"Arbuckle Fluid Disposal Considerations – Regional and Local Perspectives in the Context of the Mississippian Play in Kansas"

Lynn Watney and Jason Rush
Kansas Geological Survey
and collaborating team

PRODUCTION GEOLOGY
OF THE NORTH MIDCONTINENT
December 4-5, 2012
Outline

• Overview
• Mississippian Lime Play
  – Drilling activity
  – Stratigraphy, reservoir properties, and implications for water production
• Arbuckle Fluid Disposal
  – UIC Class I and II wells in Kansas
  – Stratigraphy
  – Hydrostratigraphy
  – Petrophysical and geophysical properties
  – Controls on Ø-k – Lithofacies, diagenesis, fracturing
  – Preview western Kansas portion of DOE-CO$_2$ study
“Mississippian Carbonates in Kansas: Integrating Log, Core & Seismic - An AAPG E-Symposium”

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August 2012

http://www.aapg.org/education/online/details.cfm?ID=249
Paleogeographic map during the Osagean-Meramecian

Young (2007) modified from Lane and DeKeyser (1980)
Mississippian Reservoirs
-- Long-term importance to Kansas oil and gas production

Pre-Pennsylvanian Subcrop Map of Kansas
Miss Oil Production in Green

Mississippian
- >1 Billion BO Cumulative
- 33% of Current Production

Gerlach, 1998

http://www.kgs.ku.edu/DPA/Plays/ProdMaps/miss_sub_oil.html

Dubois (2003)
Regional Structural Features-Horizontal Wells

LEGEND
- Horizontal Oil/Gas Permian
- Horizontal Oil/Gas Missourian
- Horizontal Oil/Gas Desmoinesian
- Horizontal Oil/Gas Mississippian
- Horizontal Oil/Gas Woodford
- Horizontal Oil/Gas Hunton
- Arbuckle oil

4,237
Horizontal Completions Thru Feb. 2012

Structure Map from H.G. Davis, 1985

John Mitchell,
Senior Geologist
SM Energy Co.
Tulsa, Oklahoma
March 2012
Email: jmitchell@sm-energy.com
Horizontal Wells In Kansas
Permitted wells in blue; wells drilled in red; 2012 wells circled

HORIZONTAL WELL DRILLED BY YEAR
2009-6  2010-10  2011-44  2012-114

http://www.kgs.ku.edu/PRS/wellStats.html
Higher gas:oil ratio in south-central and southwest Kansas

Thickess of residual chert & basal Pennsylvanian conglomerate

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

Watney, Guy, and Byrnes (2001)
Thickness of low resistivity* Mississippian strata and structural lineaments important in deposition and later uplift

*Low resistivity, <2 ohm-m, equivalent to “in situ” chert
“TRIPOLITE”

Watney, Guy, and Byrnes (2001)
Total Magnetic Field Intensity

Nichols Field  Glick Field  Spivey-Grabs Field

Basal Pennsylvanian Subcrop

Wellington Field

LINEAMENT "X"

LINEAMENT "D"
Glick Field

Isopach map, top of productive tripolitic chert reservoir

Line of cross section

Lineaments added

Montgomery et al. (1998)
After J. Rogers et al. (1995)
Structural cross section through tripolitic, low resistivity chert pay Mississippian reservoir in Glick Field

No horizontal scale, section length ~9 mi
Equidistant wells

*Annotated with Rt of chert bearing strata at horizon of the pay zone
Crinoids, forams, bivalves, brachiopods, monaxon sponge spicules
Brecciated microporous chert with complex textures infilled by crinoidal packstone (tripolite)

P&M #12
529.4 ft
2nd tripolite sequence
Air permeability versus porosity for normalized whole core and plugs for four chat fields

- Anson-Bates sucrosic dolomites (blue square) lie off chert trend

Byrnes in Watney et al. (2001)
Capillary pressure curves – Glick Field

- Autoclastic chert facies and clay
- All curves exhibit high irreducible saturations indicative of microporosity and consistent with wireline log measurements of high water saturation
- Purple diamond shows the curve for the green infilling clay

(after Duren, 1960)
Relative gas permeability versus water saturation

- Saturations $-P_c_{\text{air-brine}} = 33 \text{ psia, 55 feet above free water level}$
- Relative permeabilities to gas decrease rapidly at water saturations greater than 60%
- Nodular cherts, dolomite mudstones, and bioclastic wackestones exhibit low $k_{rg,Sw}$

Byrnes in Watney et al. (2001)
West side
Hartner Field
Barber Co.

