SMALL SCALE FIELD TEST DEMONSTRATING CO_2 SEQUESTRATION IN ARBUCKLE SALINE AQUIFER AND BY CO_2-EOR AT WELLINGTON FIELD SUMNER COUNTY, KANSAS DE-FE0006821

W. Lynn Watney & Jason Rush (Joint PIs)

Jennifer Raney* (Asst. Project Manager)

Kansas Geological Survey

Lawrence, KS 66047

*speaker

KANSAS GEOLOGICAL SURVEY
The University of Kansas

Presentation Outline

1. Benefits to the Program
2. Project Overview
3. Technical Status
4. Accomplishments to Date
5. Summary

1. Benefits to the Program

- **Program goals being addressed –**
  - Demonstrate that 99 percent of injected CO_2 remains in the injection zone
  - Conduct small field test to support characterization, site operations, monitoring, and closure practices for <u>Class VI geosequestration Permit</u> , Region 7 EPA, Kansas City
- **Project benefits of this small scale field test:**
  - Advance the science and practice of carbon sequestration in the Midcontinent
  - Evaluate reliable, cost effective MVA tailored to the geologic setting
  - Optimize methods for remediation and risk management
  - Provide technical information to local petroleum industry for implementation of CCUS
  - Enable additional projects and facilitate discussions on regulations and policy

Project Team

DOE-NETL Contract #FE0006821

KU KANSAS GEOLOGICAL SURVEY — The University of Kansas

L. Watney (Joint PI), J. Rush (Joint PI), T. Bidgoli, J. Doveton,
E. Holubnyak, M. Fazelalavi, R. Miller, D. Newell, J. Raney
(static & dynamic modeling, well test analysis, high-resolution seismic, passive seismic, accelerometers, geomechanical analysis, project management)

BERKELEY LAB — LAWRENCE BERKELEY NATIONAL LABORATORY

Tom Daley, Barry Freifeld *(soil gas, CASSM, U-Tube, cross well seismic)*

DEPARTMENT OF GEOLOGY — **KANSAS STATE UNIVERSITY**

Saugata Datta *(brine and USDW monitoring)*

TBirdie Consulting, Inc
4705 McCormick Street • Lawrence • KS 66047 • 785 843 1085 • 785 865 0678 (fax) • tbirdie@sunflower.com

T. Birdie *(engineering, monitoring synthesis, reporting, closure)*

Brian Dressel, P.M.

BEREXCO

Dana Wreath, Adam Beren
(field operator and operations, repeat 3D multicomponent seismic)

THE LINDE GROUP — **Linde** / **PRAXAIR** *Making our planet more productive*

CO$_2$ supply

IRIS PASSCAL — INSTRUMENT CENTER — Program for Array Seismic Studies of the Continental Lithosphere

seismometers

KU THE UNIVERSITY OF KANSAS — **Department of Geology**

Mike Taylor *(cGPS, InSAR)*, **George Tsoflias** *(passive seismic)*

Project Overview:
Goals and Objectives

1. Obtained most cost effective reliable source of CO_2 and commence field activities September 2014.

2. Begin injection of 26,300 metric tons of CO_2 into Mississippian oil reservoir April 2015 using 5-spot pattern to demonstrate optimization for carbon sequestration.

3. Obtain Class VI permit in 2015.

4. *Pending approval of Class VI injection application* -- Inject under supercritical conditions up to 40,000 metric tons of CO_2 into the underlying Arbuckle saline aquifer in November 2015.

5. Demonstrate state-of-the-art MVA (monitoring, verification, and accounting) tools and techniques

6. Integrate MVA data and analysis with reservoir modeling studies to demonstrate and ensure 99% CO_2 storage permanence.

Technical Status
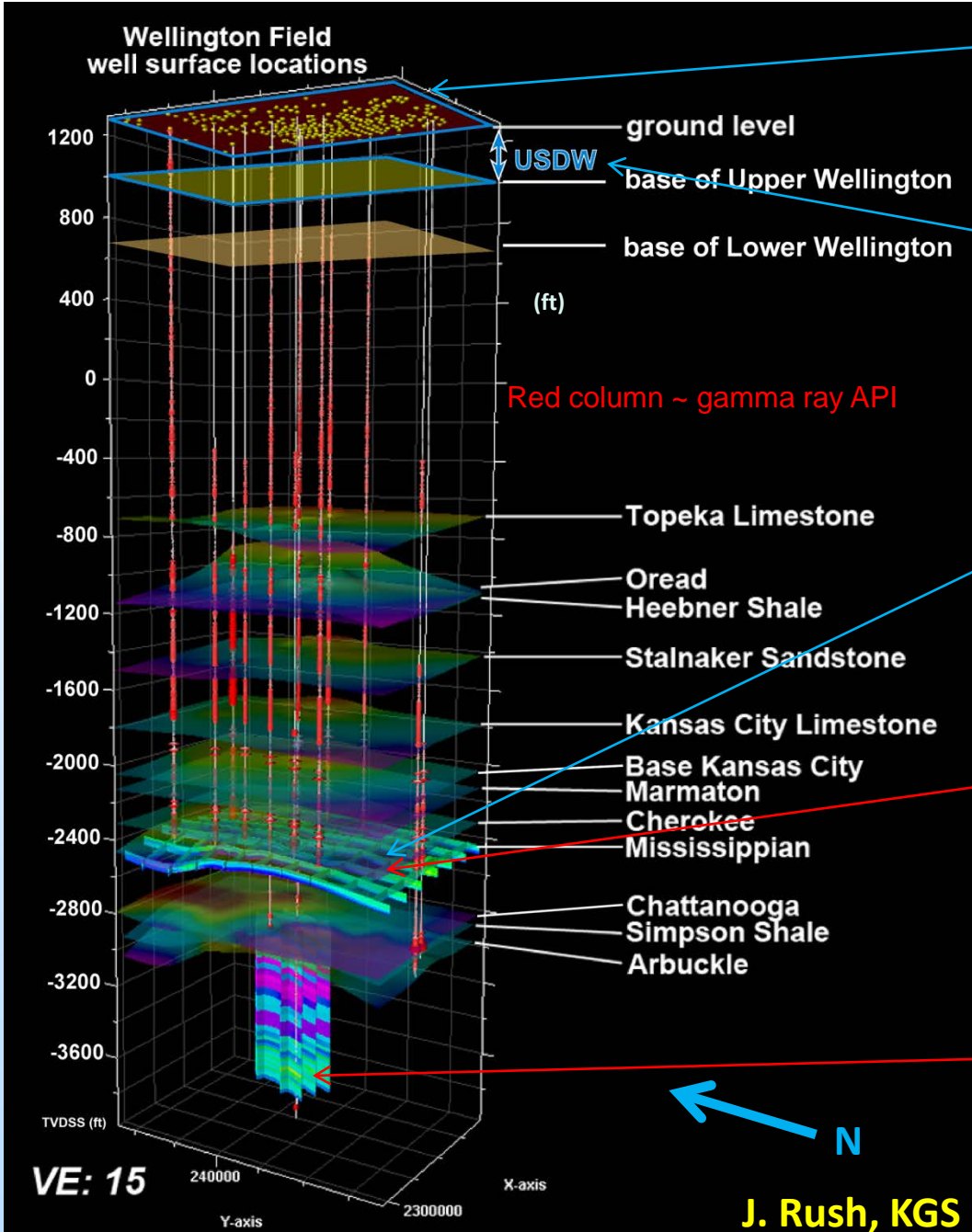## Mississippian oil reservoir test first

- **Refined characterization and modeling of the Mississippian reservoir to confirm location of monitoring wells**

- **Installation of a 15-seismometer array**

  Use to further resolve CO_2 movement and regional seismic activity

- **KGS purchased and preparing to install and activate three 3-component active accelerometers**

  - Greater acoustic sensitivity over seismometers and more precise timing of smaller seismic events useful for CASSM research

  - Baseline monitoring to gain understanding to fund additional seismometers and use to resolve behavior of CO_2 plume

Technical Status
Class VI Geosequestration Injection Permit

- **Submittal of Class VI application**:
  - June 2014
- **Static and coupled dynamic modeling of Arbuckle saline aquifer** for up to 40k tonnes CO_2 injection
- **Injection zone** –
  - Highly permeable 150+ ft thick Lower Ordovician Arbuckle (Gasconade Dolomite, 100s of md to >1 D)
  - Multiple flow units decreasing thickness of buoyant supercritical CO_2 plume
- **Baffle and trapping of CO_2 plume (final model)** –
  - Multilayer plume under a ~400 ft thick shaly, low perm/aquiclude middle Arbuckle (lower Jefferson City-Cotter & Roubidoux formations)
  - Low pressure CO_2 injection **(<325 psi)** and multi-layer plume **(~1800 ft radius)** within lower Arbuckle (Gasconade) presents very low risk for caprock
- **Primary caprock interval** – ~230 ft gross thickness including Lower Mississippian argillaceous, organic dolosiltstone (Pierson/St. Joe Limestone), Chattanooga Shale and seals in the Simpson Group
- **USDW and interaction with subsurface brines** –
  - Marginal surface aquifer, its potentiometric surface ~500 ft above that of saline aquifer
  - Multiple secondary caprock/seals – 1000's feet of shale, and 200 ft shallow evaporites

CO2-EOR, saline injection, Class VI, MVA - Wellington Field

Wellington Field
well surface locations

ground level

USDW

base of Upper Wellington

base of Lower Wellington

(ft)

Red column ~ gamma ray API

Topeka Limestone

Oread
Heebner Shale

Stalnaker Sandstone

Kansas City Limestone

Base Kansas City
Marmaton
Cherokee
Mississippian

Chattanooga
Simpson Shale
Arbuckle

N

VE: 15

J. Rush, KGS

- InSAR, CGPS surface deformation/IRIS seismometers
- Measure soil gas flux

- Monitor for tracers, CO_2, aqueous geochemistry in shallow freshwater wells
- Monitor ~600 ft deep well below shallow evaporite cap rock

- Test for CO_2 and analyze fluid samples from Mississippian wells (if positive, run 2D seismic)
(*Underpressured oil reservoir should trap any vertically migrating CO_2*)

