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

1. Identification Number:	2. Program/Project Title:
DE-FE0002056	**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 CO2 Sequestration in Saline Aquifer and Depleted Oil Reservoir To Evaluate Regional CO2 Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas"

Project Director/Principal Investigator: W. Lynn Watney
Principal Investigator: Jason Rush

Sixteenth Quarter Progress Report

Date of Report: 10-31-13

Period Covered by the Report: July 1, 2013 to September 30, 2013

Contributors to this Report: Brent Campbell, John Doveton, Mina Fazelalavi, Paul Gerlach, Tom Hansen, Dennis Hedke, Eugene Holubnayak, Larry Nicholson, Jennifer Raney, Jason Rush, Ray Sorenson, John Victorine, Lynn Watney, John Youle, Dana Wreath

EXECUTIVE SUMMARY

The project “Modeling CO2 Sequestration in Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO2 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 CO2-EOR potential in the Mississippian tripolitic chert reservoir and CO2 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 CO2 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 mi2 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

Task Name	Planned Start Date	Actual Start Date	Planned Finish Date	Actual Finish Date	% Complete
1.0 Project Management & Planning	12/8/2009	12/08/09	2/7/2014		80%
2.0 Characterize the OPAS (Ozark Plateau Aquifer System)	1/1/2010	01/01/10	9/30/2013		90%
3.0 Initial geomodel of Mississippian Chat & Arbuckle Group - Wellington field	1/1/2010	01/01/10	9/30/2010	09/30/10	100%
4.0 Preparation, Drilling, Data Collection, and Analysis - Well #1	9/15/2010	12/15/10	3/31/2011	08/30/11	100%
5.0 Preparation, Drilling, Data Collection and Analysis - Well #2	1/1/2011	02/20/11	6/30/2011	08/30/11	100%
6.0 Update Geomodels	5/1/2011	05/01/11	9/30/2011	10/31/12	100%
7.0 Evaluate CO2 Sequestration Potential in Arbuckle Group Saline Aquifer	8/1/2011	08/01/11	12/31/2011	10/31/12	100%
8.0 Evaluate CO2 Sequestration Potential in Depleted Wellington field	10/15/2011	10/15/11	7/30/2013	+++	90%
9.0 Characterize leakage pathways - risk assessment area	1/1/2010	01/01/10	6/30/2012	10/31/12	100%
10.0 Risk Assessment related to CO2-EOR and CO2 Sequestration in saline aquifer	6/1/2012	06/01/12	9/30/2013	**	90%
11.0 Produced water and wellbore management plans - Risk assessment area	1/1/2012	01/01/12	7/30/2013		95%
12.0 Regional CO2 sequestration potential in OPAS	8/1/2012		9/30/2013		80%
13.0 Regional source sink relationship	1/1/2010	1/1//2010	9/30/2013		95%
14.0 Technology Transfer	1/1/2010	01/01/10	2/7/1014		85%

