DOE F 4600.2
(5/09)
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ATTACHMENT 3
U.S. Department of Energy
FEDERAL ASSISTANCE REPORTING CHECKLIST
AND INSTRUCTIONS

1. Identification Number: **DE-FE0002056**	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**
3. Recipient: University of Kansas Center for Research	

4. Reporting Requirements:	Frequency	No. of Copies	Addresses
A. MANAGEMENT REPORTING			
☒ Progress Report	Q	Electronic Version to NETL>	FITS@NETL.DOE.GOV
☒ Special Status Report	A		
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)			
Report/Product — Form			
☒ Final Scientific/Technical Report — DOE F 241.3	FG	Electronic Version to E-link>	http://www.osti.gov/elink-2413
☒ Conference papers/proceedings/etc.* — DOE F 241.3	A		http://www.osti.gov/elink-2413
☐ Software/Manual — DOE F 241.4			http://www.osti.gov/estsc/241-4pre.jsp
☒ Other (see special instructions)			
Topical — DOE F 241.3	A		
* *Scientific/technical conferences only*			
C. FINANCIAL REPORTING			
☒ SF-425, Federal Financial Report	Q, FG	Electronic Version To NETL>	FITS@NETL.DOE.GOV
D. CLOSEOUT REPORTING			
☐ Patent Certification	FC	Electronic Version To NETL>	FITS@NETL.DOE.GOV
☐ Property Certificate	FC		
☐ Other			
E. OTHER REPORTING			
☒ Annual Indirect Cost Proposal	A	Electronic Version To NETL>	FITS@NETL.DOE.GOV
☒ Annual Inventory Report of Federally Owned Property, if any	A		
☐ Other			
F. AMERICAN RECOVERY AND REINVESTMENT ACT REPORTING			
☐ Reporting and Registration Requirements			http://www.federalreporting.gov

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.

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

Seventh Quarter Progress Report

Date of Report: July 30, 2011

Period Covered by the Report: April 1, 2011 through June 30, 2011

Contributors to this Report: Saibal Bhattacharya, Ken Cooper, Saugata Datta, John Doveton, Martin Dubois, Paul Gerlach, Tom Hansen, Dennis Hedke, Randy Koudele, Larry Nicholson, Jason Rush, John Victorine, Lynn Watney, 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 conducted to estimate CO_2 sequestration potential in selected area around Oxy-Chem #10 well, 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., and 13) initial core description and sampling begun for special and routine core analysis.

CHANGES IN PERSONNEL

Saibal Bhattacharya, previous Joint PI, resigned from the KGS in May. His managerial studies have been taken on by Jason Rush, who has been Co-PI on this project. A search is underway for a permanent simulation engineer. In addition, Gene Williams, a consultant, the principal in Williams Petroleum Consulting in Houston, was contracted to build the series of simulations required for the project. He has considerable experience with CO2-EOR comes highly recommended by staff at CMG. Mr. Williams comes with the expertise and experience that is needed to fit into the project and no disrupt the workflow. Simulations are required at Wellington Field (Mississippian oil reservoir and Arbuckle saline aquifer), eight locations in the regional study area to model the Arbuckle saline aquifer, and four Chester/Morrow sandstone fields and underlying Arbuckle located in the Western Annex/Southwestern Kansas.

KGS has also hired undergraduate engineer, Aadish Gupta, whose primary is to coordinate handling of well data and building input data files for geomodels and simulation. Also, Mina Fazelalavi, a graduate engineer from KU to conduct quality control, normalization, and analysis of LAS wireline log files for the DOE projects and to assist in building integrated geomodels suited for simulation.

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

Scanning and digitizing of well data for the regional part of the project continues in earnest. Additional type wells are being added for the entire state to develop stratigraphic correlation and petrophysical information of the Arbuckle aquifer and overlaying caprocks. Total well count is currently 144,000. Total stratigraphic tops stand at 630,000 including existing tops harvested from the KGS database and new ones being established with the new regional stratigraphic correlations that are underway.

Updating software for managing petrophysical/log data

The Java application, Profile, http://www.kgs.ku.edu/stratigraphic/PROFILE/, has been updated to include new data types, provide a new interface, and a help section. Profile will build composite LAS 3.0 files that can integrate well information in addition to wireline data, including regional stratigraphic classification, georeports/sample descriptions, drill stem test information, and brine and geochemistry data (**Figure 1**). Profile also creates standard well log profiles and cross sections to display composite information and save images (png) and Java process files to the project website.

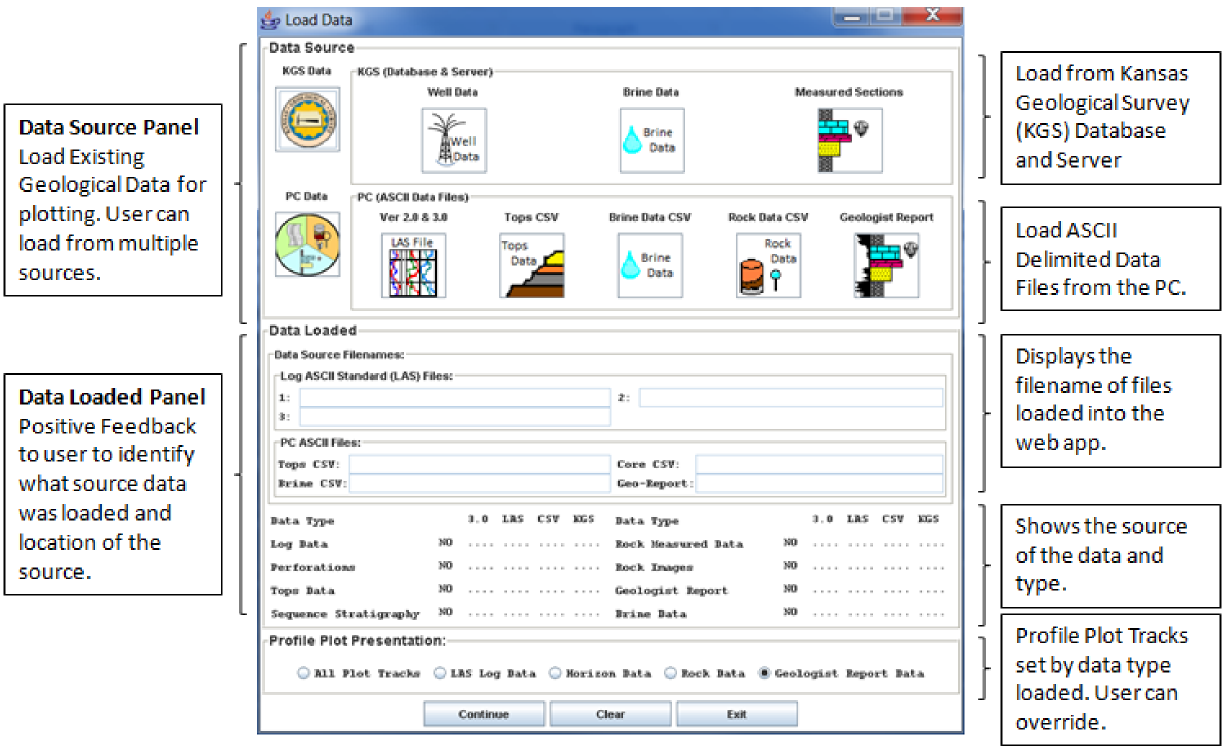


Figure 1. This panel allows the user to load multiple data types from multiple sources, i.e. the ASCII Delimited Data Files on your PC and the Kansas Geological Survey (KGS) Database & File Server. As the ASCII files are read in, the filenames are inserted into the text fields to give the user a positive feedback. Once the user has loaded the data from the sources, select the "Continue" Button to create the Profile Plot. NOTE: The User can load up to 3 Log ASCII Standard (LAS) version 2.0 & 3.0 files from either your PC or the KGS File Server.

This version allows the user to read & parse a delimited geologist report ASCII file data, which can provide vital information about lithology, pores, and fluids including oil and gas shows. This information displayed alongside the wireline log data can aid in analysis of aquifer, flow units, and caprocks.

The new version of Profile also allows easier linking of LAS log curves with standard mnemonics (**Figure 2**).

List of Log ASCII Standard (LAS) Curves from the Newby 2-28R File.

Note: The Color Coding is to make it easier to distinguish type of curves.

A number of curves can not be mapped to the KGS Standard Mnemonics so a General Linear Curve and Log Curve tracks are provided.

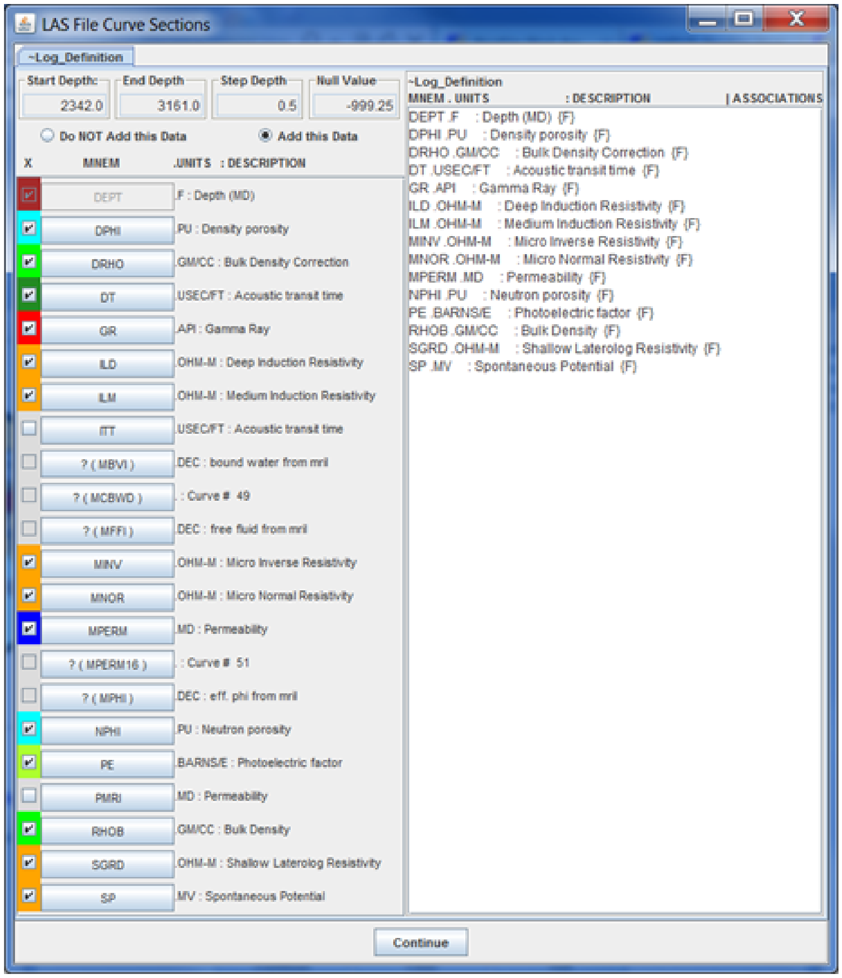


Figure 2. Standard log types and mnemonics can be associated and linked with curve names on the LAS files that is to be imported.

The added versatility of curve selection as augmented by permitting the user to access open tracks to allow mapping any curve to a linear or a log track (**Figure 3**). This will permit user to display computed log analysis or display less common log values such as bound water from MRIL tool (nuclear magnetic resonance).

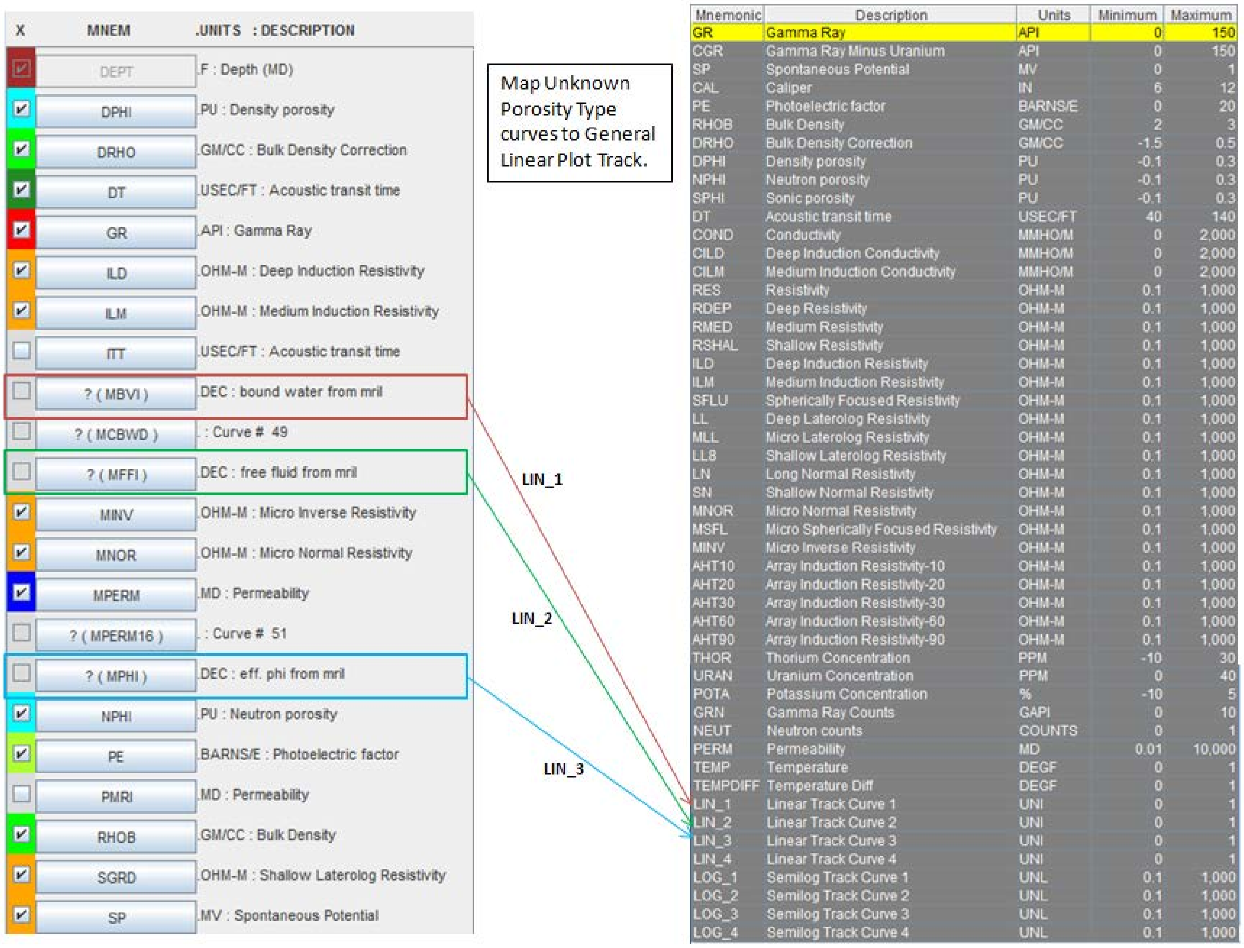


Figure 3. New menu of curve identification permits the user to select and define atypical data to plot in depth alongside other standard log data.

Main control panel has remained very similar to earlier version, thus continuity. Added features are within. Control panel defines log curves to be displayed, depth intervals, and scales (**Figure 4**).

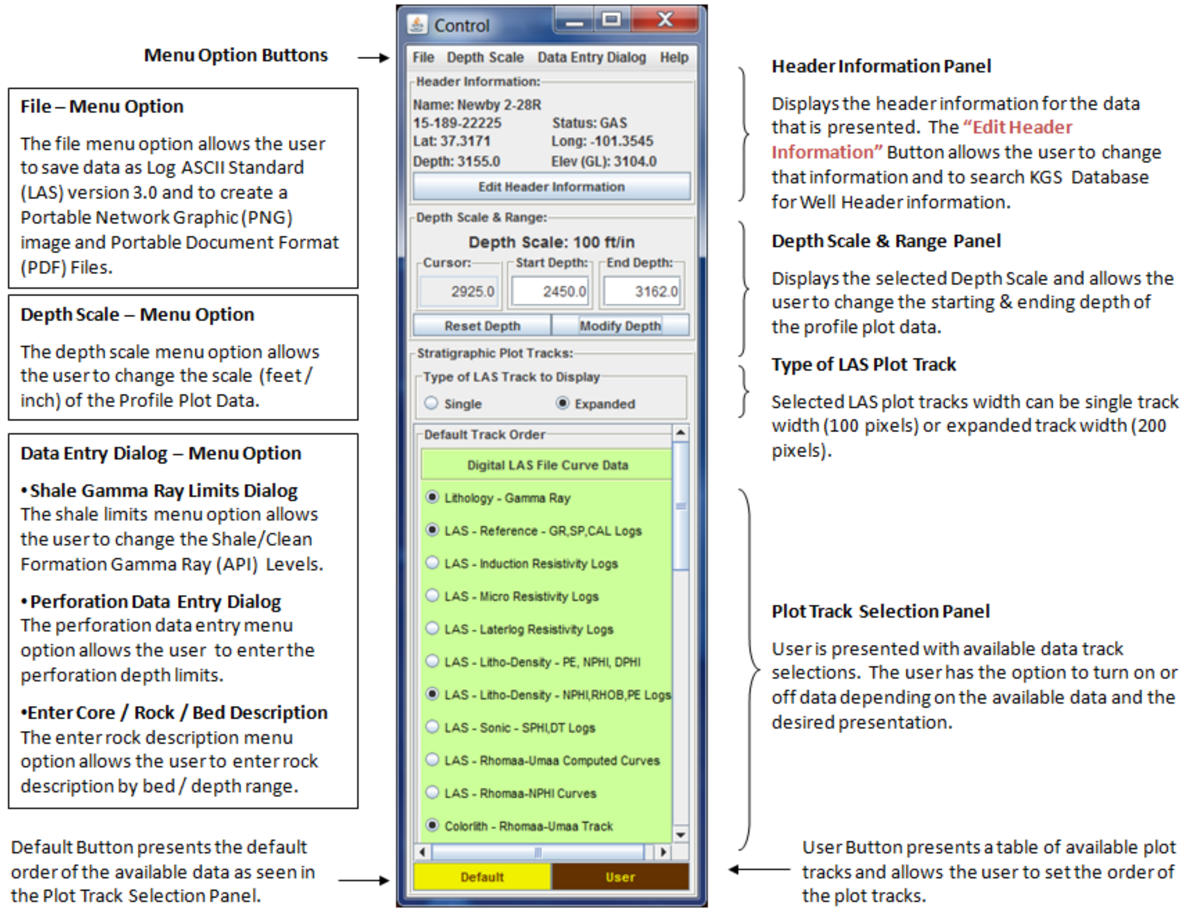


Figure 4. Control panel included in Profile Java software.

