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

U.S. Department of Energy

National Energy Technology Laboratory

Carbon Storage R&D Project Review Meeting

Developing the Technologies and Infrastructure for CCS

August 12-14, 2014

Brighton 3 & 4

10 am, August 14, 2014

KU KANSAS GEOLOGICAL SURVEY The University of Kansas

NETL

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 Class VI geosequestration Permit , 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

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)

BEREXCO

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

Brian Dressel, P.M.

BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY

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

THE LINDE GROUP
Linde
PRAXAIR
Making our planet more productive

CO_2 supply

DEPARTMENT OF GEOLOGY

KANSAS STATE UNIVERSITY

Saugata Datta ***(brine and USDW monitoring)***

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

seismometers

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)***

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**

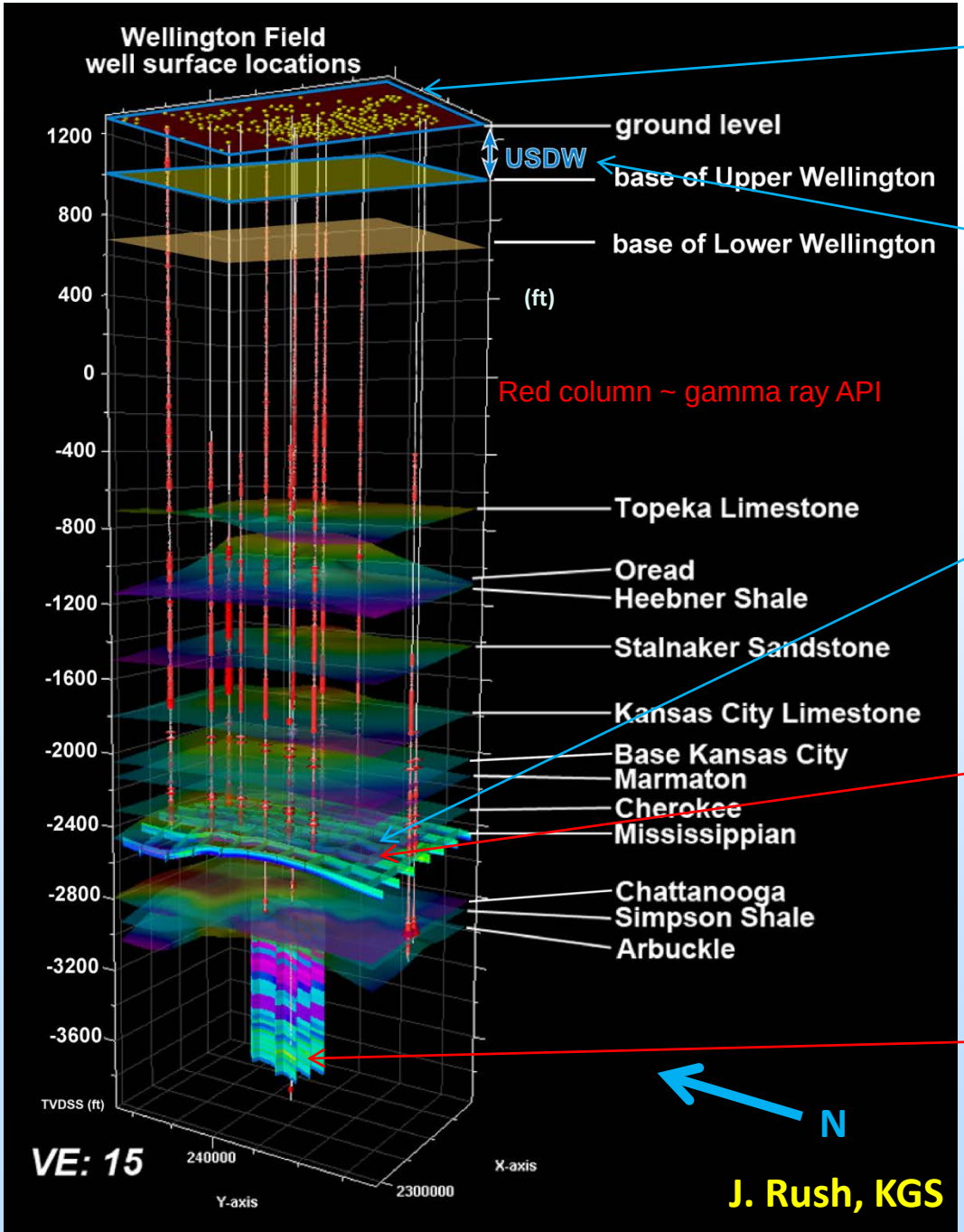
  Use to further resolve CO_2 movement and regional seismic activity
- **KGS purchased and preparing to install and activate three 3-component active accelerometers**
  - Greater acoustic sensitivity over seismometers and more precise timing of smaller seismic events useful for CASSM research
  - Baseline 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



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

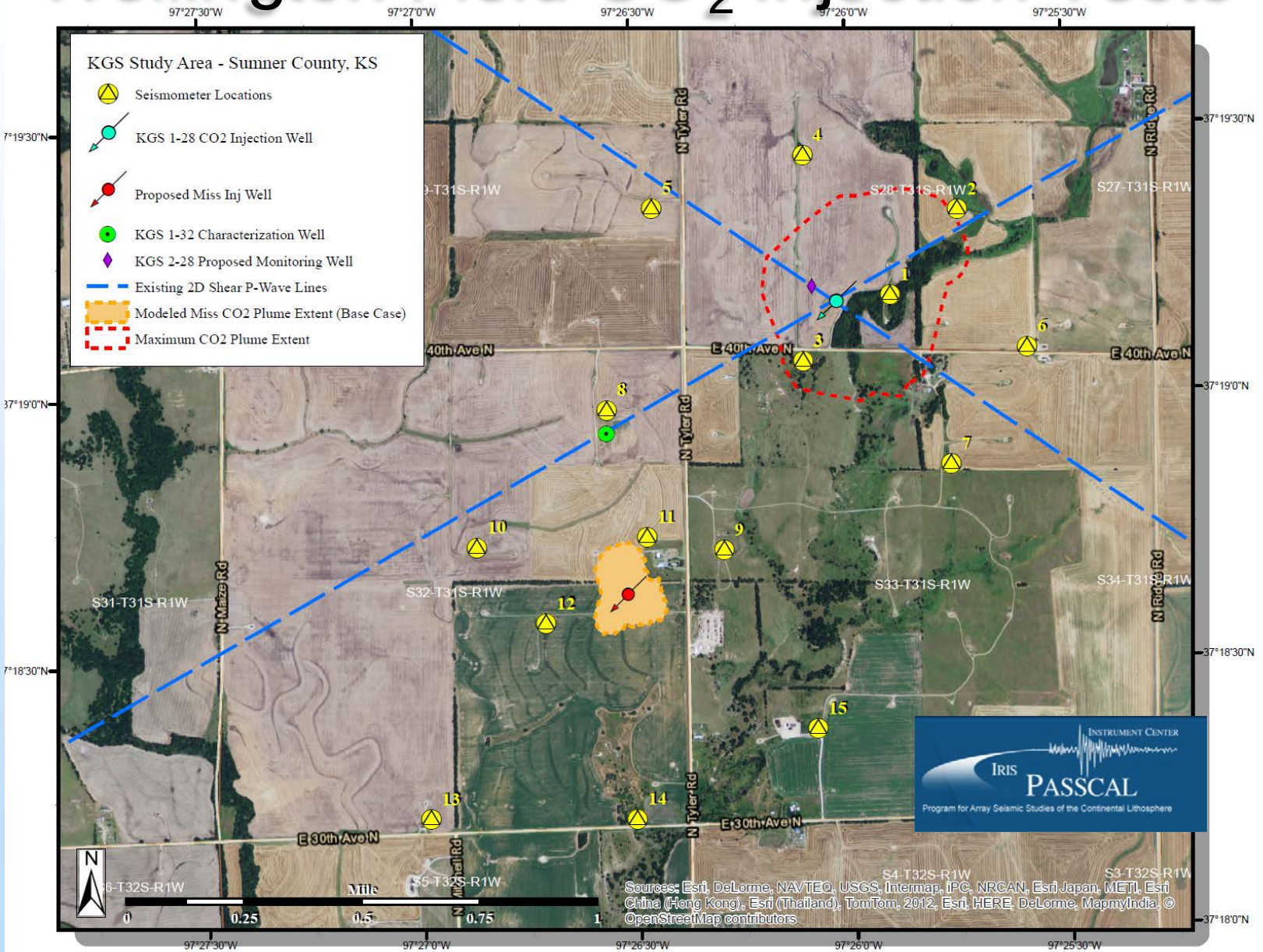
- Monitor for tracers, CO_2, aqueous geochemistry in shallow freshwater wells
- Monitor ~600 ft deep well below shallow evaporite cap rock