Inject 26,300 tonnes of CO_2 into Mississippian oil reservoir **to demonstrate CO_2-EOR and 99% assurance of storage with MVA**

Pending Class VI permit and DOE funding -- Inject up to 40,000 tonnes of CO_2 with tracers into lower Arbuckle saline aquifer and seismically image and sample in situ CO_2 plume to validate geomodel and simulations - U-Tube, CASSM and cross hole seismic with DTS. Acoustic fiber optics VSP pending, DE-FE0012700, R. Trautz

Extensive monitoring network
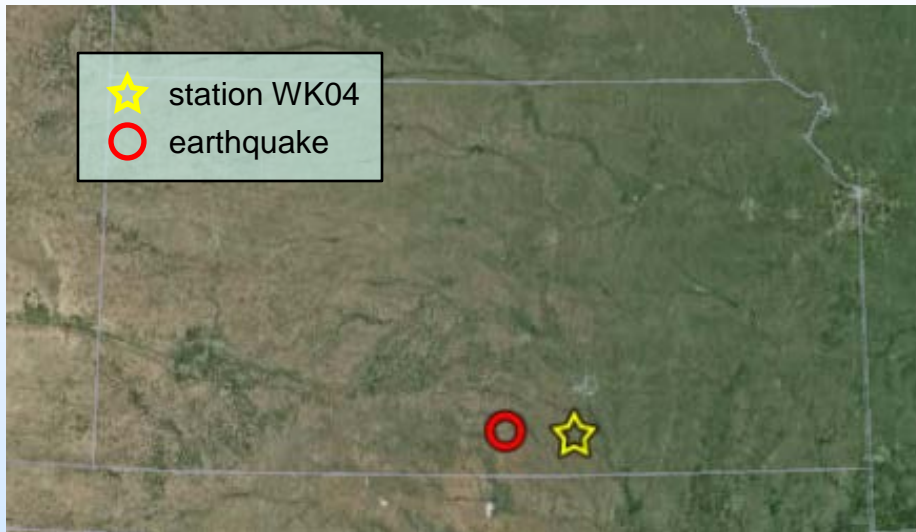# Wellington Field CO$_2$ Injection Tests
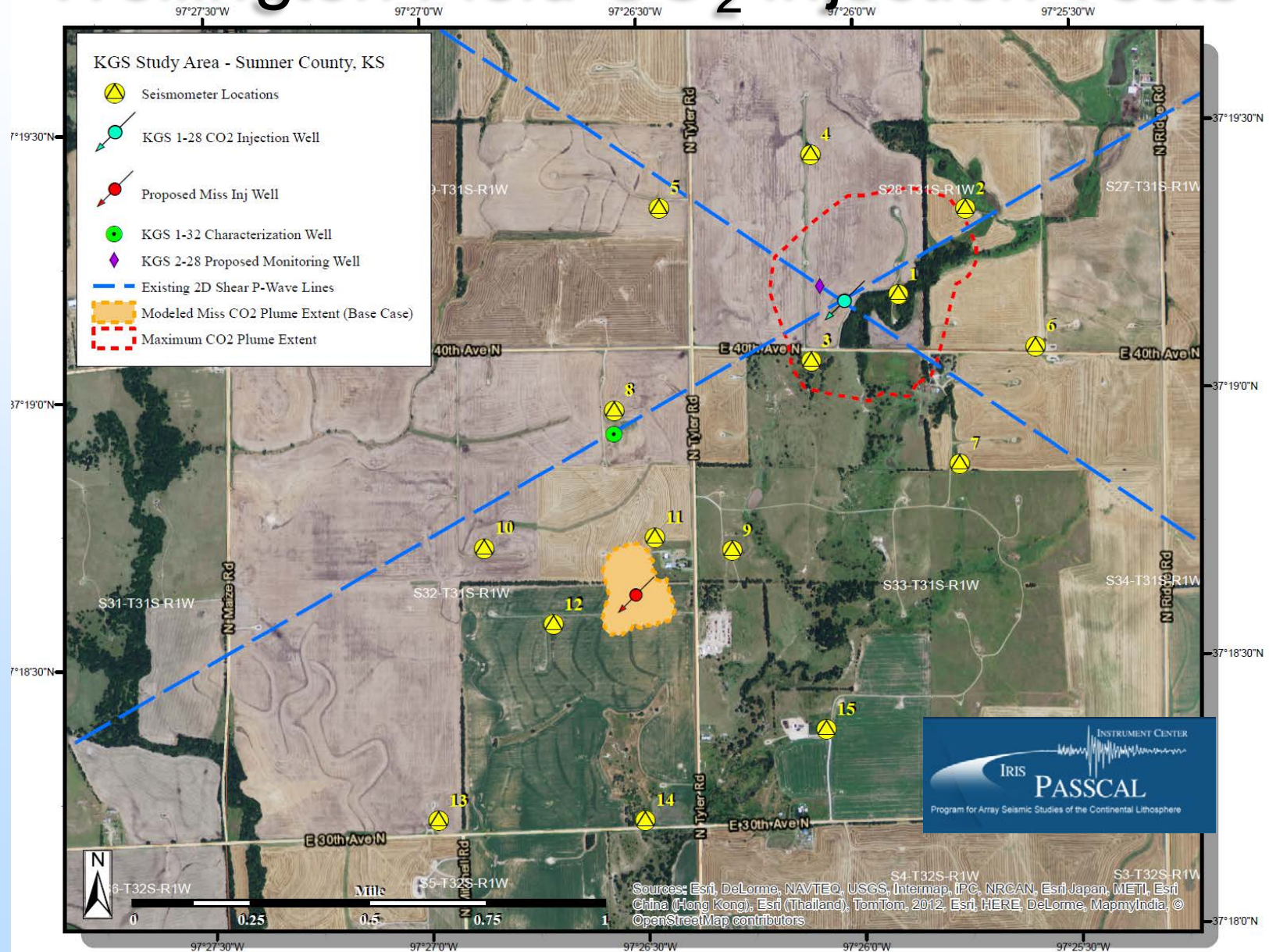
IRIS seismometer installation --
~5 ft below surface to minimize surface noise; installed below frost line in bedrock
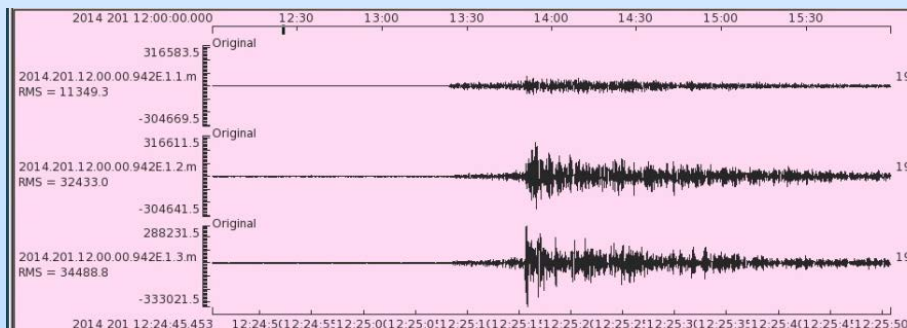

Shelby Peterie, KGS Exploration Services, checking installation in July 2014
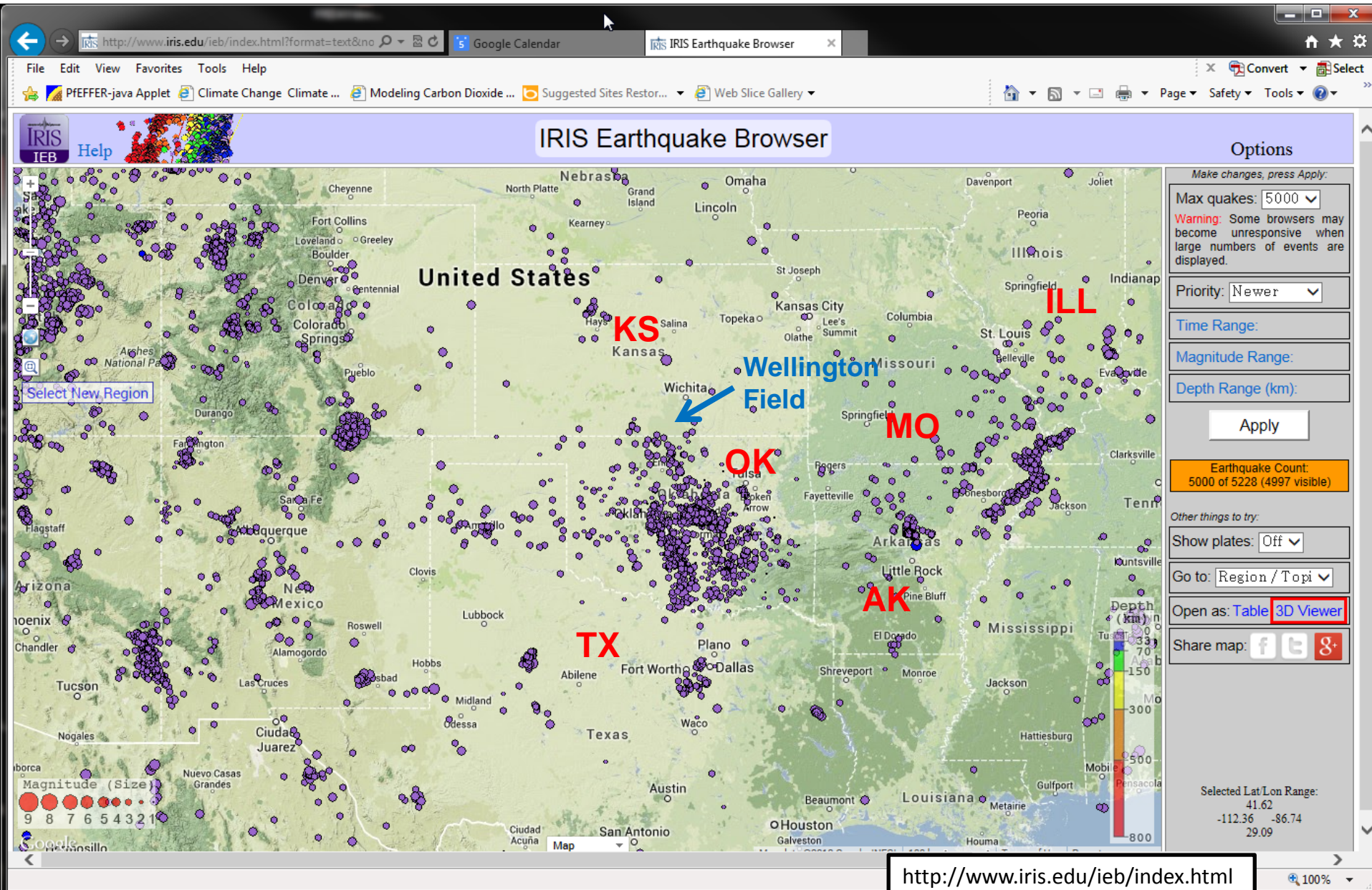
Wellington CO$_2$ WK04

