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

Project Number (DE-FE0002056)

W. Lynn Watney & Jason Rush (Joint PIs)
Kansas Geological Survey
Lawrence, KS 66047

U.S. Department of Energy
National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the Infrastructure for CO_2 Storage
August 21-23, 2012

KU KANSAS GEOLOGICAL SURVEY
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Presentation Outline

- Benefits to the Program
- Project Overview
- Technical Status
- Accomplishments to Date
- Summary

Partners
FE0002056

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U.S. DEPARTMENT OF ENERGY

DEPARTMENT OF GEOLOGY
KANSAS STATE UNIVERSITY

KU THE UNIVERSITY OF KANSAS Department of Geology

Wellington Field Operator
BEREXCO

fairfieldnodal

PARAGON GEOPHYSICAL SERVICES, INC

ECHO GEOPHYSICAL CORPORATION
INTEGRITY · STABILITY · INNOVATION

noble energy

Devilbiss Coring Service
Basic Energy Services

LOCKHART GEOPHYSICAL

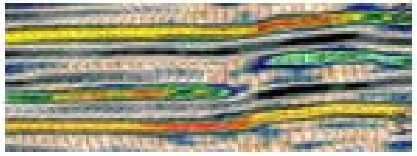
MUDCO

Weatherford LABORATORIES

TRILOBITE TESTING, INC.

HALLIBURTON

HEDKE-SAENGER GEOSCIENCE, LTD



Bittersweet Energy Inc.

Charter Consulting
Integrated Geology & Geophysics

Petrotek

KOGER REMOTE SENSING

LOGDIGI
A LEADING CONSULTING COMPANY

Southwest Kansas CO_2-EOR Initiative

Industry Partners (modeling 4 Chester/Morrowan oil fields to make CO2 ready)

IHR Improved Hydrocarbon Recovery LLC

HEDKE-SAENGER GEOSCIENCE, LTD

SUNFLOWER ENERGY LLC

+drilling and seismic contractors TBN

CIMAREX

GloriOil

Anadarko Petroleum Corporation

Dawson-Markwell Exploration Co.

BEREXCO

CELEBRATING 20 YEARS

MERIT ENERGY COMPANY

Industrial and Electrical Power Sources of CO_2

Conestoga Energy Partners, LLC
fueling the new frontier

SUNFLOWER ELECTRIC POWER CORPORATION
A Touchstone Energy® Cooperative
. . . energy done right

Abengoa Bioenergy : The Global Ethanol Company

Benefit to the Program

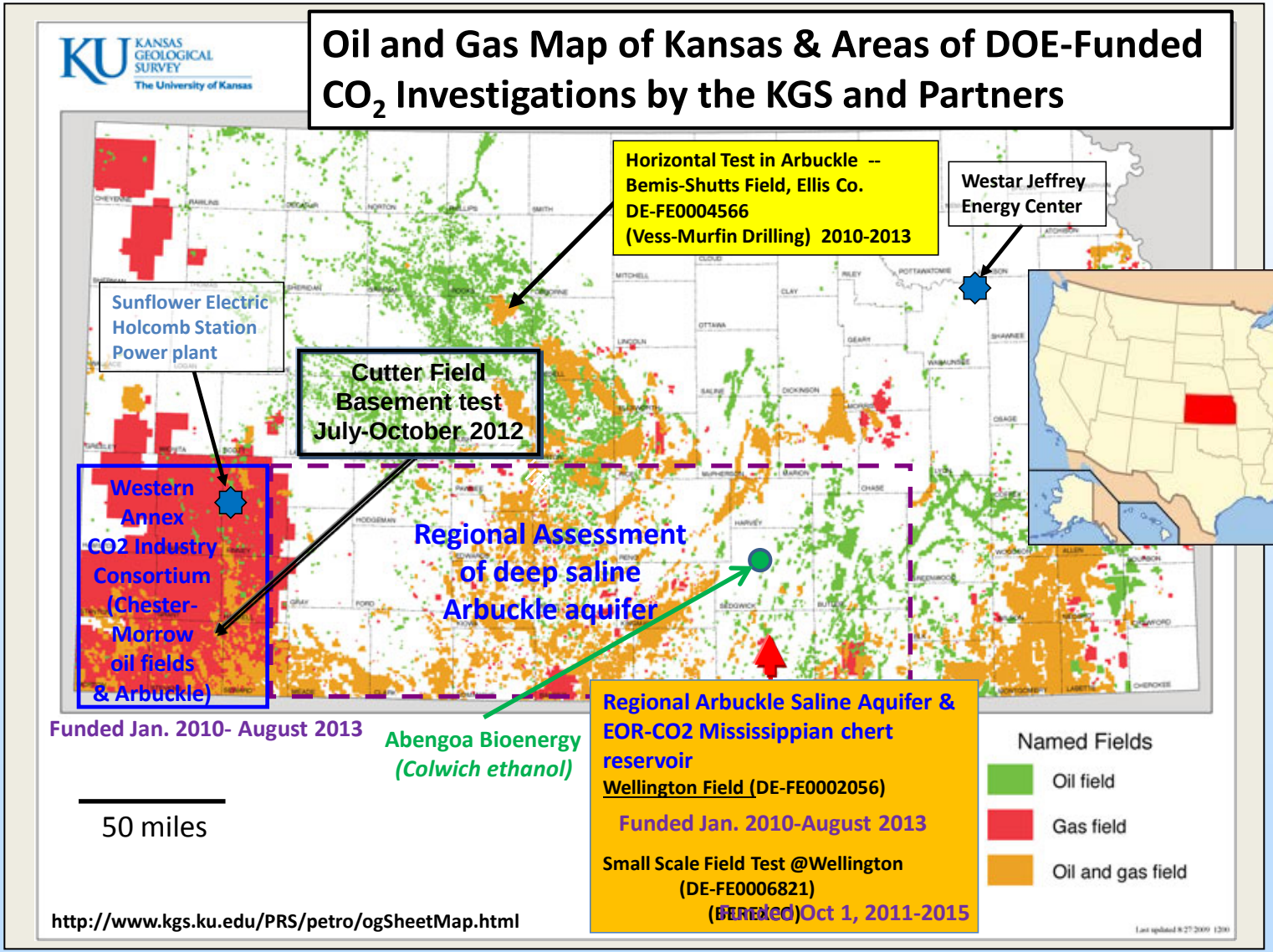
- **Program goal being addressed –**
  - **Develop technologies that will support industries' ability to predict CO_2 storage capacity in geologic formations to within ±30 percent.**
- **Project benefits --**
  - Refine and document CO_2 storage capacity
  - Utilize online interactive map to access information
  - Calibrate regional analysis at Wellington and Cutter fields
  - Extend structural and stratigraphic analysis & validate well based mapping using donated regional scale 3D seismic, reprocessed state-wide gravity-magnetics, and remote sensing
  - Evaluate CCUS feasibility and risk at five oil fields and 8 regional sites
  - Resolve heterogeneity in ~500-1000 ft thick Lower Ordovician Arbuckle saline aquifer
  - Provide information to evaluate geologic conditions best suited for CO_2 management

Project Overview:
Goals and Objectives

- Characterize the Lower Ordovician Arbuckle Group in southern Kansas covering approximately 33 counties in 25,000 mi^2 area *(Predict CO2 storage within ±30 percent)*
  - ***Success*** *-- Scan, digitize, and correlate key wells; Develop key maps to evaluate storage and risk*
- Model carbon dioxide injection within the Arbuckle Group saline aquifer and the overlying Mississippian siliceous dolomite oil reservoir at Wellington Field (Sumner County, Kansas) (*Calibration site for storage and evaluate suitability of site for CO_2 injection*)
  - ***Success*** *– Drill, core, test in two 5200' basement tests; acquire, process, interpret 12 mi^2 of multicomponent 3D seismic; model for CCUS*
- Evaluate CO_2 sequestration potential in Arbuckle Group saline aquifer and CO_2-EOR in four fields in southwestern Kansas (*Calibration site for storage and evaluate suitability of site for CO_2 injection*)
  - ***Success*** *– Drill, core, test 7500' basement test at Cutter Field, Stevens County, KS; acquire 10 mi2 of multicomponent 3D seismic;*
  - *Simulate CO_2-EOR @ four fields -- Cutter, South Pleasant Prairie, Eubanks North, and Shuck fields*

Technical Status

Characterize regional Arbuckle saline aquifer and overlying CO_2-EOR in 5 fields



Structure Contour Map -- Top Mississippian with regional faults

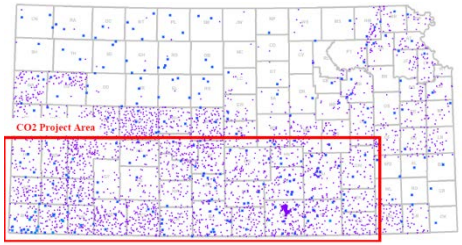
Subcontractor
Bittersweet Energy

(Gerlach, Nicholson, Hansen)