- 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

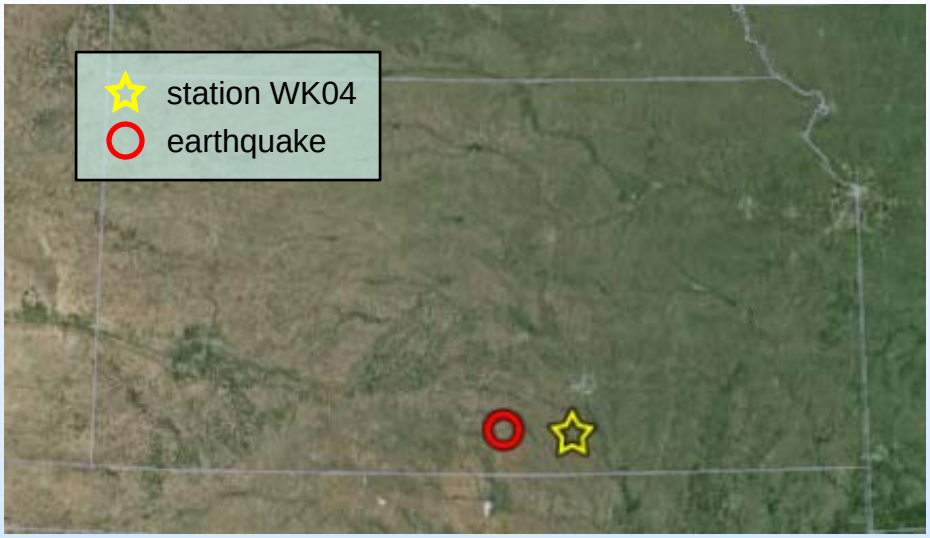
Extensive monitoring network Wellington Field CO_2 Injection Tests

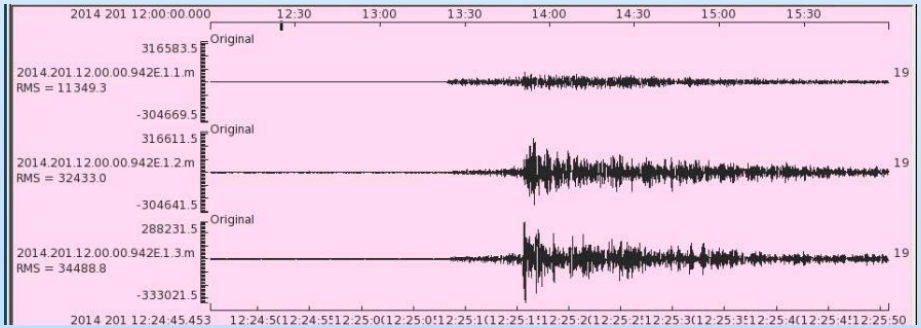


IRIS seismometer installation -- ~5 ft below surface to minimize surface noise; installed below frost line in bedrock

Shelby Peterie, KGS Exploration Services, checking installation in July 2014

Wellington CO_2 WK04

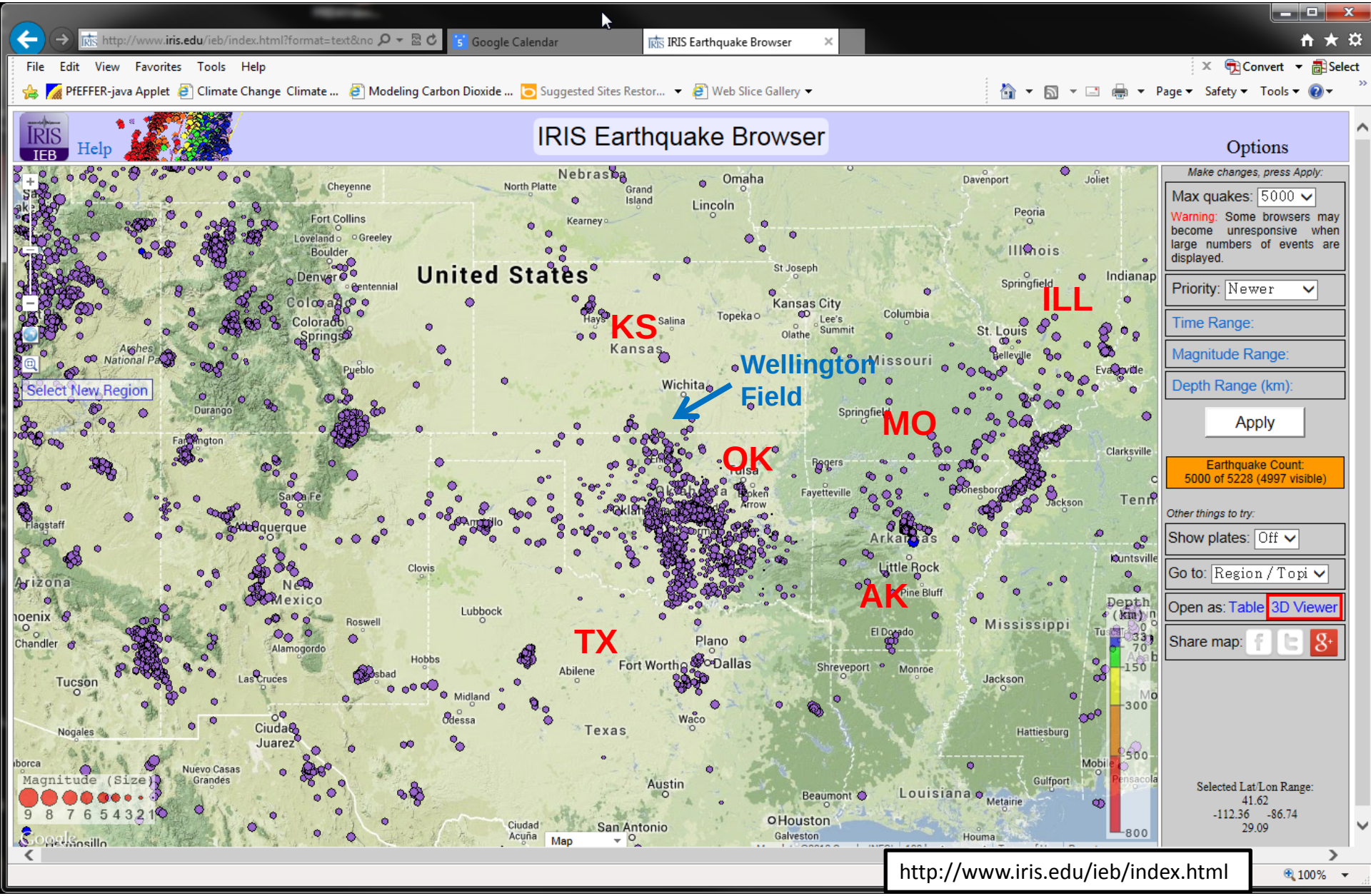




- Newly installed seismometer detected seismic event in Kansas
- Date: July 20, 2014
- Time: 12:24:58
- Distance from WK04: 58 km
- Magnitude: 3.3

