"Geologic assessment of the Mississippian System in southern Kansas incorporating log and core petrophysics and seismic data from Wellington Field, Sumner County, Kansas – implications for horizontal drilling"

W. Lynn Watney1, Jason Rush1, John Doveton1, Mina Fazelalavi1, K. David Newell1, Dennis Hedke2, Aimee Scheffer2,3, Jennifer Roberts3, David Fowle3, Dana Wreath4, Randy Koudele4, Paul Gerlach5, Larry Nicholson6, Tom Hansen7, John Victorine1, Georgios Tsoflias3, Ayrat Sirazhiev3, Robin Barker8, Saugata Datta8



1Kansas Geological Survey, Lawrence, KS 2Hedke-Saenger Geoscience, Ltd., Wichita, KS 3Department of Geology, University of Kansas, Lawrence, KS 4Berexco, LLC, Wichita, KS 5Consultant, Miramar, FL 6Consultant, Hanover, KS 7Bittersweet Energy, Wichita, KS 8Department of Geology, Kansas State University, Wichita, KS Mississippian Oil Play Stacked and shingled Mississippian Strata developed along the southern Kansas and northern Oklahoma



DOE Contract #FE0002056 and partner cost share



AAPG GeoScience Technology Workshop (GTW)

"New Directions in Carbonates" February 27-29, 2012

Fort Worth, Texas



Outline

- Background to "Mississippi Lime" play in southern Kansas
- Summarize near surface with subsurface geology
 - Stratigraphy and lithofacies
 - -Reservoir rock, distribution, controls
 - Tripolite and siliceous dolo-siltite Ø
 - -Key petrophysical observations
- Introduction to the Wellington Field test site
- Summary

Mississippian Oil and Gas Fields in Kansas

Approximate outline of southern Kansas Mississippian Oil Play & cumulative oil and gas production (BOE)



<u>Spivey-Grabs Basil</u> is the largest Mississippian oil field in Kansas with 69 MM BO & 841 BCFG Produces from the <u>tripolite</u> and could benefit from horizontal drilling and, in later maturity, by CO₂-EOR

Kansas Mississippian Stratigraphic Column

Lower Carboniferous – Mississippian Subsystem



The record of sea level and <u>major glacial episodes</u> from Veevers and Powell (1987) and isotope data from various authors compiled by T. Rasbury



Paleogeography of the midcontinent U.S. during the mid-Mississippian



Lane and DeKeyser (1980)





Gros Isopach Late Devonian- Early Mississippian Chattanooga Shale & Kinderhook Shale



Watney, Guy, Byrnes (2001)



- Late Devonian to Early Mississippian, NW-trending sag basin overlying Midcontinent Rift System
- During late Kinderhookian abrupt change to shelf margin in southern Kansas, bordering early Anadarko and Arkoma basins
- Tripolitic chert cycles developed along shelf margin

Magnetics with regional lineaments – Kruger (1997)



Isopach of Low Resistivity Mississippian"Cowley Formation"



*Low resistivity "in situ" chert/tripoloite

Watney et al. (2001)

Isopachous map, Residual Chert beneath base Penn unconformity*



*Residual chert conglomerate – silt & sand matrix with chert at basal Pennsylvanian unconformity, not clean, low resistivity chert

Watney et al. (2001)

Case study: Data from "Characterization of the Mississippian Osage Chat in South-Central Kansas" by Alan P. Byrnes, Willard J. Guy, W. Lynn Watney (KGS)





line of section





Compartments of more highly productive chat In Spivey-Grabs-Basil Field Barber, Harper, and Kingman County Kansas





General Atlantic Tjaden A-1 WIW



Watney et al. (2001)

Log-Core Description -

General Atlantic Tjaden A-1

T30S-R8W-Section 24

Barber County, Kansas

Derived from wireline log (LAS file)

Derived from core



Log-Core Description -General Atlantic Tjaden A-1 T30S-R8W-Section 24 Barber County, Kansas

GR = gamma ray, SP = spontaneous potential CAL = caliper, PE = photoelectric curve NPHI = neutron porosity, RHOB = bulk density DPHI = density porosity API: 15-095-21688 Spud Date: Jan-18-1994 Completion Date: Feb-26-1994 Plugging Date: Well **Type: INJ** Status: Well Drilled Total Depth: 4500







Cycle dependent, depth-based

petrophysical patterns

Depth profile of m (cementation exponent) for chert cycles

Petrophysical (PfEFFER) analysis of the tripolitic (microporous brecciated) chert



