DOE F 4600.2
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ATTACHMENT 3
U.S. Department of Energy
FEDERAL ASSISTANCE REPORTING CHECKLIST AND INSTRUCTIONS

<table>
<tr><td>1. Identification Number:
DE-FE0002056</td><td colspan="3">2. Program/Project Title:
Modeling CO2 Sequestration in Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO2 Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas</td></tr>
<tr><td colspan="4">3. Recipient:
University of Kansas Center for Research</td></tr>
<tr><td>4. Reporting Requirements:</td><td>Frequency</td><td>No. of Copies</td><td>Addresses</td></tr>
<tr><td>A. MANAGEMENT REPORTING
☒ Progress Report
☒ Special Status Report</td><td>Q
A</td><td>Electronic Version to NETL></td><td>FITS@NETL.DOE.GOV</td></tr>
<tr><td>B. SCIENTIFIC/TECHNICAL REPORTING *
(Reports/Products must be submitted with appropriate DOE F 241. The 241 forms are available at https://www.osti.gov/elink)
<u>Report/Product</u> — <u>Form</u>
☒ Final Scientific/Technical Report — DOE F 241.3
☒ Conference papers/proceedings/etc.* — DOE F 241.3
☐ Software/Manual — DOE F 241.4
☒ Other (see special instructions)
Topical — DOE F 241.3
* Scientific/technical conferences only</td><td>FG
A

A</td><td>Electronic Version to E-link></td><td>http://www.osti.gov/elink-2413
http://www.osti.gov/elink-2413
http://www.osti.gov/estsc/241-4pre.jsp</td></tr>
<tr><td>C. FINANCIAL REPORTING
☒ SF-425, Federal Financial Report</td><td>Q, FG</td><td>Electronic Version To NETL></td><td>FITS@NETL.DOE.GOV</td></tr>
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☐ Property Certificate
☐ Other</td><td>FC
FC</td><td>Electronic Version To NETL></td><td>FITS@NETL.DOE.GOV</td></tr>
<tr><td>E. OTHER REPORTING
☒ Annual Indirect Cost Proposal
☒ Annual Inventory Report of Federally Owned Property, if any
☐ Other</td><td>A
A</td><td>Electronic Version To NETL></td><td>FITS@NETL.DOE.GOV</td></tr>
<tr><td>F. AMERICAN RECOVERY AND REINVESTMENT ACT REPORTING
☐ Reporting and Registration Requirements</td><td></td><td></td><td>http://www.federalreporting.gov</td></tr>
<tr><td colspan="4">FREQUENCY CODES AND DUE DATES:
A - As required; see attached text for applicability.
FG - Final; within ninety (90) calendar days after the project period ends.
FC - Final - End of Effort.
Q - Quarterly; within thirty (30) calendar days after end of the calendar quarter or portion thereof.
S - Semiannually; within thirty (30) calendar days after end of project year and project half-year.
YF - Yearly; 90 calendar days after the end of project year.
YP - Yearly Property - due 15 days after period ending 9/30.</td></tr>
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QUARTERY PROGRESS REPORT

Award Number: DE-FE0002056

Recipient: University of Kansas Center for Research &

Kansas Geological Survey

1930 Constant Avenue

Lawrence, KS 66047

"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 Director/Principal Investigator: W. Lynn Watney

Principal Investigator: Jason Rush

Eighth Quarter Progress Report

Date of Report: October 31, 2011

Period Covered by the Report: July 1, 2011 through September 30, 2011

Contributors to this Report: Ralph Baker, Robinson Barker, Ken Cooper, Saugata Datta, Martin Dubois, Paul Gerlach, Dennis Hedke, Tom Hansen, Dave Koger, Randy Koudele, Larry Nicholson, Jen Roberts, Jason Rush, Aimee Scheffer, John Victorine, Lynn Watney, John Youle, Dana Wreath

EXECUTIVE SUMMARY

The project "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" is focused on the Paleozoic-age Ozark Plateau Aquifer System (OPAS) in southern Kansas. OPAS is comprised of the thick and deeply buried Arbuckle Group saline aquifer and the overlying Mississippian carbonates that contain large oil and gas reservoirs. The study is collaboration between the KGS, Geology Departments at Kansas State University and The University of Kansas, BEREXCO, INC., Bittersweet Energy, Inc. Hedke-Saenger Geoscience, Ltd., Improved Hydrocarbon Recovery (IHR), Anadarko, Cimarex, Merit Energy, GloriOil, and Cisco.

The project has three areas of focus, 1) a field-scale study at Wellington Field, Sumner County, Kansas, 2) 25,000 square mile regional study of a 33-county area in southern Kansas, and 3) selection and modeling of a depleting oil field in the Chester/Morrow sandstone play in southwest Kansas to evaluate feasibility for CO2-EOR and sequestration capacity in the underlying Arbuckle saline aquifer. Activities at Wellington Field are carried out through BEREXCO, a subcontractor on the project who is assisting in acquiring seismic, geologic, and engineering data for analysis. Evaluation of Wellington Field will assess miscible CO_2-EOR potential in the Mississippian tripolitic chert reservoir and CO_2 sequestration potential in the underlying Arbuckle Group saline aquifer. Activities in the regional study are carried out through Bittersweet Energy. They are characterizing the Arbuckle Group (saline) aquifer in southern Kansas to estimate regional CO_2 sequestration capacity. Supplemental funding has expanded the project area to all of southwest Kansas referred to as the Western Annex. IHR is managing the Chester/Morrow play for CO2-EOR in the western Annex while Bittersweet will use new core and log data from basement test and over 200 mi^2 of donated 3D seismic. IHR is managing the industrial partnership including Anadarko Petroleum Corporation, Cimarex Energy Company, Cisco Energy LLC, Glori Oil Ltd., and Merit Energy Company. Project is also supported by Sunflower Electric Power Corporation.

Project Status: Subtasks completed till date include: 1) 3D seismic survey at Wellington field (Sumner County, KS) processed and p-wave interpreted, 2) Wellington field seismic data merged with donated 3D seismic data from the adjacent Anson and Bates fields, 3) Wellington 3D seismic interpretation includes structure, time slices, volumetric coherency, curvature, and fault/flexure mapping, 4) two test boreholes drilled in Wellington Field, 5) gravity and magnetic surveys over 17+ county regional study area have been reprocessed and suggested basement faults/fracture trends mapped for validation, 6) remote sensing data over 17+ county regional study area analyzed and surface lineaments mapped, 7) multiple stratigraphic horizons have been mapped over regional study area, 8) multi-township areas selected within regional study area for detailed characterization and simulation studies to evaluate CO_2 sequestration potential in Arbuckle Group saline aquifer, 9) depth-constrained cluster analysis conducted on petrophysical properties to identify Arbuckle flow-units and analysis tool incorporated into Java petrophysical application, 10) initial simulation studies of Arbuckle conducted at Oxy-Chem #10 well to north of Wellington Field in Sedgwick County and at Wellington Field in Sumner County to make preliminary estimates of CO_2 sequestration potential, 11) available Arbuckle DST data collected, analyzed, and mapped showing hydraulic communication with northwestern Ozark uplift outcrop in Missouri, 12) website has been updated to include maps of latest subsurface geology, remote sensing analysis, and reprocessed gravity and magnetic information, 13) initial core description made, 14) release new log analysis Java web tool, and 15) updated interactive mapper with new legend and map section window.

Subtasks in progress: 1) nearly complete (75%) processing of converted (shear) wave and depth migrated seismic data at Wellington Field, 2) nearly completed with swab testing of #1-32 well to proceed when refined list of intervals is determined, 3) initial geochemical and microbiological analyses and results available from DSTs and existing swab tests from #-1-28 and #1-32, 4) special and routine core analysis from #1-32 is over 75% completed, 5) establishing consistent regional internal stratigraphy of the Arbuckle, 6) defining process to evaluate and establish regional faults and evaluate as potential leakage pathways, 7) re-evaluate selection of sites for more detailed mapping and later simulation using regional mapping, 8) nearly completed assessment of need to reprocess regional seismic donated by industry from southwestern Kansas, 9) collection and evaluation of geologic and engineering data from four Chester/Morrow sandstone producing fields in southwestern Kansas is well underway to use in evaluation fields as drilling locations and input for simulation, 10) proposals submitted by collaborating petroleum companies who operate Chester/Morrow fields in western Kansas to refine scoping cost for drilling, budget, and select operator for actual drilling, and 11) conducting intensive effort to evaluate quality control, normalize log response, and calibrate old log data.

ACCOMPLISHMENTS

Methods/Approach

REGIONAL STUDY

ONGOING AND COMPLETED ACTIVITIES concerning all or parts of 33 county study area

TASK 2. CHARACTERIZE THE OPAS

Subtask 2.2. Acquire geologic, seismic and engineering data

Updating software for managing petrophysical/log data

New petrophysical modules were added to the suite of Java routines including new tools for cross plots in 2D and 3D. The new tool is located under http://www.kgs.ku.edu/Gemini/Tools/Tools.html

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

The profile example is of the Mississippian System consisting of chert, dolomite, and shaly dolomite in the Berexco Wellington KGS #1-32. Depth-constrained clustering of the log curves gamma ray, Pe, and neutron and density porosity were used to divide the interval into 10 groups.

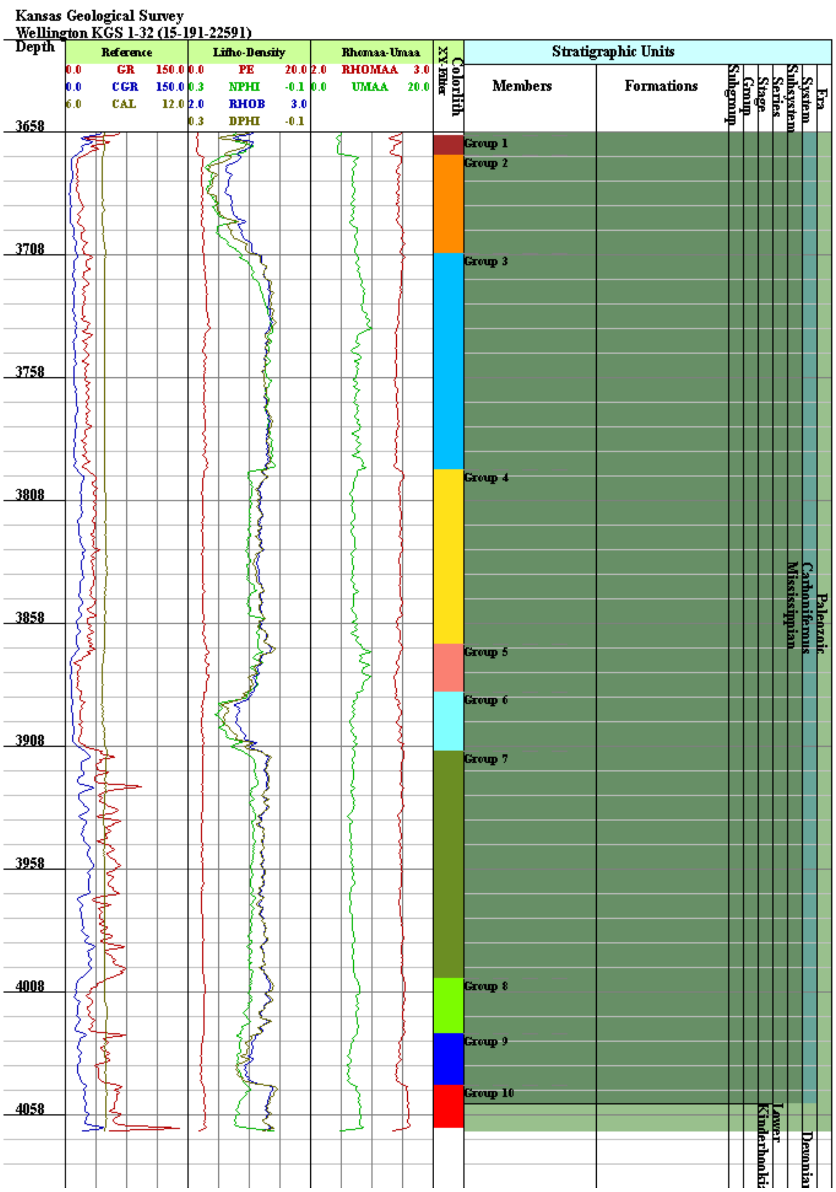


Figure 1. 10 division stratigraphy donated by depth-constrained clustering using petrophysical attributes of GR, Pe, neutron and density porosity.

Group 2 is the tripolite chert oil reservoir in Wellington Field. Group 9 is a probably new oil reservoir and the low porosity intervals, particularly Group 4 and 7 are tight intervals and may serve as barriers to augment the caprocks below the Mississippian in the Simpson Group and Chattanooga Shales, and above the Mississippian in the shales of the Cherokee Groups.

The new 3D plot option to show Rhomaa-Umaa and gamma ray is illustrated below based the Mississippian interval shown above in Figure 1.

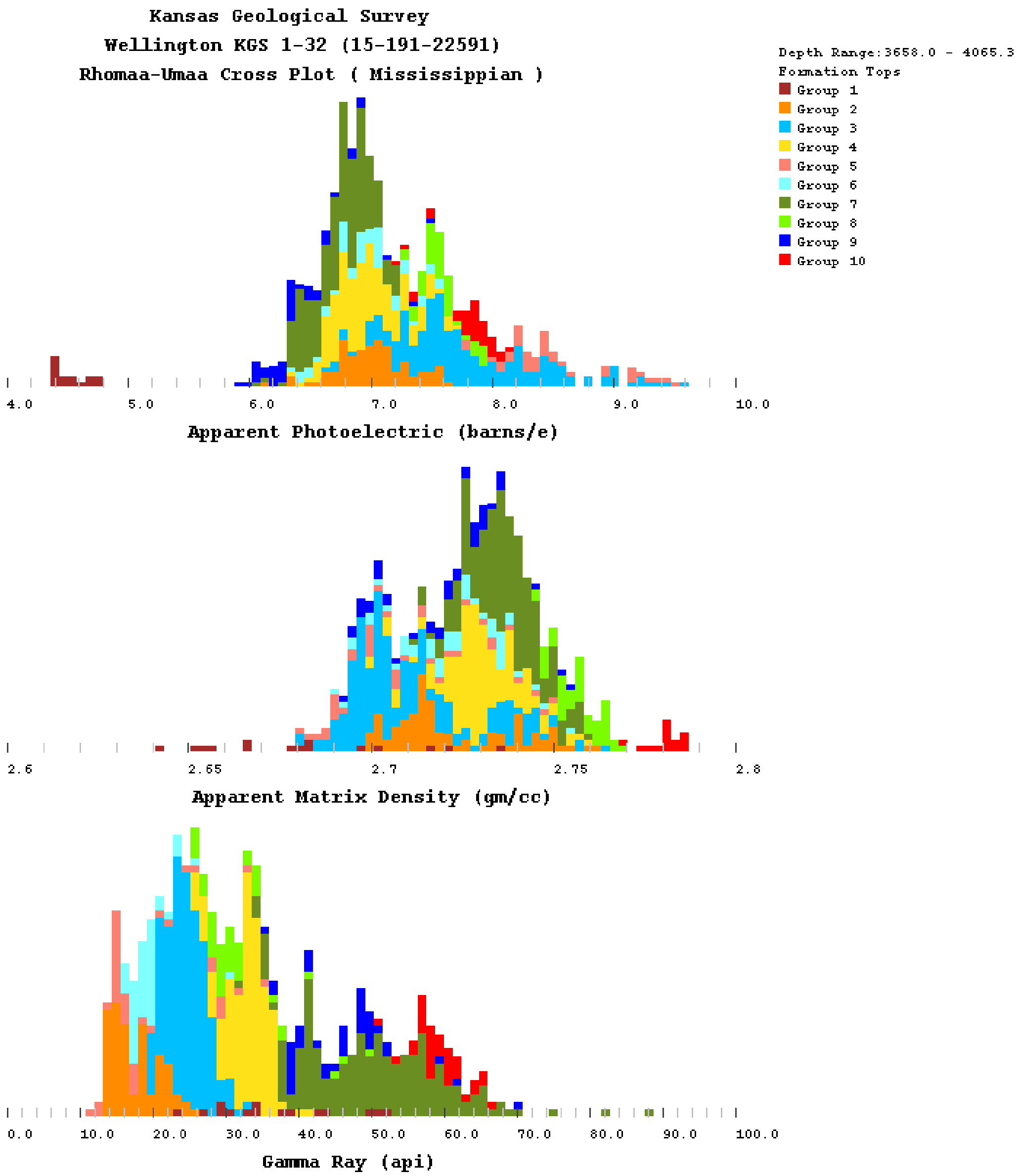


Figure 2. Cumulative histogram plots showing response of various layers from Figure 1 including apparent Pe, apparent matrix density, and gamma ray.

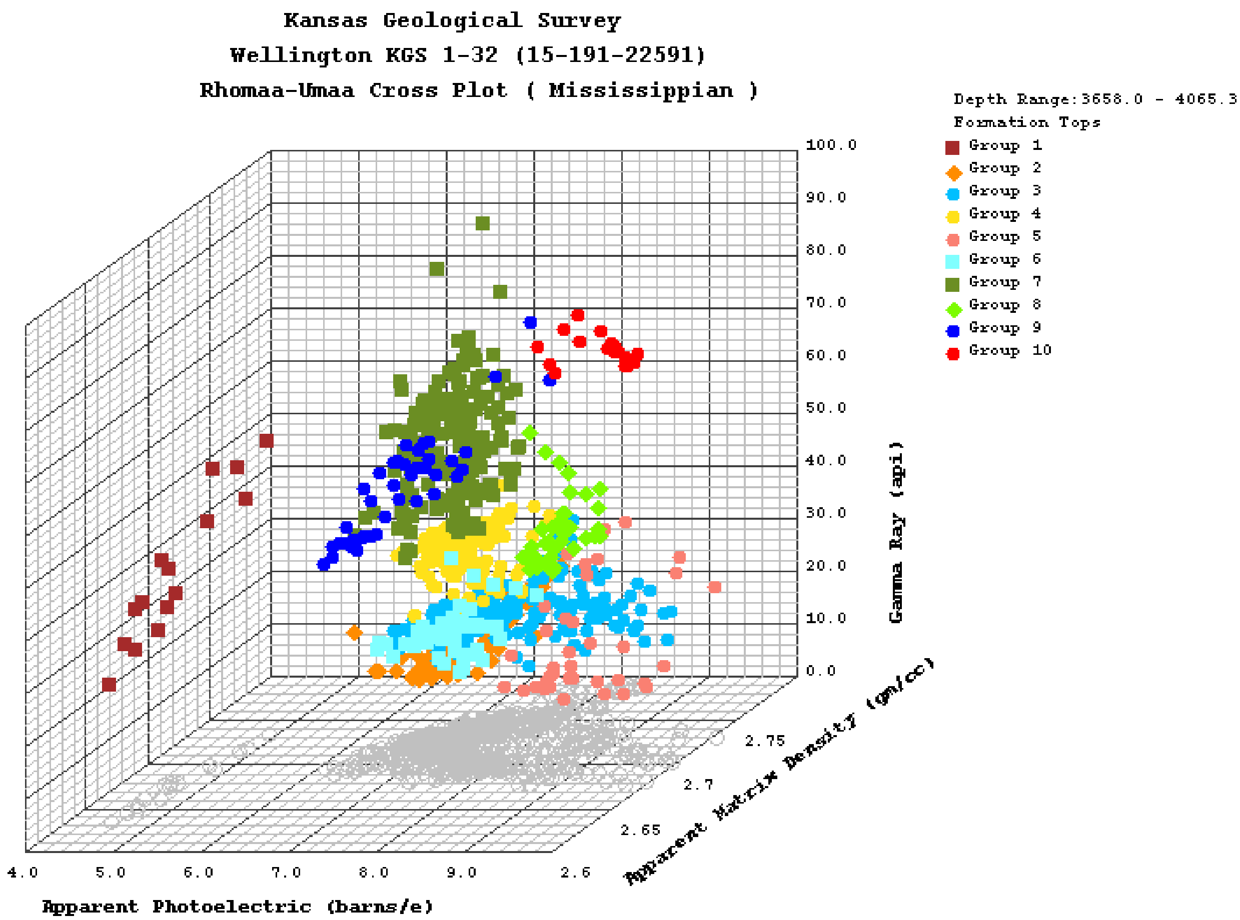


Figure 3. The 3D plot showing the 10 groups identified by color from Figure 1.

Figures 2 and 3 illustrate the cumulative histogram and the 3D plot for the Mississippian interval in Berexco Wellington KGS#1-32. The 3D plot has an interactive interface that permits changes in scales of the depth plot and axes of plots to be able to compare zones by key petrophysical properties.

Key Section 1 T: 7S R: 9E S: 3
Latitude: 39.471955 Longitude: -96.397877 Elevation (GL): 1425.0 Depth: 60.1

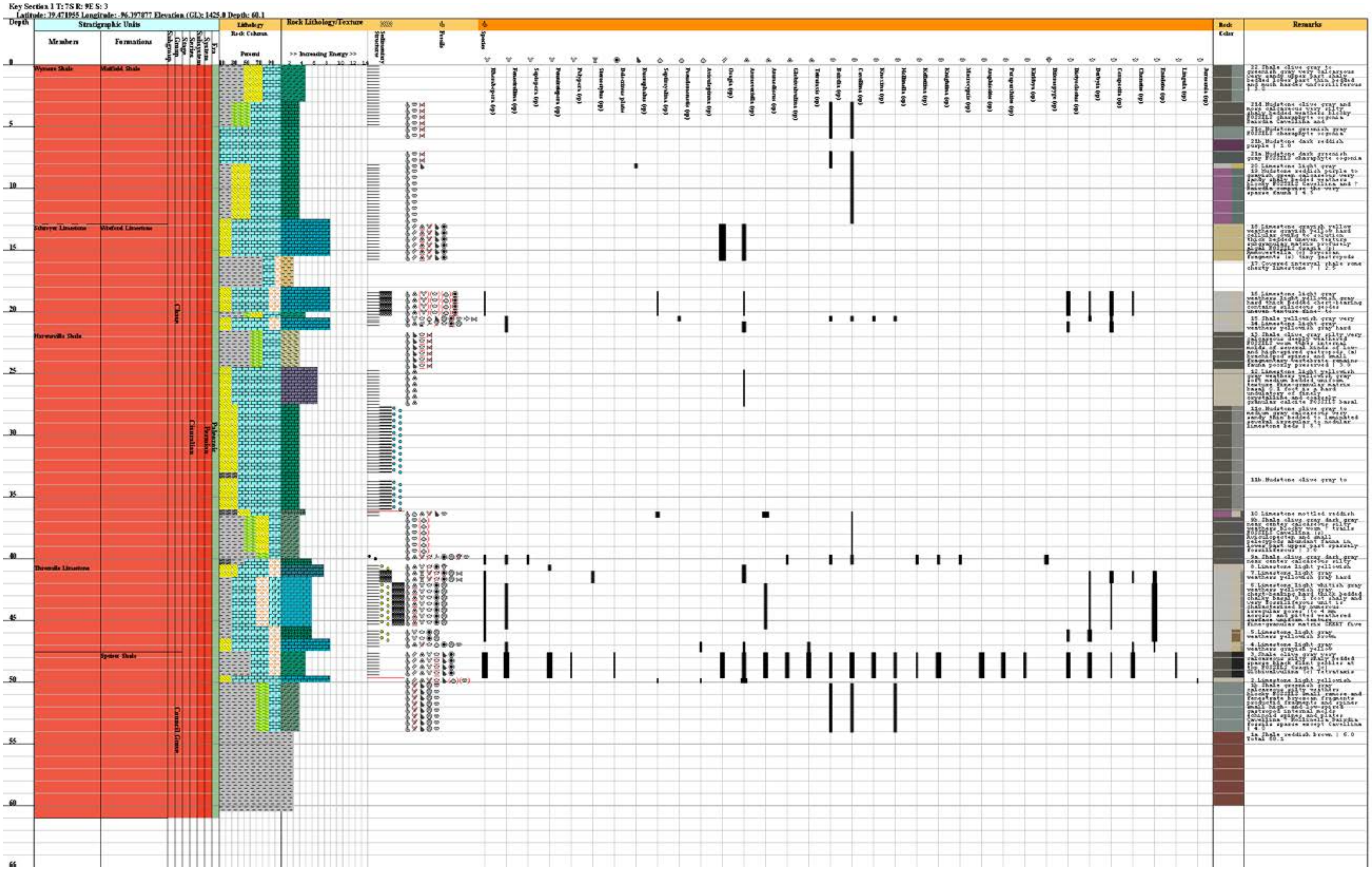


Figure 4 is beta version of stratigraphic profile parsed from a written geologic description that lists fossils, showing their relative abundances.

Task 9. Characterize leakage pathways - Risk assessment area

Subtask 9.2. Map fracture-fault network

Preliminary examination of previously published maps of faults is being compiled. Methodologies are also being examined to compare maps such as in Figure 5 to look for correlations (for example between subsurface structure and surface lineaments.

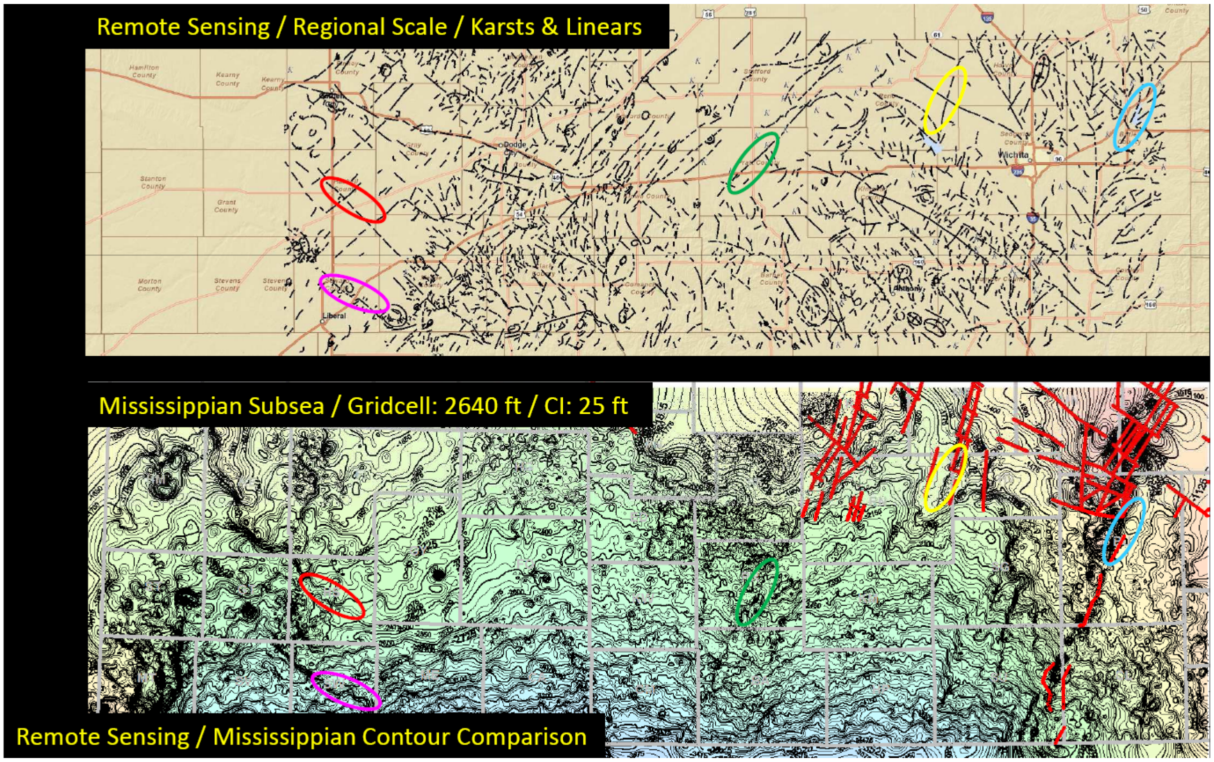


Figure 5. Visual correlation of surface lineaments (top) and subsurface structure (below).

