Small Scale Field Test Demonstrating CO_2 sequestration in Arbuckle Saline Aquifer and by CO_2-EOR at Wellington field, Sumner County, Kansas --

W. Lynn Watney and Jason Rush
Kansas Geological Survey
Lawrence, KS 66047

Regional Carbon Sequestration Partnerships
Annual Review Meeting
October 15-17, 2011
Pittsburgh, PA

Funding Opportunity Number: DE-FOA-0000441
Contract #FE0006821
$11,484,499 DOE
$3.236 million cost share

KANSAS STATE UNIVERSITY

Outline

- Background
- The Participants
- The Plan
- Leveraging Current Research at Wellington Field
- Inject, Monitor, Verification, and Accounting of CO_2

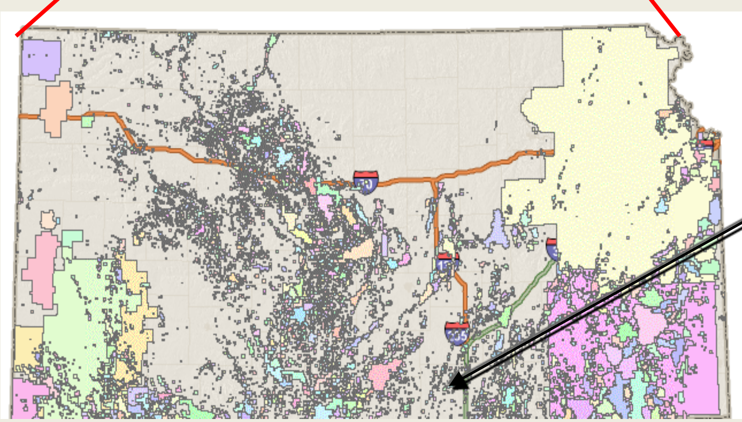
KANSAS GEOLOGICAL SURVEY
The University of Kansas

Project Team
Small Scale Field Test – Wellington Field (FE0006821)

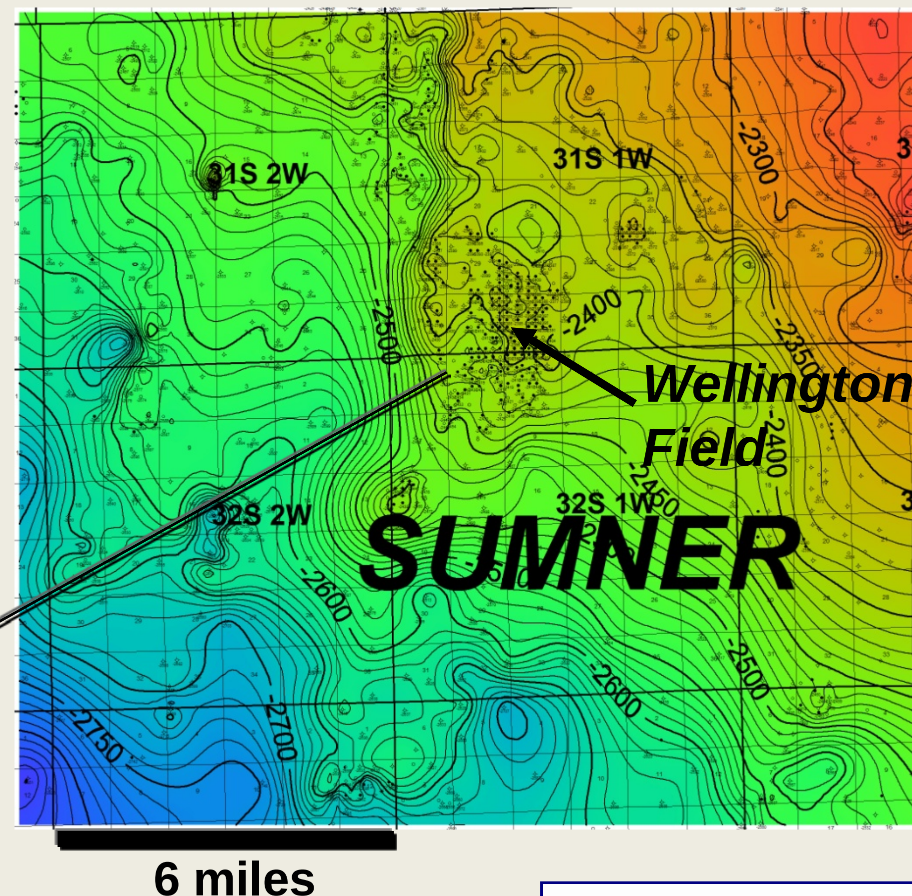
Name	Project Job Title	Primary Responsibility
Lynn Watney	Project Leader, Joint Principal Investigator	Geology, information synthesis, point of contact
Tiraz Birdie	Consulting Engineer	Reservoir engineer, dynamic modeling, synthesis
Jason Rush	Joint Principal Investigator	Geology, static modeling, data integration, synthesis
John Doveton	Co-Principal Investigator	Log petrophysics, geostatistics
Dave Newell	Co-Principal Investigator	Fluid geochemistry
Rick Miller	Geophysicist	2D seismic aquire & interpretation
		LiDAR support, water well drilling/completion
TBN	Geology Technician	Assemble and analyze data, report writing
TBN	Engineering Technician	Assemble and analyze data, report writing
KU Department of Geology		
Michael Taylor	Co-Principal Investigator	Structural Geology, analysis of InSAR and LiDAR
TBN	Graduate Research Assistant	Structural Geology, analysis of InSAR and LiDAR
Kansas State Unversity		
Saugata Datta	Principal Investigator	
TBN	Graduate Research Assistant	Aqueous geochemistry
TBN	3- Undergraduate Research Assistants	
Lawrence Berkeley National Laboratory		
Tom Daley	Co-Principal Investigator	Geophysicist, analysis of crosshole and CASSM data
Jennifer Lewicki	Co-Principal Investigator	Hydrogeology, analysis of soil gas measuremnts
Barry Freifeld	Co-Principal Investigator	Mechanical Engineer, analysis of U-Tube sampler
Sandia Technologies, Houston		
Dan Collins	Geologist	Manage CASSM and U-Tube operation
David Freeman	Field Engineer	Manage field install of CASSM and U-Tube
Berexco, LLC		
Dana Wreath	VP Berexco	Engineering, Manager of Wellington Field
Randy Kouedele	Reservoir engineer	Enginering
Staff of Wellington Field		field operations
Beredco Drilling team		Mississippian and Arbuckle drilling operations
Abengoa Bioenergy Corp. - Colwich, KS		
Christopher Standlee, Danny Alllison		CO2 supply – Colwich Ethanol Facility

Wellington Field

Site of proposed Small Scale Field Test



Top Mississippian Structure, 10 ft C.I.



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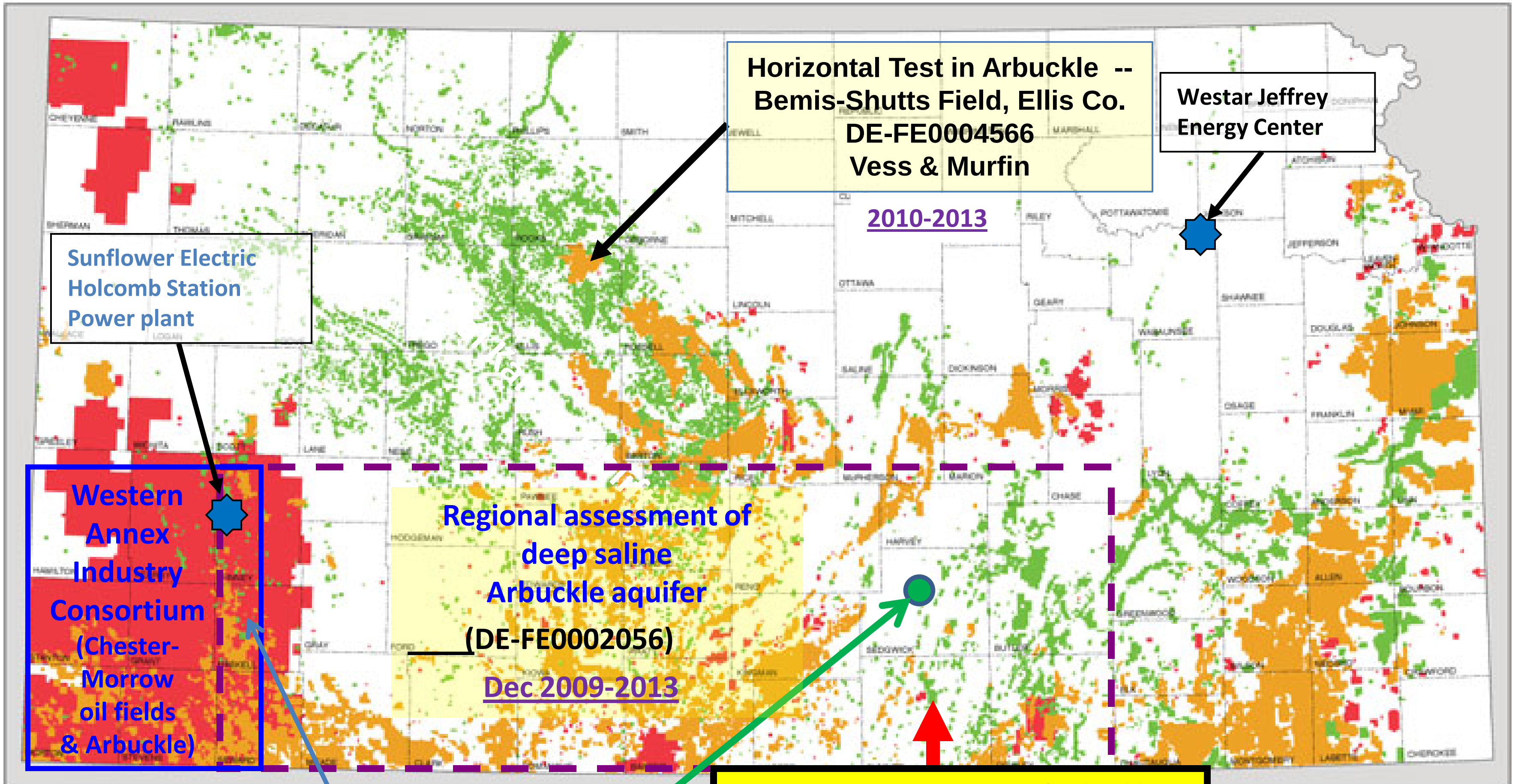
OIL AND GAS FIELDS OF KANSAS
2009



Feb 2011-2013

Abengoa Bioenergy
(Colwich ethanol)

Deep Arbuckle/basement
Test – scheduled for 2nd
quarter 2012

Sequestration capacity of Arbuckle
saline aquifer & EOR-CO_2 Mississippian
chert reservoir
WELLINGTON FIELD (Berexco)
(DE-FE0002056) Dec 2009-2013

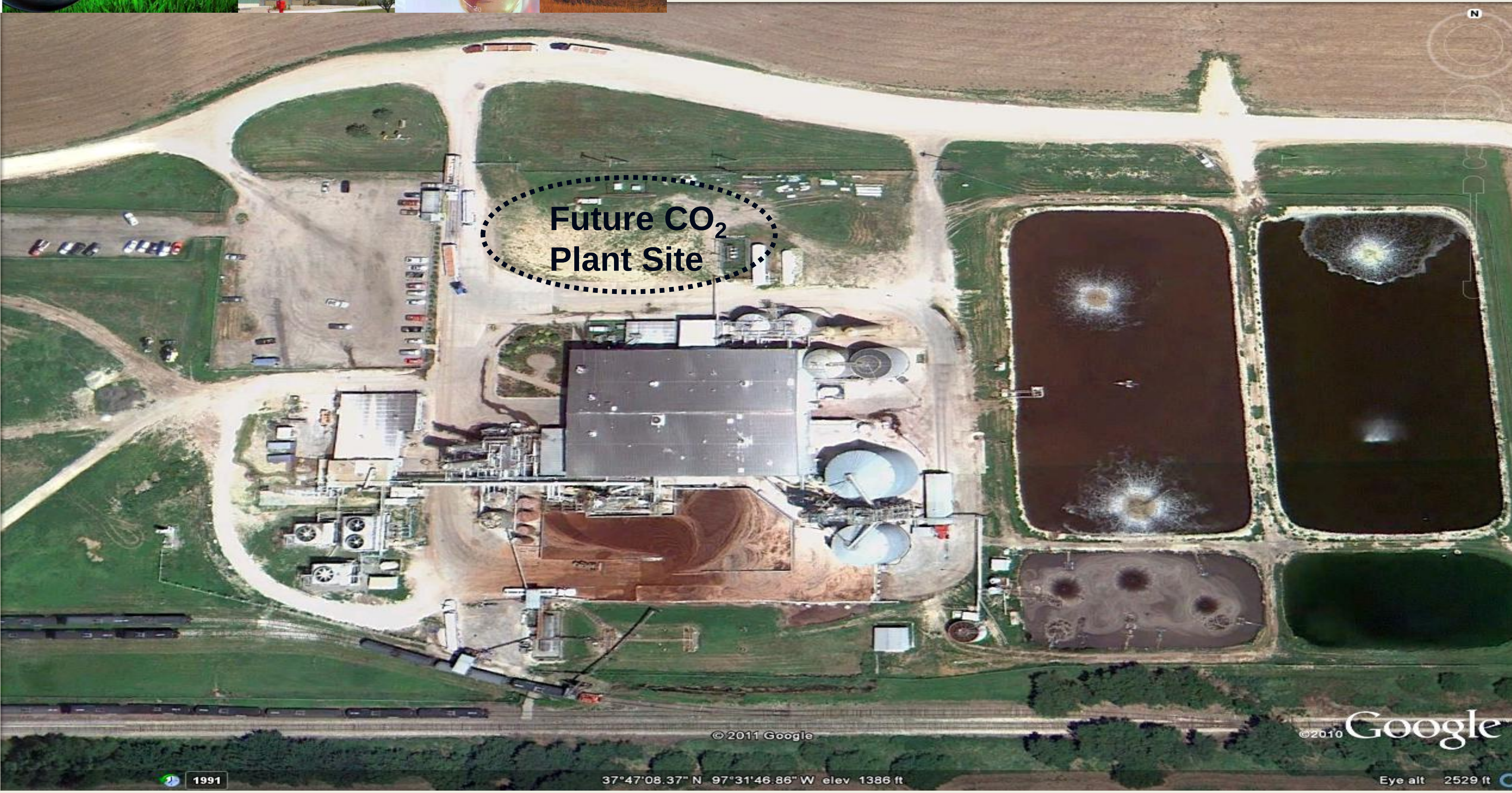
Small Scale Field Test @ Wellington
(DOE-FOA-441)
Funded 10-1-2011 (through 2015)