DOE Contract #FE0002056
and partner cost share

Current Status
Of
2) Fault Detection & Verification – Regional & Compartment

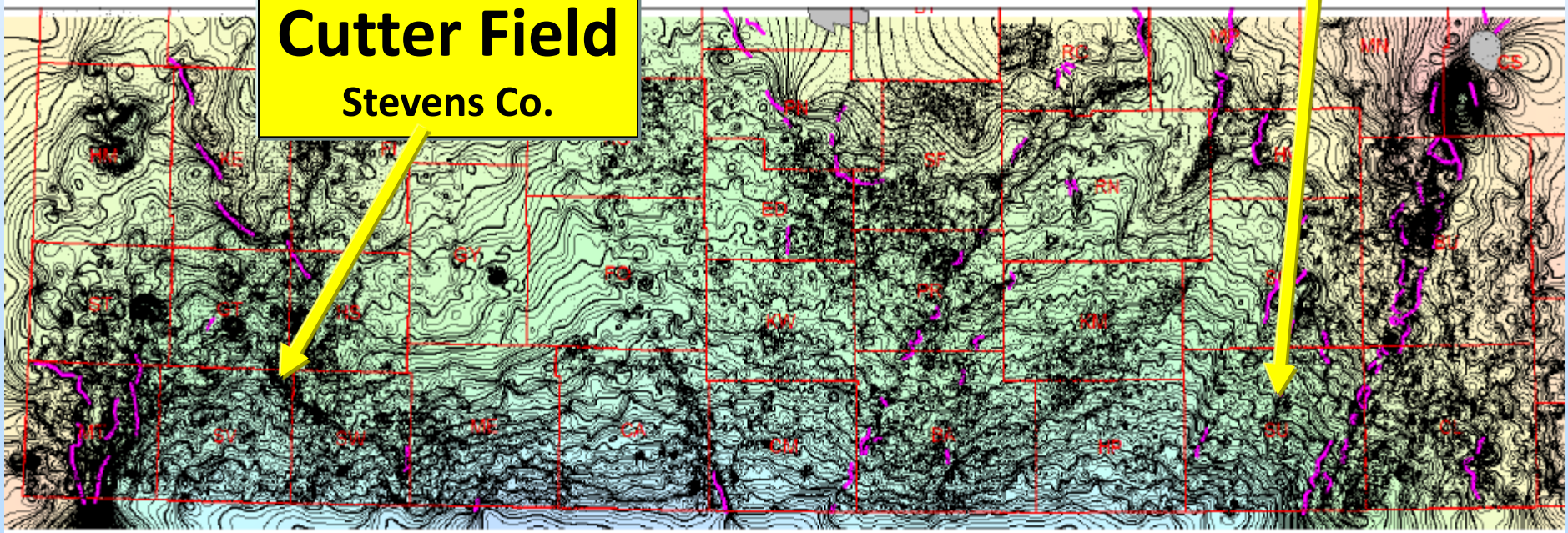
Well header records: 3170
Formation tops records: 66,309
LAS & scanned Logs for project



MISS Subsea ci: 25 ft with ARBK Verified Faults

Wellington Field
Sumner Co.

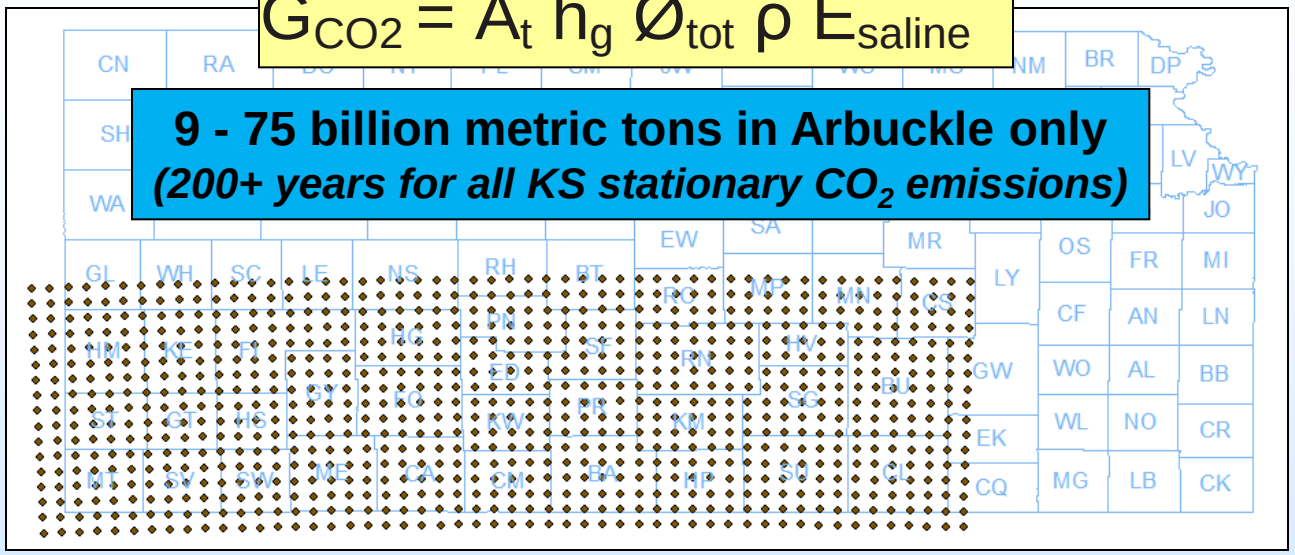
Cutter Field
Stevens Co.



Initial CO_2 storage capacity

(reported April 2011 to NATCARB) Arbuckle Saline Formation

$$G_{CO2} = A_t\ h_g\ \emptyset_{tot}\ \rho\ E_{saline}$$



9 - 75 billion metric tons in Arbuckle only

(200+ years for all KS stationary CO_2 emissions)

Metric tons CO_2 per Grid Cell 10 km² (3.8 mi²)

Each grid cell is 10K (+/-)

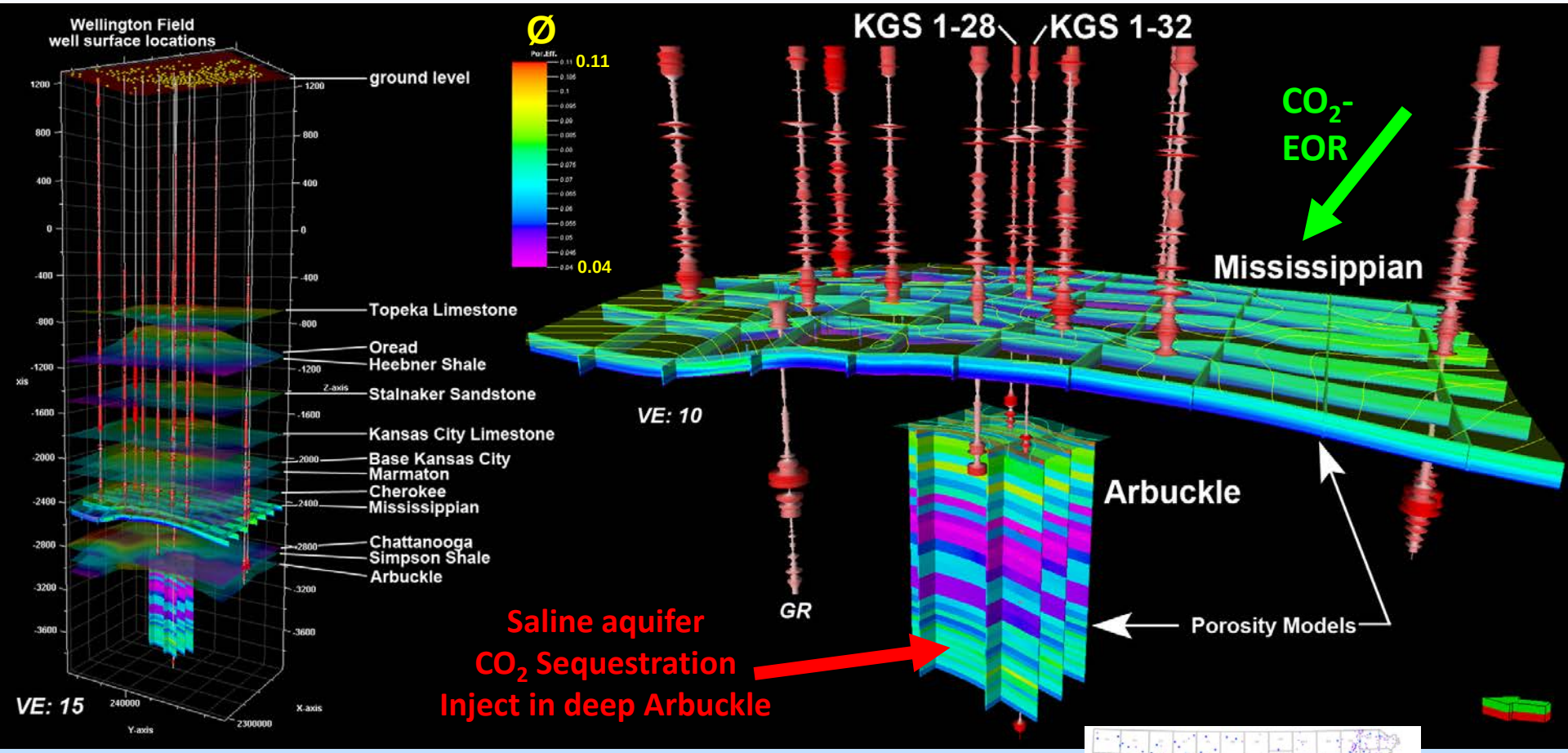
P10	
8,781,380,535	Total All Cells
22,214,247	High Cell
10,287,863	Median Cell
10,554,544	Mean Cell

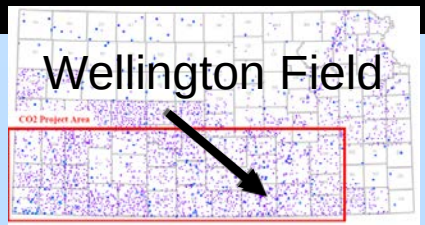
P90	
75,464,988,970	Total All Cells
190,903,682	High Cell
88,411,323	Median Cell
90,703,112	Mean Cell