- Newly installed seismometer detected seismic event in Kansas
- Date: July 20, 2014
- Time: 12:24:58
- Distance from WK04: 58 km
- Magnitude: 3.3

Historical Earthquakes in U.S. Midcontinent
long term trend of generally low magnitude events from north TX, OK, Ark, MO, Ill

http://www.iris.edu/ieb/index.html

Porosity inversion of the 3D Seismic Wellington Field

Complex offlapping geometries of porous lithofacies resulting from the westward progradation of the Mississippian -- Looking SW
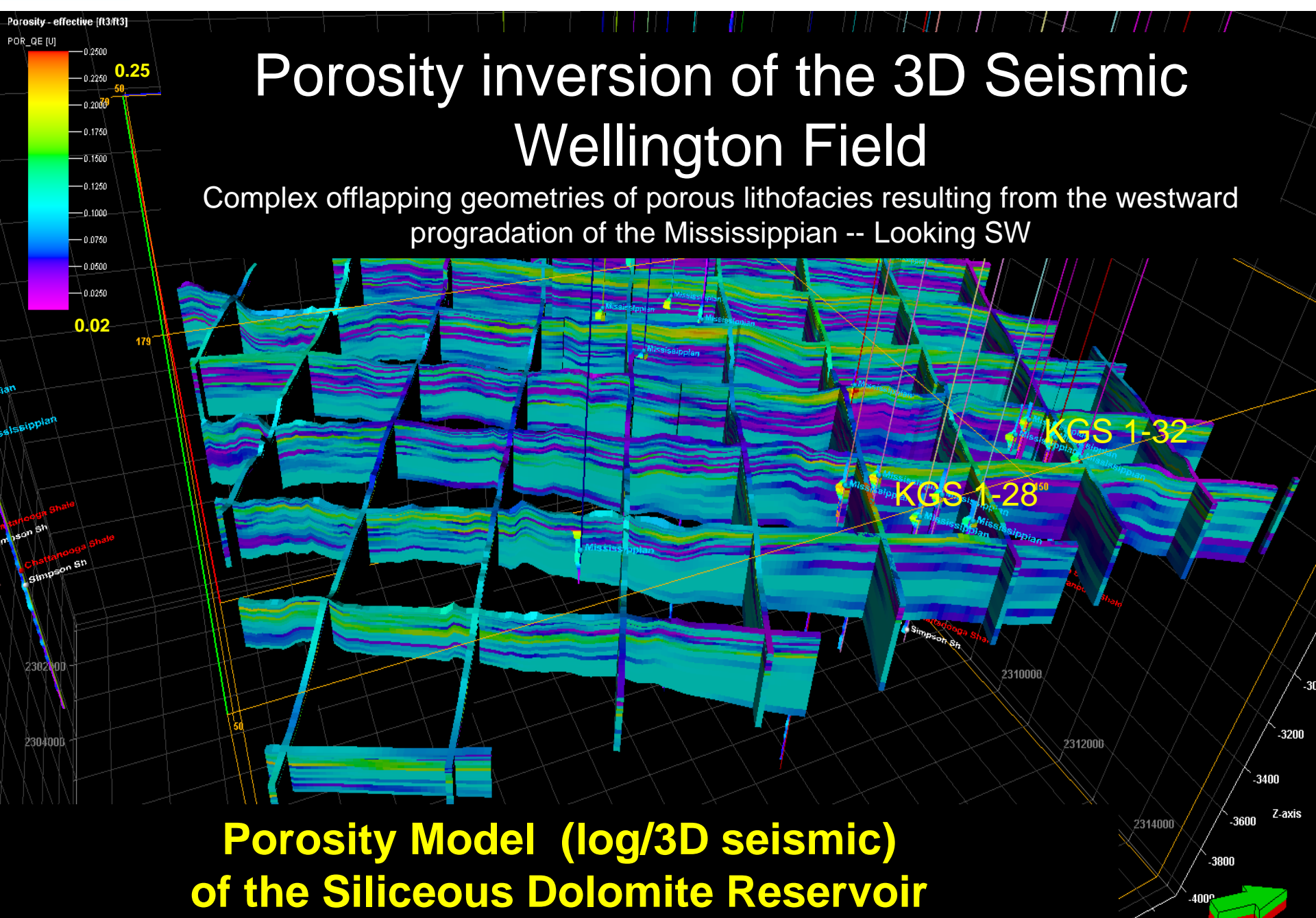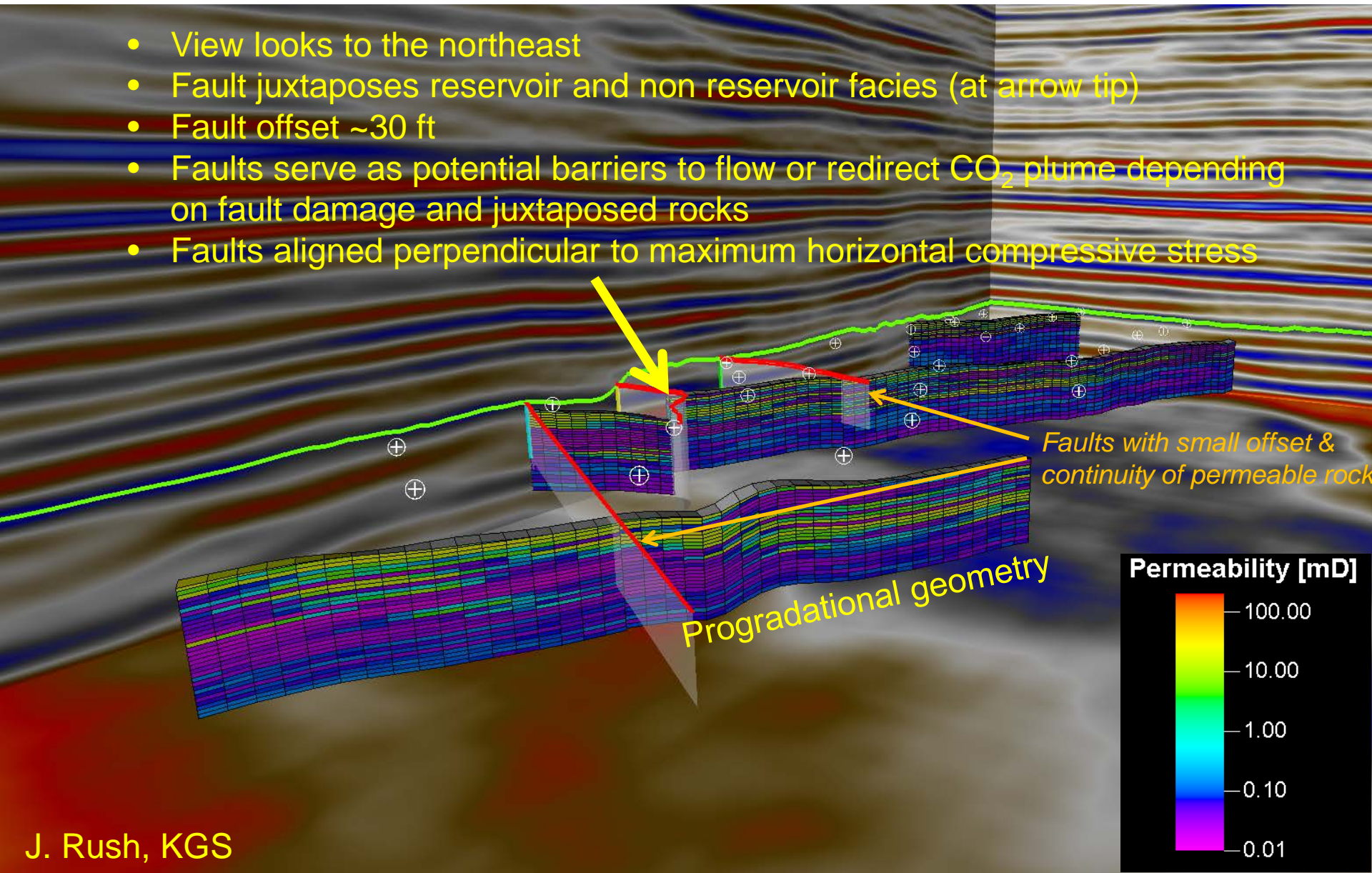
Porosity Model (log/3D seismic) of the Siliceous Dolomite Reservoir Upper Mississippian, Wellington Field

Rush, KGS

Permeability fence diagram of Mississippian oil reservoir within 3D seismic

--Small faults that tip out above the top of the Mississippian reservoir

- View looks to the northeast
- Fault juxtaposes reservoir and non reservoir facies (at arrow tip)
- Fault offset ~30 ft
- Faults serve as potential barriers to flow or redirect CO_2 plume depending on fault damage and juxtaposed rocks
- Faults aligned perpendicular to maximum horizontal compressive stress

Faults with small offset & continuity of permeable rock

Progradational geometry

Permeability [mD]

- 100.00
- 10.00
- 1.00
- 0.10
- 0.01

J. Rush, KGS

CO_2 plume from latest simulation of Mississippian test injection (26,300 tonnes)

Gas Mole Fraction(CO_2) 2025-01-01   K layer: 8

New injection well to be drilled -- Wellington KGS #2-32

Elongate N-S CO_2 plume influenced by newly mapped N-S faults acting as both barriers and conduits to CO_2