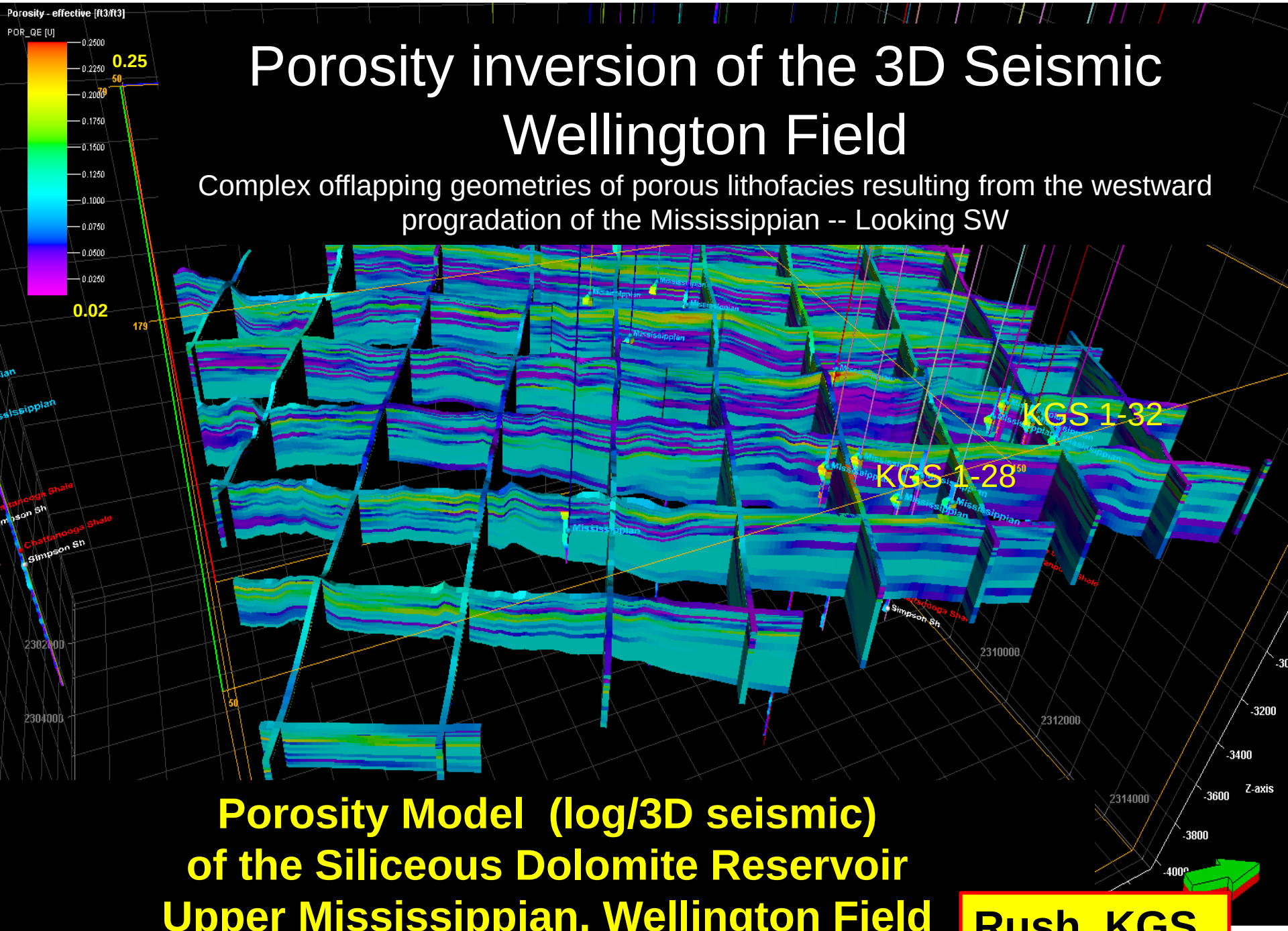
Historical Earthquakes in U.S. Midcontinent

long term trend of generally low magnitude events from north TX, OK, Ark, MO, Ill



Porosity inversion of the 3D Seismic Wellington Field

Complex offlapping geometries of porous lithofacies resulting from the westward progradation of the Mississippian -- Looking SW

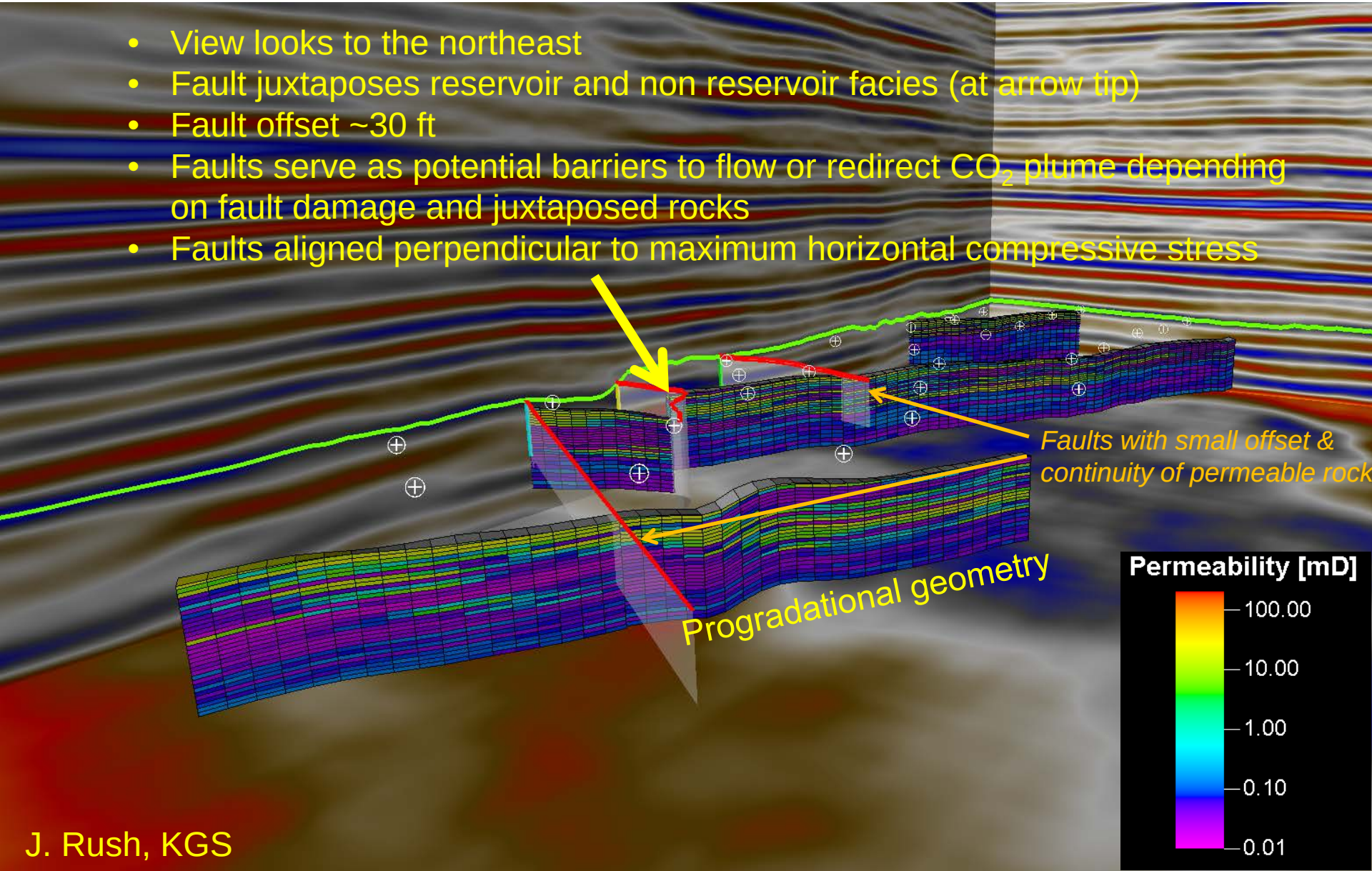


Porosity Model (log/3D seismic) of the Siliceous Dolomite Reservoir Upper Mississippian, Wellington Field