Named Fields
- Oil field
- Gas field
- Oil and gas field

50 miles

Source of CO2

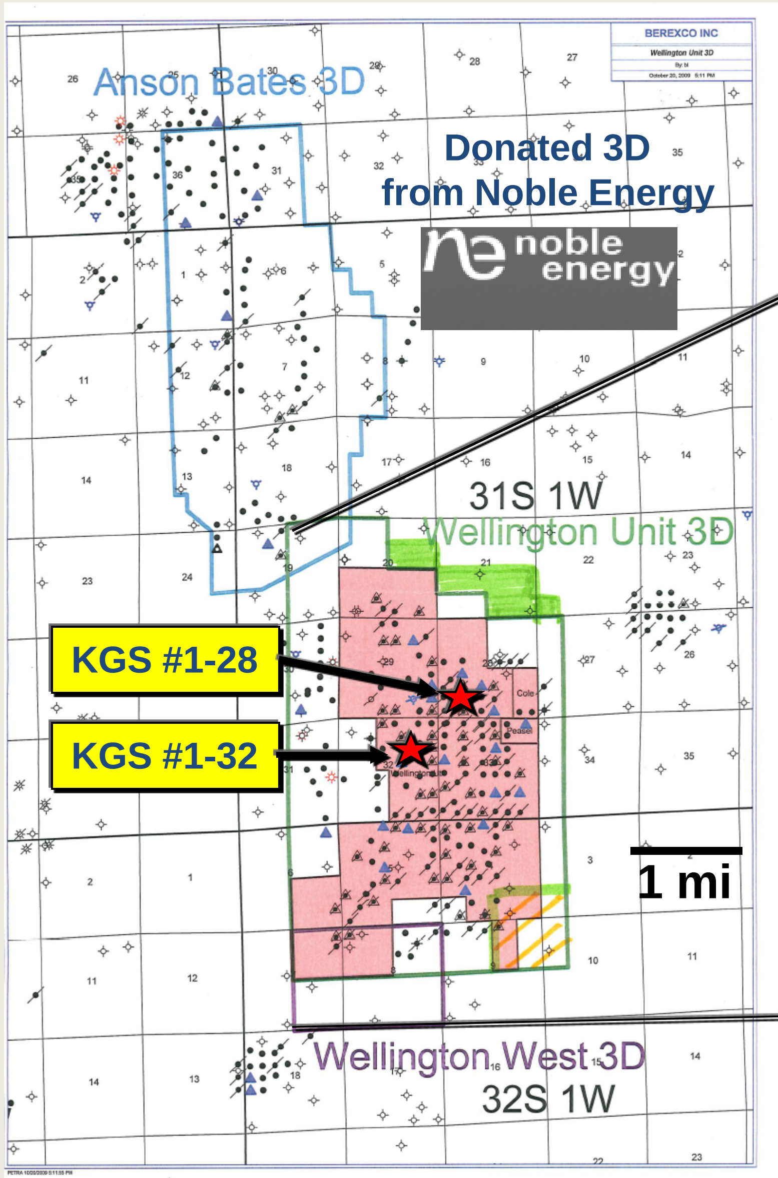
Abengoa Colwich plant and CO_2 site

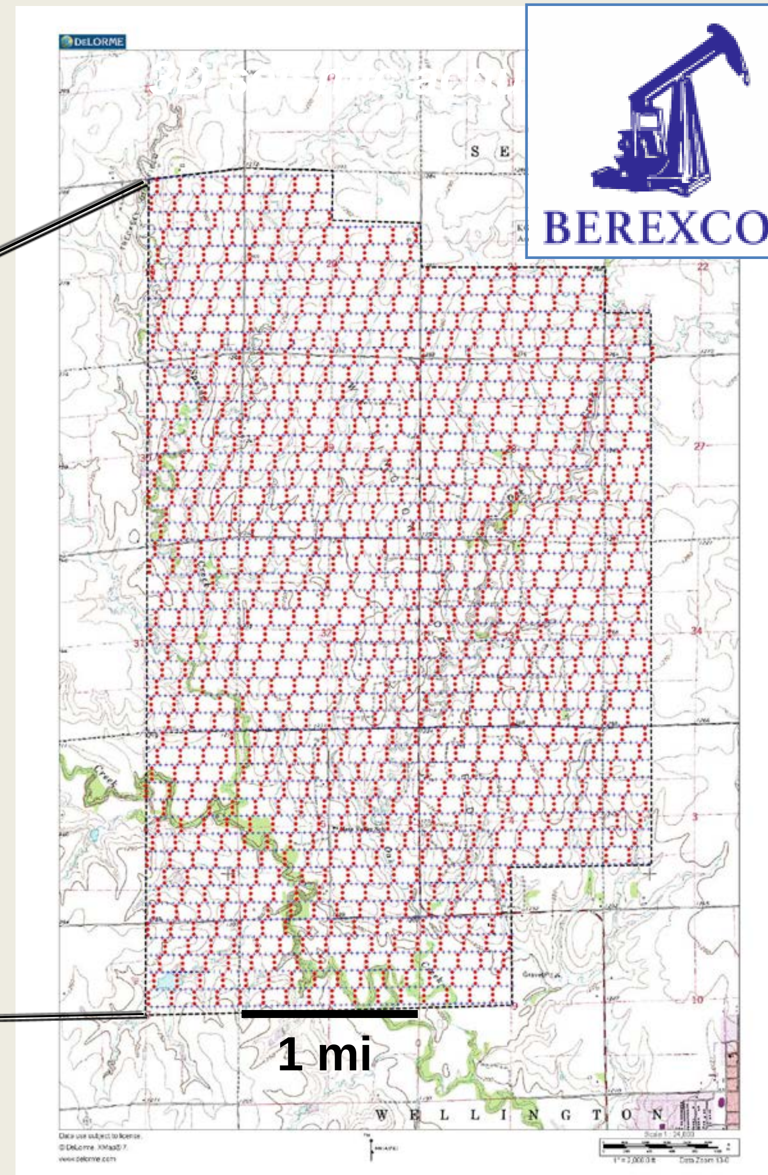


- Constructed in 1982, has been upgraded and expanded many times over the years, and is a modern well equipped plant.
- Production capacity of approximately 25 M gallons of ethanol per year and produces over **200 tons per day of raw CO_2**.
- CO_2 was captured, processed and sold for approximately 10 years from this facility.

Wellington Field

3D Multicomponent 3D Seismic survey & 2 basement tests



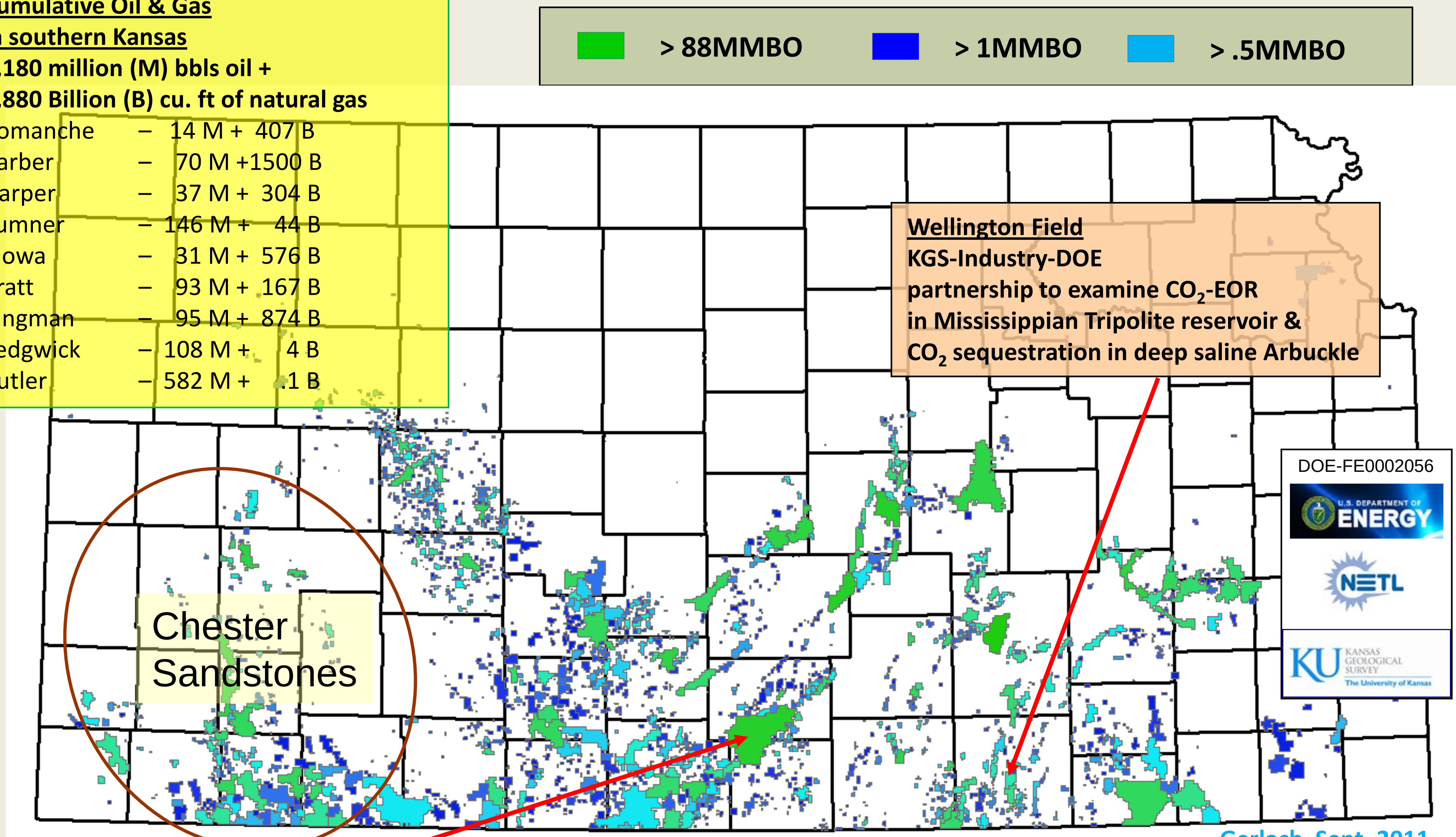


BEREXCO

Tripolite Chert Reservoir at Wellington Field is Analogous to Many Mississippian Oil and Gas Fields in Southern Kansas

<u>Cumulative Oil & Gas in southern Kansas</u>
1,180 million (M) bbls oil +
3,880 Billion (B) cu. ft of natural gas

Comanche	–	14 M + 407 B
Barber	–	70 M +1500 B
Harper	–	37 M + 304 B
Sumner	–	146 M + 44 B
Kiowa	–	31 M + 576 B
Pratt	–	93 M + 167 B
Kingman	–	95 M + 874 B
Sedgwick	–	108 M + 4 B
Butler	–	582 M + .1 B



<u>Wellington Field</u>
KGS-Industry-DOE partnership to examine CO_2-EOR in Mississippian Tripolite reservoir & CO_2 sequestration in deep saline Arbuckle

Gerlach, Sept. 2011

<u>Spivey-Grabs Basil</u> is the largest Mississippian oil field in Kansas with 69 MM BO & 841 BCFG
Produces from the <u>tripolite</u> and could benefit from horizontal drilling and, in later maturity, by CO_2-EOR

Gantt Chart

Small Scale Field Test Wellington Field (FE0006821)

BP1 (Oct. 2011- Sept. 2012), Tasks 1-5

Yr 1 - 2012

O N D Jan '12 F M A M J Jul A S

Task 1.	Project Management and Reporting		
	Subtask 1.1.		Finalize Program Management Plan
	Subtask 1.2.		Planning and Reporting
	Subtask 1.3.		Develop Interface Capability to NATCARB Database
	Subtask 1.4.		Develop Project Web Site
	Subtask 1.5.		Drilling and Well Installation Plan
	Subtask 1.6.		Monitoring Verification and Accounting (MVA) and Mitigation Plan:
	Subtask 1.7.		Public Outreach Plan
	Subtask 1.8.	Go-No Go1	Arbuckle Injection Permit Application
	Subtask 1.9.	Go-No Go2	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 Go3	
Task 3.	Site characterization of Mississippian Reservoir for CO2 EOR - Wellington Field		
		Go-No Go4	
Task 4.	Drill Monitoring Borehole for CO2 Sequestration in Arbuckle Saline Aquifer		
	Subtask 4.1.		Obtain permit to drill monitoring well
	Subtask 4.2.		Drill and DST monitoring well
	Subtask 4.3.		Log monitoring well
	Subtask 4.4.		Complete monitoring well as per MVA requirements
	Subtask 4.5.		Conduct mechanical integrity test
	Subtask 4.6.		Analyze wireline log
	Subtask 4.7.		Perforate, test, and sample fluids
Task 5.	Drill CO2 Injection Borehole at the Center of Mississippian CO2-EOR Pattern		
	Subtask 5.1.		Obtain permit to drill injection well for CO2-EOR
	Subtask 5.2.		Drill and DST injection well
	Subtask 5.3.		Log injection well
	Subtask 5.4.		Complete injection well as per KCC requirements
	Subtask 5.5.		Conduct mechanical integrety test
	Subtask 5.6.		Analyze wireline log
	Subtask 5.7.		Perforate, test, and sample fluids

Permitting by March 2012 (EPA Class VI)

Site Characterization by Jan-Feb. '12

Gantt Chart
Small Scale Field Test Wellington Field (FE0006821)
BP1 (Oct. 2011- Sept. 2012), Tasks 6-12

Yr 1 - 2012

O | N | D | Jan '12 | F | M | A | M | J | Jul | A | S

Task 6	Reenter, Deepen, & Complete Existing Plugged Arbuckle Borehole (Peasel 1)	
	Subtask 6.1.	Obtain permit to re-eneter, drill, and recomplete borehole
	Subtask 6.2.	Drill the borehole into upper Arbuckle
	Subtask 6.3.	Log borehole
	Subtask 6.4.	Complete borehole as per MVA requirements
	Subtask 6.5.	Conduct mechanical integrity test
	Subtask 6.6.	Analyze wireline log
	Subtask 6.7.	Perforate, test, and sample fluids
Task 7.	Revise Site Characterization Models and Simulations for CO2 Sequestration and submit a revised Site Characterization, Modeling, and Monitoring Plan to DOE:	
	Subtask 7.1	Revise geomodel with new data
	Subtask 7.2.	Update Arbuckle and Mississippian simulations
Task 8.	Inventory Well and Borehole Completions within Area of Influence of Small Scale CO2 Sequestration Project	
Task 9.	Establish MVA Infrastructure - Around CO2 Injector for CO2 Sequestration	
	Subtask 9.1.	Custom designing MVA components and fabrication
	Subtask 9.2.	Install LIDAR Survey Reflectors, CGPS, and Seismometers in a Grid Pattern near the Injection borehole
	Subtask 9.3.	Establish protocols for InSAR data collection
	Subtask 9.4.	Drill two cluster of shallow fresh water monitoring boreholes
	Subtask 9.5.	Drill two monitoring wells below shallow evaporite tertiary cap rock
	Subtask 9.6.	Establish soil gas chemical and CO2 flux monitoring grid and install soil gas sampling points around injector.
	Subtask 9.7.	Outfitting existing Mississippian boreholes for head gas sampling
Task 10	Pre-injection MVA - Establish Background (Baseline) Readings	
	Subtask 10.1	Analysis of InSAR data
	Subtask 10.2.	Collect and analysis LiDAR data
	Subtask 10.3.	Shallow ground water sampling and analysis
	Subtask 10.4.	Soil gas chemistry and CO2 flux sampling and analysis
	Subtask 10.5.	Head gas & water sampling and analysis - existing Mississippian wells
	Subtask 10.6.	High resolution 2D seismic lines targeting Mississippian reservoir
Task 11.	Design and Construct CO2 Compression & Loading Facility at CO2 Source	
	Subtask 11.1	Design CO2 Compression and Loading Facility
	Subtask 11.2.	Submit CO2 Capture and Compression Design
	Subtask 11.3. Go-No Go5	Procure CO2 Compression and Loading Equipment
	Subtask 11.4.	Install CO2 Compression and Loading Facilities at CO2 Source
Task 12.	Build Infrastructure for CO2 Pressurization at Arbuckle Injection Borehole for CO2 Sequestration	
	Subtask 12.1.	Build a Receiving and Storage Facility at the Injection Site
	Subtask 12.2.	Install Pumping Facility at Well Site for Super Critical CO2 Injection

Review Design of CO_2 Supply April 2012

Small Scale Field Test Wellington Field (FE0006821)

BP2 (Oct. 2012- Sept. 2013)