Lithologies Within the Mississippian Oil Play
(Chert Embayment, South Central Kansas)

Datum: Top Arbuckle Group

Cored Well Wellington Fld.

Compton Ls.

Viola

Cherokee

Mississippian

Chattanooga

Simpson

Gross isopach of low resistivity chert

200 ft

Cross section Index

Compton Ls.

Compton Ls.

Compton Ls.

Rhomax-Umax Colorlith

- Dolomite
- Anhydrite
- Quartz
- Calcite
- Anhydrite
- Cyprem
- Halite
- Orthoclase
- Illite
- Smectite
- Muscovite
- Glauconite

Watney, Guy, Byrnes (2001)

DOE-FE0002056
Structure Top Mississippian with oil and gas fields
- interactive map for project area of DOE-CO2 project (DE-FE0002056)
- access to map layers and digital (LAS) logs and viewer

http://maps.kgs.ku.edu/co2/?pass=project
Cored Well, Berexco Wellington KGS #1-32
Top Mississippian to Kinderhook Shale (410 ft)

- Siliceous dolo-packstone
- Argillaceous siliceous dolosiltite (pico/nano darcy perm)
- Vuggy siliceous Dolosiltite (oil show)
- Argillaceous dolosiltite
- Nodular chert, argillaceous dolosiltite
- Siliceous Dolosiltite (pay)

110 ft. dark Tight dolosiltite

Freeware: http://www.kgs.ku.edu/stratigraphic/PROFILE/
Wellington Field
Porosity Fence Diagram
Pay zone at top of the Mississippian

Porosity

Test Borehole ~Location #32-1
Test Borehole ~Location #28-1

Impedance
Upper Miss.

J. Rush, 2011 – Petrel™ using modern Ø logs

D. Hedke

North
Mississippian pay zone in Berexco Wellington KGS #1-32

Top Cherokee Breccia

Mixed, weathered pebble chert conglomerate

siliceous dolosiltite (1 ohm-m pay)
Mississippian Pay Zone Mineralogy

3670.6’

• Plain Light (10x zoom)
• Finely crystalline subhedral dolomite with intercrystalline porosity (micropores)
• Opaque oxide/sulfide (?) present and secondary replacive anhydrite present

TS provided by Datta & Barker, KSU
Mississippian Pay zone
Wellington Field

Upper pay is in transition zone
Oil shows in lower Mississippian

Hydrocarbon show

Argillaceous, with organic matter in lower Mississippian, elevated uranium

1 ohm-m

1 ohm-m

10 ohm-m
230 ft gross thickness interval of primary caprock in KGS #1-28 (injection well) including lower Mississippian tight dark dolomitic siltstone – illustrated by nuclear magnetic resonance log

Caprock evidence of lower Miss.:  
- Micro-nano darcy perm  
- Quiet fracture wise in interval  
- Organic matter ~2% TOC
Arbitrary seismic impedance profile

distinct Mississippian pay and dark argillaceous siltstone facies in “Pierson Fm.”
also mid-Arbuckle tight, lower Arbuckle injection zone

**Impedance = \( \rho \times \phi \)**
Summary of Kansas Mississippian Play

- Stratified reservoir with distinct pay lithofacies with contrasting petrophysical properties that affect ability to produce from them.
  - Dolomitic grainstone-packstones, tripolitic (microporous) chert, & dolosiltite are primary pay lithofacies
  - Tripolites are distinct microporous chert lithofacies capping shallowing upward cycles
  - Capillary pressure measurements indicated long (>40 ft) transition zones that are lithofacies dependent
  - Southern shelf margin distinguished by complex stacking and progradation into developing Arkoma and Anadarko basins
- Significant local and regional structure coupled with changes in sea level affect --
  - Shelf configuration and depositional facies, early & late diagenesis
  - Pay compartmentalization by early and late structural movement
Arbuckle Fluid Disposal