Milestone	Planned Completion Date	Actual Completion Date	Validation
HQ Milestone: Kick-off Meeting Held	3/31/2010	03/31/10	Completed
HQ Milestone: Begin collection of formation information from geologic surveys and private vendors	6/30/2010	01/01/10	Completed
HQ Milestone: Semi-Annual Progress Report on data availability and field contractors	9/30/2010	07/30/10	Submitted to Project manager
HQ Milestone: Establish database links to NATCARB and Regional Partnerships	12/31/2010	12/31/10	Completed
HQ Milestone: Annual Review Meeting attended	3/31/2011	10/05/10	Completed
HQ Milestone: Complete major field activities, such as drilling or seismic surveys at several characterization sites	6/30/2011	Note: This milestone was met collectively by all projects. No one project was held accountable to the milestone.	Completed
HQ Milestone: Semi-Annual Progress Report (i.e. Quarterly Report ending June 30, 2011)	9/30/2011	09/30/11	Completed
HQ Milestone: Yearly Review Meeting of all recipients; opportunities for information exchange and collaboration	12/31/2011	11/15/11	Attended meeting
HQ Milestone: Complete at least one major field activity such as well drilling, 2-D or 3-D seismic survey, or well logging	3/31/2012	08/15/12	Completed 3D seismic Cutter compete
HQ Milestone: Complete at least one major field activity such as well drilling, 2-D or 3-D seismic survey, or well logging	6/30/2012	10/09/12	Completed cutter well reach TD
HQ Milestone: Semi-annual report (i.e. Quarterly Report ending June 30, 2012) on project activities summarizing major milestones and costs for the project 9/30/2012	9/30/2012	09/30/12	Completed
FOA Milestone: Updated Project Management Plan	3/31/2010	03/31/10	
FOA Milestone: Submit Site Characterization Plan	5/28/2010		Completed
FOA Milestone: Notification to Project Manager that reservoir data collection has been initiated	9/15/2010	01/01/10	Completed
FOA Milestone: Notification to Project Manager that subcontractors have been identified for drilling/field service operations	7/30/2010	01/01/10	Completed
FOA Milestone: Notification to Project Manager that field service operations have begun at the project site	7/1/2010	01/01/10	Completed
FOA Milestone: Notification to Project Manager that characterization wells have been drilled	6/3/2011	03/09/11	Completed
FOA Milestone: Notification to Project Manager that well logging has been completed	6/3/2011	03/09/11	Completed
FOA Milestone: Notification to Project Manager that actvities on the lessons learned document on site characterization have been initiated	7/15/2012		Completed
FOA Milestone: Notification to Project Manager that activities to populate database with geologic characterization data has begun	12/31/2010	12/31/10	Completed, email summary
KGS Milestone 1.1: Hire geology consultants for OPAS modeling	3/31/2010	03/31/10	Completed
KGS Milestone 1.2: Acquire/analyze seismic, geologic and engineering data - Wellington field	6/30/2010	06/30/10	Completed, quarterly rpt
KGS Milestone 1.3: Develop initial geomodel for Wellington field	9/30/2010	09/30/10	Completed, email summary
KGS Milestone 1.4: Locate and initiate drilling of Well #1 at Wellington field	12/31/2010	12/25/10	Completed, email summary
KGS Milestone 2.1: Complete Well#1 at Wellington - DST, core, log, case, perforate, test zones	3/31/2011	08/30/11	Completed, email summary
KGS Milestone 2.2: Complete Well#2 at Wellington - Drill, DST, log, case, perforate, test zones	6/30/2011	08/30/11	Completed, email summary
KGS Milestone 2.3: Update Wellington geomodels - Arbuckle & Mississippian	9/30/2011	10/31/12	completed
KGS Milestone 2.4: Evaluate CO2 Sequestration Potential of Arbuckle Group Saline Aquifer - Wellington field	12/31/2011	10/31/12	Completed
KGS Milestone 3.1: CO2 sequestration & EOR potential - Wellington field	3/31/2012		90% complete
KGS Milestone 3.2: Characterize leakage pathways - Risk assessment area	6/30/2012	10/31/12	Completed
KGS Milestone 3.3: Risk assessment related to CO2-EOR and CO2-sequestration	9/30/2012		90% complete
KGS Milestone 3.4: Regional CO2 Sequestration Potential in OPAS - 17 Counties	12/7/2012		80% complete

COMPLETED ACTIVITIES

Task 7.0 Evaluate CO2 Sequestration Potential in Arbuckle Group Saline Aquifer in Wellington Field.

Task 9.0 Characterize leakage pathways - risk assessment area.

ONGOING ACTIVITIES - REGIONAL STUDY INCLUDING SOUTHWEST KANSAS

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

1) Analysis of Cutter Field data including well logs, core, and seismic data

Weatherford Labs has completed 190 of the 307 whole core analyses and 42 of the 55 plug analyses of the 1024 ft of core acquired in the Berexco Cutter KGS #1. Whole core analysis include Kmax, K90, and Kvert, porosity, grain density, and fluorescence. Plug samples included analysis for air and klinkenberg permeability, porosity, grain density, and fluid saturations. The phi & k plotted versus depth (**Figure 1**) shows preliminary, incomplete analytical results for the core interval extending from the Morrow sandstone to the lower portion of the Arbuckle Group, the Gasconade Dolomite.