Yr 2 - 2013

O | N | D | Jan '13 | F | M | A | M | J | Jul | A | S

Task 1.	**Project Management and Reporting**	
	Subtask 1.2.	Program management and reporting
Task 10.	**Pre-injection MVA - establish background (baseline) readings**	
	Subtask 10.1	Analysis of INSAR data
	Subtask 10.2.	Collect and analysis LIDAR data
	Subtask 10.3.	Shallow ground water sampling and analysis
	Subtask 10.4.	Soil gas chemistry and CO2 flux sampling and analysis
	Subtask 10.5.	Head gas & water sampling and analysis - existing Mississippian wells
	Subtask 10.7.	1st crosshole tomograpahy - pre-injection
Task 13.	**Retrofit Arbuckle Injection Well (#1-28) for MVA Tool Installation**	
	Subtask 13.1.	Install CASSM source(s)
Task 14.	**Retrofit Arbuckle Observation Well (#2-28) for MVA Tool Installation**	
	Subtask 14.1.	Install U-tube
	Subtask 14.2.	Install CASSM receiver (applicable for cross-hole tomography)
	Subtask 14.3.	Install DTPS sensors
Task 15.	**Begin Injection at Arbuckle Injector**	
	Subtask 15.1.	CO2 Transportation to Arbuckle Injector
	Subtask 15.2.	Inject supercritical CO2
Task 16.	**MVA During Injection - Arbuckle CO2 Sequestration**	
	Subtask 16.1.	CASSM monitoring
	Subtask 16.2.	Soil gas chemistry and CO2 flux sampling and analysis
	Subtask 16.3.	U-tube monitoring
	Subtask 16.4.	Shallow ground water sampling and analysis
	Subtask 16.5.	Head gas & water sampling and analysis - existing Mississippian boreholes
	Subtask 16.6.	LiDAR surveys
	Subtask 16.7.	InSAR data analysis
	Subtask 16.8.	Second Crosswell Tomography Halfway Through Injection
	Subtask 16.9.	Integration of CASSM and Crosswell Tomography

Start injection in Arbuckle, April '13

Small Scale Field Test Wellington Field (FE0006821)

BP3 Yr 1 (Oct. 2013- Sept. 2014)

Yr 3 - 2014

O | N | D | Jan '14 | F | M | A | M | J | Jul | A | S

Task 1. **Project Management and Reporting**

Subtask 1.1. Program management and reporting

Task 15. Continue Injection in Arbuckle

Subtask 18.1. CO2 Transportation to Arbuckle Injector

Subtask 18.2. Inject supercritical CO2

End Injection in Arbuckle, May '14

Task 16. **MVA during injection - CO2 Sequestration site**

Subtask 16.1. CASSM monitoring

Subtask 16.2. Soil gas chemistry and CO2 flux sampling and analysis

Subtask 16.3. U-tube monitoring

Subtask 16.4. Shallow ground water sampling and analysis

Subtask 16.5. Head gas & water sampling and analysis - existing Mississippian wells

Subtask 16.6. LiDAR surveys

Subtask 16.7. InSAR data analysis

Subtask 16.8. 2nd crosshole tomography halfway through injection (optional)

Subtask 16.9. Integration of CASSM and crosswell tomography

Task 17. **Risk Management Related to CO2 Sequestration in Arbuckle Saline Aquifer**

Subtask 17.1. Integrate MVA analysis and observations to detect CO2 leakage

Subtask 17.2. Activate mitigation plans if leakage detected

Task 18. **Compare Simulation Results with MVA Data and Analysis and Submit Update of Site Characterization, Modeling, and Monitoring Plan**

Subtask 18.1. Revise Geomodel to Improve Match with MVA Data

Task 19. **Post injection MVA - Arbuckle CO2 Sequestration**

Task 20. **Evaluate CO2 Sequestration Potential in Arbuckle Saline Aquifer at Wellington**

Task 21. **Evaluate Regional CO2 Sequestration Potential in Arbuckle Saline Aquifer in Kansas**

Task 22. **Recondition Mississippian Boreholes Around Mississippian CO2-EOR injector**

Subtask 25.1. Recondition existing boreholes around CO2-EOR injector

Task 23. **Equipment Dismantlement**

Task 24. **CO2 Transported to Mississippian Injector**

Subtask 24.1. Transport CO2 to injection borehole

Subtask 24.2. Inject CO2 at CO2-EOR injection borehole under miscible conditions

Start injection in Mississippian, June '14

Task 25. **Monitor Performance of CO2-EOR Pilot**

Task 26. **Compare Pilot EOR Performance with Model Results**

Subtask 26.1. Compare field performance with simulation studies

Subtask 26.2. Revise geomodel - if necessary

Subtask 26.3. Update simulation - if necessary

Small Scale Field Test Wellington Field (FE0006821)

BP3 Yr 2 (Oct. 2014- Sept. 2015)

Yr 4 - 2015

O | N | D | Jan '15 | F | M | A | M | J | Jul | A | S

Task 1.	**Project Management and Reporting**	
	Subtask 1.1.	Program management and reporting
Task 17.	**Risk Management Related to CO2 Sequestration in Arbuckle Saline Aquifer**	
	Subtask 17.1.	Integrate MVA analysis and observations to detect CO2 leakage
	Subtask 17.2.	Activate mitigation plans if leakage detected
Task 19.	**Post injection MVA - CO2 sequestration site**	
Task 20.	**Evaluate CO2 Sequestration Potential in Arbuckle Saline Aquifer at Wellington**	
Task 21.	**Evaluate regional CO2 Sequestration Potential in Arbuckle Saline Aquifer in Kansas**	
Task 24.	**CO2 Transported to Mississippian Injector**	
	Subtask 24.1.	Truck CO2 to injection well
	Subtask 24.2.	Inject CO2 at CO2-EOR injection well under miscible conditions
Task 25.	**Monitoring Performance of CO2-EOR Pilot**	
Task 26.	**Compare Pilot EOR Performance with Model Results**	
	Subtask 26.1.	Revise geomodel - if necessary
Task 27.	**Evaluate CO2 Sequestration Potential of CO2-EOR Pilot**	
Task 28.	**Evaluate Potential of Incremental Oil Recovery and CO2 Sequestration by CO2-EOR - Wellington field**	
	Subtask 28.1.	Revise Wellington field geomodel
	Subtask 28.2.	Use simulation studies to estimate field-wide CO2-EOR potential
	Subtask 28.3.	Estimate field-wide CO2 sequestration potential of CO2-EOR
Task 29.	**Closure of CO2 Sequestration Project in Arbuckle Saline Aquifer at Wellington field**	
	Subtask 29.1	Acquire and process 3D seismic data around Arbuckle injector (#1-28)
	Subtask 29.2	Interpret newly acquired 3D data and compare with baseline survey
	Subtask 29.3.	Integrate MVA analysis results with 3D survey to establish CO2 containment
	Subtask 29.4.	Seek regulatory permission for closure
Task 30.	**Develop a Best Practice Manual:**	

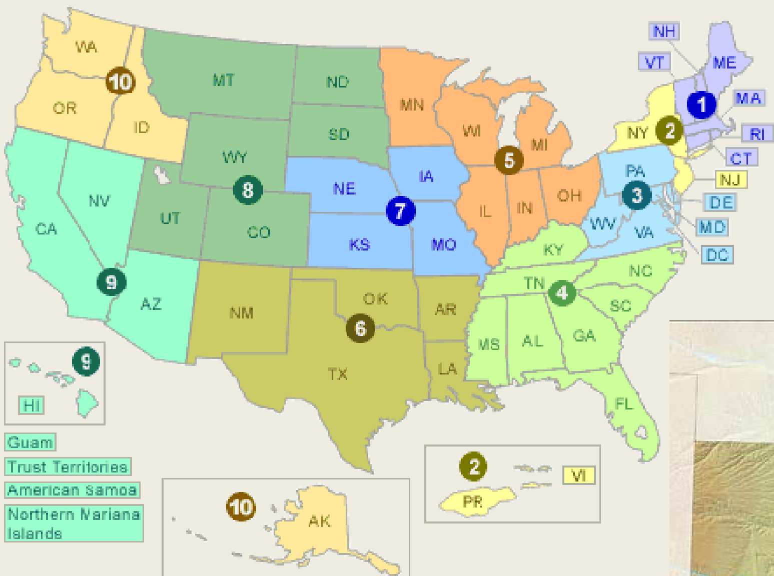
End Injection in Mississippian, Feb. '15

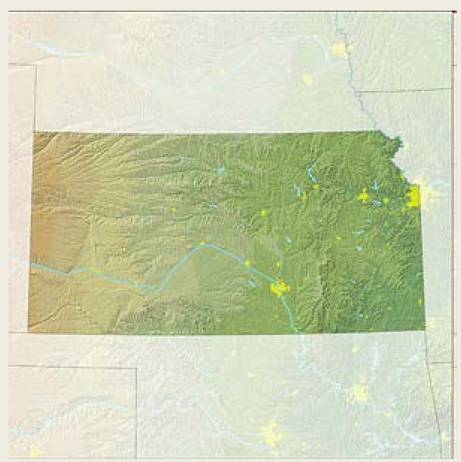
Seek Regulatory Closure September 2015

Current Status

Application Underway for EPA Class VI Injection Well for Geologic Sequestration of CO_2

U.S. EPA, Region 7
Air, RCRA, and Toxics
Kansas City, KS 66101





ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 124, 144, 145, 146, and 147

[EPA–HQ–OW–2008–0390 FRL–9232–7]

RIN 2040–AE98

Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO2**) Geologic Sequestration (GS) Wells**

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

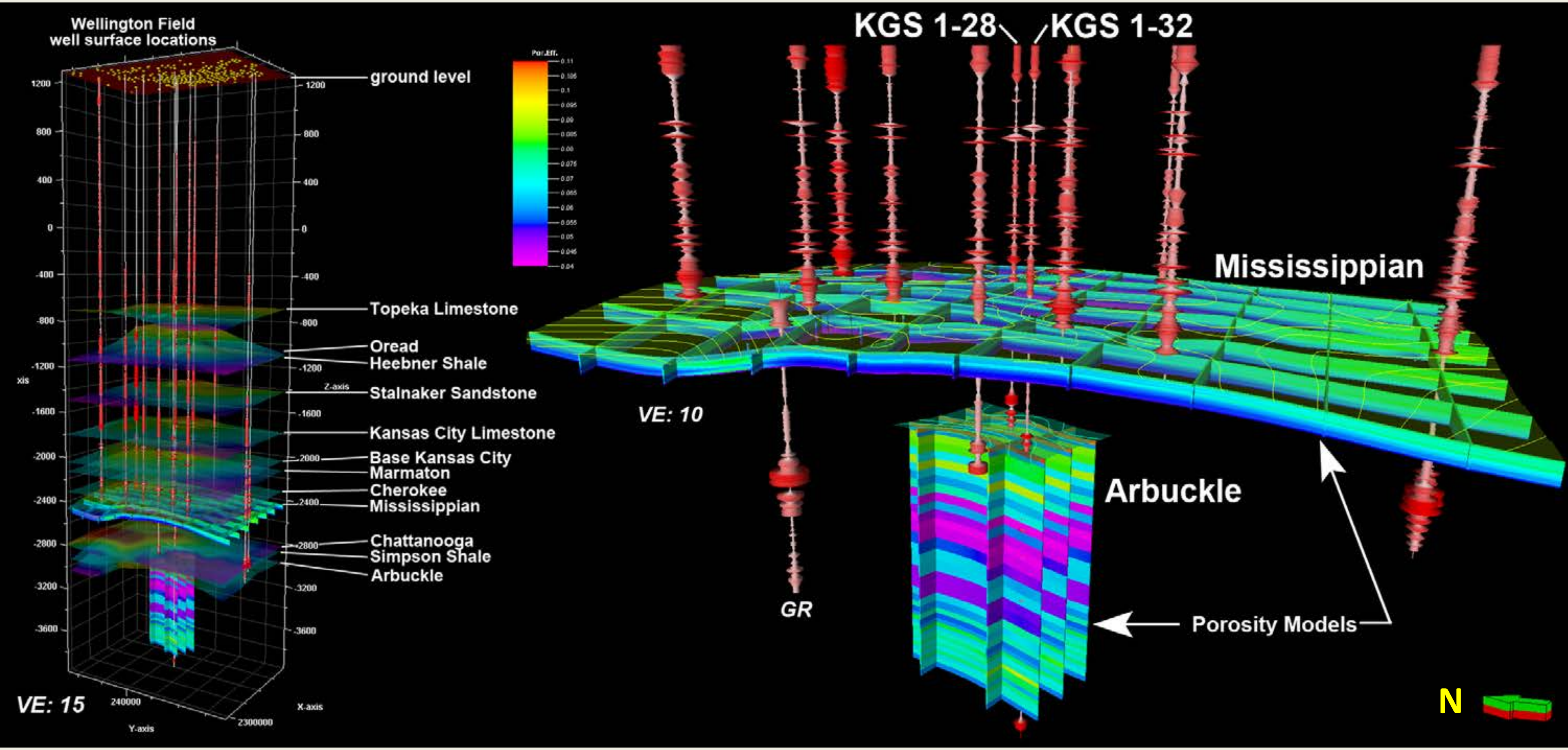
DATES: This regulation is effective January 10, 2011. For purposes of judicial review, this final rule is promulgated as of 1 p.m., Eastern time on December 24, 2010, as provided in 40 CFR 23.7.

Wellington Field

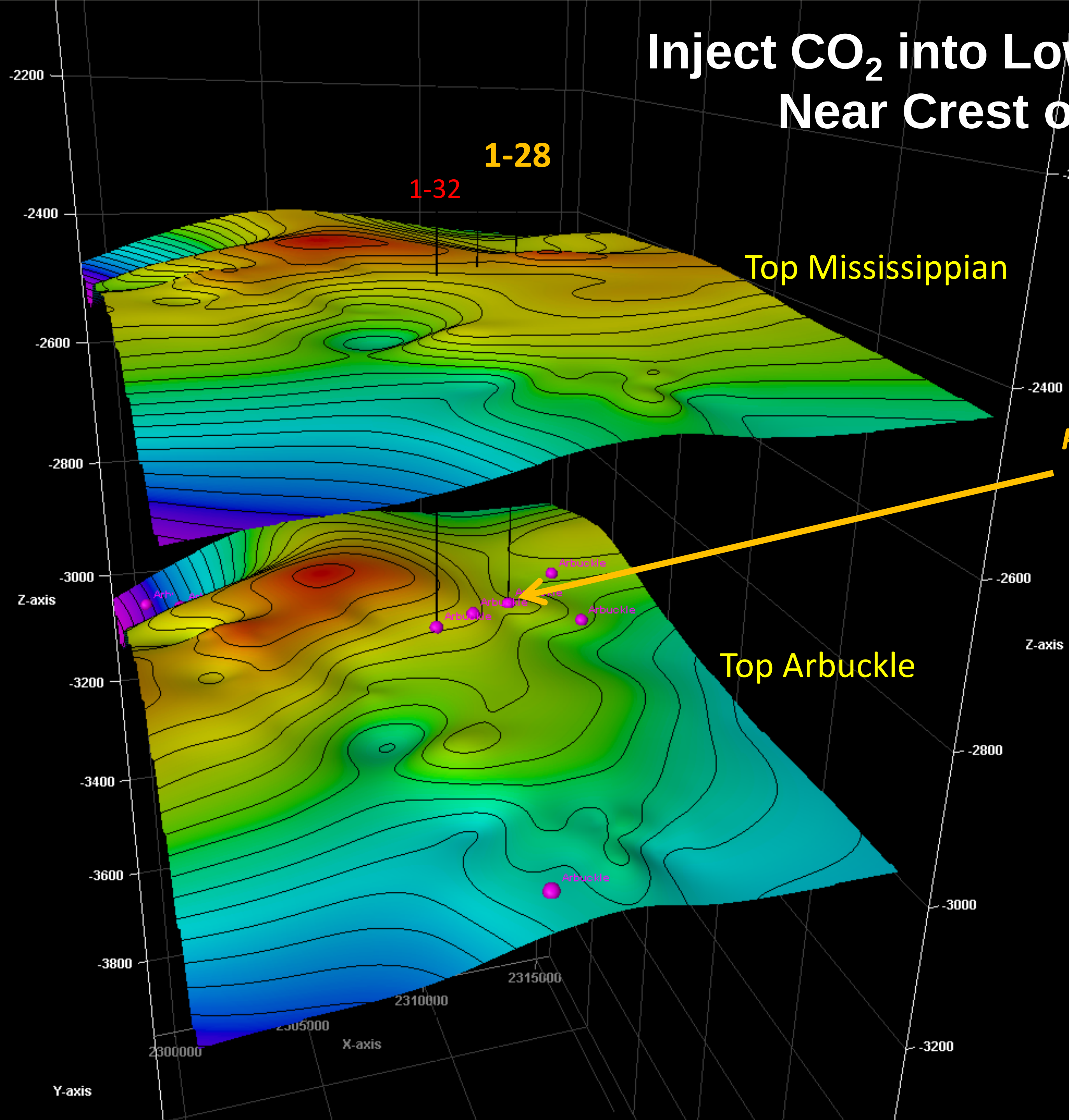
Porosity Fence Diagram

Mississippian Tripolitic Chert Oil Reservoir & Arbuckle Saline Aquifer

(Preliminary Petrel model pending integration of 3D seismic)