Gerlach and Bittersweet team, 2012

Wellington Field – eastern calibration site

Mississippian siliceous dolomite reservoir & Arbuckle aquifer saline aquifer





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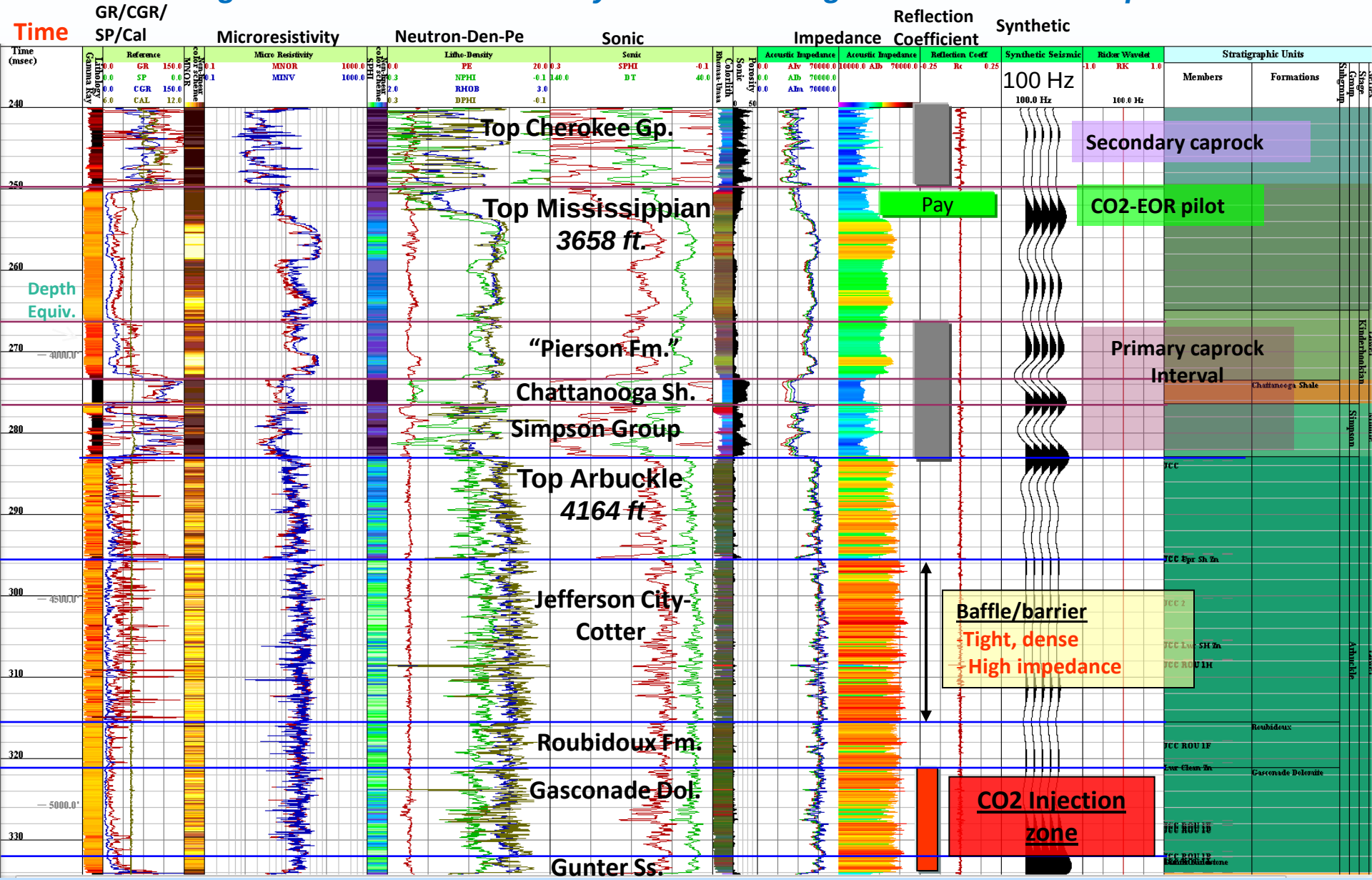
CO_2 injection zones in Arbuckle and Mississippian