- UIC Class I and II wells
- Stratigraphy
- Hydrostratigraphy
- Petrophysical properties
- Controls on permeability — Lithofacies, diagenesis, fracturing
- Preview western Kansas portion of DOE-CO2 study
A) Structure map (subsea elevation) on Arbuckle

B) Arbuckle cumulative oil production (MMBO) by county

--- Of the 31 counties in which the Arbuckle has been productive, over 70% of the production has come from the 10-county area coinciding with the CKU.
K. Cooper and T. Hansen (2009)
Why is Class I injection technology so safe for use in Kansas? (continued)

- Well developed UIC programs at both the State and Federal levels (regulation, policy, and procedure)

- Available injection zones with substantial injectivity and other required properties
  - Depth – relatively large separation between USDW and injection
  - Thickness – relatively large, several hundred to 1,000 feet
  - Permeability – relatively high
  - Reservoirs cover large areas
  - Confinement – pervasive, thick, low permeability
  - Injection Pressure – mandated gravity flow
  - Natural Pressure Gradients – fluid stands below ground level
  - Often no cone of influence (fluid can naturally flow downward into injection zones)

Typical Class I well:
10 to 1000 gpm
(460 to 46,000 bbls/day)

K. Cooper and T. Hansen (2009)
Structural features and aquifer systems of the mid-continent

IHS (2009); KGS data; Adler and others (1971), modified after Bayley and Muehlberger (1968)
Map of corrected BHT values in Arbuckle for Kansas based on 19,161 points (CI = 2°F) overlain on structure top Arbuckle
Total dissolved solids in Arbuckle brines (color C.I. = 2500 ppm TDS)

All TDS concentrations more than 100,000 ppm are shown in red. Data were derived from Arbuckle water samples from various sources (2929 records).
Regional Arbuckle Saline Aquifer & EOR-CO\textsubscript{2} Mississippian chert reservoir
Wellington Field (DE-FE0002056)

Small Scale Field Test @Wellington (DE-FE0006821) (BEREXCO)

Western Annex CO\textsubscript{2} Industry Consortium (Chester-Morrow oil fields & Arbuckle)

Abengoa Bioenergy (Colwich ethanol)

Horizontal Test in Arbuckle -- Bemis-Shutts Field, Ellis Co. DE-FE0004566 (Vess-Murfin Drilling) 2010-2013

Cutter Field Basement test July-October 2012

Regional Assessment of deep saline Arbuckle aquifer

Westar Jeffrey Energy Center

Regional Arbuckle Saline Aquifer & EOR-CO\textsubscript{2} Mississippian chert reservoir Wellington Field (DE-FE0002056)
Funded Jan. 2010-August 2013

Small Scale Field Test @Wellington (DE-FE0006821) (BEREXCO)
Funded Oct 1, 2011-2015

http://www.kgs.ku.edu/PRS/petro/ogSheetMap.html
Arbuckle saline aquifer is an open system

Arbuckle Saline Aquifer Connected to Outcrop

Arbuckle exposure at base of Missouri River, north-central Missouri –
Elevation 450 ft; surface exposures located ~200 mi northeast
Assume hydrostatic gradient = 0.465 psi/ft

Map of the difference between estimated hydraulic head at base of Arbuckle test interval and measured shut-in pressure

Permian Hugoton Gas Field
Western Kansas
Original SIP = 435 psi

Sorenson (2005)
Lowest elevation of exposed Arbuckle strata on west flank of Ozark Uplift is along Missouri River at Jefferson City, MO (450 ft)

Study Area

Structure contour Top Arbuckle
Initial CO₂ Storage Capacity Estimate
(reporting April 2011 for NATCARB) Deep Arbuckle Saline Formation

\[ G_{CO₂} = A_t \ h_g \ \bar{\rho}_{tot} \ E_{saline} \]

9-75 billion metric tons in Arbuckle only
(200+ years for all KS stationary CO₂ emissions)

Metric tons CO₂ per Grid Cell
10 km²
(3.8 mi²)