Comparison also extends to gravity and magnetic maps (tilt angle processing) and structure (Precambrian surface) as illustrated in this set of maps (Figures 6 and 7).

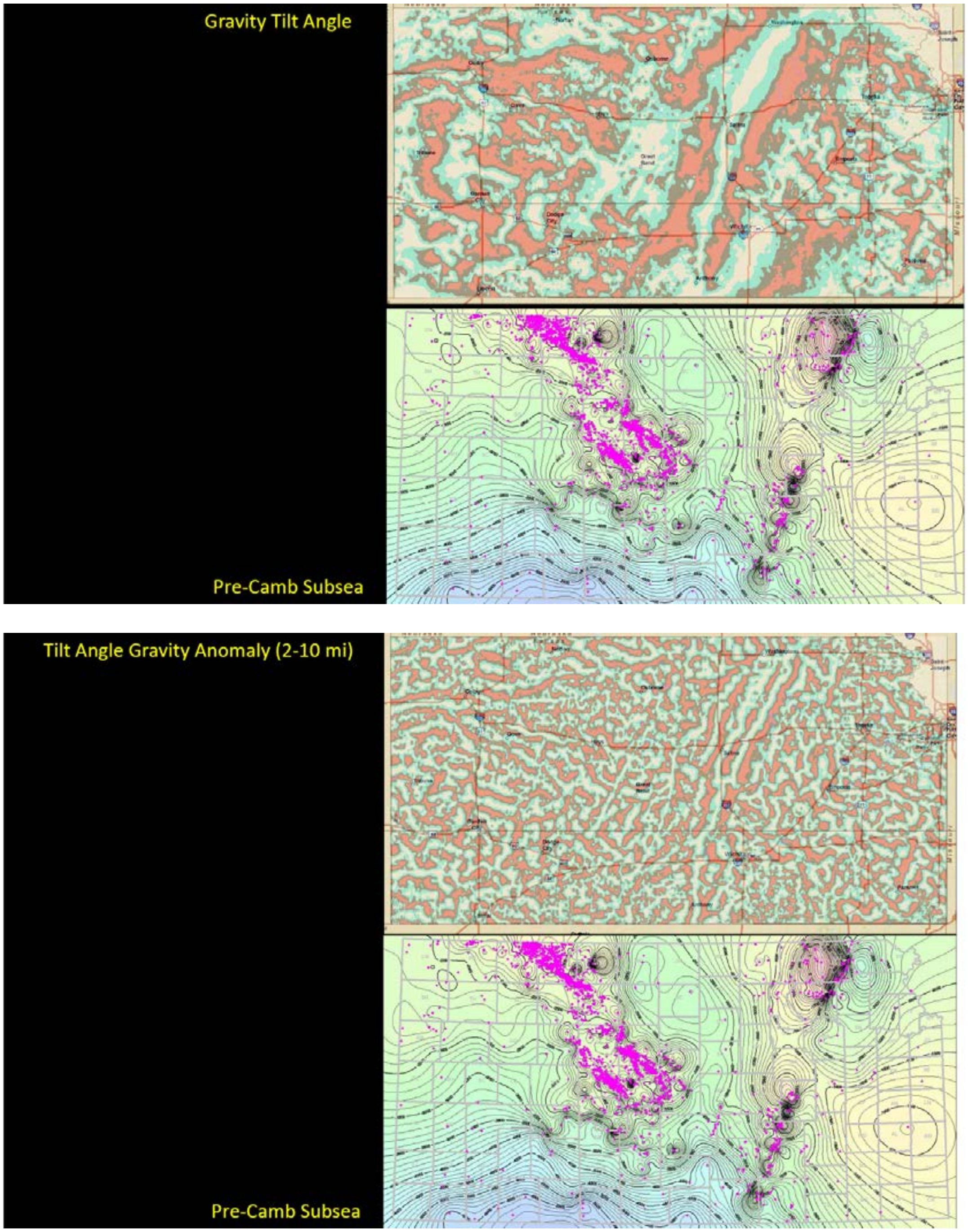
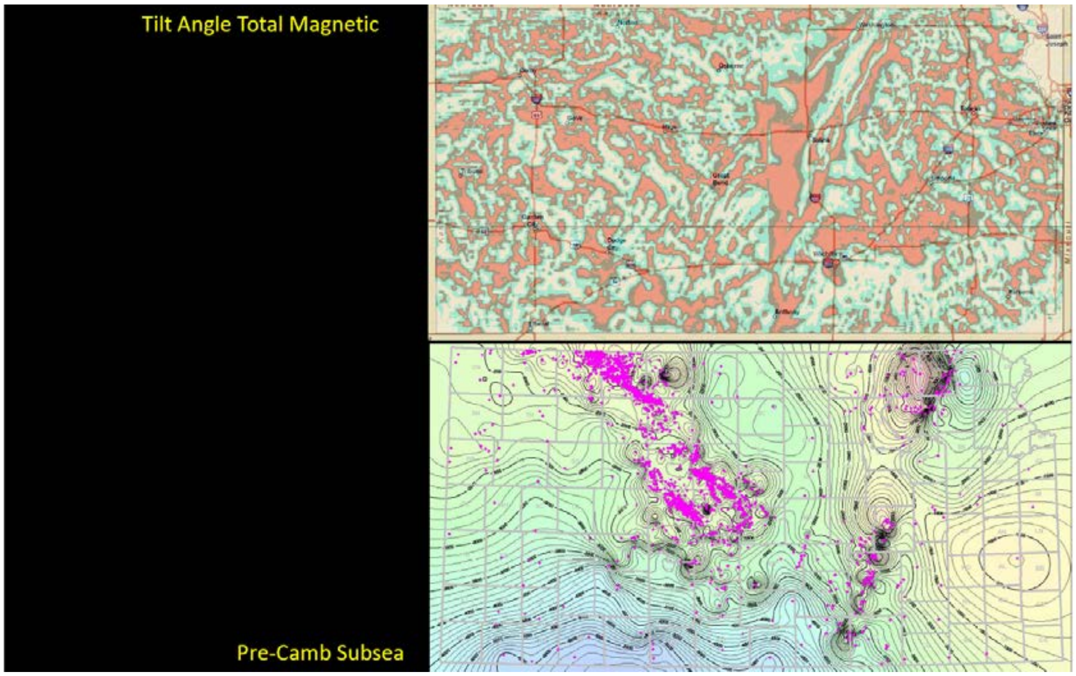


Figure 6. Gravity maps compared with Precambrian surface.



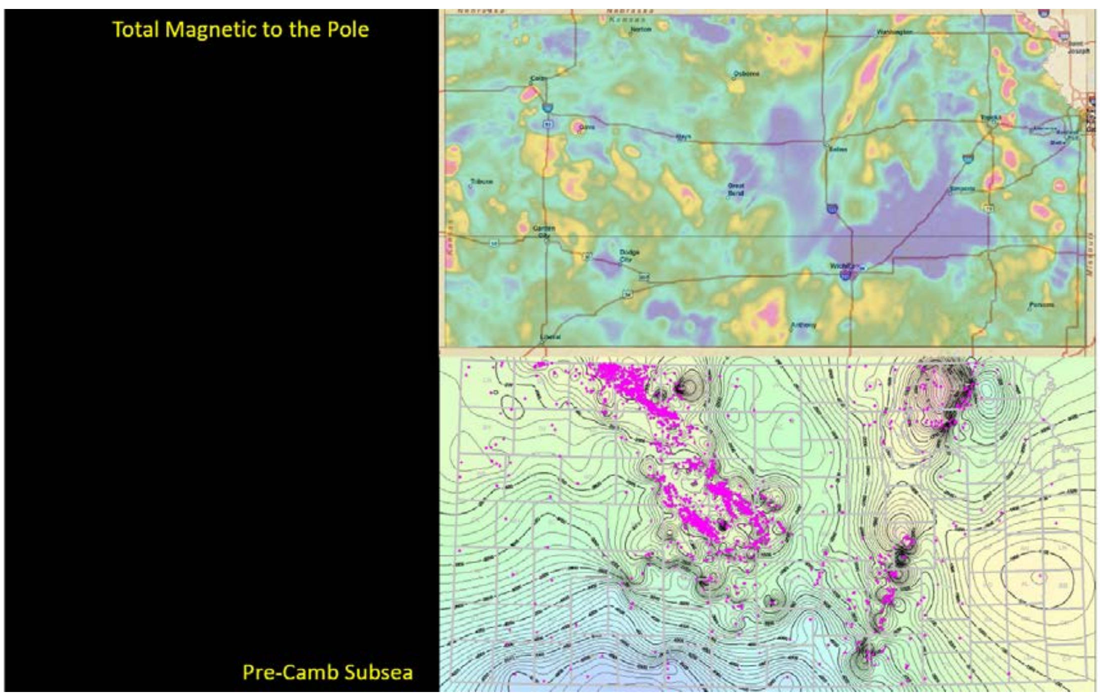


Figure 7. Magnetic maps compared with Precambrian surface.

Subtask 12.1. Map Arbuckle reservoir compartments

Eight (8) locations are being reevaluated from regional mapping as more likely sites for carbon sequestration. In addition criteria are being reviewed to define these areas that will eventually have coarse-grid geomodel built that will be used in simulations to estimate regional sequestration capacity.

WELLINGTON FIELD

Task 4. Preparation, Drilling, Data Collection and Analysis - Test Borehole #1

Subtasks 4.7. Perf, test, and sample fluids in Borehole #1 (BEREXCO Wellington KGS #1-32)

Step-Rate/Pulse Test Between Wellington #1-32 and #1-28 Wells in Wellington Field

Swab test and cross flow test intervals in Arbuckle and Simpson intervals (left side) & compared to DST intervals

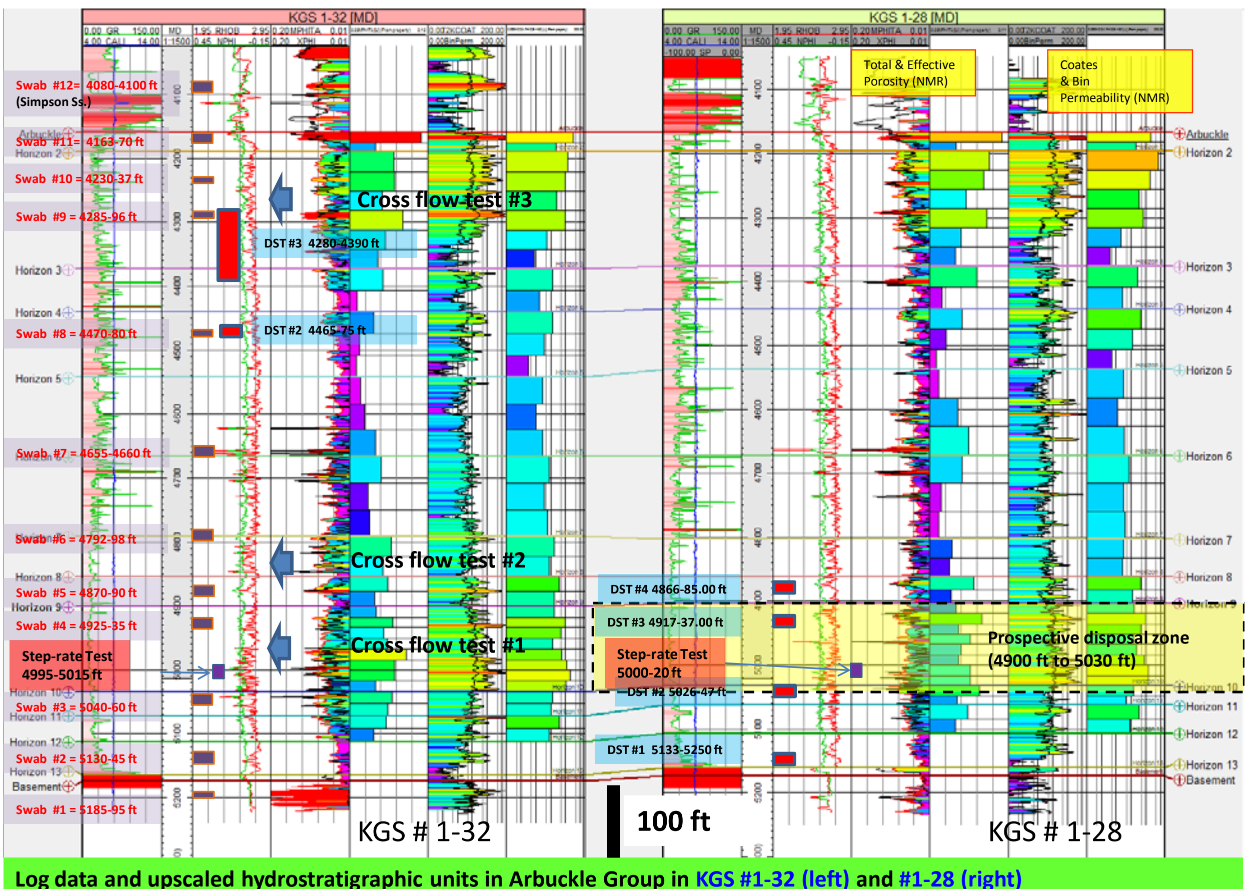


Figure 8. Step-rate test in correlatable 20 ft thick intervals in a high porosity-high permeability interval in lower Arbuckle Group. Correlations are shown between #1-32 left and #1-28 on right.

A step-rate test was conducted in August 2011 to measure fluid connectivity and estimate effective permeability between the two basement tests that reside 3000 feet apart in Wellington Field, the Wellington KGS #1-28 and #1-32. A single, 20-foot thick flow unit was perforated in the lower Arbuckle saline aquifer to help evaluate the use of this interval as a viable injection zone for CO_2.

The thin 20 ft thick flow unit resides within a longer ~120 interval containing stacked flow units that can be correlated with wireline logs (Figure 8). The objective of the test was to determine whether -- 1) zone has adequate permeability, 2) zone is isolated as a layer, 3) whether barrier may limit flow to the nearby well, and 4) whether fractures allow this flow unit to communicate with other flow unit above and below and thereby dispersing the fluid with a negative result.

Results indicate a successful pressure transient was established between the two boreholes. In fact, each step in varying injection rates in #1-32 were detected as pressure changes in the observation well, #1-28 (Figures 9 and 10). This positive test in the range of anticipated pressures indicates multiple darcies of permeability within this perforated flow unit. This high permeability unit is not unexpected from the NMR and imaging log response suggesting the best permeability in the entire Arbuckle. At this stage, we believe there is no detectable communication with other layers by cross cutting beds or fractures, otherwise it would be expected that the pressure would have been dispersed and no pressure response would be observed in the observation well. It may be that this zone will not be the optimal injection zone since it could act as a “thief zone” and take up CO_2 much like zones that are avoided in oil reservoirs. There remains other nearby flow units that may be better suited for injection.

Our geomodel to date consists of multiple, thin porous and permeable layers in the lower Arbuckle that could serve as an injection zone for CO_2. This ~120 ft thick interval is overlain by a notable interval of low porosity and lower permeability layers in the Arbuckle that could serve as baffles or barriers to vertical flow before reaching the primary caprock. These aquitards could also aid in the dispersal of the CO_2 plume to limit its continuous column and inferred buoyancy pressure and facilitate in the exposure of the CO_2 plume to brine and fine pore spaces promoting the degradation of the free phase CO_2. The results of this step-rate test suggest good conformance of a flow unit and a confirmation of the flow unit concept in this geomodel.

The converted shear wave of the multicomponent 3D seismic will further investigate the role of fracturing. Thus far, without core analysis data available, permeability in flow units is indicated in the core from #1-32 including bed-limited fractures in dolomite beds that also have primary matrix pores such as autoclastic breccias and grainstones. Tighter intervals without visible pores also have argillaceous (shale) content that tend not to promote fractures and at this point appear to serve as viable barriers to vertical flow.

Properties of the flow units and aquitards of the Arbuckle geomodel including porosity will be examined in a 3D volume around the two boreholes using attribute processing of the soon to be available depth-migrated 3D seismic volume. At this juncture, this successful test result is an important, positive step toward this continuing evaluation of this lower Arbuckle flow units as the preferred CO2 injection zone.

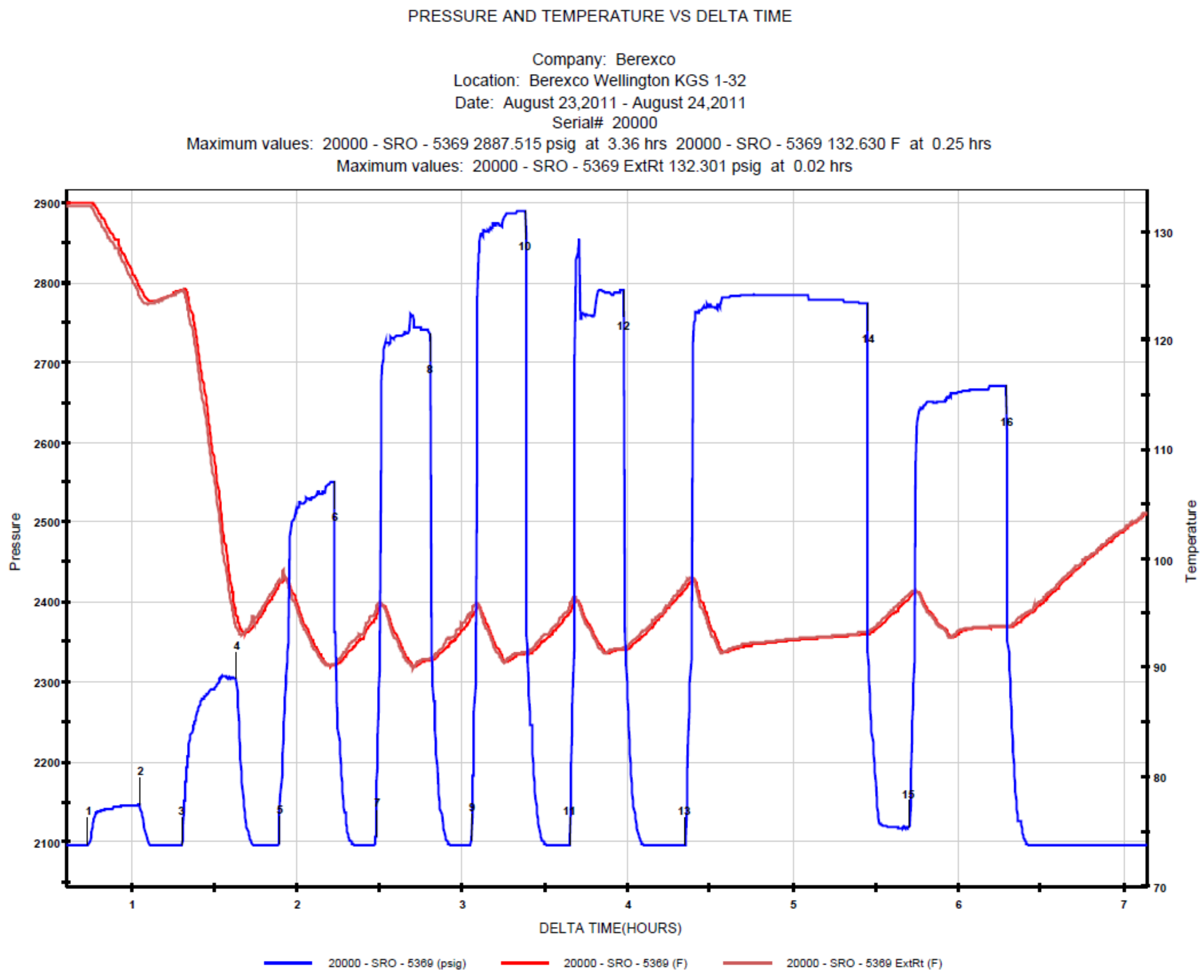


Figure 9. Pressure and temperature vs. delta T in the test injection well, Berexco Wellington KGS #1-32. Note eight separate periods of injection (blue) that are labeled consecutively as at beginning and end of each period.

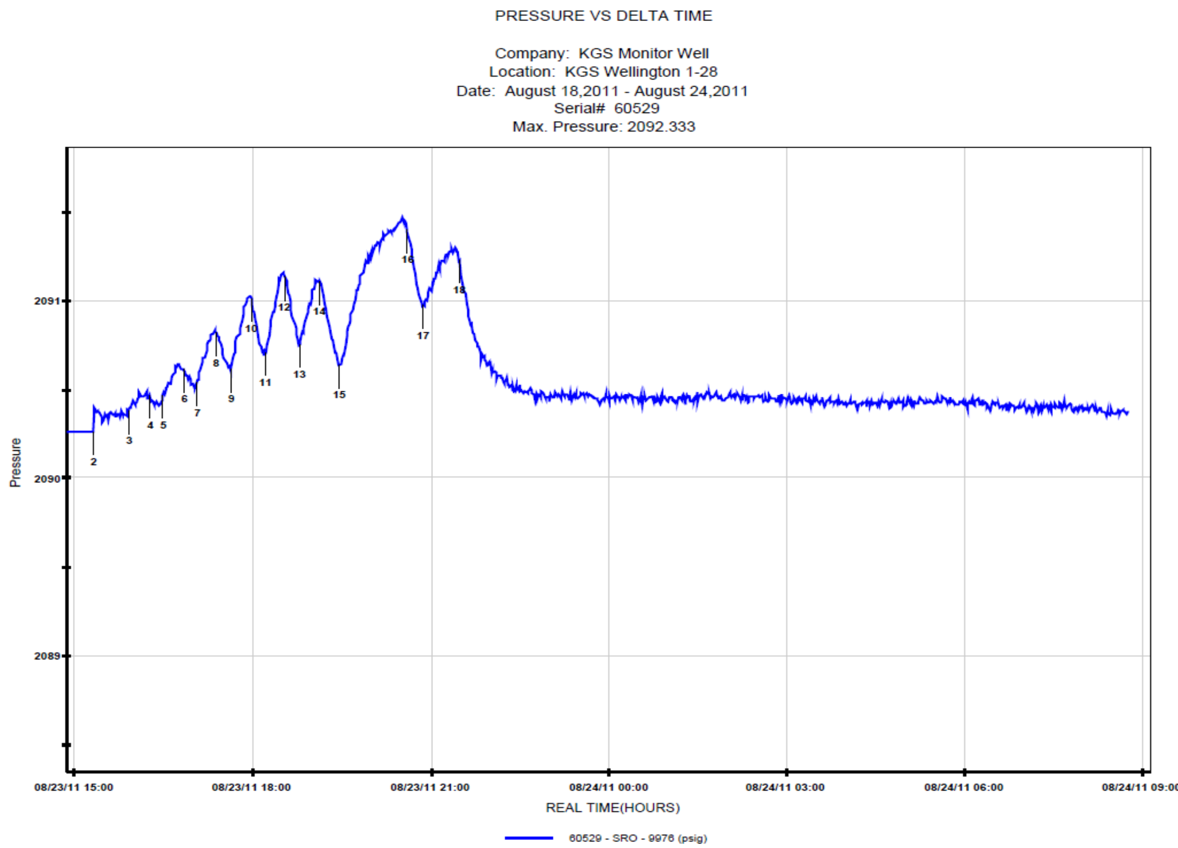


Figure 10. Pressure response in Berexco Wellington KGS #1-28 showing extremely close pattern to pressure introduced in #1-32.

Subtask 4.11. Geochemical analysis of water samples

Analyses by Kansas State of the brine samples from drill stem tests and the swab test in the injection zone have stated to yield results (Figure 11, 12, and 13).

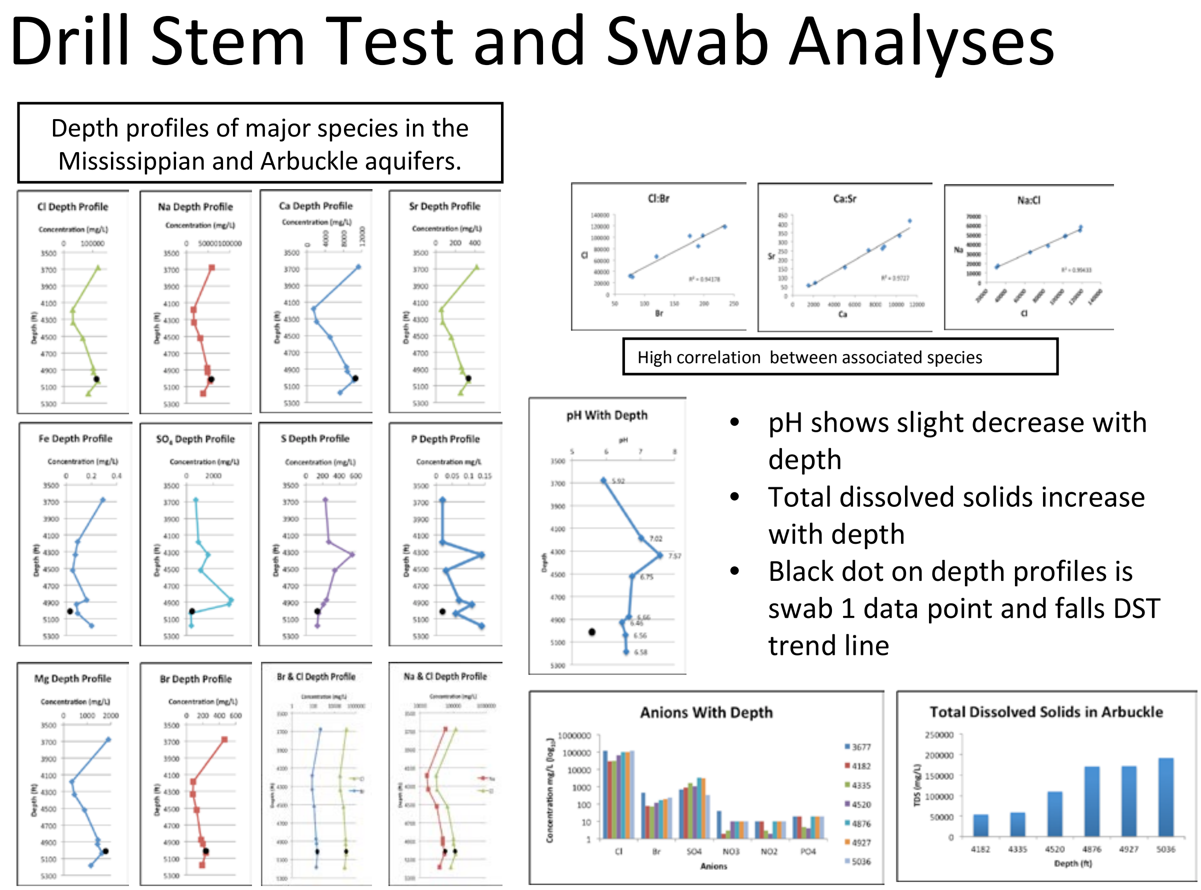


Figure 11. Drill stem test and swab water samples obtained in basement tests at Wellington Field.