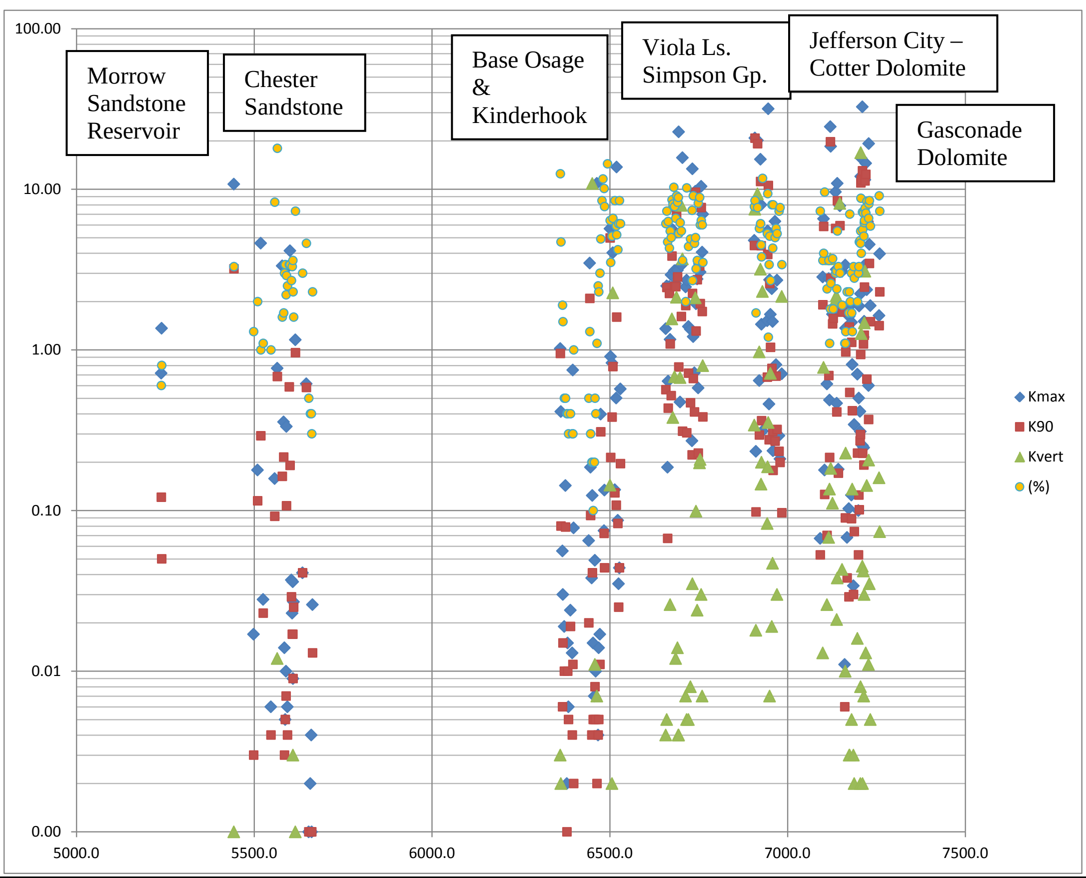


Figure 1. Porosity (%) and permeability (millidarcies) from full diameter core analysis including maximum (Kmax), 90 degrees to maximum (K90), and vertical (Kvert) vs. depth in feet below the surface.

Kmax ranges up to 10 md in the Chester to over 30 md for the portions of the Arbuckle strata. K90 and Kmax are similar in value while the Kvertical is less by up to several orders of magnitude than the other two measures of permeability. The latter suggests that fracture permeability is not significant in those intervals, at least as captured in the whole core samples. Porosity typically ranges between 1 and 10 percent, decidedly low, but in the range of the core from Wellington Field (KGS #1-32). A permeability-porosity crossplot indicates that for a single porosity value that the permeability varies by 4.5 orders of magnitude (**Figure 2**).