File: 3 5 spot generic
User: eugene
Date: 8/8/2014
Scale: 1:11733
Y/X: 1.00:1
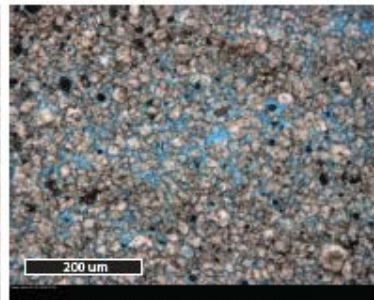Axis Units: ft

E. Holubnayak, KGS
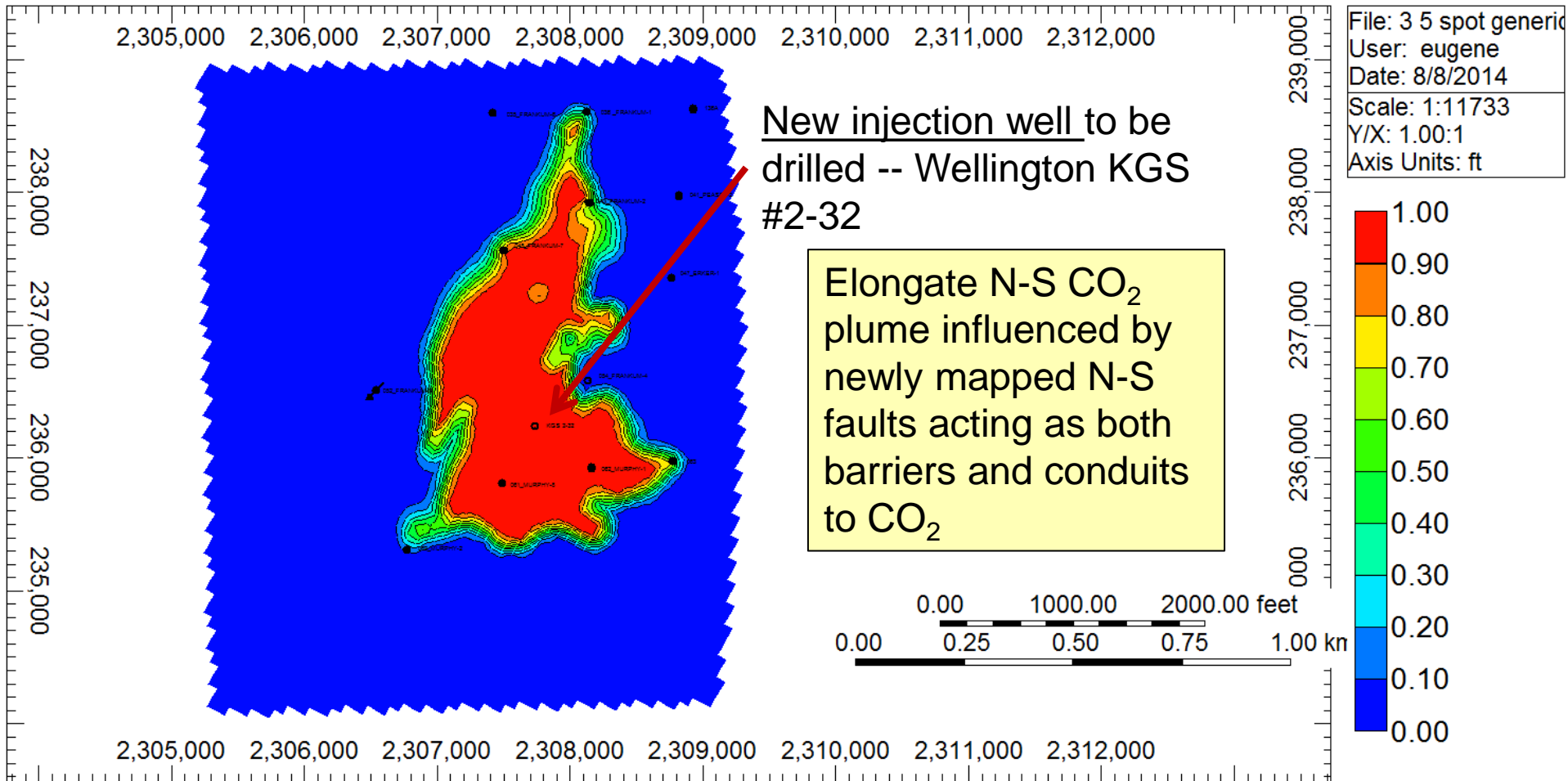
Diagenetic facies and textures
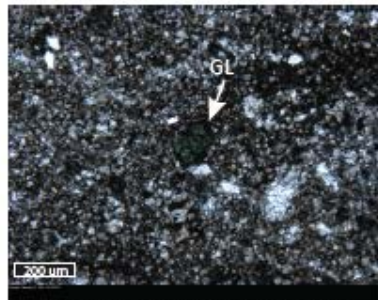
Argillaceous dolomite (WL 1-32, 4026.4 ft)
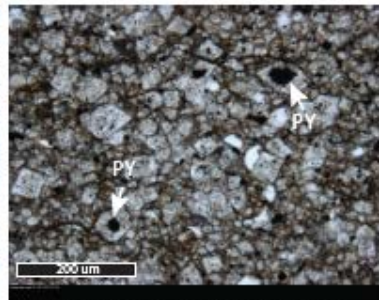
Argillaceous dolomite (WL 1-32, 4049 ft)

Dolomite (WL 1-32, 3892.25 ft)
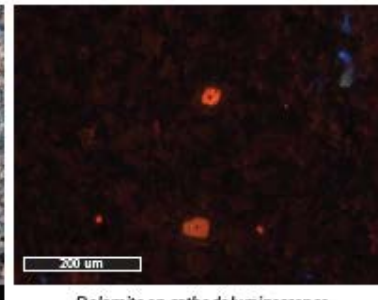
Dolomite on cathodoluminescence (WL 1-32, 3807 ft)
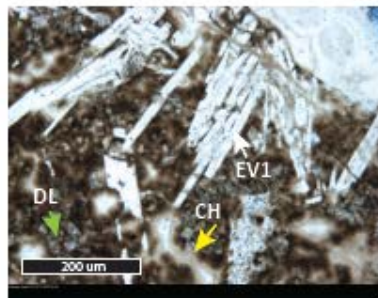
Nodular chert (WL 1-32, 3680.7 ft)
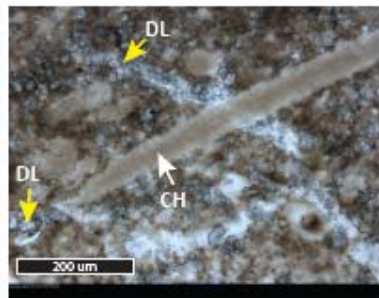
Nodular chert (WL 1-32, 3671.8 ft)
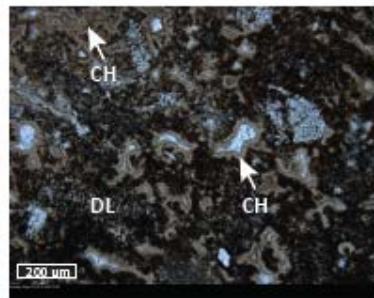
Nodular cherty dolomite (WL 1-32, 3680.7 ft)
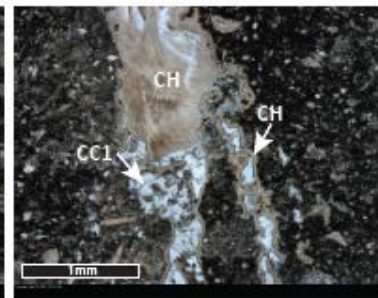
Argillaceous dolomite (WL 1-32, 3867 ft)
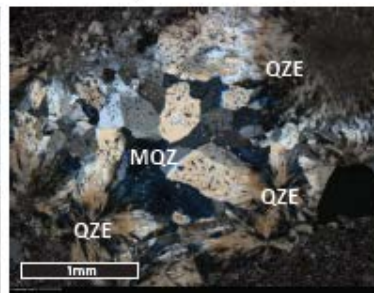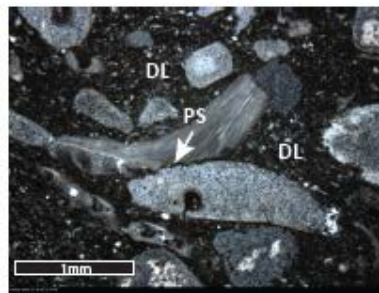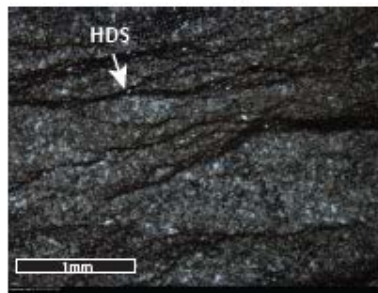
Silica-replaced evaporite nodule (WL 1-32, 4049.4 ft)

Silica-replaced evaporite nodule (WL 1-32, 3790 ft)

Silica-replaced evaporite nodule (WL 1-32, 3857.5 ft)
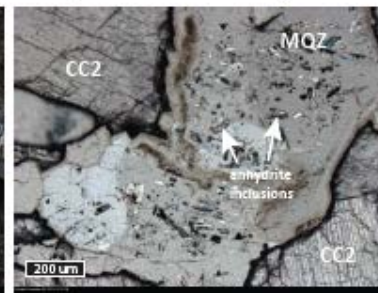
Silica-replaced evaporite nodule (WL 1-32, 3689 ft)

Petrography, Berexco Wellington KGS #1-32 Thin sections from the <u>Mississippian oil reservoir</u> -- dolomite, silica, minor amounts of anhydrite, organic matter, pyrite