Inject CO_2 into Lower Arbuckle Near Crest of Dome



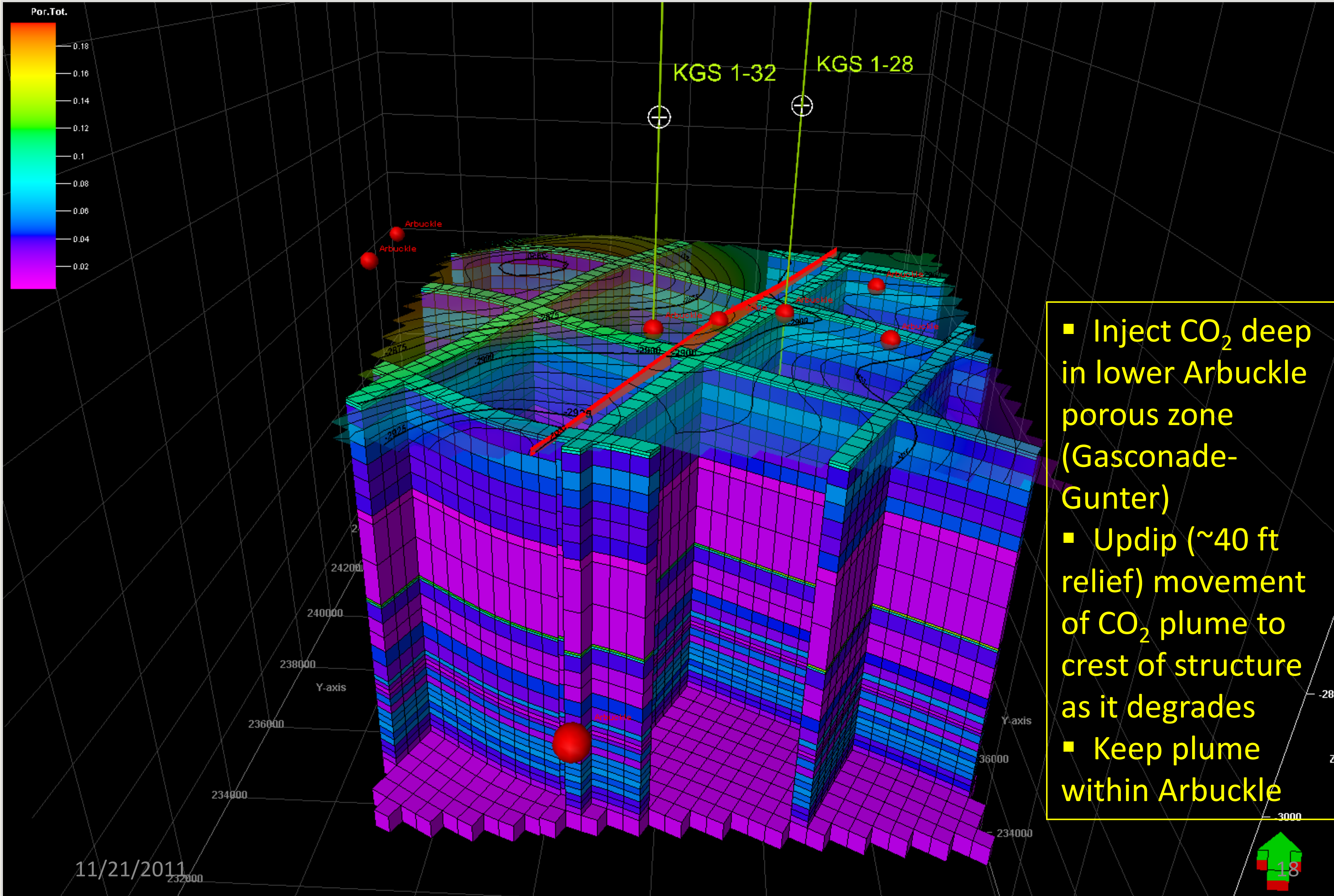
Proposed – convert new well, #1-28 to CO_2 "disposal" well in the lower Arbuckle

(in location offset from CO2-EOR pilot in the Mississippian)

North

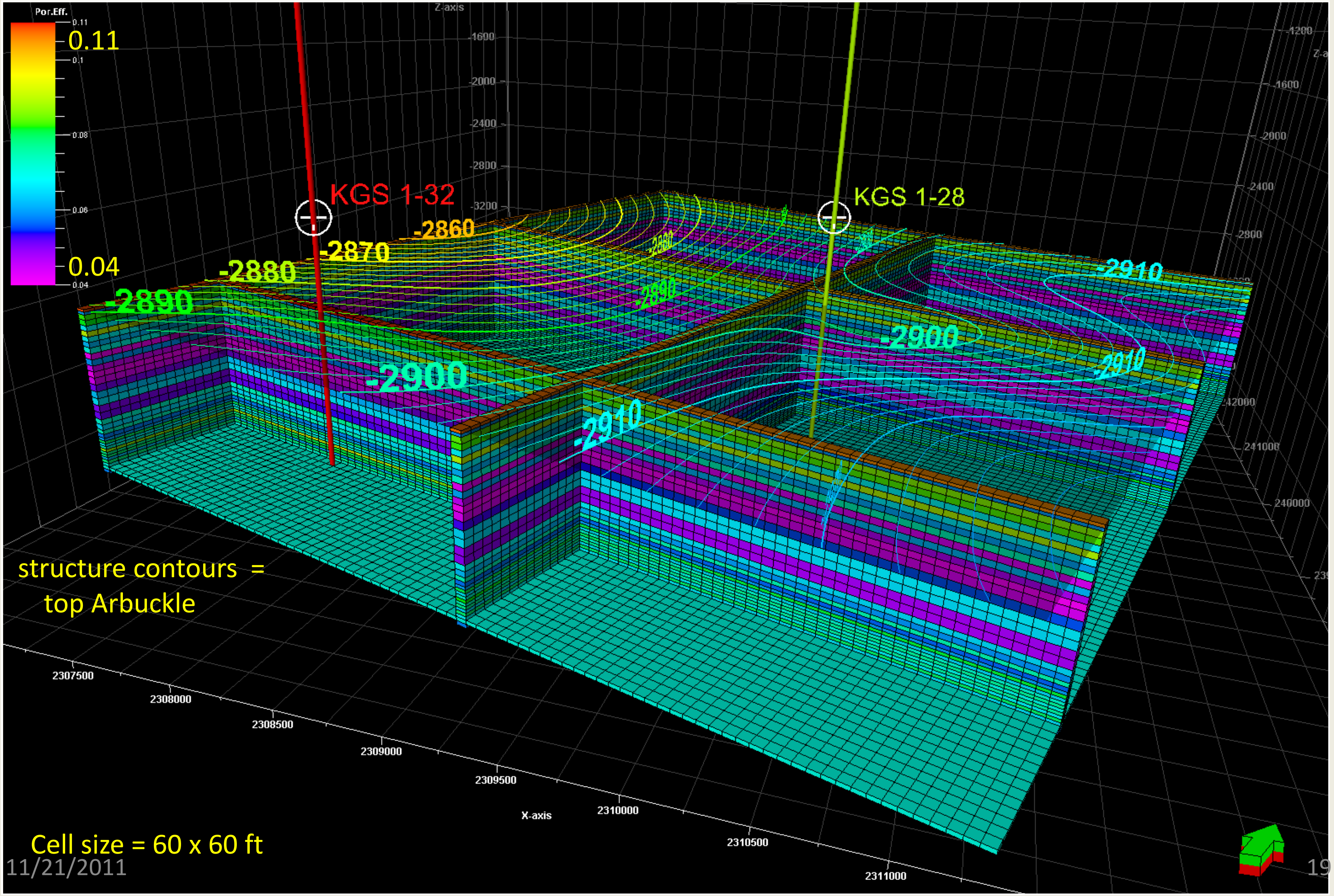
Initial geomodel of Arbuckle (porosity & structure)

Cored well (#1-32) & (#1-28), latter to be used to as CO_2 injector

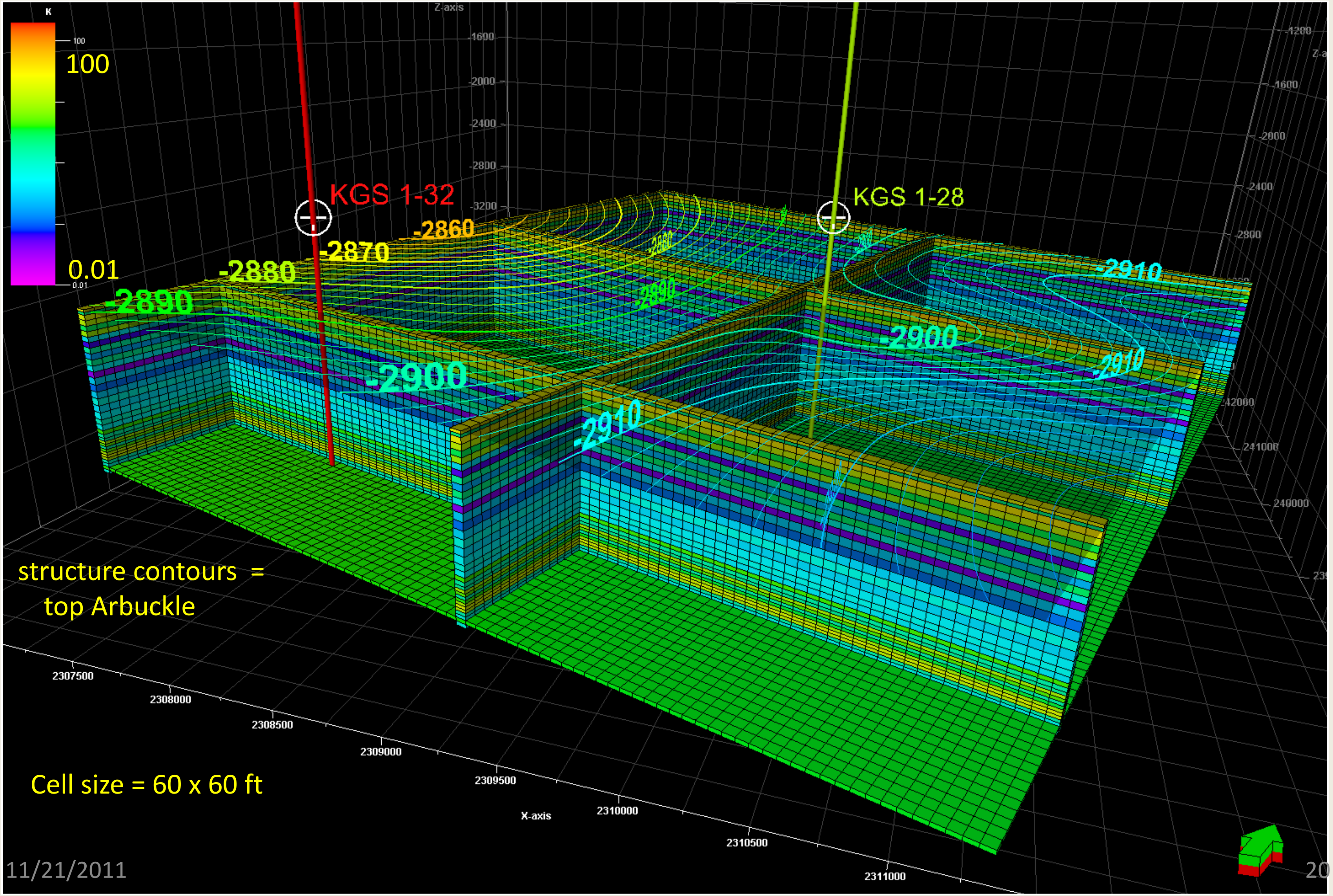


- Inject CO_2 deep in lower Arbuckle porous zone (Gasconade-Gunter)
- Updip (~40 ft relief) movement of CO_2 plume to crest of structure as it degrades
- Keep plume within Arbuckle

Upscaled Average Porosity (effective Φ from NMR)
for Arbuckle Group using new well data from KGS #1-32 & #1-28



Upscaled Permeability
in vicinity of KGS #1-32 & #1-28
using geometric mean of k (Coates NMR), porosity used for trend

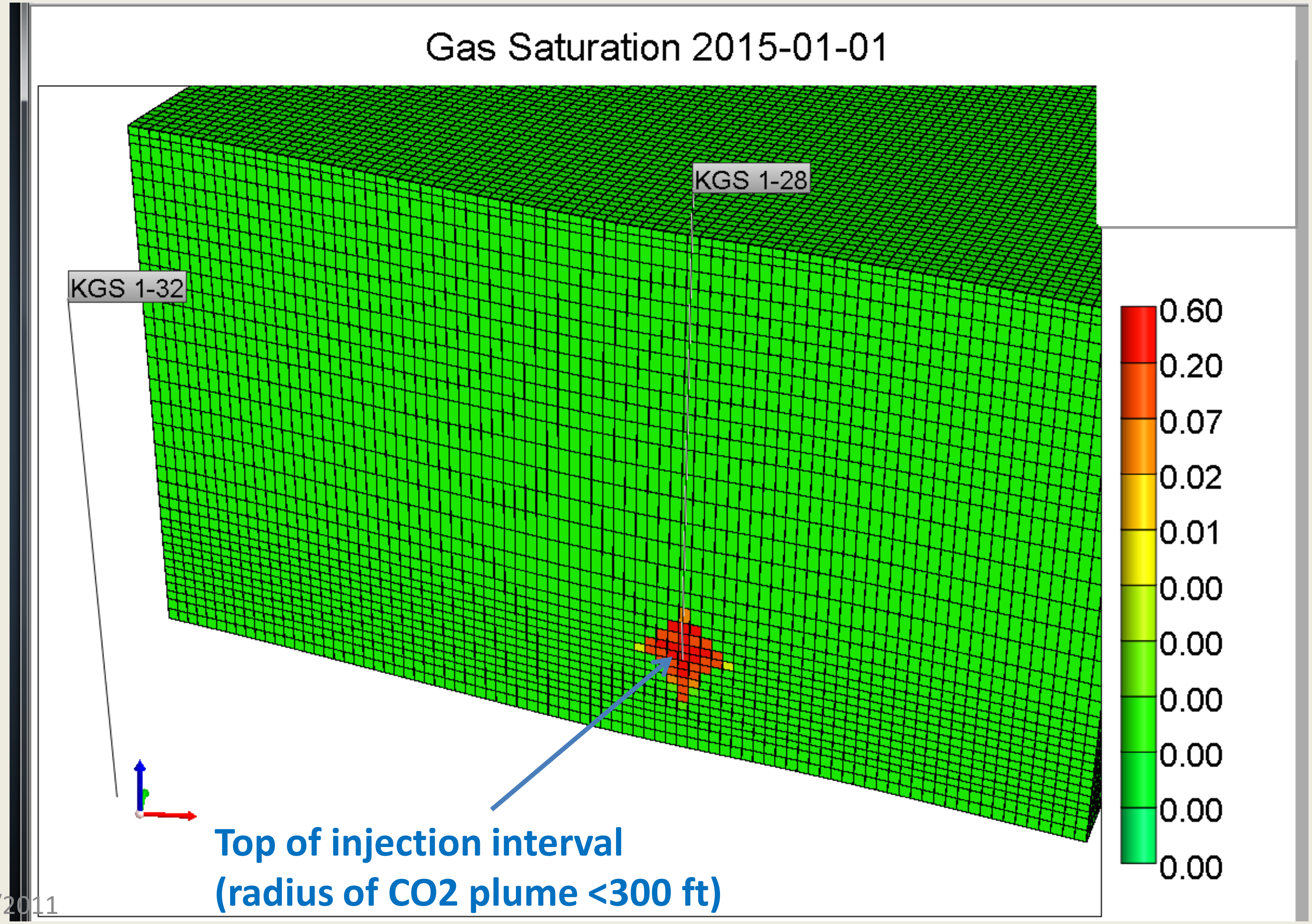


Injection Scenario – Start on Jan 1, 2011 (for 9 months)