Gerlach and Bittersweet team, 2012
P10 (top) and P90 (bottom) storage volume CO₂ (million tonnes)
Selection and correlation of Digital Type Wells for DOE-CO2 project

Bittersweet team (Gerlach, Nicholson, Hansen)

Regional stratigraphic correlation

Internal Arbuckle correlations and petrophysical properties

Southern Kansas Study Area

Top Arbuckle

Precambrian
Example cross section of lower Arbuckle from top Roubidoux (datum) to basement including new and old well data (insoluble residue logs, georeports, and modern suite of logs managed as LAS files) – Bittersweet (Gerlach et al.)
Published faults have been compiled and new ones are under investigation.

Focus on quantitative assessment of CO₂ storage capacity of Arbuckle saline aquifer is within dashed blue area.
Web-based Interactive DOE-CO2 Project Mapper
Overlay of Oil and gas field outlines and Top Arbuckle Group in study area of southern Kansas

http://maps.kgs.ku.edu/co2/?pass=project
Lower porous zone in Arbuckle
ISOPACH GASCONADE to GUNTER SS

Wellington Field

This isopach interval would contain Gasconade minus the Gunter SS

This isopach appears to be similar to Franseen’s work.

C - Van Buren-Gasconade dolomites

Early Ordovician (approx Gasconade time)
Paleogeography, Chenoweth, 68

Van Buren Gasconade Isopach, Franseen et al., 2004
Tilt angle map of the total magnetic field intensity in Kansas overlain with isopachous contours of Arbuckle Group’s Gasconade to Gunter Sandstone interval.

Snapshot from project’s interactive mapper -- http://maps.kgs.ku.edu/co2/?pass=project
Wellington Field Area
Landsat lineaments and gravity tilt angle map
Northeast trending surface lineament bisecting Wellington Field as viewed on interactive mapper

Gravity Tilt Angle = arctangent of the ratio of the 1st-order vertical derivative by the 1st-order horizontal derivative of the Bouguer anomaly.
Wellington Field
3D Multicomponent 3D Seismic Survey & 2 Basement Tests

Wellington Field
3D Seismic: Acquisition in March 2010
Surface footprint = 11.05 sq mi.
At 4500 ft: Fold = ~50 & footprint = 8.8 sq mi

Donated 3D from Noble Energy

KGS #1-28
KGS #1-32
Stratigraphic Column New Basement Test
Berexco Wellington KGS #1-32
Completed at Wellington Field
February 2011
Conventional 4.5 inch core from base Pennsylvanian shales to basement
(3550-5178 interval, 1628 gross ft, 1528 net feet)

- Mississippian – dolomite (EOR)
- Chattanooga-Simpson Group caprock
- Pennsylvanian shales – caprock
- Arbuckle Group
- Baffles/barriers
- Top core = 3550 ft

Additional geological information can be found at:
http://www.kgs.ku.edu/stratigraphic/PROFILE/
Wellington Field

1) Mississippian tripolitic chert/dolomite reservoir (20+ million barrels produced)
2) Arbuckle saline aquifer
3) Intervening caprocks

- Core and logs from KGS #1-32 and logs from #1-28 obtained in Jan-Feb. 2011
- Using to assess --
  - Integrity of caprocks
  - Porosity types, injectivity, and storage
  - Model potential for CO2-EOR in Mississippian saline aquifer
  - Sequestration in Arbuckle
Prestack Depth Migration (PSDM) 3D Seismic Wellington Field

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

Test Borehole Location #28-1

Test Borehole Location #32-1

SW - NE
Prestack Depth Migrated
Multicomponent 3D Seismic Volume in Wellington Field
Coincident w/ Shear Wave Line #1

Howard
Oread
KC
Miss
Arbk

Top Arbuckle Saline Aquifer
(multiple reflectors in layered aquifer with baffles)
Porosity Inversion & Structure
Depth-Migrated 3D Seismic at Wellington Field

North direction into the right side of image

Top Arbuckle surface (worms eye view)