Wellington Field KGS #1-28 --- Synthetic seismogram and seismic impedance

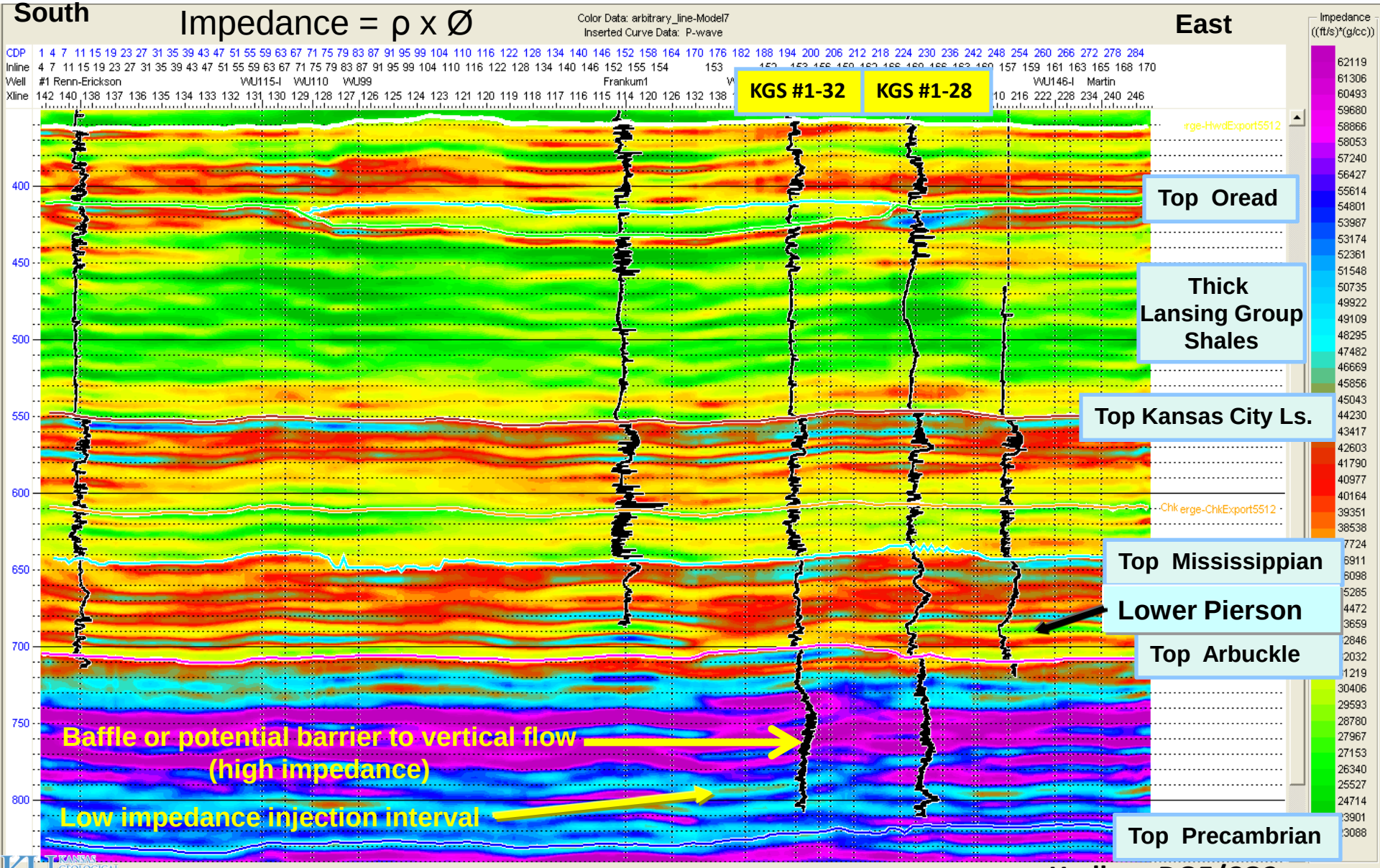


Precambrian granite – bottom of core = *5174 ft*

http://www.kgs.ku.edu/software/SS/

Arbitrary seismic impedance profile

distinct caprock, mid-Arbuckle tight, lower Arbuckle injection zone



Uppermost primary caprock interval

Wellington Field

120’ thick Lower Mississippian dark, argil. siltstone

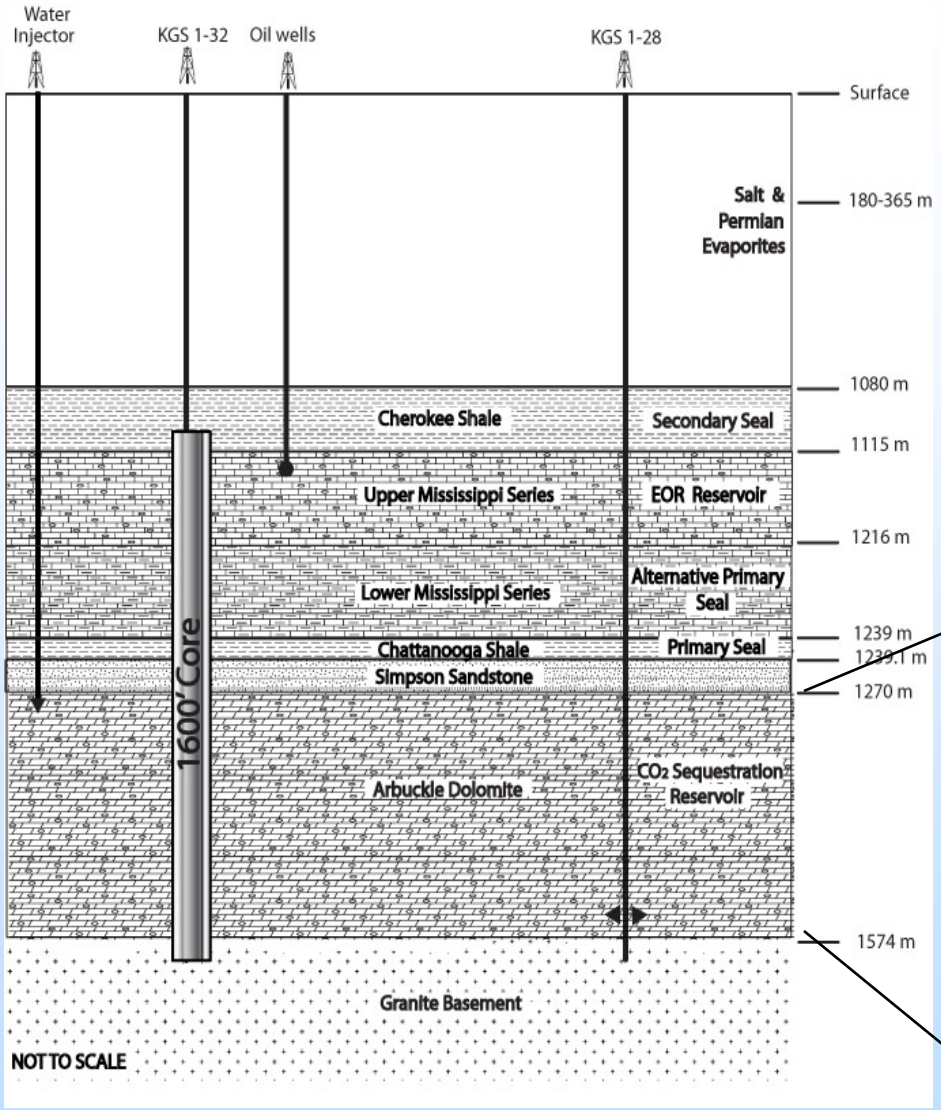
Low impedance

3927- 3939: olive gray, argillaceous dolomitic siltstone; wispy shale laminations; indistinct bedding; faint discontinuous laminations; gradational contact

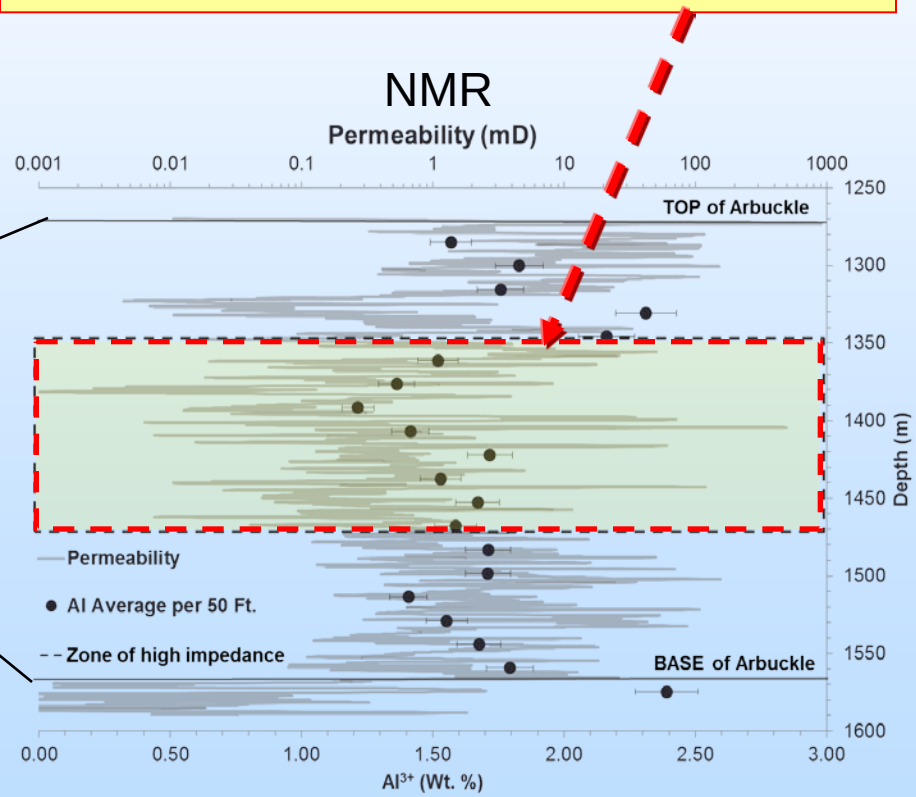
3939-3975.6: medium dark gray; very argillaceous dolomitic siltstone; faintly laminated irregular; 30% silt; 3972-3973 cm-sized irregular calcareous nodules

3975.6-3993: very dark greenish gray; shale; tight; dolomitic; around 20% silt; scattered black shale laminae; uniform; scattered pyrite; 3983 starts increasing silt; gradational contact

Mid-Arbuckle flow barrier



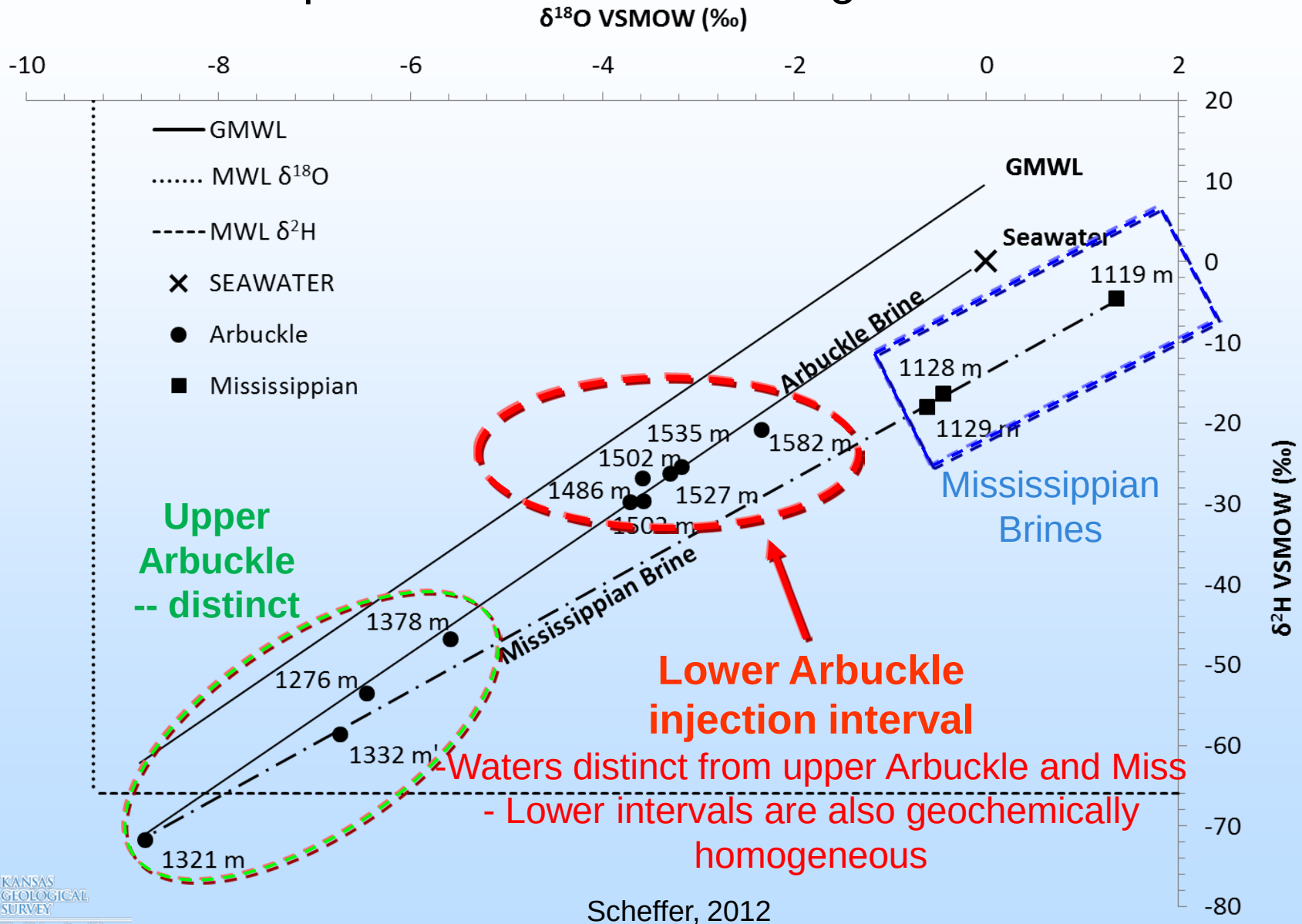
- 400 ft of tighter rock
- Widespread high seismic impedance



