GC44A-02. Modeling CO_2 Sequestration in Saline Aquifer and Depleted Oil Reservoirs to Evaluate Regional CO_2 Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas

W. Lynn Watney, Jason Rush, and collaborators

Kansas Geological Survey
1930 Constant Avenue
Lawrence, KS 66047
lwatney@kgs.ku.edu

AGU FALL MEETING 2011
San Francisco, California, USA | 5-9 December

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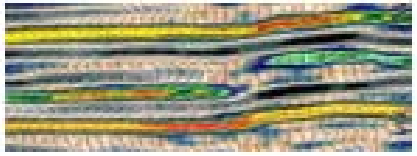

Bittersweet Energy Inc.

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Petrotek

KOGER REMOTE SENSING

LOGDIGI
A LEADING CONSULTING COMPANY

Industry Partners

Southwest Kansas CO_2 Consortium

IHR
Improved Hydrocarbon Recovery LLC

HEDKE-SAENGER GEOSCIENCE, LTD

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+drilling and seismic contractors TBN

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Outline

- Background
- Status of Project
- Overview of Regional Structural and Stratigraphic Analysis
- Focus on Two Wellington Field Activities
  - 1. Drilling/coring and subsequent core and log analysis
  - 2. 3D multicomponent (converted wave) and 2D-9C seismic processing and interpretation → toward refined 3D geomodel and simulation
- Summary

NETL Program Manager: Brian Dressel

Wellington Field Operator

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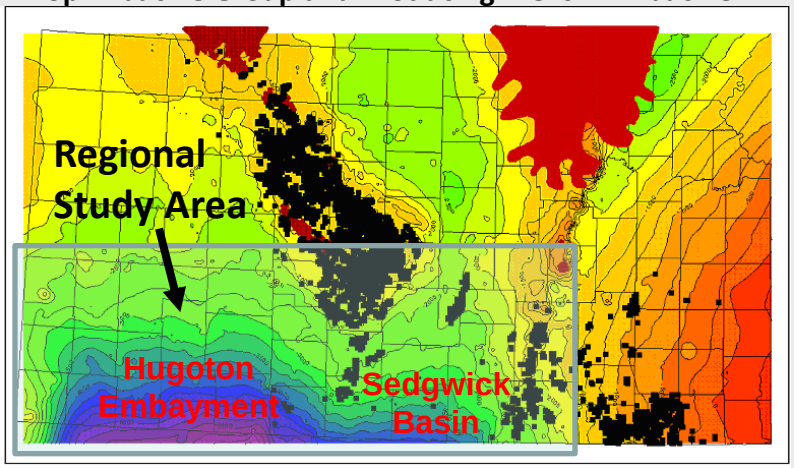
Project Overview

Top Arbuckle Group and Producing Wells in Arbuckle



- Start Date - Dec 2009
- Build static geomodels
  - *<u>Wellington field</u> (Sumner County, KS)*
    - *Depleted Mississippian oil field*
    - *Underlying Arbuckle saline aquifer*

Ozark Plateau Aquifer System

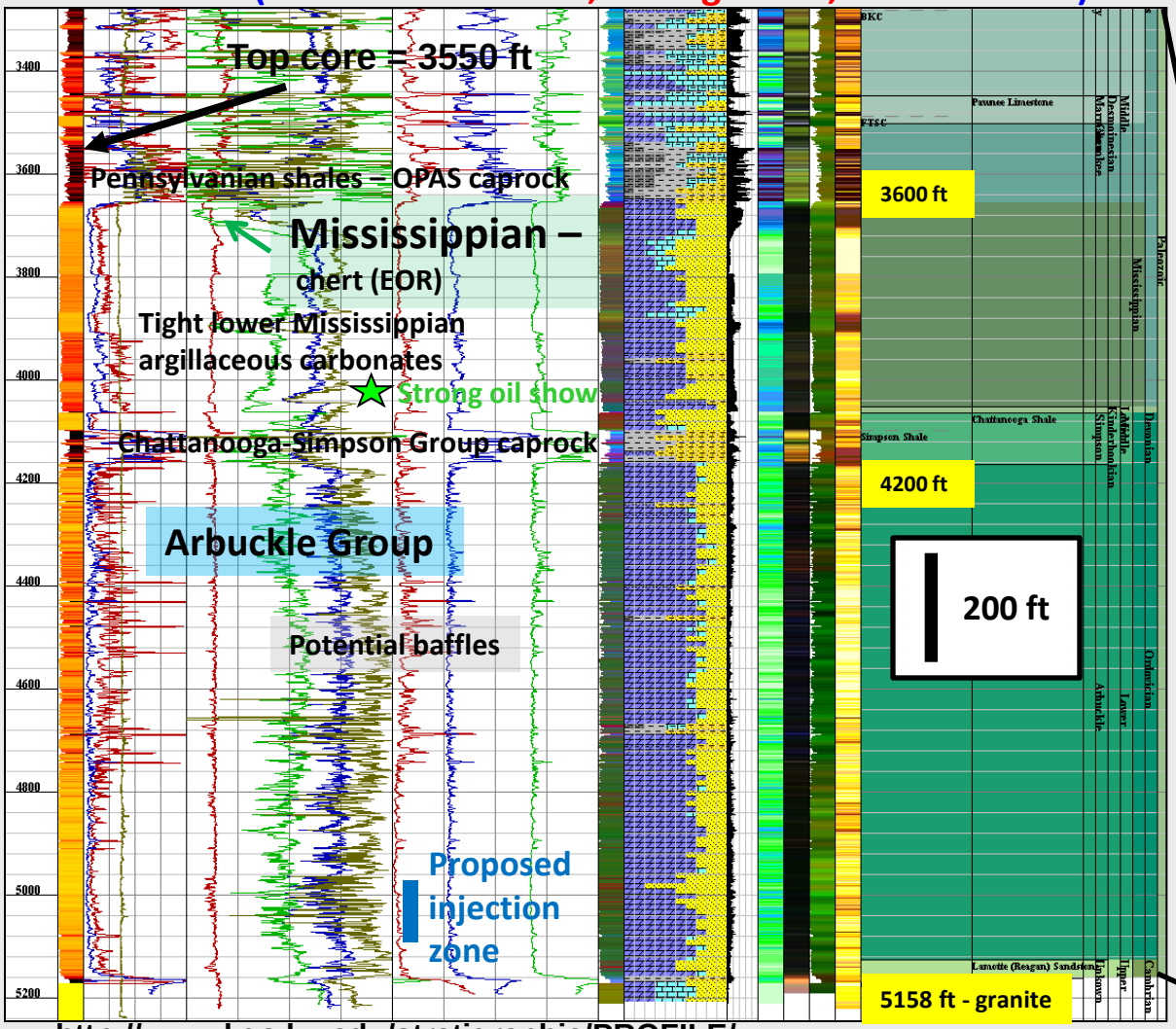
  - *Four Chester/Morrow field in SW KS*
  - *Regional Arbuckle saline aquifer in S. KS*
- Conduct simulation studies to estimate