Subtask 2.3. Develop regional correlation framework and integrated geomodel

Regional well data has continued to be gathered, scanned, and digitized. Well data is being correlated through the regional study area. Stratigraphic units being correlated span the interval from above the main Permian evaporites to the Precambrian basement (**Figure 5**). Available stratigraphic data is being utilized to aid correlations. Stratigraphic units are being identified and verified are being uploaded to the KGS database and website so that they can be selected and displayed with well profiles and cross sections generated using the web-based Java software Profile and Cross Section.

ADMIRE	Gunter SS of VB	MAQU SH	WBNS GRP
ARBK GRP	HBNR SH	MARM GRP	WEIR COAL
ATKN GRP	HERRINGTON	MINERAL COAL	WINF
B BLAINE	HUNTON	MISS Base	WREFORD
B KCTY GRP	HUTCH SALT	MISS SYS	WRSW
B PENN LM	IOLA	MRMC GRP	COWLEY FACIES
B STNC	JCC	MULKY COAL	SQUIRREL SD
B-FT HAYS	JCC 1	NEVA	WAYSIDE SD
BERN LS	JCC 2	NIOBRARA	LAYTON SD
BEVIER COAL	JCC 3	OSGN GRP	BURGESS SD
BLAINE Top	JCC 4	PERM SYS	BARTLESVILLE SD
BONNETERRE	JCC Lwr SH Zn	PRE-CAMB	CATTLEMAN SD
CARLILE	JCC ROU 1	RIVERTON COAL	OSWEGO
CEDAR HILLS SD	JCC ROU 1 Base	ROOT SH	PERU SD
CGRV GRP	JCC ROU 1A	ROUBIDOUX	PAWNEE
CHASE GRP	JCC ROU 1B	SEVERY SH	ALTAMONT
CHATT SH	JCC ROU 1C	SIMP GRP	
CHRK GRP	JCC ROU 1D	ST LOU A	
CHST GRP	JCC ROU 1E	STALNAKER	
CHST SD LWR	JCC ROU 1F	STARK SH	
CHST SD UPR	JCC ROU 1G	STNC Top	
CODELL SD	JCC ROU 1H	SUPER TYPE	
DAY CRK DOLO	JCC Upr Sh Zn	SWOPE	
EMINENCE	KCTY GRP	TARKIO	
FT HAYS	KDHK GRP	TEBO COAL	
FT RILEY	LAMOTTE	TECUMSEH SH	
GAGE SH	LANS GRP	TOPEKA	
GRANEROS SH	LECOMPTON LS	TOWANDA	
GREENHORN	Lwr Clean Zn	Van Buren Gasconade	
	M MRW LM	VIOLA	

Figure 5. List of stratigraphic units that are being correlated among supertype wells range from Permian to Precambrian basement.

LAS and raster data now now encompass greater Kansas to extend log data to understand the distribution the Arbuckle saline aquifer so that larger scale simulations of fluid flow can be addressed with adequate information availed by the available well data (**Figure 6**).

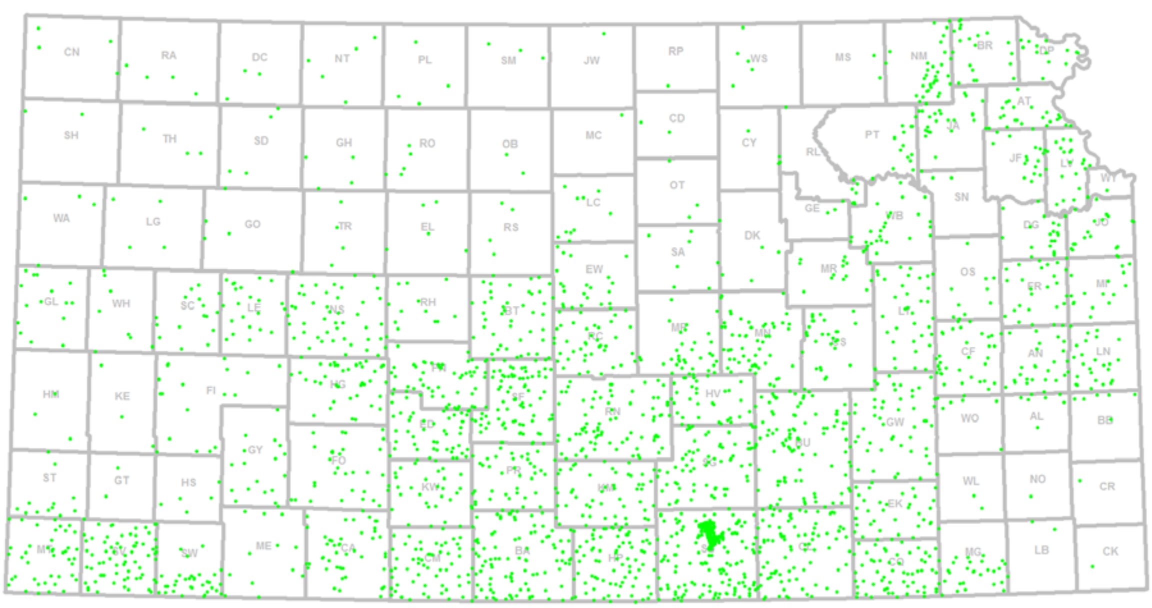


Figure 6. Current status of the LAS and Raster log database (5-19-11).

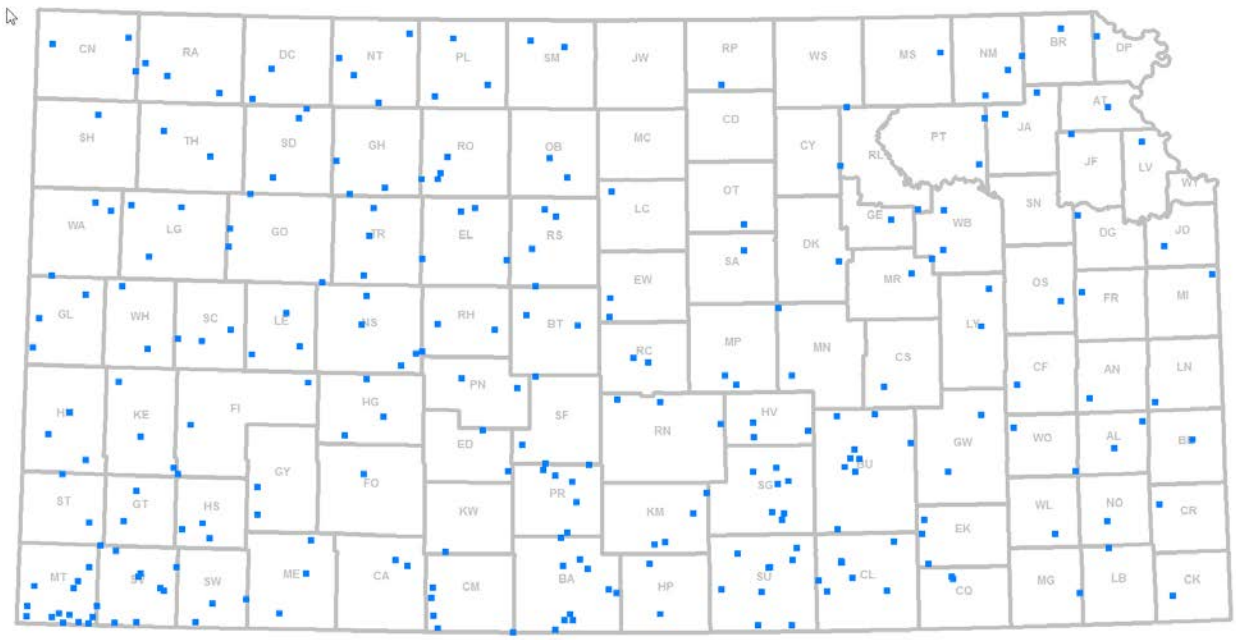


Figure 7. Current status of supertype well (5-19-11) – wells with nearly complete penetration of Arbuckle with modern log suite

Super type wells have rich datasets and are particularly useful in quantitative analysis of the well log data. Supertype logs now encompass most of Kansas to full encompass the reaches of the Arbuckle saline aquifer (**Figure 7**).

All well data being used is concentrated in the primary study area of southern Kansas. Wells outside of the study area represent "deepest" well in each section (**Figure 8 and 9**). Stratigraphic units included are extended from the shallowest unit recognized to the deepest.

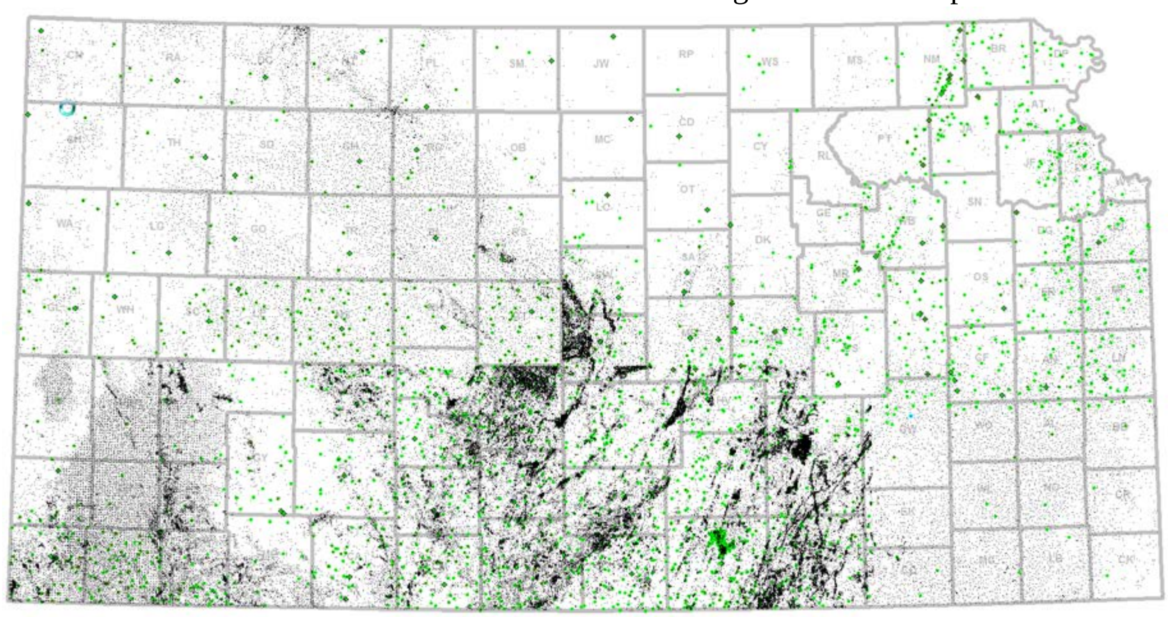


Figure 8. Current total well database including those used for tops only (black), e-logs (green).

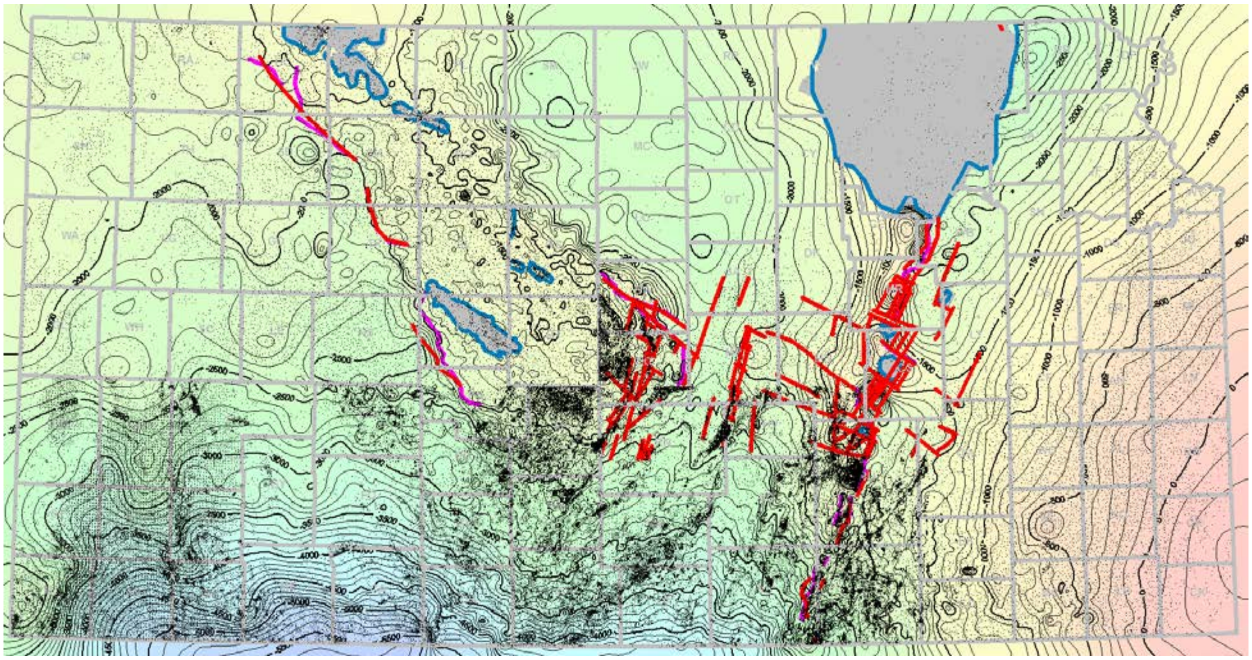


Figure 9. Top Arbuckle structure and other key formations are now being mapped statewide. Published faults are also being compiled, shown here in draft form as red and pink lines. Gray areas on the map have no Arbuckle where the units subcrops beneath the Pennsylvanian strata across major uplifts. Additional data will permit analysis of Arbuckle aquifer system in greater area of hydraulic continuity outside of the original study area.

Kinderhook/Chattanooga shales serve as a primary caprock above the Arbuckle in the eastern Kansas, but strata are thin to absent in western Kansas. Properties of overlying strata need to be carefully analyzed relative to their properties to seal potentially migrating CO2. Strata above contain addition thick shales and tight shaly strata. Their properties and behavior with CO2 leakage from the Arbuckle need to closely evaluated (**Figures 10 and 11**).

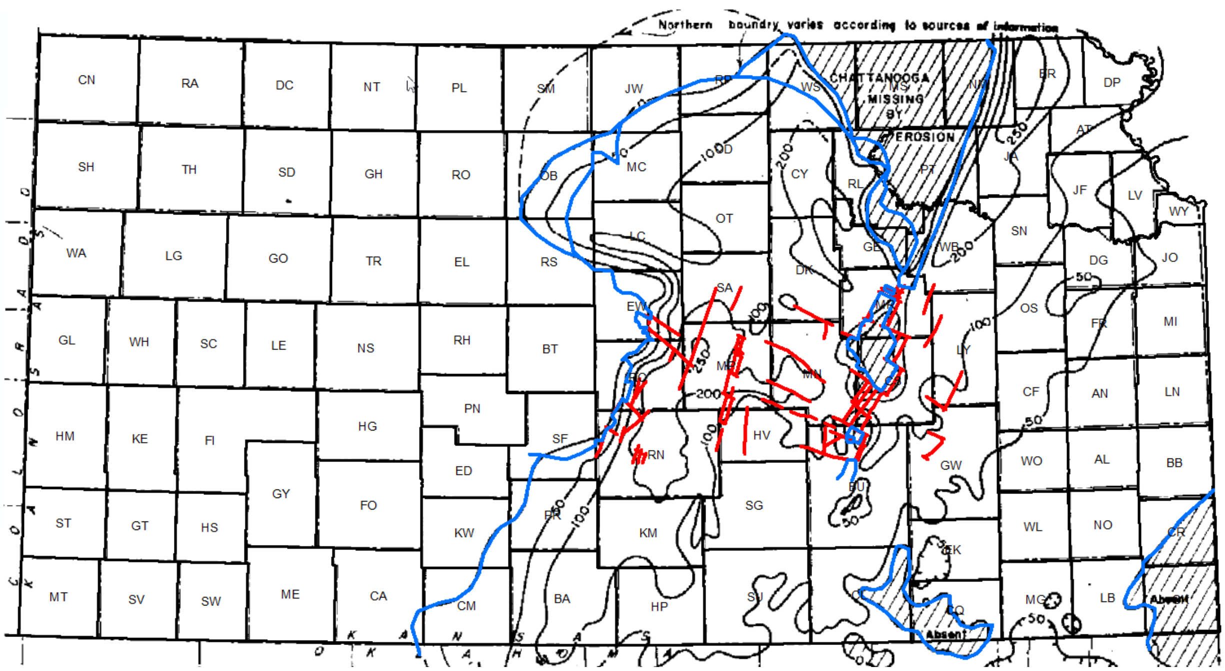


Figure 10. (Previous page) Lower Mississippian-Upper Devonian age Kinderhook/Chattanooga Shale isopach showing outline of boundaries in blue with published faults in red. Not that this shale interval can serve as caprock above the Arbuckle in eastern Kansas, but is not a primary caprock in western Kansas where it is absent.