Grid cells 60' by 60'

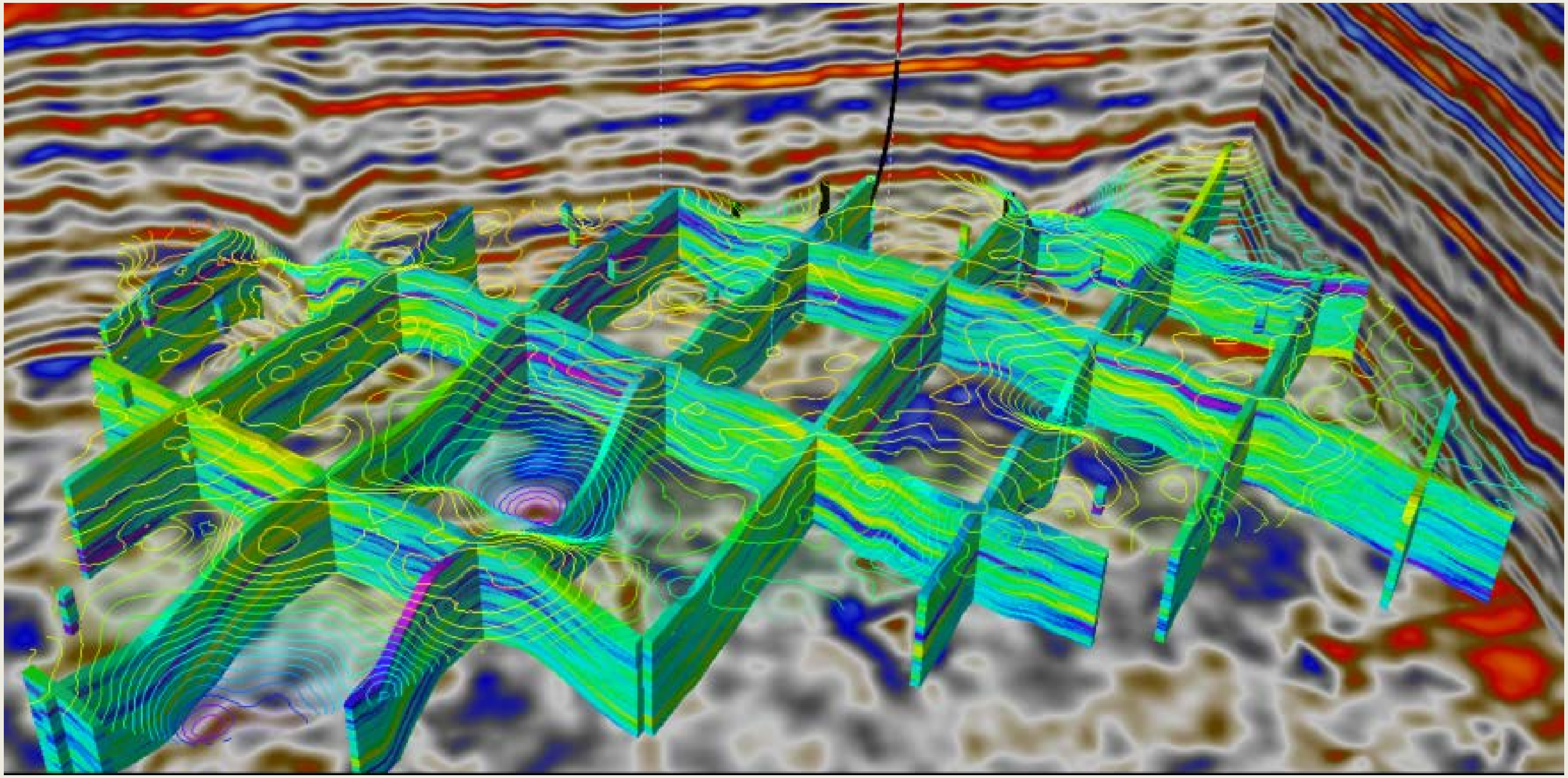
Total CO_2 injected ~ 40,000 tons

Injection layers – L25 to L30, each ~20 ft thick, 120 ft total



Top of injection interval
(radius of CO2 plume <300 ft)

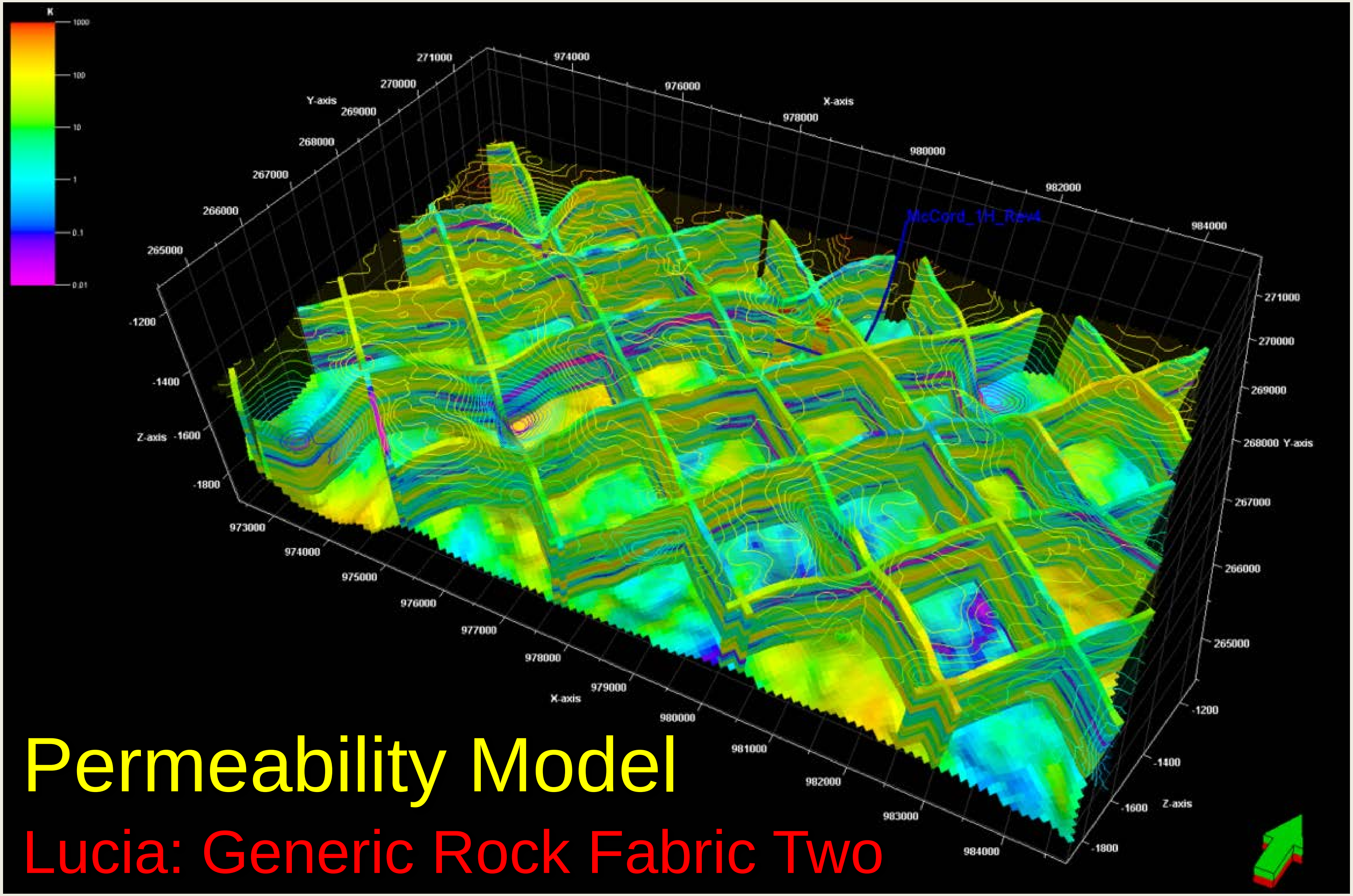
Porosity Model using 3D depth migrated seismic for uppermost Arbuckle being used to design and geosteer a 2000 ft lateral through karst at Bemis-Shutts Field (under FE0004556, J. Rush, PI)



Gaussian Simulation
using vertical & horizontal variograms

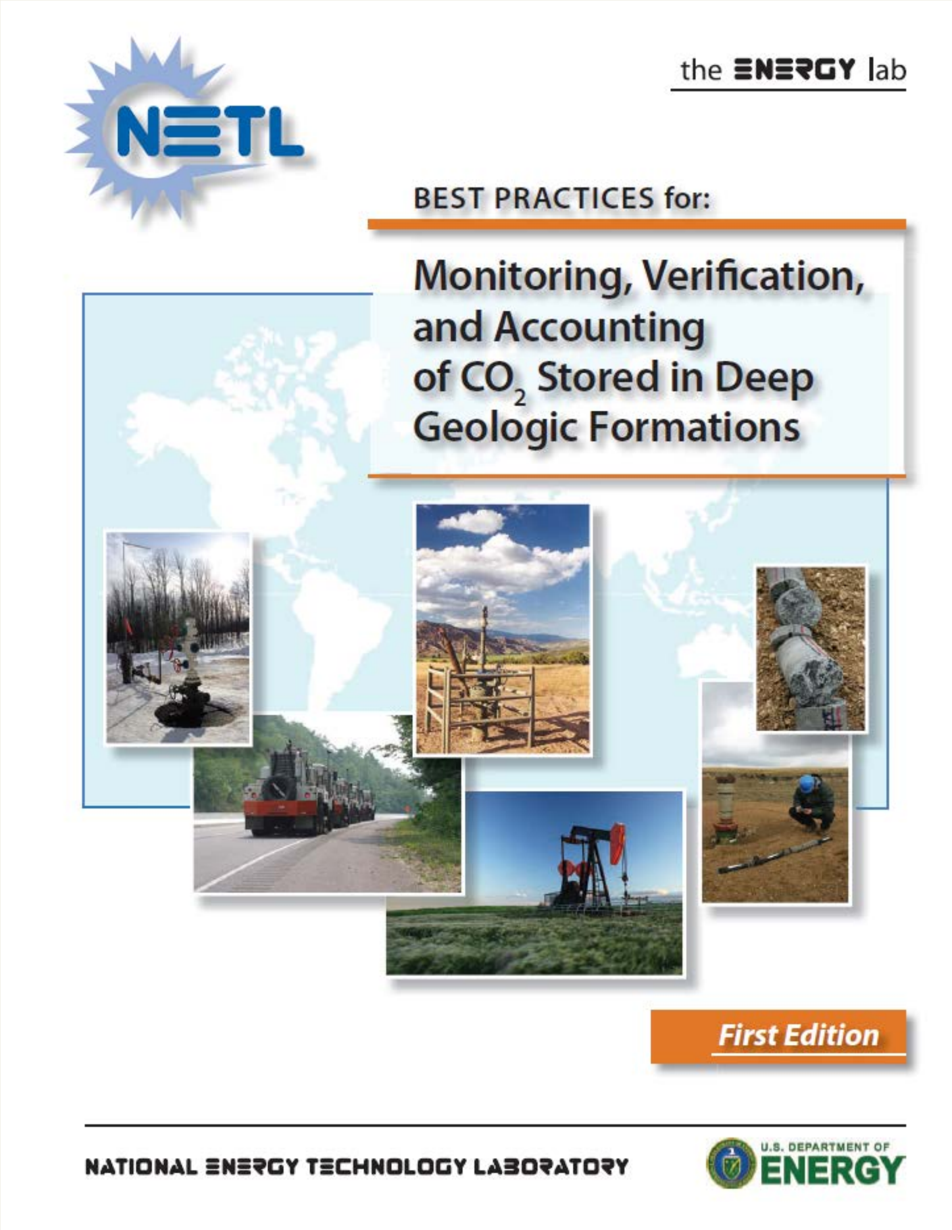
Current DEPTH: 4193 ft at 86.6 degree, 270 degree azimuth, 268 ft from surface location

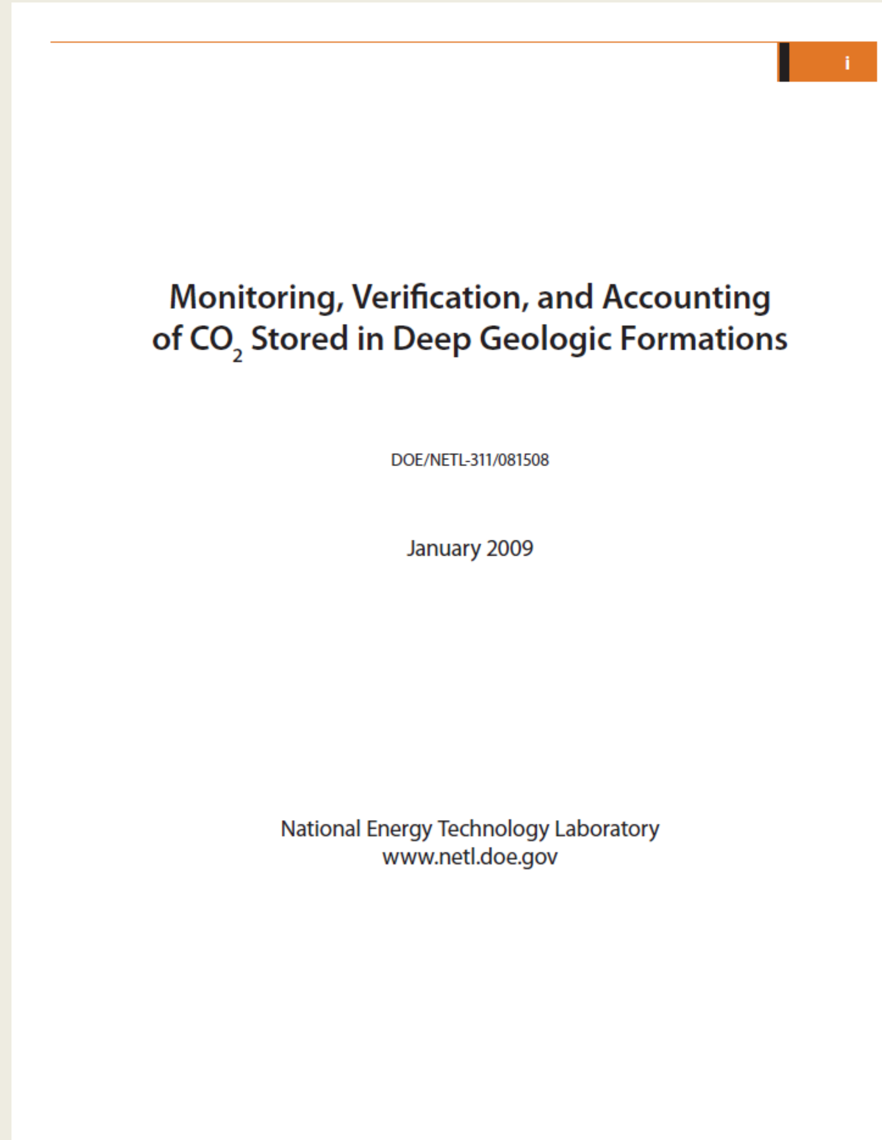
KU KANSAS GEOLOGICAL SURVEY The University of Kansas


