Geologic Carbon Sequestration -- Characterizing Pore Space & Managing CO_2 Plume

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KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

KANSAS LEGISLATURE

Outline

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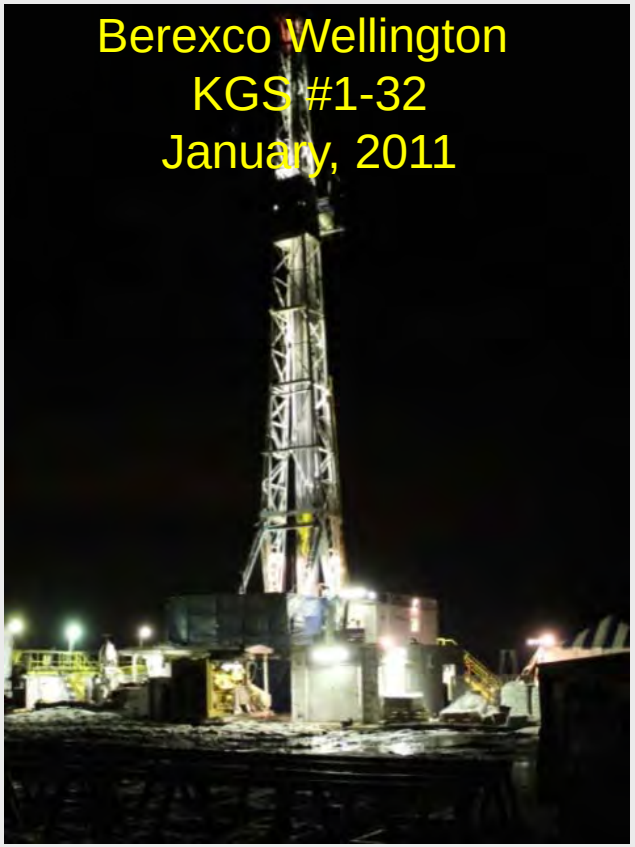
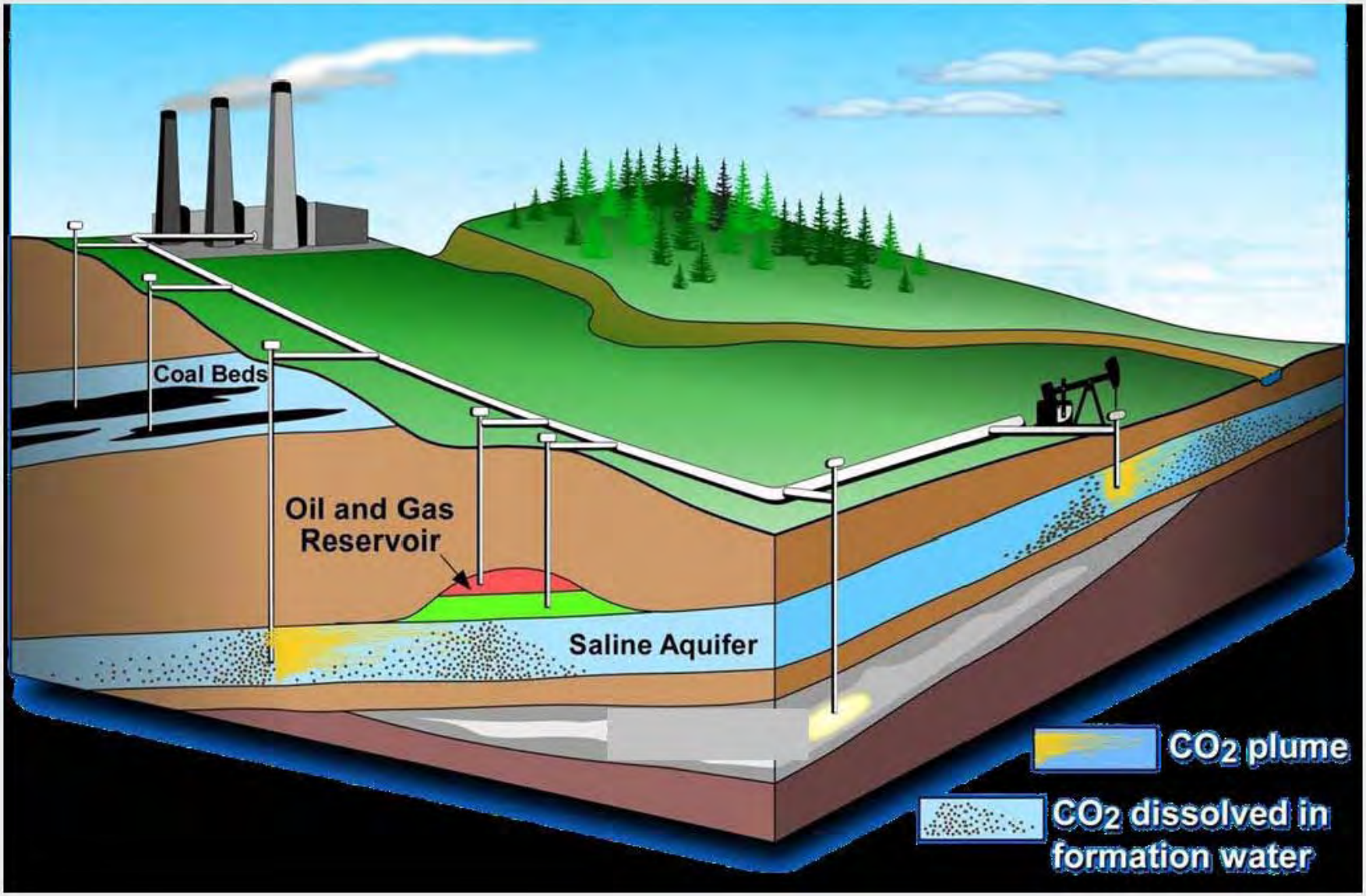
- ***CCUS*** **– Carbon Capture, Utilization, and Sequestration**
- **Processes in carbon dioxide sequestration leading to its entrapment**
- **Characterizing pore space to evaluate CO_2 sequestration in Kansas**



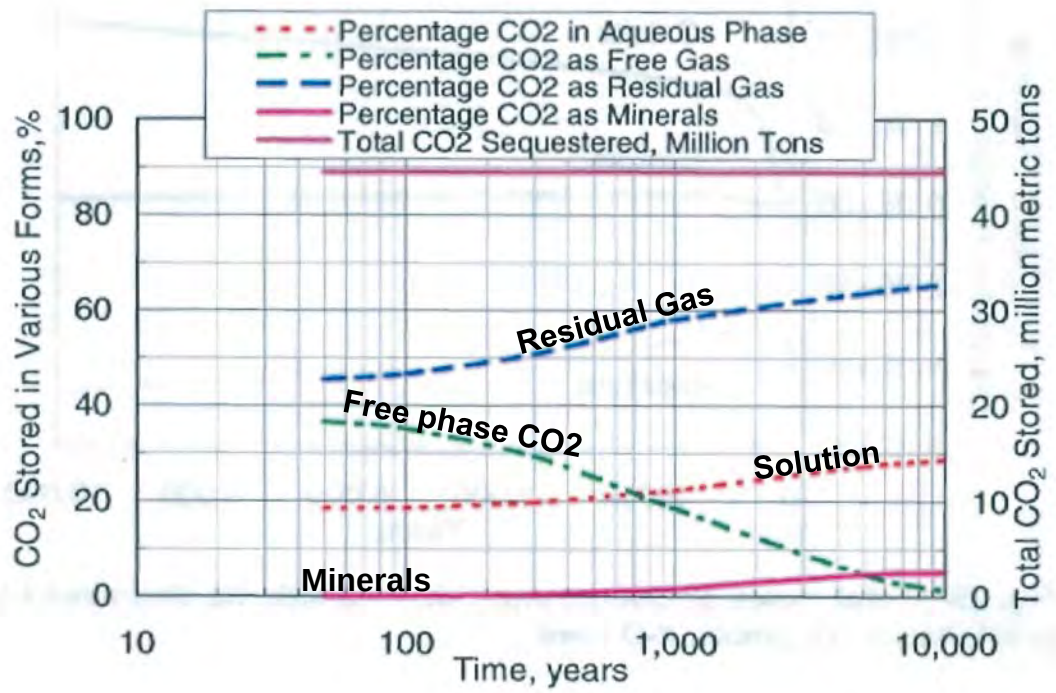
Carbon Capture, Utilization, and Sequestration



Fate and Entrapment of CO_2 in Saline Aquifers

Injected CO_2 entrapped in 4 ways --

- some dissolves in brine
- some gets locked as residual gas (saturation)
- some trapped as minerals
- Remaining CO_2 – resides as free phase
  - Sub- or super-critical as per *in situ* conditions (depth/pressure and temperature)