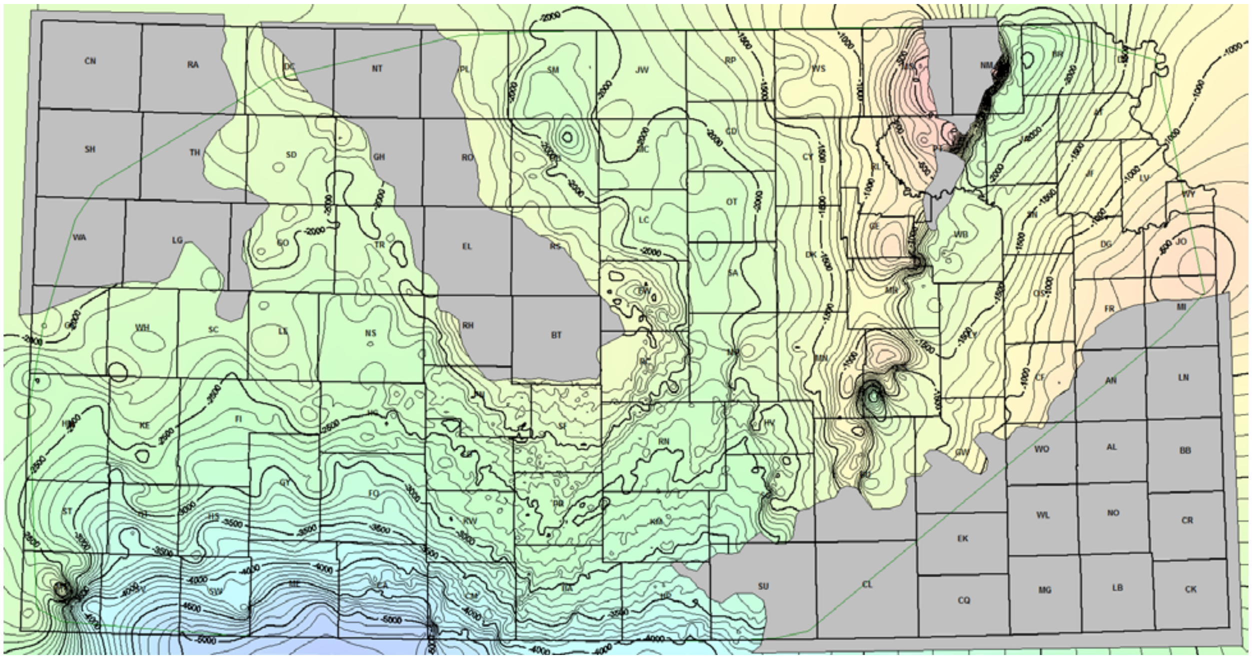


Figure 11. Structure contour map on top of Middle Ordovician Viola Limestone. Tighter shaly facies within the thick Viola Limestone and Mississippian strata that overlie the Arbuckle in southwestern Kansas will be examined for their sealing properties. Thick Pennsylvanian shales above that may also serve as caprock.

Correlation and mapping of stratigraphic units will be complimented by a quantitative analysis of key stratigraphic intervals necessary to for obtaining physical properties to evaluate fluid flow, storage, reactivity with CO2, and characteristics of the caprock intervals. Ultimately the quantitative data will be used in compositional simulation to assess CO2 capacity and containment. Cross section in **Figure 12** is an example of the use of new digital log data and old sample log and insoluble residues to establish stratigraphic correlations and, in turn, use the digital logs to establish quantitative properties of the strata.

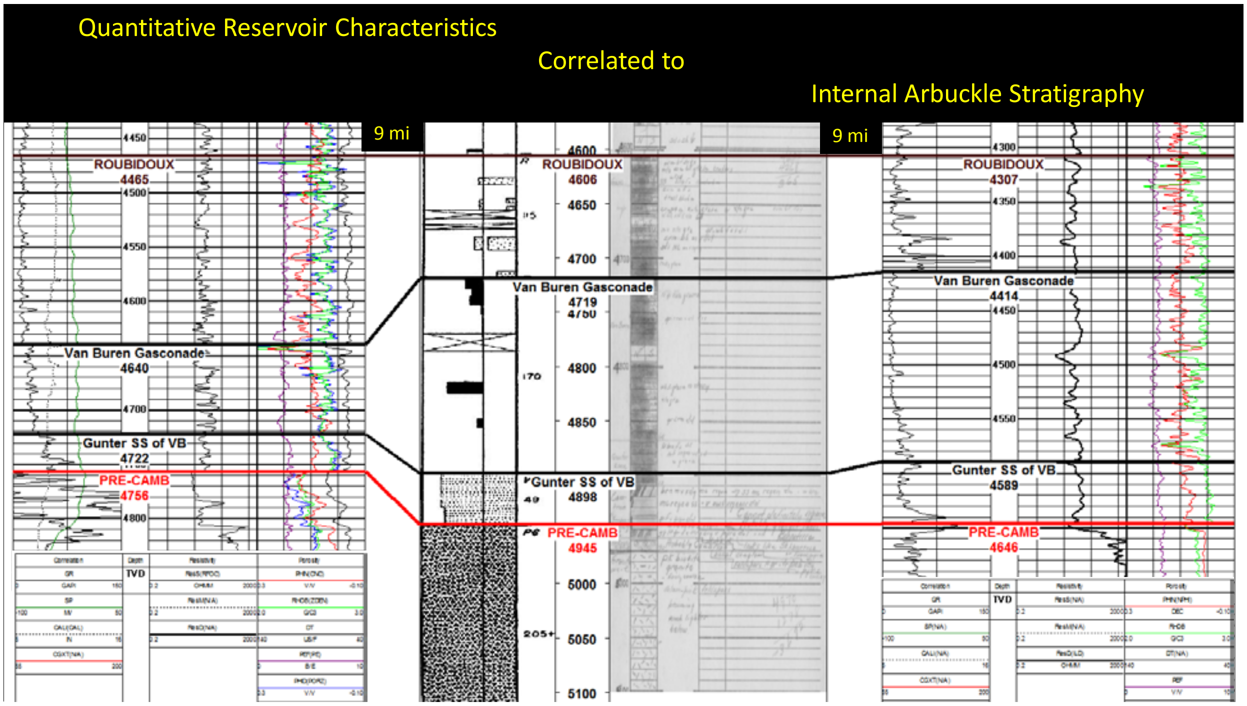
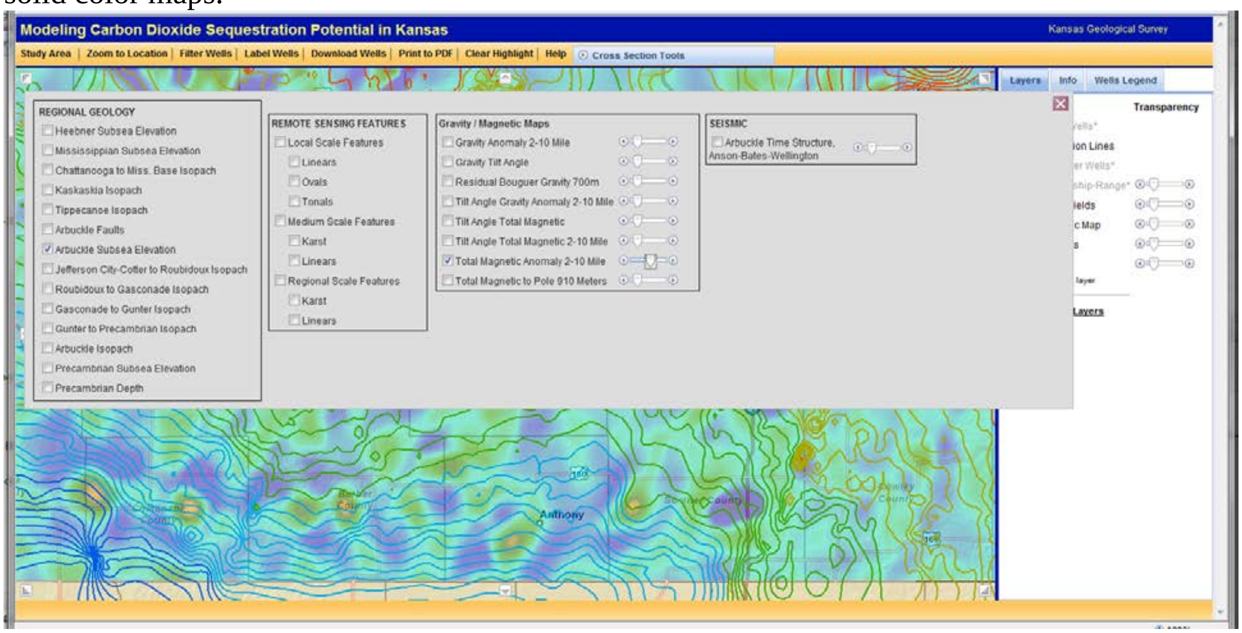


Figure 12. Example cross section of lower Arbuckle from Roubideaux to basement including new and old well data. All are useful to establish and validate lithofacies and pore type.

Interactive Web-based Project Mapper Update

The interactive project mapper is being revised to accommodate the addition of many additional layers that will be forthcoming. The map selection menu has been expanded to become a large table with buttons alongside stratigraphic, geophysical, and remote sensing data to use in the selection of maps to be shown and overlain (**Figure 13**). The transparency slider is available for solid color maps.



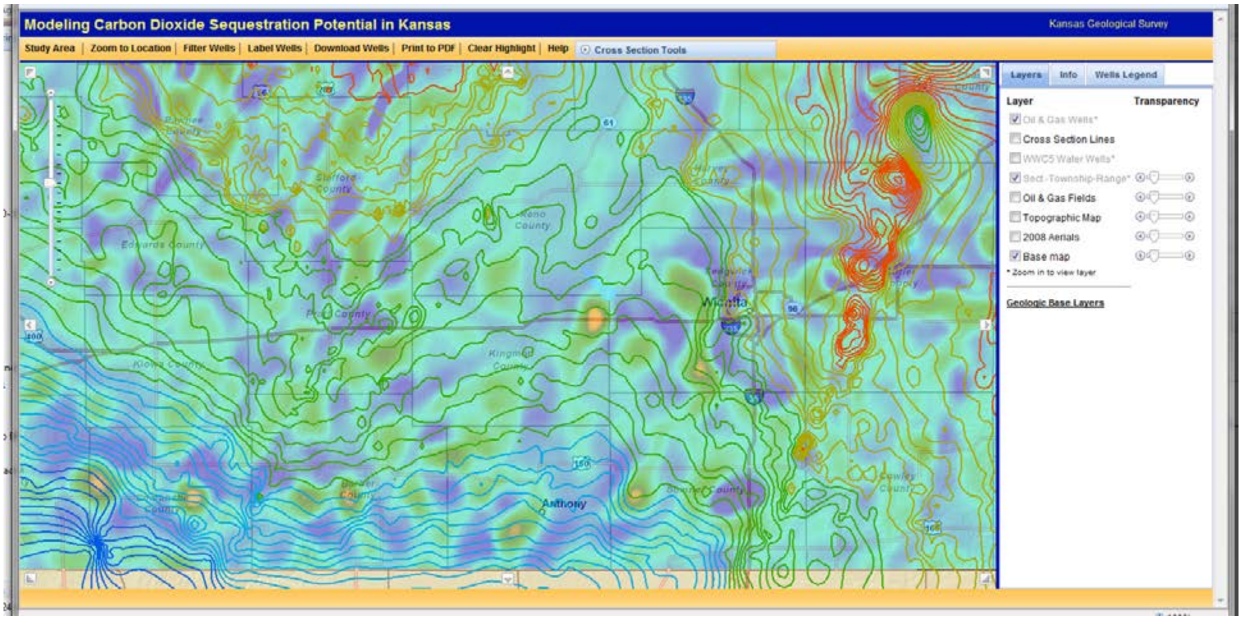


Figure 13. (upper map, previous page and lower map. above) Latest revision of interactive oil and gas map viewer with upper figure showing the new expanded map menu to display all of the latest maps. Two maps that are overlain a) total magnetic anomaly using a 2 to 10 mile filter (solid colors) overlain by Arbuckle subsea elevation (contours).

In addition to new subsurface maps, the initial seismic map was uploaded as a test in determining the degree that original map information is preserved. Image is dynamic scalable and resolution is maintained (**Figure 14**). Map is the time structure of the top of Arbuckle in Wellington Field.

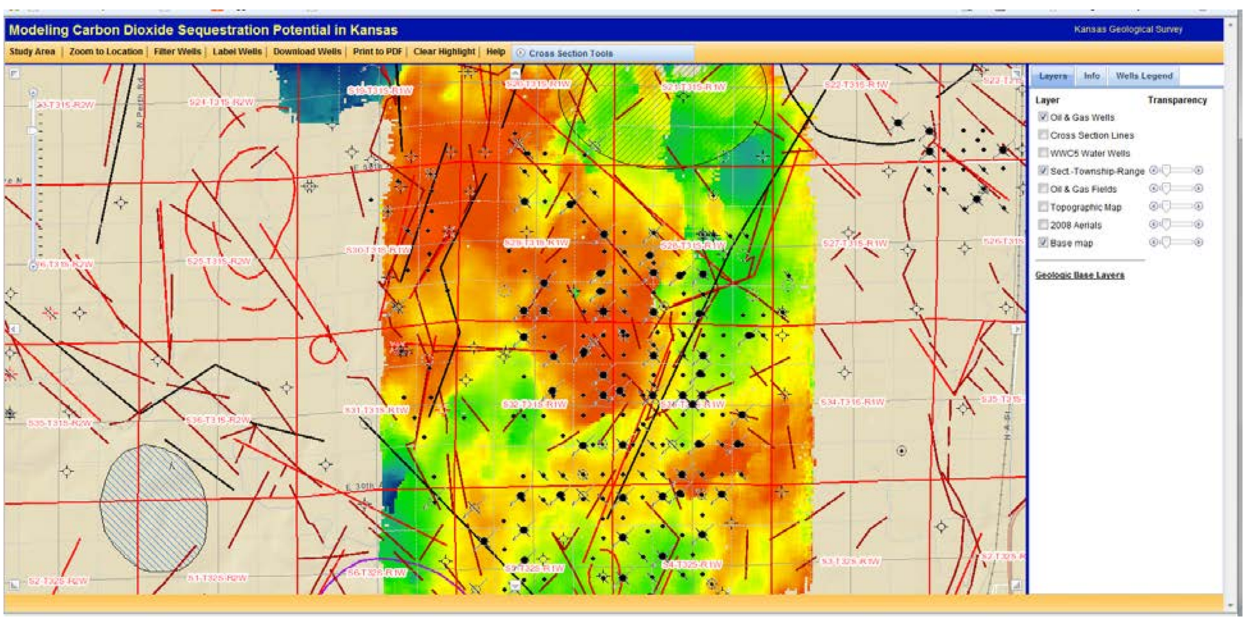


Figure 14. New layers were added to project's interactive web-based mapper including this 2D map of the time structure of the Arbuckle in Wellington Field.

New maps added to the interactive mapper include interval isopachs of the Arbuckle (**Figures 15-19**). The succession is shown below beginning with the bottom to the top and ending with the total thickness map of the Arbuckle. These correlations represent the most recent contribution of the regional team.

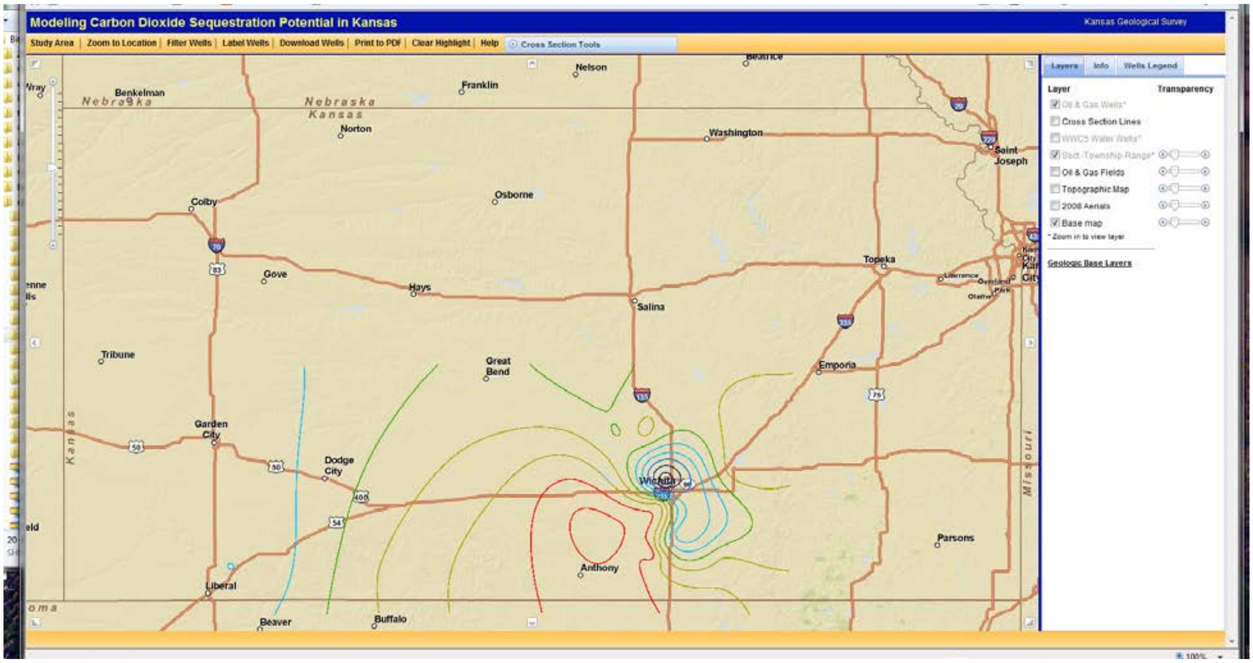


Figure 15. Preliminary isopach Gunter Sandstone to Top Precambrian as shown on the project's interactive mapper. Red contour = thin, blue to purple = thick. Map area is entire state of Kansas.