CO2 Injector

Horizon 3

Horizon 7

1-32 w/GR log

1-28

Precambrian granite basement

Mid Arbuckle tight

Lower Arbuckle injection zone

Porosity inversion on intermediate PSDM in (Petrel™) Geocellular model

J. Rush
2012

~3500 ft
Arbitrary seismic impedance profile

distinct caprock, mid-Arbuckle tight, lower Arbuckle injection zone

Impedance = \( \rho \times \varnothing \)

Baffle or potential barrier to vertical flow
(high impedance)

Low impedance injection interval

Hedke, 2012
CO₂ injection zones in Arbuckle saline formation and Mississippian oil reservoir, and associated caprocks
-- Well profile in 2-way travel time of KGS #1-28 illustrating synthetic seismogram and seismic impedance (velocity x density) and well log suite used to derive these seismic properties

Precambrian granite – bottom of core

Freeware: http://www.kgs.ku.edu/software/SS/
Arbuckle Group
Integration of logs, core, water, and DST analysis, core description, links to core images via an LAS 3.0 file

http://www.kgs.ku.edu/stratigraphic/PROFILE/applet.html
Nuclear magnetic resonance (Halliburton’s MRIL) log in Arbuckle Group compared with core lithofacies, Arbuckle in Berexco Wellington KGS #1-32

Lithofacies from core (vertical columns) (x)
0 = no core recovered
1 = shale
1.5 = argillaceous dolomudstone
2 = mudstone-wackestone
3 = packstone-grainstone
4 = grainstone
5 = incipient autoclastic brecca
6 = autoclastic brecca
7 = quartz sandstone

Derived from relaxation time of NMR log:
PHI (+) = sum of porosity in T2 channels
CG (Δ) = center of gravity of T2 spectrum
units are powered relaxation times
e.g. T2 = CG²
=>larger number, larger the size of pores

- Discontinuous fracturing
- Autoclastic breccia (dissolved evaporites)
- Lithofacies control porosity & permeability in persistent stratal packages
Arbuckle Hydrostratigraphy at Wellington Field
obtained from DST and perf & swab test

Zonation Evidence in Arbuckle and Mississippian Formation Brines

Scheffer (2012)
Permeability profile of Arbuckle in cored well - #1-32 with concentrations of redox reactive ions \((\text{Fe}^{2+}, \text{SO}_4^{2-}, \text{CH}_4, \text{NO}_3^-)\) from KGS #1-32 & #1-28

Redox reactive ions reflect changes in biogeochemistry (microbial) occurring between upper and lower Arbuckle, in turn attributed to lack of hydraulic communication.

Scheffer, 2012
Lower and upper Arbuckle are not in hydraulic communication.

Oxygen & Hydrogen isotopes of brines from DST and perf & swabbing.

Upper Arbuckle -- distinct

Lower Arbuckle injection interval
- Waters distinct from upper Arbuckle and Miss
- Lower intervals are also geochemically homogeneous → infer fracture connectivity

Scheffer, 2012
Zonal fracturing in entire Arbuckle

Spectral (dipole) acoustic log and visual core description

- Top Arbuckle
- Precambrian
- Stacked baffles and barriers to vertical flow
- No core recovery in gray areas

Scheffer, 2012; Lorenz and Cooper, 2011
Surface location of basement test (#1-32 & 31-28) drilled in Wellington Field during Jan-Feb 2011

KGS 32-1 (Cored Well)

KGS 28-1 (Proposed injector Small scale field test)

3000 ft apart

Step-rate (pulse test) between wells conducted August 2011
Cross section showing 20 ft interval of step rate test in lower Arbuckle injection zone

Prospective disposal zone
(4900 ft to 5030 ft)

Preliminary upscaled hydrostratigraphic units in Arbuckle Group

Coates & Bin Permeability
(0.008-200 md)

Total & Effective Porosity (NMR)
0.2 to 0.01 Ø

Middle Arbuckle (aquitards)
Step-Rate Test Pressure-Time Plot
Source Well (#1-32) and Observation Well (#1-28) Pressures in 20 ft Perforated Zone in Lower Arbuckle Injection Interval

Est. fracture pressure = 0.7 psi/ft x 5000 ft = 3500 psi (to create new fracture)