Arbuckle Mineralogy

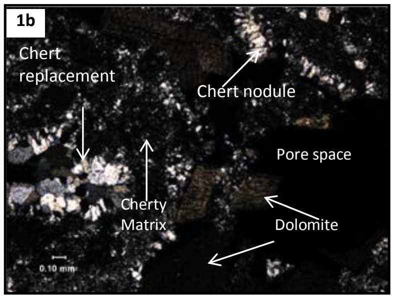


Figure 1b. 31-19 in xpl, large pore visible, notice microcrystalline chert matix, chert replacement and chert nodule.

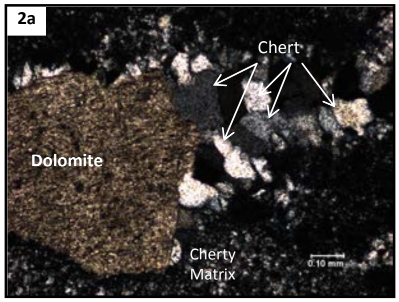
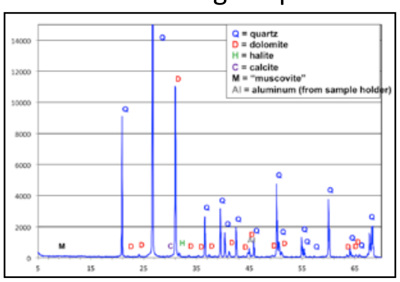


Figure 2. a) 31-19 in xpl. Secondary dolomitization (?) of chert.

Core plug 31-19 between platens at the NETL before being wrapped for CO_2 flow

XRD of 31-19, 4977' used in NETL flow-through experiment



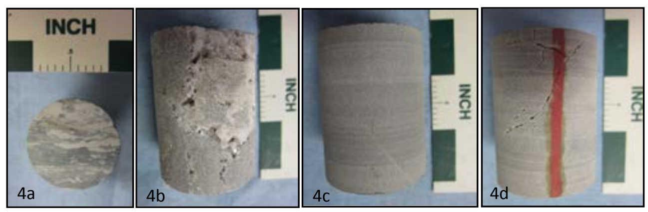
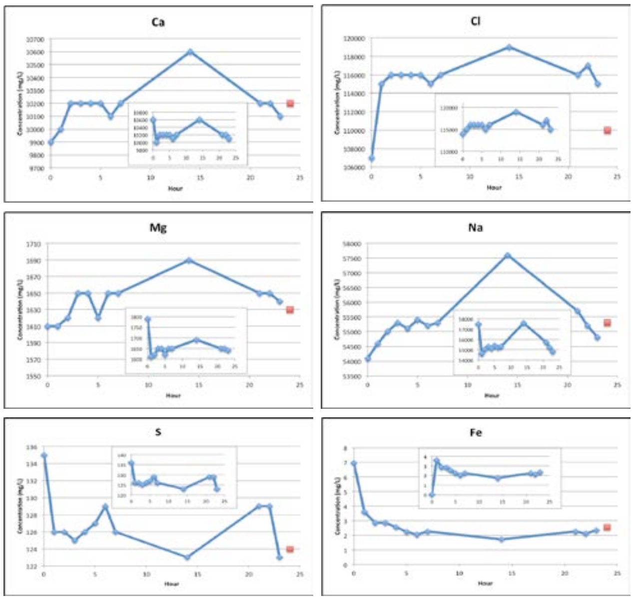


Figure 4. Selected core plug pictures. **a)** 27-22, 4748.25 ft. Shale laminations (green) within an otherwise carbonate rich rock (light). **b)** 29-3, 4801.3 ft. Vuggy dolomites with secondary filling of fractures with dolomitic carbonates. **c)** 20-3, 4523.1 ft. Homogenous dolomitic carbonate packstone. **d)** 20-37, 4557.1 ft. Fluid enhanced fractures with calcite growth.

Figure 12. In addition to the brine analyses, Kansas State is analyzing plug samples by X-ray diffraction and thin section. Flow through of brine in the core plugs is being used to establish the reaction of CO2 with the brine and the rock for use in obtaining reaction kinetics for use in the compositional simulator.

NETL Flow-through Data



- Time series (24 hour) analysis for CO2-brine flow-through experiment using water collected from swab test 1 from KGS-1-28 (5000-5020') and core plug number 31-19 (4977').
- Hour zero represents 13 hours flow of only brine through the core plug at 0.2 mL/min.
- CO2 injection began at hour 1, with a flow rate of 1 mL/min for both CO2 and brine.
- Pre-flow analysis of swab 1 show different initial brine composition. The inset graphs show the 'hour zero' data replaced with the pre flow swab 1 data.
- The values for pre flow brine were either higher (SO4, Mg, Ca, Na) or lower (Cl, Fe, Mn). The difference in brine compositions could be due to contamination or chemical changes prior to CO2 introduction.
- The red data point represents 'hour 24' and is separate due to an experimental uncertainty.

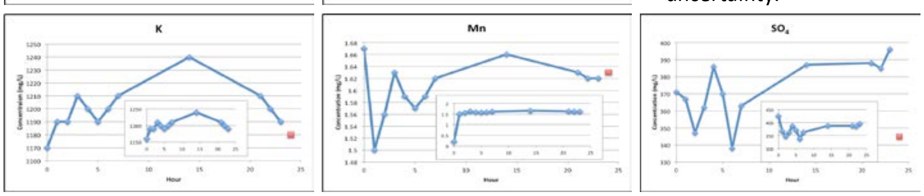


Figure 13. Some of the flow experiments were done under in situ conditions at DOE-NETL lab facilities in Pittsburgh.

Subtask 4.12. Microbiological/biogeochemistry studies on produced water and core plugs from #1-32.

(Contributed by Aimee Scheffer, KU Geology)

The first phase of our research was to characterize the ecology and physiology of the microbial community in the Arbuckle saline aquifer. This was accomplished using both culturing and DNA molecular methods. Culturing methods were applied to every interval where brine was collected to identify the microbial physiology. In addition, the Most Probable Number (MPN) method is being used to determine the concentration of specific physiologic types. Molecular methods, due to cost constraints, were only applied to brine collected from Drill Stem Tests (DST) 3 and 4 to identify detailed microbial ecology. All of the previously mentioned methods will then be used again on the waters collected during swabbing of Well #1-32. This will allow us to decipher any results contributed from drilling mud contamination during the DST sampling, as well as identify changes in geochemistry, biogeochemistry and the microbial community due to oxidation of the well bore from the drilling process.

Culturing of the DST brine identified the presence of iron reducing bacteria at an average depth of 4335' and fermentative bacteria at an average depth of 5190'. The fermentative bacteria were detected by culturing methods in both the DST and swabbed waters. A piper plot of drill stem test brine display high similarity suggesting the brine in the Arbuckle is may be the result of mixing (Figure 14). Major elements do increase with depth (Figure 15).

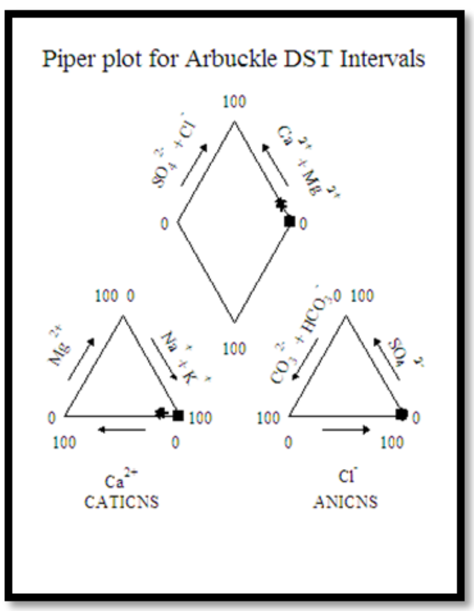


Figure 14: Piper plot showing major elements in drill stem test brine collected from Well #1-32. Plots show high similarity between the waters and suggest that the Arbuckle waters are undergoing mixing.

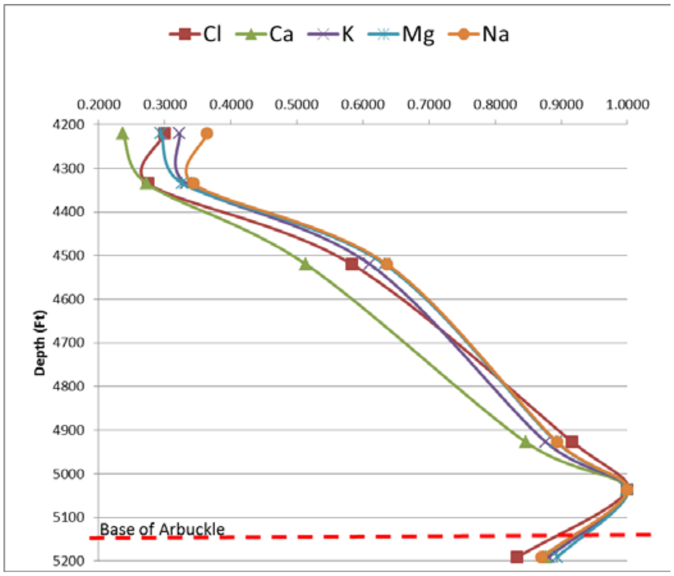


Figure 15: Graph showing depth profile of major ionic species.

Microbial metabolism is evident from the aqueous geochemistry (Figures 16, 17). At a depth of 4520' (DST 2) both DOC and PO_4 are at a minimum in the Arbuckle aquifer profile. This suggests that higher biomass may be expected at depth. Dissimilatory iron reduction, sulfate reduction and methanogenesis are indicated by the data. The methanogenesis is likely CO_2 reduction.

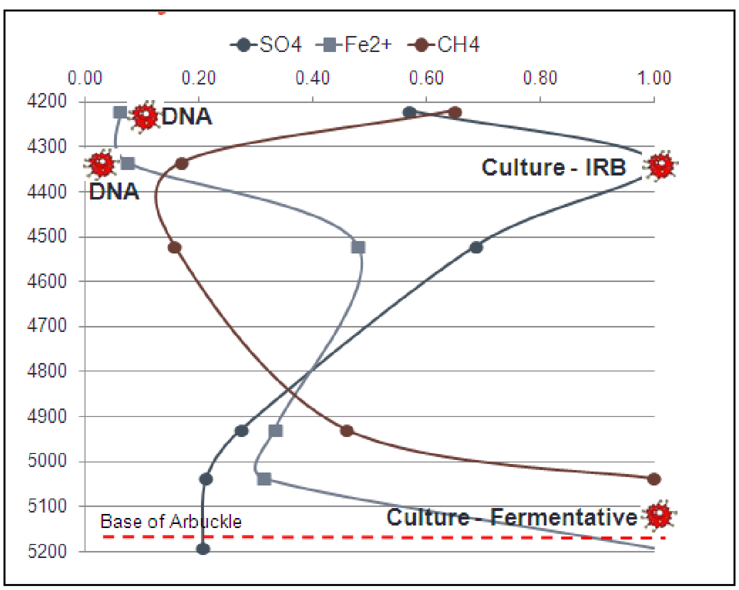


Figure 16: Depth profile of relative concentrations of sulfate, reduced iron and methane indicating the likely locations of active microbial metabolism.

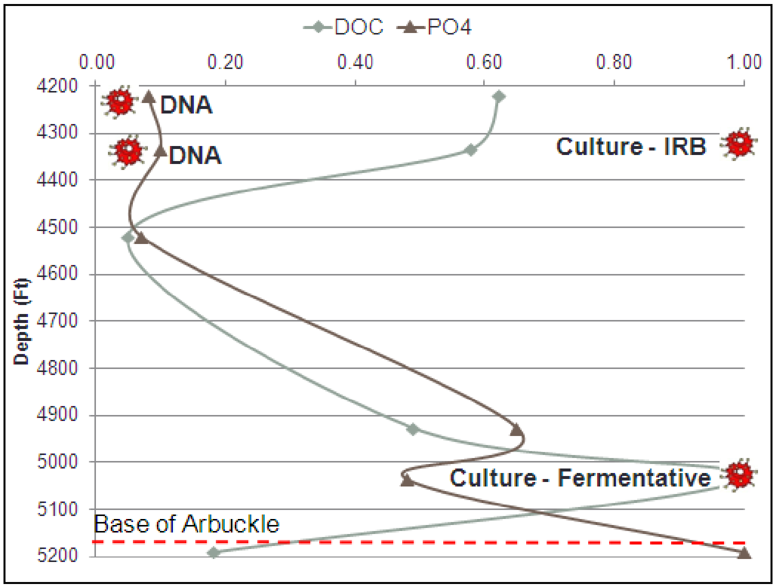


Figure 17: Depth profile of relative concentrations of dissolved organic carbon and phosphate highlighting changes in biomass concentration with depth.

A second round of culturing will be conducted using the waters collected from swabbing. Culturing is expected to be more successful in this subsequent round due to targeted salinities of the growth media. Detailed brine chemistry was not available during the initial culturing and an average salinity of 8% was used in the media. Geochemical analyses showed the salinity varied greatly within the Arbuckle, from 3.3-12%. Large variations in the salinity, often several percent from the organisms' natural conditions, would easily prevent growth and could even kill large portions of the population.

Molecular DNA sequencing methods were used on brine collected from average depths of 4335' (drill stem test 3) and 4220' (drill stem test 4) to identify the microbial ecology. These methods identified four different Phyla of bacteria; Actinobacteria, Bacteriodetes, Firmicutes, and Proteobacteria (Table X). No Archaea were identified. The largest percentage of the microbial community is comprised of Halomonadaceae (38%), Mariniilabiaceae and Clostridiales (14% each), and Cyclobacteriaceae (12%). These organisms range from halotolerant to halophilic, and thermophilic to hyperthermophilic. Many of these bacterial Phyla are known to have fermentative and heterotrophic metabolisms. However, the culturing methods mentioned previously will help identify the microbial physiology.

Phylum	Family	Total %	Environments colonized	Characteristics
Actinobacteria		8	**salt marshes**, wetlands, open ocean, deep sea	

Bacteroidetes	Cyclobacteriaceae	12	soda lake, south-west China; hot spring, southern Taiwan; Lunar Lake, India;	**Halotolerant**
	Marinilabiaceae	14	**oil fields; gas storage aquifer**; soda lake,	**Acidogenic, Fermentative**
Firmicutes	Erysipelotrichi	7	biogas plant, mostly anaerobic digestors	
	Natranaerobiaceae	2	alkaline hypersaline lake, Egypt	**Halophilic, Fermentative**
	Clostridiales (order)	14	mid atlantic ridge hot vents; deep coal seam, Australia	**Heterotrophic, Hyperthermophilic**
	Bacillaceae	4	terrestrial **hot spring**, Tunisia; alkaline hotspring, central Mongolia	**Thermophilic**
Proteobacteria	Halomonadaceae	38	**salt lake**, China; Indian Ocean; Titanic	**Halophilic**

Table 1: DNA Sequencing results of brine from drill stem tests 3 and 4 (Courtesy of Djuna Gulliver, NETL and Carnegie Mellon University).

Ongoing Experiments at NETL

The next phase of our research is to examine caprock integrity of the Arbuckle saline aquifer and how the indigenous microbial population may impact that integrity. I am conducting a series of experiments at the Geomechanics and Core-flow Laboratory at NETL in Pittsburgh, Pennsylvania as part of an ORISE research fellowship with the Department of Energy. I have two different types of experiments I am working on at NETL: 1) Batch experiments, performed in biotic/abiotic pairs, exposing powdered caprock seals to CO_2 saturated brines, 2) Core-flow experiments, performed in biotic/abiotic pairs, using core- plugs of caprock, CO2 acidified brine at reservoir temperatures, pressures and flow rates.

Batch Experiments

I have completed two experiments and am currently running the third experiment. The first experiment I completed was a 45-day experiment on the Chattanooga Shale and Cherokee Shale. I am using 4 1.3-L vessels. The materials placed into the vessels were 40.0 grams of caprock powdered to <150um fraction, raw DST 3 brine (either sterilized by filtration or left raw), 100% pCO2 to a total pressure of 2000 psi and the vessels are kept at a constant temperature of 50°C (Figure 18). The brine for one vessel of each pair has been sterilized by filtration with a 0.2 um filter. The experimental goal is to setup identical experiments except for the presence or absence of the native microbes to identify what effect they have on the system. The second experiment conducted was a 15-day experiment using research grade single-mineral samples, dolomite and pyrite. These minerals were selected because the Arbuckle is predominately dolomite and pyrite is a major accessory mineral. The materials placed into the vessels were 20.0 grams of dolomite powdered to <150um fraction or 20.0 grams of pyrite powdered to <150um fraction, raw DST 3 brine (either sterilized by filtration or left raw), 100% pCO2 to a total pressure of 2000 psi and the vessels are kept at a constant temperature of 50°C (Figure 5). The brine for one vessel of each pair has been sterilized by filtration with a 0.2 um filter. Again, the experimental goal is to setup identical experiments except for the presence or absence of the native microbes to identify what effect they have on the system.

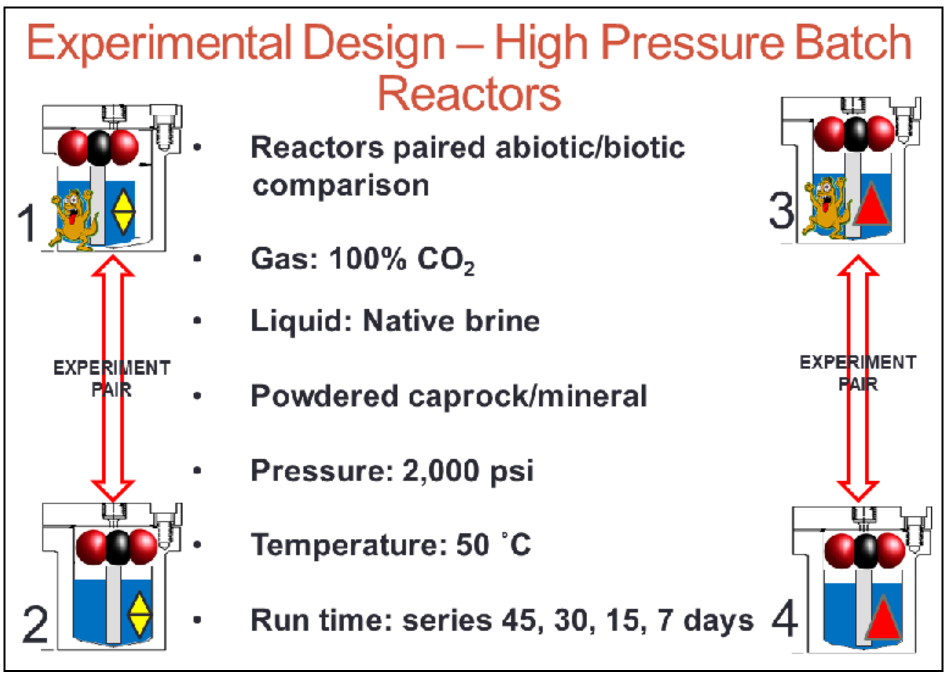


Figure18: Experimental setup for high-pressure batch experiments being conducted at the Geomechanics and Core-flow laboratory at NETL in Pittsburgh, Pa.

We have 5 additional experiments planned during my time at NETL. The experiments will be setup similarly to the previous experiments except brine from a different DST will be used (didn't collect enough brine from any one interval to use it all of our experiments) and the duration will be different. We have decided to focus exclusively on the caprock samples for the remainder of the batch experiments. We are currently running an experiment identical to the first experiment, with Chattanooga and Cherokee shales for 30 days. We will then repeat for 15 day and 7 day experiments. This will give us a time series for the Chattanooga and Cherokee shales and CO_2 acidified brine exposure at 45, 30, 15, and 7 days. I then hope to examine the argillaceous dolomite, and potential, located in the Lower-Mississippi. If time allows, I will conduct 15 and 7 day experiments of that caprock, powdered to the 150um fraction.

The solid materials that were put in to the vessels were examined using XRD and SEM prior to CO2 exposure. The solid materials will then be examined again after exposure to look for physical and chemical changes caused by acidified brine exposure. The geochemistry of the brine was also examined before and will undergo the same chemical analyses afterwards to look for changes. Immediately after opening the vessels, the ferrozine method was used to test for changes in iron concentrations in the brine and pH was measured. The samples were then centrifuged to separate the solids. Solids were then treated for microbial preservation, XRD, and SEM and brine was sent off for geochemical analyses.

Core-flow Experiments

Our experimental goals for the core-flow experiments are to examine the effects on fractures that may form in the primary, secondary and lower-Mississippian potential caprocks. We have 6 core-flow experiments planned using the equipment available at NETL (Table 2). The cores will be exposed to CO_2 acidified brine at 0.231 mol/kg CO_2. This value is not saturation and was selected based on data collected by our collaborator at NETL, Djuna Gulliver. Djuna's experiments found that with a pCO2 of 10% (Total pressure of 2000 psi), approximately half of the microbial community is killed. We are aiming to complement her experiments with ours. The duration of the experiments will range from 2-7 days but will depend on flow rates and an instrument limitation of 2 Liters of brine per experiment.

Before the Experiment

The core-plug "ends" provided by Weatherford were powdered to get a bulk mineralogy for each core using XRD. The core-plugs are being artificially fractured using the Brazilian method which is regularly used by researchers at NETL, WVU and University of Texas. The intact core-plugs were CT-Scanned on the medical CT Scanner at the NETL facility in Morgantown, WV. The samples were then fractured at West Virginia University. The fractures were then offset slightly and epoxied together. (This is the step I am currently at.) One end of the core will be cut off to use to examine the fracture on SEM. The cores will then be CT-Scanned again. We will then begin out core-flow experiments. The biotic brine will be treated prior to experimentation to lyse all the cells. We believe the experiment duration is too short to allow for microbial metabolism to play a major role so we are lysing all the cells to examine what role the released organic material plays on the geochemistry. It is likely to affect the geochemistry by introducing complexes with released cations and could have other impacts as well. The abiotic brine will be sterilized by filtrations with a 0.2um filter. Biotic and abiotic brine controls will be set aside for analyses. The core will be imbibed with brine prior to the start of the experiment using a vacuum chamber.

During the Experiment

Flow rates, delta P, geochemistry, and dissolved organic carbon will be monitored during the experiment. Flow rates and delta P are measured using the core-flow instrumentation and will indicate dissolution or precipitation reactions. Brine samples will be collected regularly to monitor geochemistry and DOC in particular.

After the Experiment

The core plug will be CT-Scanned again to look for changes in fracture aperture and other physical changes or density changes that may be detectable. It is unsure if we will see changes on the scale necessary to be detected by the medical CT-Scanner. A slice of the core will be collected to examine changes to the fracture by SEM. This sample will be preserved in gluteraldehye to allow for the examination of microbes under SEM as well. A thin section will be made and a slice will be collected and powdered for XRD to look for bulk mineralogy changes.

Experiment	Formation	Caprock	Biotic/Abiotic
1	Chattanooga	Primary	Abiotic
2	Chattanooga	Primary	Biotic
3	Cherokee	Secondary	Abiotic
4	Cherokee	Secondary	Biotic
5	Lower Mississippi	Potential Secondary	Abiotic
6	Lower Mississippi	Potential Secondary	Biotic

Table 2: Planned core-flow experiments.

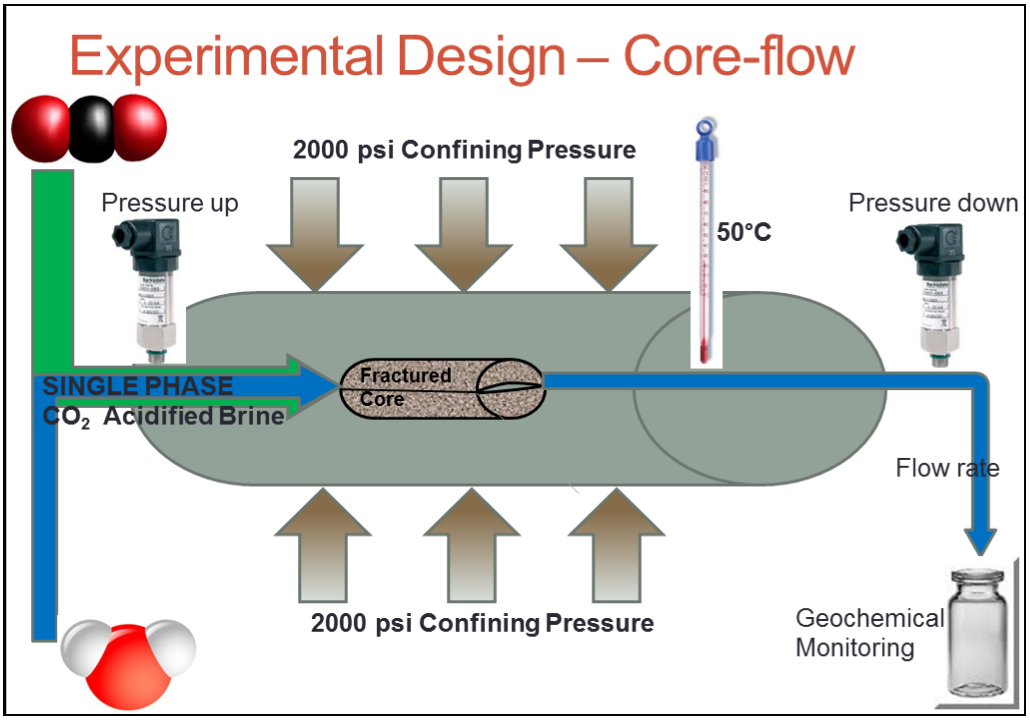


Figure 19: Experimental setup for core-flow experiments being conducted at the Geomechanics and Core-flow laboratory at NETL in Pittsburgh, Pa.

Task 6. Update Geomodels

Subtask 6.2. 2D shear wave survey

Paragon Geophysical Services, Inc. currently operates throughout the continental United States and India. Work is ongoing in Kansas, Colorado, Nebraska, Oklahoma, Texas, and Wyoming. Recording is ongoing in these areas, with the majority of work in the Midwest. In 1999 Paragon upgraded to the Inova System II and purchased three Inova Scorpion Systems from 2005 to 2008. The Inova Scorpion is the most advanced cable based seismic recording system, featuring the flexibility of using Three Component Digital Sensors or analog geophones. In 2010 Paragon purchased its first wireless system, the Sercel Unite. Paragon has nine new (2004-2008 model) high frequency Inova AHV-IV all terrain Buggy Vibrators.

Hardwire Similarity Analysis Vibrator Make/Model: AHV- IV (P-wave)

Vibrator Unit IDs: 2-5776 and 4-6368

Electronics: Pelton Vib Pro

Recording System: INOVA Scorpion

Paragon Crew 206, Berexco Inc., hardwire test data were acquired at KGS Wellington 2D/9C. The data were recorded August 01, 2011 at approximately 8:00 AM. The test data were delivered to S&R offices August 01, 2011.