Luis G. Montalvo 1, Luis Gonzalez 1, Lynn Watney 2, 2014,
1) Department of Geology, University of Kansas, Lawrence, KS, 2) Kansas Geological Survey
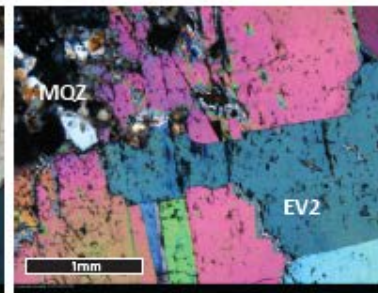
Aquiclude layer in Arbuckle detectable on seismic
(*brighter blue layer*)
Seismic impedance profile (left) and stratigraphic profile from well log (right) of the #1-28 Arbuckle injection well
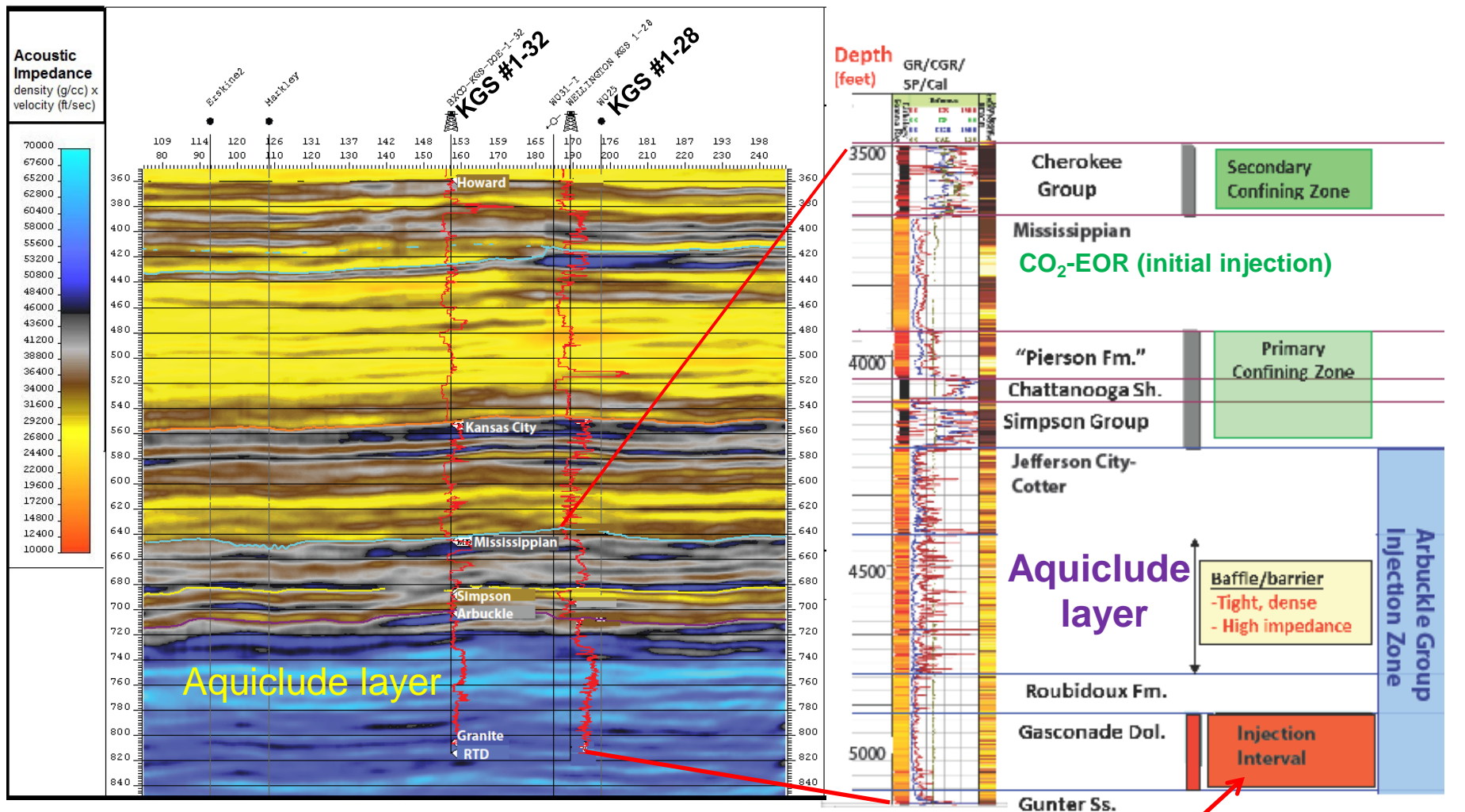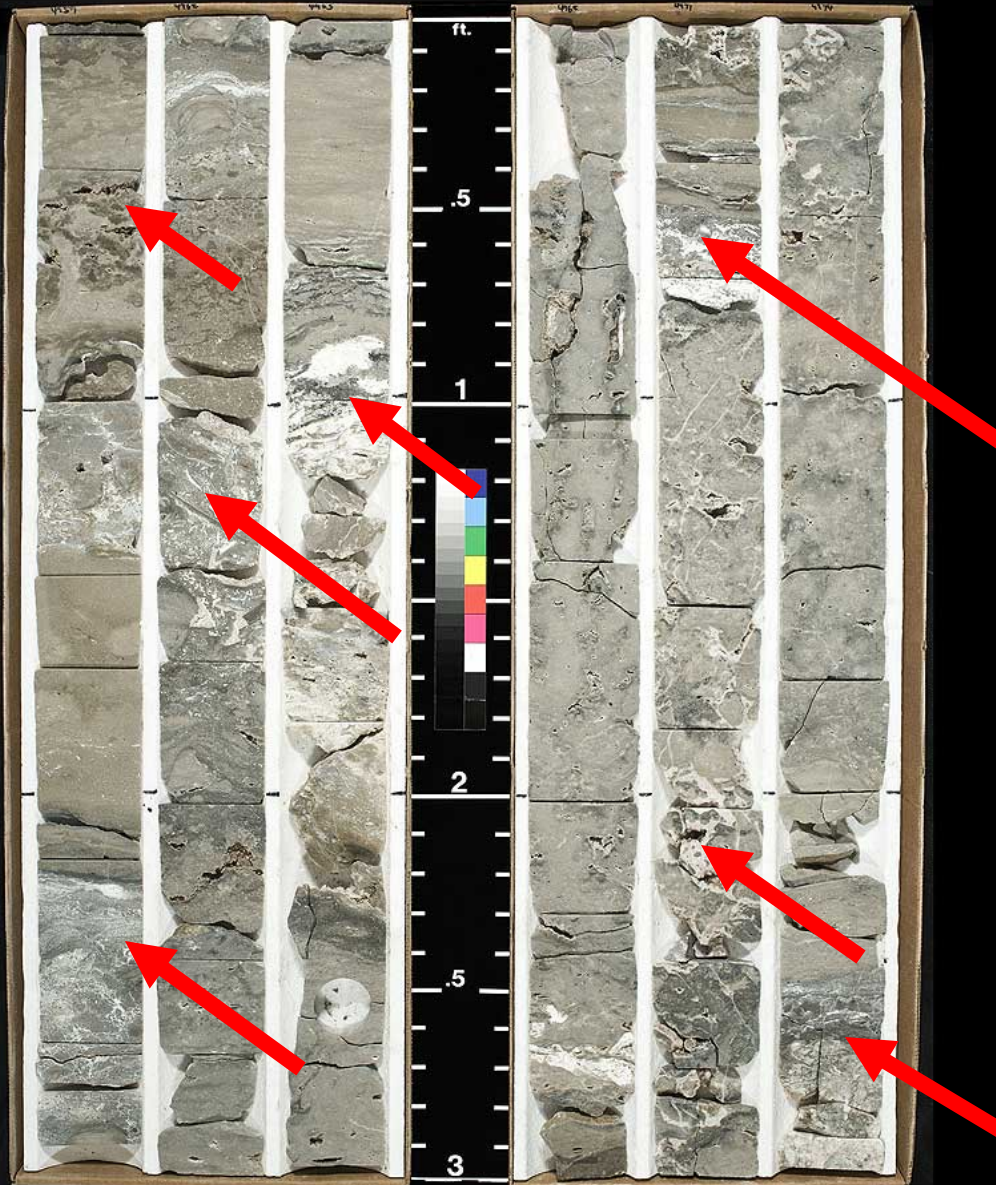
CO$_2$ injection zone in lower Arbuckle

Thin, shallowing-upward peritidal cycles, topped with autoclastic/crackle breccias, silicified in places

vuggy and intergranular pores, and discontinuous fractures
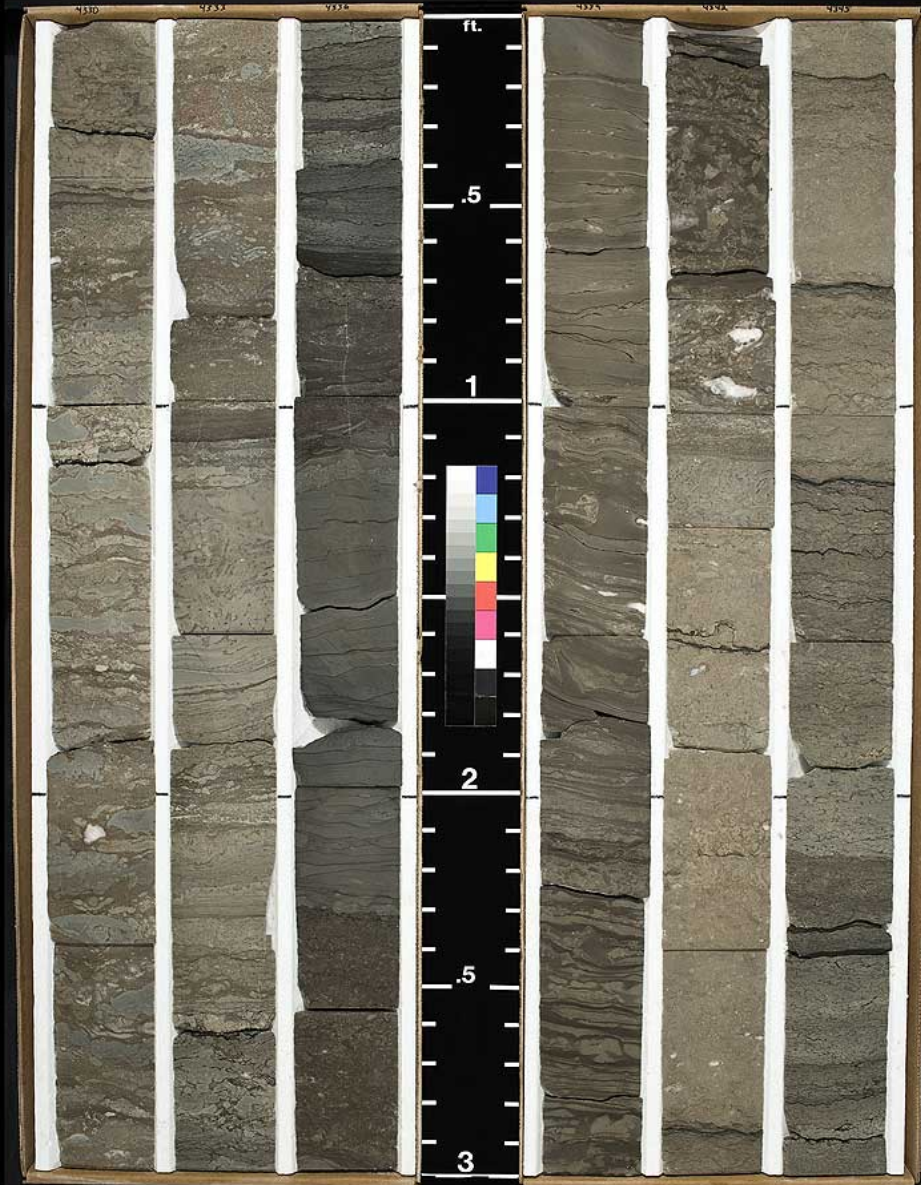
Aquiclude/baffle in the middle of the Arbuckle