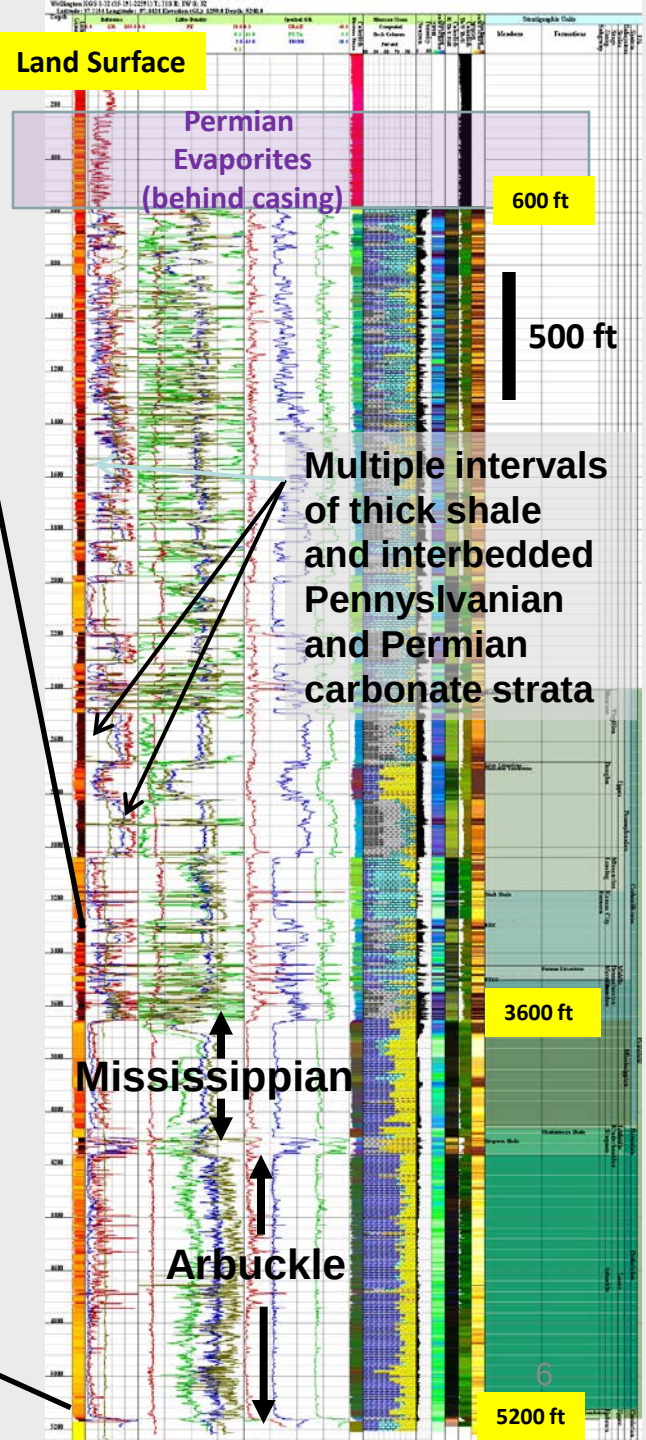
  CO_2 storage capacity of Ozark Plateau Aquifer System (OPAS) Miss
- Arbuckle saline aquifer – 23 county area
  - CO_2 storage efficacy and capacity
  - Identify potential ~8 CO_2 storage sites
- Risk analysis related to CO_2 sequestration
  - Caprock integrity
  - Rock heterogeneity including fault mapping
  - Assess abandoned wells
- Technology transfer

DOE-FE0002056

Stratigraphic Column New Basement Test
Berexco Wellington KGS #1-32

Completed at Wellington Field
February 2011
Conventional 4.5 inch core from base Pennsylvanian shales to basement (3550-5178 interval, 1628 gross ft, 1528 net feet)

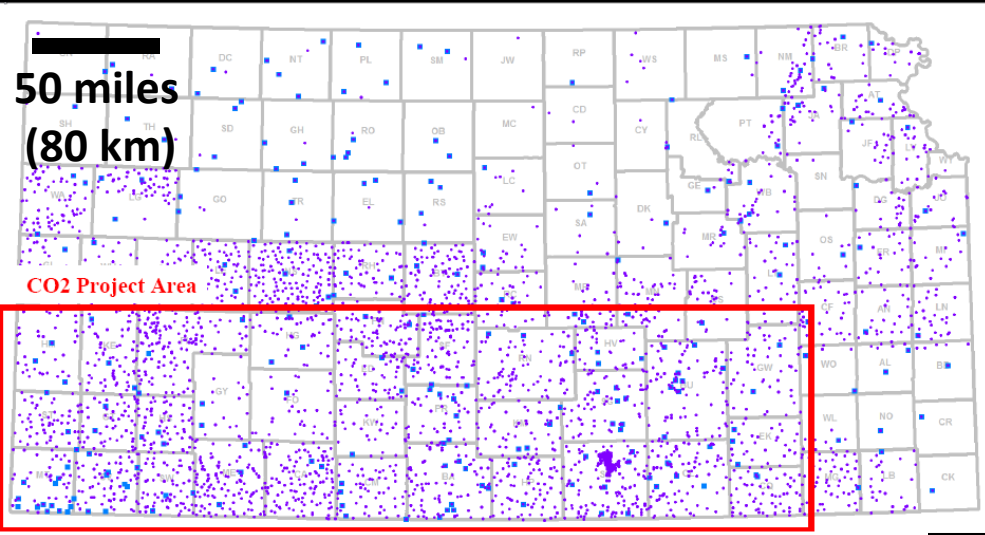




http://www.kgs.ku.edu/stratigraphic/PROFILE/

Well Data Inventory

Wells with LAS or Raster = 3792



Regional Team

Developed regional database

- **Correlated logs and identified Type Wells for digitizing to LAS files**
- **Established that Arbuckle is an open aquifer system, hydraulically connected to outcrops in Missouri (~150 miles to east)**
- **Evaluating faults, fractures, flexures**
- **Establishing additional 8+ sites in region for additional simulation beyond field studies**

Non-Faulted

Structural Closures

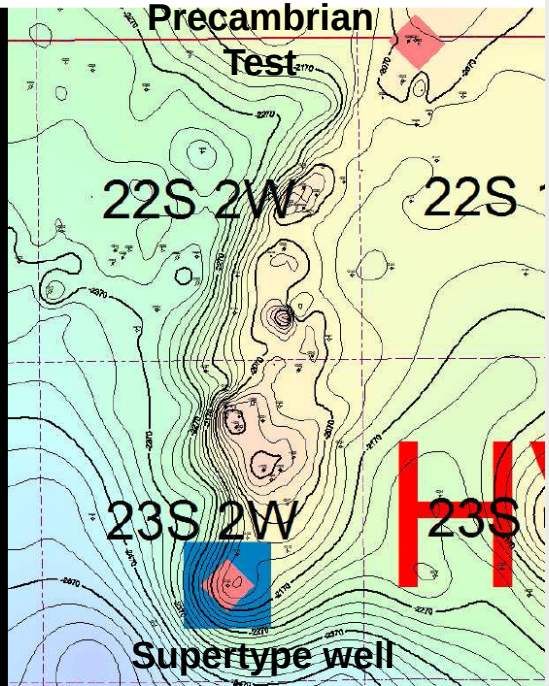
Candidate:

Township

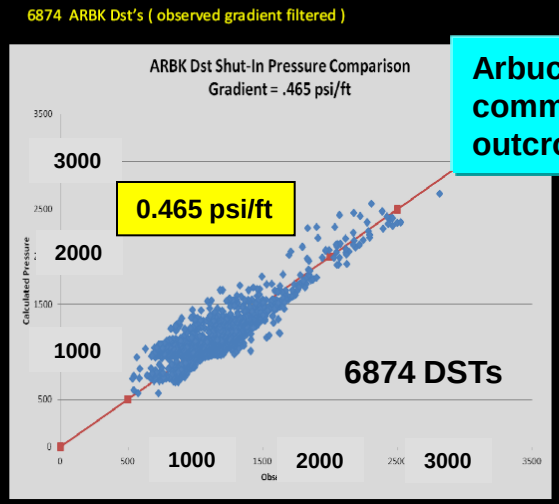
22S-2W

Arbuckle Subsea

C.I. 25 ft



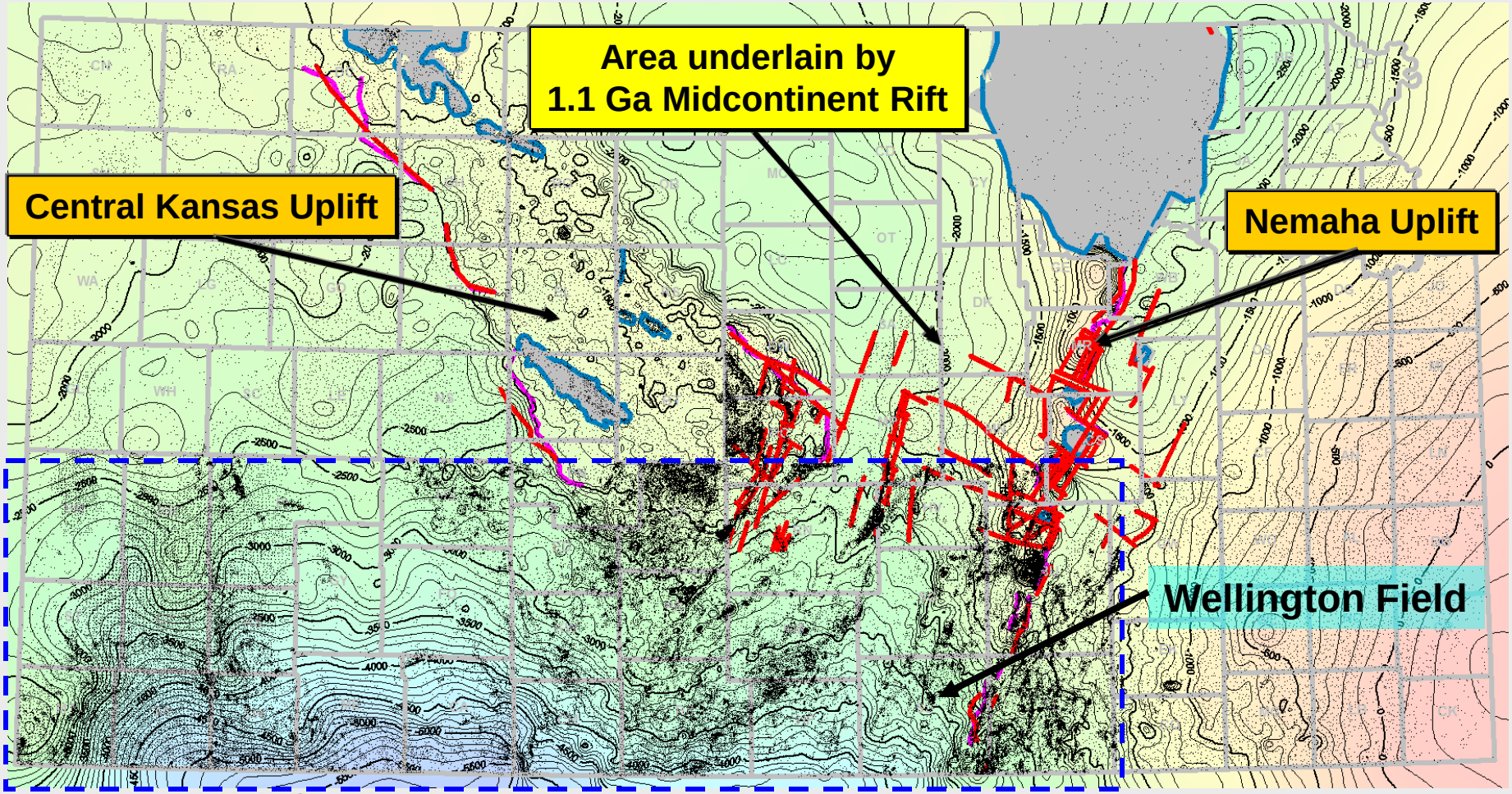
Calculated Pressure vs. Observed Pressure (psi)



Arbuckle aquifer communicating with outcrop in Missouri

Structural mapping and evaluation of faulting

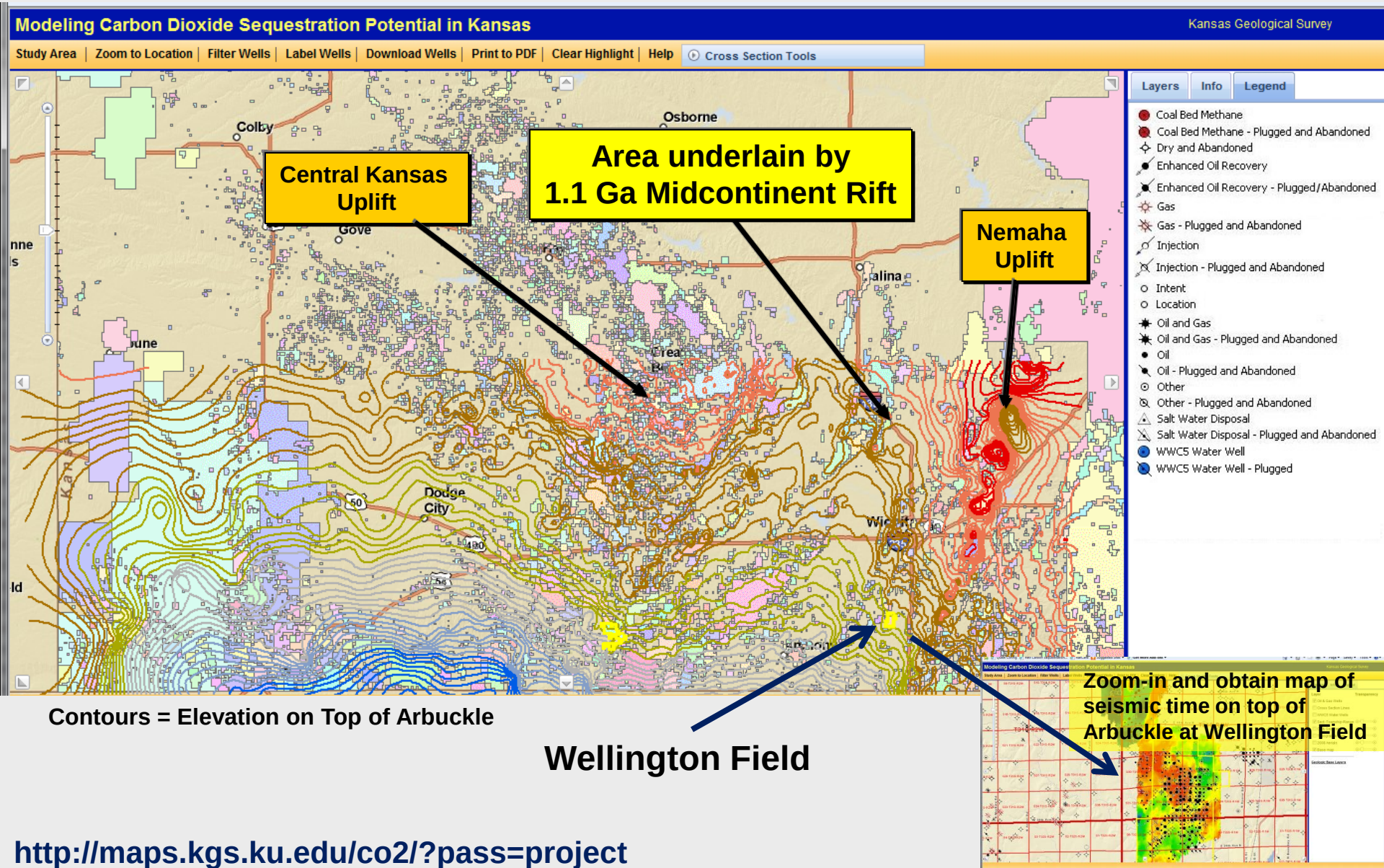
Top Arbuckle Group



- Published faults are being compiled and new ones are under investigation
- Focus on <u>quantitative</u> assessment of CO_2 storage capacity of Arbuckle saline aquifer is within dashed blue area

Web-based Interactive Project Mapper

Overlay of Oil and gas field outlines and Top Arbuckle Group in study area of southern Kansas



Contours = Elevation on Top of Arbuckle

Wellington Field

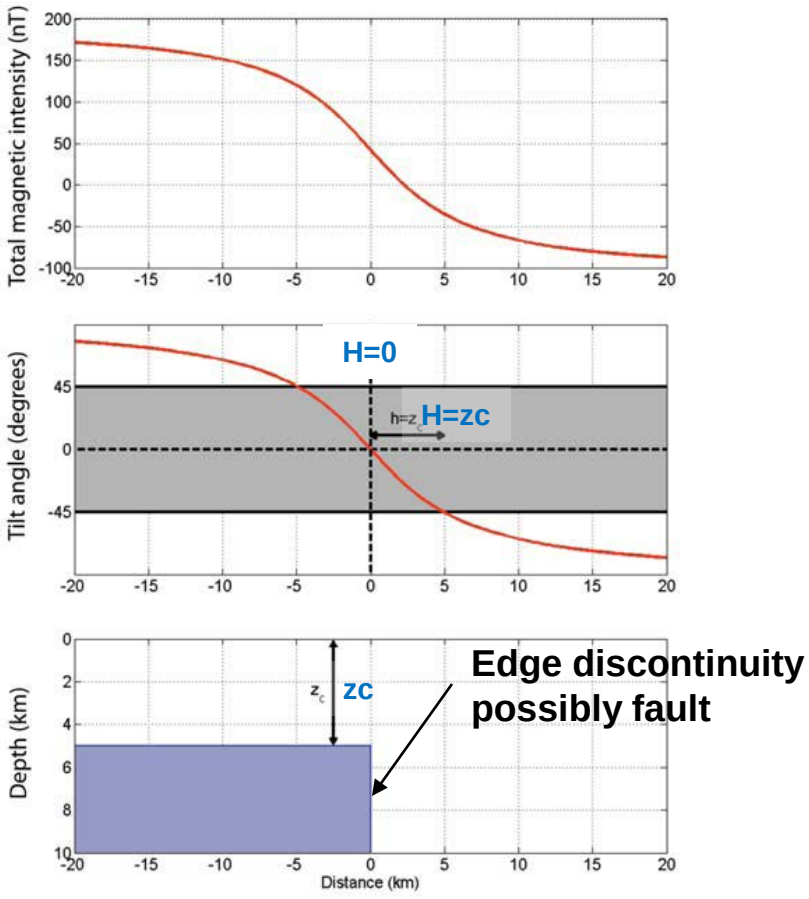
http://maps.kgs.ku.edu/co2/?pass=project