Two (2) units (2-5776 and 4-6368) were analyzed. Both units are showing very slightly elevated noise on the positive side of the ground force Correlation Signal to Noise analysis for these units. This noise can be seen on TVSA plots which show some broadband low energy (–35 dB) noise from about 25.2 seconds into the sweep to the end of the sweep, which is causing this correlation noise. Unit 2 is about 12% ground force output lower than unit 4. Unit 2 is showing 56% distortion at about 4.3 seconds and 9 seconds into the sweep. Harmonic analysis of the ground force channel for this unit show the source of the high distortion is the 3rd harmonic. This may be the vibrator reacting to the ground induced distortion; however, the crew may want to monitor this unit for a few days.

The correlation of the true reference (pilot) signal with the wireline signal shows a correct delay of 2.761 ms.

The true reference signals showed a 1.5 dB/Oct nonlinearity, which yields correlated data of 3dB/Oct nonlinearity. The Wireline reference and Vib reference showed less than 1.5 dB/Oct nonlinearity. This is due to the slight attenuation with time seen on the Wireline reference and Vib reference channels (Figure 20-22).

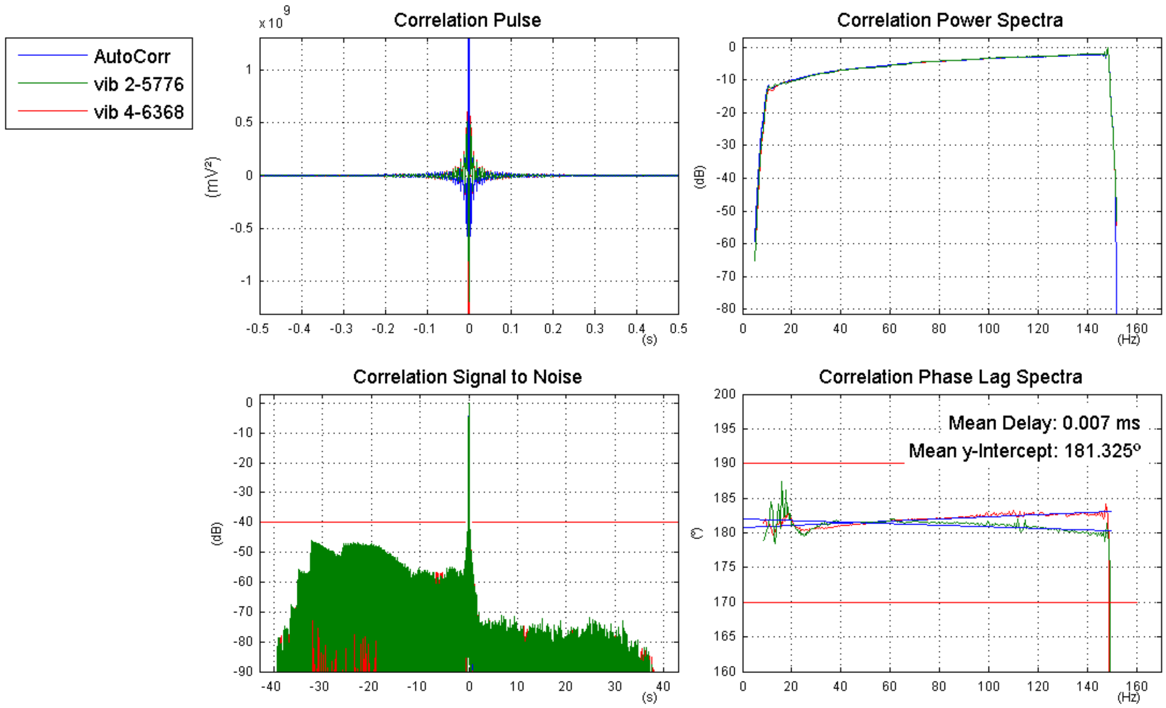


Figure 20. Hardware similarity Analysis of the AHV-IV (P-wave) vibrator.

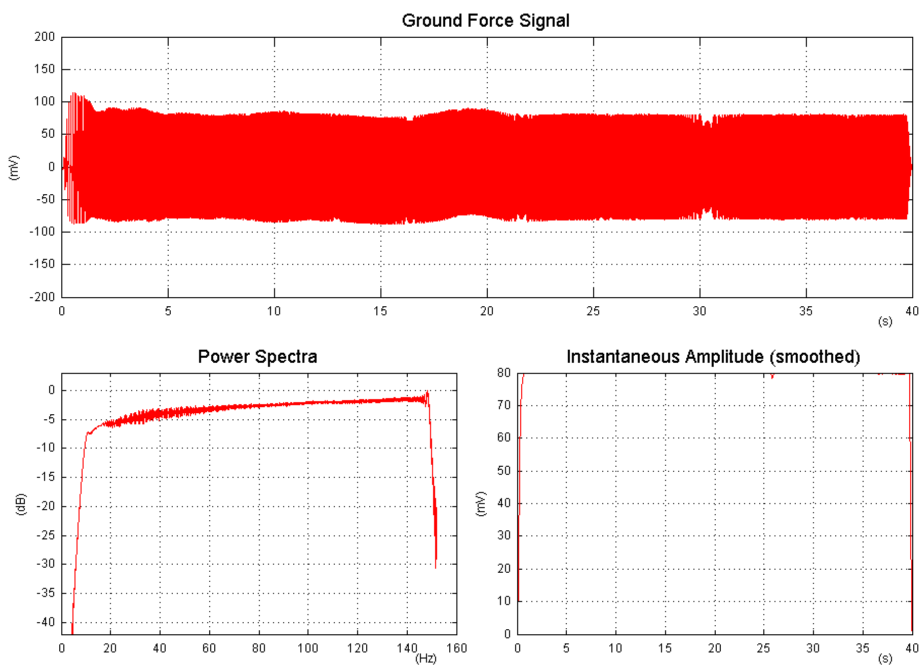
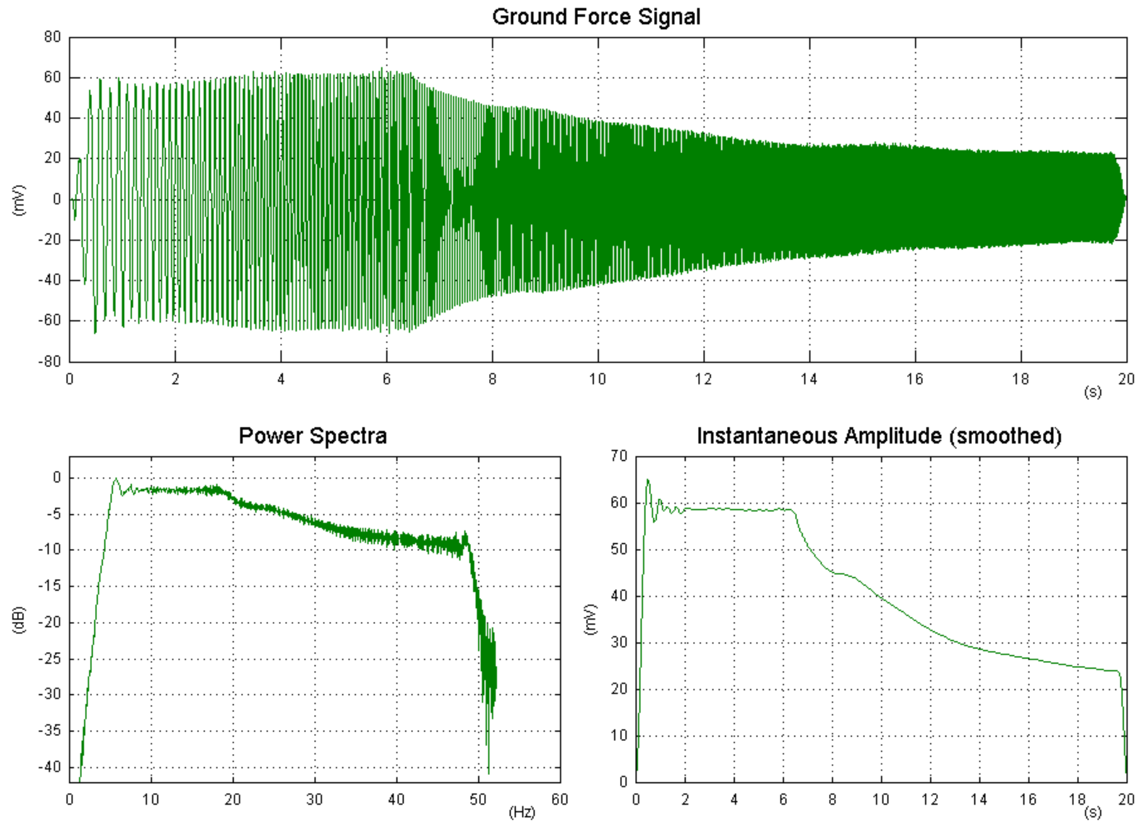


Figure 21. Equipment test.



Hardwire Similarity Analysis

Shear Wave Crossline vib 3 and Shear Wave Inline vib 1 Vibrator Make/Model: Mertz 18 Universal

Vibrator Unit IDs:	3 and 1
Electronics:	Pelton Vib Pro
Recording System:	INOVA Scorpion

Figure 22. Hardware similarity analysis.

Shearwave vibraseis.

Test P-wave

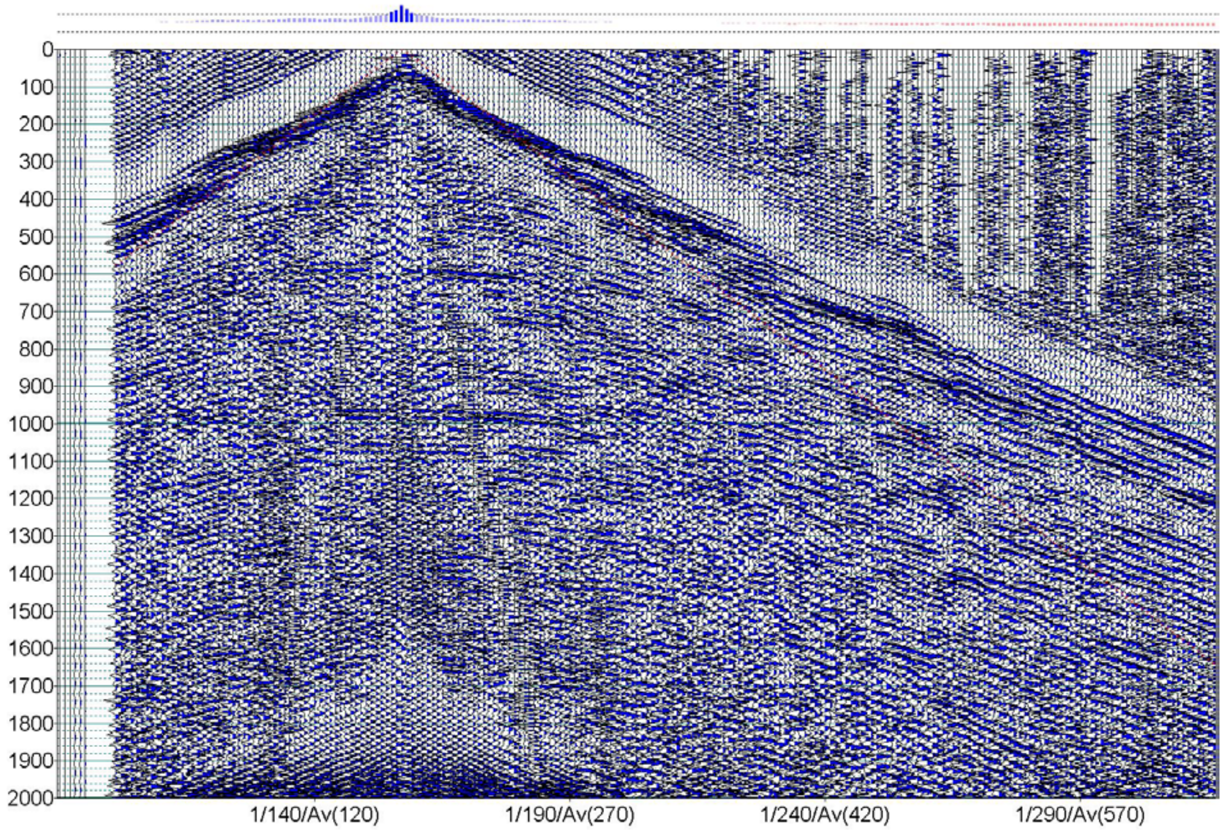


Figure 23. Test P-wave.

Further test information for the 2-D shear wave survey is provided in Figures 23-25.

P-wave Parameters

KGS WELLINGTON 2D/3C P-WAVE SEISMIC SURVEY

BERREXCO, INC.

SUMNER COUNTY, KANSAS T31-32S, R1W

JULY, 2011

CREW CONTACTS

PARAGON GEOPHYSICAL SERVICES CREW 206	
SUPERVISOR	John Aguilar 316-708-2863
CREW MANAGER	Travis pearson 316-706-6429
OBSERVER	Travis Pearson 316-706-6429
OBSERVER	Javier Arriaga 316-249-3219
SURVEY	Justin Yost (GeoNav) 303-253-5299
PERMIT	Paragon Geo - Jerry Erwin 316-641-4006
FIELD CONTACT	Jason Bruns(Berexco) 620-440-0170

RECORDING SYSTEM

INSTRUMENT TYPE	ION Scorpion			
SOFTWARE VERS.	4.11.16 (2578 A)			
SYSTEM OUTPUT	External Hard Drive			
TAPE TYPE	LTO II			
TAPE FORMAT	SEG Y			
	VIB.		DYN.	
AUX CHANNEL 1	1		1	N/A
AUX CHANNEL 2	2	Clock Time Break	2	N/A
AUX CHANNEL 3	3	True Reference	3	N/A
AUX CHANNEL 4	4	Wireline Reference	0	
AUX CHANNEL 5	0	Radio Reference	0	
AUX CHANNEL 6	0	Radio Similarity	0	

GEOPHONES

TYPE / MODEL	SVSM (Vector Seis)
FREQUENCY	Digital
PATTERN	Point Receiver
PHONES / GROUP	1 (3 C) Inline horiz. Element, Ln 1 @ 55 degrees
	Ln 2 @ 135 degrees. Connector toward high #s

Client Representative: Dana Wreath
DWreath@berexco.com
316-337-8331

Field Representative: Larry Stafford
720-252-3770
Lstafford@convergingpoint.com

RECORDING PARAMETERS

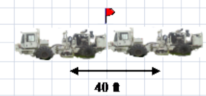
SAMPLE RATE	2	ms	
LOW CUT FILTER/SLOPE	3	hz	
ANTI-ALIAS FRQ./SLOPE	187	hz	.8 Nyquist, Linear
PREAMP GAIN	36	db	(G-6)
NOISE EDIT	Diversity Stack		
DATA TO TAPE TYPE	Correlated after stack		
RECORD LENGTH	3	sec	
LINE TYPE	2D		
ACTIVE LINES	1		
ACTIVE CHAN / LINE	224		
ROLL ON / OFF	Static - All live		
RP / LINEAR MILE	64		
RCV GROUP INTERVAL	82.5		
TOTAL RCV LINES	2		
TOTAL RCV GROUPS	Line 1 - 216, Line 2 - 219		
LINE ORIENTATION	135 & 55 degrees		
SP/ LINEAR MILE	31		
SRC POINT INTERVAL	165		
TOTAL SRC LINES	2		
TOTAL SRC POINTS	218		
TOTAL LINEAR MILES	7.0		

SOURCE PARAMETERS

ENERGY SRC TYPE	Vibrators	
VIBRATORS		
TYPE / MODEL	ION AHV-IV	
INSTRUMENTS	Pelton - Vib Pro	
HOLD DOWN WEIGHT	60,00	lbs
DRIVE LEVEL	80	%
PHASE LOCK	Ground Force	
FORCE CONTROL	Fundamental Grnd Force	
NUMBER VIBRATORS	2	
PATTERN	40 ft. centered on stake	

SWEEP

NUM. SWEEPS	2	
MOVE UP	Stacked	
START FREQ.	6	hz
END FREQ.	150	hz
SWEEP LENGTH	40	sec
NON LINEARITY	+3db/oct	post corr.
START TAPER	300	ms
END TAPER	300	ms



PROCESSING

Fairfield Industries
1776 Lincoln St. #1200, Denver, CO 80203
Attn: Bruce Karr 720-963-2119
bkarr@fairfield.com

Figure 24. P-wave parameters.

Shear-wave parameters

KGS WELLINGTON 2D/9C SHEAR WAVE SEISMIC SURVEY

BEREXCO, INC.

SUMNER COUNTY, KANSAS T31-32S, R1W

JULY, 2011

CREW CONTACTS

PARAGON GEOPHYSICAL SERVICES CREW 206	
SUPERVISOR	John Aguilar 316-708-2863
CREW MANAGER	Travis pearson 316-706-6429
OBSERVER	Travis Pearson 316-706-6429
OBSERVER	Javier Arriaga 316-249-3219
SURVEY	Justin Yost (GeoNav) 303-253-5299
PERMIT	Paragon Geo - Jerry Erwin 316-641-4006
FIELD CONTACT	Jason Bruns(Berexco) 620-440-0170

RECORDING SYSTEM

INSTRUMENT TYPE	ION Scorpion			
SOFTWARE VERS.	4.11.16 (2578 A)			
SYSTEM OUTPUT	External Hard Drive			
TAPE TYPE	LTO II			
TAPE FORMAT	SEG Y			
	VIB.		DYN.	
AUX CHANNEL 1	1		1	N/A
AUX CHANNEL 2	2	Clock Time Break	2	N/A
AUX CHANNEL 3	3	True Reference	3	N/A
AUX CHANNEL 4	4	Wireline Reference	0	
AUX CHANNEL 5	0	Radio Reference	0	
AUX CHANNEL 6	0	Radio Similarity	0	

GEOPHONES

TYPE / MODEL	SVSM (Vector Seis)
FREQUENCY	Digital
PATTERN	Point Receiver
PHONES / GROUP	1 (3 C) Inline horiz. Element, Ln 1 @ 55 degrees Ln 2 @ 135 degrees. Connector toward high #s

Client Representative: **Dana Wreath**
DWreath@berexco.com
316-337-8331

Field Representative: **Larry Stafford**
720-252-3770
Lstafford@convergingpoint.com

RECORDING PARAMETERS

SAMPLE RATE	2	ms	
LOW CUT FILTER/SLOPE	3	hz	
ANTI-ALIAS FRQ./SLOPE	187	hz	.8 Nyquist, Linear
PREAMP GAIN	36	db	(G-6)
NOISE EDIT	Diversity Stack		
DATA TO TAPE TYPE	Correlated after stack		
RECORD LENGTH	4	sec	
LINE TYPE	2D		
ACTIVE LINES	1		
ACTIVE CHAN / LINE	224		
ROLL ON / OFF	Static - All live		
RP / LINEAR MILE	64		
RCV GROUP INTERVAL	82.5		
TOTAL RCV LINES	2		
TOTAL RCV GROUPS	Line 1 - 216, Line 2 - 219		
LINE ORIENTATION	135 & 55 degrees		
SP/ LINEAR MILE	62		
SRC POINT INTERVAL	165		
TOTAL SRC LINES	2		
TOTAL SRC POINTS	436		
SRC ORIENTATION	SE & NE		
TOTAL LINEAR MILES	7.0		

SOURCE PARAMETERS

ENERGY SRC TYPE	Vibrators	
VIBRATORS		
TYPE / MODEL	Mertz M-18 Universal	
INSTRUMENTS	Pelton - Vib Pro	
HOLD DOWN WEIGHT	41,600	lbs
DRIVE LEVEL	60	%
PHASE LOCK	Ground Force	
FORCE CONTROL	Fundamental Grnd Force	
NUMBER VIBRATORS	1	
PATTERN	On flag	

SWEEP

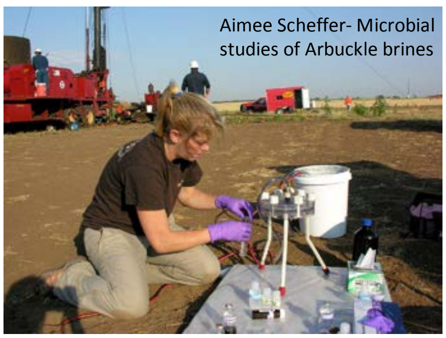
NUM. SWEEPS	6	
MOVE UP	Stacked	
START FREQ.	4	hz
END FREQ.	50	hz
SWEEP LENGTH	20	sec
NON LINEARITY	Linear	
START TAPER	300	ms
END TAPER	300	ms

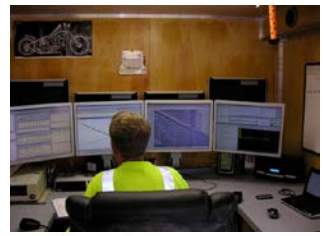
PROCESSING

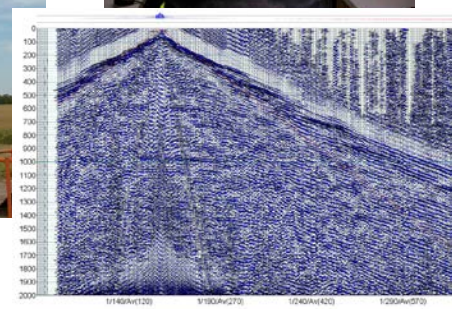
Fairfield Industries
1776 Lincoln St. #1200, Denver, CO 80203
Attn: Bruce Karr 720-963-2119
bkarr@fairfield.com

Figure 25. Shear-wave parameters.

Weekend July 31st @ Wellington







Subtask 6.3. Process & interpret 2D shear

Current Status:

- PSDM volume undergoing iterative velocity / depth conversion
- 2D Shear Wave undergoing diagnostics to ascertain proper vib orientations
- Converted wave undergoing azimuthal anisotropy / sector analysis
- Awaiting PSDM final as input for Inversion, contemplating Simultaneous Inversion to obtain impedance and elastic inversions

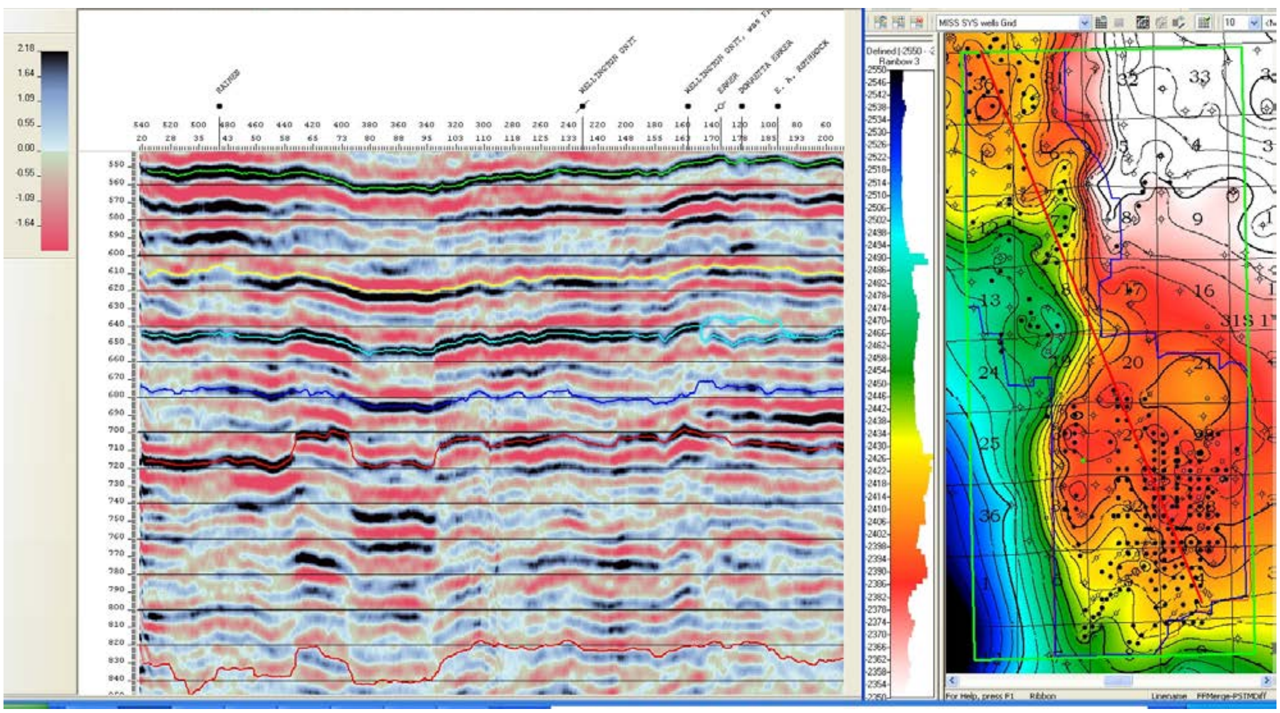


Figure 26. P-wave Arbitrary Profile Anson-Bates to Wellington
Miss ~ 640 ms, Mid-Miss ~ 680 ms, Arbk ~ 710 ms, Bsmt ~ 830 ms

P-wave seismic profile running NW-SE from Anson-Bates to Wellington Field is illustrated in (Figure 26). Anson-Bates shows block faulting at depth. Prestack time migrated data compared to new converted wave along a NW-SE profile similar to orientation of profile in Figure 26 is shown in Figure 27. Converted data still is undergoing processing, but the preliminary data shows lower frequency clearly defined reflection events.