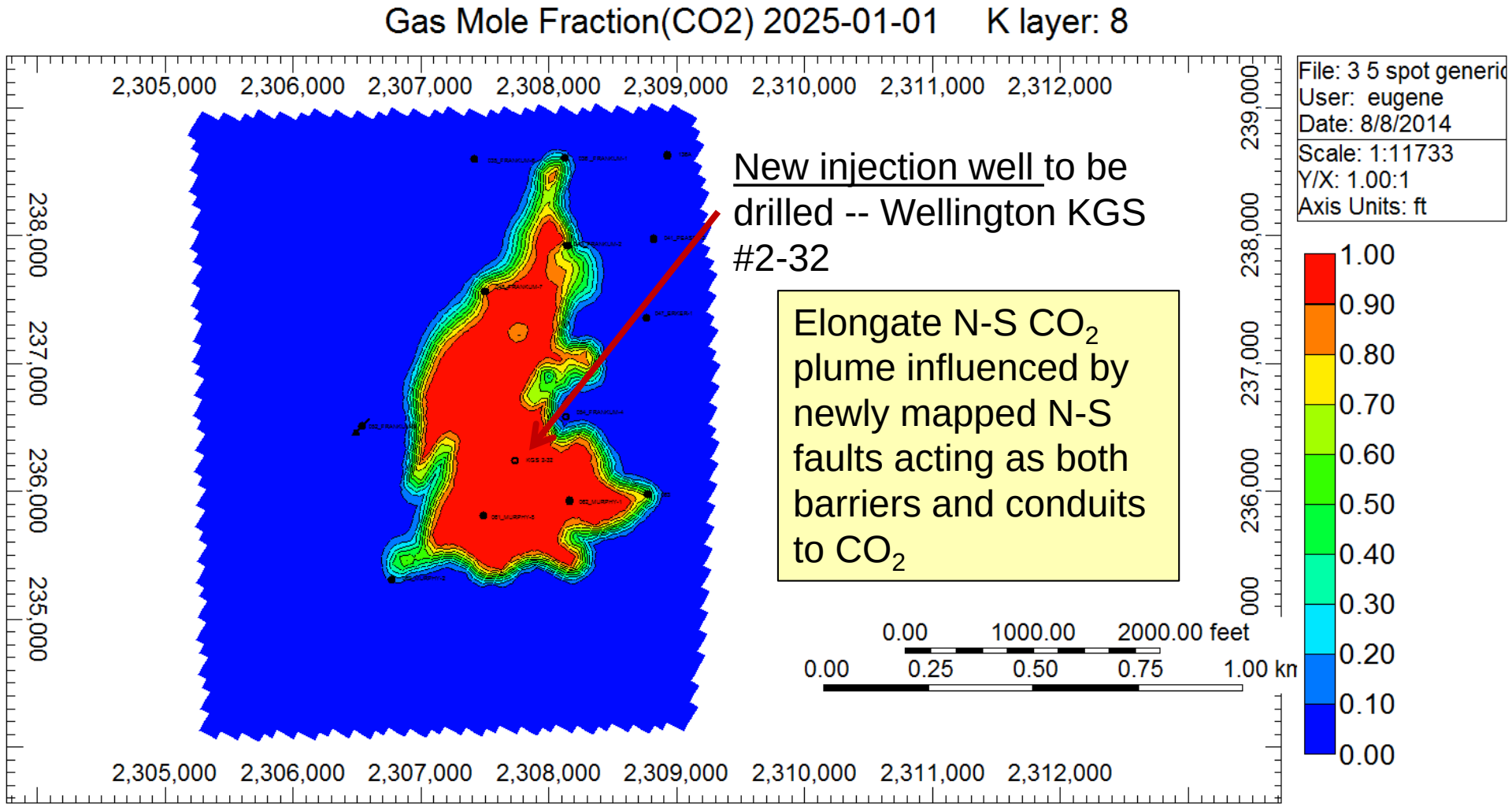
Rush, KGS

Permeability fence diagram of Mississippian oil reservoir within 3D seismic

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

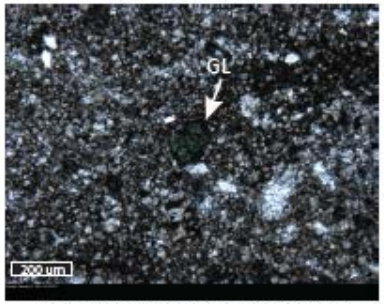


CO_2 plume from latest simulation of Mississippian test injection (26,300 tonnes)

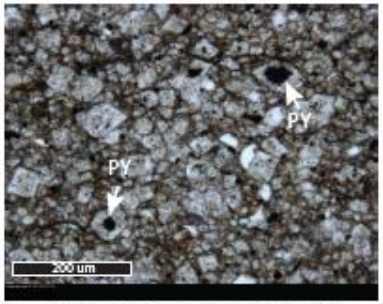


E. Holubnayak, KGS

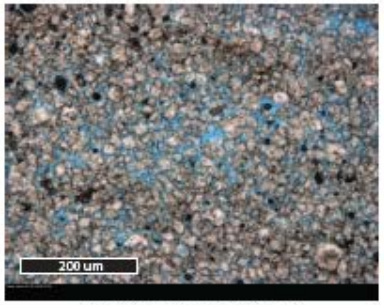
Diagenetic facies and textures



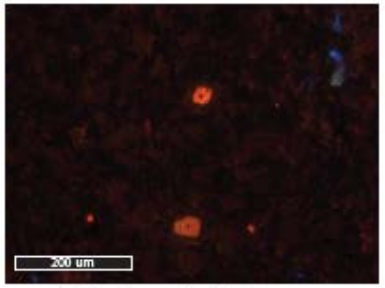
Argillaceous dolomite (WL 1-32, 4026.4 ft)



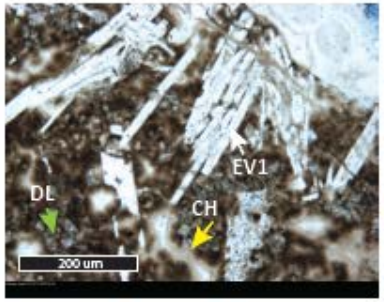
Argillaceous dolomite (WL 1-32, 4049 ft)



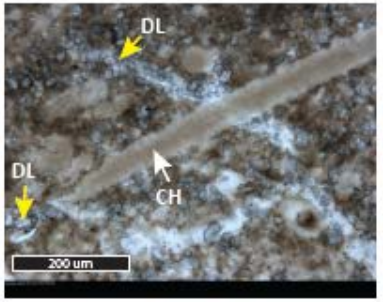
Dolomite (WL 1-32, 3892.25 ft)



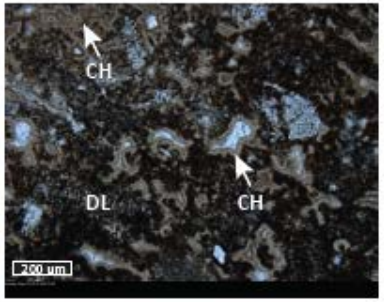
Dolomite on cathodoluminescence (WL 1-32, 3807 ft)



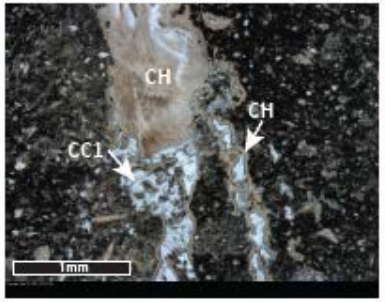
Nodular chert (WL 1-32, 3680.7 ft)



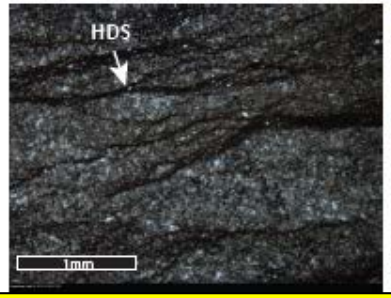
Nodular chert (WL 1-32, 3671.8 ft)

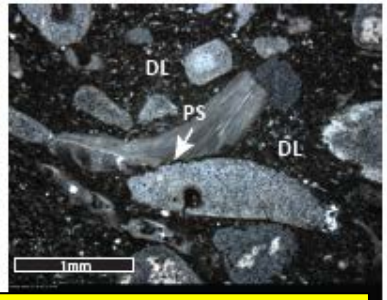


Nodular cherty dolomite (WL 1-32, 3680.7 ft)

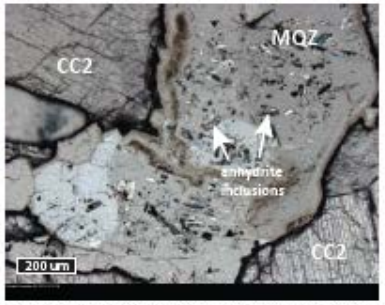


Argillaceous dolomite (WL 1-32, 3867 ft)



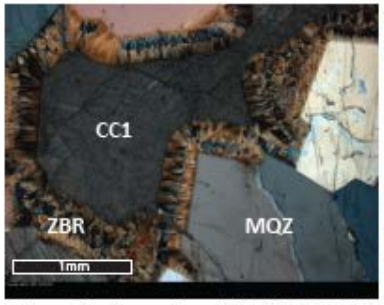


Silica-replaced evaporite nodule (WL 1-32, 4049.4 ft)

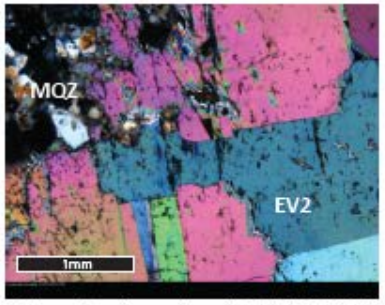


Silica-replaced evaporite nodule (WL 1-32, 3790 ft)