- Estimated permeability ~1 darcy
- Pressure dispersal into multiple communicating layers comprising 200+ ft thick injection zone

Time for observation well (#1-28) based on clock and start time for source well (#1-32)
Flow units in the lower Arbuckle injection zone

KGS #1-32

KGS #1-28

Wells 3500 ft apart

50 ft

Porosity%

0 2 4 6 8 10 12 14

4900 4910 4920 4930 4940 4950 4960 4970 4980 4990 5000 5010 5020 5030 5040 5050 5060 5070 5080 5090 5100 5110 5120 5130 5140 5150 5160

Flow unit boundaries

Step rate test perforations

Utilize whole core analysis, NMR, spectral sonic, and resistivity logs

Doveton and Fazelalavi, 2012

Connected vugs → Solution & fracture

Nonconnected vugs

Interparticle/matrix

Wellington #1-32

Wellington #1-28

0 2 4 6 8 10 12 14

4900 4910 4920 4930 4940 4950 4960 4970 4980 4990 5000 5010 5020 5030 5040 5050 5060 5070 5080 5090 5100 5110 5120 5130 5140 5150 5160

Porosity%

KGS #1-32

KGS #1-28

Wells 3500 ft apart

50 ft

Porosity%

0 2 4 6 8 10 12 14

4900 4910 4920 4930 4940 4950 4960 4970 4980 4990 5000 5010 5020 5030 5040 5050 5060 5070 5080 5090 5100 5110 5120 5130 5140 5150 5160

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Interparticle/matrix

Wellington #1-32

Wellington #1-28

0 2 4 6 8 10 12 14

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Porosity%

KGS #1-32

KGS #1-28

Wells 3500 ft apart

50 ft

Porosity%

0 2 4 6 8 10 12 14

4900 4910 4920 4930 4940 4950 4960 4970 4980 4990 5000 5010 5020 5030 5040 5050 5060 5070 5080 5090 5100 5110 5120 5130 5140 5150 5160

Flow unit boundaries

Step rate test perforations

Utilize whole core analysis, NMR, spectral sonic, and resistivity logs

Doveton and Fazelalavi, 2012
Possible use of apparent “m”, cementation exponent to indicate greater abundance of fractures (m <2) and vugs (m>2), injection zone.
Stoneley wave used to estimate permeability, $k$ compared to Coates $k$ derived from MRIL

Dipole (Spectral™) sonic log interpretation at lower Arbuckle injection zone 4900 to 5150 ft
Kmax
Ranges from 0.01 to 425 md (whole core)

Porosity – predominately between 1-10%

Shale = 1
Mudstone = 2
Packstone = 3
Grainstone = 4
Incipient breccia = 5
Breccia = 6
Sandstone = 7
Microbialite = 8

Top Missippian
Top Arbuckle

Lithofacies
Vugs
Fractures

Vugs (small to large, 1-5)

KGS #1-32 whole core analysis compared to core derived lithofacies
Core-Log integration of Wellington KGS #1-32 using well profile tool – INJECTION INTERVAL (4900-5200 ft)

http://www.kgs.ku.edu/stratigraphic/PROFILE/applet.html
Core from Lower Arbuckle Injection Interval

5089-92 ft
3.4 %; 14.13 md

5080-83

5053-56
2.3%, 108 md

4995-97.7 ft
4.8%, 0.29 md
Middle Arbuckle - lower Jefferson City Cotter
Baffle to barrier?

17-27
4379.1'

whole core: phi 4.4%, 10 md

4379.1 ft

Middle Arbuckle - lower Jefferson
City Cotter
Baffle to barrier?

19-41
4504'

whole core: phi 3%, 8.1 md

4505 ft

calcagony and dolomudstone

Fine-med. xln. dolomite

Thin sections and photomicrographs by Robin Barker, KSU, 10-25-12
Thin Sections – Baffle Zone (Mid Arb.)

