sliding sleeves with swell-packers
  - 3,137’ lateral length
  - 5 stages
  - 1,500 bbls/stage w/ diesel

Keystone South Field
Woodford Structure
C.I. = 50’
Results

• Seamless drilling of the lateral resulting in excellent hole quality

• Poor frac execution
  • 2 out of 5 stages screened out
  • Cautiously pumped stage 5 to avoid additional screen out

• Cumulative production = 7,800 BO & 28,000 MCF
  • Currently producing ~7 BOPD
Learnings

What we know now!

• $R_o \sim 0.7\%$ is too immature
• Normally pressured reservoir
• Fracture network alone is not enough storage
• 41 API product – viscosity too high
• Unsure of the necessity of oil-based drilling mud
• Insufficient stimulated rock volume
• Unnecessary sliding-sleeve completion