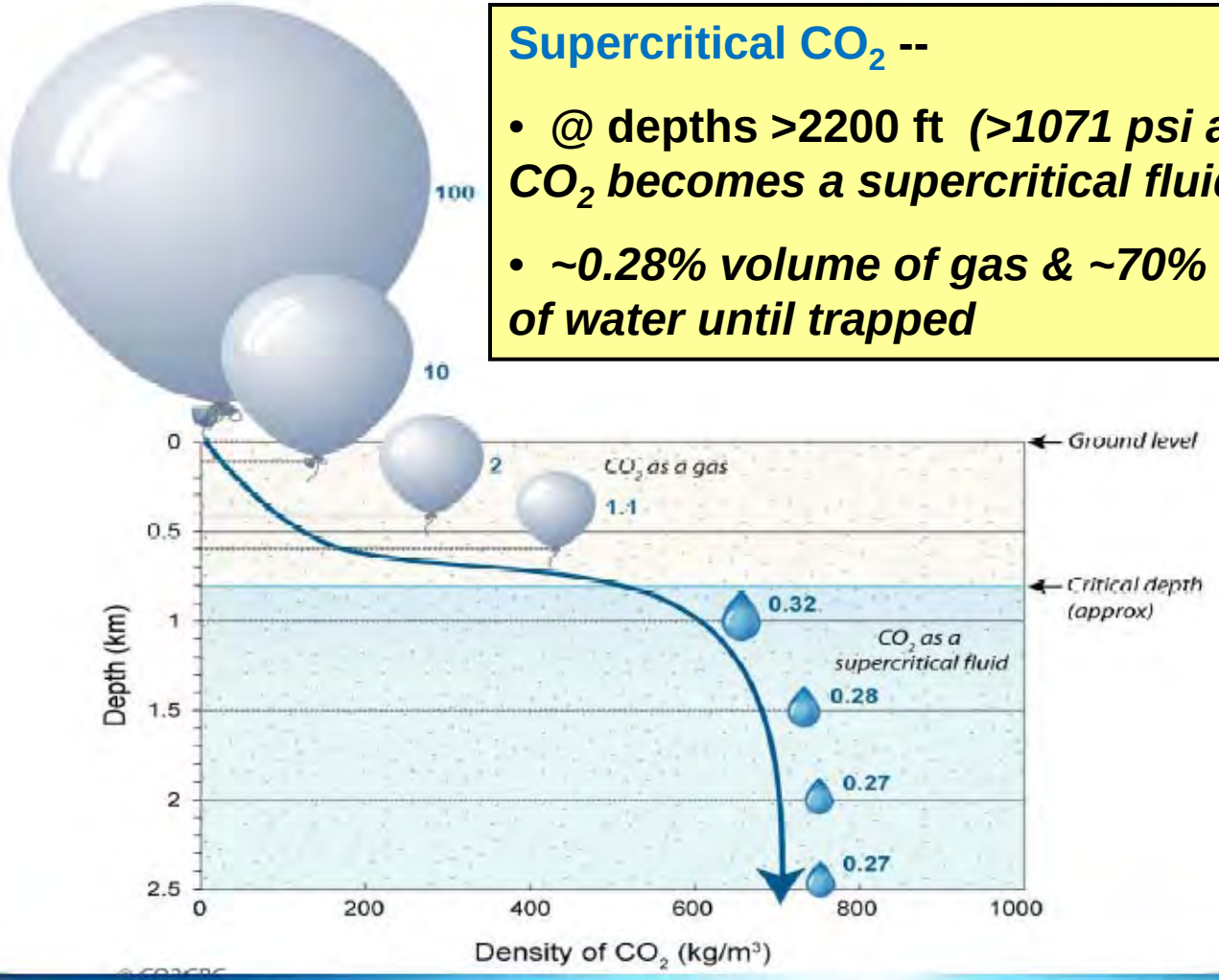
Ozah, 2005 – In situ CO_2 distribution after 50 years of injection

CO_2 Entrapment Audit:

1. ***Residual gas***
   - ***Start 45% to End 65%***
2. ***Solution***
   - ***Start 18% to End 28%***
3. ***Minerals***
   - ***Start negligible to End 5%***
4. ***Free Phase***
   - ***Start 37% to End 2%***

Effectiveness of Injecting Supercritical CO_2

CO2 storage effectiveness increases with depth



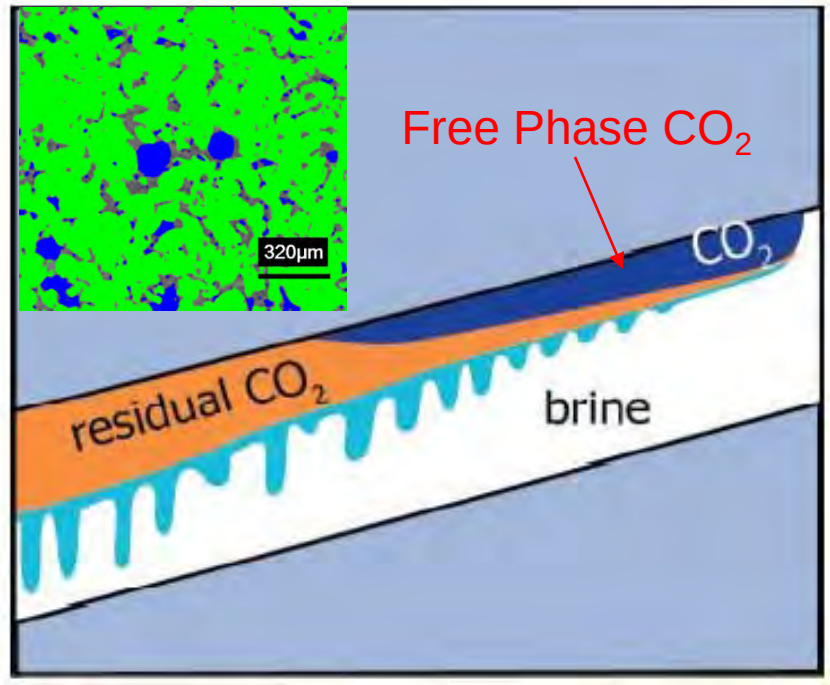
Supercritical CO_2 --

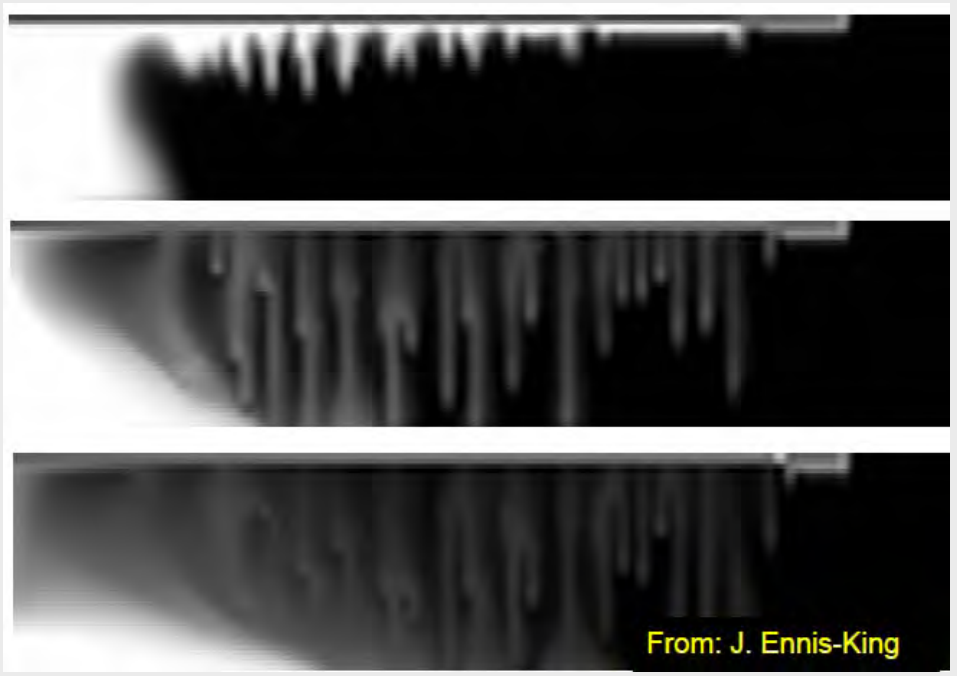
- **@ depths >2200 ft *(>1071 psi and 87.8°F) CO_2 becomes a supercritical fluid***
- ***~0.28% volume of gas & ~70% the density of water until trapped***