Scheffer, 2012

Oxygen & hydrogen isotopes of brine

from DST and perforation and swabbing of #1-32 and #1-28



Scheffer, 2012

Selected core from Lower Arbuckle

Proposed Injection Interval

5089-92 ft

Vug and interparticle Ø

5080-83

Crackle breccia w/ Ø

5053-56

Fracture Ø

4995-97.7 ft

Vugs and interparticle Ø

Fine interparticle Ø

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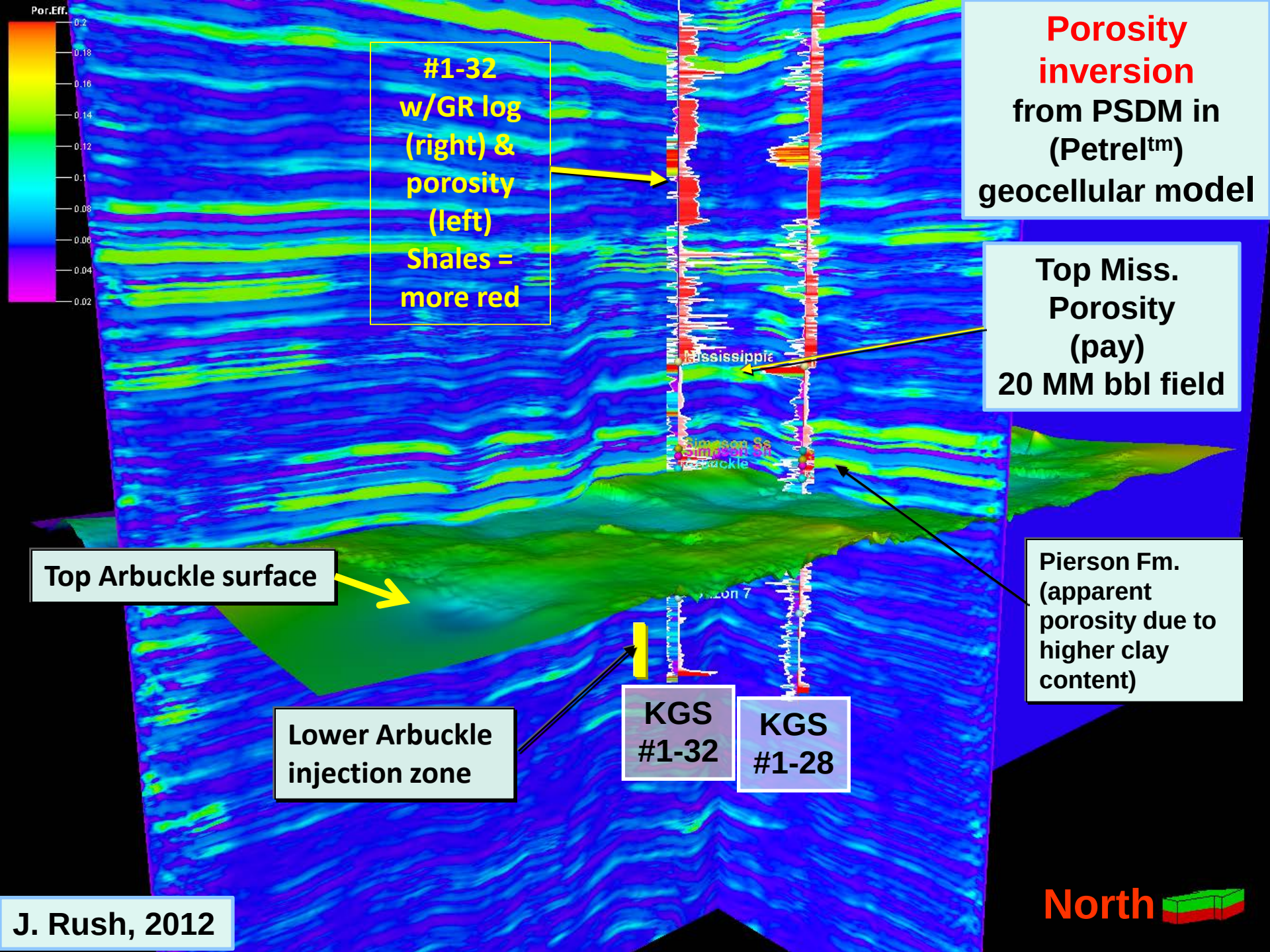
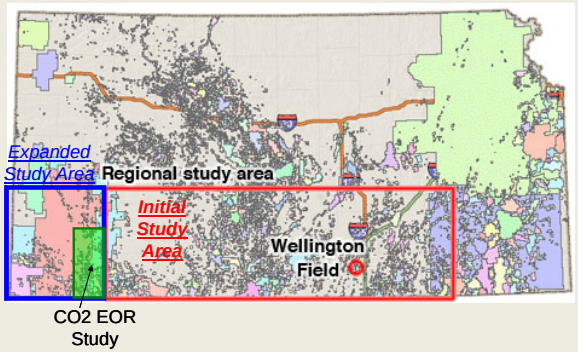

Por.Eff.
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
#1-32 w/GR log (right) & porosity (left) Shales = more red
Porosity inversion from PSDM in (Petrel™) geocellular model
Top Miss. Porosity (pay) 20 MM bbl field
Mississippi
Simpson Ss
Simpson Sh
Arbuckle
Top Arbuckle surface
Pierson Fm. (apparent porosity due to higher clay content)
Lower Arbuckle injection zone
KGS #1-32
KGS #1-28
North
J. Rush, 2012

Technical Status

Evaluate CO_2 sequestration potential in Arbuckle Group saline aquifer and CO_2-EOR in four fields in southwestern Kansas

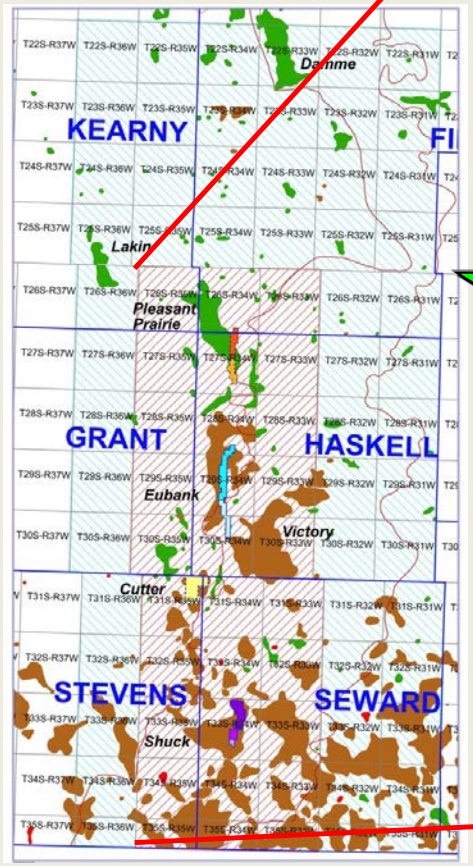
Southwest Kansas CO2 Consortium (*Western Annex*)

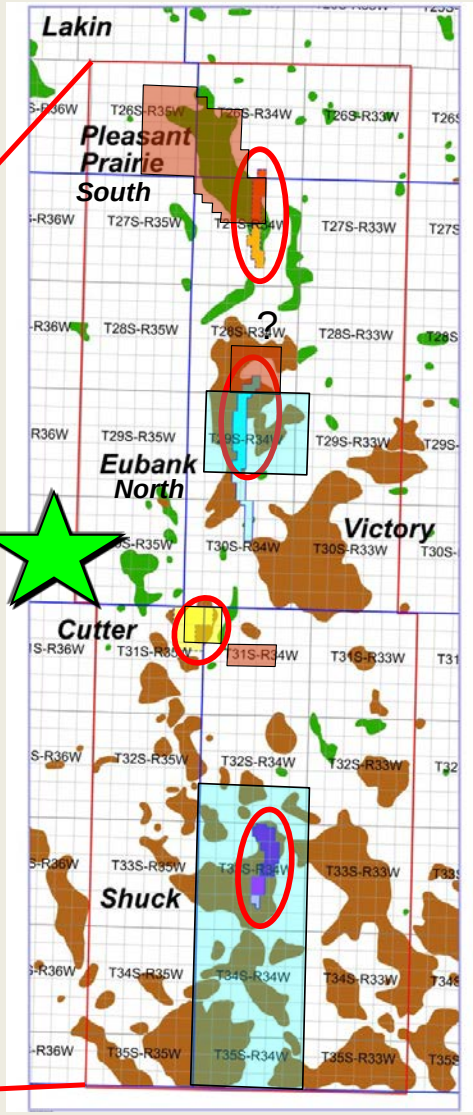


Chester/Morrow Sandstone (IVF) &

Deep saline Arbuckle aquifer

Seismic blocks are color coded by operator (~120 mi^2 of 3D seismic)





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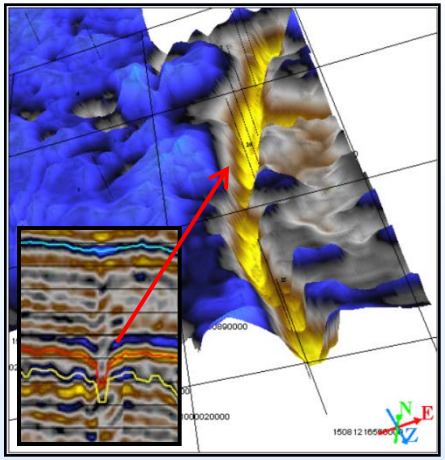
The University of Kansas