Illustration of tilt angle computation to locate discontinuities and ~depth to gravity and magnetic anomalies as an aid to identifying possible basement faults

(Xia, 2011)

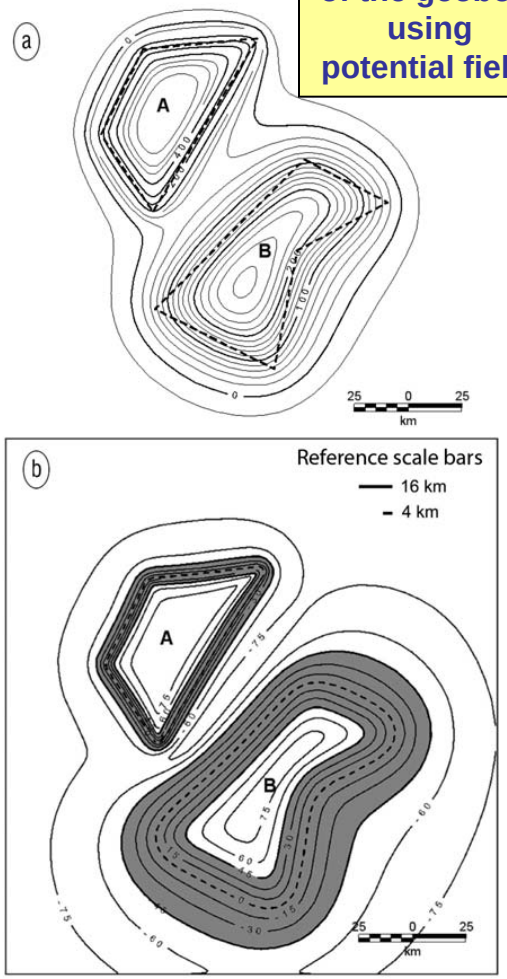
$$\theta = \tan^{-1}\left[\frac{\partial M}{\partial z} \Big/ \frac{\partial M}{\partial h}\right]$$

arctangent of the ratio of the 1st-order vertical derivative by the 1st-order horizontal derivative



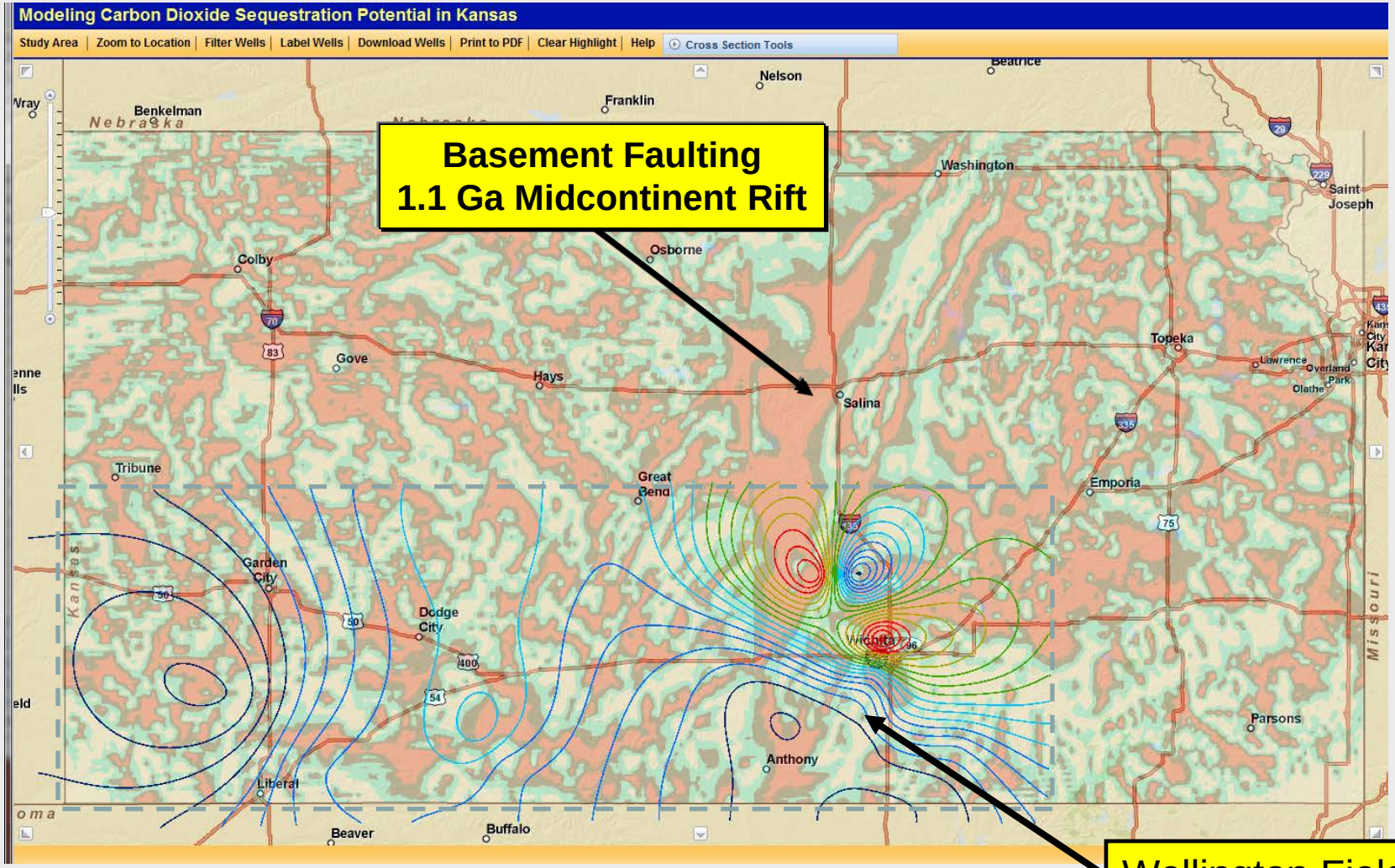
Salem et al., 2007

Expression of the geobody using potential fields



Tilt angle map of the total magnetic field intensity in Kansas

overlain with isopachous contours of Arbuckle Group's Gasconade to Gunter Sandstone interval



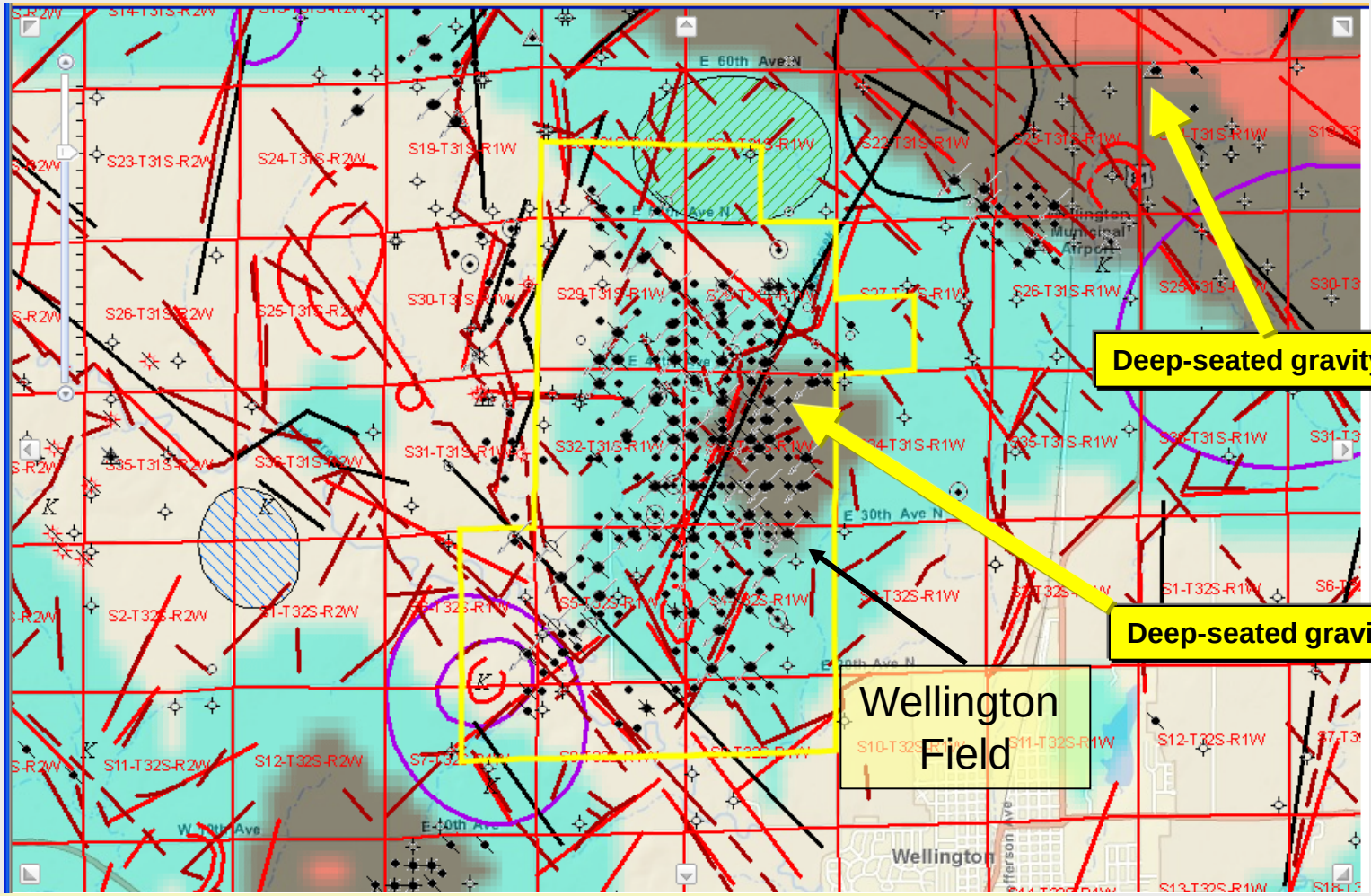
isopach -> Red contour = thin, blue to purple = thick