CO2CRC

Dissolution of CO_2 in Brine

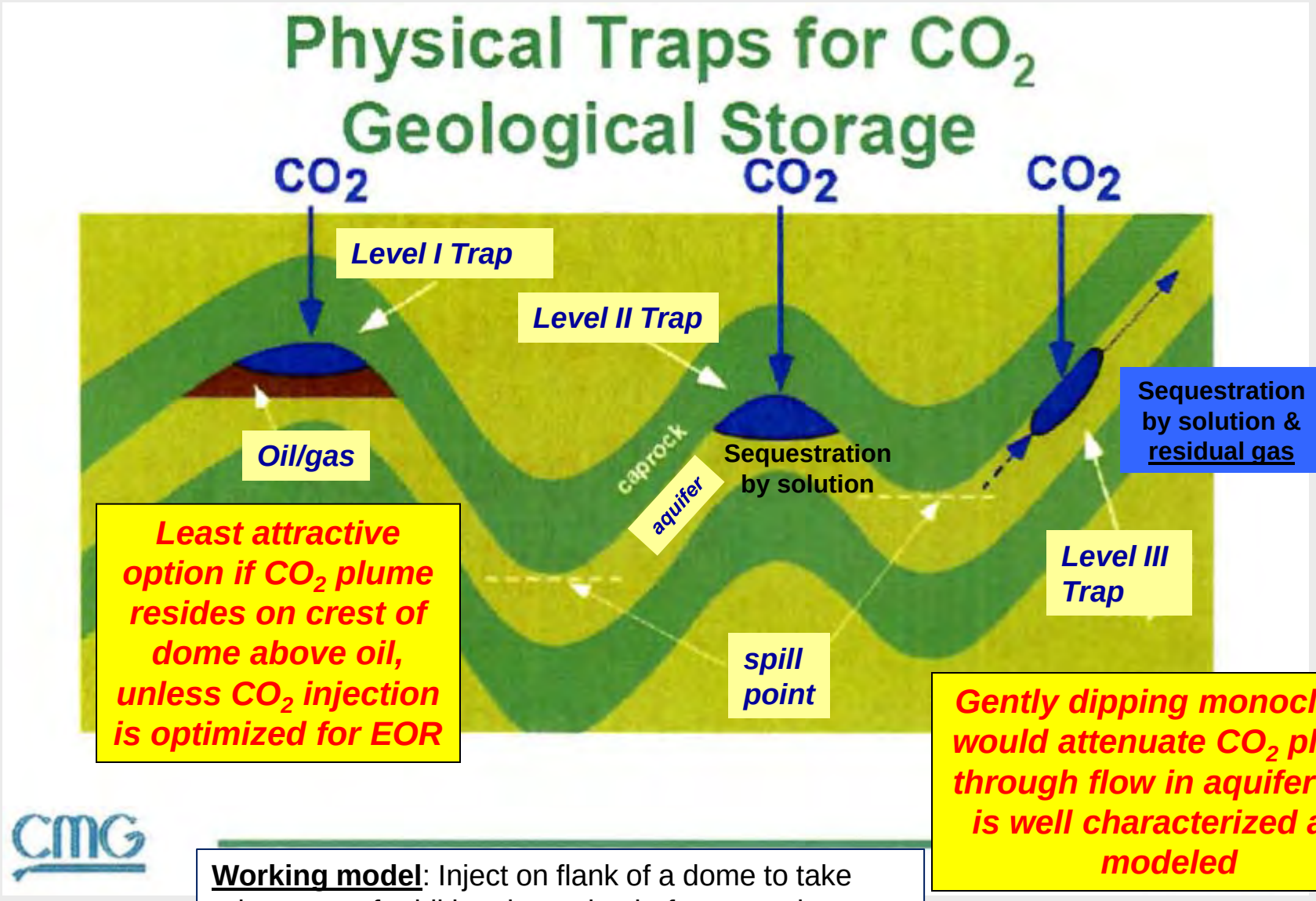
Convection Cycle increases entrapment





CO2CRC

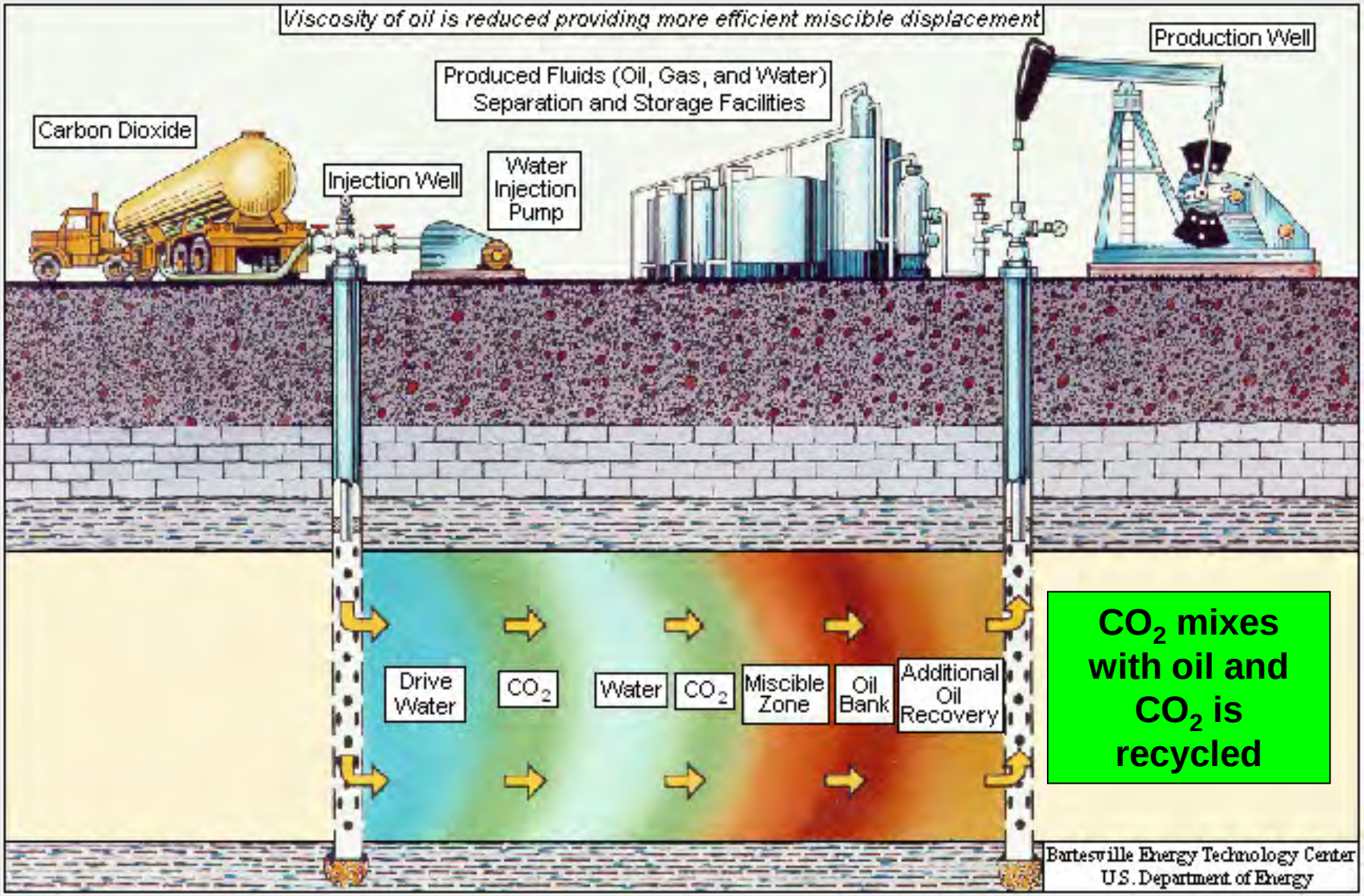
Locating Optimal Sites for CO_2 Sequestration



CMG

Working model: Inject on flank of a dome to take advantage of additional trapping before containment in the dome.

CO_2 Utilization in Enhanced Oil Recovery (EOR)