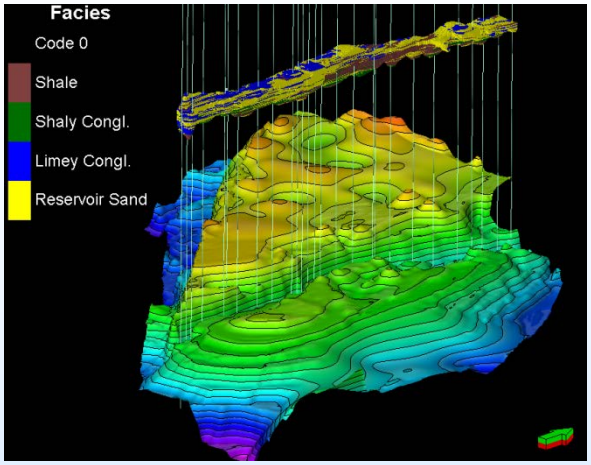
Southwest Kansas CO_2-EOR Initiative

Integrated Multi-Discipline Project for CO_2-EOR Evaluation

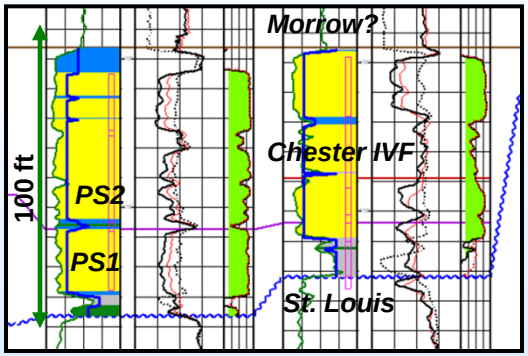
Static Model

Geophysics:
structure, attributes, faults

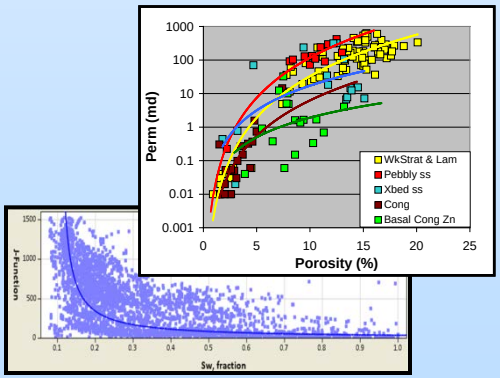




Geology:
Formation tops, sequence stratigraphy, core lithofacies, lithofacies prediction (NNet)

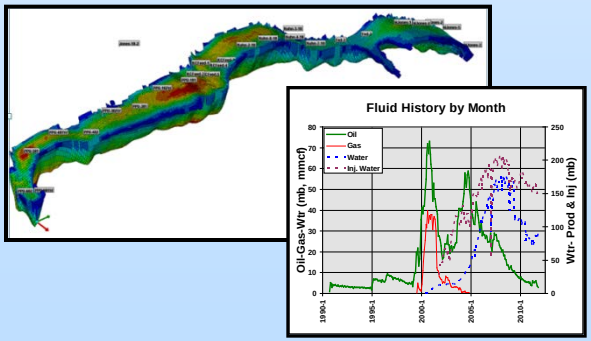


Petrophysics:
Core K-Phi, corrected porosity, free water level, J-function



Engineering:
PVT and fluid analysis, recurrent histories, dynamic modeling

Dynamic Model

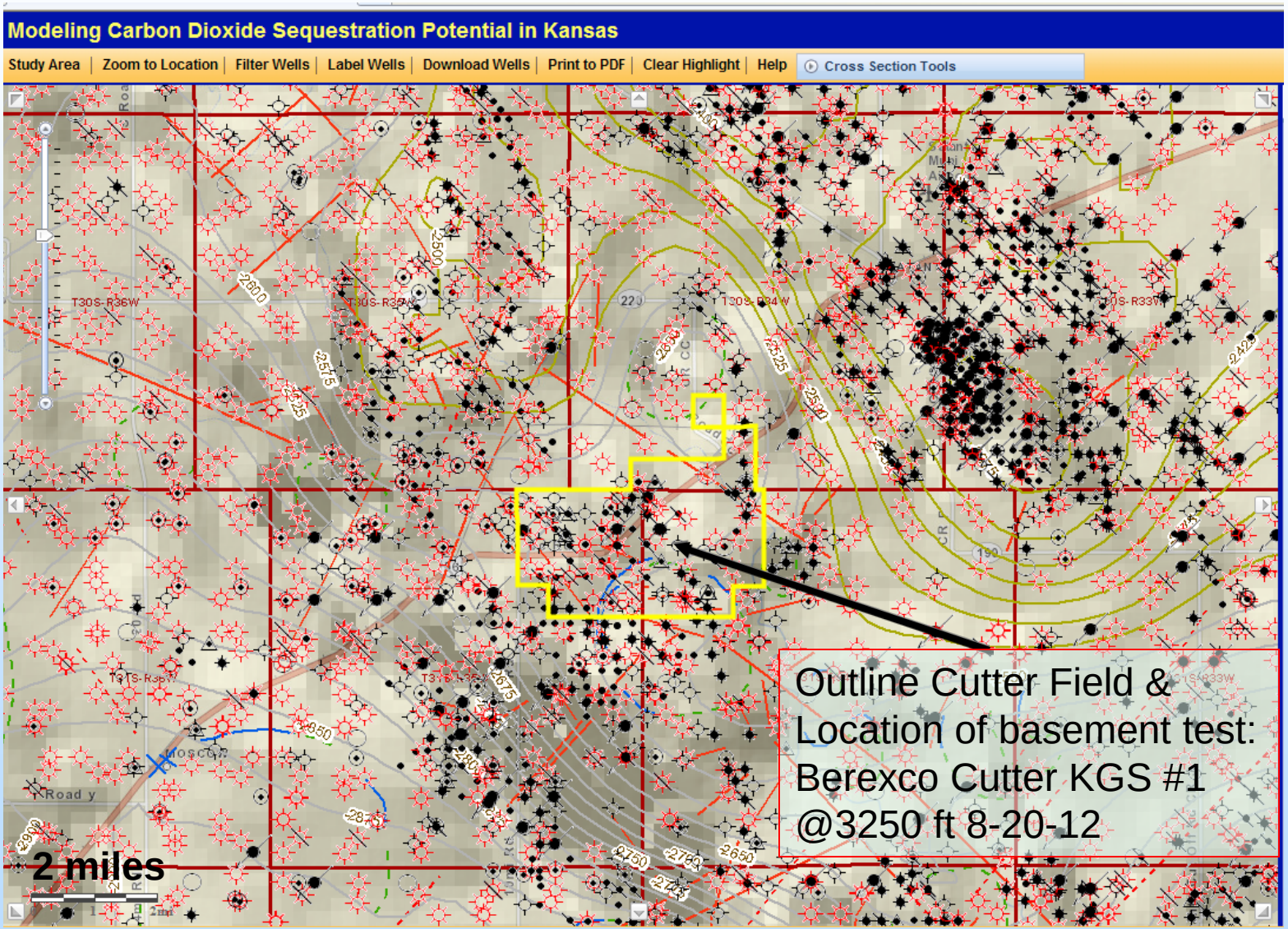


Dubois, 2012

Example from modeling of Pleasant Prairie South

Cutter Field drill site, SW Kansas

Top Mississippian (contours), surface lineaments (red lines), Lower Permian top Ft. Riley Ls. dip gradient (gray shading)



Accomplishments to Date

- KGS Milestone 1.2: Acquire/analyze seismic, geologic and engineering data - Wellington field -- COMPLETED
- KGS Milestone 1.3: Develop initial geomodel for Wellington field -- COMPLETED
- KGS Milestone 1.4: Locate and initiate drilling of Well #1 at Wellington field -- COMPLETED
- KGS Milestone 2.1: Complete Well#1 at Wellington - DST, core, log, case, perforate, test zones -- COMPLETED
- KGS Milestone 2.2: Complete Well#2 at Wellington - Drill, DST, log, case, perforate, test zones -- COMPLETED
- KGS Milestone 2.3: Update Wellington geomodels - Arbuckle & Mississippian – 85%
- KGS Milestone 2.4: Evaluate CO2 Sequestration Potential of Arbuckle Group Saline Aquifer - Wellington field – 85%
- KGS Milestone 3.1: CO2 sequestration & EOR potential - Wellington field – 85%
- KGS Milestone 3.2: Characterize leakage pathways - Risk assessment area – 85%
- KGS Milestone 3.3: Risk assessment related to CO2-EOR and CO2-sequestration – 70%
- KGS Milestone 3.4: Regional CO2 Sequestration Potential - 33 Counties – 50%

Summary

- **Key findings**
  - 1. Initial estimates of CO_2 P10 & P90 Arbuckle aquifer storage are 8.8 and 75.5 billion metric tons.
  - 2. Core, logs, seismic, DST, geochemical and microbial analysis, and step-rate test at Wellington Field indicates that lower Arbuckle is *a primary injection interval* (~200 ft thick) overlain by widespread thick (400 ft) *baffle/barrier in mid Arbuckle*.
  - 3. Geochemical and microbial analyses indicate that upper and lower portions of the Arbuckle saline aquifer are not in hydraulic communication.
  - 4. Thick (~120 ft) primary caprock in lower Mississippian ("Pierson Fm.") augments the Chattanooga Shale in south-central Kansas.
  - 5. Simulation of Pleasant Prairie South, indicates 1.38 million tons of CO_2 could be injected during CO_2-EOR at ~5 mcf CO_2/bbl of oil.
- **Lessons Learned**
  - Seismic processing and interpretation is an iterative process.
  - Working with enthusiastic and engaged petroleum industry partners incorporates local knowledge and extend ownership of CCUS in Kansas.
- **Future Plans**
  - Complete geomodels and simulations in SW Kansas fields and Wellington
  - Refine regional CO_2 storage estimates from quantitative analysis of LAS log files and static and dynamic modeling at 8 sites
  - Complete drilling and evaluation of Cutter KGS #1
  - Complete project 8-7-13

Appendix

Organizational Chart

W. Lynn Watney & Jason Rush, Joint PIs,
Kansas Geological Survey
Kansas Center for Research (KUCR) – contracting, financial assurance, compliance

UNIVERSITY OF KANSAS

Kansas Geological Survey
Co-Principal Investigators
Kerry D. Newell, Co-PI -- stucture and diagenesis
Jason Rush, Co-PI -- Petrel geomodeling and data integration
Richard Miller, Co-PI -- seismic interpretation, shearwave analysis
John Doveton, Co-PI -- log petrophysics and core-log modeling
Jianghai Xia, Co-PI -- gravity-magnetics modeling & interpretation
Marios Sophocleous, Co-PI -- aquifer modeling & well testing