Snapshot from project's interactive mapper -- http://maps.kgs.ku.edu/co2/?pass=project

Wellington Field Area

Landsat lineaments and gravity tilt angle map

Northeast trending surface lineament bisecting Wellington Field



Interactive project map -http://maps.kgs.ku.edu/co2/?pass=project

6 miles

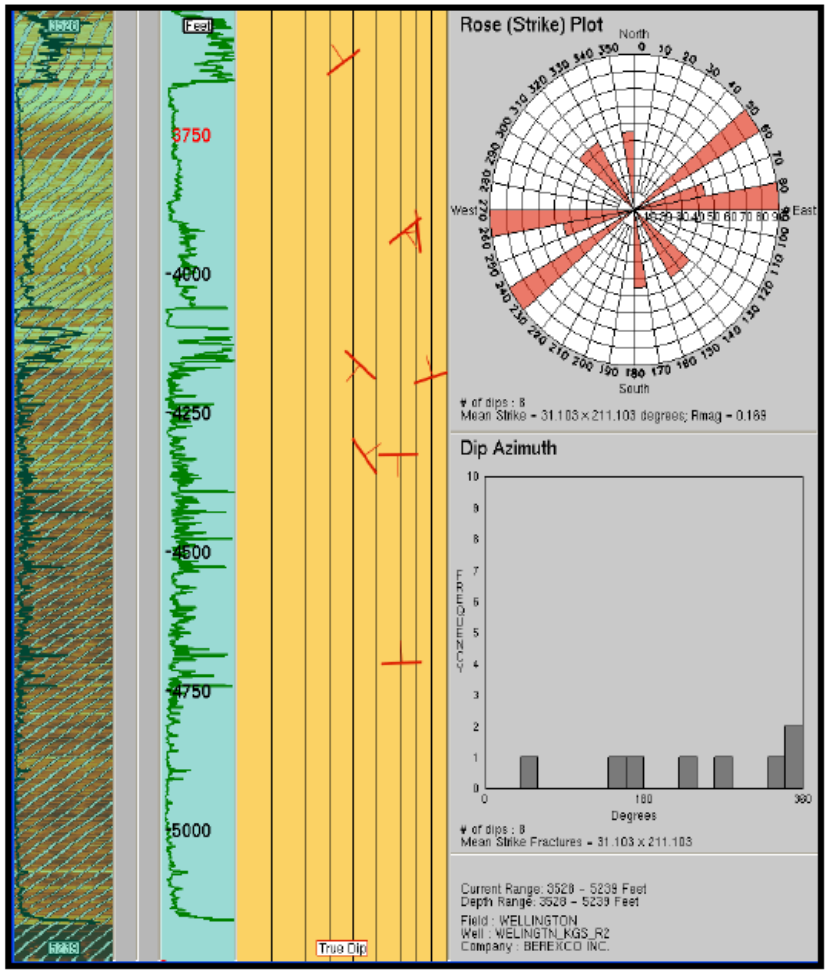
Gravity Tilt Angle = arctangent of the ratio of the 1st-order vertical derivative by the 1st-order horizontal derivative of the Bouguer anomaly.

MAXIMUM HORIZONTAL COMPRESSIVE STRESS (East-Northeast)

from microresistivity imaging and dipole sonic logs (KGS #1-32)

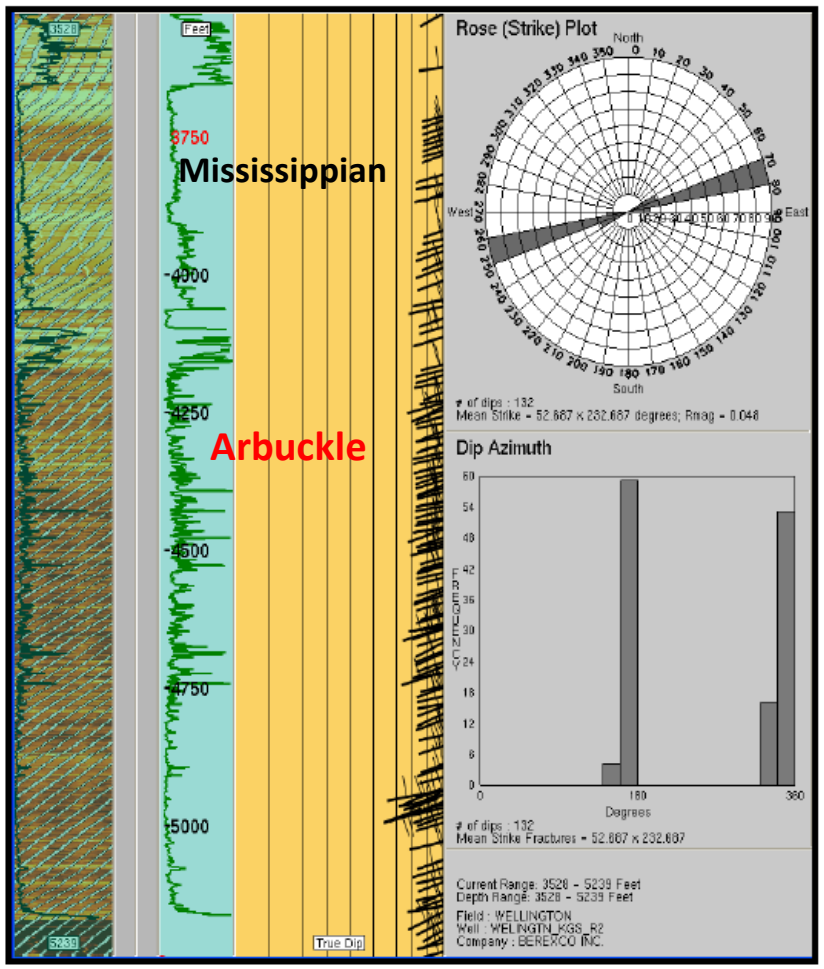
Fracture Statistics: 5239'-3528'