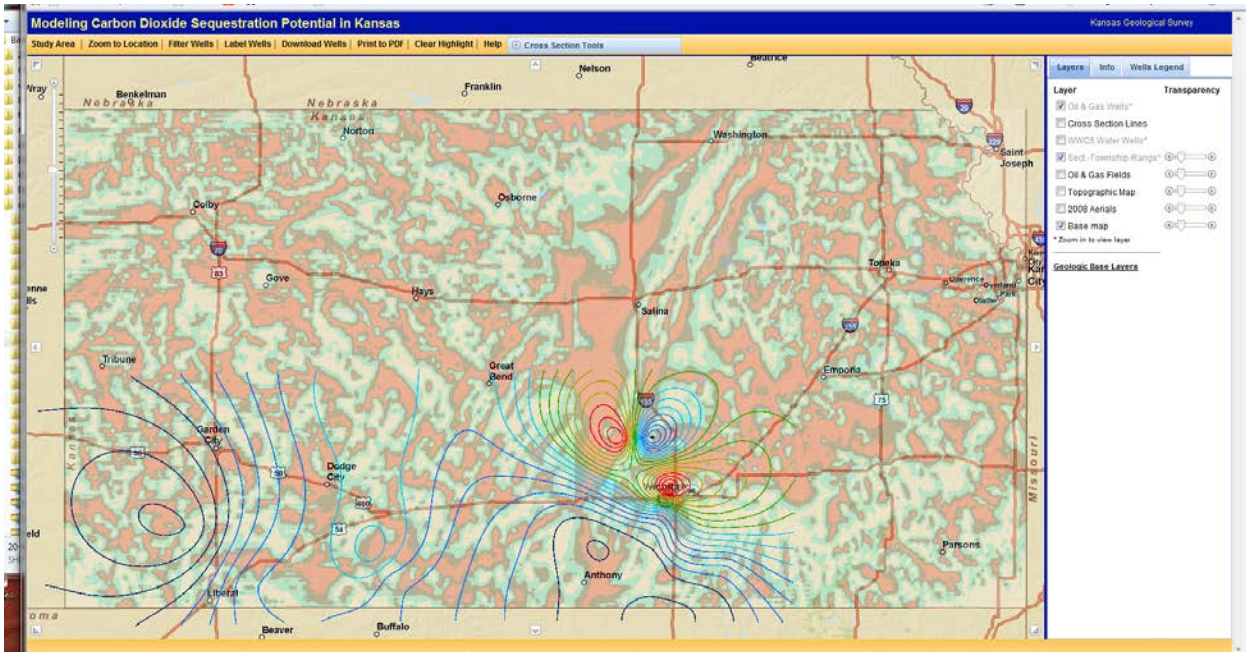


Figure 16. Preliminary isopach Gasconade to Gunter Sandstone as shown on the project's interactive mapper. Red contour = thin, blue to purple = thick. Isopach map is overlain on the tilt angle map of the total magnetic field intensity. Tilt map depicts discontinuities in the magnetic field interpreted as basement faults or intrusive. Contact between white and red areas outline

these discontinuities. Note the conformance of the isopach with the southern magnetic province, a younger accretionary terrain that apparently behaved as a separate structural block, apparently with greater subsidence and more sediment accommodate, more proximal to subsidence to the south in the Anadarko Basin. Also, thick south-central Kansas location overlies the Midcontinent Rift where additional subsidence appears to be localized south of Wichita. Gasconade to Gunter interval corresponds to the higher porosity of the lower Arbuckle.

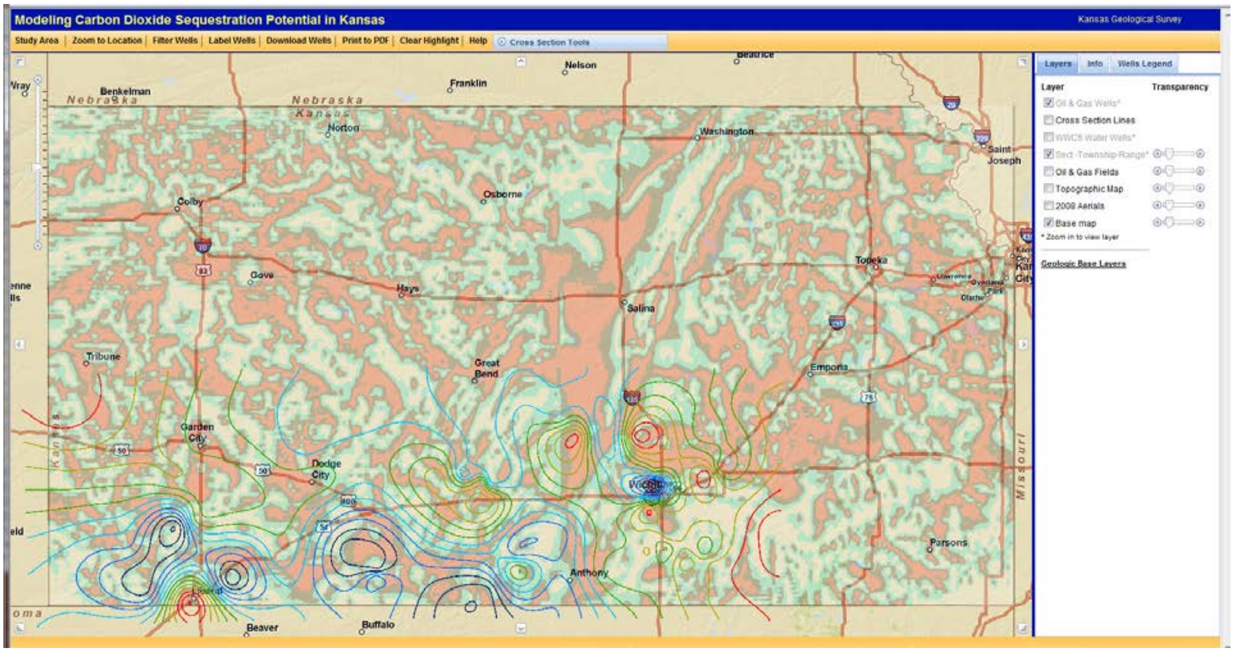


Figure 17. Preliminary isopach of Roubidoux to Gasconade as shown on the project's interactive mapper. Red contour = thin, blue to purple = thick. Isopach map is overlain on the tilt angle map of the total magnetic field intensity. Again there is subsidence focused on a southern element of the younger Precambrian terrane (source of magnetism) in southern Kansas. Light blue band on magnetic map indicates the depth to the magnetic discontinuity. In southern Kansas the depth is roughly 1.5 miles (8000 ft), well within the Precambrian.

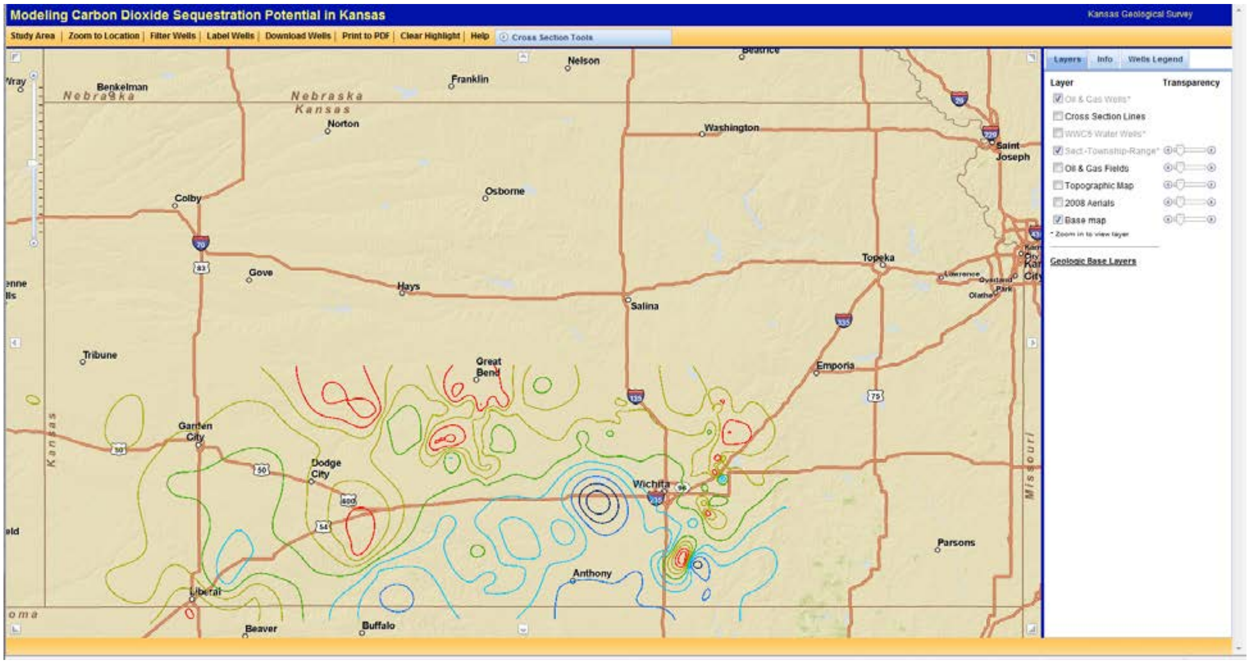


Figure 18. Preliminary isopach Jefferson City-Cotter to Roubidoux as shown on the project's interactive mapper. Red contour = thin, blue to purple = thick.

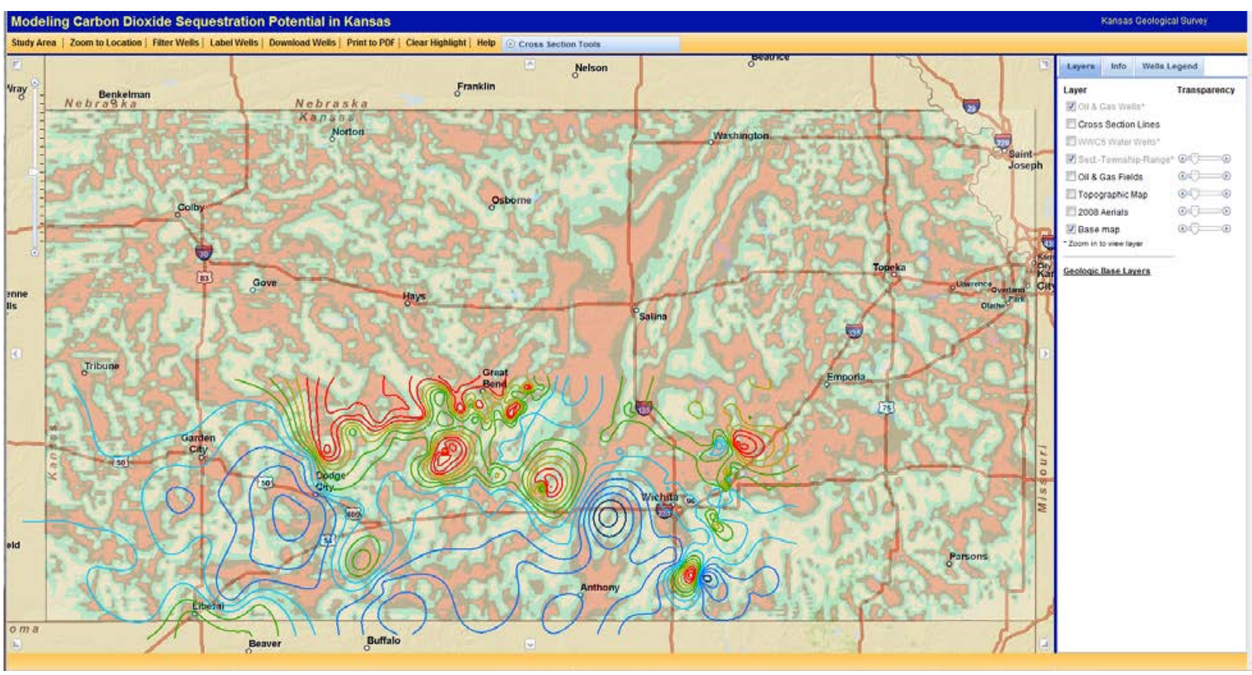


Figure 19. Preliminary isopach of the total Arbuckle on the project's interactive mapper. Red contour = thin, blue to purple = thick. Isopach map is overlain on the tilt angle map of the total magnetic field intensity. Thick region of Arbuckle corresponds closely to the younger southern accretionary terrain of the basement as inferred by the magnetic map.

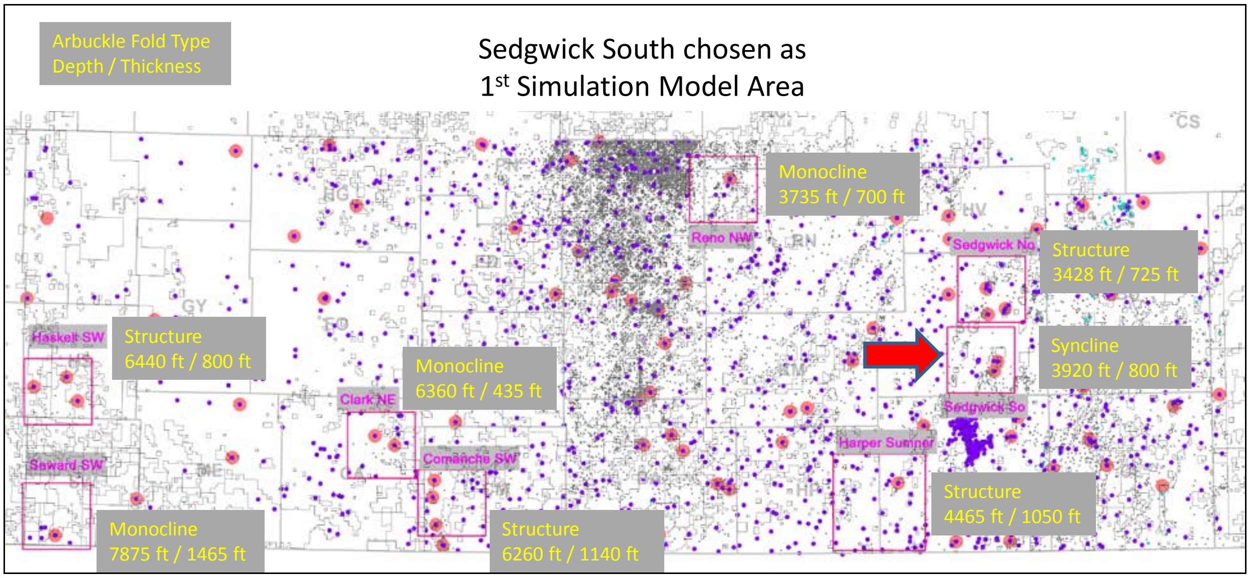


Figure 18. Current locations of planned coarse grid simulations in southern Kansas.

Sites that have been identified regionally as potential locations for further examination as potential sites for coarse grid simulation modeling are shown in Figure 18 with indications of structural type, depth, and thickness of the Arbuckle. Additional mapping and analysis of physical properties will continue before decisions are made as to where to model.

TASK 9. CHARACTERIZE LEAKAGE PATHWAYS - RISK ASSESSMENT AREA

Subtask 9.2. Map fracture-fault network

Identification of published faults and fracture systems has begun (back to **Figure 9**). Published faults will be compiled as a guide to our regional mapping as we evaluate the presence for faults. Faults noted on seismic and cutting wells is evidentiary information to confirm the presence of faults. Sharp flexures will be examined using mapping tools such as second vertical derivative (slope change). A list of criteria will be developed to identify suspected faults when the information is limited to verify.

Subtask 9.3. Verify seal continuity and integrity

Rock properties are being addressed through extensive petrophysical, geomechanical, image analysis, and pore characterization of core from Wellington KGS #1-32. An exhaustive wireline log suite obtained from Wellington KGS #1-32 and #1-28 continues to be analyzed and will be integrated with core analyses as they become available this fall. Converted shear wave seismic data will also be processed and integrated to evaluate general location and orientation of fracture/faults and whether they are open – as discerned by shear wave splitting/anisotropy.

WELLINGTON FIELD STUDY, SUMNER COUNTY, KS

ONGOING & COMPLETED ACTIVITIES concerning Wellington Field, Sumner County, KS -- -

A proposal was submitted to DOE-NETL in early April to conduct a small scale test of CO2 injection at Wellington Field. New well data were used to create a Petrel geomodel of the Arbuckle and to simulate the injection of 40 tonnes of CO2 in the lower higher porosity interval. Results indicated a CO2 plume would span ~300 ft diameter. This contract is under budget negotiations. Integrated model of Wellington is shown in **Figure 18**.

Details of well completions and testing of new boreholes in Wellington were further analyzed and confirmed and a workover rig was scheduled for next quarter. An step rate interference test was designed to attempt to evaluation fluid communication between #1-28 and #1-32 in the lower Arbuckle. Also, up to three cross flow experiments would be carried out between 3 pairs of perforations in #1-32. Furthermore, up to 14 zones will be perforated and fluid samples taken in the interval spanning the Arbuckle through the Mississippian.

The design of two, 2D shear wave seismic surveys was reviewed and a contract was let to acquire this data at Wellington to use for converted wave processing of the Wellington 3D survey.

Processed high resolution gravity at Wellington was completed using tilt angle processing, the same as used for the regional gravity data.