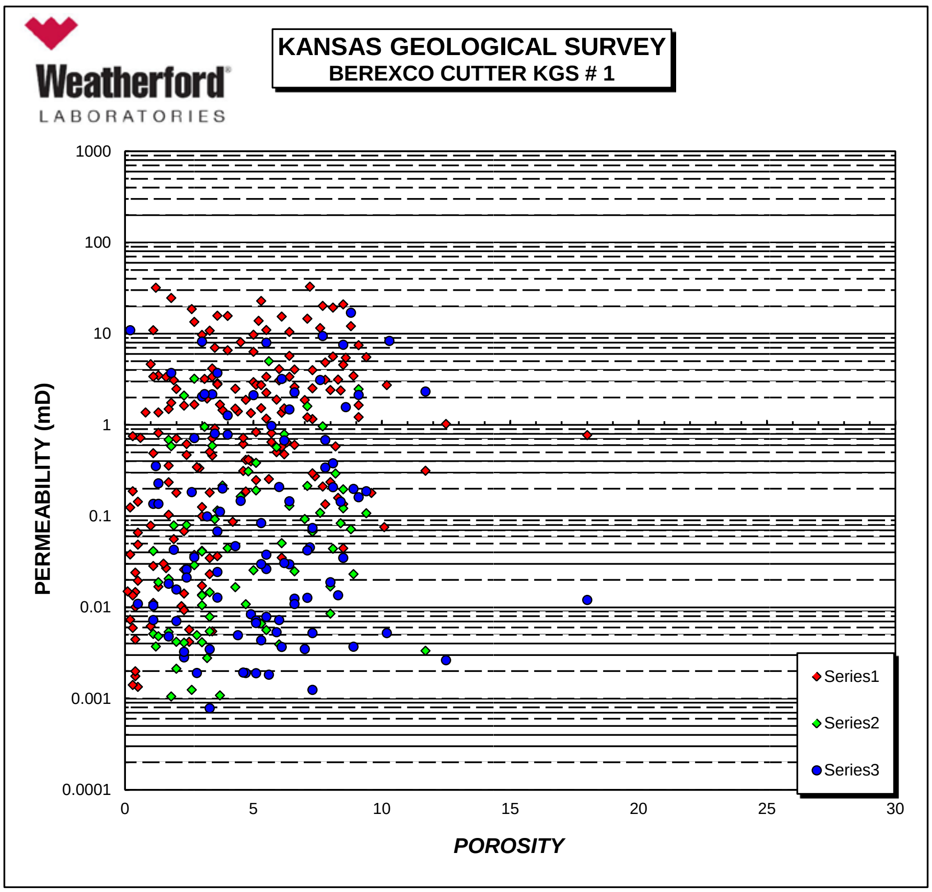


Figure 2. Permeability vs. porosity.

A crossplot of Klinkenberg permeability, ambient porosity, and water and oil saturations obtained from core plugs indicate Darcy-scale permeability, higher porosity, and oil saturation are present in the Lower Pennsylvanian Morrow oil reservoir sandstone while marginal permeability and slightly less oil saturations are noted in core plugs from the Chester (Upper Mississippian) sandstone. Core plugs from the lower Arbuckle indicate low permeability and porosity below 10% while samples selected to analyze hydrocarbon shows (flurescence) also contain residual oil saturation at levels similar to the Morrow and Chester intervals (**Figure 3**).