Natural mineralized "closed" fractures



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

Induced fractures



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

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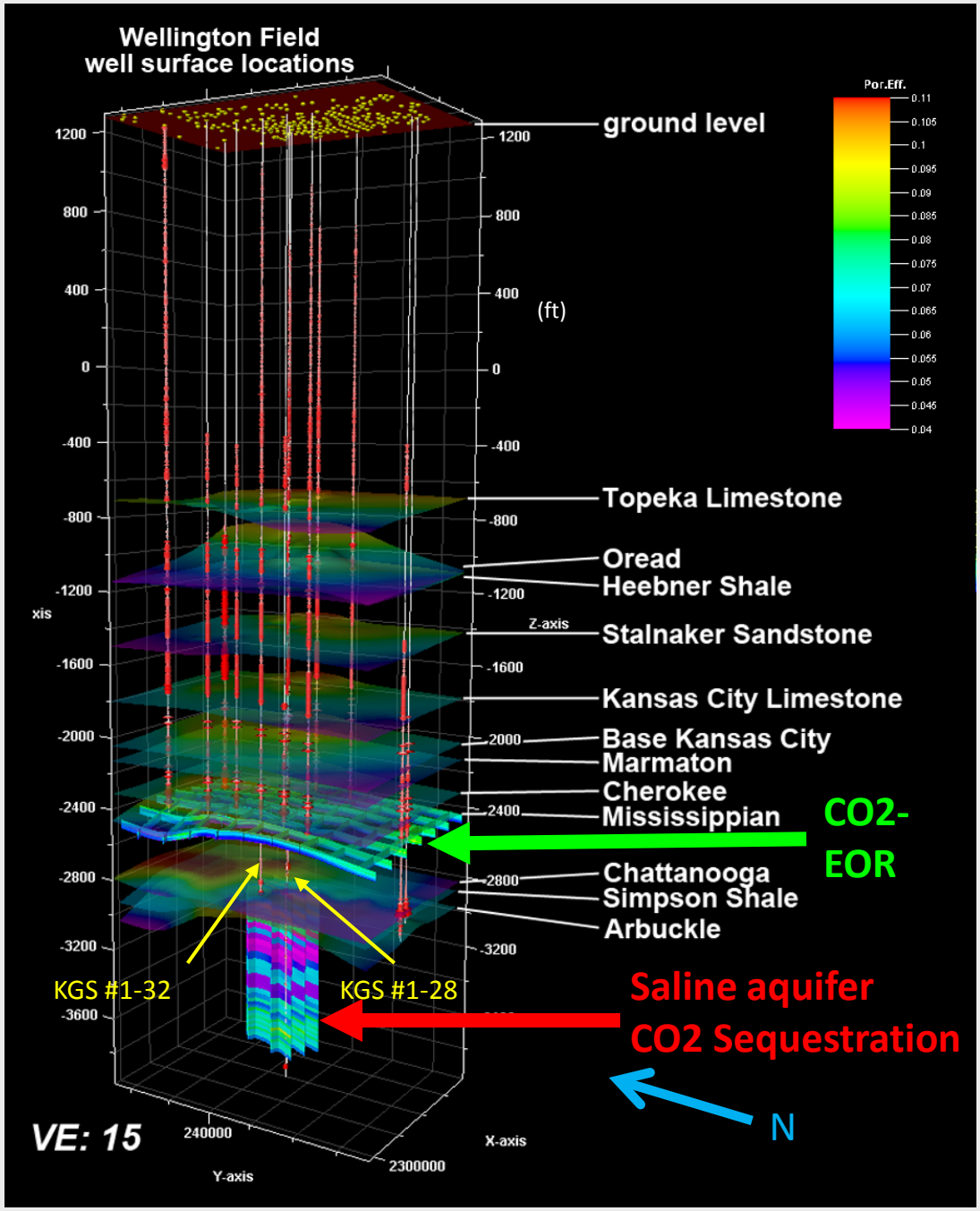


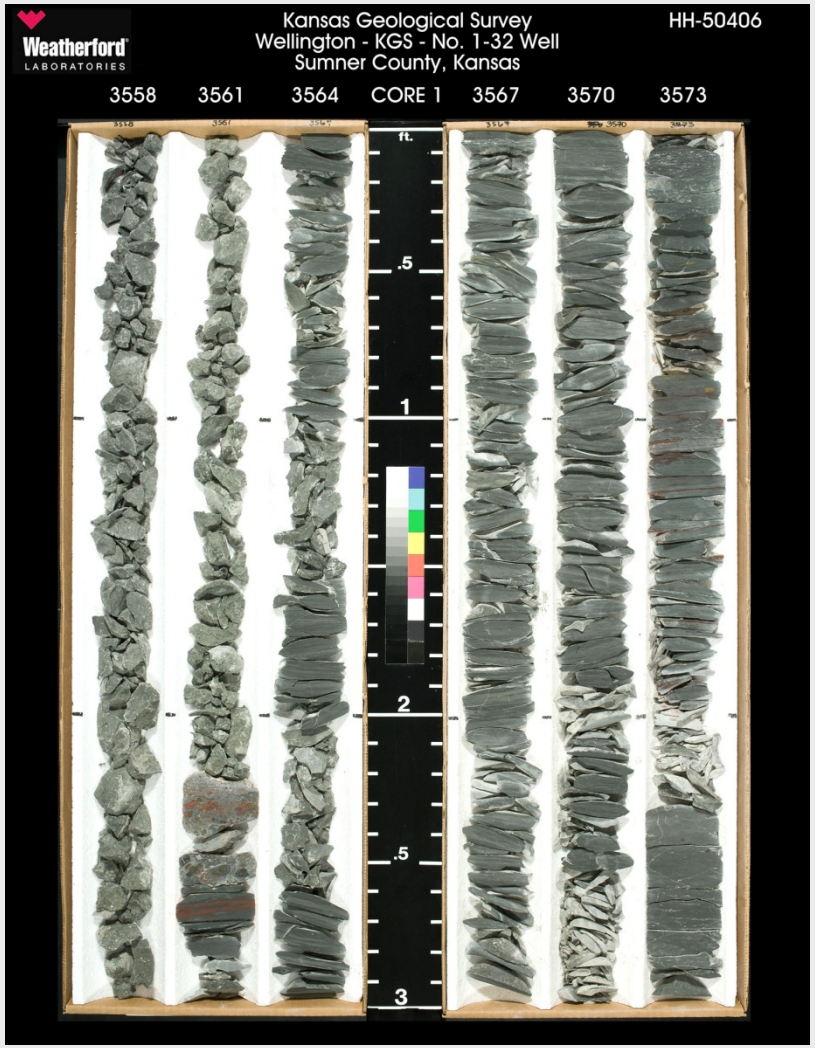
Wellington Field

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

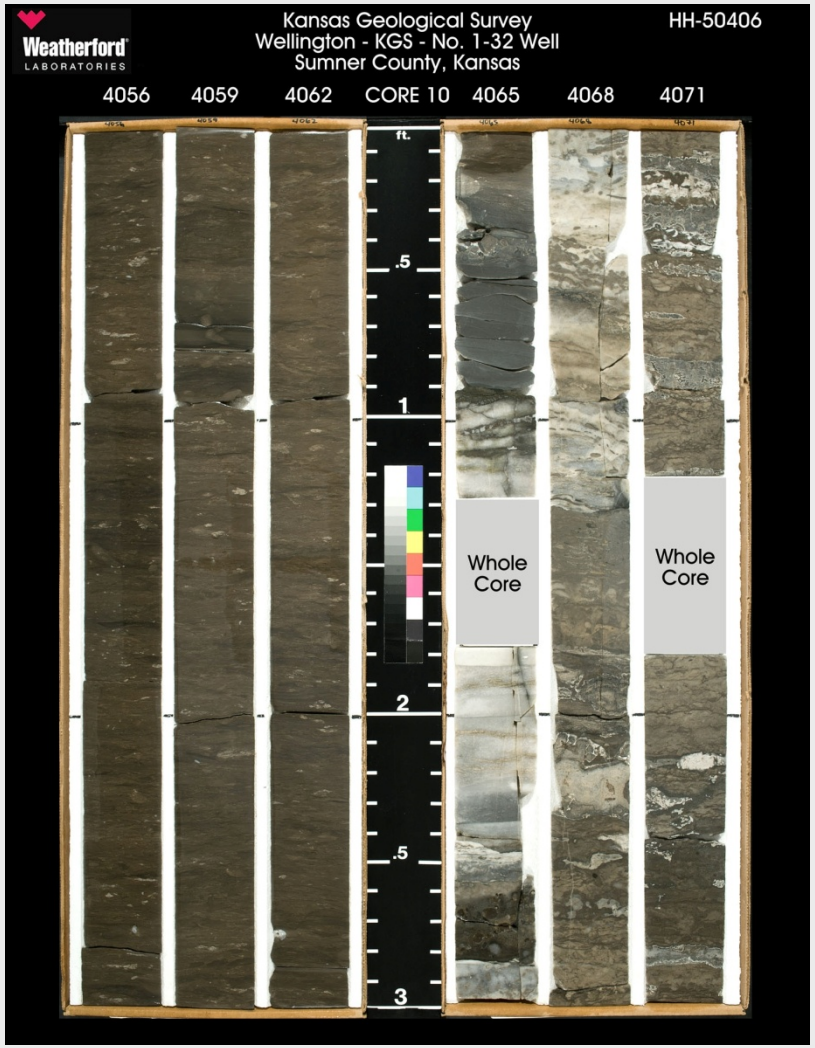
- New core and logs from KGS #1-32 and logs from #1-28 obtained in Jan-Feb. 2011
- Using to assess --
  - Integrity of caprocks
  - Porosity types, injectivity, and storage
  - Model potential for C02-EOR in Mississippian saline aquifer
  - Sequestration in Arbuckle