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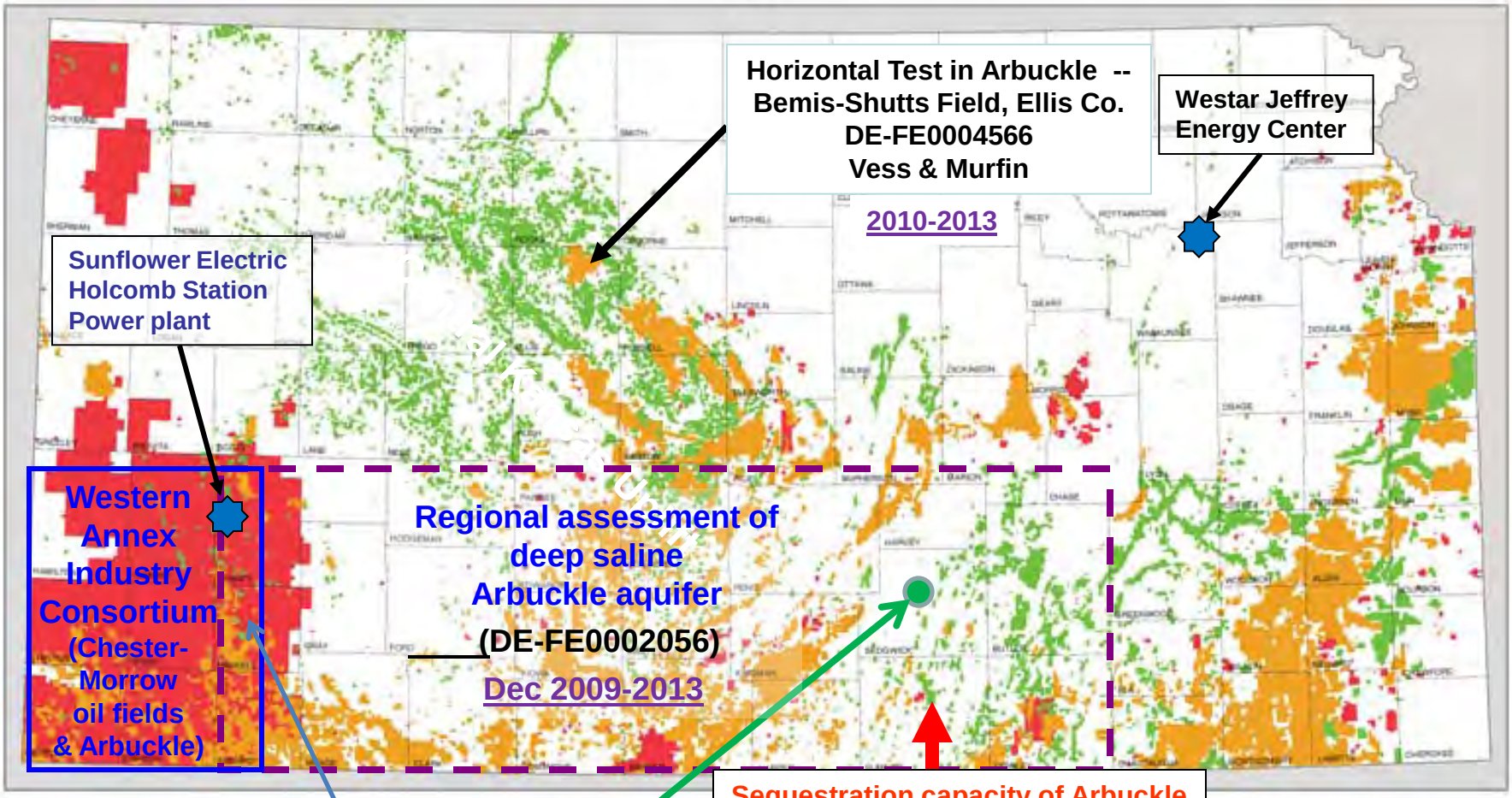
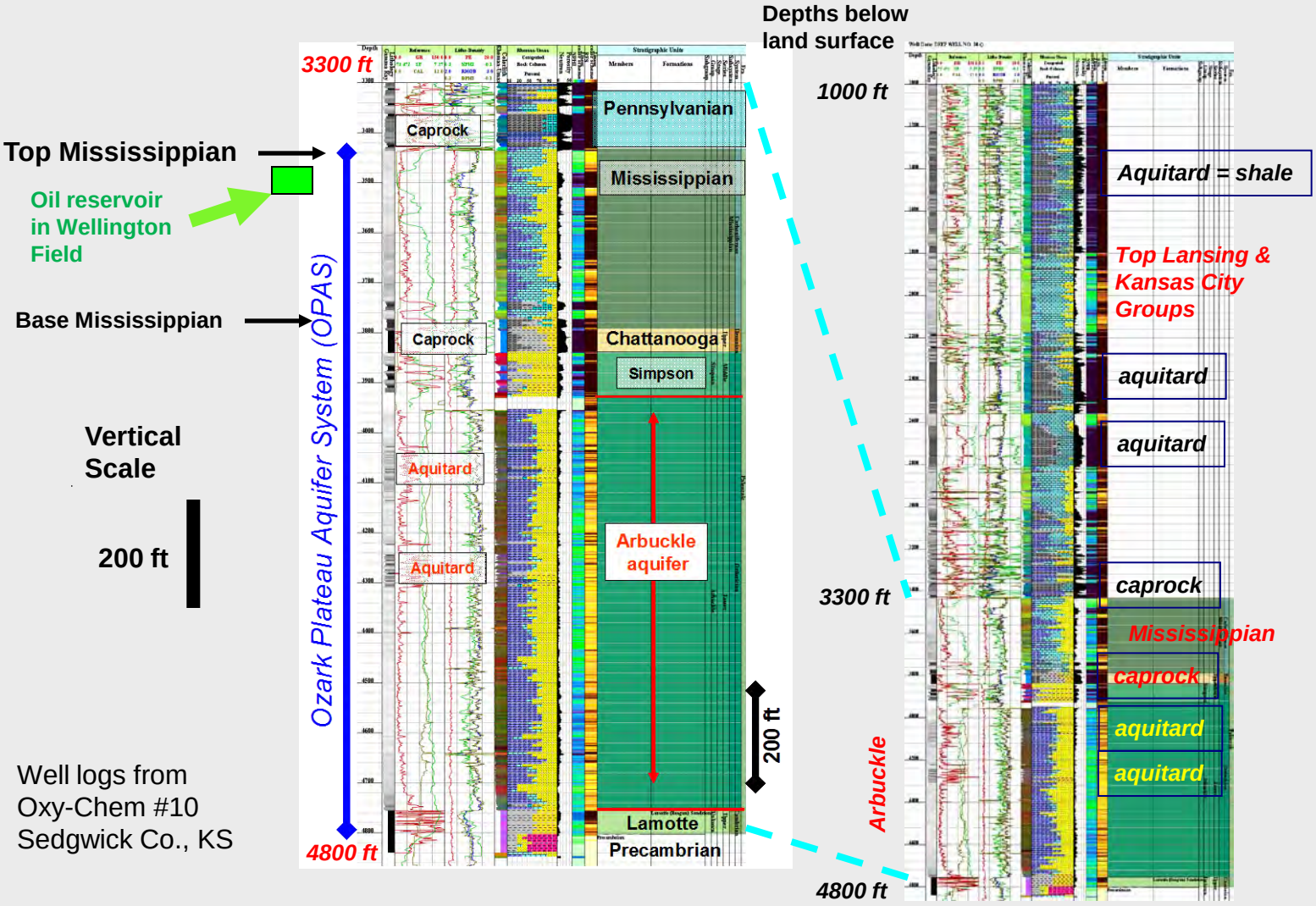
OIL AND GAS FIELDS OF KANSAS

2009



Ozark Plateau Aquifer System (OPAS) lies ~3500 feet below the surface in southern Kansas

Multiple Caprocks & Aquitards above the Mississippian – serve as <u>barriers to fractures and migration of fluids above the Mississippian</u>



Well logs from Oxy-Chem #10 Sedgwick Co., KS

DOE-FE0002056

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

Funding Opportunity Number:
DE-FOA-0000441

Funded October 1, 2011
Through September 30, 2015

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DEPARTMENT OF GEOLOGY

KANSAS STATE UNIVERSITY

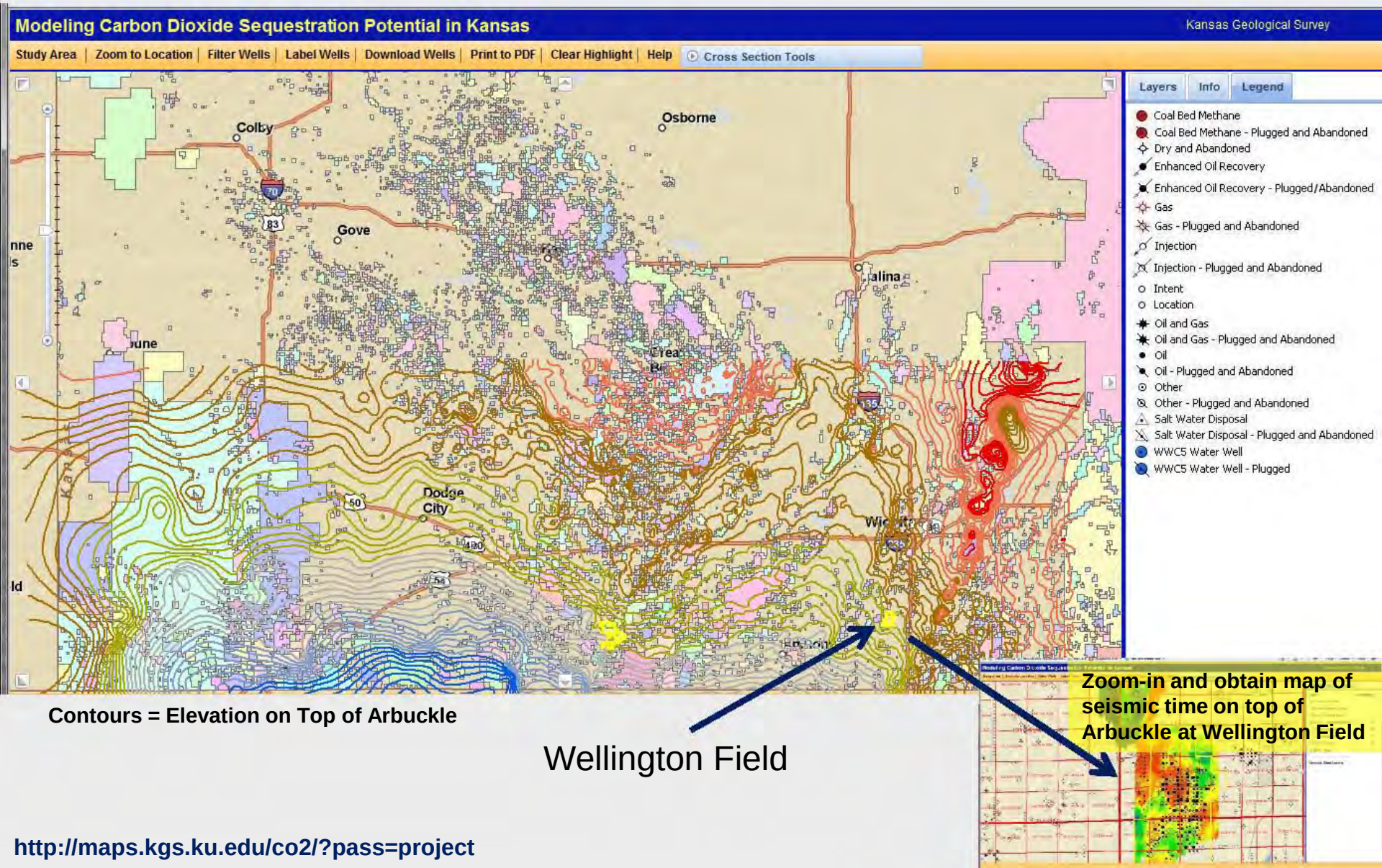
Abengoa Bioenergy : The Global Ethanol Company