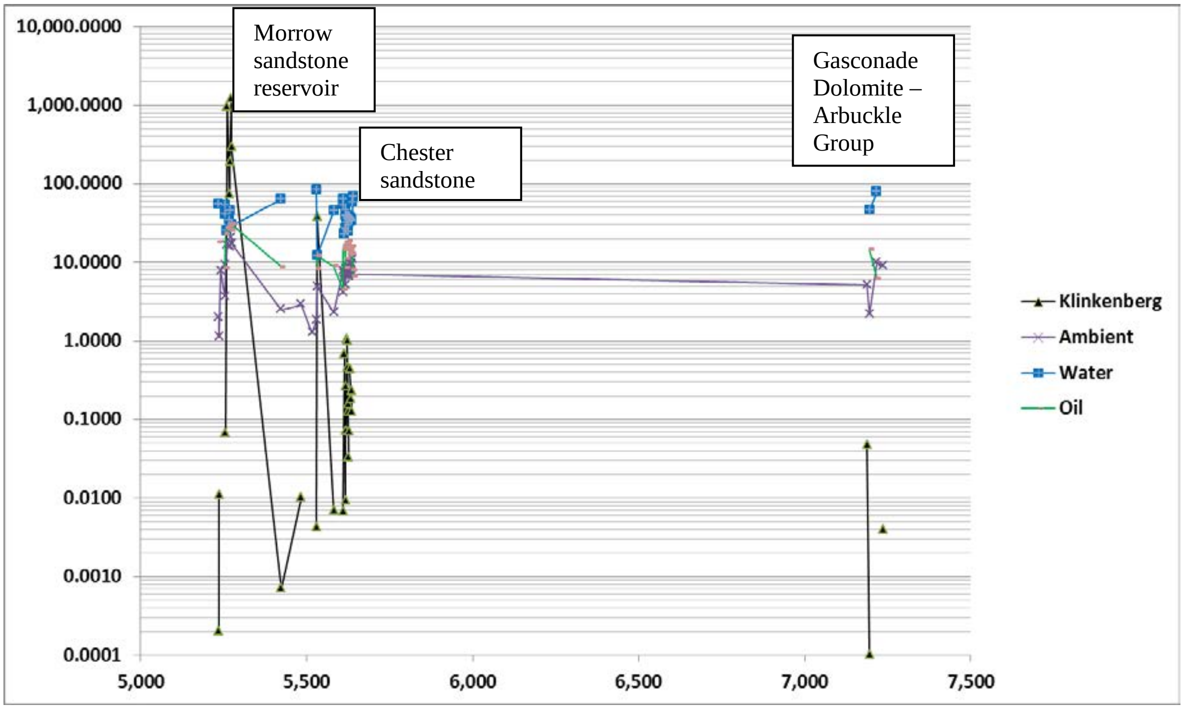


Figure. 3. Crossplot of permeability, ambient porosity, and water and oil saturations versus depth obtained from saturation analysis of core plugs selected from the Berexco Cutter KGS #1 core.

Also, 2 inch diameter horizontal plugs were sent to KSU for flow studies. End trimmings to make a right cylinder are being sent to Spectrum Petrographics Inc for thin section preparation. End samples of the core will also being used to obtain X-ray diffraction mineral composition.

2) Well testing and pressure buildup tests in lower Paleozoic strata at Cutter Field

Following drilling of the well, it was cased and cemented top to bottom. Eleven zones were selected to obtain connate fluids for geochemical analysis by perforating and swabbing the major hydrostratigraphic units that lie between the basal Pennsylvanian strata to the Proterozoic basement. Teams from Kansas University and Kansas State University joined in the sampling that will lead to analyses of cation and anions in solution, microbial content, and crude oil, the latter analysis following up on a series of oil shows.

The perforating and swabbing were started in June 2013 and extended through July 2013. Lower zones of the tests in the Arbuckle were also subjected to pressure buildup test to estimate permeability.

Eleven intervals were tested after casing was set and two DSTs were acquired during drilling (**Figures 4 and 5**). The protocol for acquiring fluid samples follows.