Caprock and Seals Cored in Berexco Wellington KGS #1-32

Pennsylvanian Cherokee Shale (primary caprock on top of OPAS /Mississippian)



Lower Mississippian-Devonian shale& argillaceous carbonate on shale and sandstone of Upper Ordovician Simpson Group (caprock on top of Arbuckle)



ZONAL FRACTURES AND AUTOCLASTIC BRECCIAS IN THE POROUS INTERVALS OF THE ARBUCKLE

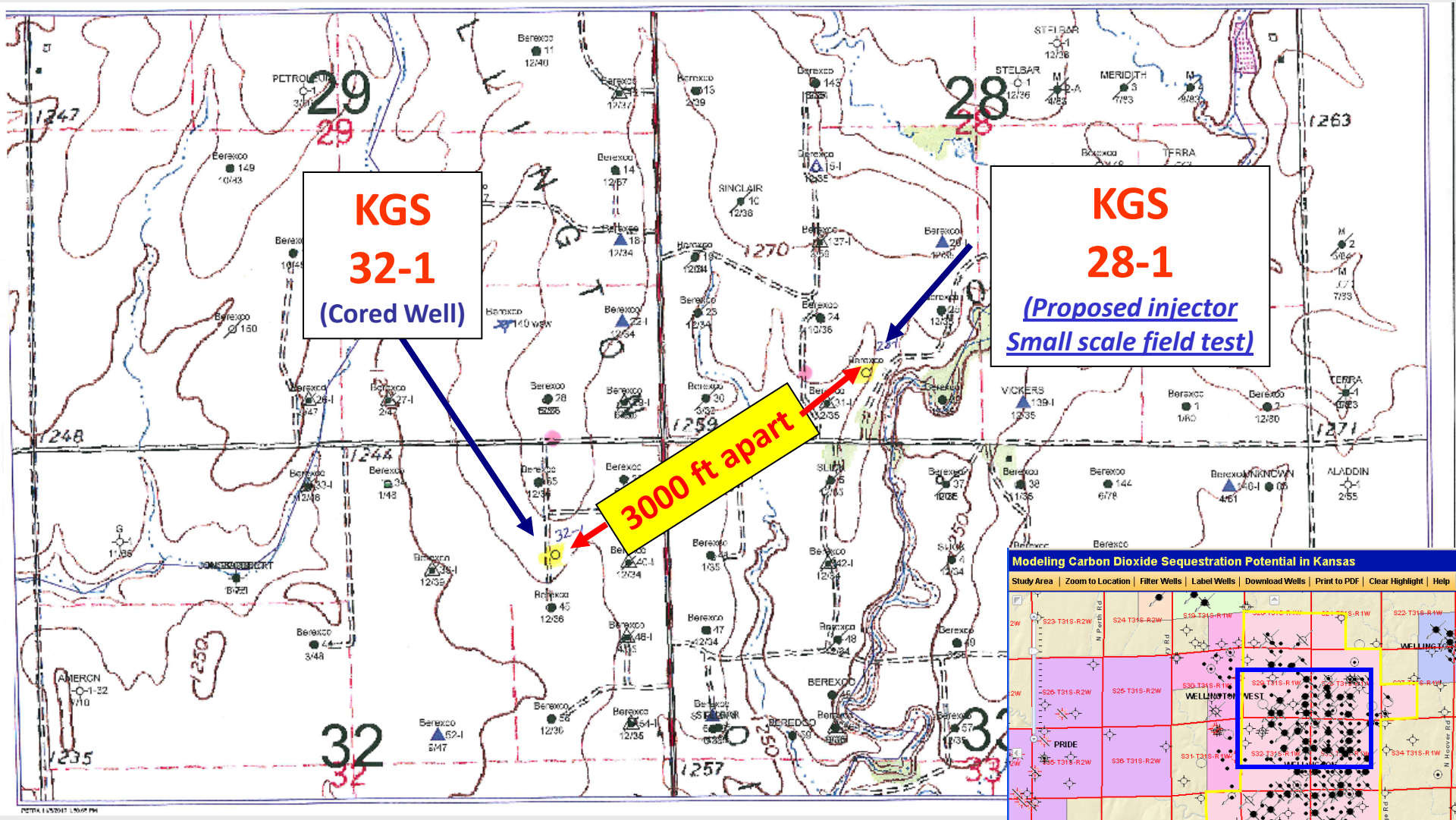
4593 ft

4556.2 ft

4609 ft

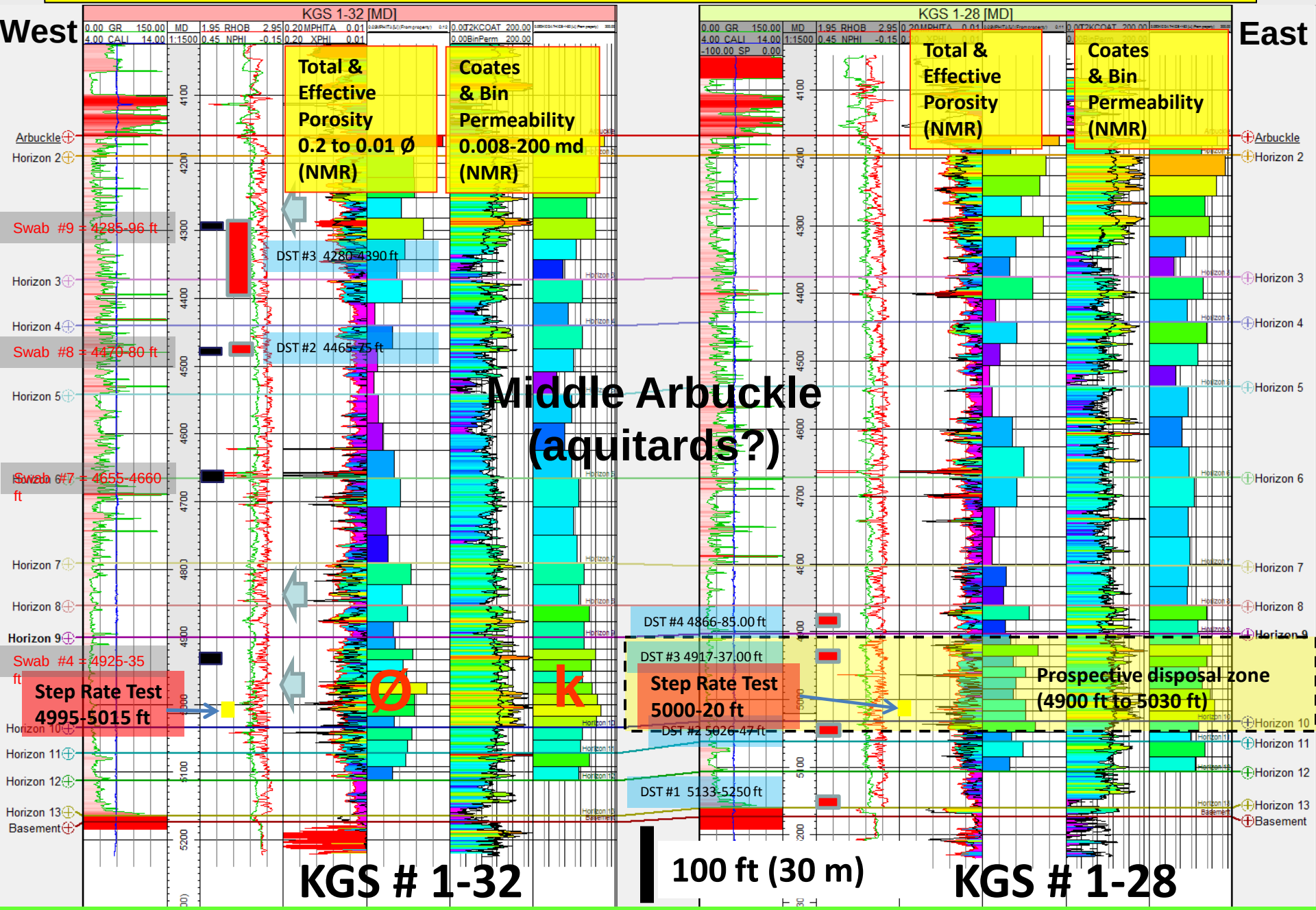
Core from KGS #1-32

Surface location of basement test (#1-32 & 31-28) drilled in Wellington Field during Jan-Feb 2011