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



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



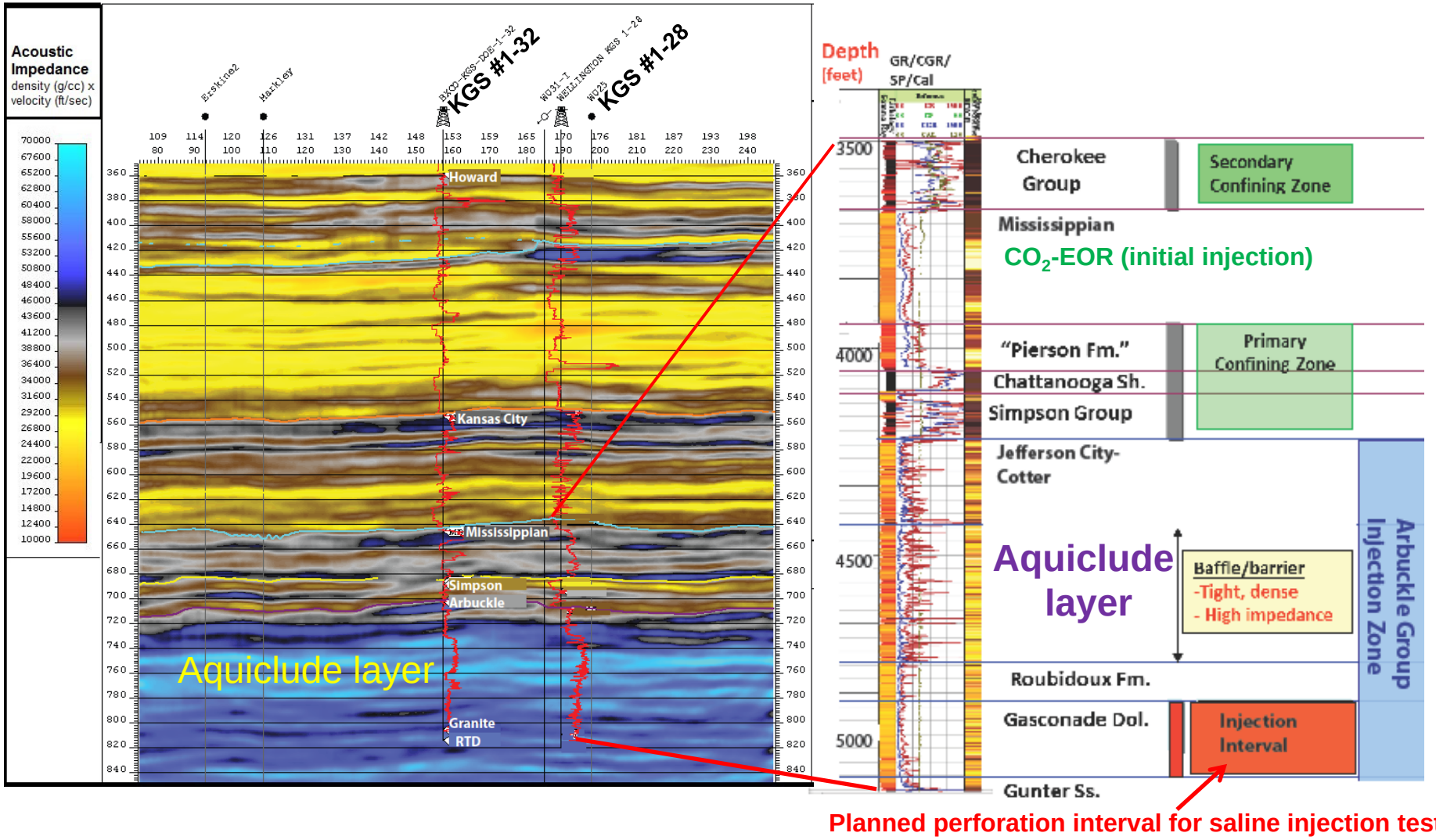
Silica-replaced evaporite nodule (WL 1-32, 3689 ft)

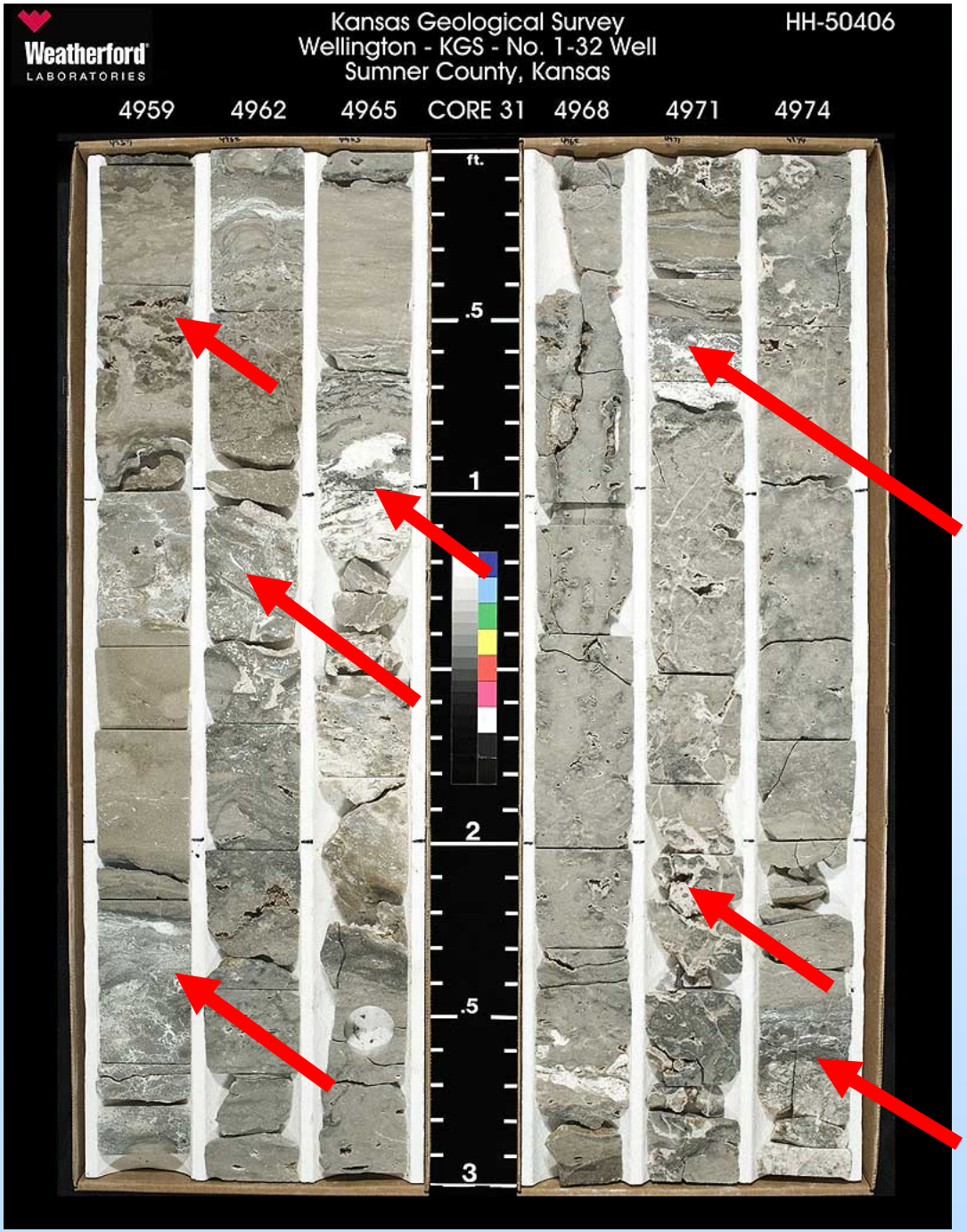
Luis G. Montalvo 1, Luis Gonzalez 1, Lynn Watney 2, 2014,
1) Department of Geology, University of Kansas, Lawrence, KS, 2) Kansas Geological Survey

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

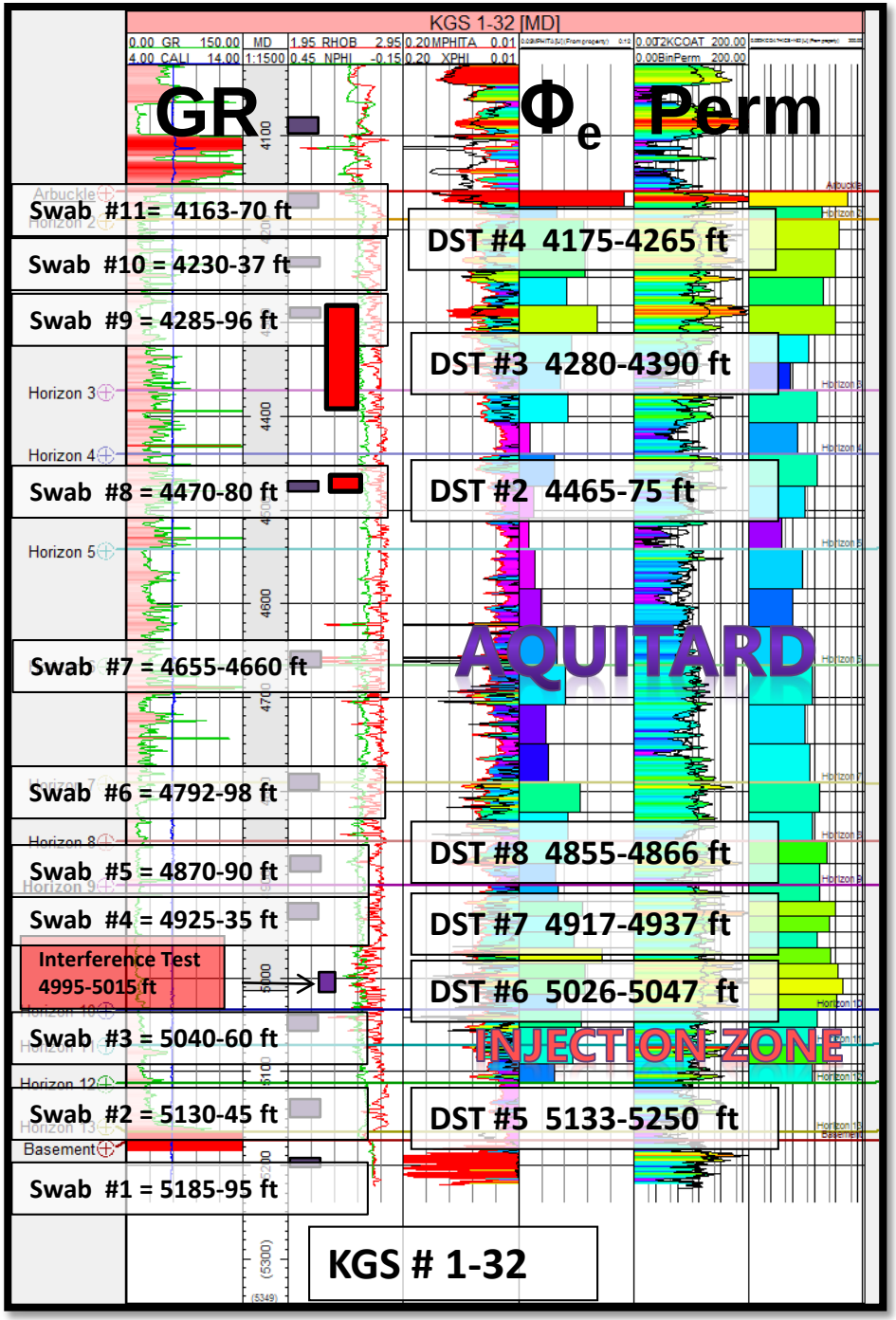
vuggy and intergranular pores, and discontinuous fractures