THE UNIVERSITY OF KANSAS
Department of Geology

Sandia Technologies, LLC

Web-based Interactive Project Mapper

-- Access point for project maps and well data

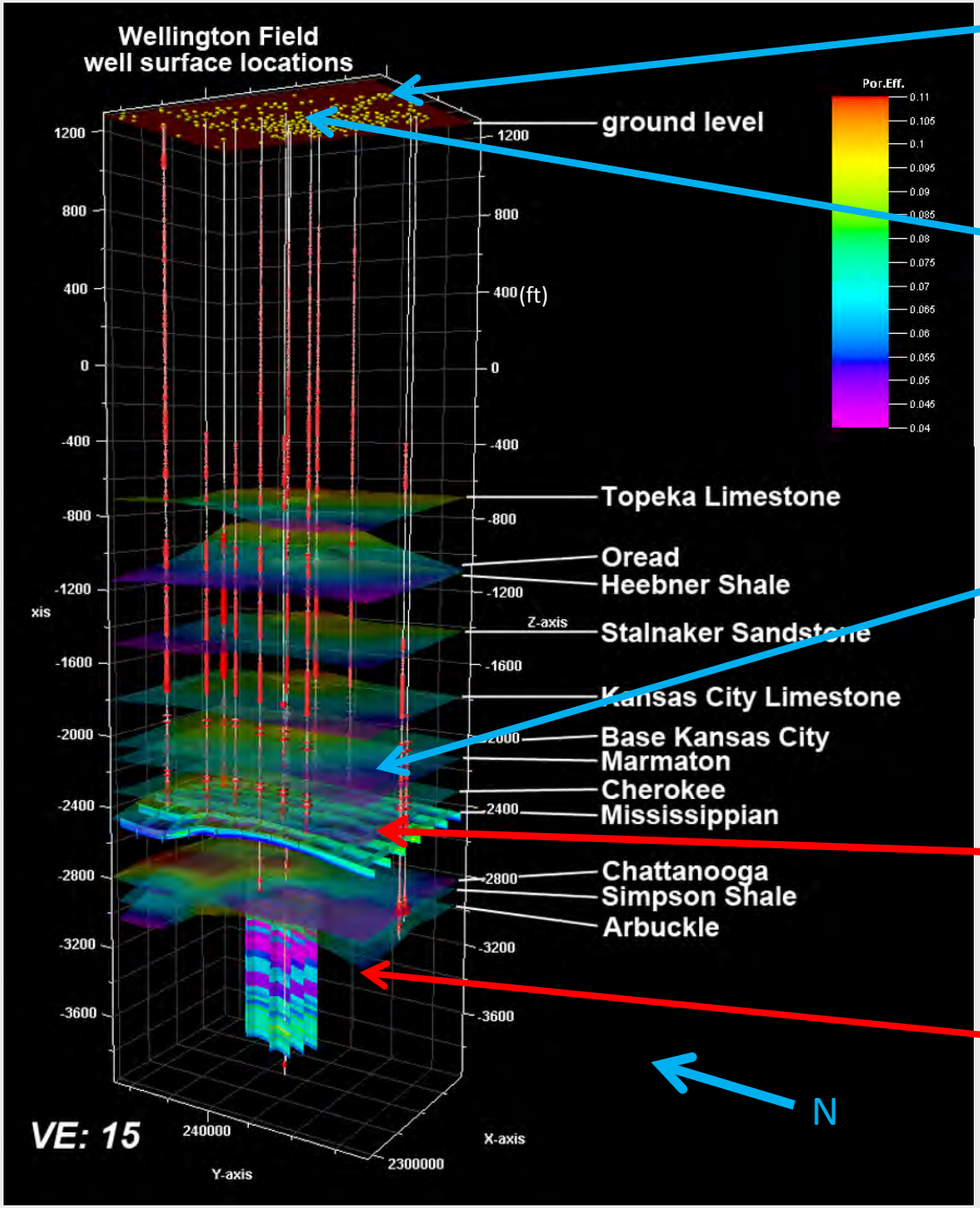


Contours = Elevation on Top of Arbuckle

Wellington Field

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

Optimal Injection and Best Practice Monitoring



- Measure soil gas flux and chemistry through series of shallow probes.

- Monitor for tracers, CO2, 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

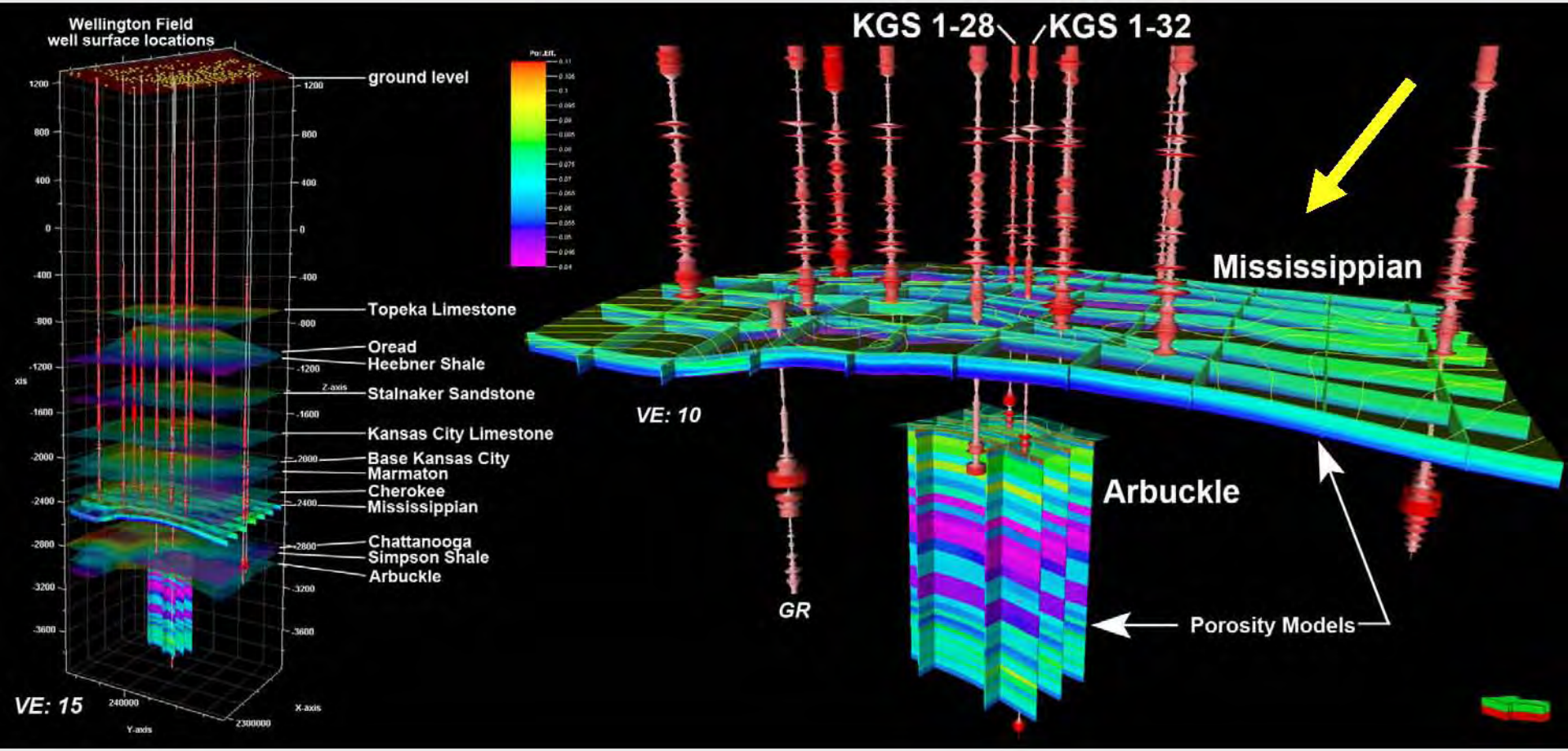
- Measure for tracers and CO2 casing head gas and fluid samples from Mississippian wells (if positive, run 2D seismic) (*Underpressured oil reservoir [900 psi] should trap any vertically migrating CO2*)

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

Inject 40,000 tonnes of CO2 with SF6 and krypton tracers into lower Arbuckle saline aquifer and image and sample in situ CO2 plume development to verify geomodel and simulations