Step-rate (pulse test) between wells conducted August 2011

Cross section showing 20 ft interval of step rate test and proposed swab intervals in the Arbuckle



Preliminary upscaled hydrostratigraphic units in Arbuckle Group

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Completing Converted (Shear) Wave Processing and Depth Migration of 3D Seismic

6.5 miles 2D-9C seismic survey obtained in July-August 2011 for calibration of multicomponent 3D seismic

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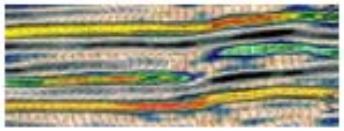
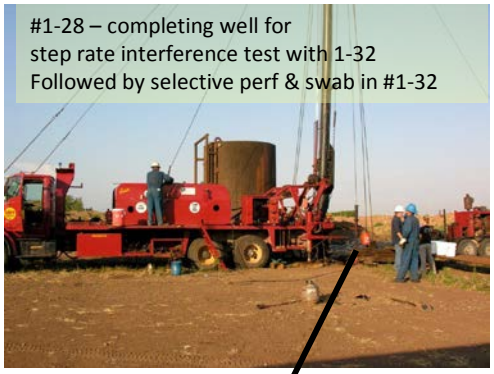


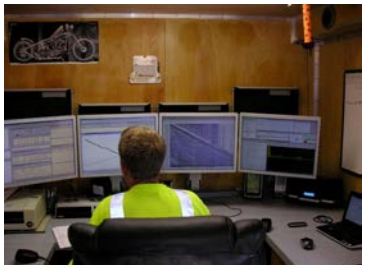
Weekend July 31st @ Wellington

#1-28 – completing well for
step rate interference test with 1-32
Followed by selective perf & swab in #1-32



2D-9C survey
by Paragon

Wireless recording



Aimee Scheffer- Microbial studies of Arbuckle brines

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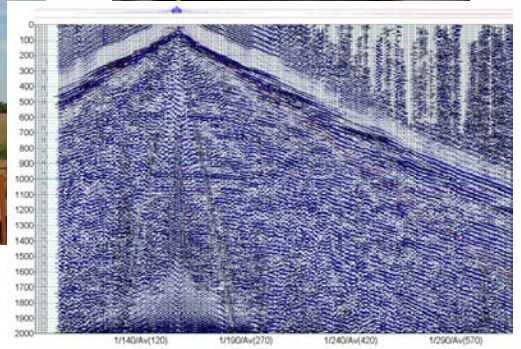

2D Shear Wave Line #1 Index Map, Wellington Field

Prestack Time Migrated (PSTM) –
Top Pennsylvanian Kansas City Group

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Geophysical Contractors

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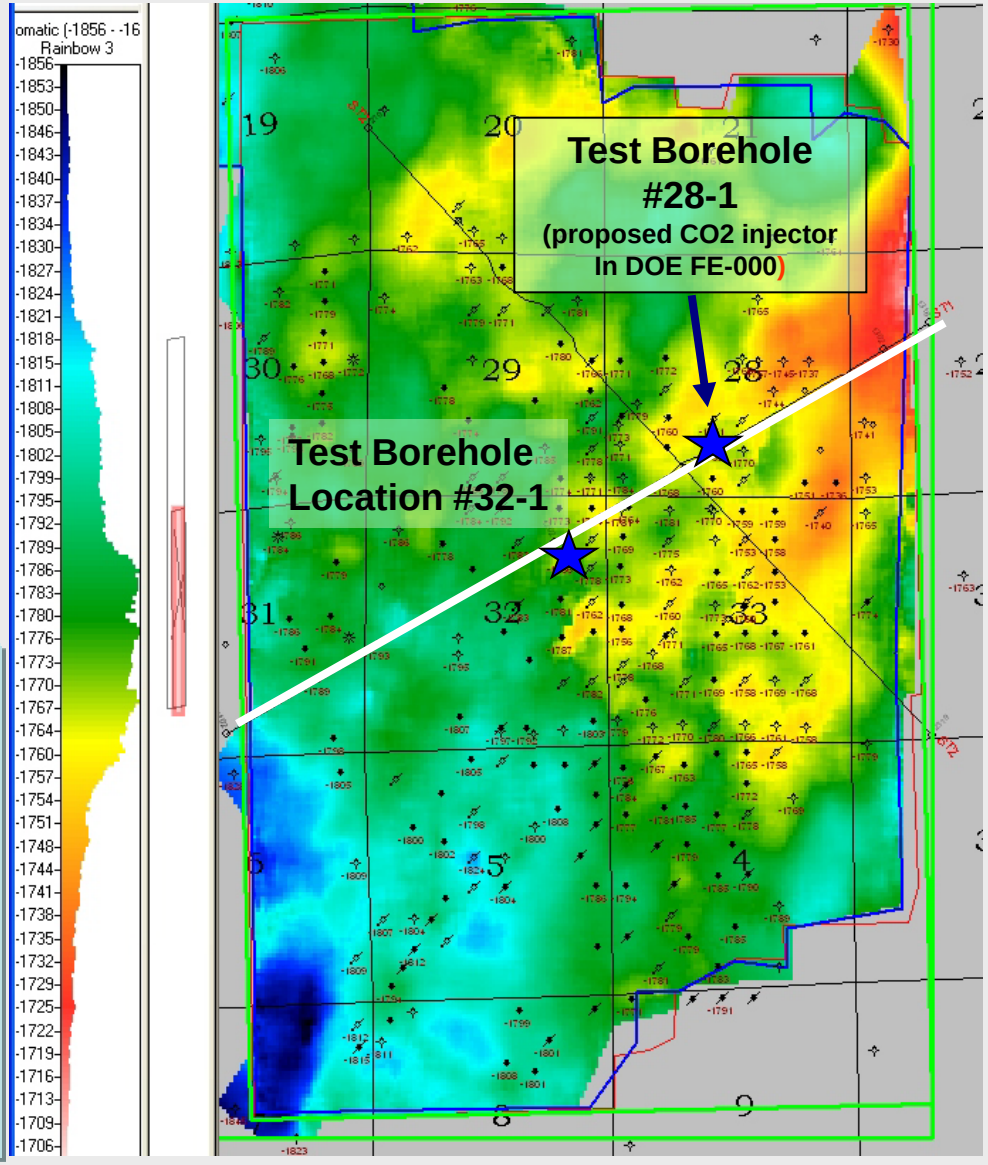

Multicomponent 3D Survey ~12 mi²

Preview of Converted Wave, Prestack Depth Migrated Multicomponent 3D Seismic Volume in Wellington Field

Coincident w/ Shear Wave Line #1

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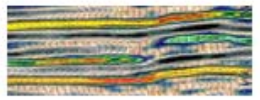

#1-32

#1-28

Howard

Oread

KC

Miss

Arbk

Top Arbuckle Saline Aquifer

(multiple reflectors in layered aquifer with baffles)

Summary

- Original Project Start Date Dec. 8, 2009; End date: August 7, 2013
- $10 million project including $5 million budget enhancement to fund Southwest Kansas CO_2 Sequestration Consortium to anchor western side of regional study area --
  - *Led by additional science team with five industry partners*
  - *120+ mi^2 3D seismic donation*
  - *Reprocess portion of and interpret donated 3D seismic*
  - *Field data on four major Chester/Morrow sandstone oil fields*
  - *Simulate reservoirs to maximize CO_2 storage*
  - *Select field for 10 mi^2 multicomponent 3D seismic and basement test with ~2200 ft core*
- 2D shear wave survey acquired in Wellington Field in August
  - *Use to refine processing and interpretation of existing 12 mi^2 multi-component 3D seismic survey*
- Core Analysis – delivery December 2011
- Geochemistry & Geobiology – ongoing into 2012
- Revise Geomodel & Simulation – early 2012

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New Project

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

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

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Sandia Technologies, LLC

Acknowledgements & Disclaimer

Acknowledgements

- *The work supported by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) under Contracts #DE-FE0002056 and #DE-FE0006821, W.L. Watney and Jason Rush, Joint PIs. Project is managed and administered by the Kansas Geological Survey/KUCR at the University of Kansas and funded by DOE/NETL and cost-sharing partners.*