Aquiclude/baffle in the middle of the Arbuckle

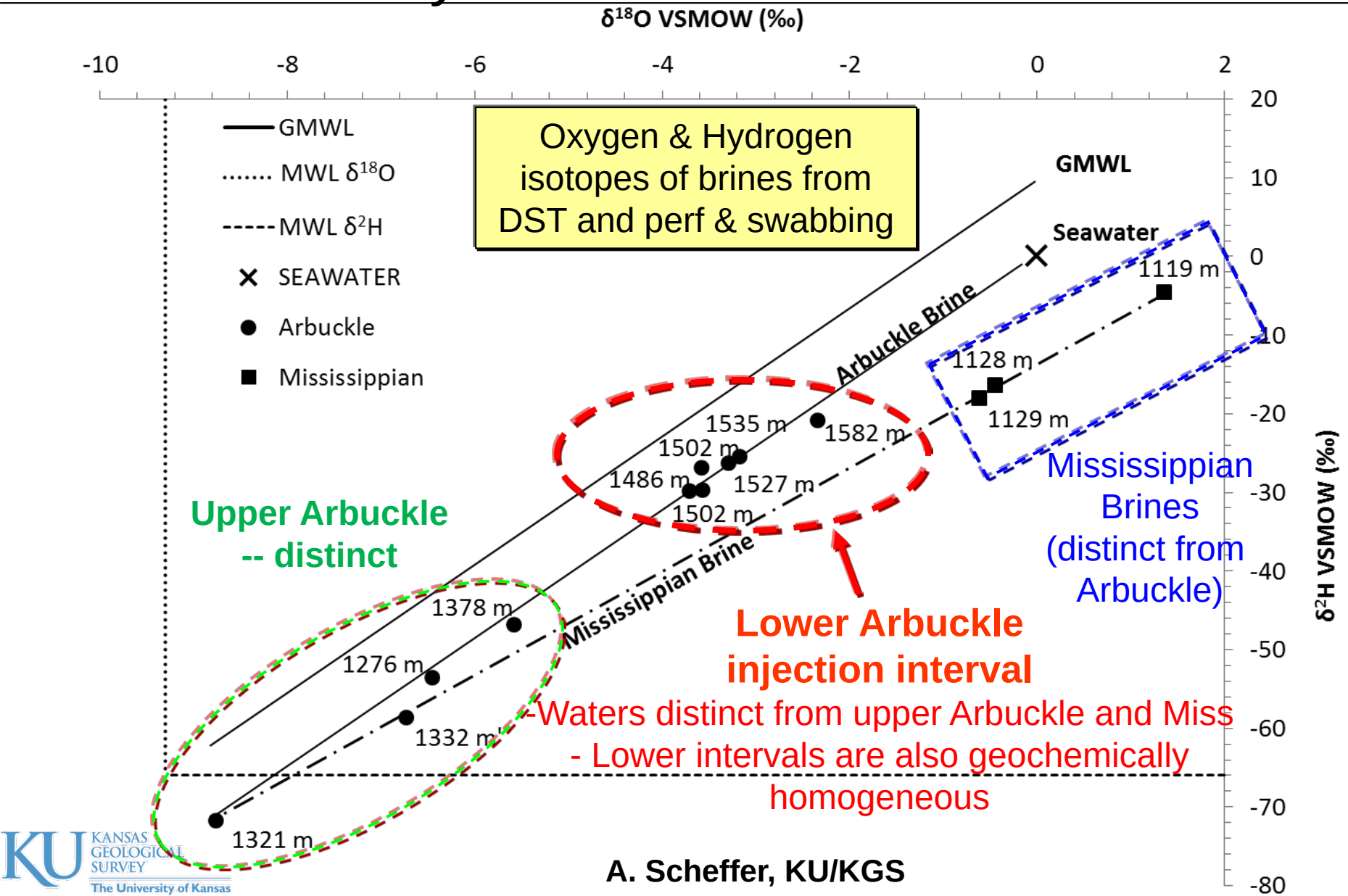
argillaceous dolomite and thin beds of clay over extended interval (seismically resolvable)

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

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The University of Kansas

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.

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

DOE project -- DE-FE002056

Principal Investigators

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

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

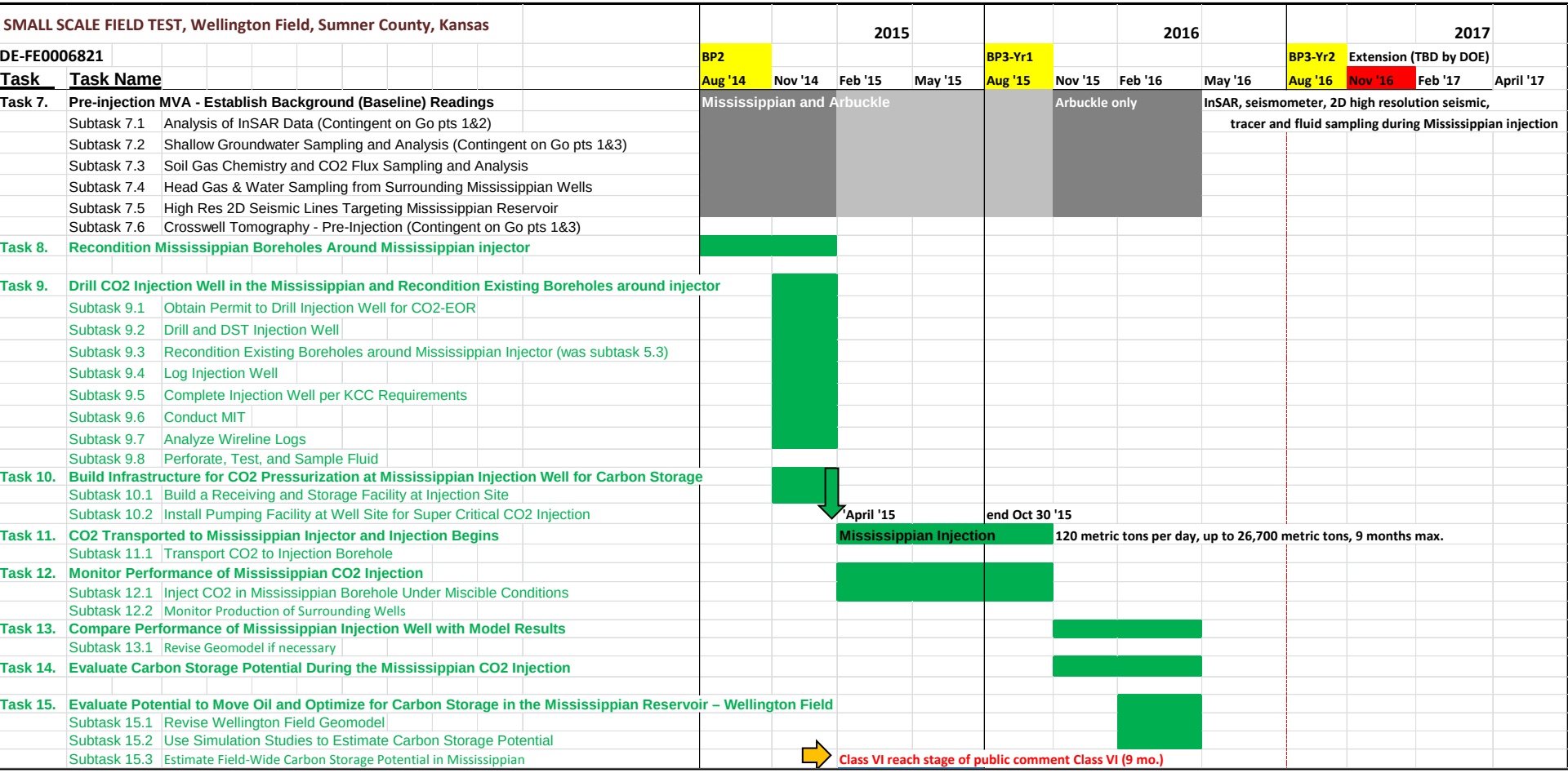
LOGDIGI, LLC, *Katy, TX* - wireline log digitizing
David G. KOGER, *Dallas, TX* - remote sensing data and analysis
Weatherford Laboratories, *Houston, TX* -- core analyses
CMG - Simulation Services, *Calgary, Alberta* --greenhouse gas simulation and software
Halliburton, *Liberal, KS* -- wireline logging 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