Flow units in the lower Arbuckle injection zone

- KGS #1-32
- KGS #1-28
- Wells 3500 ft apart

- Connected/Disconnect
- Flow unit/boundaries
- Step rate test perforations
- Interparticle/matrix

Utilize whole core analysis, NMR, spectral sonic, and resistivity logs

Pairs of photomicrographs
Plane light and crossed nichols
MAXIMUM HORIZONTAL COMpressive STRESS (East-Northeast)
from microresistivity imaging and dipole sonic logs (KGS #1-32)

Fracture Statistics: 5239’-3528’

Natural mineralized “closed” fractures

There are natural mineralized “closed” fractures with two orientations, one E x W and the other NE x SW.

Induced fractures

There are 132 drilling induced fractures in this pass, oriented 75°/255°, indicating the maximum stress direction.

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Fracture Statistics: 5239’-3528’
Wellington KGS #1-32

There are 485 partial fractures in this pass with random orientation.

There are 12 natural open fractures (360° conductive fractures) with an overall NNE x SSW orientation.
Dynamic Simulation of CO$_2$ Injection in Saline Aquifer, Arbuckle Fm. in Wellington Field

Yevhen Holubnyak

GeoFest 2012
Lawrence, KS

October 26, 2012
Area of Review for small scale Arbuckle injection

**CO₂ Plume Extent**

- 40 kt
- 16 Mt

**Pressure Response**

- Dynamic Simulation of CO₂ Injection in Saline Aquifer, Arbuckle Fm. in Wellington Field

Yevhen Holubnyak, KGS
3D Volume Footprints for DOE-CO2 study

Gross Extent of Seismic coverage verify structure and use in Chester/Morrow EOR Study
= 112 mi N-S, 11 mi E-W

- **Pleasant Prairie Merge** ~ 32.5 sq mi, processed 1999, can be interpreted as is, bin size 110’ x 110’

- **Eubanks Merge** ~ 37.5 sq mi; 3 surveys acquired 1996 – 2001, bin size 110’ x 110’, reprocessing underway

- **Cutter** ~ 3.4 sq mi, acquired 2009, bin size 82.5 x 82.5, can be interpreted as is

- **Adamson-Wide Awake (Shuck)** ~ 81.5 sq mi, acquisition /processing date unknown, bin size 82.5’ x 110’, can be interpreted as is

Donated to DOE-CO2 project by industry members of Southwest Kansas CO2-EOR Initiative
Managed by M. Dubois
Seismic data management and interpretation by D. Hedke
Western Annex
ARBK Penetrations

N-S Cross Section
3 Intervals
ARBK to Pre-Camb
MRMC to ARBK
MRRW to MRMC

Pre-Camb Penetrations

Bittersweet Team
N-S X-Section
ARBK to Pre Camb Interval

Arbuckle

Bittersweet team

Precambrian
KGS Cutter #1 well on Mississippian structural plateau on local structural high

Gerlach and Bittersweet team, 2012
West side of field --
~800 ft reverse fault at top of basement

W-E Time Section
Time Slice at top of Meramec

Interpretation by D. Hedke, 2012
DOE-CO2 project
Pleasant Prairie Arbitrary Profile NW - SE

Interpretation by D. Hedke, 2012
DOE-CO2 project

Kansas City

Top Arbuckle

Precambrian

NW-SE Time Section
Summary of Arbuckle Section of Presentation

- Many UIC Class I and II wells successfully operating in the Arbuckle in Kansas
- Complex cyclical internal stratigraphic units important to distribution of petrophysical properties
- Hydrostratigraphy of Arbuckle includes flow (high injectivity), baffle (low injectivity), and vertical barriers to flow
- Petrophysical properties of deep, thick, saline Arbuckle aquifer are similar to shallower oil reservoirs characterized by a layered pore network dependent on depositional texture modified by karst, brecciation, and fracturing
- Well logs, seismic, well tests, and core provide means to distinguish and quantify fractures, connected and unconnected vugs, and interparticle pores to define permeable intervals and aid in selection of injection intervals.
Southwest Kansas CO₂-EOR Initiative

Industry Partners (modeling 4 Chester/Morrowan oil fields to make CO₂ ready)

+drilling and seismic contractors TBN

Dawson-Markwell Exploration Co.
Project Team – Small Scale CO2 Injection Project at Wellington

DOE-NETL Contract #FE0006821

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