argillaceous dolomite and thin beds of clay over extended interval (seismically resolvable)

Brine Sampling of the Arbuckle was extensive

- 11 swabbing intervals and 8 DSTs targeted both tight and high porosity zones in all parts of the Arbuckle

- Overlapped sampling for comparison

- Fluids collected, preserved and analyzed for:
  - Geochemistry
  - Microbiology
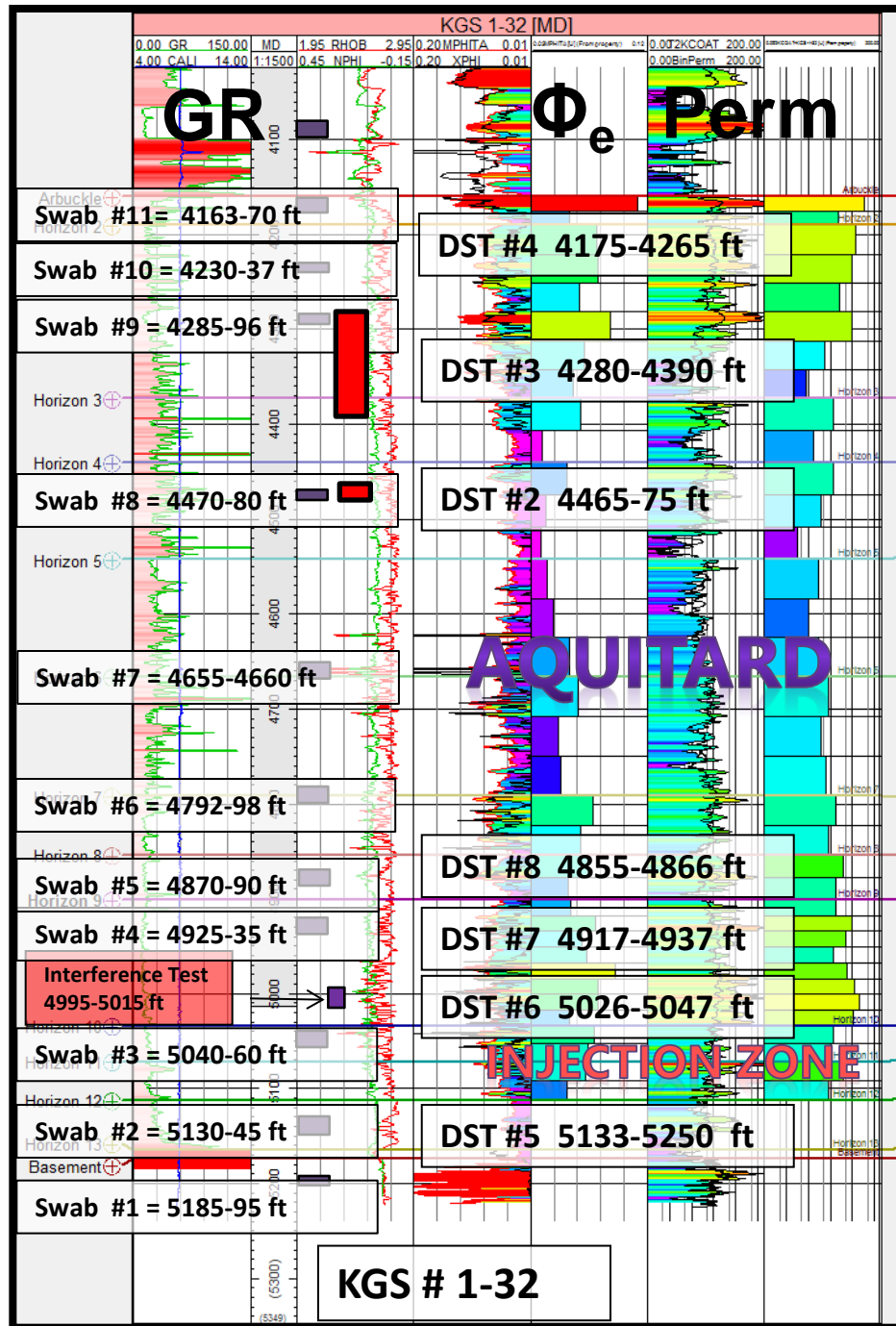
Lower and Upper Arbuckle Are Not in Hydraulic Communication

A. Scheffer, KU/KGS
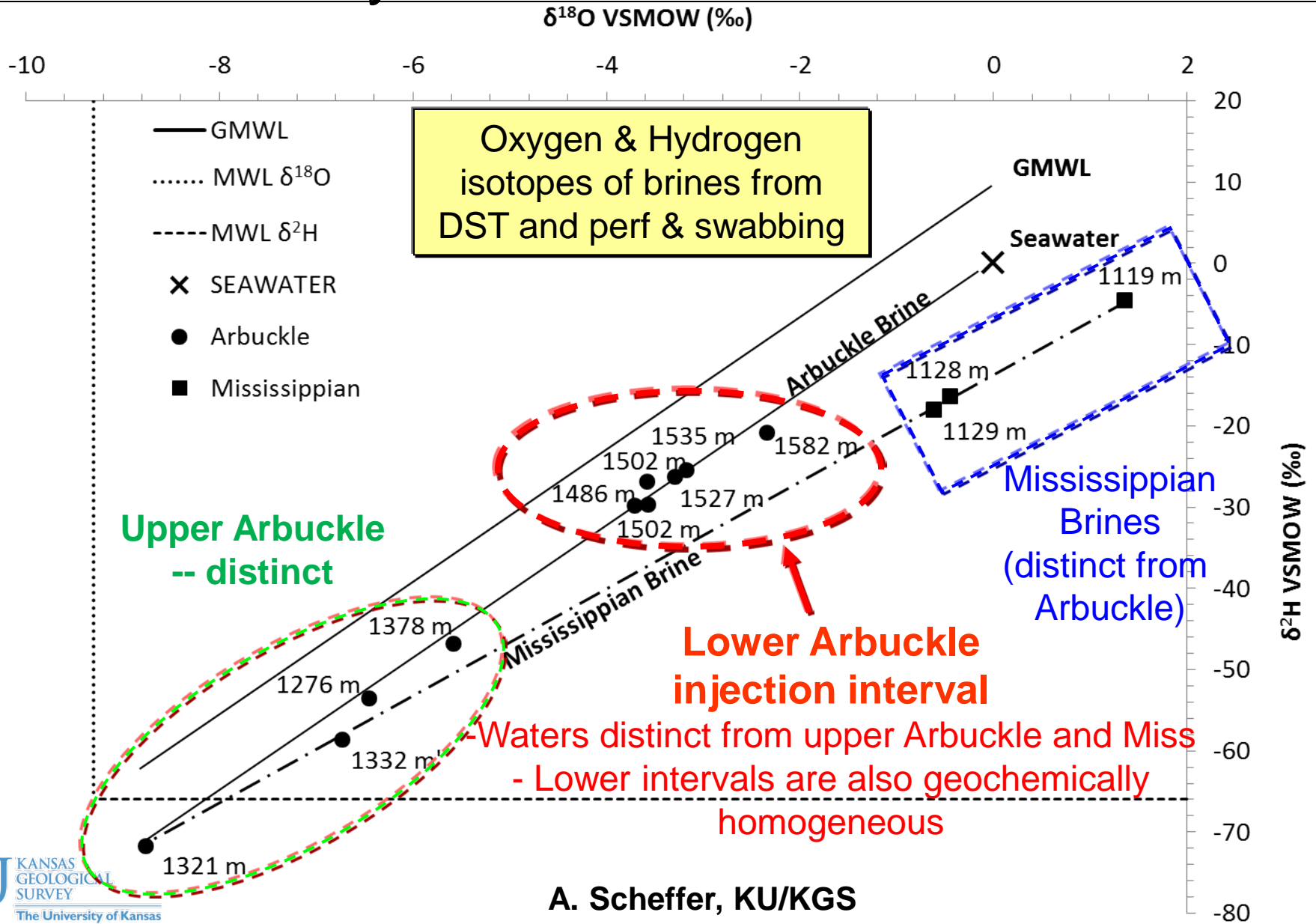
Summary

- **Key findings**
  - Class VI application submitted and under review by EPA and Deliverable in Subtask 1.8 "Arbuckle Injection Permit Application Review go/no go Memo" was submitted.
  - CO2 suppliers have been secured.
    - Praxair and Linde Group have been secured as vendors to supply CO2 under the Berexco subcontract.
  - Science further enhanced
    - Receipt of 15 seismometers for IRIS-PASSCAL, Seismic array deployment
    - Three active 3-component active seismometers purchased with KGS funds to compliment array
    - Including high-resolution seismic, high-resolution cGPS/InSAR, and downhole U-tube sampling and CASSM.
  - Important science questions directed toward to improved prediction and evaluation of dynamic changes in the CO_2 plumes are anticipated using recent refinements in existing Petrel-CMG models
  - Increased relevancy of this project to the DOE Portfolio.
    - Potential for next generation active steering of the CO_2 plume using passive seismic
    - Understanding seismicity in region and use of passive seismic and multi-component 3D for geomechanical modeling to characterize faults and fractures in carbonates.
- **Future Plans**
  - Begin field activities.