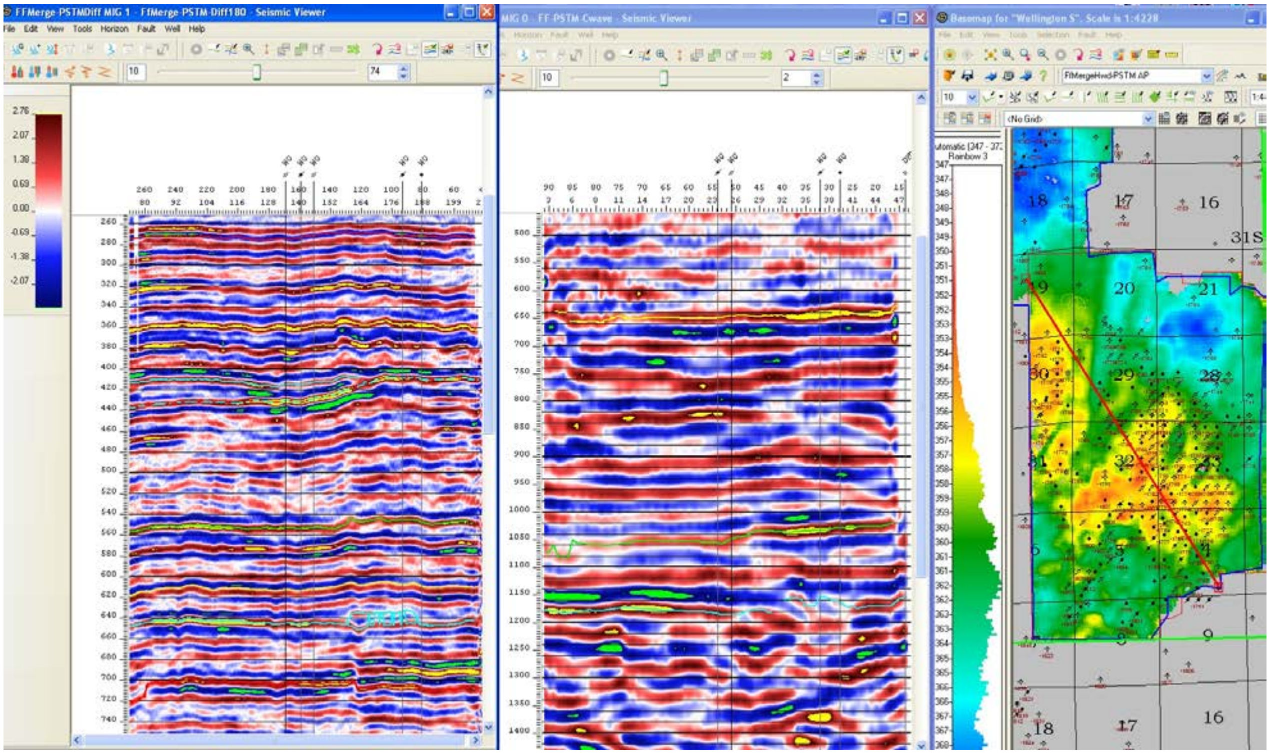


Figure 27. Arbitrary Profile, PSTM-Converted Wave-Index Map

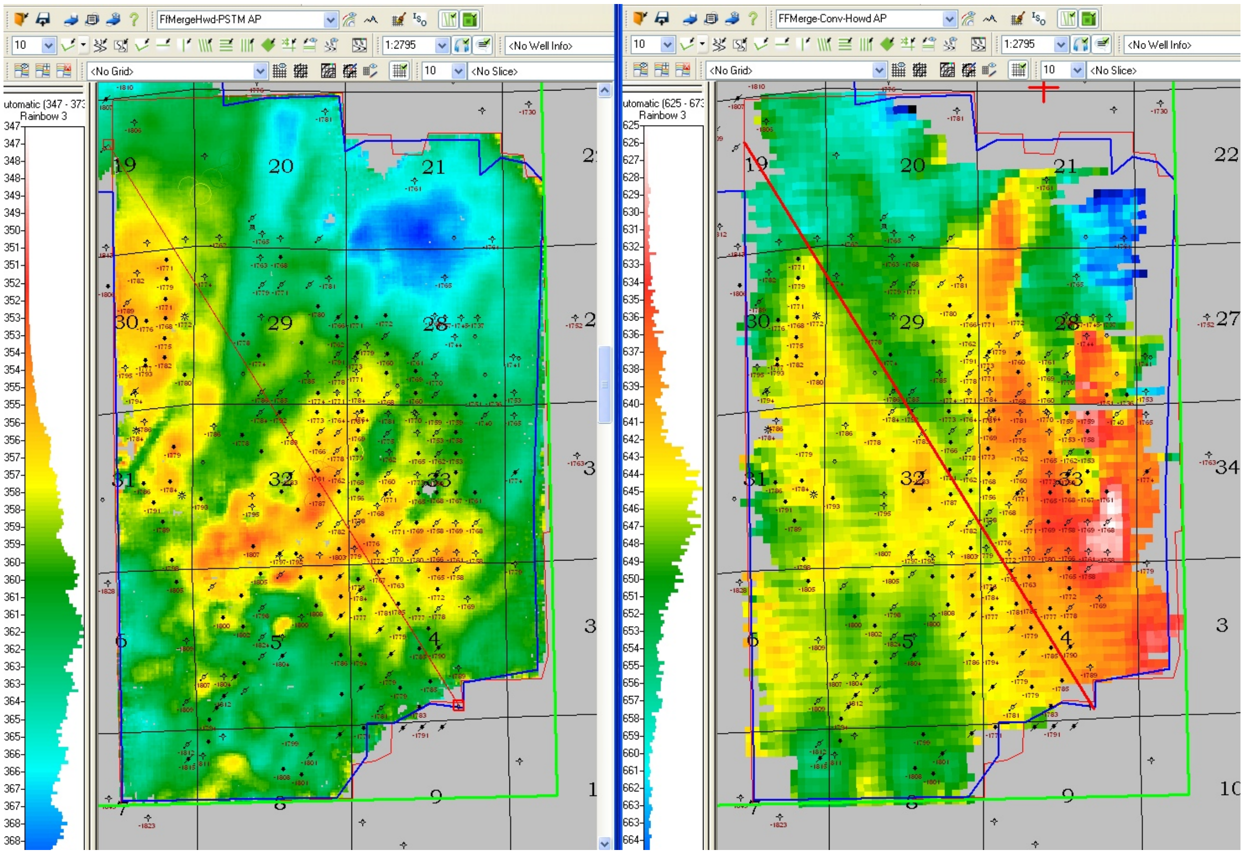


Figure 28. PSTM (left) and converted wave (right) for top of Upper Pennsylvanian Howard Limestone.

PSTM and converted wave data for the top of the Upper Pennsylvanian Howard Limestone are similar (Figure 28). Similarly, the time and converted wave surface of the Kansas City Group are very similar (Figure 29).

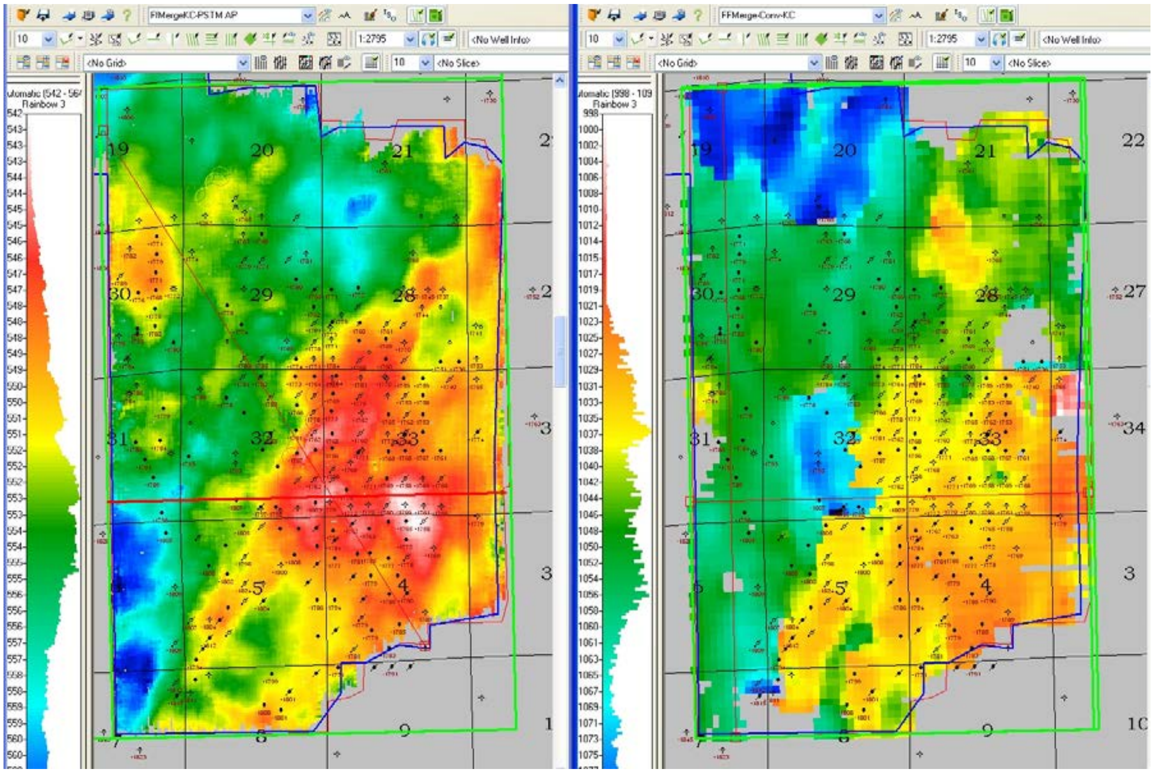


Figure 29. PSTM (left) and converted wave (right) for top Upper Pennsylvanian Kansas City Group (limestone).

Subtask 6.4. Revise 3D seismic interpretation

Receipt of final processing of the pre-stack depth migration and converted wave interpretation for Wellington Field 3D seismic is anticipated in early November.

Subtask 6.5. Update geomodel - Arbuckle & Miss

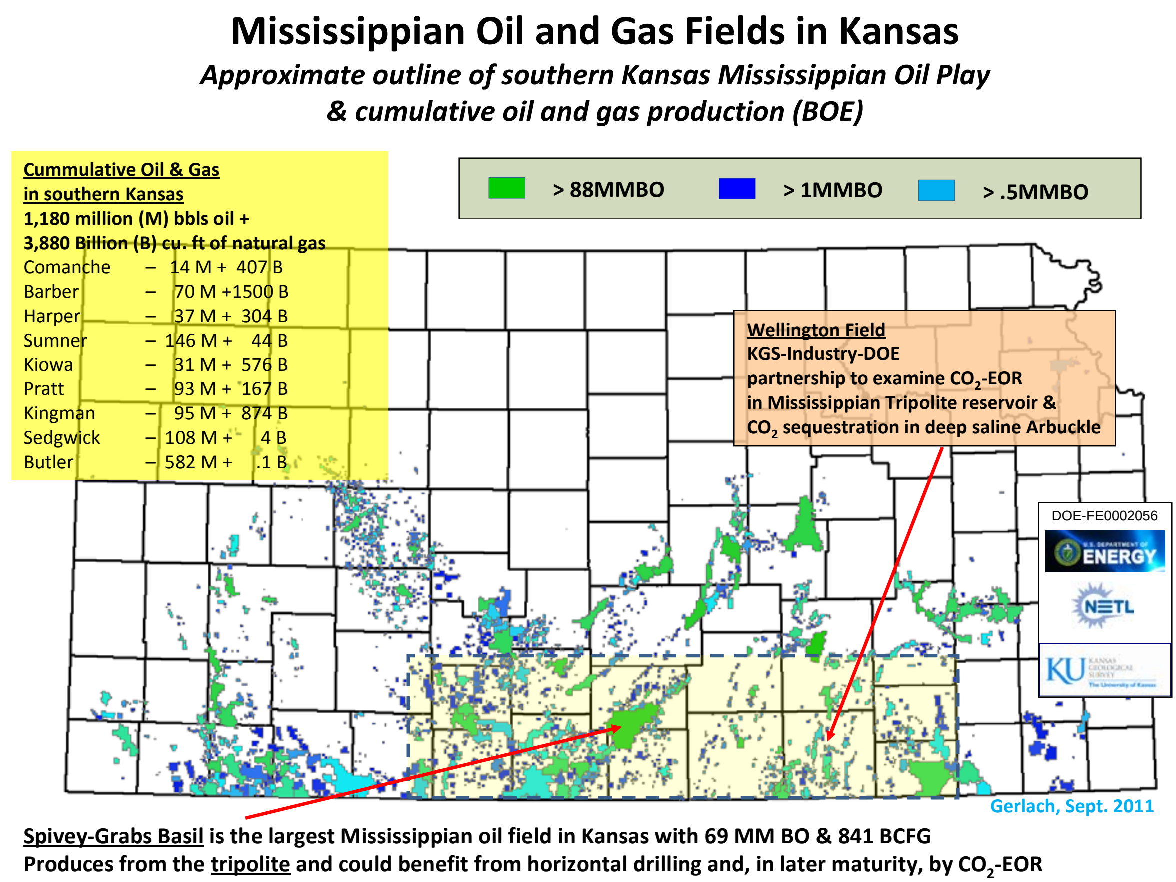


Figure 30. Wellington Field in the context of other Mississippian oil and gas fields in Kansas. Area in yellow tint denotes current revitalization of the Mississippian oil reservoirs including the area surrounding Wellington Field.

Wellington Field is located in the eastern edge of an oil and gas producing province dominated by Mississippian age reservoirs. The reservoir facies at Wellington is also analogous to that in nearby Mississippian fields, a tripolitic microporous chert. Recent leasing to find new Mississippian reservoirs and revive older fields has begun.

The Berexco Wellington KGS #1-32 basement test encountered an apparent new pay in the lowermost Mississippian, a cherty intercrystalline dolomite (Figure 31).

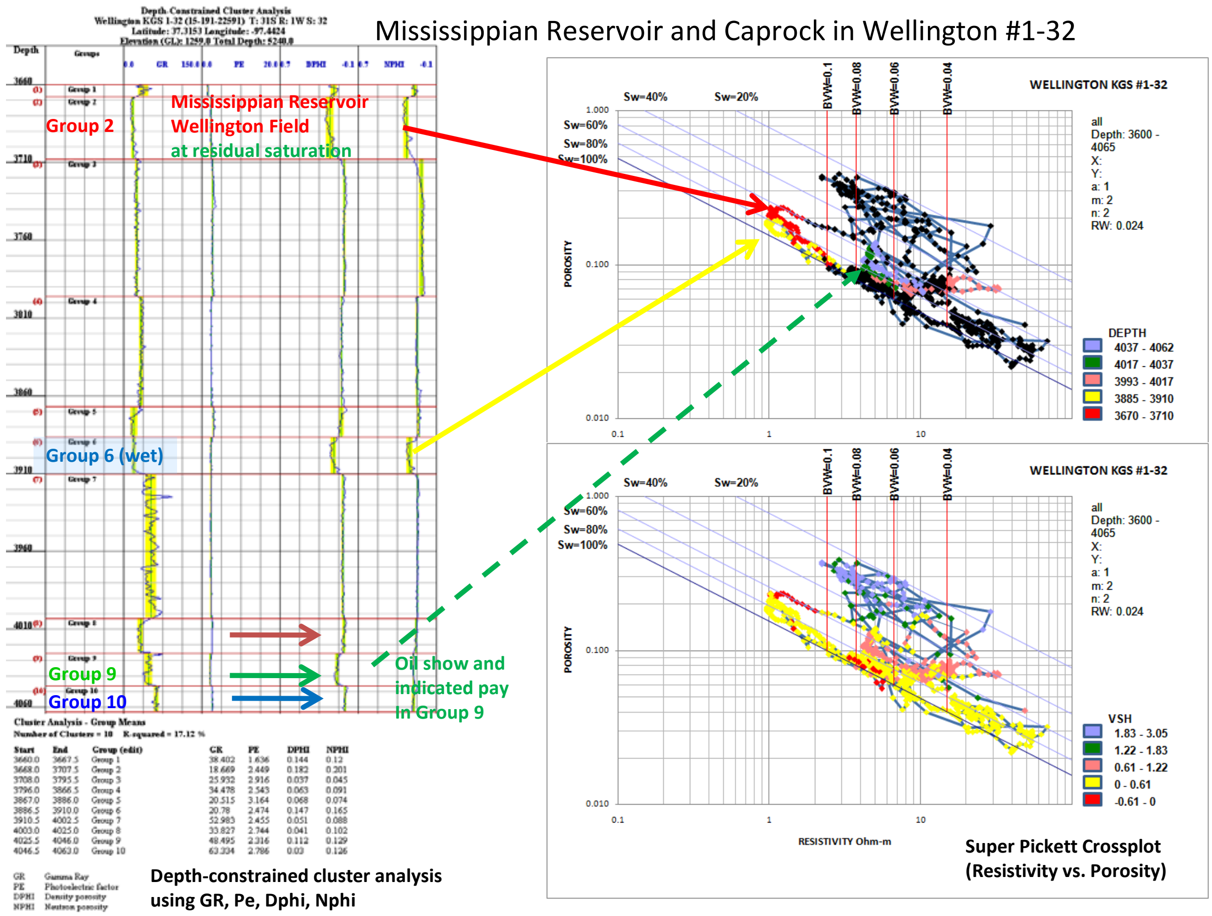


Figure 31. Upper most tripolic chert, Group 2 (red zone), above in depth plot and Super Pickett Phi-Rt plot is highlighted in red. Also, Group 9 (green zone) has notable oil show and has moderate (40%) oil saturation by initial log calculations. Intervening Group 6 zone is porous and clearly wet. Intervening strata between these porous zones appear to be tight and sealing.

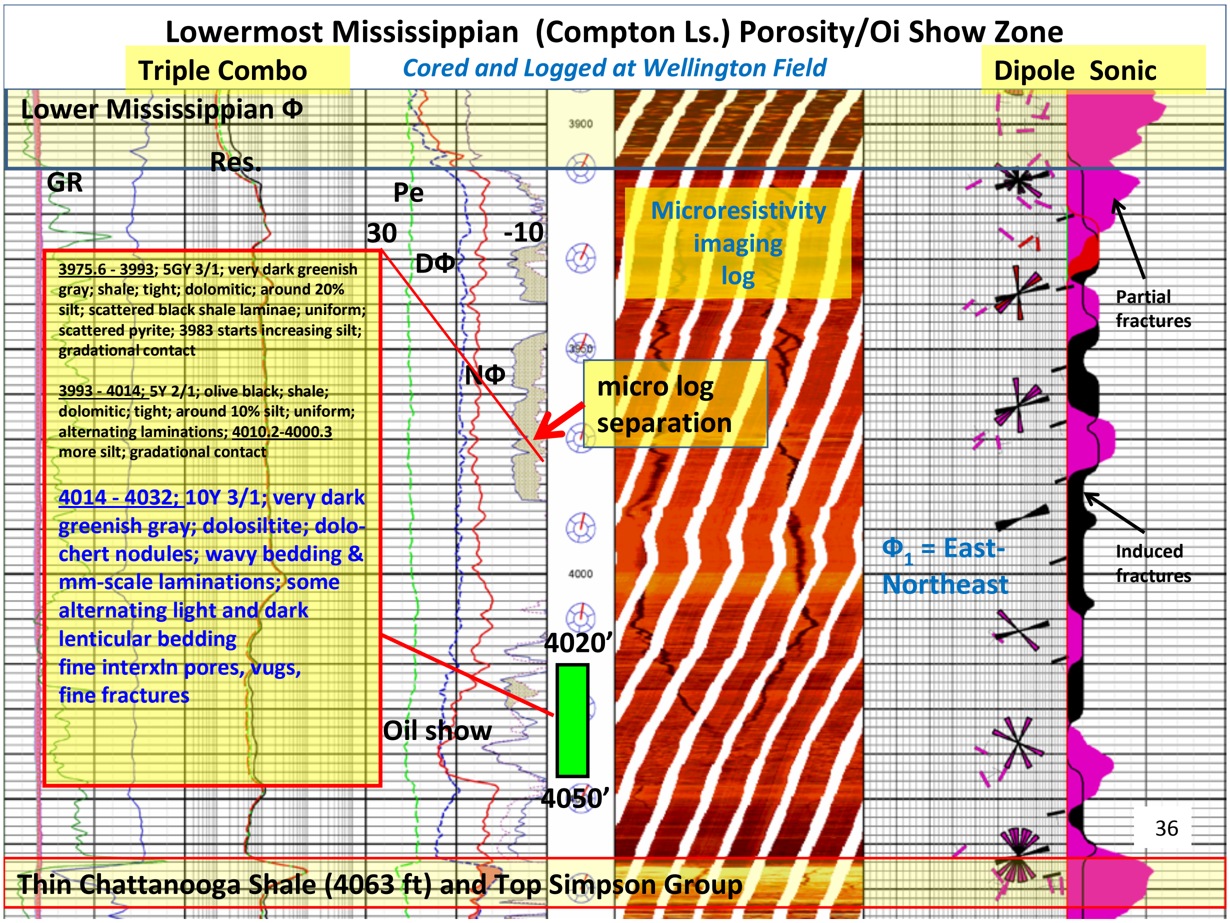


Figure 32. 30 foot thick lowermost Mississippian carbonate has oil shows and some microlog separation, the latter indicating permeability. Zone is not highly fractures. Overlying interval consists of tight argillaceous carbonate as also shown in Figure 33.

Lower Mississippian is core and logged in well #1-32 (Figure 32 and 33). CT scans of core in lower Mississippian show wavy horizontal bedding. Zone of oil show in lower right of the CT scans in Figure 33 show dark irregular porous interval that are comprised of mainly vugs.

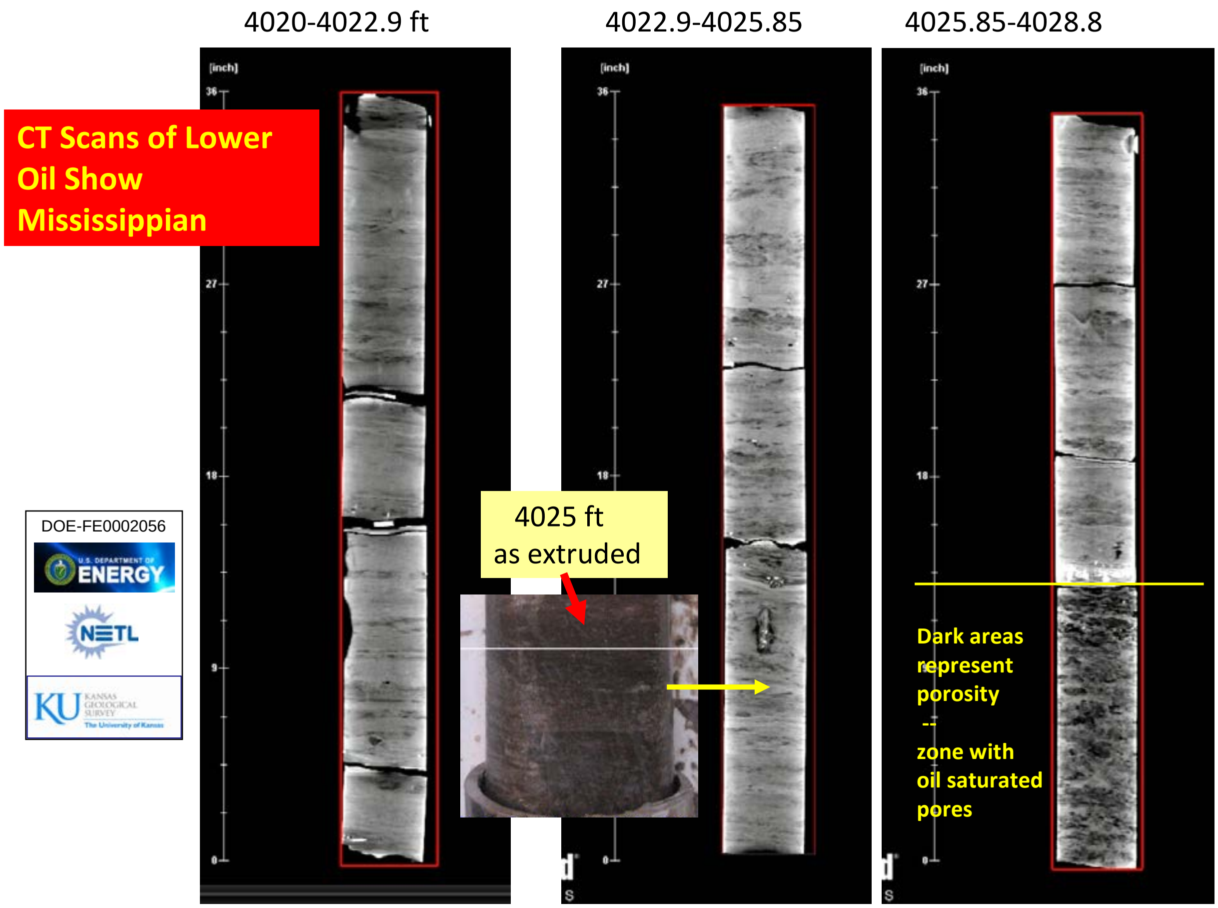


Figure 33. CT scans of lower Mississippian strata.

Task 16. Collect and Analyze Existing Data for Developing Regional Geomodel for Arbuckle Group Saline Aquifer in Western Annex

Subtask 16.1. Assemble, reprocess, and interpret existing 3D seismic and other data

Type logs have been identified for expanded areas in the Western Annex. Well log data is being digitized. Stratigraphic correlations are being established to extend structural and stratigraphic mapping from the eastern portion of the study.

Subtask 16.3. Remote sensing analysis

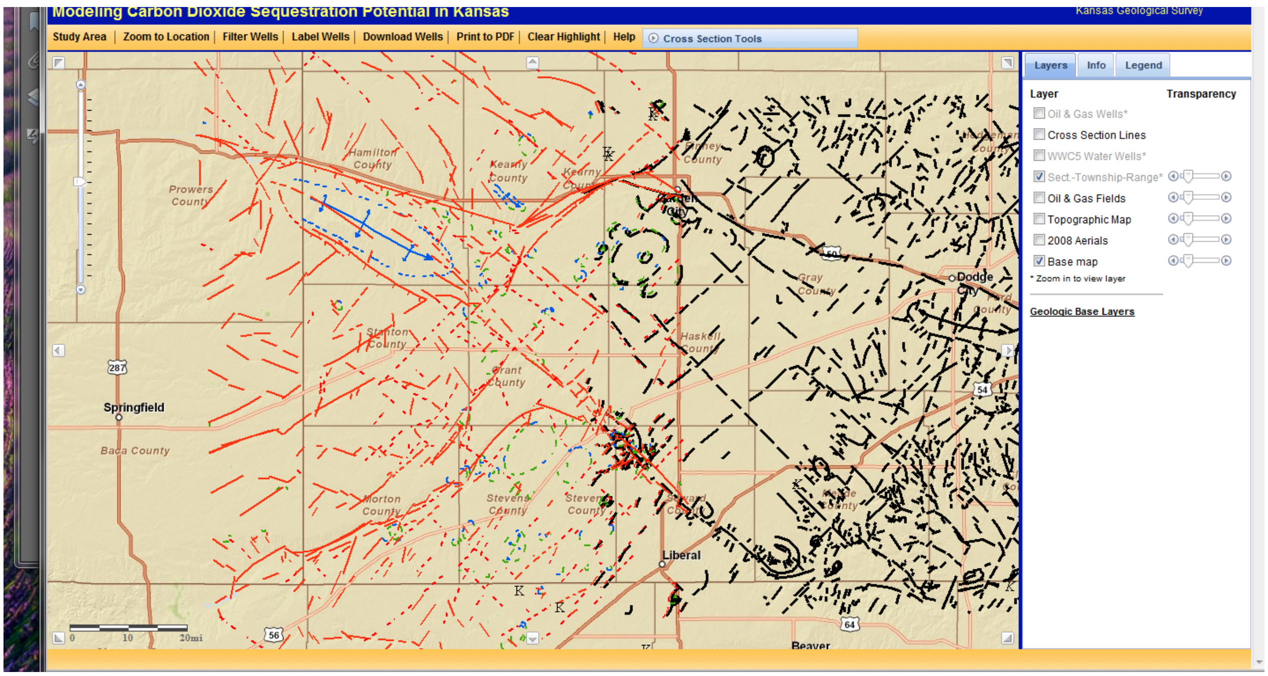


Figure 34. Project interactive mapper showing newly mapped lineaments for Western Annex in red that augments those previously established to the east identified in black.

Regional surface lineament analysis has been completed for the Western Annex in southwestern Kansas and our shown in interactive mapper in Figure 34.

Task 17. Acquire (New) Data at a Select Chester/Morrow Field to Model CO_2 sequestration Potential in the Western Annex

Subtask 17.1. Collect existing seismic, geologic, and engineering data - Chester/Morrow fields

Field data continue to be compiled on the four fields including review of the seismic data, well data, production history and fluid information, core and core analyses, acquiring digitized well log data. Over 5.1 gigabytes of field data, outside of seismic, have been collected as of late September. Figure 35 below shows the status of the field studies in late September 2011.