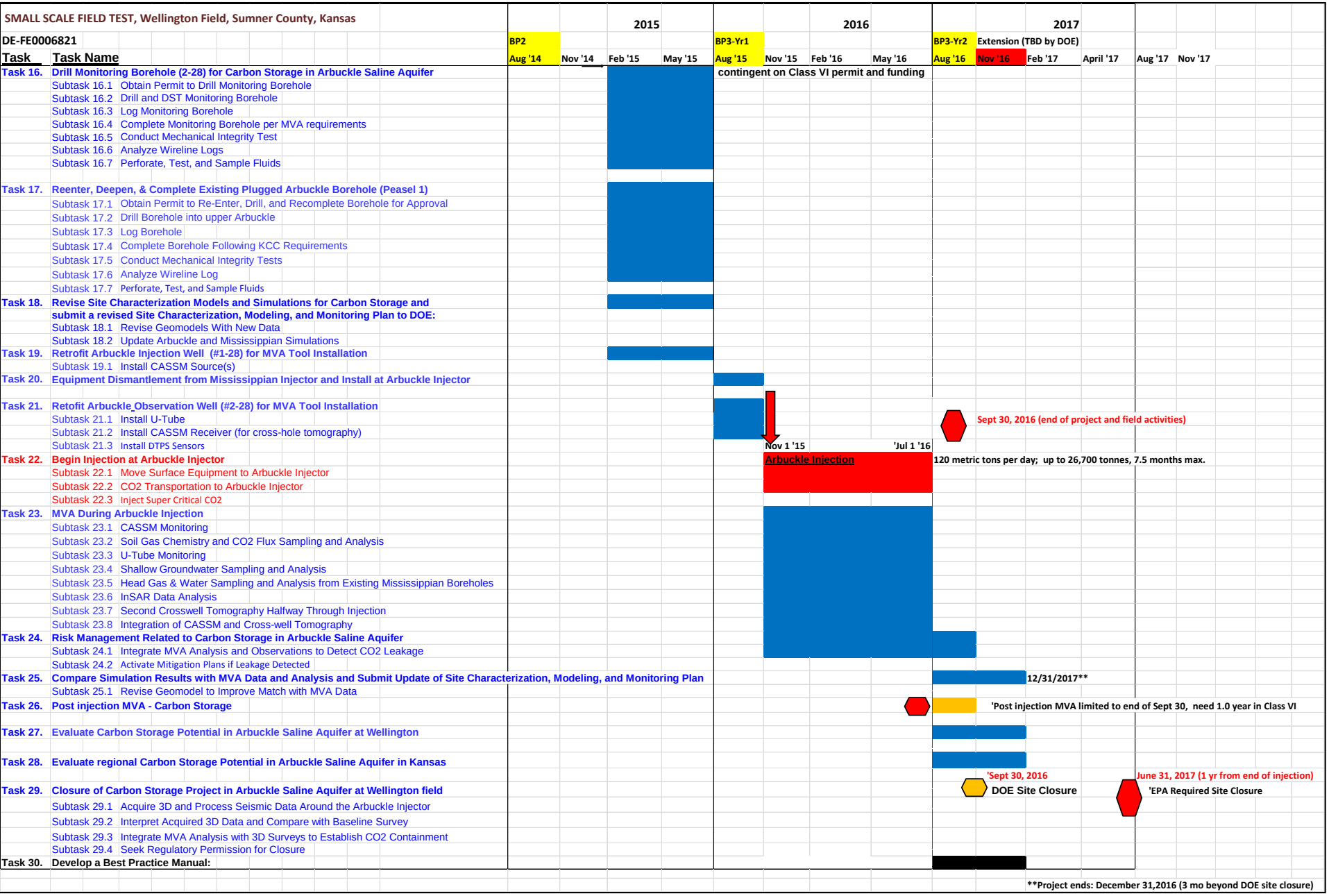
Gantt Chart – Kansas Small Scale Injection

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

DE-FE0006821

Task	Task Name	2015				2016			
		BP2				BP3-Yr1			
		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)								


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
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.)


SMALL SCALE FIELD TEST, Wellington Field, Sumner County, Kansas
DE-FE0006821
2015
2016
2017
BP2
BP3-Yr1
BP3-Yr2
Extension (TBD by DOE)
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
Task Name
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. Retofit 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 CO2, Arbuckle Group, Kansas

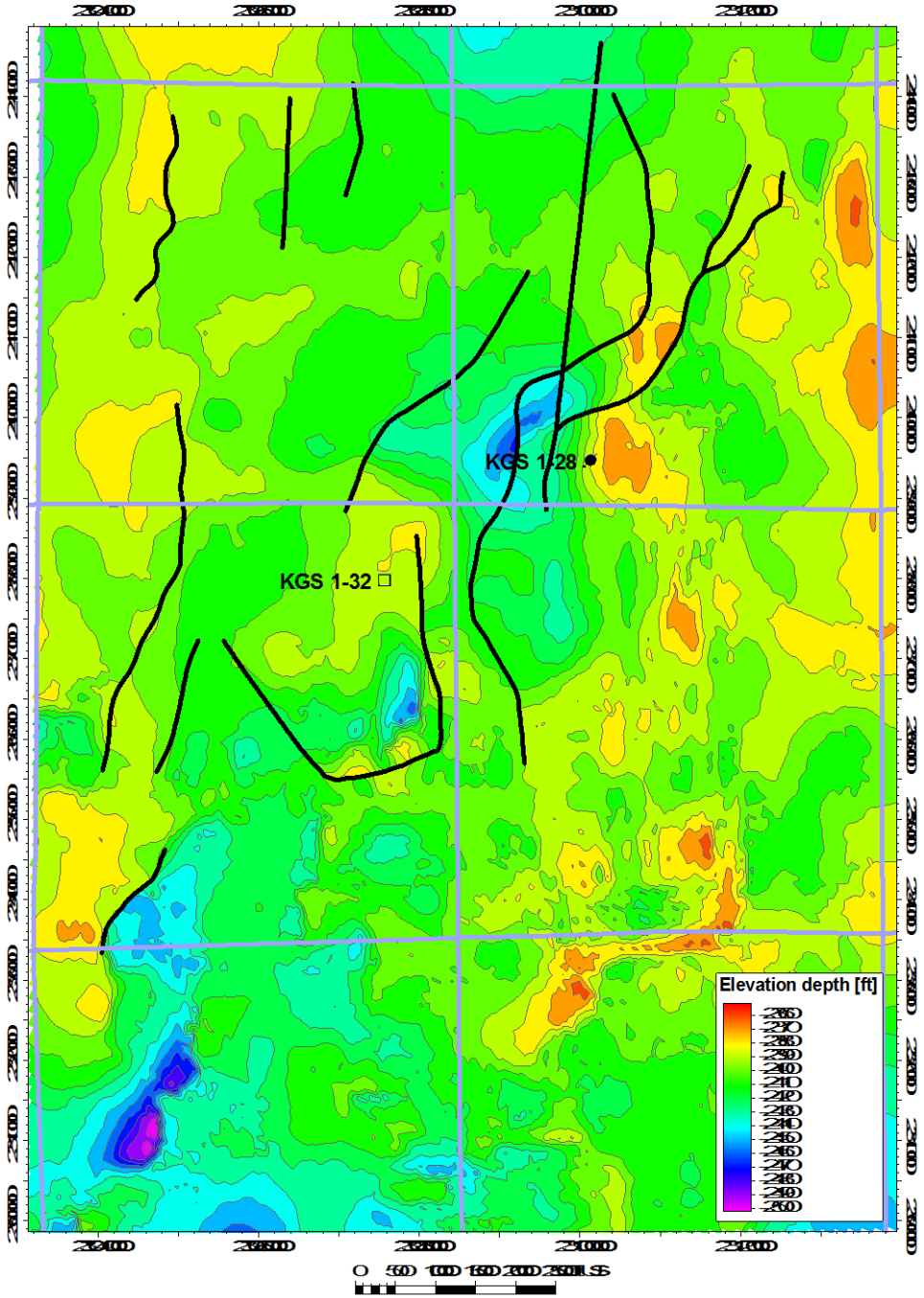
Luis Montalvo, Luis Gonzalez, Lynn Watney, Diagenesis and distribution of diagenetic facies in the Mississippian of south-central Kansas

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.