C/A by Byrnes in Watney et al. (2001)





Mid Cycle B – 4371.5 ft, nodular bedded chert



SW Missouri-SE Kansas Analog for Mississippian tripolitic chert cycles



Surface Stratigraphy and Sequence Stratigraphy Upper Kinderhook to Middle Osage



STOP 2 - BAIRD MOUNTAIN QUARRY

Handford and Manger (1993)

Location map: P&M cores, cross section index, and major structural elements







Well Data: PITTSBURG-MIDWAY PM-12 (15-021-20176) T: 32S R: 22E S: 19









582 ft dolosiltite with bioclasts and organic matter

Microporosity intercrystalline dolomite & scattered skeletal moldic





Last updated 8/27/2009 1200

Wellington Field

Porosity Fence Diagram

Mississippian Tripolitic Chert & Siliceous Dolo-Siltite Oil Reservoir

& Arbuckle Saline Aquifer



Wellington Field

Porosity Fence Diagram Mississippian Tripolitic Chert Oil Reservoir





Wellington Field

Initial P-Wave Interpretation of 3D Seismic with Location of Test Boreholes

structure



Area of **Mississippian** dual reflector identifying buildup of uppermost tripolitic chert reservoir (exhumed topography?)

Hedke (2010)

PSDM Mississippian Depth Migration (left) vs Mississippian Well Control (right)



PSDM- Arbitrary Profile 2: SW - NE



Cored Well, KGS #1-32 Top Mississippian to Kinderhook Shale

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Mississippian Pay Zone Mineralogy Berexco Wellington KGS #1-32

3670.6'



- Plain light (10x zoom)
- Fine grained
 dolomite with silica
 cement
- Silicified sponge spicule (?)
- Pore spaces filled with precipitated silica (chert)

Miss. Pay Zone Mineralogy

3670.6'



- Plain Light (10x zoom)
- Fine grained
 dolomite with
 intercrystalline
 porosity
- Opaque oxide/sulfide (?) present

Miss. Pay Zone Mineralogy

3681.95'



- Plain light (10x zoom)
- Close up of possible oil stain on chert
- Fine grained dolomite in porous zone

Cdy = Chalcedony; Dol = Dolomite



Summary

- Over 2.4 TCF gas and 278 MMBO have been produced in south-central Kansas from Mississippian reservoirs including 20 MMBO at Wellington Field.
- Reservoir strata consists of weathered and permeable, microporous and vuggy chert lithofacies that is referred to as tripolite and siliceous dolo-siltite
- <u>Cherty basal Pennsylvanian conglomerate</u> has distinct spatial distribution associated with uplifts that contrasts with the distribution of the tripolite.
- <u>Vertically stacked tripolites and siliceous dolo-siltites</u> reflect upwardshallowing, progradational, time-transgressive cycles consisting of argillaceous mudstone, siliceous dolo-siltites, and increasingly spongerich, skeletal wacke-packstones (that cap shallowest portions of cycles).
- <u>Shallowest cycles were subaerially exposed after deposition</u>.
- <u>Rock properties</u> change systematically upward through each cycle reflecting variations in moldic and vug pores, pore size, and connectedness resulting in variable cementation exponent, moderate to high bound water, often considered a low-resistivity pay.
- <u>Permeability</u> was modified by diagenesis, particularly early meteoric, as often recorded by an overlying subaerial-exposure surface.

Mississippian Oil Play Stacked and shingled Mississippian Strata developed along the southern Kansas and northern Oklahoma



Acknowledgements & Disclaimer

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INTENTS-TO-DRILL IN A SIX-COUNTY TIER IN SOUTHERN KANSAS ALONG THE OKLAHOMA STATE LINE

(Barber, Chautauqua, Comanche, Cowley, Harper, Sumner Counties) (half-month time increments. May, 2011 through mid-February, 2012)





Bottom porosity with oil show near base of Mississippian KGS Wellington #1-32



4029 ft – Bottom porosity with oil show --increased bioturbation, cmsubhorizontal; siliceous dolo-siltite









HH-50406

3905

3877 ft upper <u>Group #6</u> Fine grained siliceous calc-packstone with elongate siliceous pelloids







Bottom porosity with oil show near base of Mississippian KGS Wellington #1-32



4029 ft – Bottom porosity with oil show --increased bioturbation, cmsubhorizontal; siliceous dolo-siltite