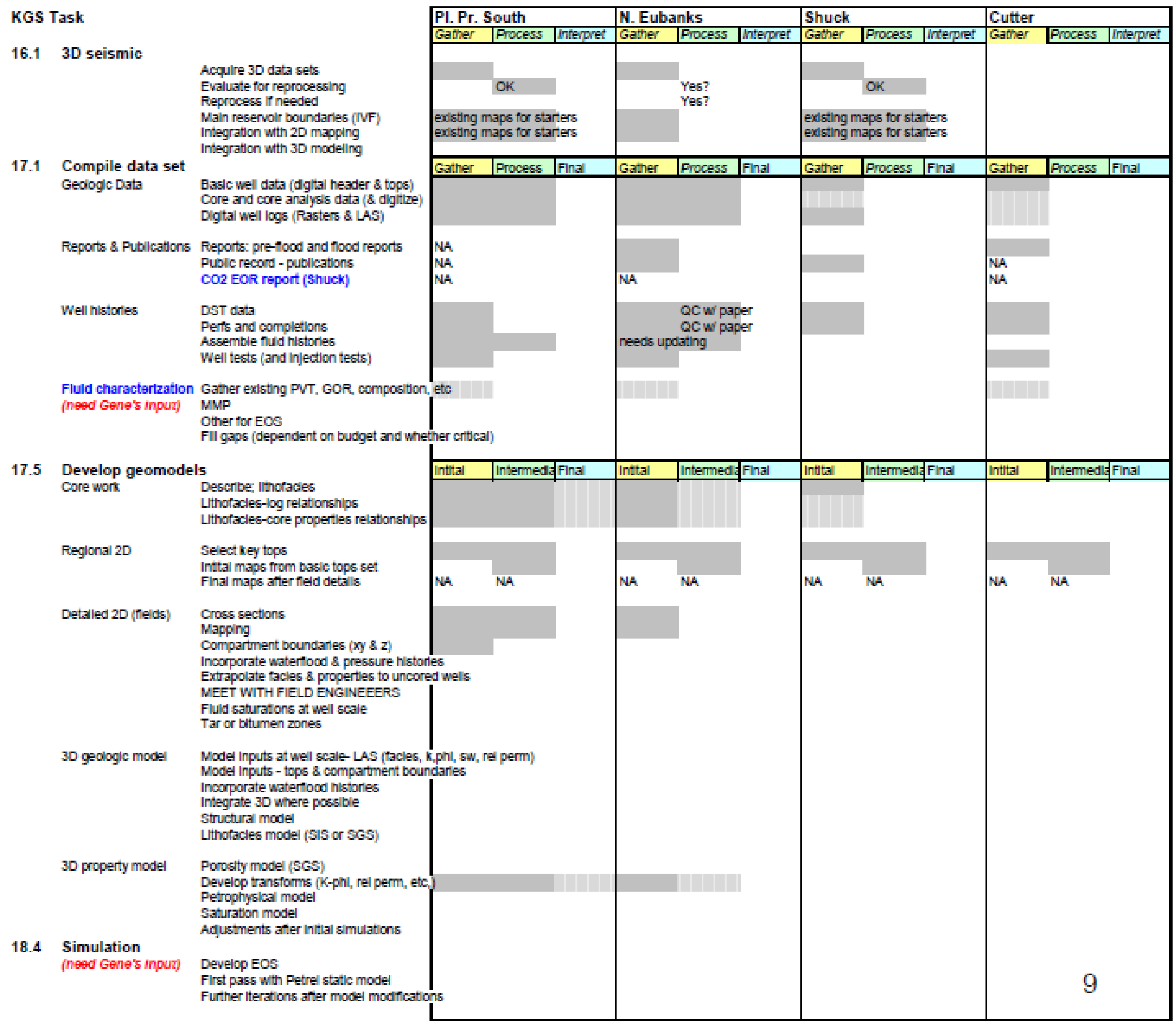


Figure 35. Status of data gathering and processing information on four field areas selected for analysis in the Western Annex.

The updated schedule for studies of Pleasant Prairie South (Pl. Pr. South) and North Eubanks fields are shown in Figure 36. Most of the data have been gathered on Pleasant Prairie and Eubanks and information on Shuck and Cutter fields is nearing completion. Fine-scale reservoir correlations are complete on Eubanks field and work has begun on the lateral compartments as illustrated below.

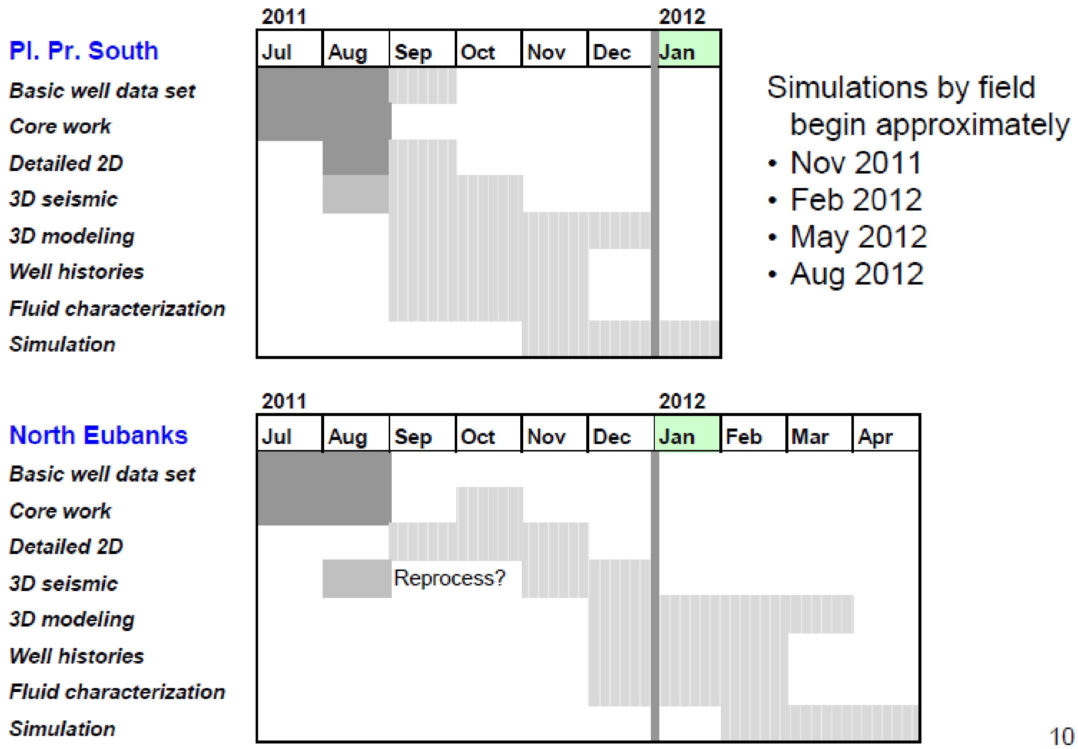


Figure 36. Intermediate revised schedule for Western Annex study.

The stratigraphic classification of the Chester/Morrow incised valley system (IVF) under study has been in question for some time with ages ranging from Meramecian to Morrow. When was the valley incised? When was it backfilled with sediment? These questions are important in terms of the processes that led to incision and understanding the stratigraphic architecture and timing of these events (Figure 37). For current purposes, until biostratigraphic data and regional stratigraphic synthesis are acquired, this IVF is referred to as Chester.

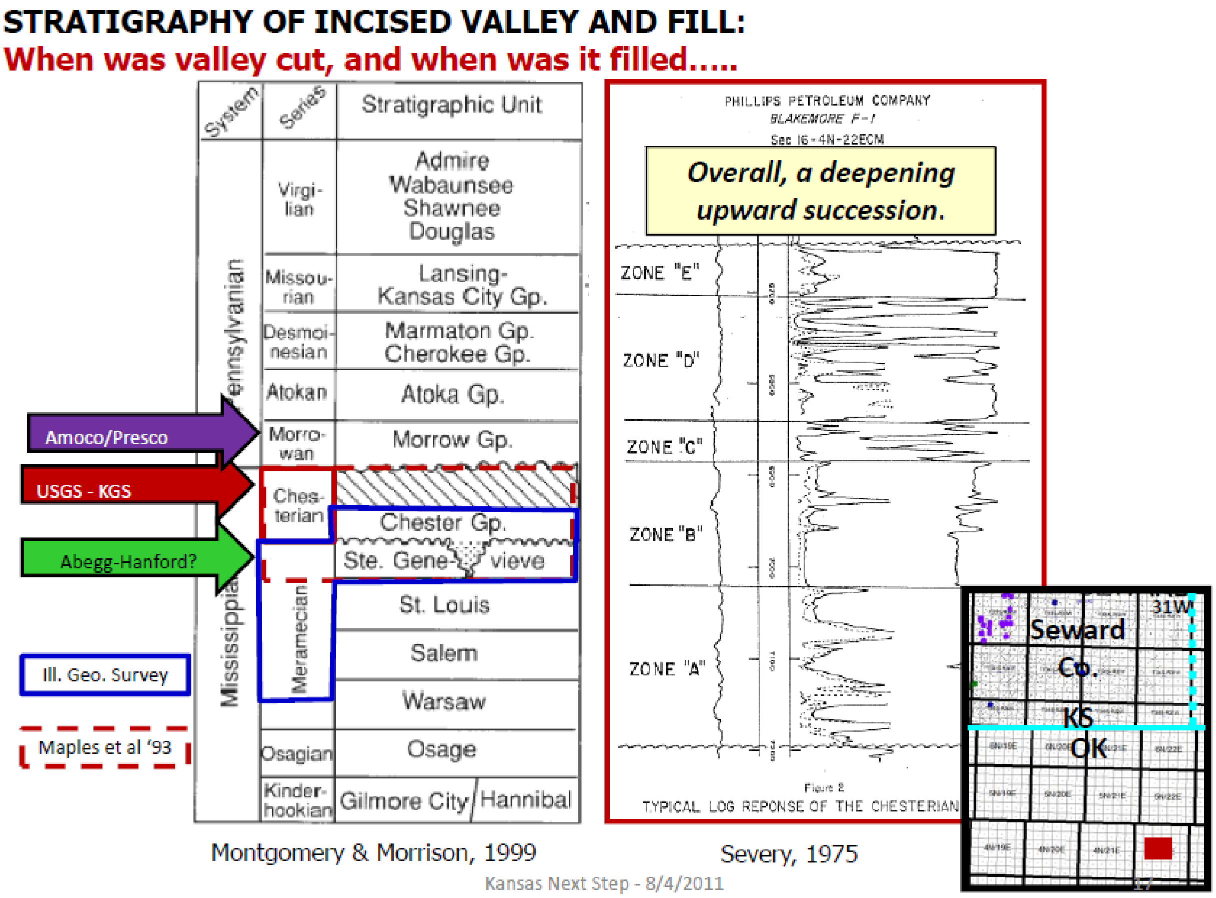


Figure 38. Stratigraphic column for the incised valley system being studied in southwestern Kansas. Note ranges in possible ages (Youle and Dubois, 2011, Next Step conference).

The Chester valley cuts 10's of miles in length across the southern part of the Hugoton Embayment in SW Kansas. The incision is oriented north-south with increasing depth to the south toward the northern margin of the Anadarko Basin. It appears the valley is cut before major structural deformation that occurred in the late Mississippian and Early Pennsylvanian (Figure 39).

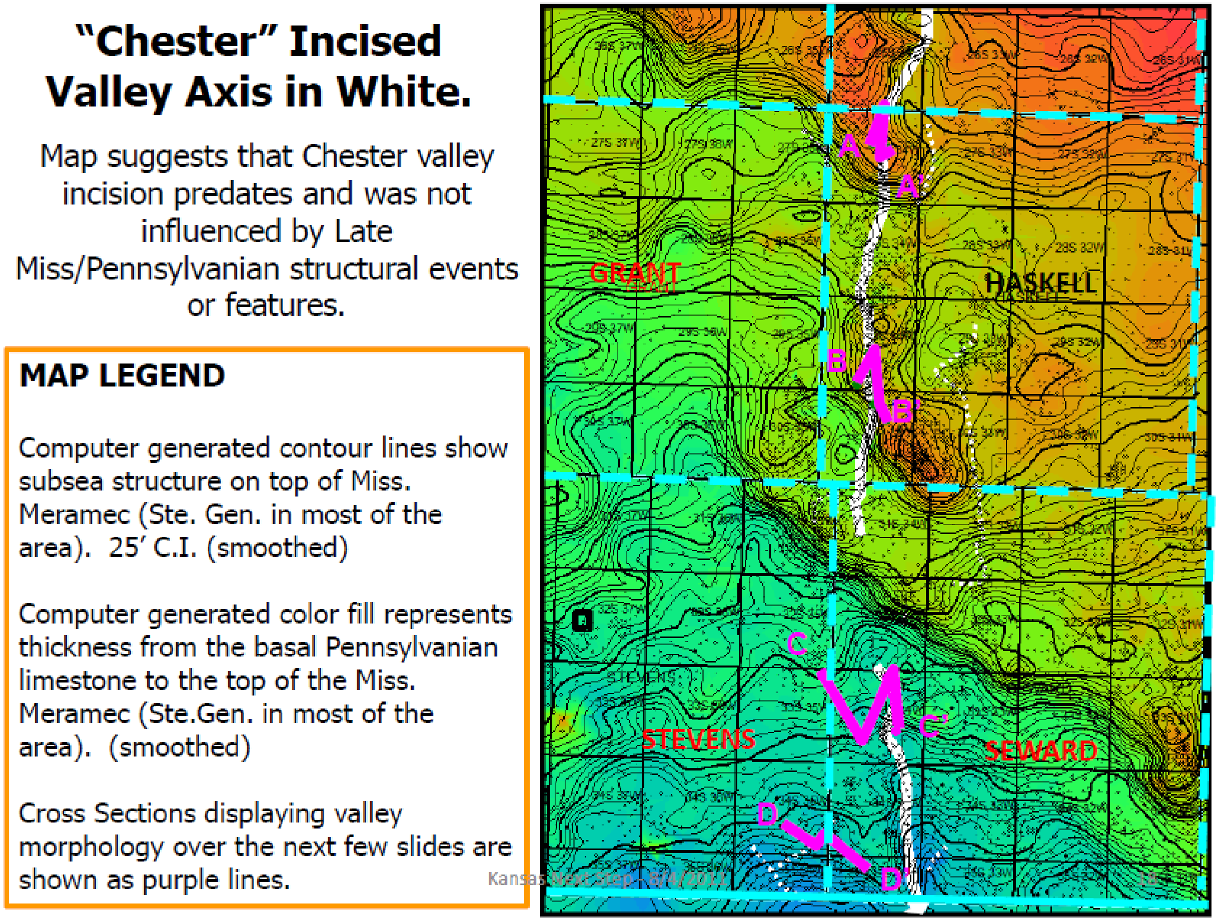


Figure 39. The map of four counties in southwestern Kansas circumscribe the Chester IVF (white line). The formation of the valley appears to predate late Mississippian and early Pennsylvanian structural events. Note cross section indices in pink lines (Youle and Dubois, 2011, Next Step conference).

The four fields being studies comprise portions of the sand filled regional-scale valley system with Pleasant Prairie Field on the north and Shuck Field on the south (Figure 40). Pleasant Prairie South Field extends for approximately 6 miles north-south and is roughly 900 ft wide. The gross interval of the sandstone is 80 ft (Figure 41). The field has produced 4.3 million barrels. Together the fields comprise approximately 20 million barrels of oil production.

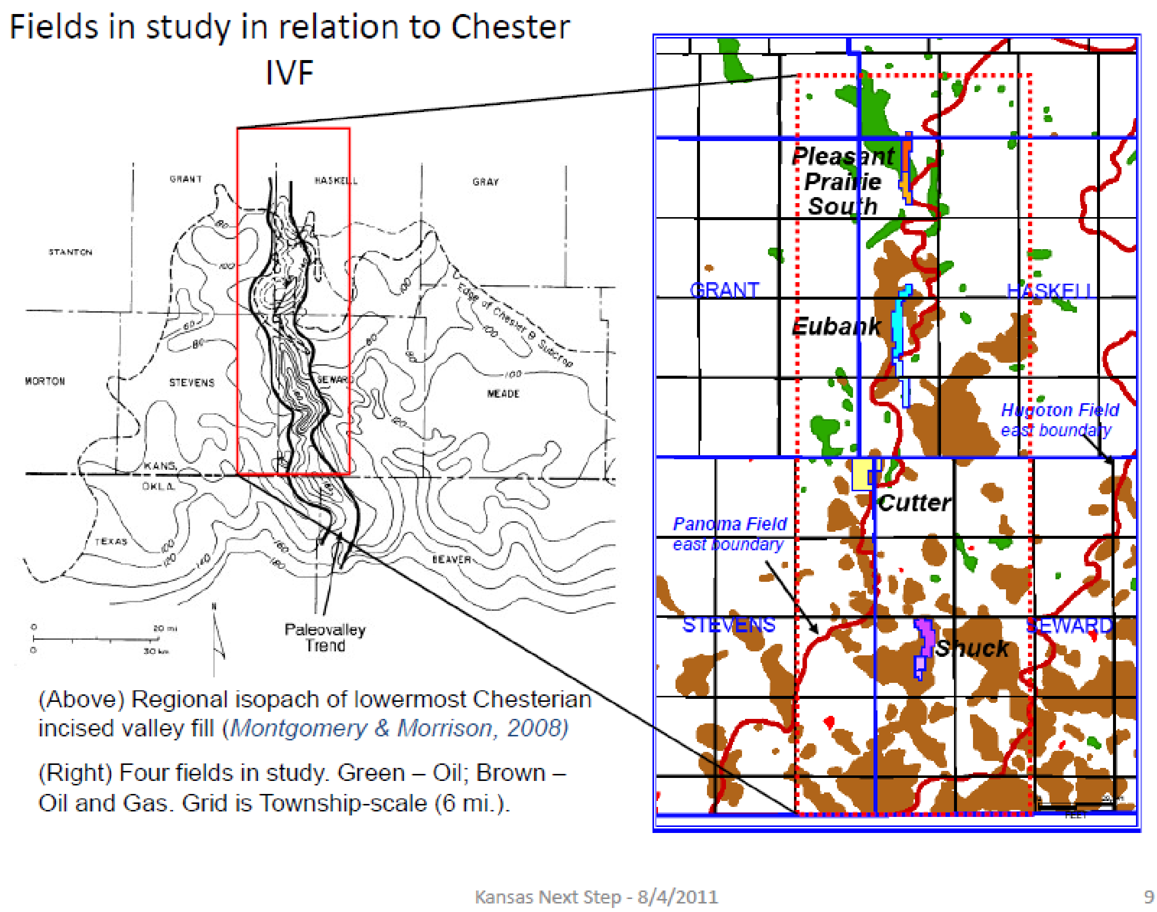


Figure 40. An isopach of the IVF system (left) and an oil and gas map (right) describing the basic distribution of the Chester IVF system (Youle ad Dubois, 2011, Next Step conference).

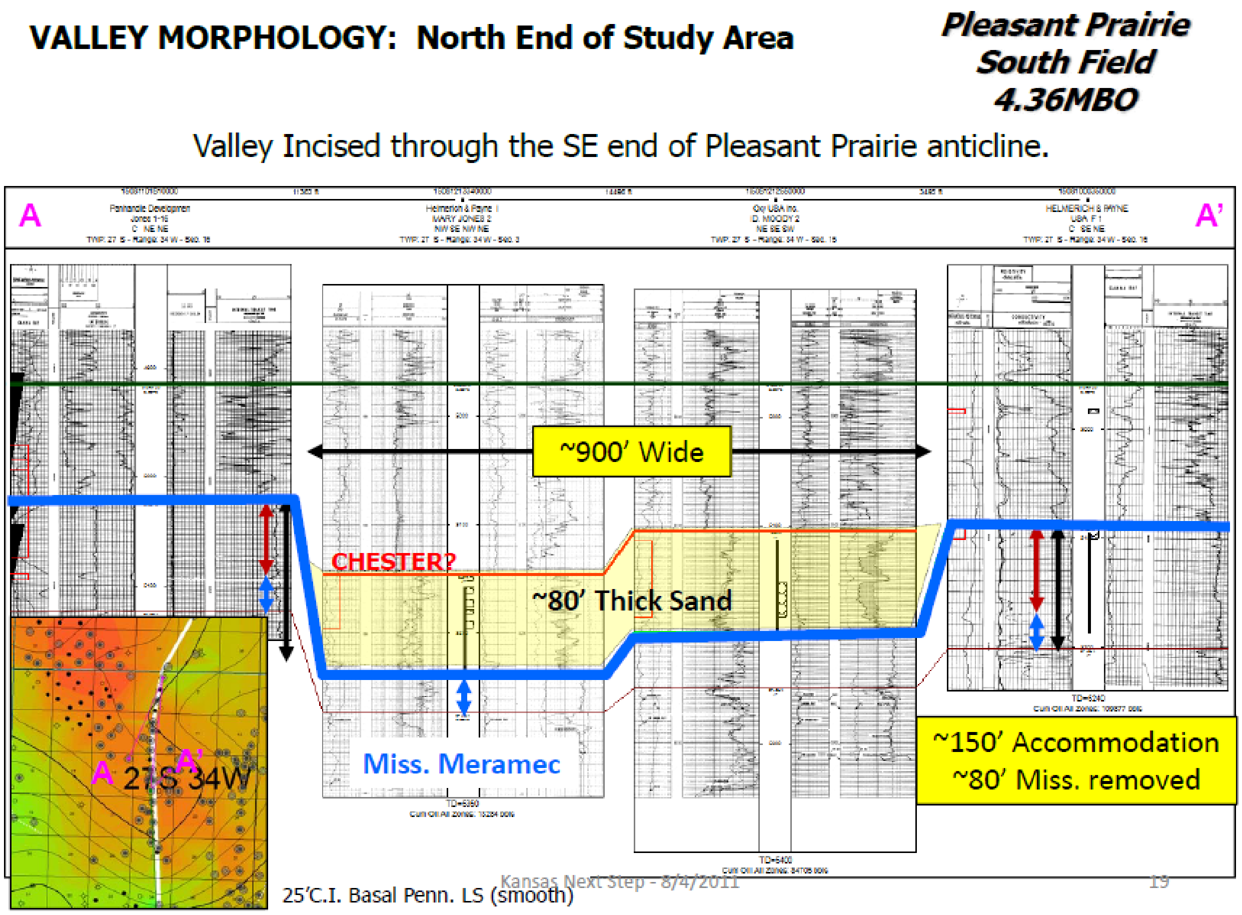


Figure 41. A south to northeast stratigraphic cross section A-A' indexed on the map in Figure 39 traverses across the IVF at Pleasant Prairie South. The smaller index is an isopach of the sandstone with red colors equaling greater thickness (Youle and Dubois, 2011, Next Step conference).

A close-up view of slabbed core illustrates relationship between sedimentary texture and porosity and permeability values for lithofacies ranging from very fine grained sandstone to pebbly sandstone at Pleasant Prairie Field (Figure 42).

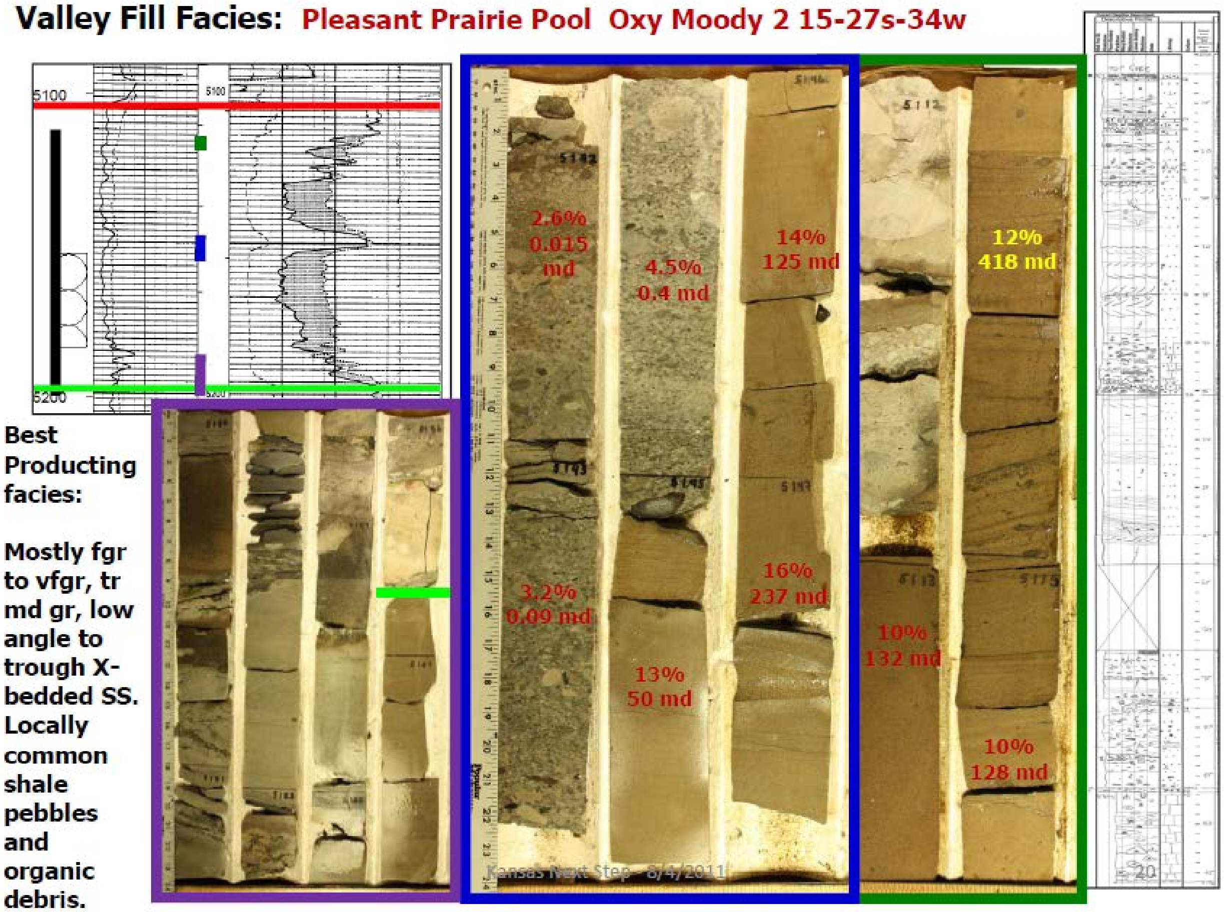


Figure 42. A slabbed core of the Chester reservoir from Pleasant Prairie Pool shows considerable variation in the texture and compositions of the sandstones (Youle and Dubois, 2011, Next Step conference).

Besides heterogeneity produced by lithofacies changes at the pore scale, stratigraphic changes at field scale can also lead to additional compartmentalization (Figures 43 and 44). Successful CO_2 EOR will be dependent on accurate mapping of these features to locate injectors and producers and perforated intervals. Imperious layers may be baffles or barriers depending on their continuity and, in the case of these sandstones, whether overlying sands cut through the impervious layers.