K
1000
100
10
1
0.1
0.01
Y-axis
X-axis
Z-axis
McCord_1H_Rev4
Permeability Model
Lucia: Generic Rock Fabric Two

Follow MVA Recommendations of DOE

Tailored, Cost Effective MVA Methodologies





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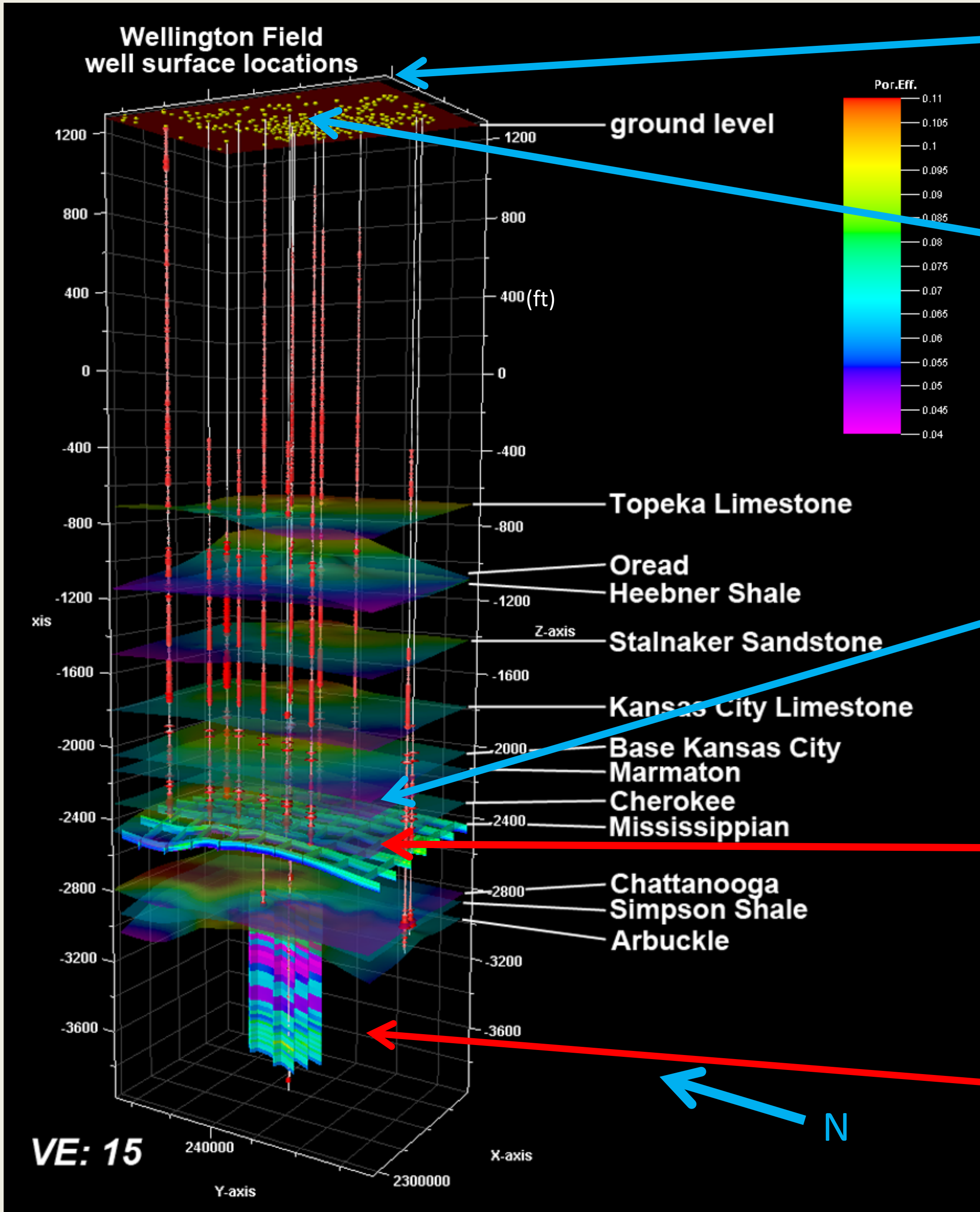
Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations

DOE/NETL-311/081508

January 2009

National Energy Technology Laboratory
www.netl.doe.gov

Optimal Injection and Best Practice Monitoring



- InSAR/LIDAR surface deformation/IRIS seismometers
- Measure soil gas flux and chemistry through series of shallow probes.

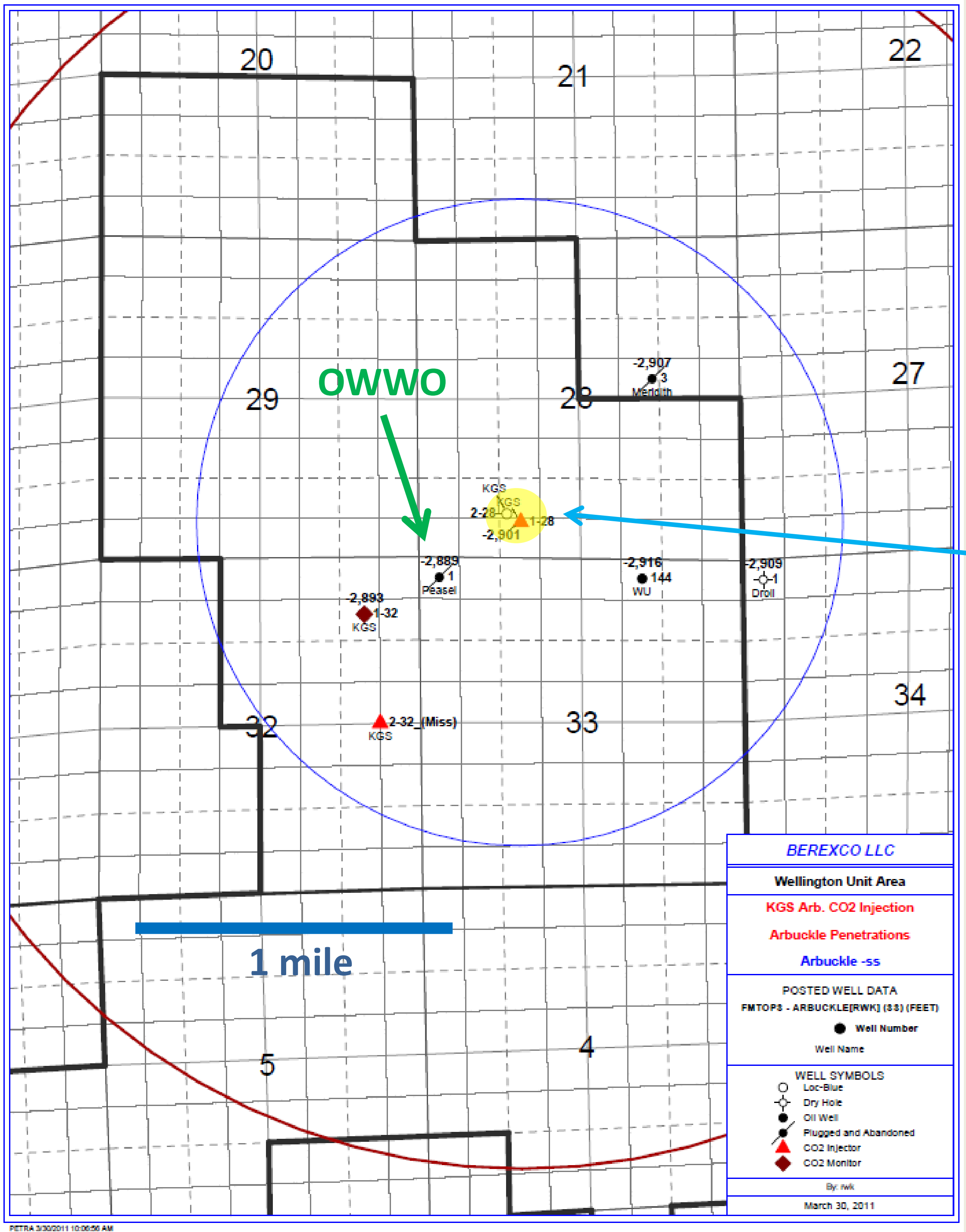
- Monitor for tracers, CO_2, inorganics and organics in 12 shallow freshwater wells (in two nests of 6 wells)
- Monitor two deeper wells ~600 ft deep below shallow evaporite cap rock

- Measure for tracers and CO_2 casing head gas and fluid samples from Mississippian wells (if positive, run 2D seismic)

(*Underpressured oil reservoir [900 psi] should trap any vertically migrating CO2*)

<u>Inject 30,000 tonnes of CO_2</u> into Mississippian chert oil reservoir to demonstrate CO2-EOR (offset injector from Arbuckle)

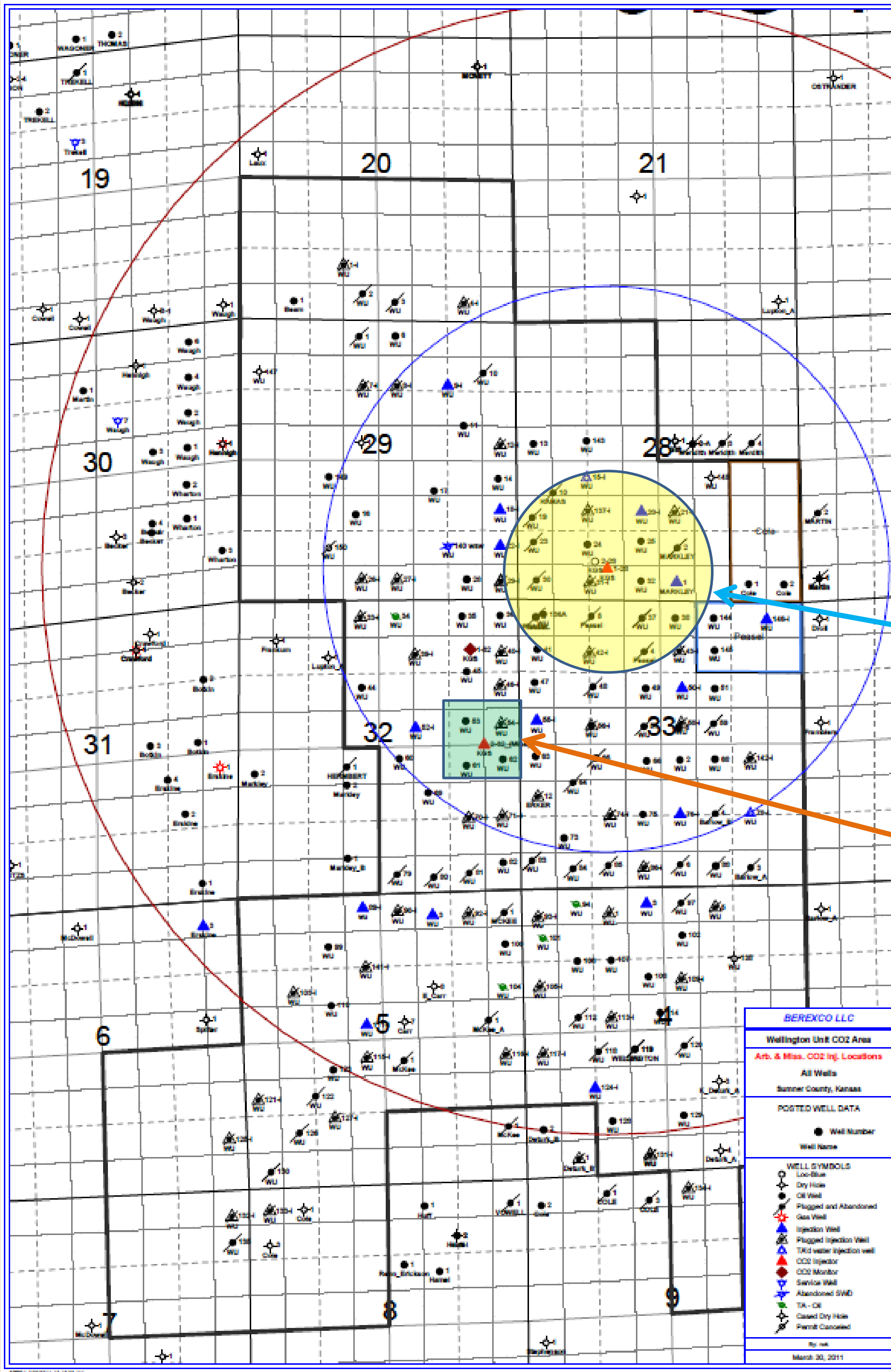
<u>Inject 40,000 tonnes of CO_2</u> with SF6 and krypton tracers into lower Arbuckle saline aquifer and seismically image and sample in situ CO_2 plume development to verify geomodel and simulations



Map showing boreholes that penetrate the Arbuckle saline aquifer in Wellington Field

- Proposed monitoring borehole (#2-28) within 300 ft of the existing #1-28 borehole to be converted into CO_2 injector for small scale field test

- Yellow dot shows estimated size of CO_2 plume after injection of 40,000 tonnes in 120 ft interval of lower Arbuckle based on preliminary simulation results



Map showing boreholes that penetrate into the Mississippian oil reservoir in Wellington Field

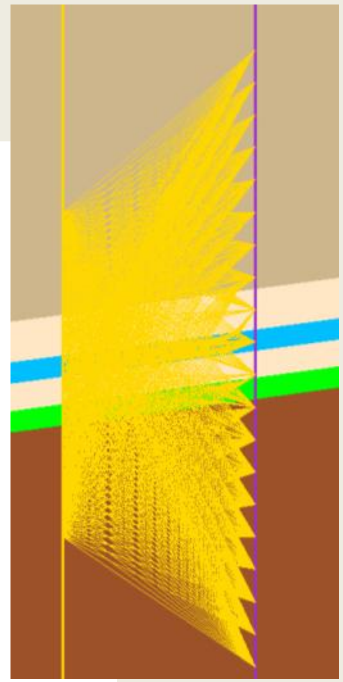
- Location of Mississippian boreholes to be monitored during and after CO_2 injection into the Arbuckle
- Location of Mississippian injection borehole and 5-spot pattern of producing boreholes