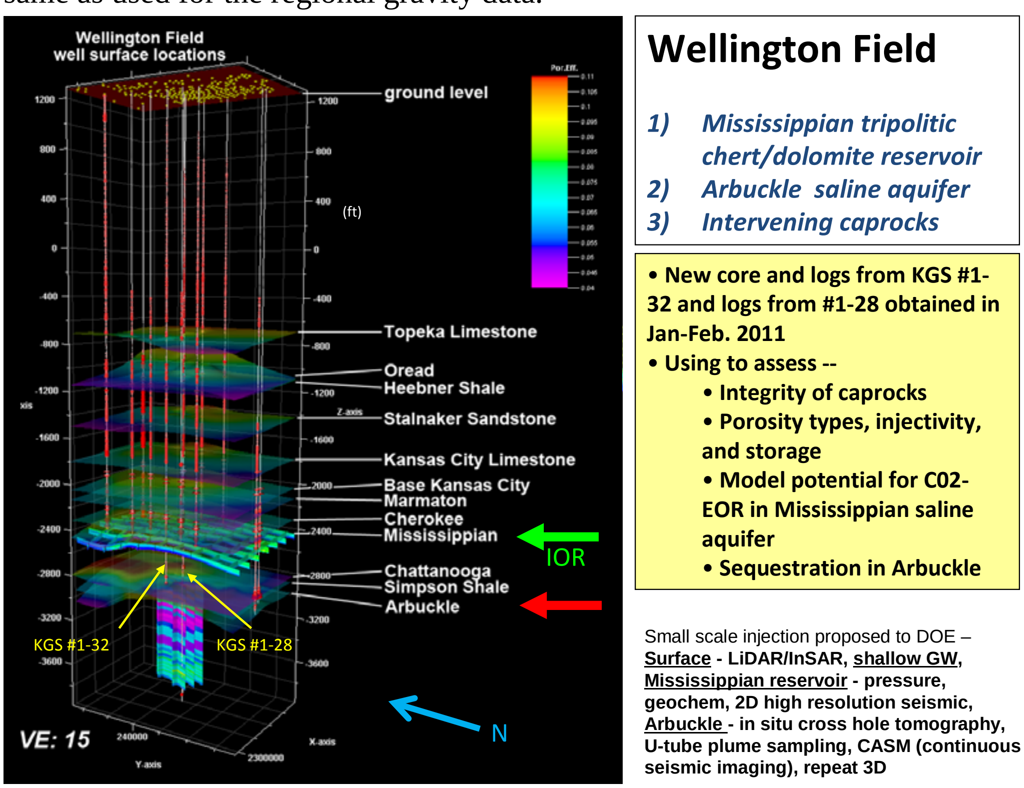


Figure 18. 3D model of Wellington Field from ground surface to Precambrian basement showing well control, geomodel in Mississippian oil reservoir, and same in the Arbuckle.

Subtask 3.5. Interpret seismic, gravimetric, and magnetic data

High resolution gravity data had been acquired and processed in 2010 at the Wellington site (**Figure 19**). These data were subjected to tilt angle analysis for resolve location of discontinuities/contacts suggested by the gravity data and the depth to these anomalies. The tilt angle is defined as the arctangent of the ratio of the 1st-order vertical derivative by the 1st-order horizontal derivative of the Bouguer anomaly.

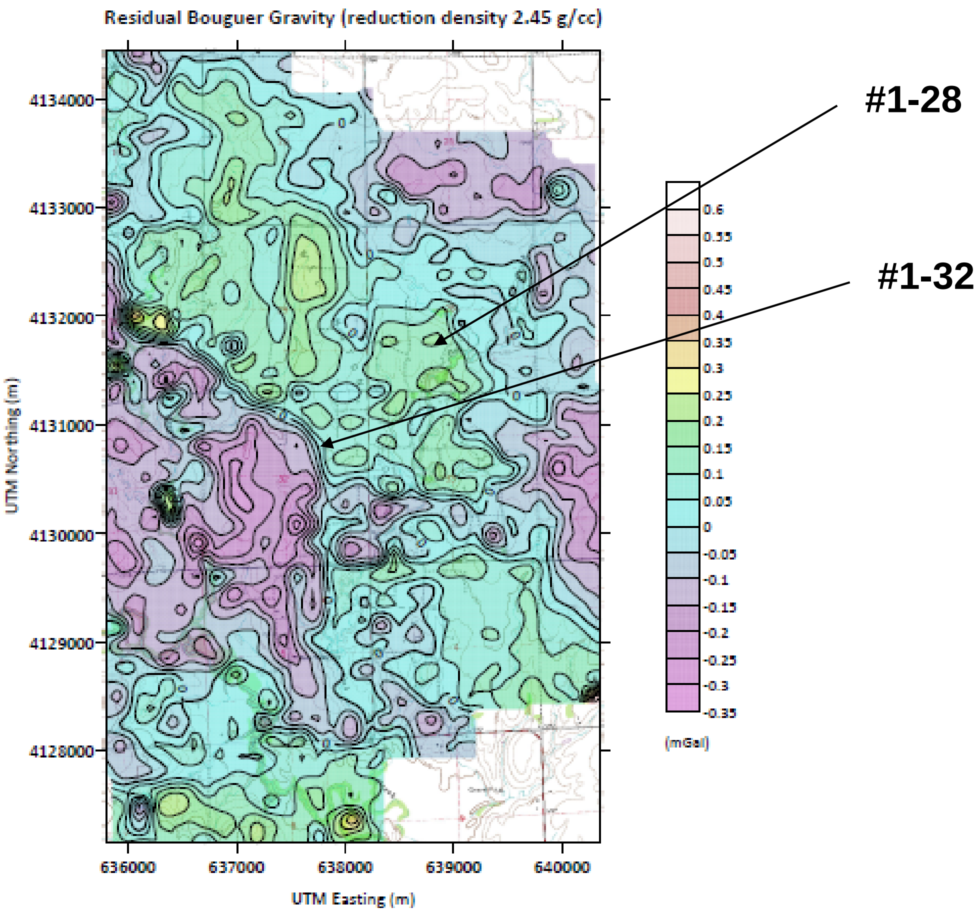


Figure 19. Residual Bouguer Gravity for Wellington Field acquired in 2010 showing locations to two new boreholes, #1-28 and #1-32. These data were the basis for the tilt angle analysis.

The tilt angle is the angle between the vertical and horizontal derivatives of potential fields (M, magnetic or gravity)

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

The tilt angle can identify the location (ϴ=00) and depth (half the physical distance between +-45° contours) of contact–like structures (Miller and Singh, 1994). The workflow involves using the raw gravity data, obtaining a topographic correction, applying a band-pass filter to examine different frequencies and therefore depth, and finally running directional derivatives and obtaining tilt angle (**Figure 20**).

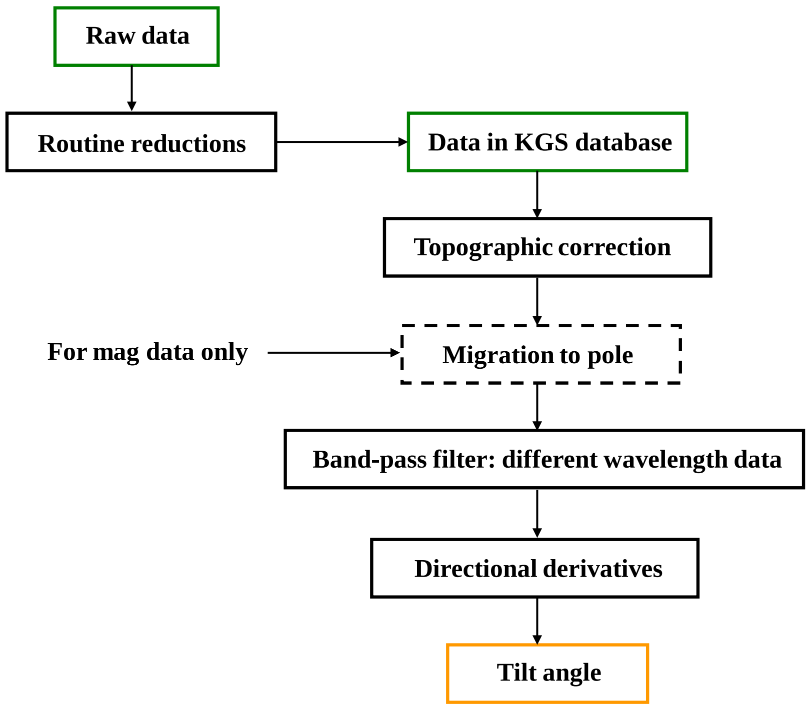


Figure 20. Workflow of tilt angle analysis used to analyze high resolution gravity data from Wellington Field.

Figure 21 illustrates how the tilt angle is used to define edges of gravity anomalies.

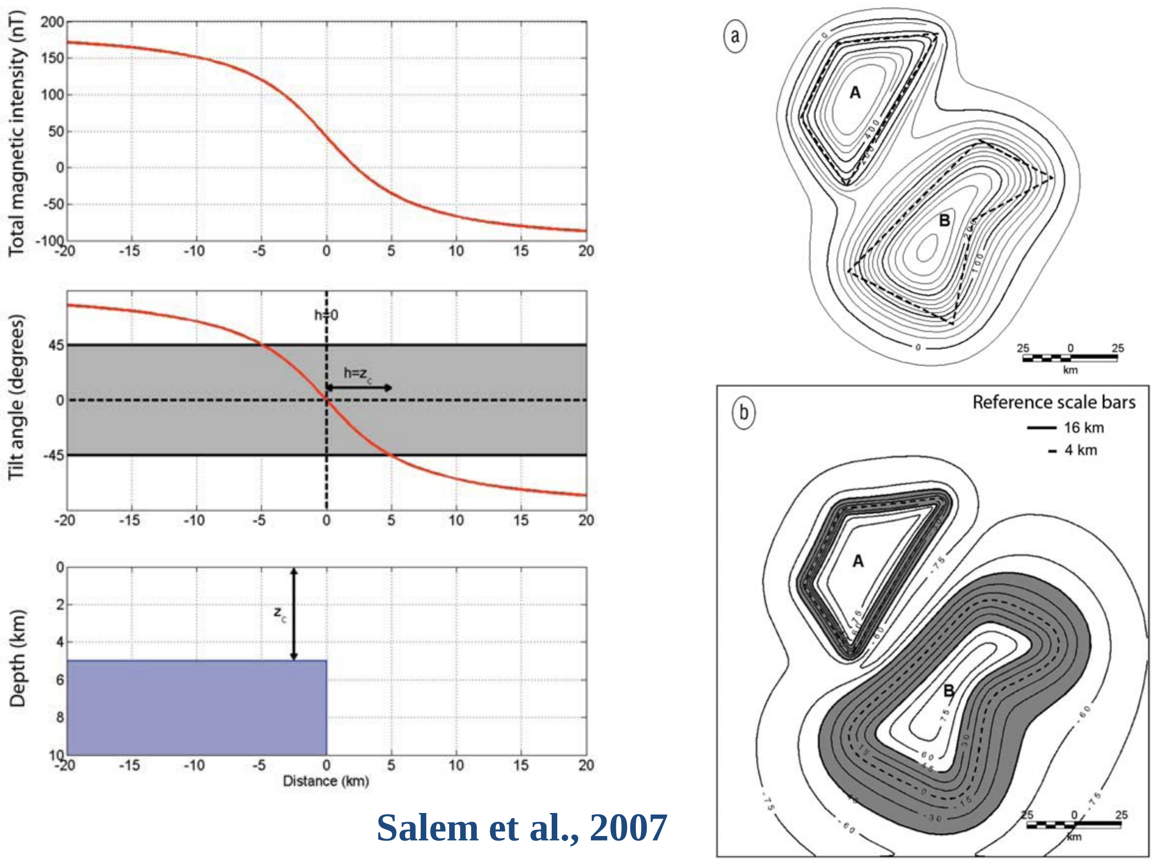


Figure 21. Illustration of tilt angle calculation.

The tilt map of Bouguer anomaly or Residual Bouguer anomaly reveals a striking density contact trending NE-SW. An estimated depth to the top of the SE part is around 750 to 800 m (**Figure 22 b and e**). The NW part is at a greater depth. Shallower density contacts are revealed by shorter wavelength results (wavelength from 0.4 to 1.5 mi) **(Figure 22 a and d**). The sharply defined, downlap/thinning of the Oread Limestone at relatively shallow depths (2200 ft, 670 m) into a thicker shale on either side of a NE-SW trending lineament as inferred from both seismic and well logs (**Figure 23 and 25**).

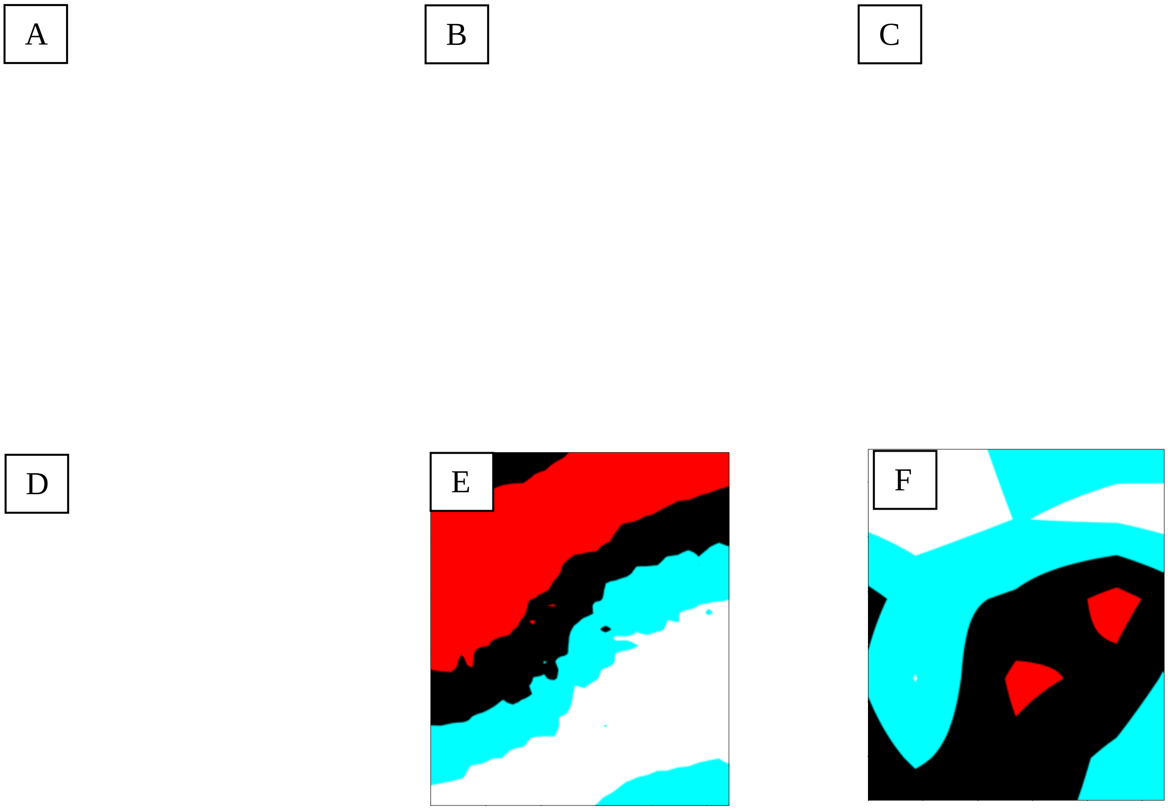


Figure 23. A) Residual anomaly, 2^{nd} order polynomial removed (wavelengths from 0.4 to 1.5 mi). B) Residual Bouguer anomaly with 2^{nd} order polynomial trend removed (no filter). C) Topographic surface. D) Tilt angle (wavelengths from 0.4 to 1.5 mi) with density contact indicated by line or zero degree. E) Tilt angle (no filter) with a density contact indicated by a line of zero degree (black/blue boundary) and average depth to tops of anomalous bodies indicated by width of blue band, around 200 meters. F) Tilt angle (wavelengths from 2 to 5 mi) with much deep anomaly. Positive value is blue and white and negative is black and red.

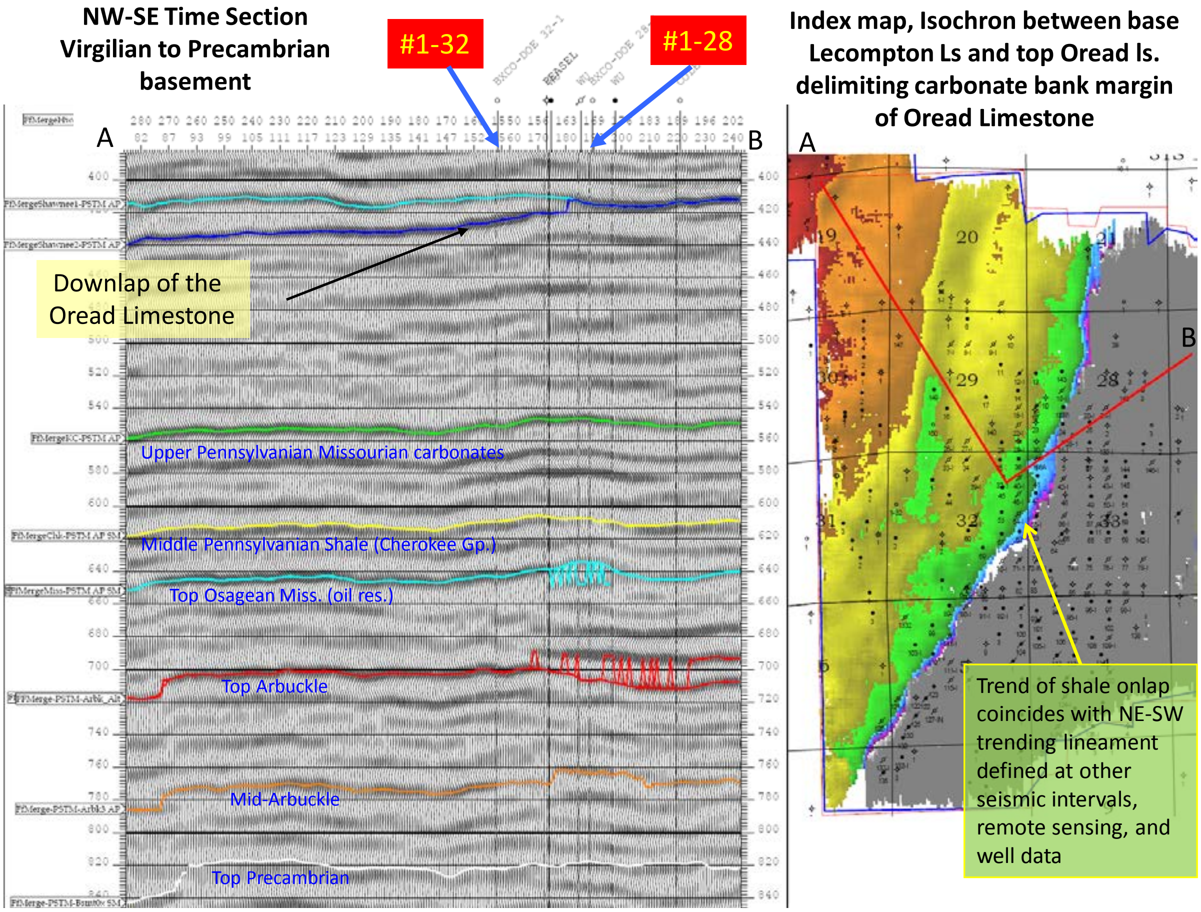


Figure 24. Seismic time section (left) and index map for section (right) showing location of the downlap (thinning) of the Oread Limestone to the west portion of the cross section. Map depicts time thickness of the shale that overlies the Oread Limestone, which thickens to west. Estimate depth of the change from thick limestone to thick shale corresponds is 750-800 meters (2400 to 2600 ft).