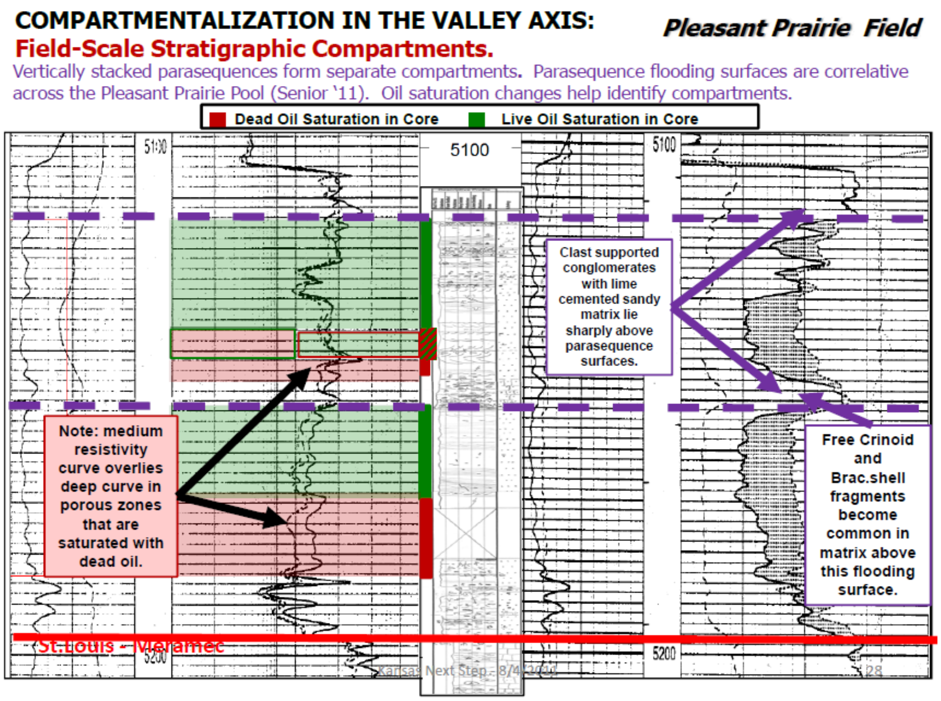


Figure 43. Reservoir compartmentalization in Pleasant Prairie Field (Youle and Dubois, 2011, Next Step conference).

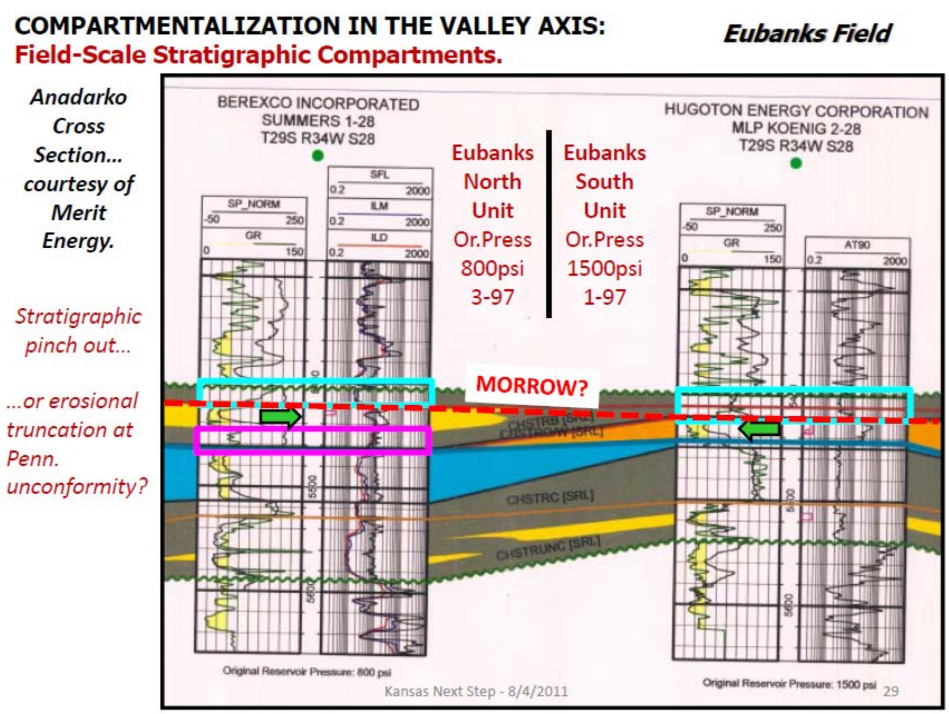


Figure 44. Reservoir compartmentalization in Eubanks Field (Youle and Dubois, 2011, Next Step conference).

Shuck Field near the south end of the study area has a 160 ft thick sandstone reservoir filling a valley that is again around 900 ft wide, but can have terraces that are as much as 50,000 ft wide (Figure 45). The lithofacies of the reservoir in Shuck Field are very fine grained sandstone to bioclastic sandstones, the latter of poorer reservoir quality (Figure 46).

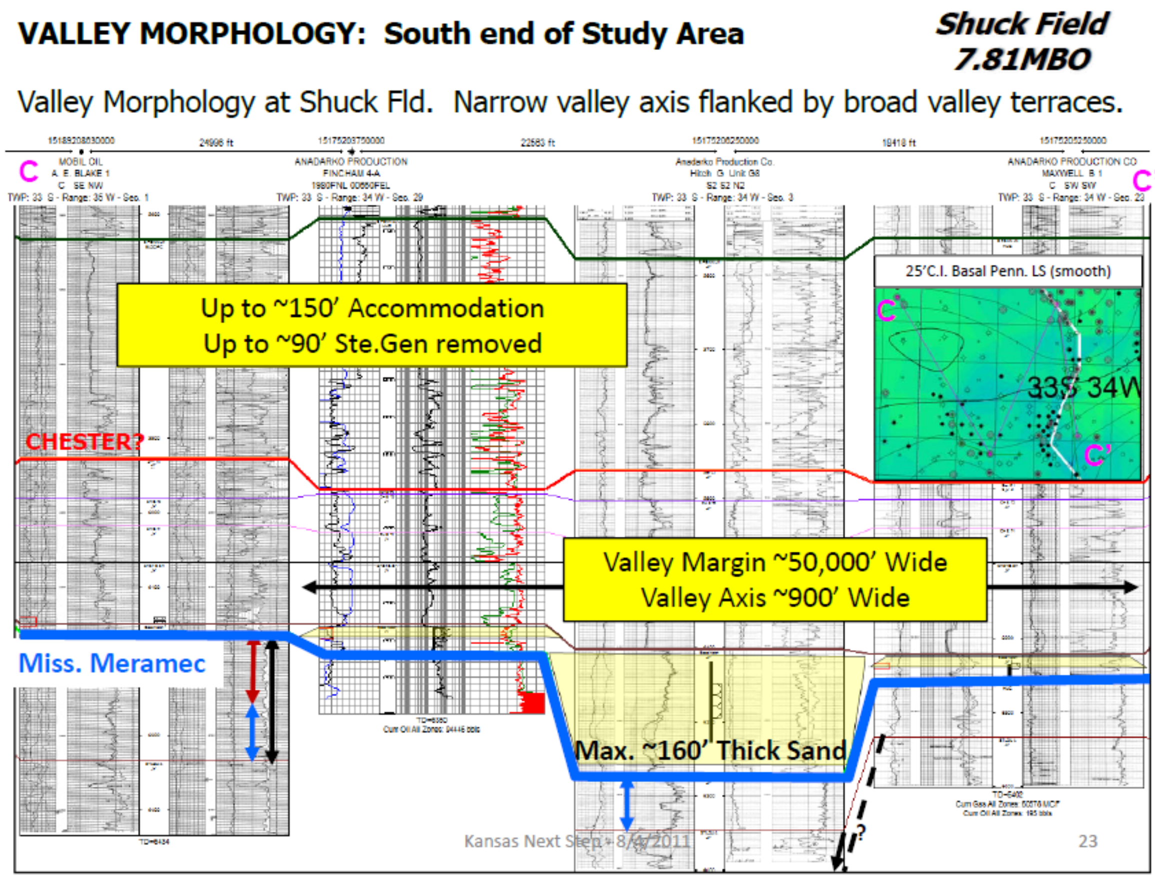


Figure 45. Stratigraphic cross section across Shuck Field (Youle and Dubois, 2011, Next Step conference).

Shuck Field sandstones vary from very fine grained to locally conglomeratic. Diagenesis also plays a role with dissolution of carbonate grains adding pore space (Figure 46).

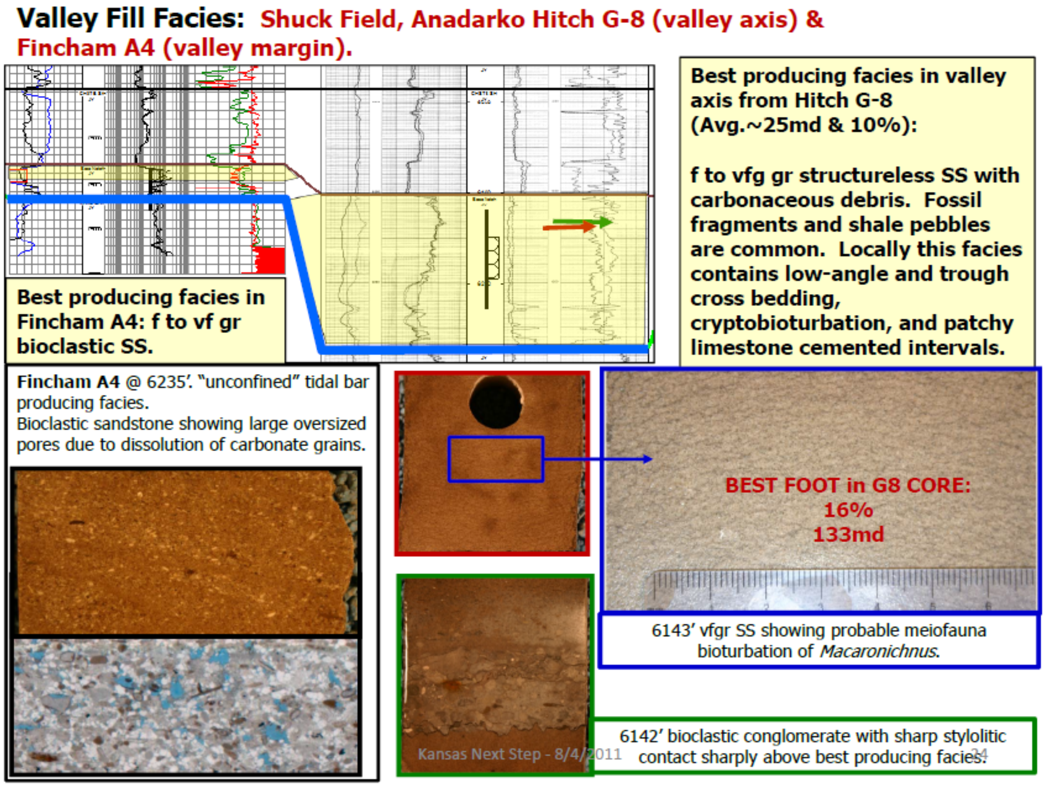


Figure 46. Valley fill lithofacies at Shuck Field (Youle and Dubois, 2011, Next Step conference).

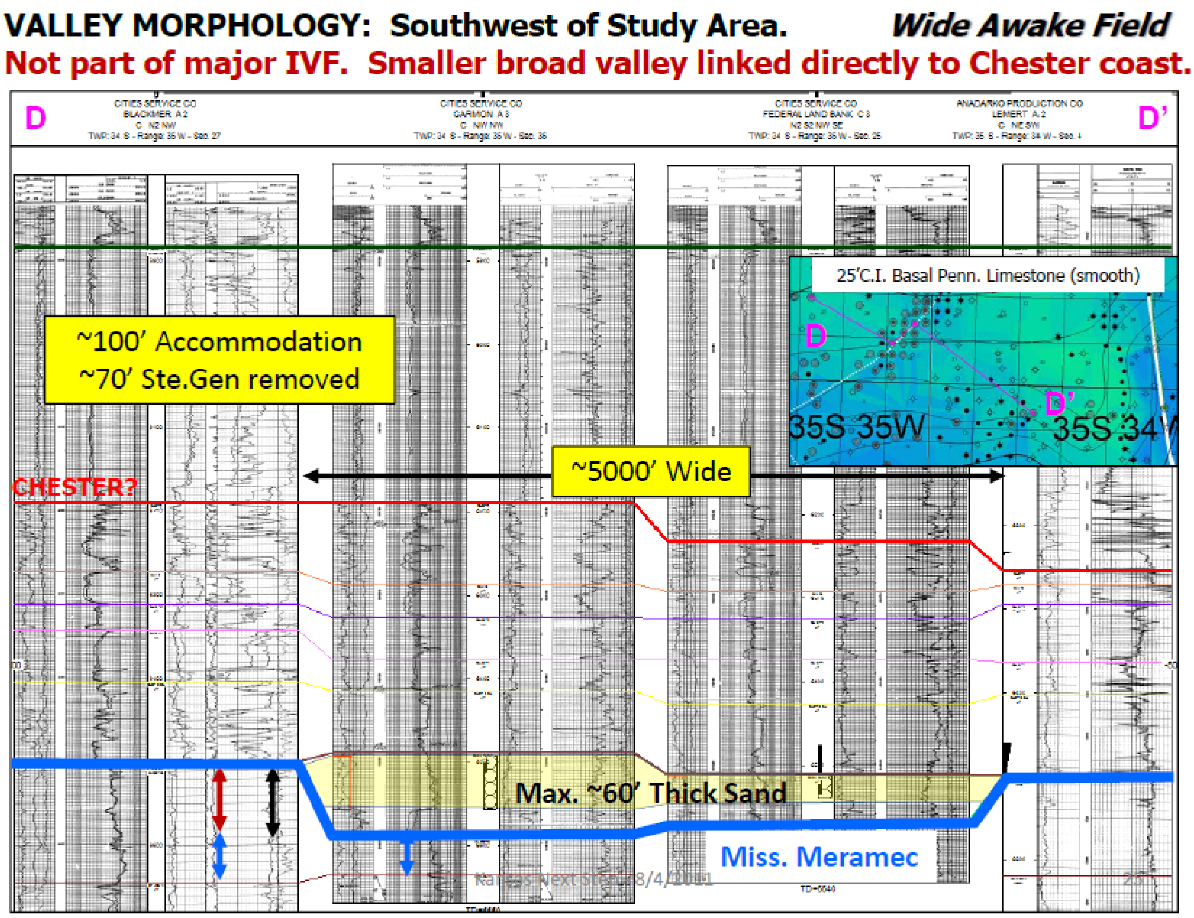


Figure 47. A stratigraphic cross section D-D' indexed in Figure 39 extends across the width of Wide Awake Field the southern-most field located near the Kansas-Oklahoma line. A 60 ft thick sandstone resides in a wide (5000 ft) valley that lies outside the IVF system along the Chester coastline.

The Wide Awake Field is the southern-most field studied and contains a thinner, but broader sandstone reservoir (Figure 47). Paleogeographically, Wide Awake Field is inferred to be near the coastline – a lowstand for this early sea level driven cycle. The broadening and shallowing of this valley as part of this coastal system, suggests an ultimate base level seaway is nearby.

The regional succession of the depositional sequences is illustrated by provisional correlations of parasequences in the Chester succession (Figure 48). The overall succession of parasequences as currently correlated is transgressive backstepping with sand accumulation at the lower reaches of the breaks in slope along the valley system. The locus of sand may reflect a combination of seal level stillstand and topography that may be some combination of structure and erosion.

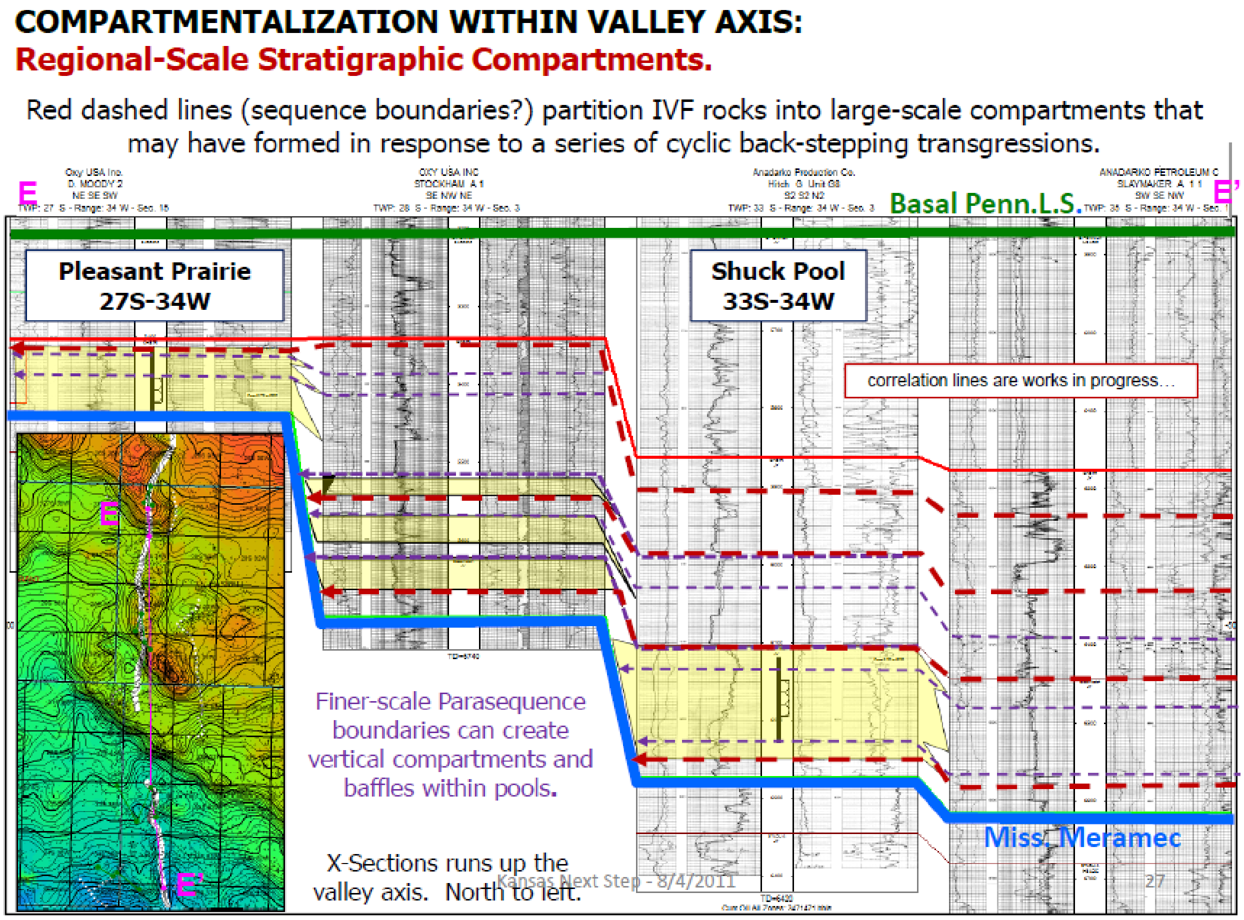


Figure 48. A regional stratigraphic cross section along the Chester incised valley-fill system illustrates provisional correlations of sandstones that fill successive portions of the valley from south (basinward, right side) to the north (landward, left side) at Pleasant Prairie Field. In this interpretation sandstones are time transgressive as the result of successive backstepping transgression of sea level. The cross section index map in Figure 39 (Youle and Dubois, 2011, Next Step conference).

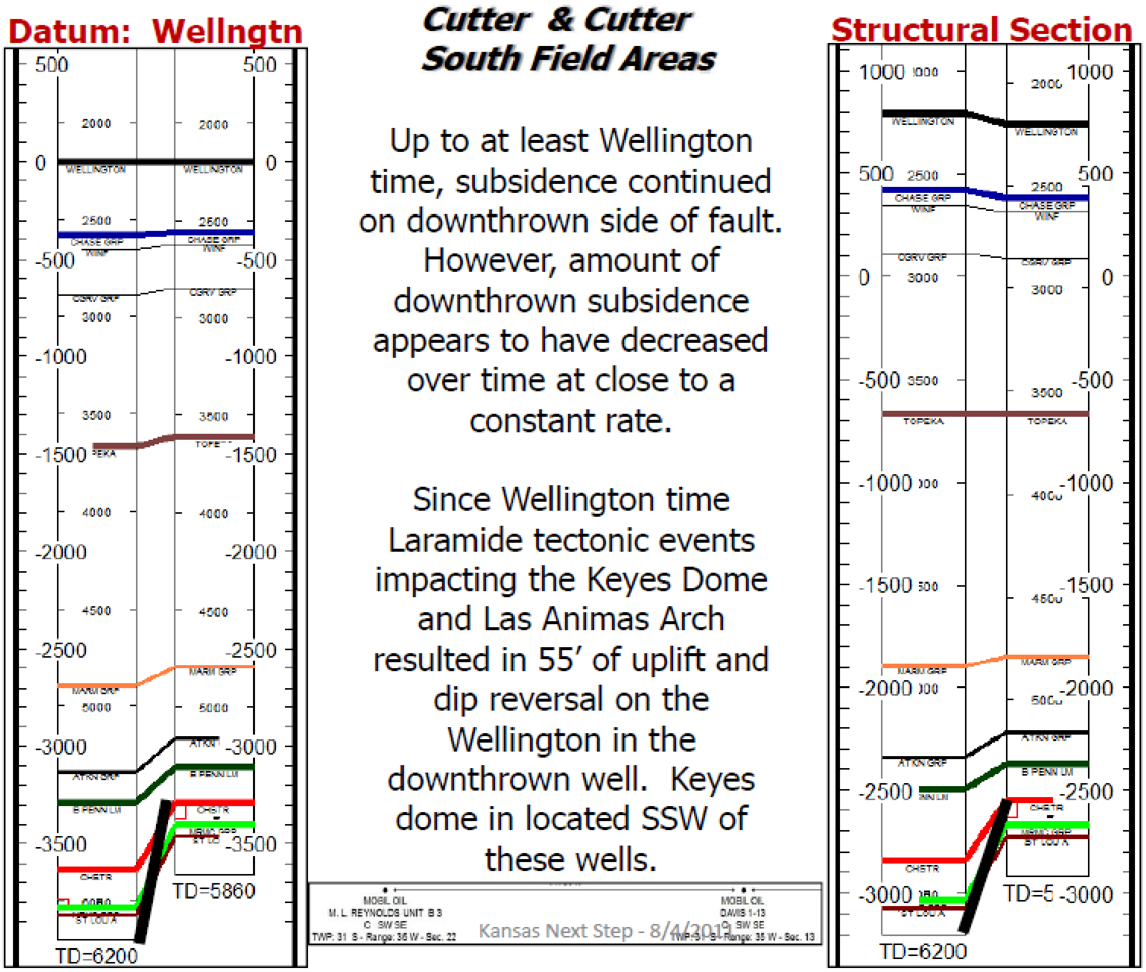


Figure 49. A cross section comparison between two wells.

The cross sections in Figure 49 illustrate the expression of a deep fault where the Chester horizon (red lined surface) is offset, but shallower horizons show much less drape or flexure. The stratigraphic section on the left is datumed at a Permian layer (Wellington – black line). The cross section on the right is a structural section that shows drape up through the orange layer (Middle Pennsylvanian Marmaton Group), but at shallower horizons, the sense of the drape is reversed in the Permian strata. This reversal suggests an even younger structural movement that is the reverse of the sense of the deep-seated fault. The deep-seated fault appears to have been reactivated, but under later compression (Youle and Dubois, 2011, Next Step conference).

Seismic information donated by the industry consortium has been loaded into seismic software and evaluated to determine the need for reprocessing in order to 1) seam together two separate surveys where they overlap or 2) improve the quality/resolution of the presentation. Part of the decision is based budget, the extent of area occupied by the incised valley fill Chester/Morrow reservoirs, and having a reprocessed survey that is of sufficient size to observe deeper stratigraphic information. Figure 50 compares total survey donations and minimum volumes for reprocessing needed to seam together overlapping surveys from the four Chester/Morrow fields.

		IVF Interpretation	
	Total	**Minimum**	**Maximum**
Pleasant Prairie South	35	3	6
31S-34W shoot	3	0	0
Eubanks North	19	0	0
Eubanks Gap	5.5	4.5	5.5
Eubanks South	12.5	7	12.5
Adamson-WideAwake	61	13.5	16.5
Apsley	60	0	0
Cutter	3.3	3.3	3.3
	199.3	**31.3**	**43.8**

Figure 50. Total donated seismic compared to minimum estimates of seismic that needs reprocessing.

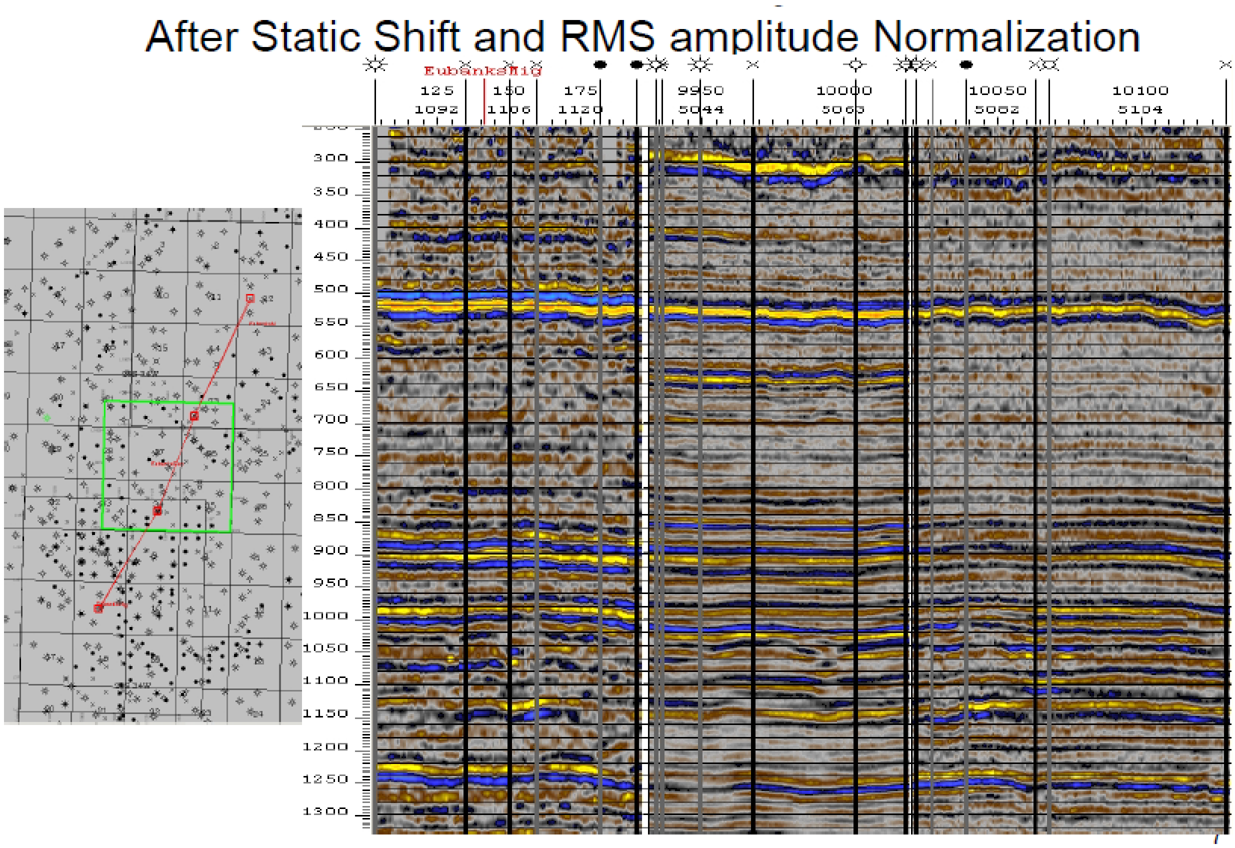


Figure 51. Eubanks arbitrary profile after static shift and RMS amplitude normalization.