Wellington Field

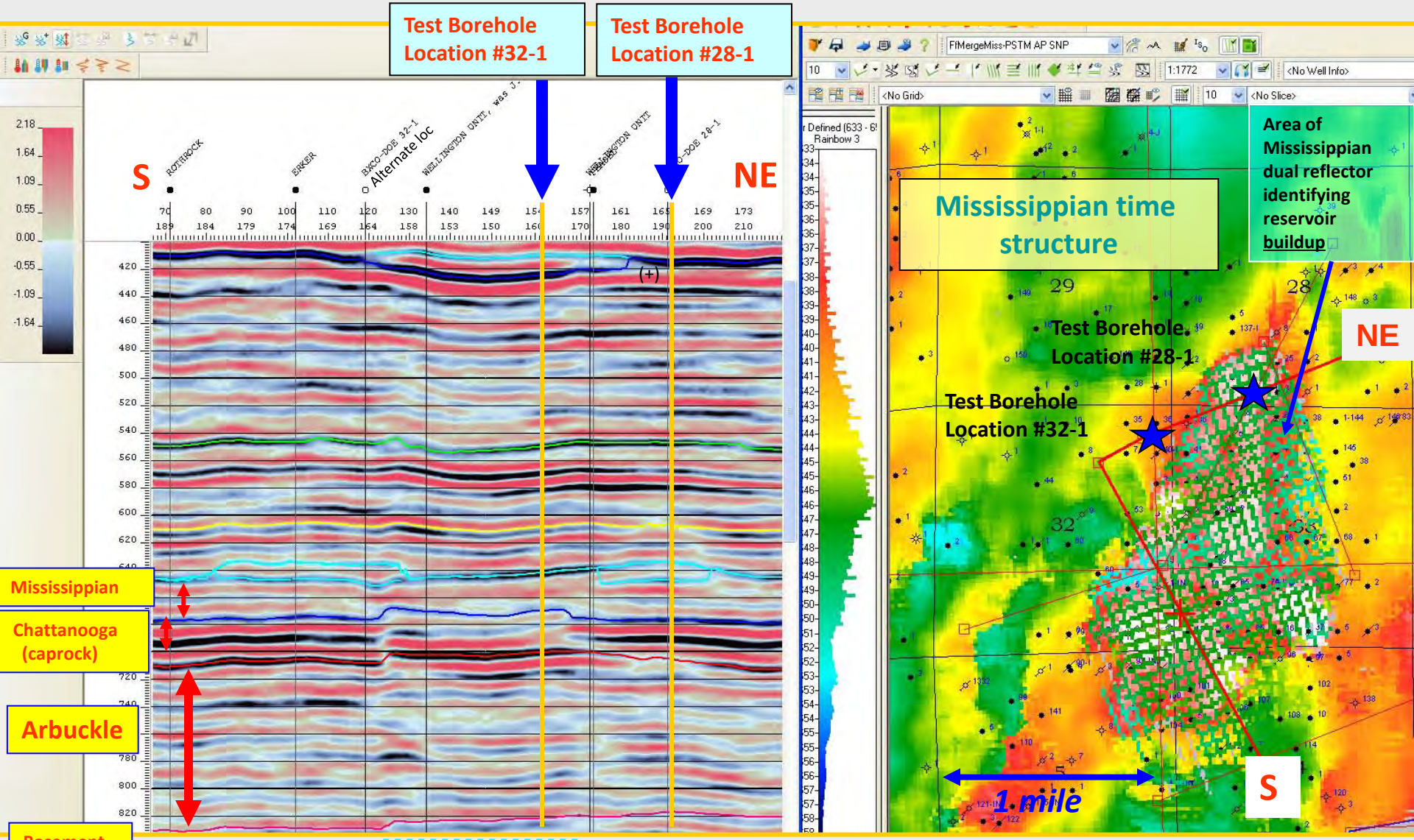
Mississippian tripolite/chert reservoir (underpressured), lower Mississippian & Simpson sealing strata, & Arbuckle aquifer



Wellington Field

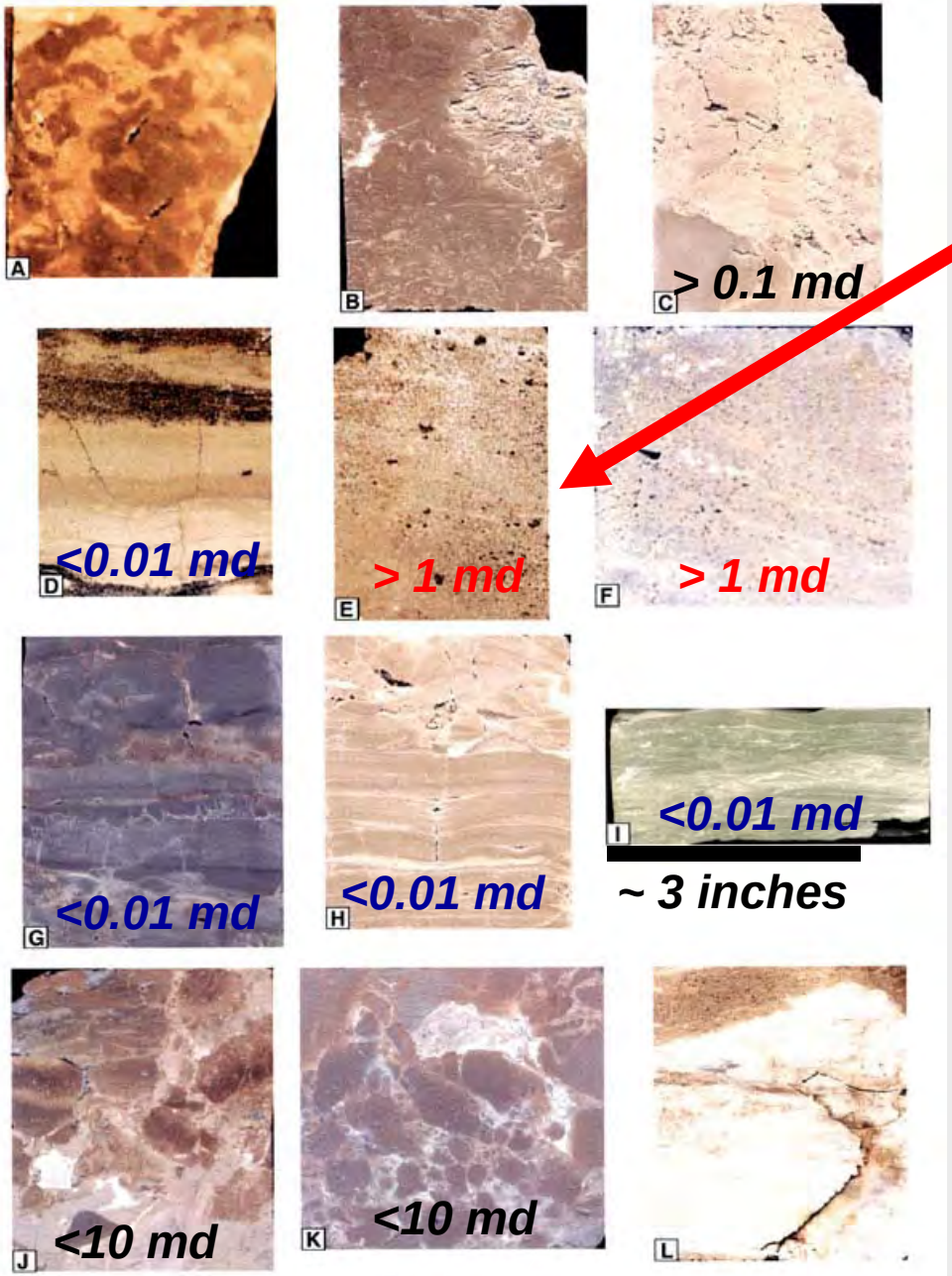
3D Seismic imaging of the subsurface with locations of new basement boreholes

Arbitrary seismic profile to compare borehole locations



Hedke, 2011

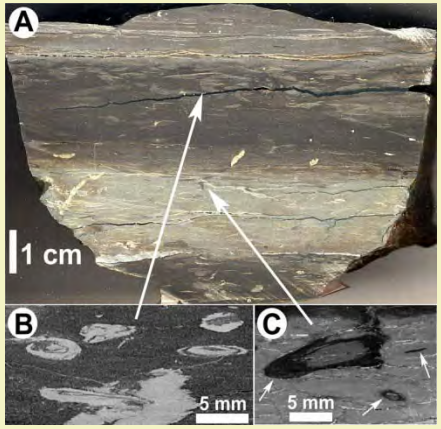
Aquifer flow units and aquitards in Arbuckle saline aquifer



Strata composing Arbuckle saline aquifer vary from porous flow units/aquifers to aquitards.