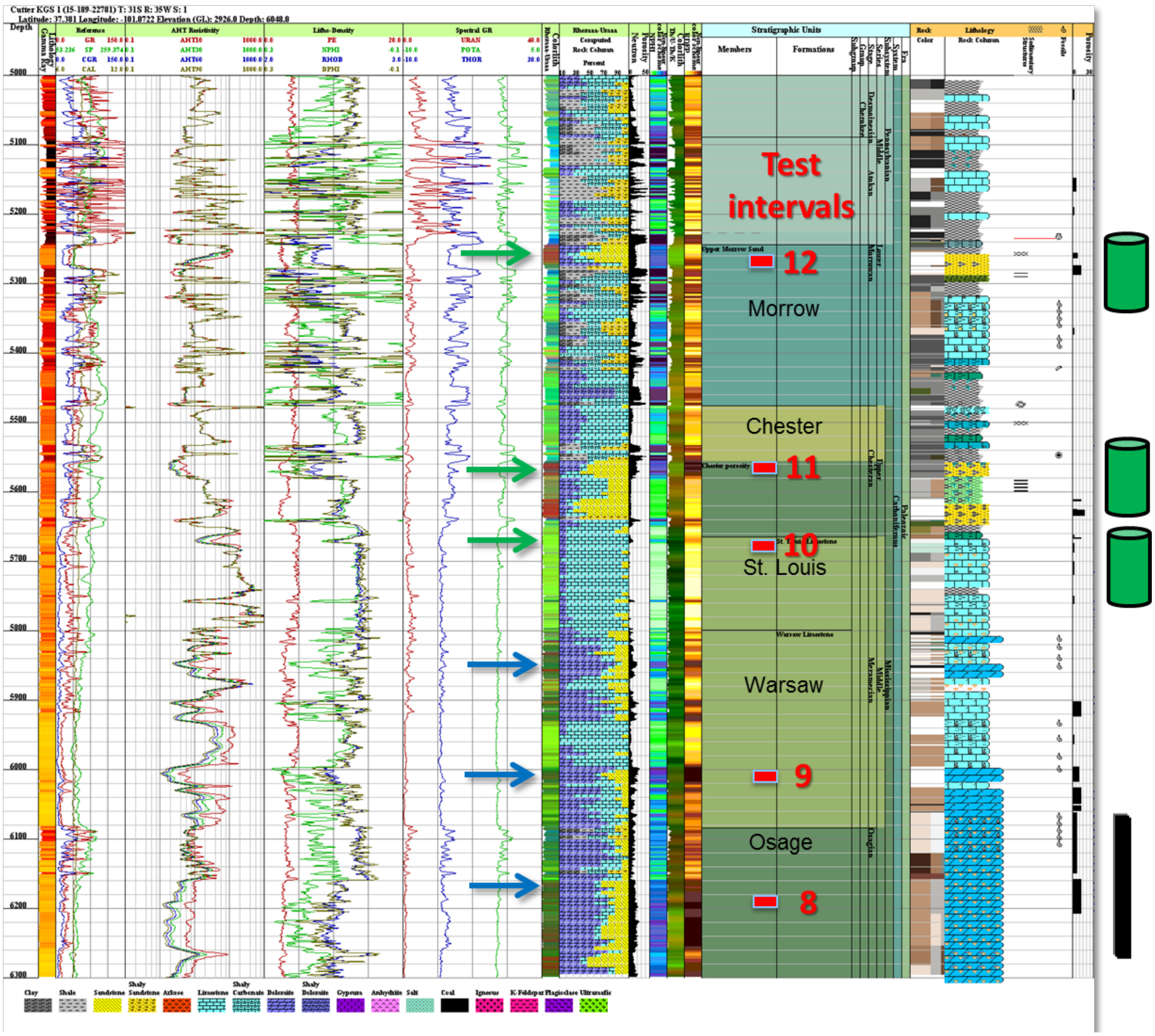


Figure 4. Upper portion of the cored interval in the Cutter KGS #1 well showing zones 8-11 that were tested.