Figure 51 is an example of the improvement to an existing seismic dataset in Eubanks field after static shift and RMS amplitude normalization is applied.

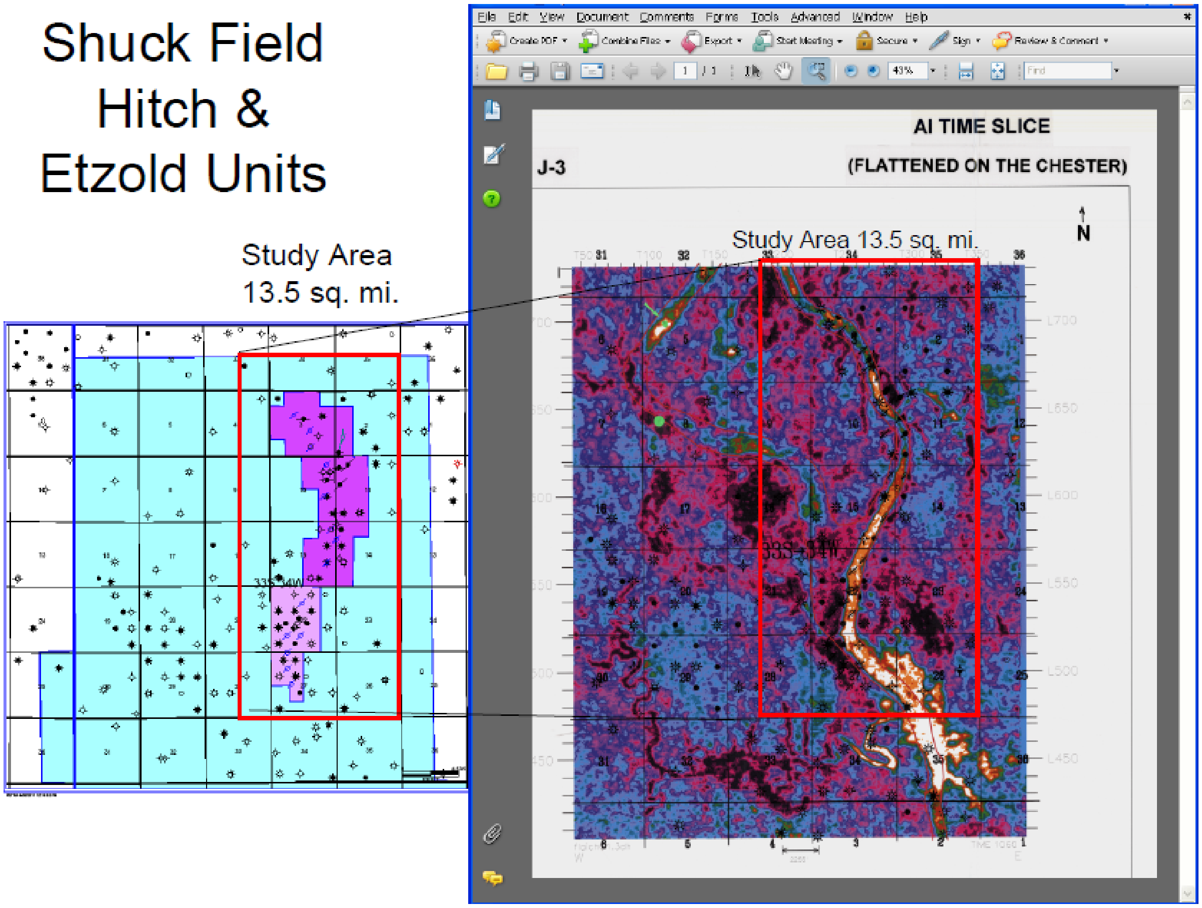


Figure 52. Example of a time slice across Shuck Field showing location of incised valley (yellow) compared to base map and outline of producing leases.

Much of the seismic data that has been donated for use in the project is of sufficient quality of processing to be useful as is seen in Figure 52. Newer processing may sharpen and enhance, but the tradeoff is cost and time vs. additional benefit to reprocessing.

Subtask. 17.2 Select Chester/Morrow field to acquire new data

A request for proposals (RFP) to drill a basement test in the Western Annex was issued to the collaborating industry partners. The goal of the RFP was to obtain a refined scoping cost to compare with that budgeted for the well. The process also clarified the needs so that all were conversant of the intent of the drilling.

The RFP contained quick summary of the drilling parameters as noted below --

QUICK SUMMARY:

Drill, core and run casing to TD in stratigraphic test well to granite (basement) generally described below:

1. Estimated TD* = 7400 ft, 90 ft into basement for Haskell County well (use TD for your proposed location)
2. Surface Casing (8-5/8", 20#), 1800 ft, cemented in accordance with KCC regulations
3. Production Casing (5-1/2", 14#) to TD, cemented to base of surface casing in accordance with KCC regulations
4. Core: continuous core from top of Morrow to Granite (approximately 2100 ft.). KGS to provide core vendor costs. Use 45 days of day work for coring in the costs estimate. Coring time will vary dependent on whether we choose to go with wireline or conventional coring.
5. DSTs: five while drilling or as straddle tests after TD and logging.
6. Qualified well site geologist from Pennsylvanian to TD.
7. Gas detector and mudlogging services.
8. Drilling mud program appropriate for extensive coring operations and lost circulation risks.
9. Complete suite of openhole logs specified in Section 2.
10. Cement bond log.

*TD would increase to 8400 ft to drill to Basement, and Morrow to Basement interval would increase to ~2700 ft in a southern location. If southern location is selected, the amount of core could stay at ~2100 ft by being more selective in cored intervals.

Perforate and run engineering tests in selected intervals

1. Perforate and swab test up to 10 intervals from Morrow through Arbuckle.
2. Up to three crossflow tests in the Arbuckle (perfs above and below packer, downhole gauges, injection below packer.

An AFE-style cost estimate was requested in excel format to include, but is not limited to items listed in the table below:

INTANGIBLE DRILLING AND TESTING COSTS
Survey and stake location
Build location
Damages
Location Closing
Rig Move
Footage Work
Day Work
(include 45 days for coring operation)
Insurance
Drilling Mud & Chemicals
"Supplies, Bits & reamers"
Casing Crew -- Surf. Csg.
Casing Crew -- Long String
Wellsite Geologist (with expenses)
Gas detector trailer and mudlogger
Drill Stem Tests
Fuel -- 600 gal/day
Water
Coring Services and Equipment
(estimate to be provided by KGS)
INTANGIBLES continued
Transportation & Hauling
Open Hole Logging
Cement & Cementing Service - Surf. Csg
Cement & Cementing Service - Long String
Completion Rig
Perforating & Cased Hole Logging
Formation Treating
Roustabout Labor
Supervision
Administrative Overhead
Trash, Toilet, Misc
Plugging (if necessary)
Miscellaneous
TANGIBLE DRILLING AND TESTING COSTS
Conductor Casing
Surface Casing (8-5/8", 20#)
Production Casing (5-1/2", 14#)
Tubing (2-7/8")
Wellhead Equipment, valves, fittings
Miscellaneous

The RFP included the following sections: 1) SCOPE OF WORK & OBJECTIVES, 2) COMPONENTS REQUESTED IN YOUR RESPONSE, 3) APPENDIX A – PRIOR EXPERIENCE IN BASEMENT TESTS AT WELLINGTON FIELD AND LESSONS LEARNED

1) SCOPE OF WORK AND OBJECTIVES OF THE BOREHOLE

The objectives of this deep borehole are stated in the Project's Statement of Project Objectives (SOPO), an official document that DOE is using to measure success in this project. The drilling, including long coring, completion, and testing from Morrowan age Kearney Shale caprock to the Precambrian basement, obviously not a common practice in industry, and will require additional rig time and services to accomplish. The following is taken directly from the SOPO pertaining to the drilling.

2) COMPONENTS

Coring Parameters

Depths and stratigraphy/rock types are based on Haskell County well described in table below with formation tops and image log. A well from Seward County is also included as representative of drilling in an alternative site in the south. TD on the southern location would be ~8400 ft and the Morrow to Basement interval ~2700 ft compared to only 7400 ft TD and 2100 ft Morrow to Basement interval in Haskell County area.

The KGS is securing cost estimates from two preferred vendors discussed below. These cost estimates will be incorporated with submitted proposals. Until estimates of time required for coring are received from the two preferred vendors, daywork is estimated to be 45 days for coring operations for 2100 ft of core. This is based on experience in the Wellington project well where it took 30 days to core 1600 ft of a similar stratigraphic interval, plus extra days for depth considerations.

Coring will start at the top of the Kearney Fm. (Morrow Shale) and continue through the base of the Arbuckle, from 5210 to 7310 ft for a total of 2100 ft of core. We are considering conventional and wireline coring options. Each has their merits and an operator may prefer one over the other. Ideally, we would core continuously, but if drilling problems are encountered or costs get excessive, we will core selected intervals of the more important sections of the stratigraphy including 1) Pennsylvanian shale caprock, 2) Chester/Morrow sandstone reservoir interval, other selected Mississippian and Viola intervals and finally, a continuous core of the Arbuckle to basement interval. Thus, for estimates, an alternative to continuous coring is for taking six 60 ft cores above the Arbuckle followed by continuous Arbuckle core (~870 ft) to basement for a total of 1230 ft.

Typical well and formation depths:

Type Well, Haskell County
TEMA OIL ETAL
DICKERSON 1-33
W2 NE SW
TWP: 29 S - Range: 34 W - Sec. 33
Datum=2993

Fm Top	MD	Thickness
Top Atokan	5072	
Top Morrow	5210	138
Top Miss	5306	96
Top Osage Miss	5893	587
Top Kinderhook	6090	197
Top Viola	6232	142
Top Arbuckle	6440	208
Roubidoux	6798	358
Precambrian	7310	512

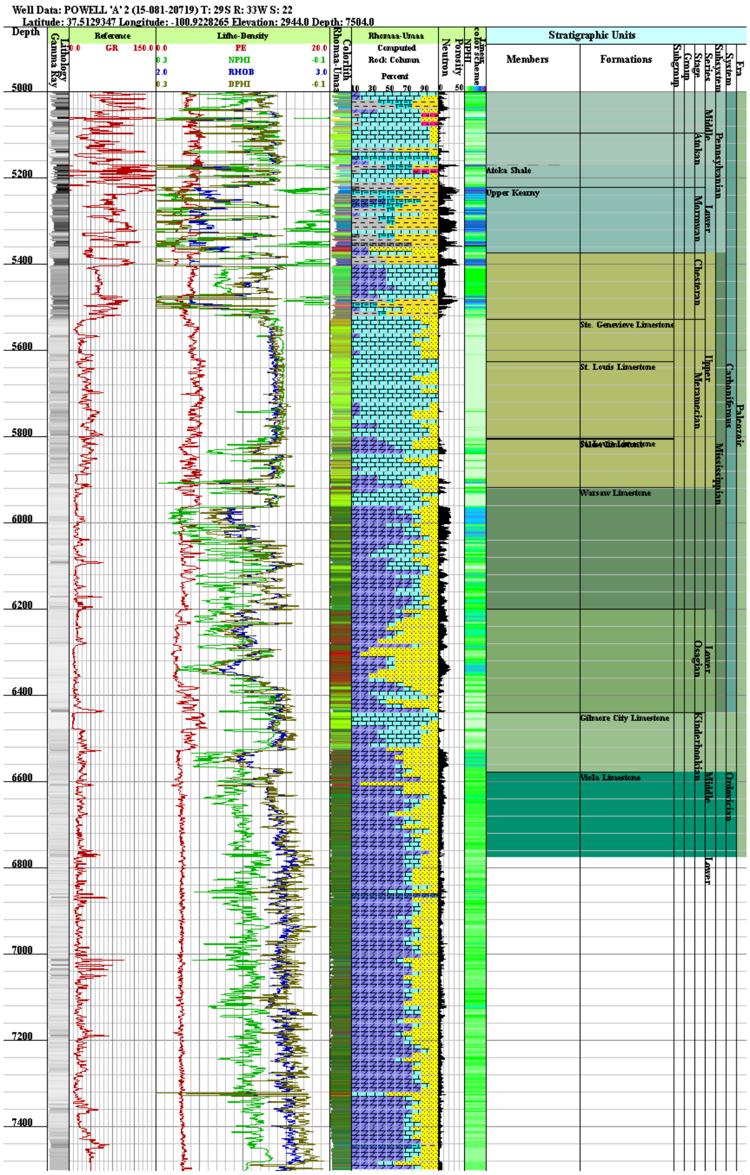
Seward County		
Verdigris	5354	
Top Atokan		
Top Morrow	5616	
Top Miss	5692	76
Top Osage Miss	6630	938
Top Kinderhook	7000	370
Top Viola	7152	152
Top Simpson Sh	7314	162
Top Arbuckle	7472	158
Roubidoux		
Reagan	8190	
Precambrian	8326	854
		Arbuckle thickness

s.

API: 15-175-20550
KID: 1006143657
Lease: HELEN SLEEPER 'A'
Well 1
Original operator: DIAMOND SHAMROCK
Current operator: First National Oil, Inc.
Field: Kismet
Location: T33S R31W, Sec. 25
W2 NW SE
2015 North, 2242 West, from SE corner
Longitude: -100.64299
Latitude: 37.14648
Lat-long from GPS
County: Seward Permit Date:
Spud Date: Oct-15-1981
Completion Date: May-10-1982
Plugging Date:
Well Type: OIL
Status: Inactive Well
Total Depth: 8370
Elevation: 2737 KB
Producing Formation: MRW L
IP Oil (bbl):
IP Water (bbl):
IP

HASKELL COUNTY LOG

Kearny Fm. To lower Arbuckle



API: 15-081-20719
KID: 1006073789
Lease: POWELL 'A'
Well 2
Original operator: HELMERICH & PAYNE, INC.
Current operator: Cimarex Energy Co.
Field: Lemon Northeast
Location: T29S R33W, Sec. 22
C SW NW
3300 North, 4620 West, from SE corner
Longitude: -100.9228265
Latitude: 37.5129347
Lat-long calculated from footages
County: Haskell Permit Date: Mar-09-1992
Spud Date: Apr-05-1992
Completion Date: Jul-16-1992
Plugging Date:
Well Type: OIL
Status: Producing
Total Depth: 7504
Elevation: 2955 KB
Producing Formation: KCTY
IP Oil (bbl):
IP Water (bbl):
IP GAS (MCF):
KDOR code for Oil: 133444

Core Handling

Core will be acquired with aluminum liners to keep core intact. Liners will cut into 3-ft sections, sealed, labeled and placed on pallets by field personnel or contractors. Liners with core will be secured and stacked on pallet with wooden spacers and straps.

Core cannot be frozen due to mechanical testing of shales and tight argillaceous intervals. Subfreezing conditions will require heated onsite storage. A well sealed tent was used to stack cores on pallets at coring in Wellington. A set of 12-14 pallets were then periodically loaded for shipment by KGS personnel to Weatherford Labs in Houston. A pallet loader with extendable, arm came in handy to place pallets in Penske 22 ft covered truck.

Wireline Logging

A minimum of 2500’ of a complete openhole wireline logging suite will be run in the interval from above the Kearney Formation to basement including sufficient rathole (~90 ft) to log the uppermost basement and Paleozoic sedimentary contact. Triple combo log suite will be run through remaining section of the borehole. Section above surface casing will also be logged to surface.

Drill Stem Tests

Five tests either during drilling or after TD is reached (straddle packer with tailpipe to set packers). Intervals to be tested include Chester/Morrow sandstone interval, mid Mississippian, and upper, mid, and lower Arbuckle. Tests will be in isolated porous intervals (~20 ft) and of sufficient duration to obtain interpretable buildup and shut-in pressures.

Well Drilling and Completion

Please include Day work rate and number of days for drilling rig. Bids may be either footage to core point and day rate beyond core point or by day rate for the entire well.

The option to drill the Arbuckle section (6440-7310 ft) as a slant hole will be investigated, but is currently not a priority. If we determine that important heterogeneity identified by 3D seismic interpretation would prove beneficial and the implementation and cost are manageable, this option will be pursued.

Surface Casing (8-5/8", 20#), 1800 ft.
Production Casing (5-1/2", 14#), 7600 ft.

Perforating and swabbing in top of basement, Arbuckle, Chester/Morrow and Other intervals to obtain connate brine for geochemical studies.

Please include hour rate and # hours for completion rig.

Up to ten intervals will be perforated and swab tested. Perforating intervals will be chosen to overlap with DST and selection of flow units with an emphasis on the Arbuckle and immediately overlying strata. Perforating other intervals, such as the Chester/Morrow will be an option for the operator after the well is released to the company. Sufficient fluid will be swabbed to obtain native connate water, approximately 500 bbls of fluid.

Test for cross flow between adjacent perforated intervals

An additional two or three perforated intervals in the Arbuckle will tested for vertical cross flow by isolating perfs by a packer and pumping into one perf interval and gauge pressure on the other. Perforations from swab tests may be utilized if feasible.

Swabbing and crossflow tests are scheduled for Berexco Wellington KGS #1-32 in Wellington Field and are illustrated in graphic in Appendix A. Completion reports for #1-28 and current activity at #1-32 are also included in Appendix A.

Requested Information

1. Standard AFE spreadsheet that includes standard drilling items, coring, logging, and borehole completion including description, quantity and cost, cost per unit, and estimated cost.

2. Additional documentation on services, to aid in description as needed.

Remember, this is a scoping cost and a good faith estimate of costs at the time the well will be drilled. We all know conditions can change and costs will need to be reviewed once we decide on the operator and location. It will be very useful to a have pre-spud meeting with all of the contractors involved in drilling.

Southern well with ~8400 ft TD (would reduce coring if drill in south)

Seward County		
Verdigris	5354	
Top Atokan		
Top Morrow	5616	
Top Miss	5692	76
Top Osage Miss	6630	938
Top Kinderhook	7000	370
Top Viola	7152	152
Top Simpson Sh	7314	162
Top Arbuckle	7472	158
Roubidoux		
Reagan	8190	
Precambrian	8326	854
		Arbuckle thickness

s.

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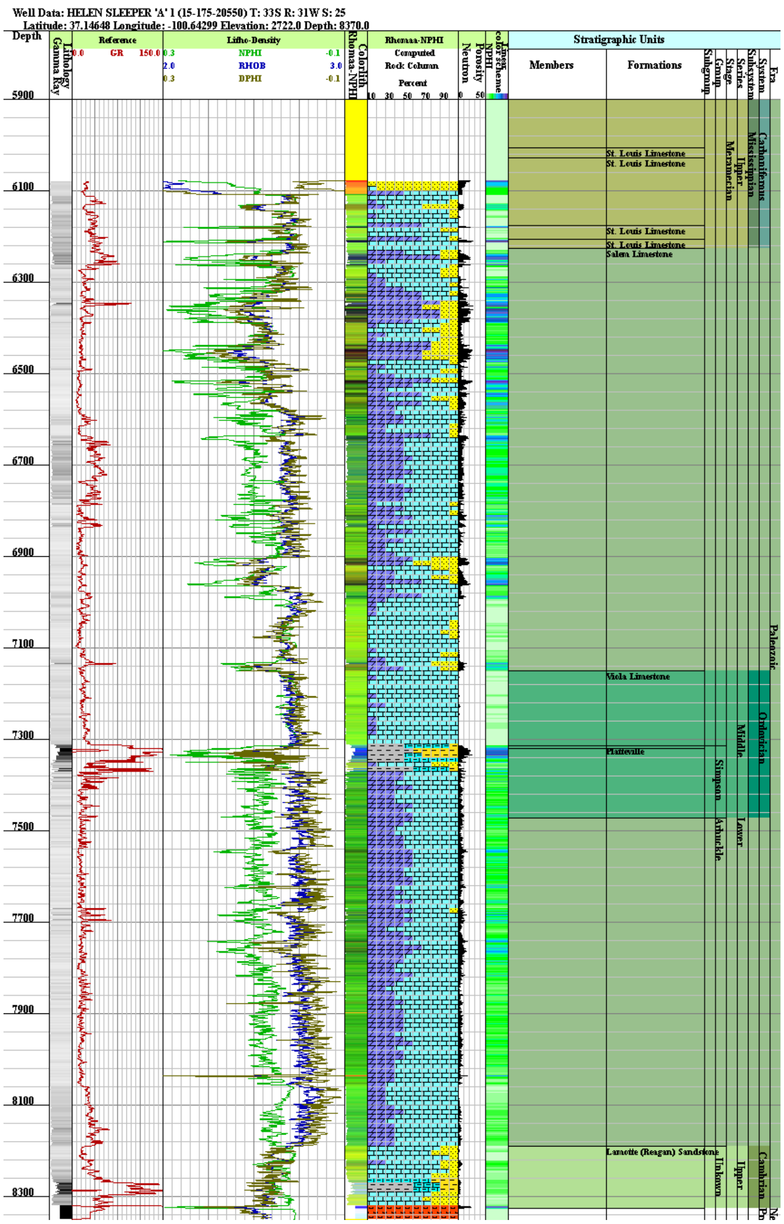
2015 North, 2242 West, from SE corner
Longitude: -100.64299
Latitude: 37.14648
Lat-long from GPS
County: Seward Permit Date:
Spud Date: Oct-15-1981
Completion Date: May-10-1982
Plugging Date:
Well Type: OIL
Status: Inactive Well
Total Depth: 8370
Elevation: 2737 KB
Producing Formation: MRW L
IP Oil (bbl):
IP Water (bbl):
IP

SEWARD COUNTY LOG

St. Louis to basement



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Status: Inactive Well
Total Depth: 8370
Elevation: 2737 KB
Producing Formation: MRW L
IP Oil (bbl):
IP Water (bbl):
IP GAS (MCF):

Presentations

Presentations made during quarter at Next Step Oil and Gas Seminar, Hays, Kansas, August 2011 and Kansas Department of Health and Environment Annual Geology Seminary, September 2011.

Key Findings

1. Project's interactive mapper was again updated and improved with ability to show many maps and display legends of maps. Western Annex remote sensing and other maps also updated.
2. Java web applications to display and analyze digital well data was improved my release of new well profile tool and 3D petrophysical visualization tool.
3. Analysis of regional map data for faulting has begun in earnest. Methodologies are being evaluated to define suspect faults and validation of those faults with well and seismic data will be undertaken.
4. Step rate test conducted in the two new basement tests in Wellington Field demonstrate that the Arbuckle is in communication in thin flow units. Current geomodel of a layered system with porous and nonporous units appears to hold.
5. DST and brine analyses are yielding useful geochemical and microbial data that indicate that they will aid in understanding how CO2 will react.
6. 2D shear wave survey was completed and processing is nearly done. Expectation is that the depth converted and migrated volume coupled with the converted shear wave data will add considerably toward building a refined geomodel of the Arbuckle.
7. The evaluation of the deeper portion of the Mississippian carbonate interval at Wellington Field has yielded indications of a new oil zone. This is at a time when a large regional lease play is underway to develop additional resources in the Mississippian of southern Kansas.
8. Western Annex study is making rapid progress in characterizing well data from Chester fields and evaluating donated seismic data for reprocessing.
9. Request for proposals to drill the basement test in southwest Kansas was sent to collaborating companies. Responses indicate costs are close to budgeted, but most are higher.

Plans

1. More swab tests are scheduled for Berexco Wellington KGS #1-32 to provide more widespread sampling of the brine to understand the geochemistry and microbial composition.
2. Steps will be taken to bring the cost of drilling in line with the budget and still accomplish the major objectives of drilling.
3. Identification and verification of faults and fracture systems will continue as regional data are processed and integrated with other information.
4. Revised geomodel for Arbuckle in Wellington Field will commence, once 1) seismic data is interpreted with depth converted and shear wave data included and 2) core analysis data is obtained from lab.

5. Considerations for drilling sites in Western Annex will be facilitated by efforts to complete initial characterizations on the four Chester fields, interpret the donated seismic data, build the geomodels, and conduction reservoir simulations.

Cost Plan/Status

Costs in the 7th quarter were incurred in Tasks.

COST PLAN/STATUS	Year 1 Starts: 12/8/09	Ends: 2/7/11				BP2 Starts 2/8/11	Ends 8/7/12	
	12/8/09-12/31/09	1/1/10-3/31/10	4/1/10-6/30/10	7/1/10-9/30/10	10/1 - 12/31/10	1/1/11 - 3/31/11	4/1/11 - 6/30/11	7/1/11-9/30/11
Baseline Reporting Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
Baseline Cost Plan (from SF-424A)	(from 424A, Sec. D)							
Federal Share	$1,007,622.75	$1,007,622.75	$1,007,622.75	$1,007,622.75	$0.00	$0.00	$0.00	$1,169,543.00
Non-Federal Share	$277,260.75	$277,260.75	$277,260.75	$277,260.75	$0.00	$0.00	$0.00	$303,182.75
Total Planned (Federal and Non-Federal)	$1,284,883.50	$1,284,883.50	$1,284,883.50	$1,284,883.50	$0.00	$0.00	$0.00	$1,472,725.75
Cumulative Baseline Cost	$1,284,883.50	$2,569,767.00	$3,854,650.50	$5,139,534.00	$5,139,534.00	$5,139,534.00	$5,139,534.00	$6,612,259.75
Actual Incurred Costs								
Federal Share	$4,019.93	$84,603.97	$494,428.37	$111,405.52	$238,675.97	$1,902,936.55	$625,853.17	$275,754.50
Non-Federal Share	$0.00	$0.00	$0.00	$84,564.82	$251,354.30	$20,887.31	$6,043.03	$552.19
Total Incurred Costs-Quarterly (Federal and Non-Federal)	$4,019.93	$84,603.97	$494,428.37	$195,970.34	$490,030.27	$1,923,823.86	$631,896.20	$276,306.69
Cumulative Incurred Costs	$4,019.93	$88,623.90	$583,052.27	$779,022.61	$1,269,052.88	$3,192,876.74	$3,824,772.94	$4,101,079.63
Variance								
Federal Share	$1,003,602.82	$923,018.78	$513,194.38	$896,217.23	-$238,675.97	-$1,902,936.55	-$625,853.17	$893,788.50
Non-Federal Share	$277,260.75	$277,260.75	$277,260.75	$192,695.93	-$251,354.30	-$20,887.31	-$6,043.03	$302,630.56
Total Variance-Quarterly Federal and Non-Federal)	$1,280,863.57	$1,200,279.53	$790,455.13	$1,088,913.16	-$490,030.27	-$1,923,823.86	-$631,896.20	$1,196,419.06
Cumulative Variance	**$1,280,863.57**	**$2,481,143.10**	**$3,271,598.23**	**$4,360,511.39**	**$3,870,481.12**	**$1,946,657.26**	**$1,314,761.06**	**$2,511,180.12**