Key Personnel
John Victorine -- Java web app development
David Laflen -- manage core & curation
Mike Killion -- modify ESRI map service for project
Database Manager (TBD) -- manage and integrate data

KU Department of Geology
Evan Franseen, Co-PI -- stratigraphy and diagenesis of OPAS
Robert Goldstein, Co-PI -- diagenesis, fluid inclusion
Grad Research Asst 2 years
David Fowle, Co-PI -- reactive pathways, microbial catalysis
Jennifer Roberts, Co-PI -- reactive pathways, microbial catalysis
Geology Technician (TBD) - fluid/rock handling
Grad Research Asst - 1 year

Services
LOGDIGI, LLC, Katy, TX - wireline log digitizing
Petrographics, Montrose, CO - thin section preparation
KOGER, Dallas, TX - remote sensing data and analysis

SUBCONTRACTS

Kansas State University - Seismic and Geochemical Services
PI- Saugata Datta -- reactive pathways and reaction constants
PI- Abdelmoneam Raef -- seismic analysis and modeling
GRA 1- Datta- aqueous geochemistry
GRA 2- Raef - seismic analysis and modeling

Bittersweet Energy, Inc., Wichita, KS
Tom Hansen, Principal, Wichita, Geological Supervision - regional data, hydrogeology of Arbuckle
Geological Consultant 1 -- regional data acquisition
Geological Consultant 2 -- regional data acquisition
Student Consultant -- regional data acquisition
Ken Cooper, Petrotek Engineering, Littleton, CO- engineer, well injection, hydrogeology
John Lorenz, FractureStudies, Edgewood, NM -- strucutural analysis

CMG - Simulation Services, Calgary, Alberta
simulation software and Greenhouse Gas Simulation Consultancy

Weatherford Laboratories, Houston, TX
core analyses

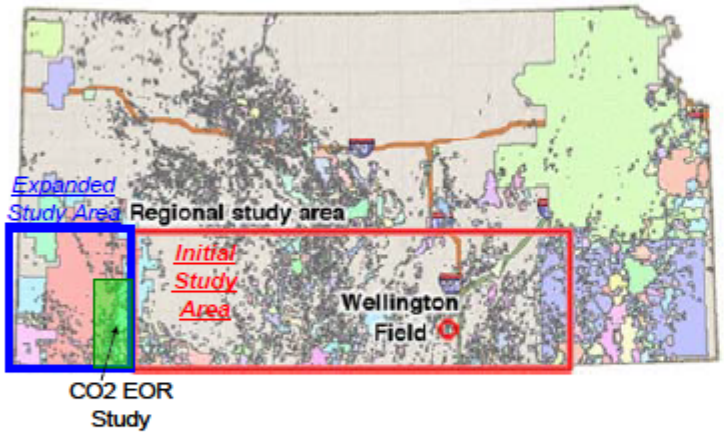
Berexco, Beredco Drilling -- Wichita, KS
access to Wellington Field; drilling, coring, completion and testing; participation in modeling and simulation
Key Berexco staff
Dana Wreath - manager, reservoir and production engineer
Randy Koudele - reservoir engineer
Bill Lamb - reservoir engineer
Halliburton, Liberal, KS -- wireline logging services
Hedke-Saenger Geoscience, LTD., Wichita, KS - geophysical acquistion design,seismic interpretation
Susan E. Nissen, McLouth, KS -- Geophysical Consultant - volumetic curvature
Lockhart Geophysical, Denver, CO -- 2D shear wave acquisition, gravity & mag acquis. & interpret
Fairfield Industries, Inc., Denver, CO -- 2D, 3D multicomponent processing
Paragon Geophysical Services, Wichita, KS -- 3D seismic acquisition
Echo Geophysical, Denver, CO -- 3D processing
Converging Point - QC seismic acquisition

Noble Energy, Houston, TX; Denver, CO -- collaborating company, fields adjoining Wellington

Organizational chart (continued)

Southwest Kansas CO2 EOR Initiative
Chester and Morrow Reservoirs

Western Annex to Regional CO2 Sequestration Project (DE-FE0002056) run by the Kansas Geological Survey



Six Industry partners:

- Anadarko Petroleum Corp.
- Berexco LLC
- Cimarex Energy Company
- Glori Oil Limited
- Elm III, LLC
- Merit Energy Company

Support by:
Sunflower Electric Power Corp.

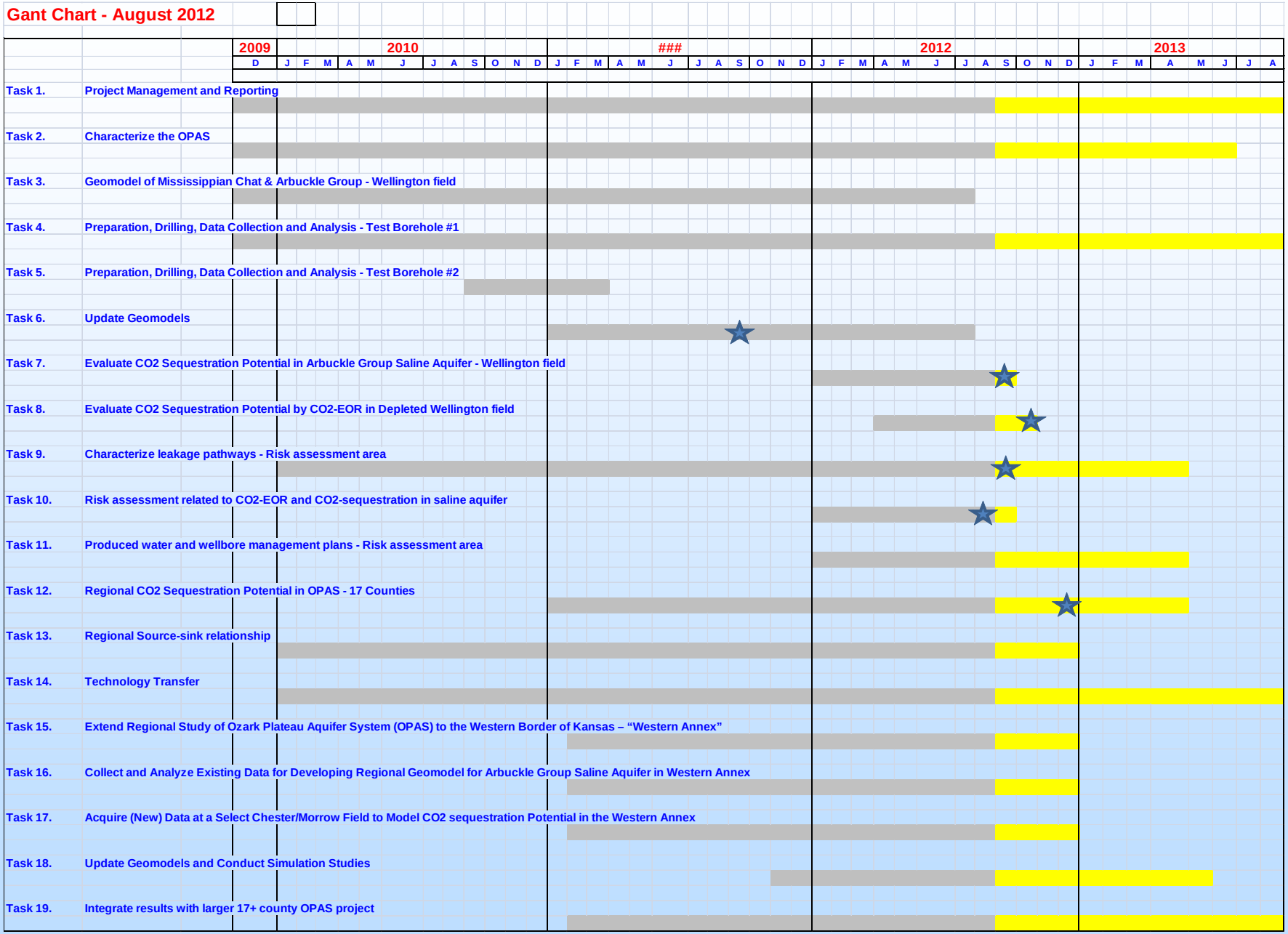
The SW Kansas part of project

- CO2 EOR technical feasibility study – Chester IVF and Morrow
- Part of larger KGS-industry CCS and EOR study
- Will not inject CO2 – paper study only
- Get fields in study "CO2-ready"

Technical Team:

	Project Role	Company
Martin Dubois	Team Lead, geo-model	IHR LLC
John Youle	Core and depo-models	Sunflower Energy
Ray Sorenson	Data sleuth and advisor	Consultant
Eugene Williams	Reservoir engineering	Williams Petroleum
Dennis Hedke	Geophysicist	Hedke & Saenger
Peter Senior	Reservoir modeling	MS student, KU
Susan Nissen	Geophysicist	Consultant
Lynn Watney	Project PI	KGS
Jason Rush	Project PI	KGS
John Doveton	Log Petrophysics	KGS
Tom Hansen	Subcontract mngr., aquifer	Bittersweet Energy
Paul Gerlach	Regional stratigraphy, data	Charter Consulting
Larry Nicholson	Regional stratigraphy, data	Consultant