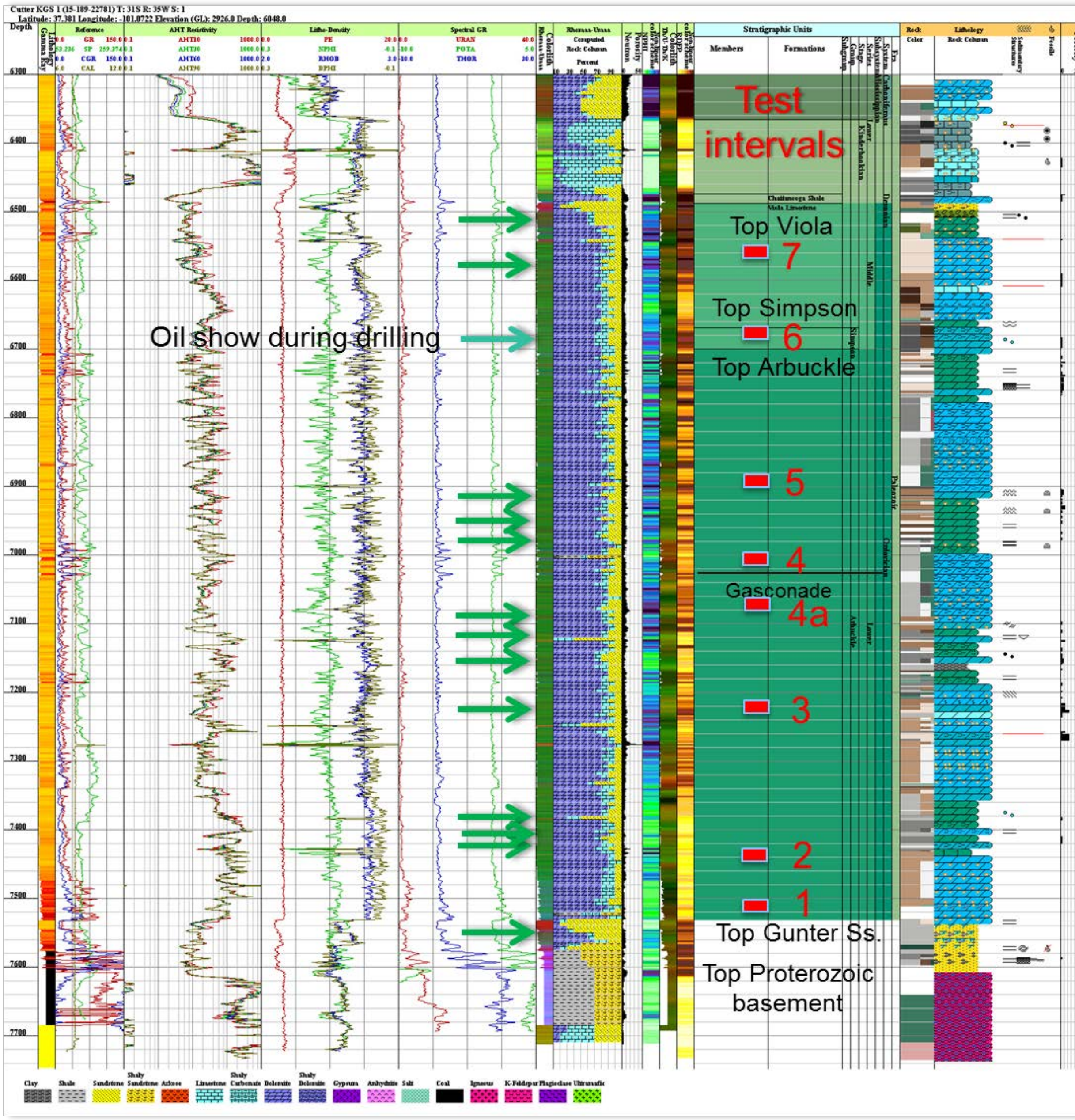


Figure 5. Lower portion of the cored interval in the Cutter showing test intervals 1 through 7.