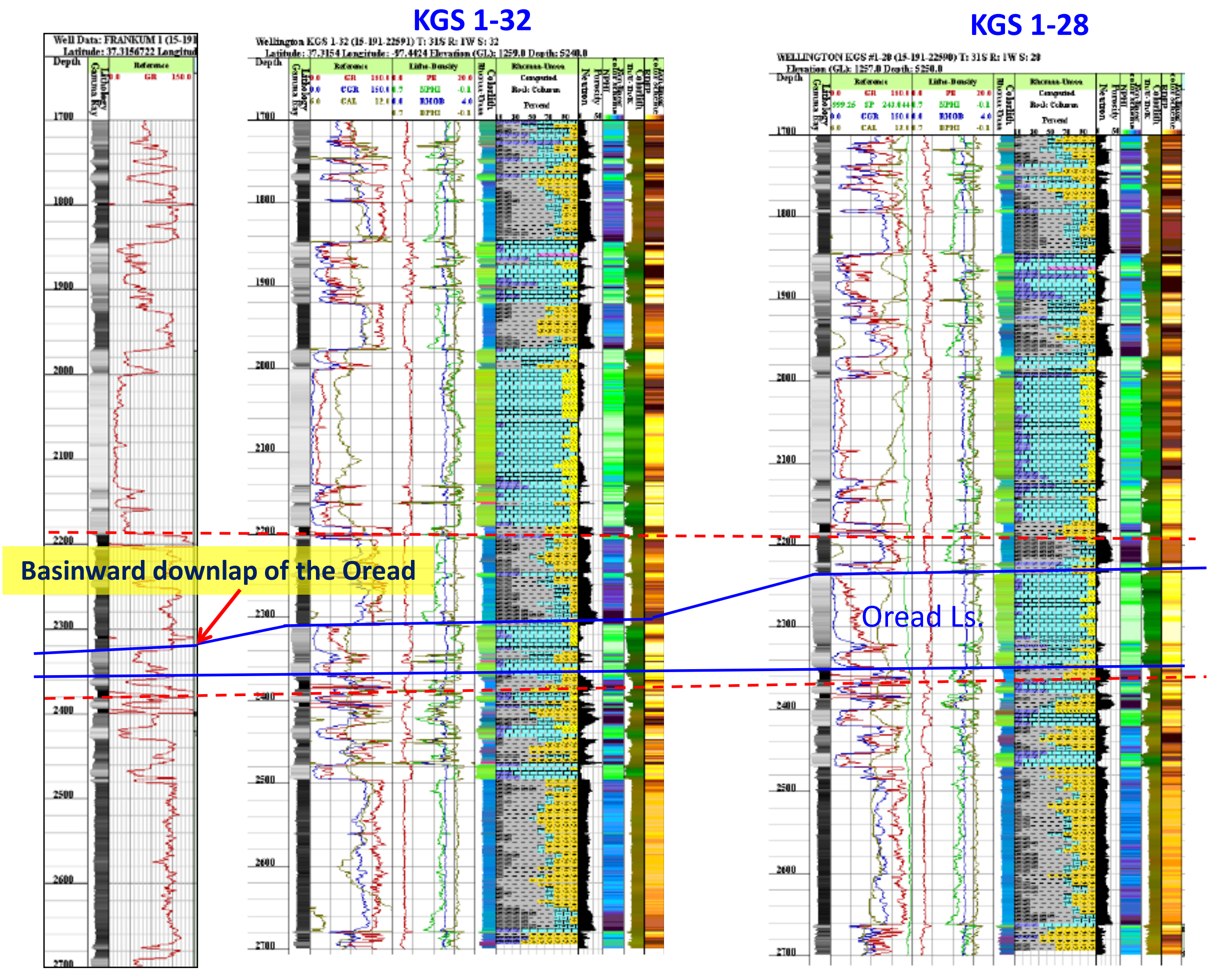


Figure 25. Log cross section is located along similar line of section of the seismic section in Figure 24. Logs have been interpreted for lithology using Profile software. Not downlapping carbonate and thickening of the overlying shale.

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

Designing Interference Test between Wellington #1-32 and #1-28

A porosity zone in the lower Arbuckle is a potential candidate for injection and will be tested in #1-28 and #1-32. A step-rate-test to inject in #1-32 to determine communication with the correlatable zone in #1-28 has been finalized. Up to fourteen zones will be perforated and water samples taken for chemical and microbial studies in borehole #1-32 (**Figure 26**). Intervals sampled span the Arbuckle up through the Mississippian strata (**Figures 26-27**). In addition, cross flow will be evaluated between up to three sets of perforations in #1-32.

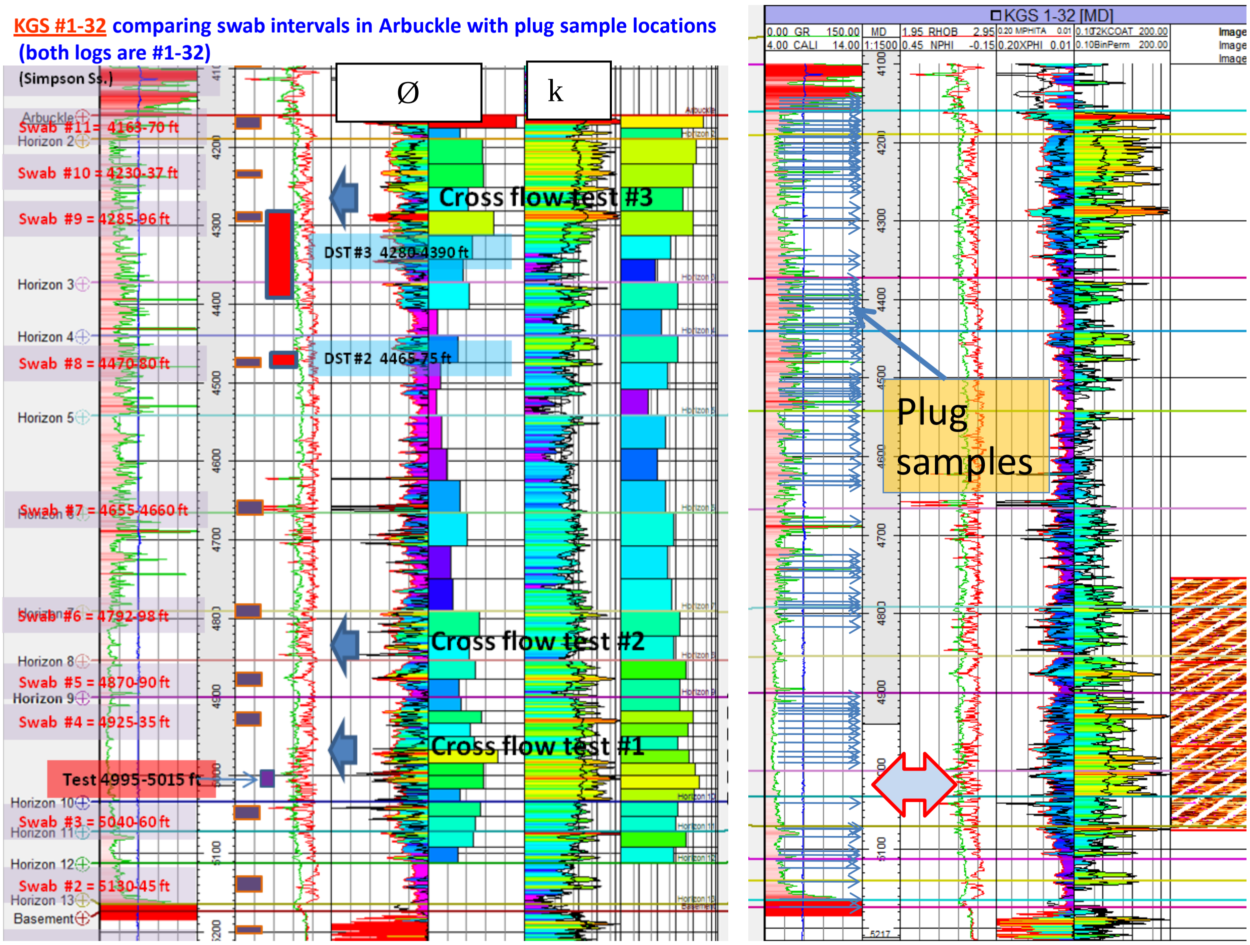
Proposed swab test intervals in BEREXCO Wellington KGS #1-32

identifier	interval	comment
Swab #1	5185-5195 ft	Precambrian basement
Swab #2	5130-5145 ft	Reagan equivalent
Swab #3	5040-5060 ft	below injection zone, Arbuckle
Step-rate test	4995-5015 ft	lower porous Arbuckle
Swab #4	4925-4935 ft	Arbuckle
Swab #5	4870-4890 ft	Arbuckle
Swab #6	4792-4798 ft	Arbuckle
Swab #7	4655-4660 ft	Arbuckle
Swab #8	4470-4480 ft	Arbuckle
Swab #9	4285-4296 ft	Arbuckle
Swab #10	4230-4237 ft	Arbuckle
Swab #11	4163-4170 ft.	top Arbuckle
Swab #12	4080-4100 ft.	mid Simpson (sand)
Swab #13	4035-4045 ft.	lower Mississippian porosity
Swab #14	3895-3906 ft	mid Mississippian porosity

Prposed cross flow test intervals

identifier	interval	swab intervals being tested
Cross flow test #1	4925-5060 ft	swab interval #3 and #4
Cross flow test #2	4792-4890 ft	swab interval #5 and #6
Cross flow test #3	4230-4296 ft	swab interval #9 and #10

Figure 26. (top table) Proposed intervals for perforating and swabbing in KGS #1-32 and proposed intervals for cross flow testing. (Log profile below) for #1-32 showing proposed perforations and cross flow tests compared to upscaled flow units showing Ø (porosity) and k (permeability) profiles from NMR log and to right location of plug samples from core (thin blue arrows) acquired for CO2 reaction experiments.



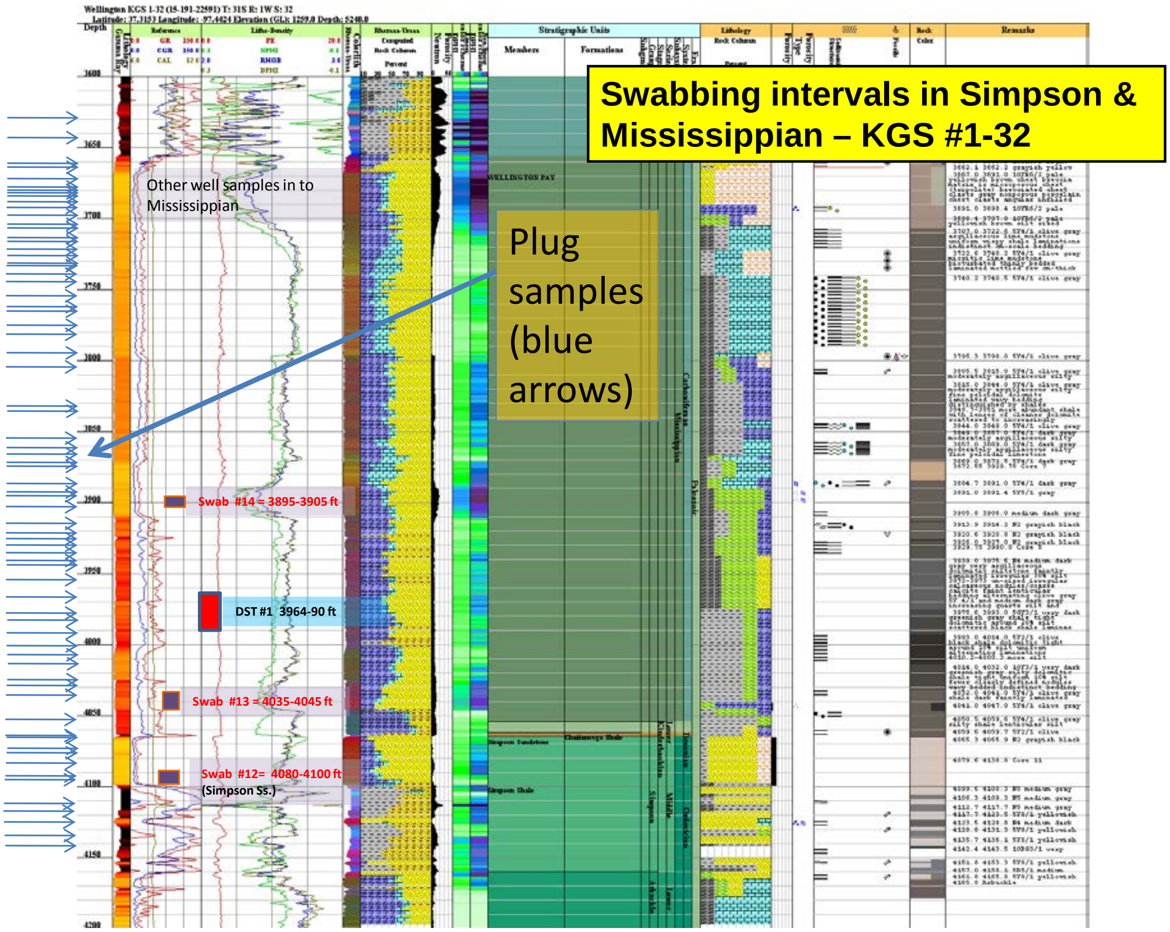


Figure 27. Perforate and swabbing intervals in the Simpson to Mississippian interval as listed in table of Figure 21. Blue arrows show plug samples taken for CO2 reaction experiments. Shown in depth plot of well log traces and lithologic interpretation. To far right is core description in text and graphical format. Depth plot generated by Profile software, reading a LAS 3.0 file containing digital well logs, stratigraphic horizons, and core description.