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Appendix

ORGANIZATIONAL STRUCTURE

Modeling CO_2 Sequestration in Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO_2
Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas

Principal Investigators
Jason Rush -- Joint PI
W. Lynn Watney - Joint PI

DOE project -- DE-FE002056

UNIVERSITY OF KANSAS

Kansas Geological Survey

Co-Principal Investigators
Kerry D. Newell -- stratigraphy, geochemistry
Jason Rush -- Petrel geomodeling and data integration
Richard Miller -- geophysics
John Doveton-- log petrophysics and core-log modeling
Jianghai Xia -- gravity-magnetics modeling & interpretation
Marios Sophocleous --geohydrology

Key Personnel
John Victorine -- Java web app development
David Laflen -- manage core & curation
Mike Killion -- modify ESRI map service for project
Jennifer Raney -- asst. project manager
Debra Stewart, Dan Suchy -- data management
Yevhen 'Eugene' Holubnyak, Petroleum Engineer
Fatemeh "Mina" FazelAlavi, Engineering Research Assistant

KU Department of Geology

Co-Principal Investigators
Evan Franseen --sedimentology, stratigraphy
Robert Goldstein -- diagenesis, fluid inclusion
David Fowle -- reactive pathways, microbial catalysis
Jennifer Roberts -- reactive pathways, microbial catalysis
George Tsoflias -- geophysics

Grad Research Assistants
Aimee Scheffer (graduated) -- biogeology & geochemistry
Breanna Huff -- biogeology
Christa Jackson -- biogeology and geochemistry
Ayrat Sirazhiev (graduated) -- geophysics
Yousuf Fadolalkarem -- geophysics
Brad King -- diagenesis

SUBCONTRACTS

Berexco, Beredco Drilling -- *Wichita, KS*

*Wellington Field access; drilling, coring, completion
and testing; modeling and simulation*

Key Personnel
Dana Wreath - manager, reservoir and production engineer
Randy Koudele - reservoir engineer
Bill Lamb - reservoir engineer

Kansas State University
Seismic and Geochemical Services

Co-Principal Investigators
Saugata Datta -- reactive pathways and reaction constants
Abdelmoneam Raef -- seismic analysis and modeling

Grad Research Assistants
Robin Barker (graduated)
Derek Ohl - seismic analysis and modeling
Randi Isham -- seismic
Brent Campbell - aqueous geochemistry

Southwest Kansas CO2 EOR Initiative - Chester Morrow
Martin Dubois, IHR, LLC -- team lead, geomodeling
John Youle, Sunflower Energy -- core and depositional models
Ray Sorenson, consultant -- data acquisition and advising
Eugene Williams, Williams Engineering -- reservoir modeling

Bittersweet Energy, Inc., *Wichita, KS*
Tom Hansen, Principal, Wichita, Geological Supervision - regional data, Arbuckle hydrogeology
Paul Gerlach -- regional data acquisition, 2 yrs.
Larry Nicholson -- regional data acquisition, 2 yrs.
Anna Smith -- regional data acquisition, 2 yrs.
Ken Cooper, Petrotek Engineering, Littleton, CO- engineer, well injection, hydrogeology
John Lorenz, Scott Cooper, FractureStudies, Edgewood, NM -- core fracture study

Services
LOGDIGI, LLC, *Katy, TX* - wireline log digitizing
David G. KOGER, *Dallas, TX* - remote sensing data and analysis
Weatherford Laboratories, *Houston, TX* -- core analyses
CMG - Simulation Services, *Calgary, Alberta* --greenhouse gas simulation and software
Halliburton, *Liberal, KS* -- wireline logging services
Hedke-Saenger Geoscience, LTD., *Wichita, KS* - geophysical acquistion, interpret & design
Susan E. Nissen, *McLouth, KS* -- Geophysical Consultant, volumetic curvature
Lockhart Geophysical, *Denver, CO* -- acquis & interpret 2D shear wave, gravity & mag
Fairfield Industries, Inc., *Denver, CO* -- 2D, 3D multicomponent seismic processing
Paragon Geophysical Services, *Wichita, KS* -- 3D seismic acquisition
Echo Geophysical, *Denver, CO* -- 3D seismic processing
Converging Point - QC seismic acquisition
Noble Energy, *Houston, TX; Denver, CO* -- collaborating co., fields adjoining Wellington

Gantt Chart – Kansas Small Scale Injection

SMALL SCALE FIELD TEST, Wellington Field, Sumner County, Kansas			2015				2016			
DE-FE0006821		BP2				BP3-Yr1				
Task	**Task Name**	**Aug '14**	**Nov '14**	**Feb '15**	**May '15**	**Aug '15**	**Nov '15**	**Feb '16**	**May '16**	
Task 1.	**Project Management and Reporting**									
	Subtask 1.1 Finalize Project Management Plan									
	Subtask 1.2 Planning and Reporting									
	Subtask 1.3 Interface Capability to NATCARB Database									
	Subtask 1.4 Project Web Site									
	Subtask 1.5 Drilling and Well Installation Plan									
	Subtask 1.6 MVA and Mitigation Plan									
	Subtask 1.7 Public Outreach Plan									
	Subtask 1.8 Arbuckle Injection Permit Application									
	Subtask 1.9 Mississippian Injection Permit Application									
	Subtask 1.10 Site Development, Operations, and Closure Plan									
Task 2.	**Site Characterization of Arbuckle Saline Aquifer System - Wellington Field**	GO/NO-GO DECISION #3		Obtain EPA approval of Class VI (anticipate March '15)						
Task 3.	**Site characterization of Mississippian Reservoir - Wellington Field**		Class II Application & GO/NO-GO DECISION #4							
Task 4.	**Inventory Well and Borehole Completions within Area of Influence of Small Scale Carbon Storage Project**									
Task 5.	**Secure CO2 source**	GO/NO-GO DECISION #5								
	Subtask 5.1 CO2 Supply									
	Subtask 5.2 CO2 Transportation									
Task 6.	**Establish MVA Infrastructure - Around CO2 Injector for Carbon Storage**		Pending update of MVA and Mitigation Plan (Secton D)							
	Subtask 6.1 Design MVA Components and Fabrication (Contingent on Go Decision pts 1&3)									
	Subtask 6.2 Install CGPS and Seismometers near Injection Borehole									
	Subtask 6.3 Establish Protocols for InSAR data collection									
	Subtask 6.4 Drill Shallow Freshwater Monitoring Boreholes (Contingent on Go Decision pts 1&3)									
	Subtask 6.5 Drill One Chase Group Monitoring Borehole (Contingent on Go Decision pts 1&3)									
	Subtask 6.6 Soil Gas Chemical and CO2 Flux Monitoring/Sampling Grid around Injector									
	Subtask 6.7 Outfit Surrounding Mississippian Boreholes for MVA (Contingent on Go pts 1&3)									

Page 1 of 3

SMALL SCALE FIELD TEST, Wellington Field, Sumner County, Kansas					**2015**				**2016**				**2017**	
DE-FE0006821				BP2				BP3-Yr1				BP3-Yr2	Extension (TBD by DOE)	
Task	**Task Name**			Aug '14	Nov '14	Feb '15	May '15	Aug '15	Nov '15	Feb '16	May '16	Aug '16	Nov '16	Feb '17	April '17
Task 7.	Pre-injection MVA - Establish Background (Baseline) Readings			Mississippian and Arbuckle					Arbuckle only			InSAR, seismometer, 2D high resolution seismic, tracer and fluid sampling during Mississippian injection			
	Subtask 7.1	Analysis of InSAR Data (Contingent on Go pts 1&2)													
	Subtask 7.2	Shallow Groundwater Sampling and Analysis (Contingent on Go pts 1&3)													
	Subtask 7.3	Soil Gas Chemistry and CO2 Flux Sampling and Analysis													
	Subtask 7.4	Head Gas & Water Sampling from Surrounding Mississippian Wells													
	Subtask 7.5	High Res 2D Seismic Lines Targeting Mississippian Reservoir													
	Subtask 7.6	Crosswell Tomography - Pre-Injection (Contingent on Go pts 1&3)													
Task 8.	Recondition Mississippian Boreholes Around Mississippian injector													
Task 9.	Drill CO2 Injection Well in the Mississippian and Recondition Existing Boreholes around injector													
	Subtask 9.1	Obtain Permit to Drill Injection Well for CO2-EOR													
	Subtask 9.2	Drill and DST Injection Well													
	Subtask 9.3	Recondition Existing Boreholes around Mississippian Injector (was subtask 5.3)													
	Subtask 9.4	Log Injection Well													
	Subtask 9.5	Complete Injection Well per KCC Requirements													
	Subtask 9.6	Conduct MIT													
	Subtask 9.7	Analyze Wireline Logs													
	Subtask 9.8	Perforate, Test, and Sample Fluid													
Task 10.	Build Infrastructure for CO2 Pressurization at Mississippian Injection Well for Carbon Storage													
	Subtask 10.1	Build a Receiving and Storage Facility at Injection Site													
	Subtask 10.2	Install Pumping Facility at Well Site for Super Critical CO2 Injection				April '15		end Oct 30 '15							
Task 11.	CO2 Transported to Mississippian Injector and Injection Begins				Mississippian Injection		120 metric tons per day, up to 26,700 metric tons, 9 months max.							
	Subtask 11.1	Transport CO2 to Injection Borehole													
Task 12.	Monitor Performance of Mississippian CO2 Injection													
	Subtask 12.1	Inject CO2 in Mississippian Borehole Under Miscible Conditions													
	Subtask 12.2	Monitor Production of Surrounding Wells													
Task 13.	Compare Performance of Mississippian Injection Well with Model Results													
	Subtask 13.1	Revise Geomodel if necessary													
Task 14.	Evaluate Carbon Storage Potential During the Mississippian CO2 Injection													
Task 15.	Evaluate Potential to Move Oil and Optimize for Carbon Storage in the Mississippian Reservoir – Wellington Field													
	Subtask 15.1	Revise Wellington Field Geomodel													
	Subtask 15.2	Use Simulation Studies to Estimate Carbon Storage Potential													
	Subtask 15.3	Estimate Field-Wide Carbon Storage Potential in Mississippian					Class VI reach stage of public comment Class VI (9 mo.)								