Gantt Chart


Gant Chart - August 2012
2009
2010
###
2012
2013
D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
Task 1. Project Management and Reporting
Task 2. Characterize the OPAS
Task 3. Geomodel of Mississippian Chat & Arbuckle Group - Wellington field
Task 4. Preparation, Drilling, Data Collection and Analysis - Test Borehole #1
Task 5. Preparation, Drilling, Data Collection and Analysis - Test Borehole #2
Task 6. Update Geomodels
Task 7. Evaluate CO2 Sequestration Potential in Arbuckle Group Saline Aquifer - Wellington field
Task 8. Evaluate CO2 Sequestration Potential by CO2-EOR in Depleted Wellington field
Task 9. Characterize leakage pathways - Risk assessment area
Task 10. Risk assessment related to CO2-EOR and CO2-sequestration in saline aquifer
Task 11. Produced water and wellbore management plans - Risk assessment area
Task 12. Regional CO2 Sequestration Potential in OPAS - 17 Counties
Task 13. Regional Source-sink relationship
Task 14. Technology Transfer
Task 15. Extend Regional Study of Ozark Plateau Aquifer System (OPAS) to the Western Border of Kansas – "Western Annex"
Task 16. Collect and Analyze Existing Data for Developing Regional Geomodel for Arbuckle Group Saline Aquifer in Western Annex
Task 17. Acquire (New) Data at a Select Chester/Morrow Field to Model CO2 sequestration Potential in the Western Annex
Task 18. Update Geomodels and Conduct Simulation Studies
Task 19. Integrate results with larger 17+ county OPAS project

Bibliography

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Software

Synthetic Seismic Profile Plot -- http://www.kgs.ku.edu/software/SS/
This web application is a well profile presentation of the well data plotted against acoustic travel time in millisecs with synthetic seismic plot tracks. In the same manner as Profile this program allows the user to turn plot tracks on or off or reorder the plot tracks. This web application requires sonic log curve data.

The synthetic seismogram is a seismic trace that has been constructed from well log data. It represents the idealize trace that should be observed with the seismic method at the location of the well. The Synthetic Seismic can be compared with the seismic trace actually measured at the well to improve the picking of seismic horizons, and to improve the accuracy and resolution of formations of interest.

The observed seismic trace is primarily a record of the ability of interfaces between formations to reflect elastic waves, which is called the reflection coefficient R. The reflection coefficient depends on the properties of the rock at the interface of the beds and in particular on its acoustic impedance. The acoustic impedance is the product of the seismic velocity and the density of the rock.
Author: John R. Victorine,
Released: 08 June 2012

Bibliography

Drill Stem Test (DST) Data Entry & Quantitative Analysis
-- http://www.kgs.ku.edu/software/DST/
This Java Applet allows the user to enter or import Drill Stem Test (DST) Data directly into the program. There are essentially no standard ASCII DST data files formats existing that will allow the user to read and process DST Data. This program was written to assist the user in entering DST data, perform quantitative analysis on the shut in pressure data and then to save the information into a Log ASCII Standard (LAS) version 3.0 File developed by the Canadian Well Logging Society.

This program has a built in digitizer to allow the user to digitize shut in pressure-temperature-time data from a DST pressure vs. time image file directly to the program to create a Horner Plot and to do Quantitative Analysis.

Note: The DST Pressure vs. Time Image must be a PNG (Portable Network Graphics), JPEG (Joint Photographic Experts Group) or GIF (Graphics Interchange Format) image file.
Author: John R. Victorine,
Released: 17 May 2012

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PfEFFER-java -- http://www.kgs.ku.edu/software/PfEFFER-java/
PfEFFER-java will replace PfEFFER Pro which is a practical tool for the real-time, interactive log analysis. "Spreadsheet" database and graphic features allow both rapid interaction and comparative evaluation of multiple interpretations or best case/worst case extremes. In addition, multiple zones are easily managed. This Applet is an interactive web application that allows the user to search & load data from the user's PC or from the Kansas Geological Survey (KGS) database & file server.
Author: John R. Victorine,
Java Math Package: Geoffrey C. Bohling
Pickett Plot: Glen Gagnon
Released: 1 March 2012

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Zone Kluster ("ZeKe") - A Depth Constrained Cluster Analysis
-- **http://www.kgs.ku.edu/stratigraphic/ZONATION/**
Depth Constrained Cluster Analysis is an interactive plot applet, which was created to allow the user the ability to pick Zones from log data using digital Log ASCII Standard (LAS) version 2.0 & 3.0 files which are ordered along the dimensions of depth. This constraint can be used to limit the analysis to the consideration of stratigraphically neighboring units, thus only vertically adjacent zones and clusters may be merged into larger clusters. Depth Constrained Cluster Analysis appeared in PfEFFER Pro an Excel Spread Sheet Program developed by the Kansas Geological Survey, released 1998. It also appeared in GEMINI (Geo-Engineering Modeling through INternet Informatics) web application developed by Kansas Geological Survey 2000 - 2003. The user can create Portable Network Graphics (PNG) images of the displayed plot.
Author: John R. Victorine,
Java Math Package: Geoffrey C. Bohling
Released: 1 January 2011

Bibliography

PROFILE
(Expanded LAS File Viewer) –
http://www.kgs.ku.edu/stratigraphic/PROFILE/
The Profile Plot Applet was created to assist the user in locating, organizing and plotting well data, rock measured & observational data and formation tops data by depth. This Applet is an interactive web application that allows the user to search, load, parse geological data from the user's PC or from the Kansas Geological Survey (KGS) database & file server. This Applet also provides edit data dialogs to add or modify geological data in the profile plot.

NOTE: This web application is an expanded version of the LAS File Viewer. This version allows the user to input up to 3 Log ASCII Standard (LAS) Files for a single well at one time. This version also allows the user to input delimited ASCII geologist report (measured sections, core description, etc.).
Author: John R. Victorine
Released: 23 May 2011

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Cross Section Web Site –
http://www.kgs.ku.edu/stratigraphic/CROSS_SECTION/
The Cross Section Plot Applets allows the user to place multiple well profiles or rock outcrops on one plot to better pick the horizons and a better understanding of the subsurface geology over an area.

"Correlation of petroleum reservoirs is a fundamental task in reservoir characterization used to establish the geometry of the reservoir and strata surrounding it and to delimit the distribution of flow units that comprise the reservoir. Correlations are primarily accomplished via construction of cross sections through the reservoir using wireline logs where depth patterns, trends, and surfaces define probable continuity within the reservoir between well locations. The correlations are validated through analyses of fluids recovered, flow tests, and possibly seismic surveys, in the later case if the reservoir is sufficiently thick to be seismically resolvable. Cross sections display the log curves at various scales and, to be effective, should show formation and reservoir tops, correlation surfaces, intervals of tests, perforations for production, and intervals that are considered flow units that are correlatable and connected between wells."
GEMINI Project
Author: John R. Victorine
Released: 01 July 2011

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Cross Plot Web Site -- http://www.kgs.ku.edu/stratigraphic/XPLOT/
The Cross Plot Applet was created to assist the user in plotting Log ASCII Standard (LAS) Data and Measured Core Data in a standard 2D Plots. This Applet is an interactive web application that allows the user to search, load, parse geological data from the user's PC or from the Kansas Geological Survey (KGS) database & file server. The user can display the following plots,

XY Plot User selects the curves from the data curves loaded.
Rhomaa-Tmaa Plot Apparent Matrix Density (Rhomaa) - Apparent Acoustic Transit Time (Tmaa) cross plot
MN Plot Litho-Porosity cross plot "M" and "N" from the Sonic-Density-Neutron logging data
Rhomaa-Umaa Plot Apparent Matrix Density (Rhomaa) - Apparent Photoelectric Factor (Umaa) cross plot
Rhomaa-NPHI Plot Apparent Matrix Density (Rhomaa) - Neutron Porosity (NPHI) cross plot
Porosity Difference Plot Porosity Difference cross plot
Th-K Plot Thorium - Potassium cross plot
Th-U Plot Thorium - Uranium cross plot
Th/K - Th/U Plot Spectral Gamma Ray Ratio cross plot

The program allows the user to filter the data by depth range, Shale Levels [Gamma Ray (API) Log Data], Clay Minerals [Thorium-Potassium Ratio Mineral data], Tops Data, Lithology/Texture Descriptions.
Author: John R. Victorine
Released: 19 September 2011

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3D Cross Plot Web Site -- http://www.kgs.ku.edu/stratigraphic/3DPLOT/
The 3D Cross Plot Applet was created to assist the user in plotting Log ASCII Standard (LAS) Data and Measured Core Data in a standard 3D Plot. This Applet is an interactive web application that allows the user to search, load, parse geological data from the user's PC or from the Kansas Geological Survey (KGS) database & file server. The user can display the following plots,

XYZ Plot User selects the curves from the data curves loaded.
Rhomaa-Tmaa-GR Plot Apparent Matrix Density (Rhomaa) - Apparent Acoustic Transit Time (Tmaa) - Gamma Ray (GR) cross plot
MN-GR PlotLitho-Porosity cross plot "M" and "N" from the Sonic-Density-Neutron logging data
Rhomaa-Umaa-GR Plot Apparent Matrix Density (Rhomaa) - Apparent Photoelectric Factor (Umaa) - Gamma Ray (GR) cross plot
Rhomaa-NPHI-GR Plot Apparent Matrix Density (Rhomaa) - Neutron Porosity (NPHI) - Gamma Ray (GR) cross plot
Porosity Difference Plot (Neutron Porosity-Density Porosity) vs Neutron Porosity (NPHI) - Gamma Ray (GR) cross plot
Th-K-U Plot Thorium - Potassium - Uranium cross plot
Th-U-K Plot Thorium - Uranium - Potassium cross plot
Th/K-Th/U-GR Plot Spectral Gamma Ray Ratio cross plot

The program allows the user to filter the data by depth range, Gamma Ray (API) Log Data, Thorium-Potassium Ratio Mineral data, Tops Data, Lithology/Texture Descriptions.
Author: John R. Victorine
Released: 28 September 2011