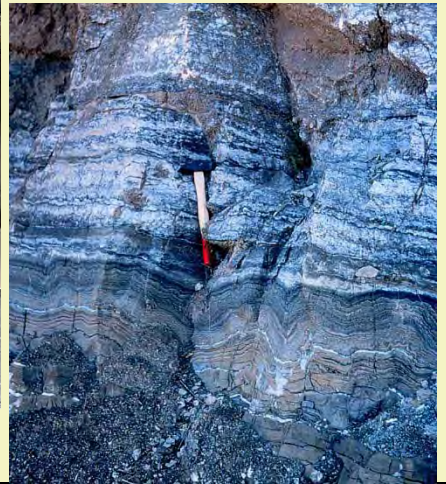
***Caprocks** = thicker shales e.g., Chattanooga Shale, succession of Pennsylvanian and Permian shales and evaporites*

Permo-Penn. shales



Lobza & Schieber (1999)

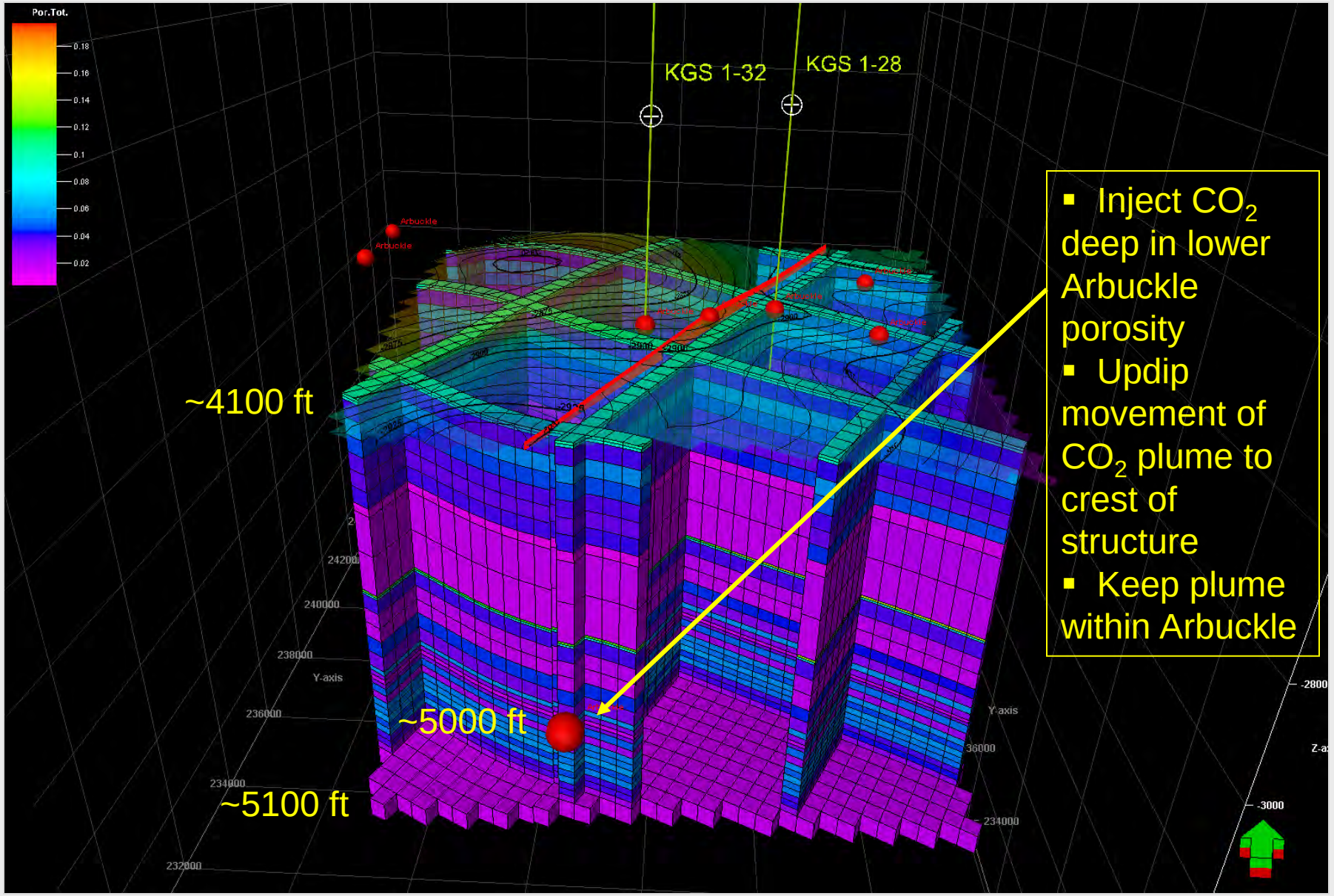
Permian evaporite beds



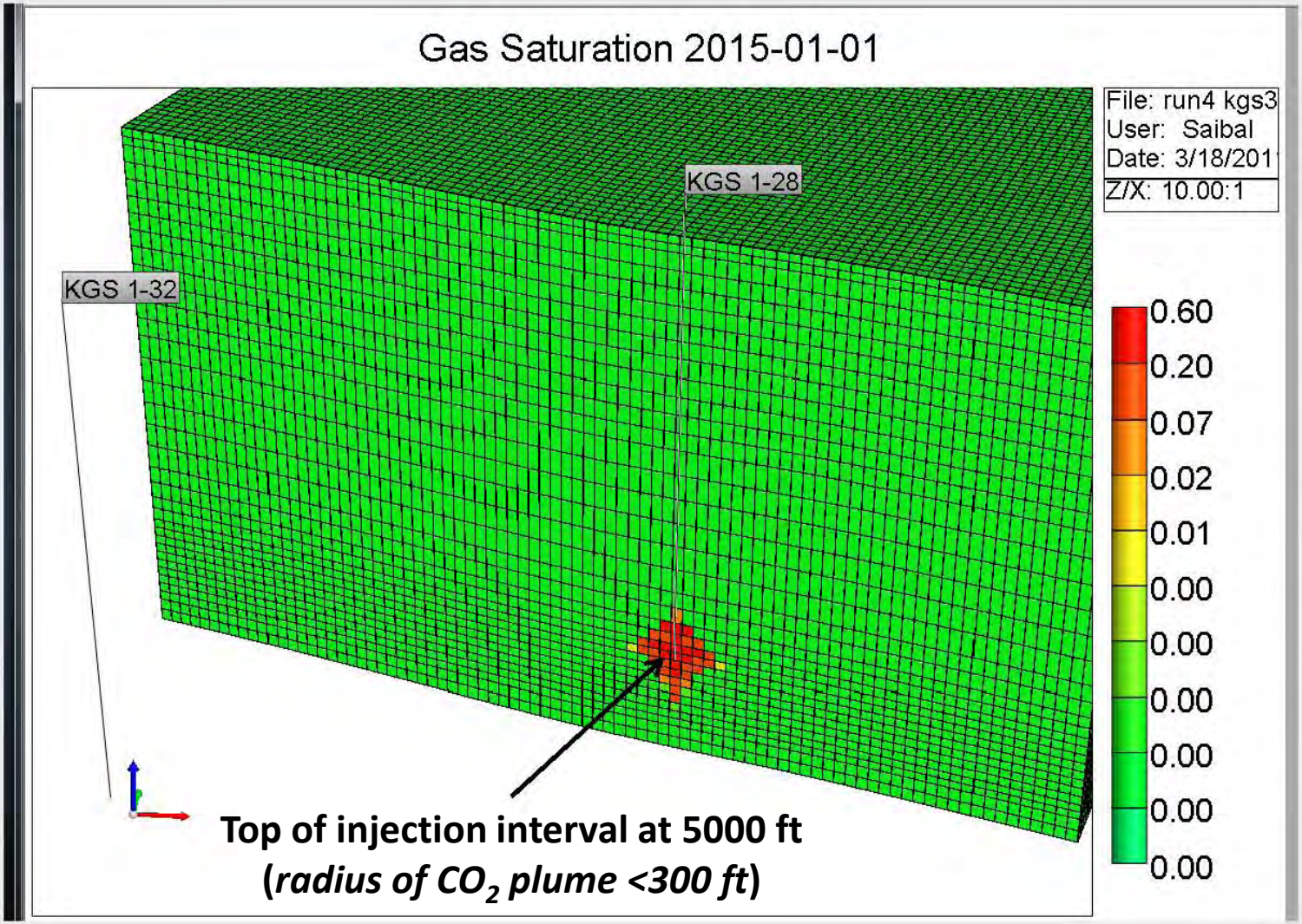
Initial geomodel of Arbuckle (porosity & structure)

Cored well (#1-32) & (#1-28)

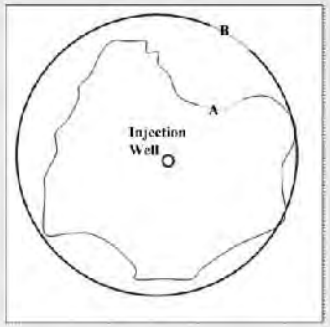
the latter to being considered as a CO_2 injector



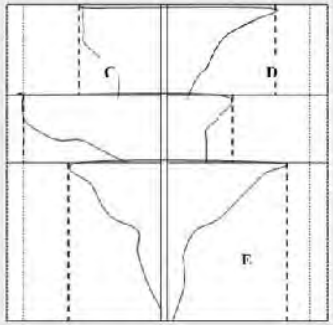
Injection Scenario in Arbuckle
Grid cells 60’ by 60’
Total CO_2 injected ~ 40,000 tons
Injection layers – L25 to L30, each ~20 ft thick, 120 ft total