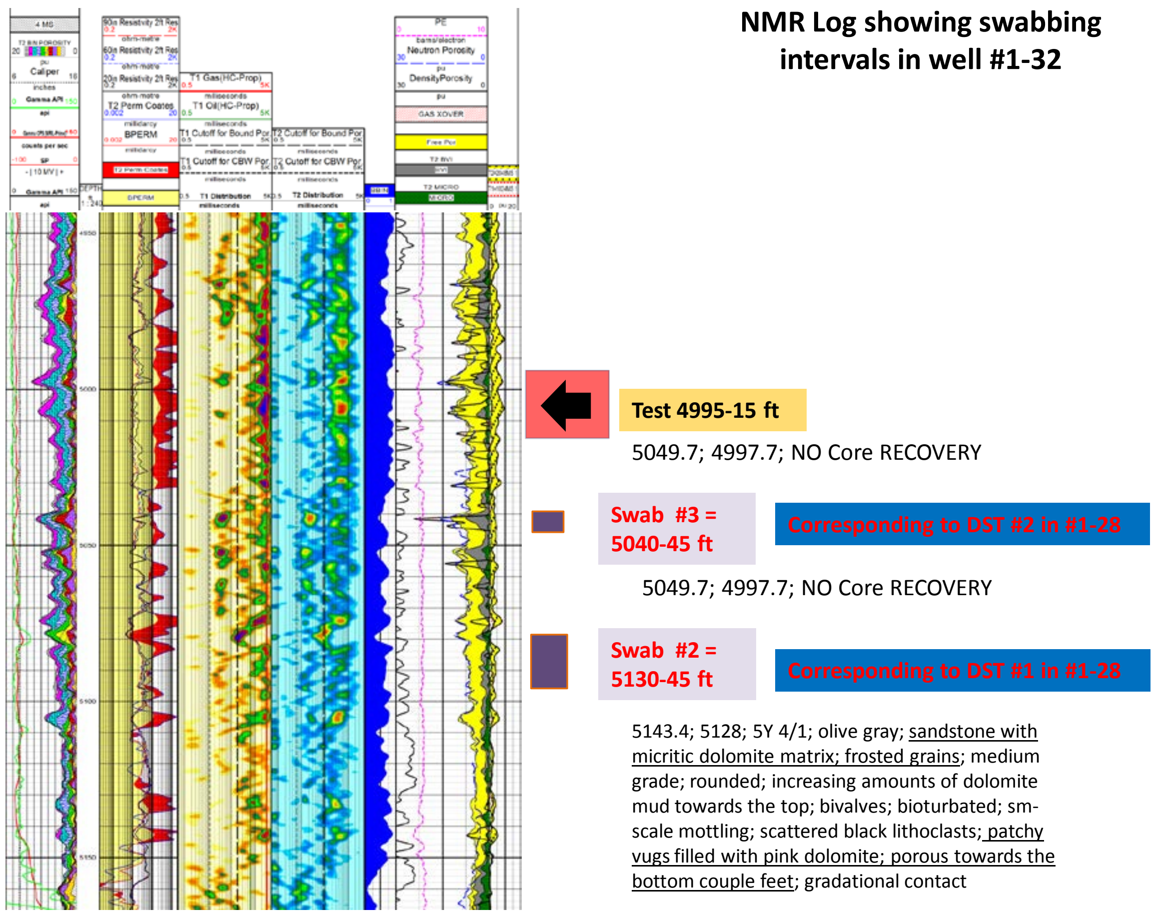
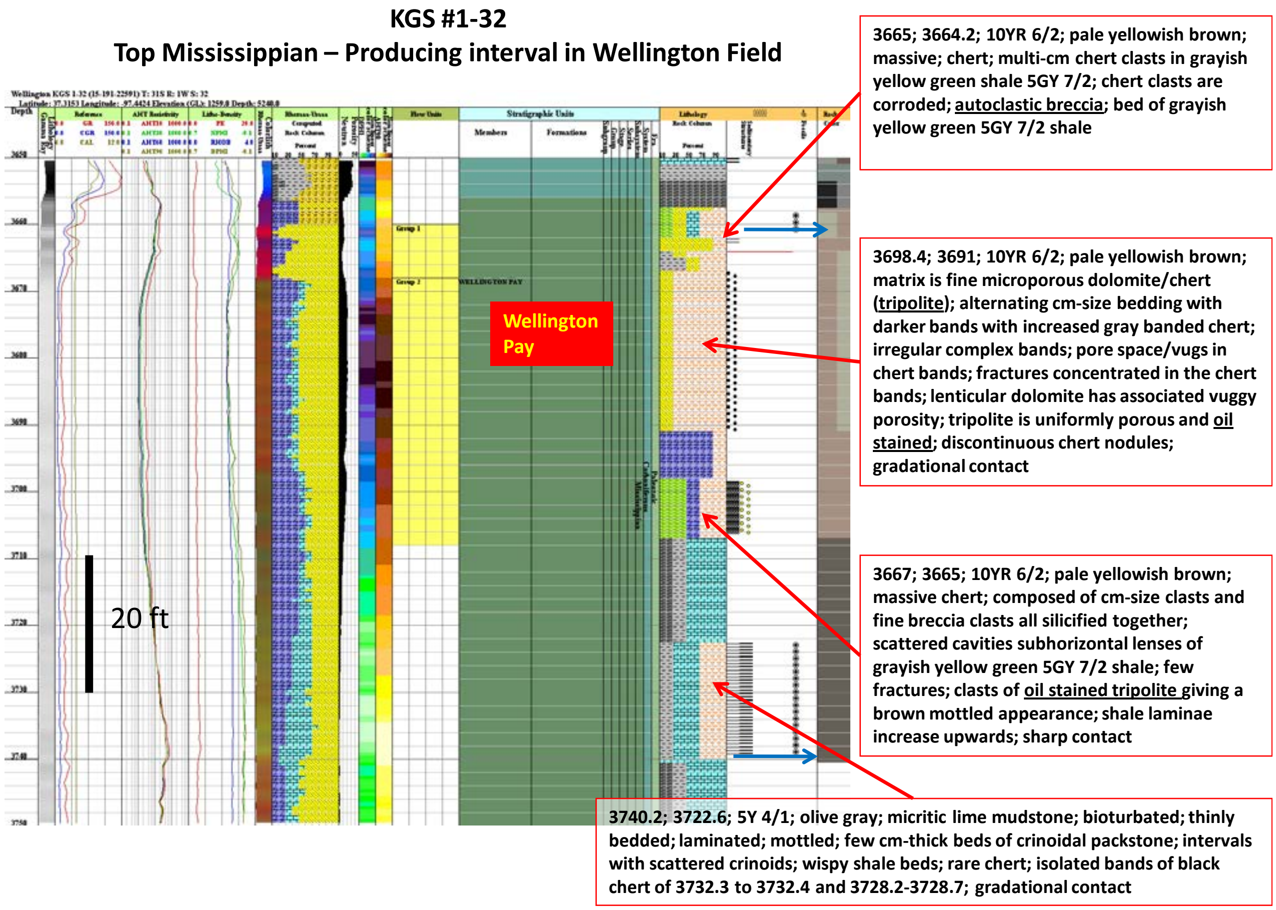


Figure 28. Lower Arbuckle section shown using results from Halliburton's MRIL, nuclear magnetic resonance too, including T2 relaxation time in blue tinted track above. The higher the T2 value (to the right on this track) the larger the pore. The interval marked test has exceptionally large and abundant pores and not surprisingly core was not recovered from the zone interval. This log and microresistivity imaging tool are excellent backups when core is not available. Core analyses will further aid in quantifying the pore size. Note that lower swab intervals were designed to be taken where DST samples have been obtained, so they could be compared. The second column from the left with red banded areas reflect higher permeability. This track will also being calibrated with the core analysis.



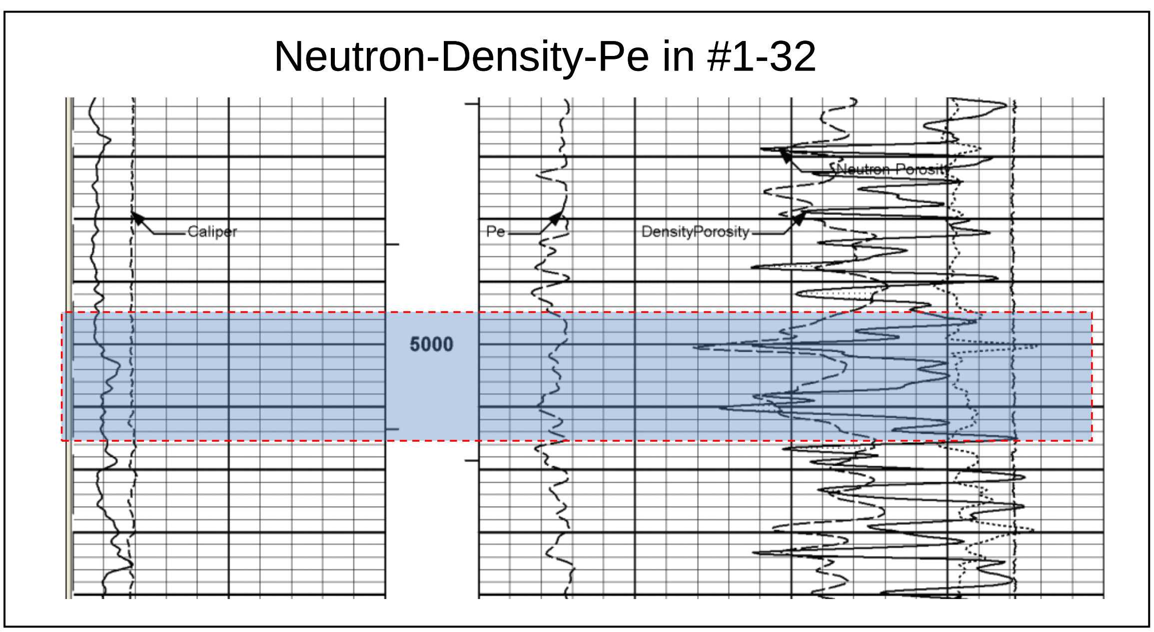


Figure 29. Additional detail is shown of the lithologies noted in core compared to the wireline lithologic solution for the Mississippian interval (upper diagram). The lower Mississippian contains considerable amounts of micritic and argillaceous lime mudstone, often laminated. Lower diagram is the neutron-density porosity log of the lower Arbuckle porosity zone in which a step-rate test will be conducted.

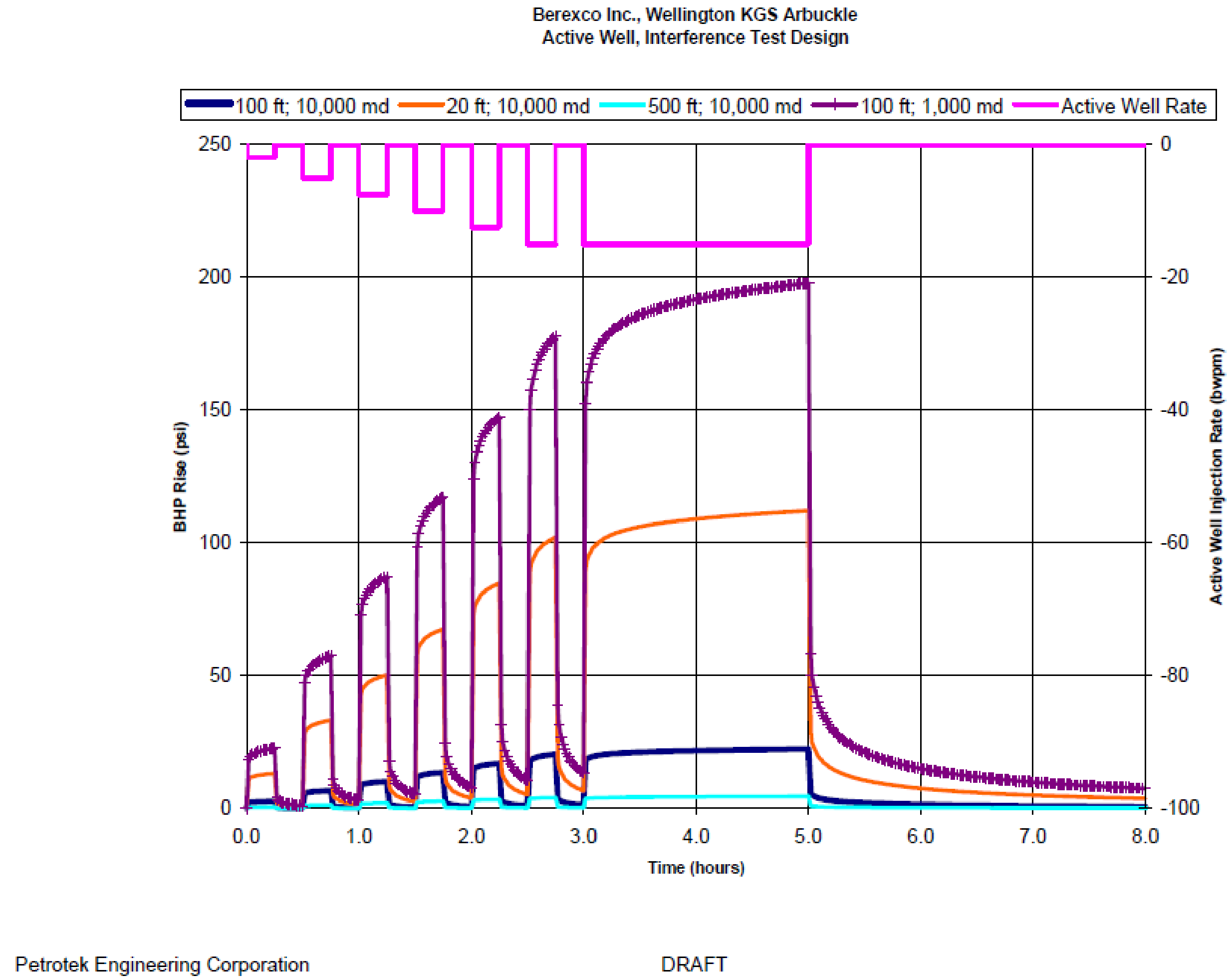


Figure 30.

Step Rate Test

A few simple cases for the test rate test were simulated to evaluate possible pressure response (shown as bottom hole pressure rise) and sensitivity to potential reservoir conditions (**Figure 30**). The test has been analytically modeled with an interwell distance of 3,000 feet (distance between #1-28 and #1-32) in a simple homogenous, single layer, single effective porosity Arbuckle unit. The stepped rates of injection are noted in **Figure 30**. Based on this sensitivity, it recommended to record data in both wells for 5-7 hours after the injection stops. An extended time-lag exists from the start of injection to the first observation well pulse arrival, so longer shut-in periods (30-60 minutes instead of 15 minutes) were recommended between injection pulses to allow better resolution of arrival times and pulse amplitudes. It was further recommended that a bottomhole gauge be used in the active well (#1-32) with clocks for the two gauges being synchronized.

The final completion came after this quarterly ended, but is included below (**Figure 31**). The actual test has yet to be conducted.

Berexco Wellington KGS 1-28 and 1-32 Completion Procedures

July 20, 2011

<u>For both 1-28 and 1-32 wells:</u>

1) Rig up workover rig. Move in 2 7/8" tubing and equipment.

2) Drill out DV's (2) and drill out to firm cement at bottom plug. Circulate clean using Wellington Unit lease water.

3) Trip out with bit. Top off casing with water. Rig down.

4) Run cement bond log using portable mast using Halliburton.

5) Pressure test casing to 2000#.

<u>Wellington KGS 1-28</u>

1) rig up workover unit.

2) Trip in hole with tubing to 4000' and swab down casing to 3500' from surface. Trip out.

3) Perforate Arbuckle 5000' to 5020' at 4 spf using expendable gun.

4) Trip in with tubing and packer to 3000' and swab with packer not set for 1 hour to verify clean fluid entry and remove Miss water.

5) Trip in hole with packer to 20' above perfs. Set packer.

6) Swab Arbuckle for 6 hours to obtain clean fluid samples.

7) Rig down leaving tubing and packer in well.

8) Run wireline pressure recorder in well to depth of perforations when ready to start 1-32 job.

<u>Wellington KGS 1-32</u>

1) rig up workover unit. Move in 5 empty 500 bbl frac tanks and hook up to swab lines.

2) Trip in hole with tubing to 4000' and swab down casing to 3500' from surface. Trip out.

3) Perforate Arbuckle 4995' to 5020' at 4 spf using expendable gun.

4) Trip in with tubing and packer to 3000' and swab for 1 hour to verify clean fluid entry and remove Miss water.

5) Trip in hole with packer to 20' above perfs. Set packer.

6) Swab Arbuckle at maximum rate for 3-4 days until swab tanks are essentially full. Monitor 1-28 pressure recorder while swabbing.

7) Pump into Arbuckle at 2 bpm to verify injectivity is OK. Record ISIP. Acidize if necessary. Monitor 1-28 pressure recorder while pumping in.

8) Pull tubing and packer.

9) Let well sit a couple days to allow pressures to equalize.

10) Run wireline pressure recorder in 1-32 well to just below depth of perforations

11) Move in pump trucks and pump down casing into Arbuckle using water from frac tanks per following schedule. If there is any indication formation is fracturing, reduce rate immediately.

A) Pump at 2 bpm for 20 minutes, then shut down for 20 minutes.

B) Pump at 5 bpm for 20 minutes, then shut down for 20 minutes.

C) Pump at 7.5 bpm for 20 minutes, then shut down for 20 minutes.

D) Pump at 10 bpm for 20 minutes, then shut down for 20 minutes.

E) Pump at 12.5 bpm for 20 minutes, then shut down for 20 minutes.

F) Pump at 15 bpm for 20 minutes, then shut down for 20 minutes.

G) Pump at 15 bpm for 2 hours, or until out of water, then shut down.

12) Move off pump trucks, let well sit overnight.

13) Haul off frac tanks, clean up, pull pressure recorders.

Figure 31. Completion orders for the Step-Rate Test between #1-28 and #1-32.

Subtask 4.8. Analyze Arbuckle core.
Subtask 4.9. Analyze Mississippian core.

Core resides in Weatherford labs in Houston and Midland and is undergoing whole core and special core analyes.

Subtask 4.10. PVT – oil and water.

Oil sample is in Weatherford’s lab in Calgary and undergoing PVT analysis.

Subtask 4.1l. Geochemical analysis of water samples

Geochemical analysis of waters obtained from DST was discussed in previous quarterly report. Additional water samples will be taken when #1-28 and #1-32 are perforated and swabbed.

Subtask 6.2. 2D Shear wave survey.

Contract was let to Paragon to collect 2D shear wave seismic survey (**Figure 32**). Crew will be onsite early next quarter.

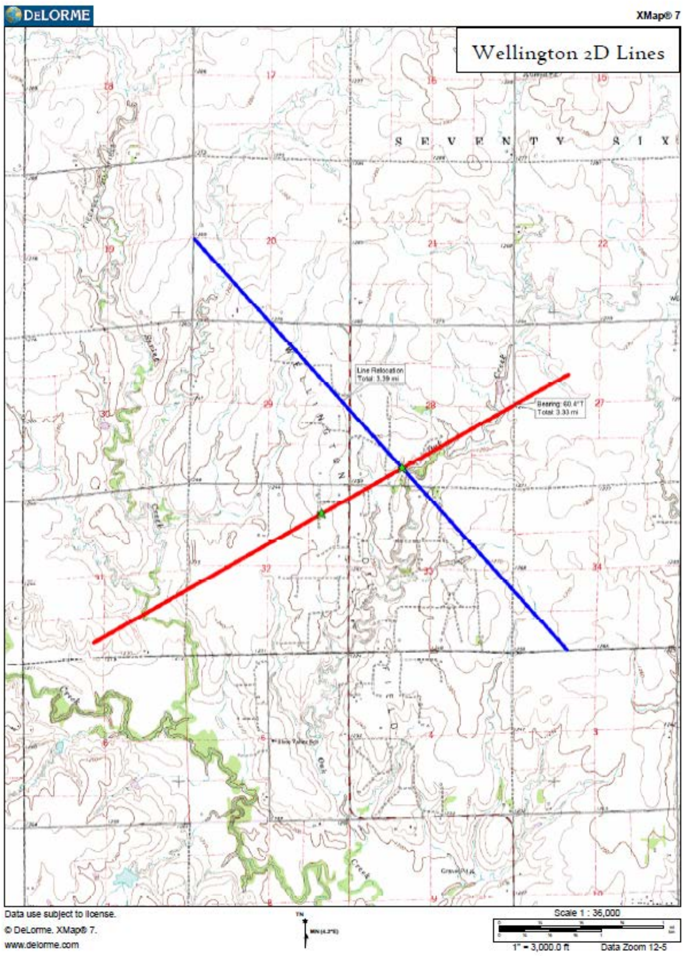


Figure 32. Layout of two 2D shear wave surveys in Wellington Field.

Subtask 6.2. Revise 3D seismic interpretation

Additional interpretation is waiting for 3D pre stack depth conversion processing.

Subtask 6.3. Process and interpret seismic – shear wave and pre-stack depth migration.

Shear wave interpretation will be accomplished after 2D shear is collected next quarter.

Subtask 13.1. Map major CO2 point sources in Kansas.