1 mile

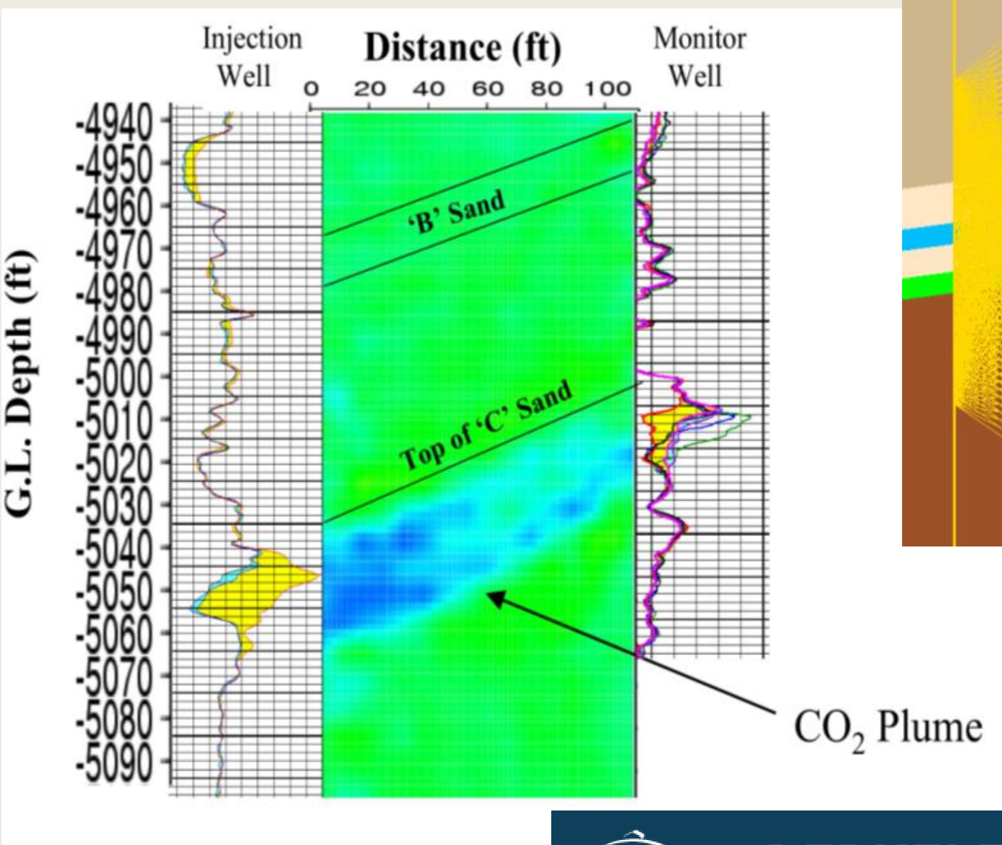
In Situ Monitoring of CO_2 Plume

Example Time Lapse Crosswell Imaging of CO2 Plumes

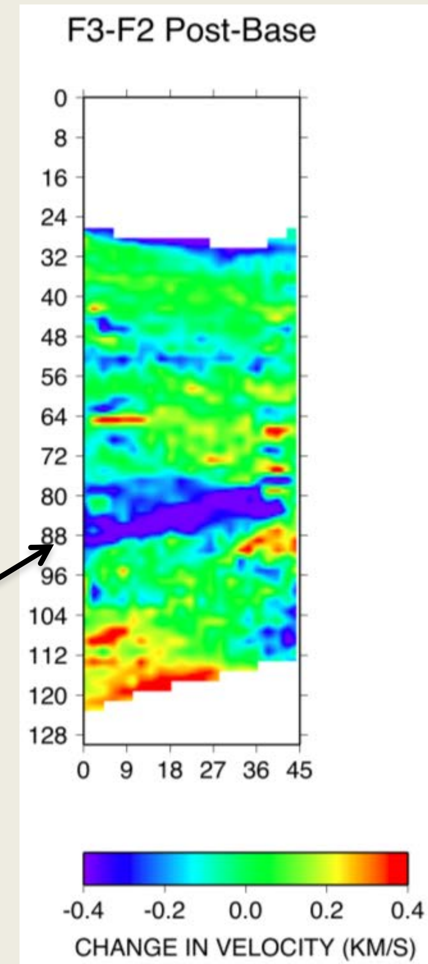
Schematic Crosswell



Frio-I 2004

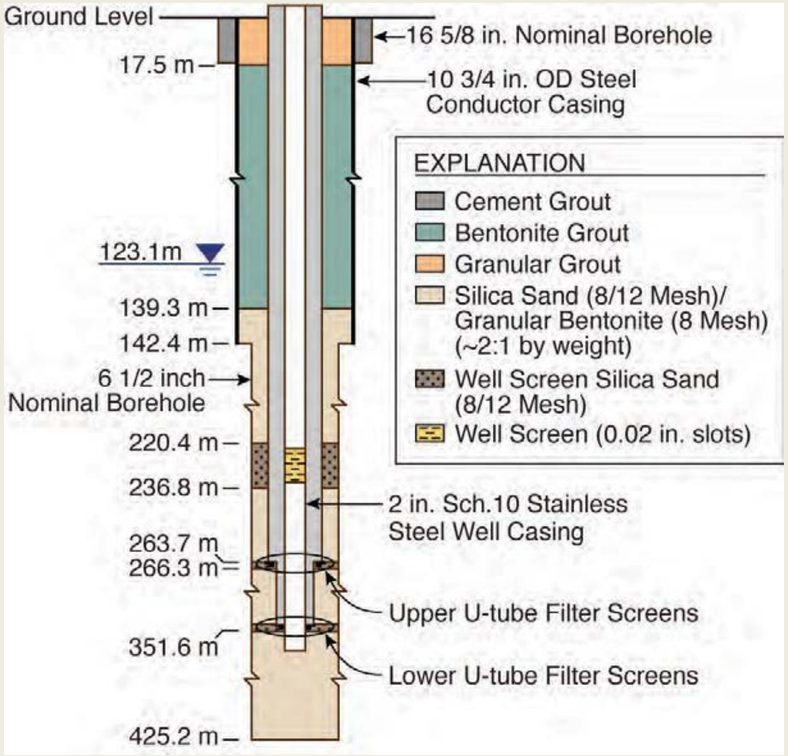


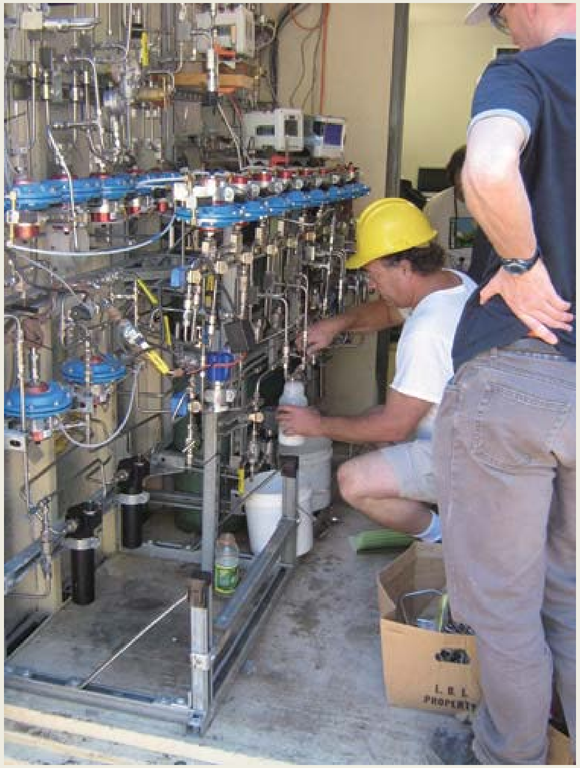
Cranfield 2010



U-Tube In Situ Sampling of CO_2 Plume

- Handling of multiphase fluid collected at high frequency





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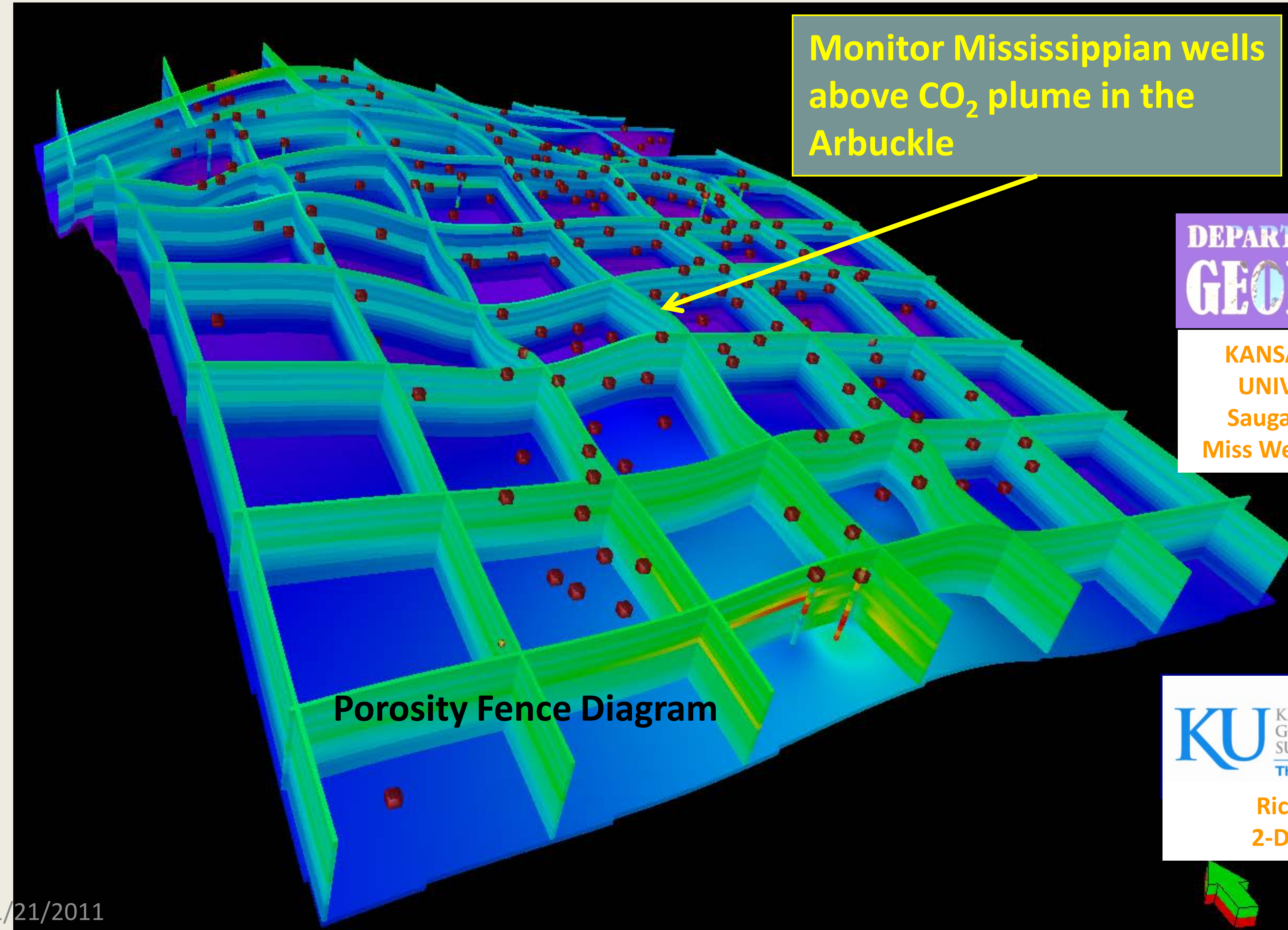
Mississippian Reservoir Will Serve as Ideal Trap for Leaking CO_2

-- is underpressured (900 psi, 0.25 psi/ft) and blanket-like in distribution

-- will act as to capture leaking CO_2 that might be lost from plume

-- if detect CO_2, run high resolution 2D seismic to characterize leakage



DEPARTMENT OF GEOLOGY

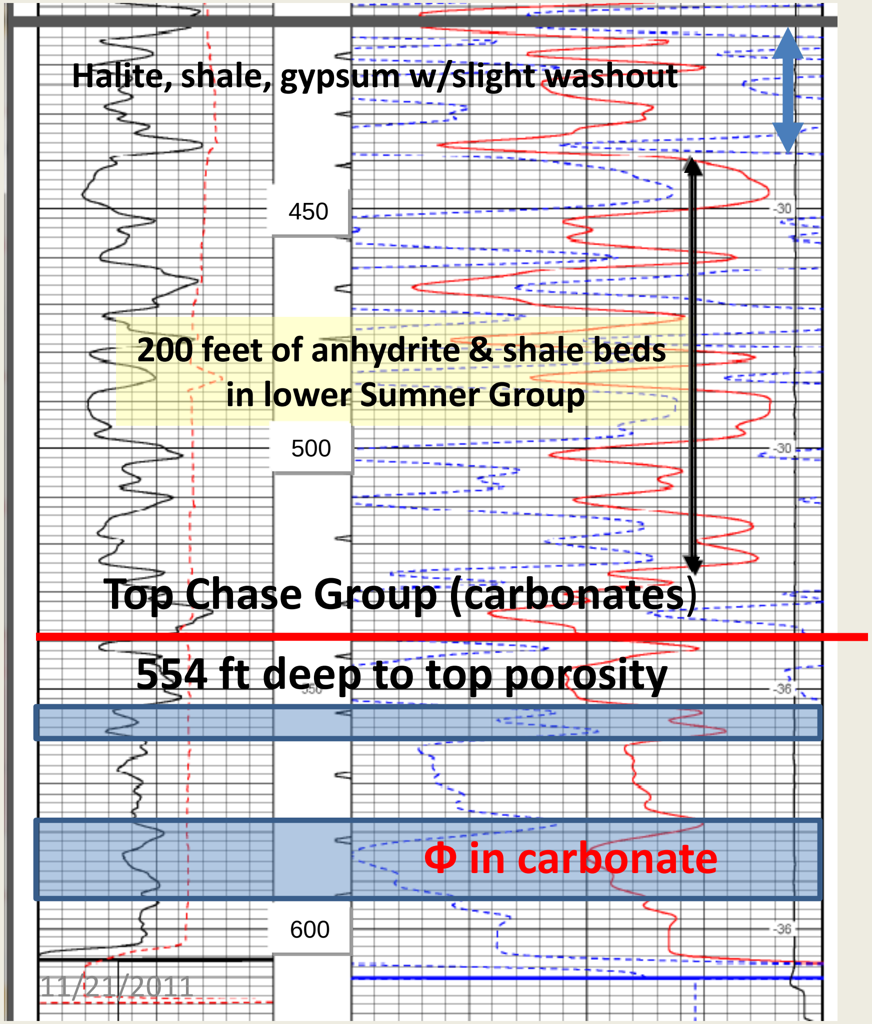
KANSAS STATE UNIVERSITY
Saugata Datta
Miss Well Monitor

KU KANSAS GEOLOGICAL SURVEY
The University of Kansas
Rick Miller
2-D Seismic

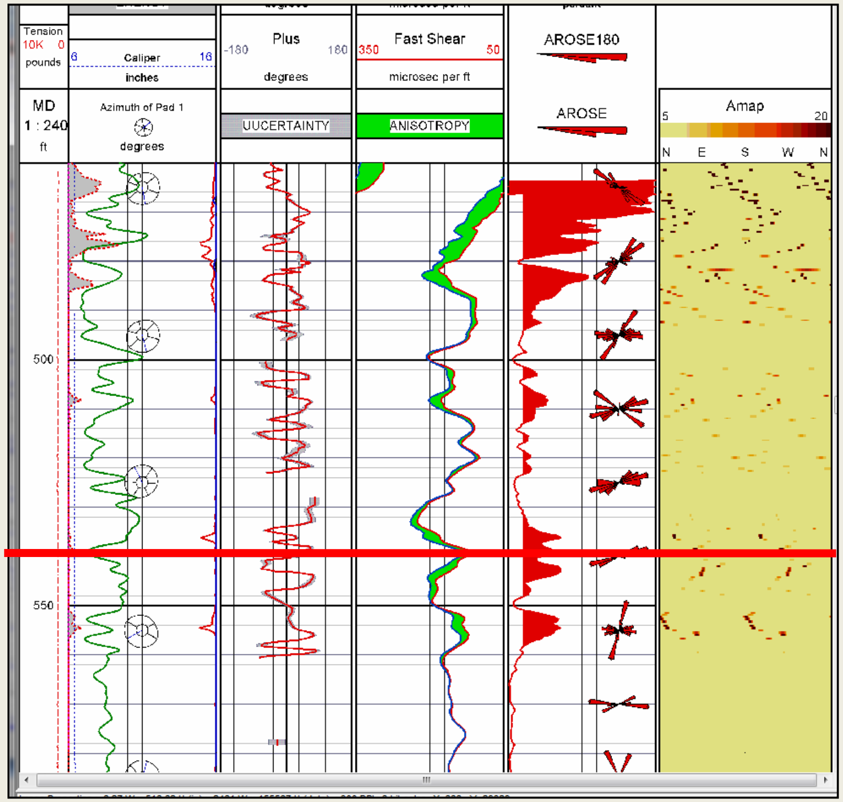
Shallow Evaporite Beds as Logged in KGS #1-32