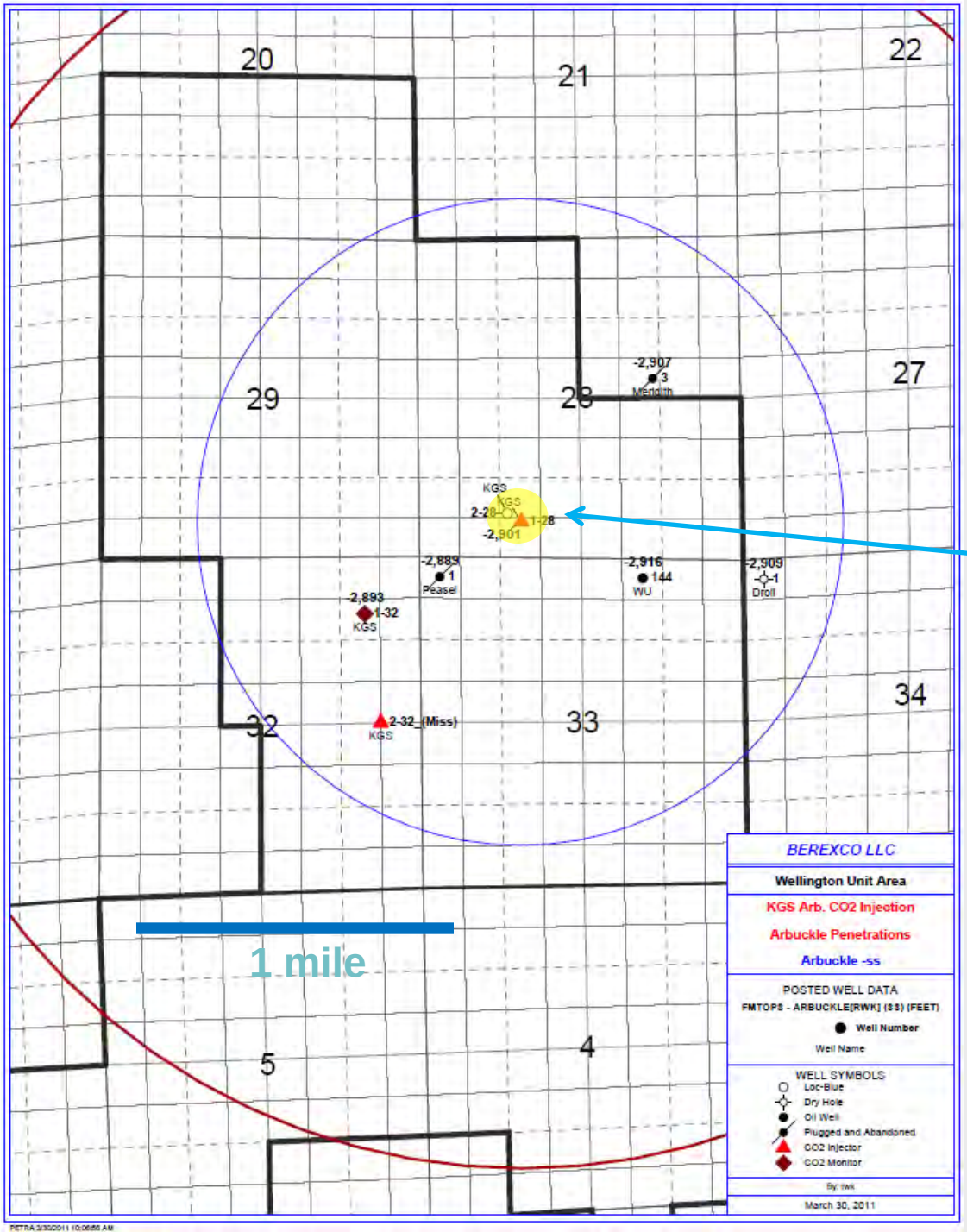


Map View



Cross section





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

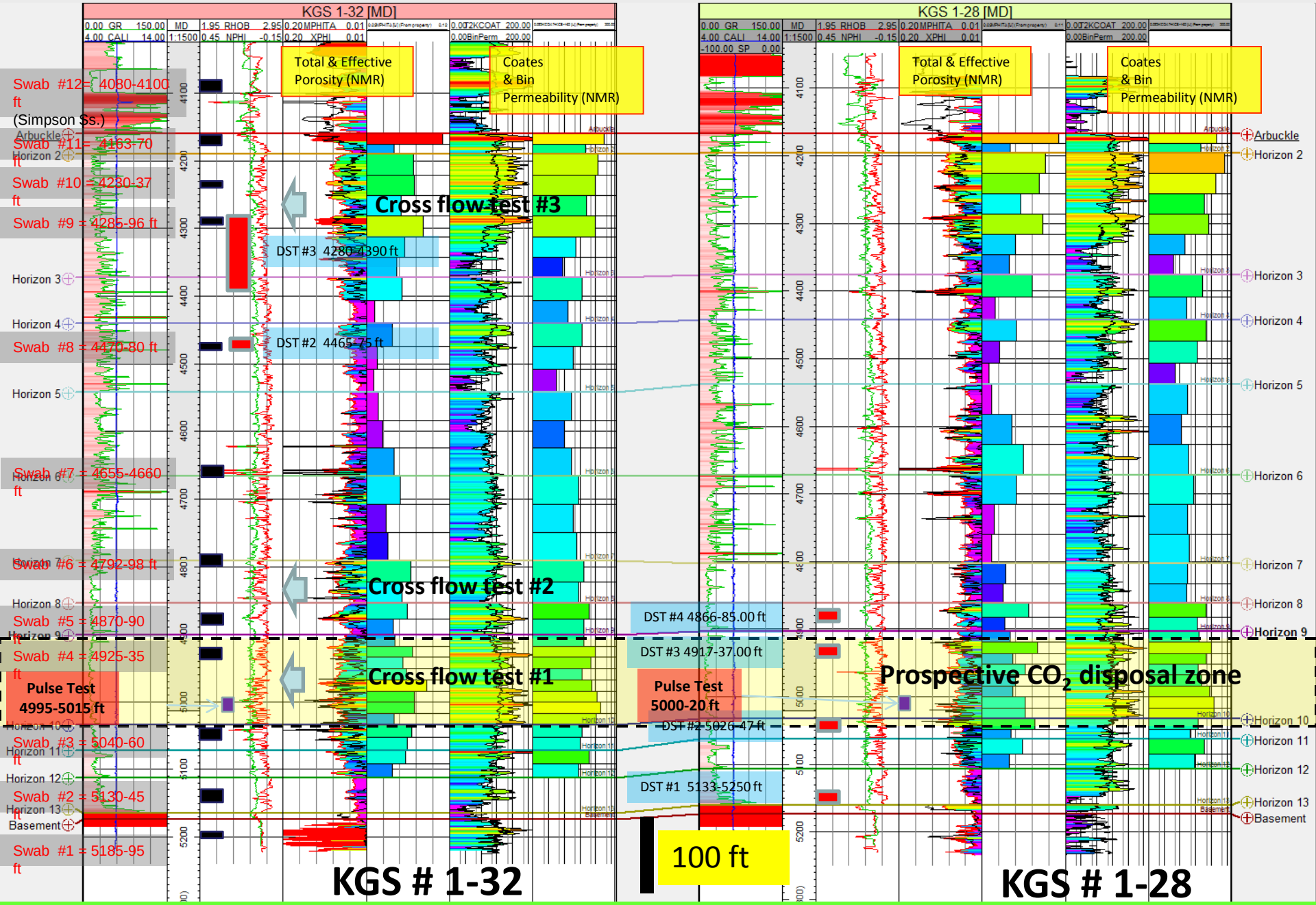
- Proposed monitoring borehole (#2-28) within 300 ft of the existing #1-28 borehole to be converted into CO_2 injector for small scale field test

- 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

Summary

- ***CCUS* – Carbon Capture, Utilization, and Sequestration**
  - **Kansas positioned to combine CO_2-EOR with saline Aquifer sequestration**
  - **Shallower oil fields and deeper saline aquifer (Arbuckle) with existing leases**
  - **Manage CO_2 within existing infrastructure of petroleum industry**
- **Managing CO_2 plume in deep saline aquifer**
  - **CO_2 plume initially a supercritical free phase liquid that is eventually trapped in the aquifer**
    - **solution, small pores, and reaction with rock**
  - **Tailor computer simulations of CO_2 sequestration based on rock and fluid data for review and permitting**
  - **Monitor CO_2 plume with latest technology**
    - **Evaluate progress compare to simulations**
    - **Demonstrate containment**
- **Current research in carbon sequestration in Kansas**
  - **Evaluate CO_2-EOR in Mississippian and Arbuckle oil reservoirs**
  - **Evaluate saline aquifer sequestration in southern Kansas**
  - **Small scale field demonstration of CO_2-EOR and saline aquifer sequestration at Wellington Field**

Arbuckle Saline Aquifer in Wellington Field consists of a multi-layered stack of flow units and aquitards



Cross section (east to west) between KGS #1-28 and #1-32 in Wellington Field and upscaled hydrostratigraphic units in Arbuckle Group