Data collection is underway.

TASK 14. TECHNOLOGY TRANSFER

Subtask 14.1. Build and maintain project website.

See earlier discussion concerning update of interactive mapper.

WESTERN ANNEX

Task 15. Extend Regional Study of Ozark Plateau Aquifer System (OPAS) to the Western Border of Kansas – "Western Annex"

Subtask 15.1. Extend regional study by evaluating CO2 sequestration potential

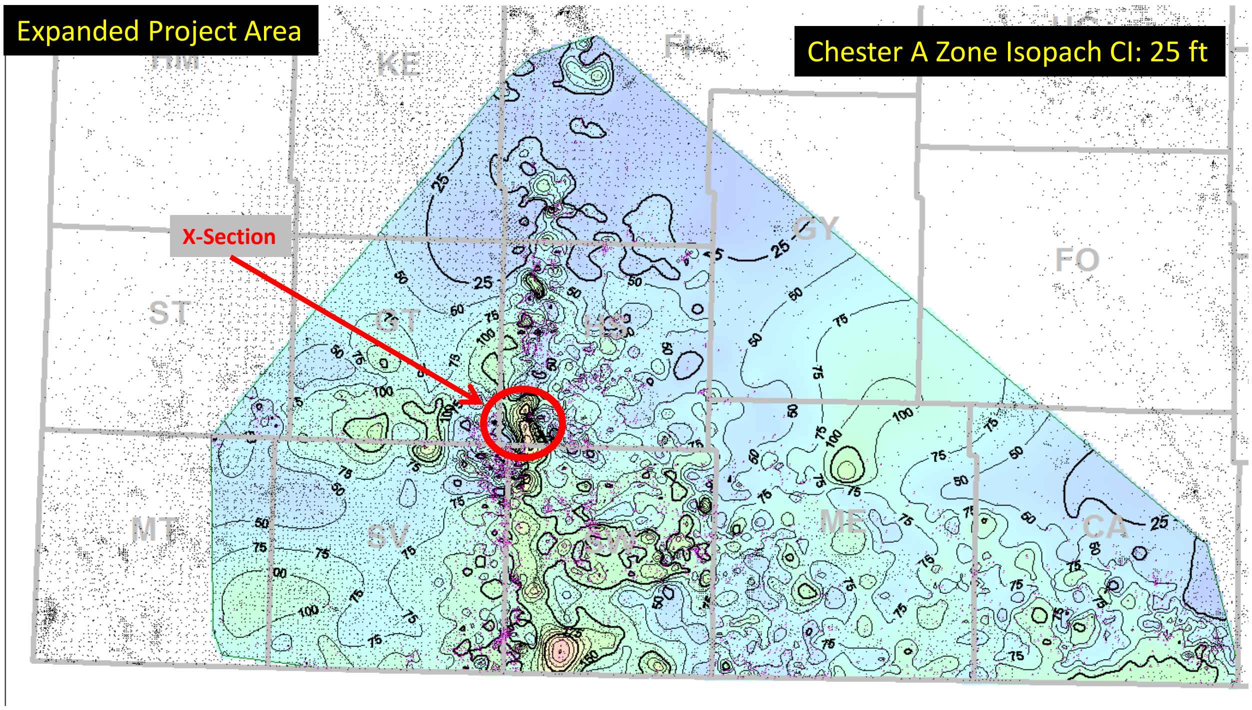


Figure 33. Regional map of the "Western Annex" in southwest Kansas has begun and an isopach map of the Chester A zone is shown here with thick central north-south trending area where A zone thickens in an incised valley and location of oil fields that will be characterized for CO2-EOR. Areas outside of the valley are sandy shelf carbonates that do not offer capacity for EOR and therefore are not of interest in this study.

Figure 33 serves as a base line map showing distrugbiton of the main oil pay zone in the Chester Fields that will be the focus of the CO2-EOR evaluation. The regional team will provide regional context for these study as well as characterize the underlying Arbuckle saline aquifer and overlying caprock. **Figure 34** is a wireline log cross section through the valley system showing the dramatic thickening of the Chester sandstones that dominate this valley and **Figure 35** is a map of the structural configuration of the strata that was incised by the Chester valley systems.

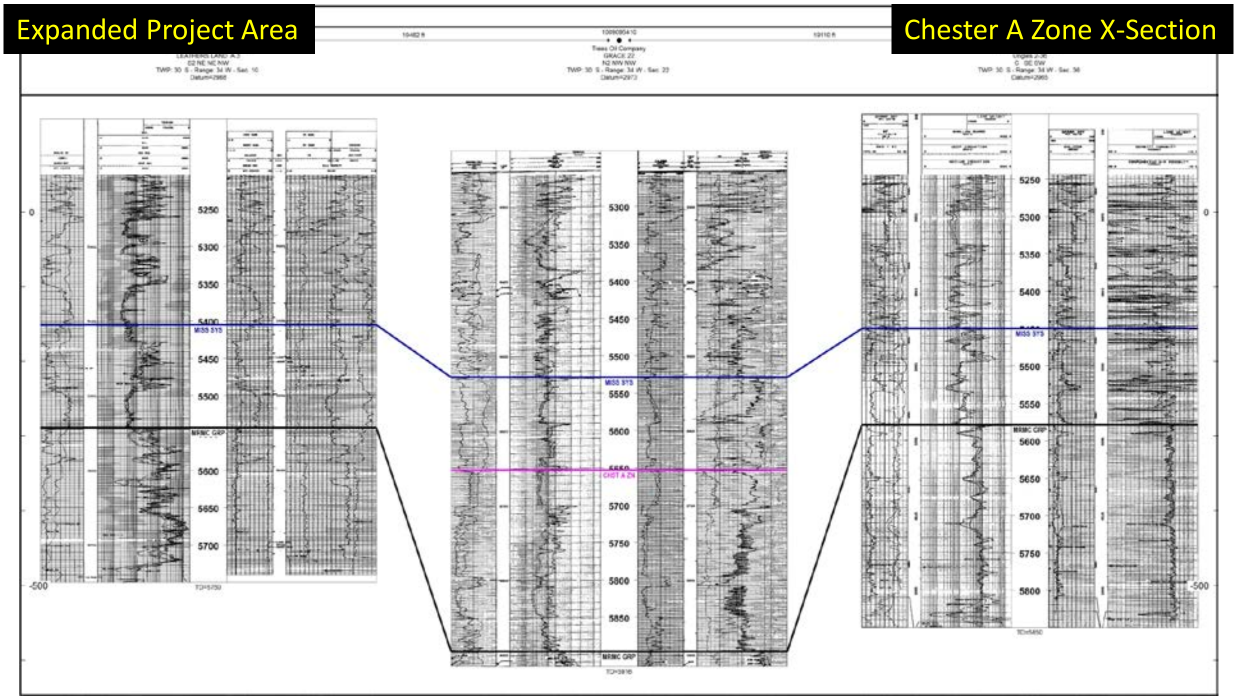


Figure 34. West to East cross section with index line shown in Figure 33.

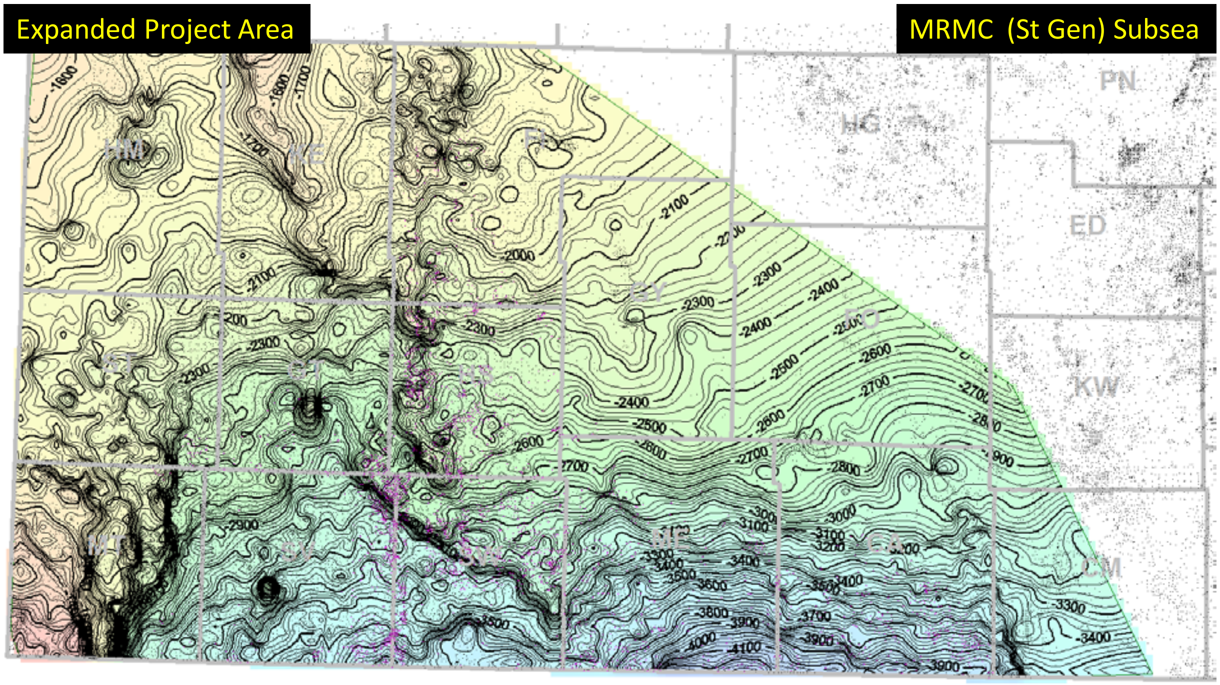


Figure 35. Regional structural map on the top of the Ste. Genevieve Limestone, underlying the Cherterian strata. Ste. Gen was incised by the Chesterian-age valley systems.

Task 17. Acquire (New) Data at a Select Chester/Morrow Field to Model CO2 sequestration Potential in the Western Annex.

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

The Western Annex team has been collecting initial well and seismic data for the study of the Chester/Morrow fields (**Figure 36**). Their data will be the basis of selecting the location of the deep borehole.

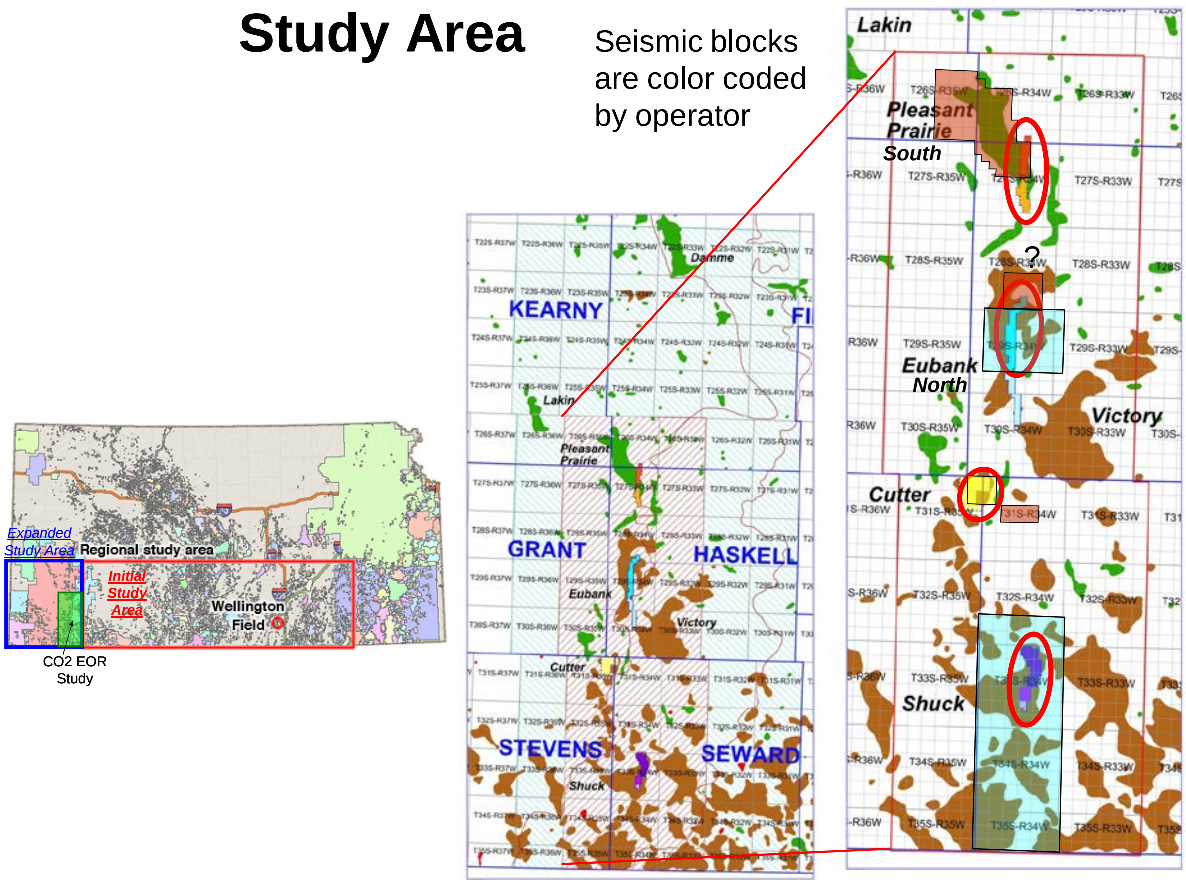


Figure 36. Western Annex area in southwestern Kansas.

Status of well information that is being gathered in the Western Annex is described in **Figure 37**. This work will continue in over the summer and early fall. Most of the seismic data has been received by the project geophysicist and steps are being taken to identify the seismic volumes to be reprocessed.

Data gathering update

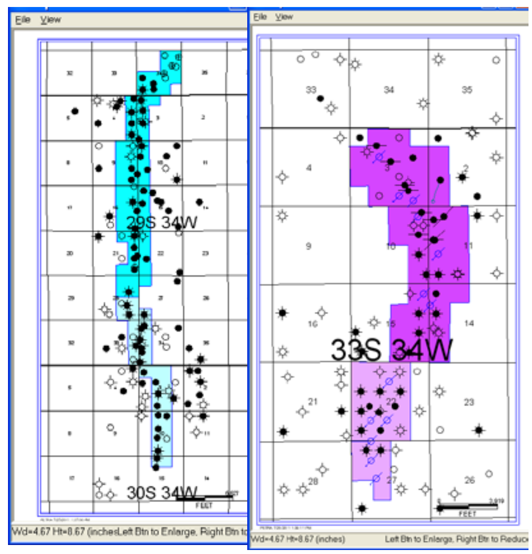
Operator Files – *to date (Jan and Feb)*

Berexco – 247 files, 350 MB of data

Merit – 2,749 files, 2.05 GB of data

Rasters and LAS files processed by KGS

- Appx 600 rasters for 255 key wells in Eubanks and Shuck
- Rasters digitized to LAS files for 159 wells (mostly inside waterflood boundaries)
- Will fill in raster and LAS data gaps in Cutter and Pleasant Prairie South after reviewing operator well files
- KGS is doing QC and calibrating LAS
- Data is placed on KGS database as they become available



Eubanks (left) and Shuck (right) rasters

Figure 37. Status of well data gathering for the Western Annex area.

Key Findings

1. Project's interactive mapper and well profile software have undergone upgrades and improvement as tools to access and work with maps and well data online and to facilitate collaborative investigations.
2. Initial synthesis of Wellington log and core data was done to evaluate the size of a small scale test injection of CO_2 and results, while preliminary, are encouraging.
3. Regional well data base has extended state-wide and information continues to be scanned and digitized to capture a larger view of the Arbuckle saline aquifer and overlying caprock. Continuity of aquifer over long distances drives the wider examination.
4. Stratigraphy is being refined considerably on a regional scale from top to bottom of the wells being used in the study.
5. Published faults are being inventoried and criteria for their recognition and validation are being established so that subsurface information can be processes consistently.
6. Areas in western Kansas and Western Annex region have limited thickness of Chattanooga Shale and intervals above this shale need to be closely studied for their caprock qualities. Numerous shales lie above the equivalent Chattanooga Shale interval.
7. Initial view of the internal stratigraphy of the Arbuckle indicates a general correlation of thickening and thinning with variations in major basement terrane as inferred from the tilt map of the magnetic field. Further correlation will require closer examination of strata including lithofacies and other rock properties that are being assembled.
8. Processing of the high resolution gravity data at Wellington Field shows good correlation to stratigraphic changes at moderate depth, ~2400 ft., but also shallow and at basement depths.
9. A number of steps have been taken to design the step-rate test to aid in a realizing a successful test. The lower porosity interval in the Arbuckle overlain by tighter and shaly intervals appears that it can serve as a zone for CO_2 injection.
10. Western Annex part of the study is "taking shape" and considerable amount of information has been identified for analysis.

Plans

1. 2D shear wave surveys at Wellington and process the multicomponent 3D seismic survey for the converted shear wave will commence are now scheduled for next quarter.
2. Swab testing of borehole #1-32 will commence in the initial part of next quarter.
3. Additional well production data found at Wellington will be incorporated in the database.
4. Detailed mapping of the Arbuckle will continue as new well data are assimilated into the study.
5. Identification and verification of faults and fracture systems will continue as regional data are processed and integrated with other information.
6. Tech transfer opportunities next quarter include abstracts for meetings, invited oral presentations, and work on an initial publication.
7. Western Annex staff will finalize collection of well data and begin processing/merging of the donated seismic data.

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
Baseline Reporting Quarter	Q1	Q2	Q3	Q4	Q5	Q6	Q7
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
Non-Federal Share	$277,260.75	$277,260.75	$277,260.75	$277,260.75	$0.00	$0.00	$0.00
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
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
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
Non-Federal Share	$0.00	$0.00	$0.00	$84,564.82	$251,354.30	$20,887.31	$6,043.03
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
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
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
Non-Federal Share	$277,260.75	$277,260.75	$277,260.75	$192,695.93	-$251,354.30	-$20,887.31	-$6,043.03
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
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**