→ Effectively isolates shallow freshwater aquifers from more deeply buried brine aquifer system

GR (black, solid) and caliper (dashed red)
sonic Δt (red solid), phi (blue dashed)



Full-waveform sonic



Soil Gas Sampling

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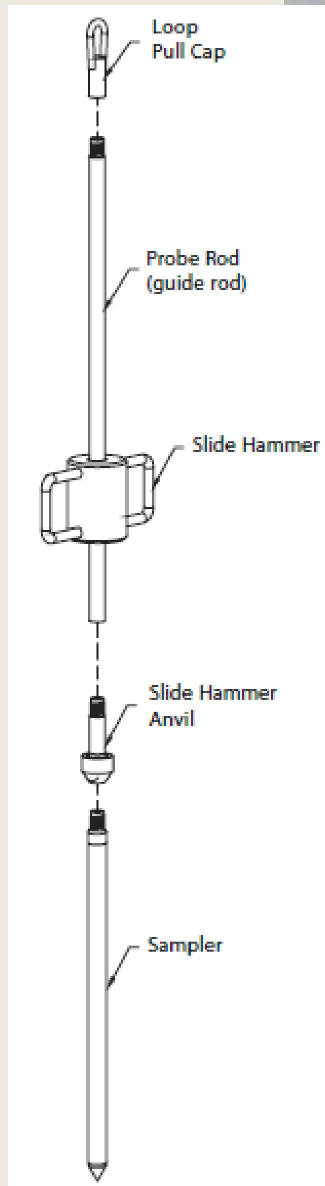
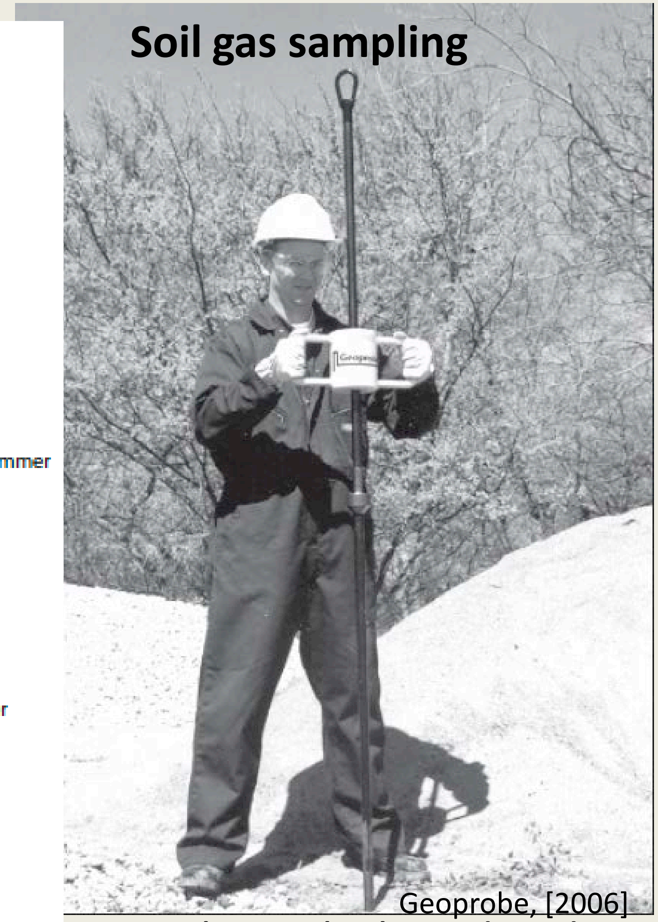
-Open-bottomed chamber placed on soil surface; gas continuously circulated through chamber and infrared gas analyzer (backpack).
-Rate of change of CO_2 concentration in chamber measured. Proportional to soil flux (g CO_2 m^{-2} d^{-1}).
-- Jennifer Lewicki





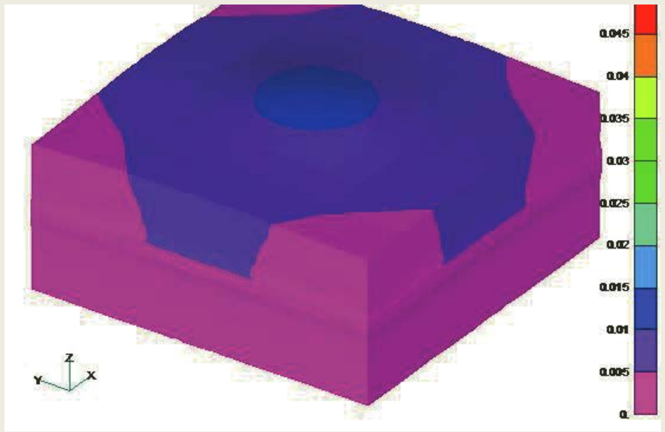
Geoprobe, [2006]

-Probe with slotted end manually driven into ground and allowed to equilibrate ~ 1 hour – sampled into preevacuated chambers
-Chemistry of interest (**bulk gas composition, stable isotopes)**

LiDAR and InSAR to Detect Any Surface Deformation Associated with CO_2 injection

Mike Taylor, University of Kansas

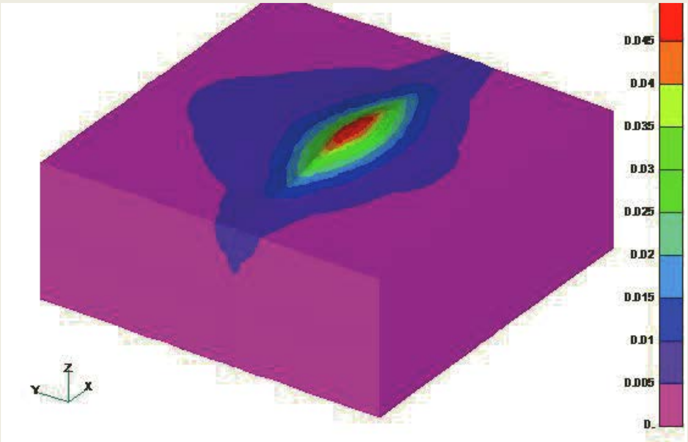
- •C-GPS
- •IRIS seismometer
- •Terra sar x (radar data)
- •LiDAR



Simulated vertical displacement (in meter) after 3 years of CO2 injection (top) without and (below) with a permeable fault intersecting the caprock.

- **Injection depth =6000 ft**
- **Injection interval = 60 ft thick**
- **Max pressure ~10 Pa above ambient**
- **Injection rate = 1 MM tons per year**
- **Observed surface displacement = 10 mm**

Modeling Ground Deformation at In Salah



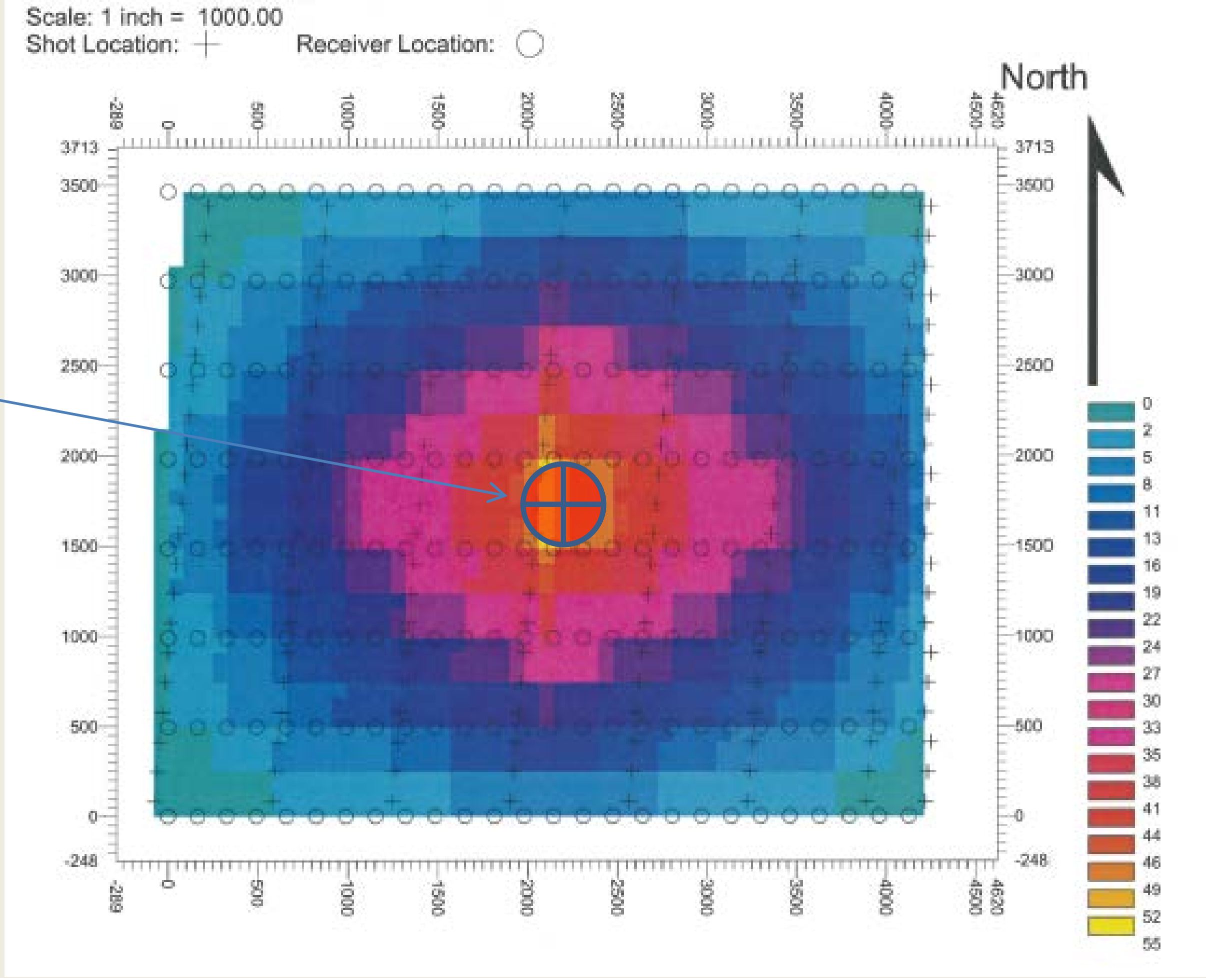
Coupled reservoir-geomechanical analysis of CO2 injection at In Salah, Algeria (CO_2 sequestration Project)

Rutqvista, Vascoa, Myera (2009)

THE UNIVERSITY OF KANSAS
Department of Geology

Repeat 3D seismic survey above Arbuckle injection well at closure of project

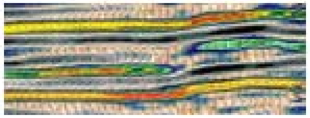
Injection Well



Seismic Fold

HEDKE-SAENGER GEOSCIENCE, LTD

HEDKE-SAENGER GEOSCIENCE, LTD

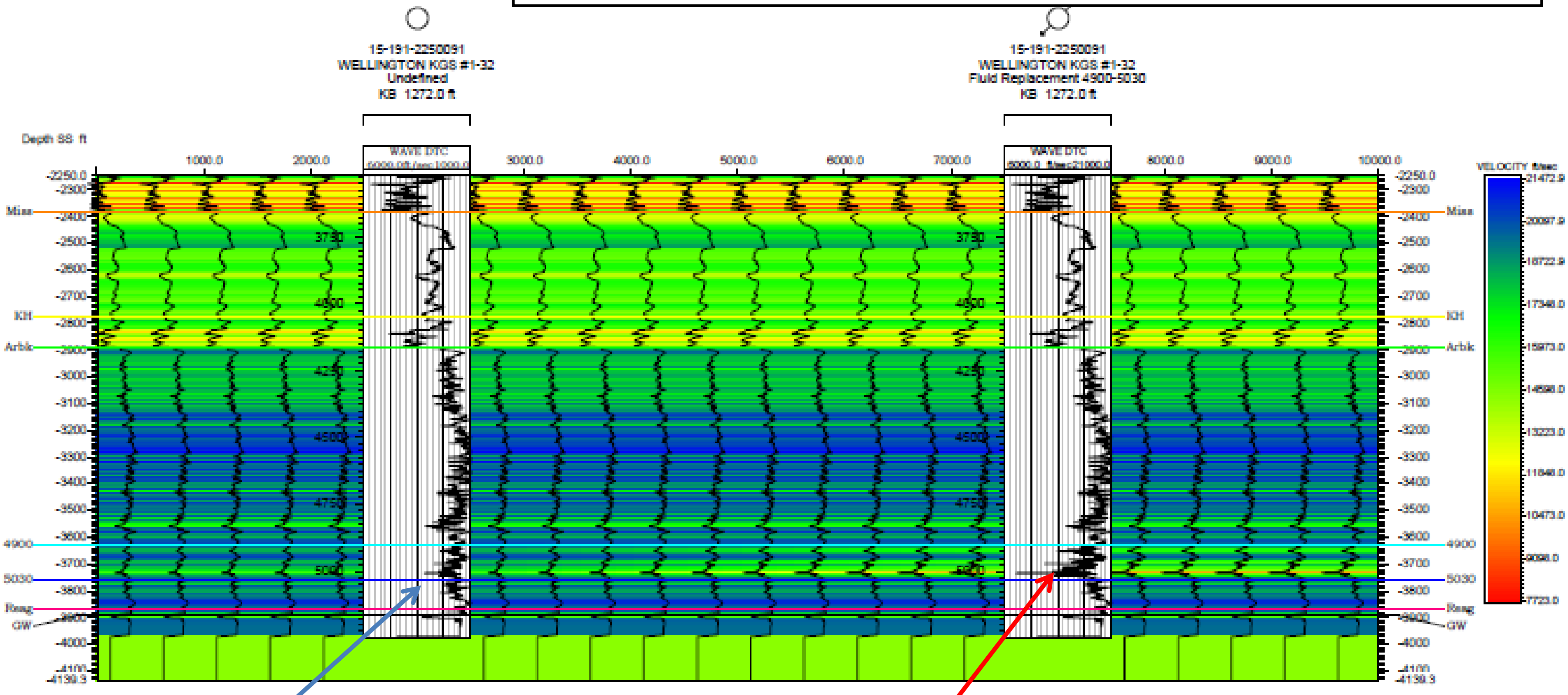


- Can seismic methods detect the CO_2 plume in injection zone in the lower Arbuckle?
  - **Modeled CO_2 plume using Gassmann fluid substitution equation**
  - **Assume 50% water saturation post injection**
  - **Answer is <u>YES</u> prior to having inversion modeling done**

KGS-DOE-BEREXCO CO2 INJECTION MODEL

Trace overlay/color underlay: P Velocity

Scales: Horizontal 1000.0 Vertical 400.0 ft/in



Before injection

GeoSyn 2D 02:31 PM Sun Mar 27, 2011

Post Injection showing detectable gas effect

Summary

KSCO2

- Start Date: October 1, 2011
- Inject Arbuckle: April, 2013
- Inject Mississippian oil reservoir: June, 2014
- End Date: September, 2015
- The Participants: KU/KGS, KSU, LBNL, Sandia Technology, Berexco, LLC, Abengoa Bioenergy, Tiraz Birdie – Consultant, Lawrence, KS
- Mississippian reservoir underpressured, blanket-like, 0.25 psi/ft (900 psi), located above Arbuckle injection to trap leaked CO_2
- Possible use operation of Mississippian field for post-project monitoring (offered by Berexco who operates unitized field)
- Separate, offset pilot CO2 for EOR evaluation in Mississippian reservoir
- Leveraging current research at Wellington Field, site of extensive aquifer, caprock, and oil reservoir characterization that began December 2009.
- Injection & Monitoring, Verification, and Accounting of CO_2 will be evaluated as appropriateness and cost-effectiveness for MVA in Kansas with potential to be utilized by local petroleum industry.

KANSAS GEOLOGICAL SURVEY
The University of Kansas

Acknowledgements & Disclaimer

Acknowledgements

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