Page 2 of 3

SMALL SCALE FIELD TEST, Wellington Field, Sumner County, Kansas

DE-FE0006821

		2015	2016	2017

BP2 | BP3-Yr1 | BP3-Yr2 | Extension (TBD by DOE)

Task | **Task Name** | Aug '14 | Nov '14 | Feb '15 | May '15 | Aug '15 | Nov '15 | Feb '16 | May '16 | Aug '16 | Nov '16 | Feb '17 | April '17 | Aug '17 | Nov '17

Task 16. Drill Monitoring Borehole (2-28) for Carbon Storage in Arbuckle Saline Aquifer — contingent on Class VI permit and funding
- Subtask 16.1 Obtain Permit to Drill Monitoring Borehole
- Subtask 16.2 Drill and DST Monitoring Borehole
- Subtask 16.3 Log Monitoring Borehole
- Subtask 16.4 Complete Monitoring Borehole per MVA requirements
- Subtask 16.5 Conduct Mechanical Integrity Test
- Subtask 16.6 Analyze Wireline Logs
- Subtask 16.7 Perforate, Test, and Sample Fluids

Task 17. Reenter, Deepen, & Complete Existing Plugged Arbuckle Borehole (Peasel 1)
- Subtask 17.1 Obtain Permit to Re-Enter, Drill, and Recomplete Borehole for Approval
- Subtask 17.2 Drill Borehole into upper Arbuckle
- Subtask 17.3 Log Borehole
- Subtask 17.4 Complete Borehole Following KCC Requirements
- Subtask 17.5 Conduct Mechanical Integrity Tests
- Subtask 17.6 Analyze Wireline Log
- Subtask 17.7 Perforate, Test, and Sample Fluids

Task 18. Revise Site Characterization Models and Simulations for Carbon Storage and submit a revised Site Characterization, Modeling, and Monitoring Plan to DOE:
- Subtask 18.1 Revise Geomodels With New Data
- Subtask 18.2 Update Arbuckle and Mississippian Simulations

Task 19. Retrofit Arbuckle Injection Well (#1-28) for MVA Tool Installation
- Subtask 19.1 Install CASSM Source(s)

Task 20. Equipment Dismantlement from Mississippian Injector and Install at Arbuckle Injector

Task 21. Retrofit Arbuckle Observation Well (#2-28) for MVA Tool Installation
- Subtask 21.1 Install U-Tube
- Subtask 21.2 Install CASSM Receiver (for cross-hole tomography)
- Subtask 21.3 Install DTPS Sensors

Sept 30, 2016 (end of project and field activities)

Nov 1 '15 | 'Jul 1 '16

Task 22. Begin Injection at Arbuckle Injector — Arbuckle Injection — 120 metric tons per day; up to 26,700 tonnes, 7.5 months max.
- Subtask 22.1 Move Surface Equipment to Arbuckle Injector
- Subtask 22.2 CO2 Transportation to Arbuckle Injector
- Subtask 22.3 Inject Super Critical CO2

Task 23. MVA During Arbuckle Injection
- Subtask 23.1 CASSM Monitoring
- Subtask 23.2 Soil Gas Chemistry and CO2 Flux Sampling and Analysis
- Subtask 23.3 U-Tube Monitoring
- Subtask 23.4 Shallow Groundwater Sampling and Analysis
- Subtask 23.5 Head Gas & Water Sampling and Analysis from Existing Mississippian Boreholes
- Subtask 23.6 InSAR Data Analysis
- Subtask 23.7 Second Crosswell Tomography Halfway Through Injection
- Subtask 23.8 Integration of CASSM and Cross-well Tomography

Task 24. Risk Management Related to Carbon Storage in Arbuckle Saline Aquifer
- Subtask 24.1 Integrate MVA Analysis and Observations to Detect CO2 Leakage
- Subtask 24.2 Activate Mitigation Plans if Leakage Detected

Task 25. Compare Simulation Results with MVA Data and Analysis and Submit Update of Site Characterization, Modeling, and Monitoring Plan — 12/31/2017**
- Subtask 25.1 Revise Geomodel to Improve Match with MVA Data

Task 26. Post injection MVA - Carbon Storage — 'Post injection MVA limited to end of Sept 30, need 1.0 year in Class VI

Task 27. Evaluate Carbon Storage Potential in Arbuckle Saline Aquifer at Wellington

Task 28. Evaluate regional Carbon Storage Potential in Arbuckle Saline Aquifer in Kansas

'Sept 30, 2016 | June 31, 2017 (1 yr from end of injection)

Task 29. Closure of Carbon Storage Project in Arbuckle Saline Aquifer at Wellington field — DOE Site Closure — 'EPA Required Site Closure
- Subtask 29.1 Acquire 3D and Process Seismic Data Around the Arbuckle Injector
- Subtask 29.2 Interpret Acquired 3D Data and Compare with Baseline Survey
- Subtask 29.3 Integrate MVA Analysis with 3D Surveys to Establish CO2 Containment
- Subtask 29.4 Seek Regulatory Permission for Closure

Task 30. Develop a Best Practice Manual:

**Project ends: December 31,2016 (3 mo beyond DOE site closure)

Bibliography

Publications, conference papers, and presentations
Papers were presented in Lawrence at an industrial associates meeting. In addition, the Wellington KGS #1-32 core was displayed and discussed. Presentations included:
Jason Rush --"Basement-Rooted Faults, Paleokarst, and Mississippian Flexures: A Compelling Story for PSDM Seismic Volumetric Curvature
Jason Rush -"The Mississippian at Wellington and Development of a Middle Eastern Giant (Idd El Shargi Field) ☐Déjà vu?
W. Lynn Watney, Jason Rush, John Doveton, Mina Fazelalavi, Eugene Holubnyak, Bob Goldstein, Brad King, Jen Roberts, David Fowle, Christa Jackson, George Tsoflias, et al., Overview, current research, and major findings for two long Paleozoic cores – Berexco Wellington KGS #1-32, Sumner County, KS and Berexco Cutter KGS #1, Stevens County, Kansas
W. Lynn Watney, Jason Rush, John Doveton, Mina Fazelalavi, Eugene Holubnyak, Bob Goldstein, Brad King, Jen Roberts, David Fowle, Christa Jackson, George Tsoflias, et al., Overview, current research, and major findings for two long Paleozoic cores – Berexco Wellington KGS #1-32, Sumner County, KS and Berexco Cutter KGS #1, Stevens County, Kansas   - four posters (2 each for Wellington and Cutter)

Mina Fazelalavi, W. Lynn Watney, John Doveton, Mohsen Fazelalavi, and Maryem Fazelalavi - Determination of Capillary Pressure Curves in the Mississippian Limestone, Kansas

 Yousuf Fadolalkarem and George Tsoflias - Pre-stack Seismic Attribute Analysis of the Mississippian Chert and the Arbuckle at the Wellington Field, South-central Kansas

Christa Jackson, David Fowle, Brian Strazisar, W. Lynn Watney, Aimee Scheffer, and Jennifer Roberts - Geochemical and Microbiological Influences on Reservoir and Seal Material During Exposure to Supercritical CO_2, Arbuckle Group, Kansas
Luis Montalvo, Luis Gonzalez, Lynn Watney, Diagenesis and distribution of diagenetic facies in the Mississippian of south-central Kansas

Bradley King and Robert Goldstein -- Controls on Hydrothermal Fluid Flow and Porosity Evolution in the Arbuckle Group and Overlying Units (3 panels)
Presentation at Geological Society of America, Regional Meeting (April 2014) – illustrating the stratigraphic and sedimentologic effects of episodic structural movement at Wellington Field:

DOVETON, John H., Kansas Geological Survey, University of Kansas, 1930 Constant Ave, Lawrence, KS 66047, doveton@kgs.ku.edu, MERRIAM, Daniel F., University of Kansas, 1930 Constant Ave, Campus West, Lawrence, KS 66047, and WATNEY, W. Lynn, Kansas Geological Survey, Univ of Kansas, 1930 Constant Avenue, Lawrence, KS, 66047, 2014, Petrophysical Imagery of the Oread Limestone in Subsurface Kansas, Paper #237642, 48th Annual Meeting, North Central Geological Society of America, Program With Abstracts. (Episodic nature of structural activity at Wellington Field)

National Groundwater Association Groundwater Summit
Watney, W.L., 2014, Integrating Modern Suite of Geophysical Logs, Geochemistry, and Seismic Data for Characterizing Deep Aquifers, NGWA Conference on Characterization of Deep Groundwater, May 8, 2014
Watney, W.L., 2014, Using Drill Stem Test Data to Construct Regional Scale Potentiometric Surface in Deep Aquifers, NGWA Conference on Characterization of Deep Groundwater, May 8, 2014
Tiraz Birdie, TBirdie Consulting, Inc., Lawrence, KS, W. Lynn Watney, Ph.D., Kansas Geological Survey, University of Kansas, Lawrence, KS and Paul Gerlach, Charter Consulting, Miramar, FL, Using Drill Stem Test Data to Construct Regional Scale Potentiometric Surface in Deep Aquifers, NGWA Conference on Characterization of Deep Groundwater, May 8, 2014

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS
A project organization chart follows (**Figure 17**). The work authorized in this budget period includes office tasks related to preparation of reports and application for a Class VI permit to inject CO2 into the Arbuckle saline aquifer. Tasks associated with reservoir characterization and modeling are funded in contract DE-FE0002056.