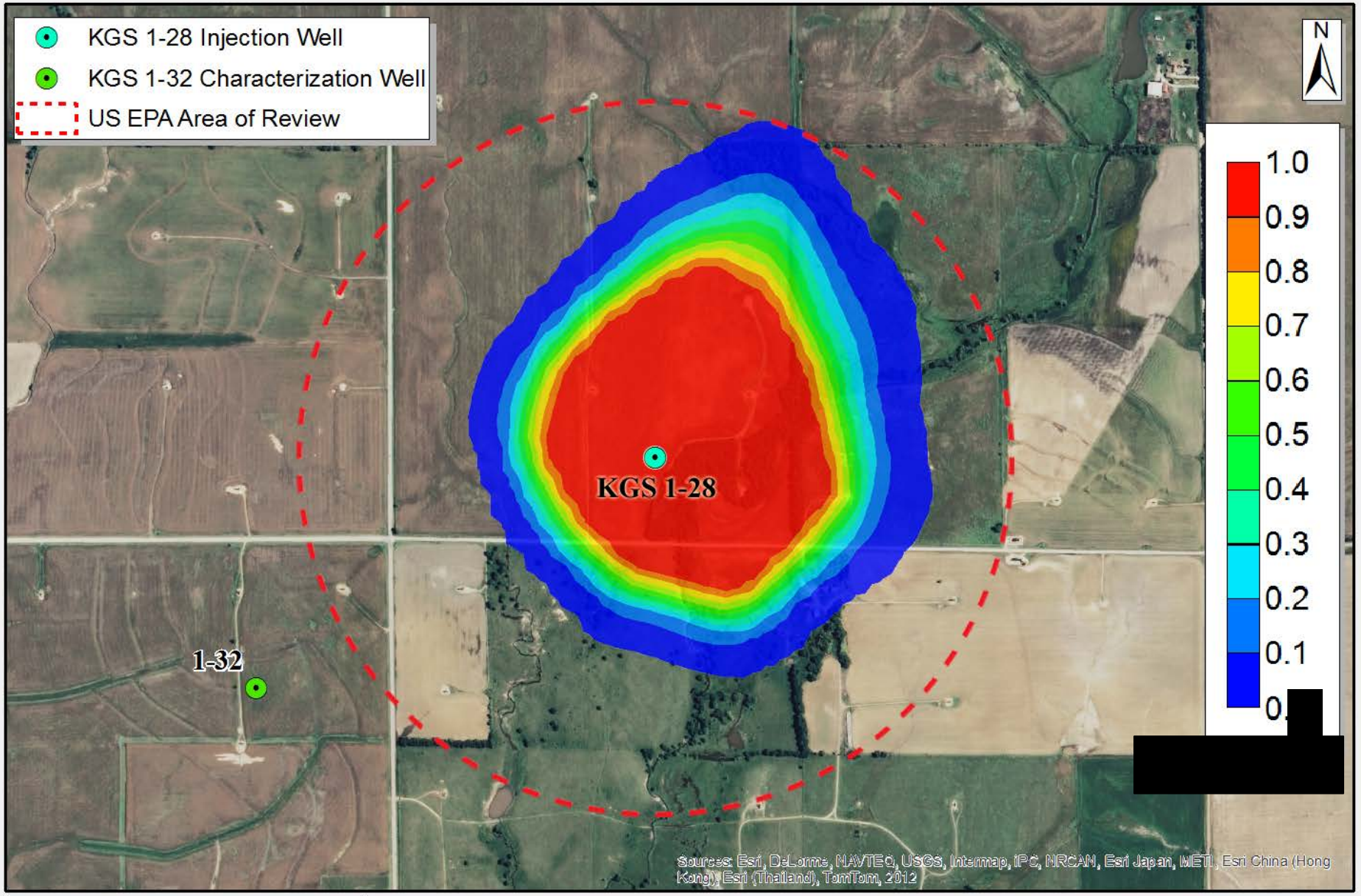


Mapped Mississipian Faults

Permeability

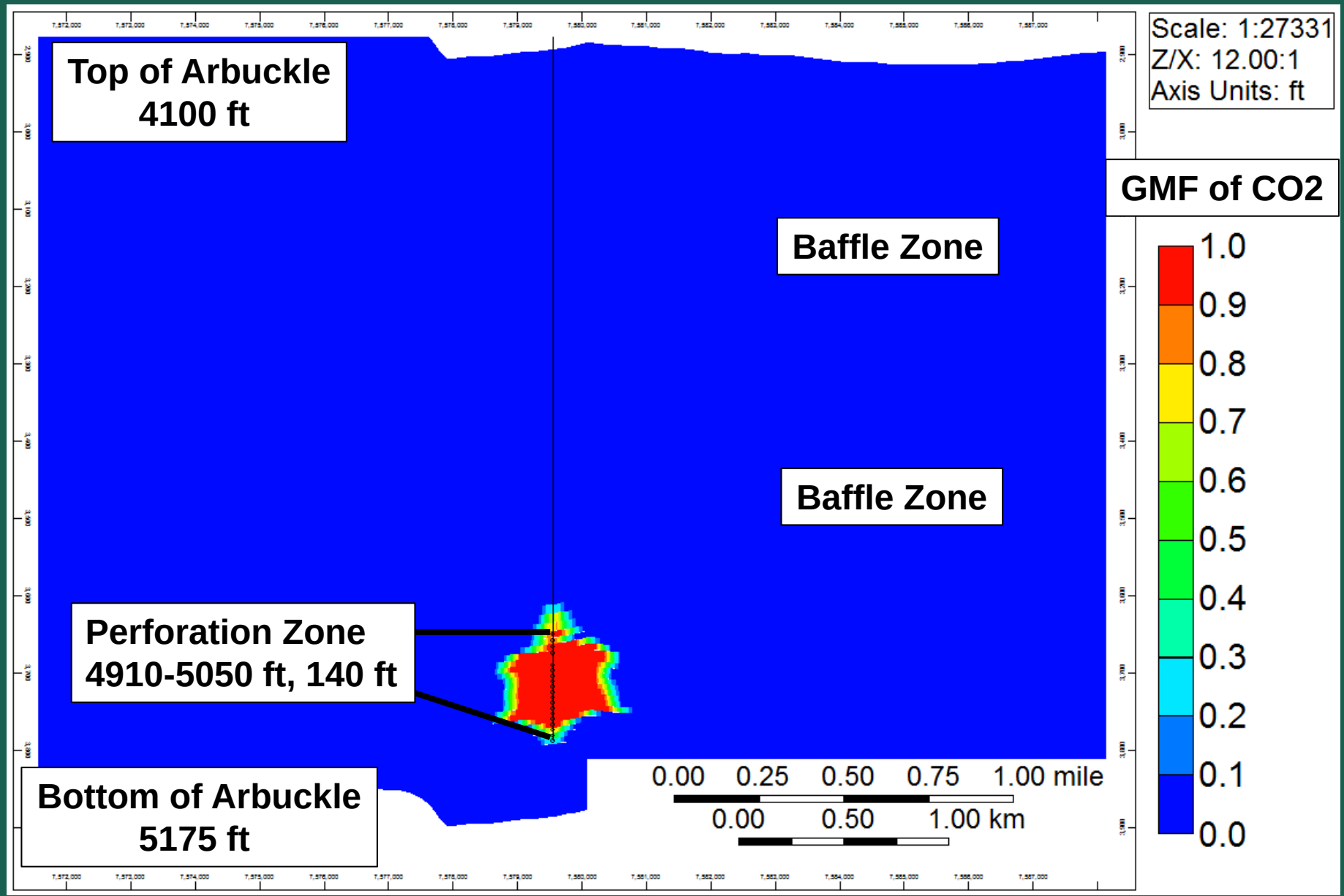
Dynamic Modeling Results - Arbuckle

Case Identifier	CO2 Maximum Diameter of Aerial Extent	Maximum Bottom-Hole Pressure, psi (5050 ft)	Max Delta Bottom-Hole Pressure, psi
K-0.75/Phi-0.75	3389 ft., 1033 m	**2535**	**442**
K-1/Phi-0.75	2629 ft., 801 m	2462	369
K-1.25/Phi-0.75	**3504 ft., 1068 m**	2418	**325**
K-0.75/Phi-1.0	2218 ft., 676 m	2512	419
K-1/Phi-1.0	2433 ft., 741 m	2428	335
K-1.25/Phi-1.0	3203 ft., 976 m	2415	322
K-0.75/Phi-1.2	1952 ft., 595 m	2525	432
K-1/Phi-1.2	2517 ft., 767 m	2459	366
K-1.25/Phi-1.2	2802 ft., 854 m	2410	317



Maximum Lateral CO_2 Distribution

Maximum Vertical CO_2 Distribution



Maximum Lateral Extent of CO_2 Plume Migration Through Time