Water sampling summary --

June-July, 2013 -- 11 perforating and swabbing, and 2 DST depth water samples were taken.
August, 2013 -- core plugs were sent off to Spectrum Petrographics Inc for thin section, 17 + 9 slides were returned.
September, 2013 -- water samples were analysed for ICP-OES for cation analysis, anion analyses are in progress.

Protocol and observations -- fluid sampling from swab tests during June-July, 2013

Water retrieved from interval was sampled inside a 5 gal jug for analysis, and two 2 gal. HDPE jugs which were filled to the top and sealed immediately upon retrieval.

As most of the water was very turbid and required filtering of most intervals before analysis could occur. Formation water in the upper intervals did allow for analysis without filtration. During filtering water was simultaneously collected in our sample packs. All containers were rinsed 3 times with formation water before taking final sample. All bottles were sealed with black electrical tape.

Sample packs included:

- 2-500ml clear HDPE bottles, Unacidified and Unfiltered
- 2-250 amber glass bottles (C^{14} dating), Unacidified and Unfiltered
- 2-125ml amber HDPE bottles, 1 Acidified and Filtered, 1 Unacidified and Unfiltered
- 2-125ml amber glass bottles, Acidified and Filtered
- 2-60ml clear glass bottles (Stable Isotopes), Unacidified and Unfiltered
- 2-50ml centrifuge tubes, 1 Unacidified and Unfiltered, 1 Acidified and Filtered
- 1-60ml clear class bottle (Oil sheen), underside of lid added aluminum foil
- 1-Vial clear glass (DIC)

Water was analyzed using the Hach Hydrolab MS5 with Hach Recon PDA, Mettler Toledo SevenGo Pro Dissolved Oxygen meter, Mettler Toledo SevenGo Conductivity meter, and Hach HQ40d Multi meter. As equalization was occurring, water was tested for Fe^{2+}, Total Fe, Alkalinity, and Sulfate using a UV-VIS spectrophotometer. Later, Nitrate, Ammonia, and an additional Total Fe test were added.Two water samples were measured to ensure accuracy and if the two results were in disagreement a third test was run.

Once equalization occurred measurements were made with the HACH Hydrolab, and 3 probes.

The 3 different probes and their tests:

- 1-Mettler Toledo SevenGo Pro meter-Dissolved Oxygen
- 2-Hach HQ40d Multi meter-pH, ORP, and Temperature
- 3-Mettler Toledo SevenGo meter-Conductivity, Resistivity, Salinity, and TDS

The Hach Hydrolab MS5 measured:

- Conductivity
- LDO
- ORP
- pH
- Resistivity
- Salinity
- Temperature
- TDS
- Turbidity

We waited for equilibration with the instruments, and then recorded measurements. Once we felt comfortable with the results we moved on to further analysis with testing kits. All testing kits were ran twice to ensure accuracy, if differed we again took a 3rd test.

Testing kits included:

- Alkalinity
- Chloride
- Do
- Nitrate
- Nitrite
- Phosphate
- Silica
- Sulfate

All 11 swab intervals and the two DST's were analysed in September 2013 for cation analysis via ICP-OES. Data received back October 1st. Information will shared in a subsequent quarterly report.

Pressure buildup test

Permeablity was measured in both core plugs and in full diameter core for the Cutter KGS #1 as noted above. Three pressure buildups were obtained following perforating and swabbing. The results are essentially parallel to a drill stem test but the packer is set above the perforation in casing and a value is opening below the tubing to allow fluid to enter the inner tubing. Pressure is recorded during the open flow period as it would during a normal DST.

Analyiss of the the pressure buildup in Test #2 (7218-7234 ft, upper Gasconade Dolomite) was analyzed using Fekete well test analysis software. Permeability and skin are calculated near the wellbore. Permeability is around 350 md and skin is 73. This results assume a thickness of 16ft, which is the perforation interval. Permeability will be changed if the thickness is larger than 16ft. This perforated interval might be connected to lower and upper layers hence, the thickness might be thicker. Computed permeability of ~200 md was obtained using nuclear magnetic resonance log for this interval, indicating close agreement (**Figure 6**).

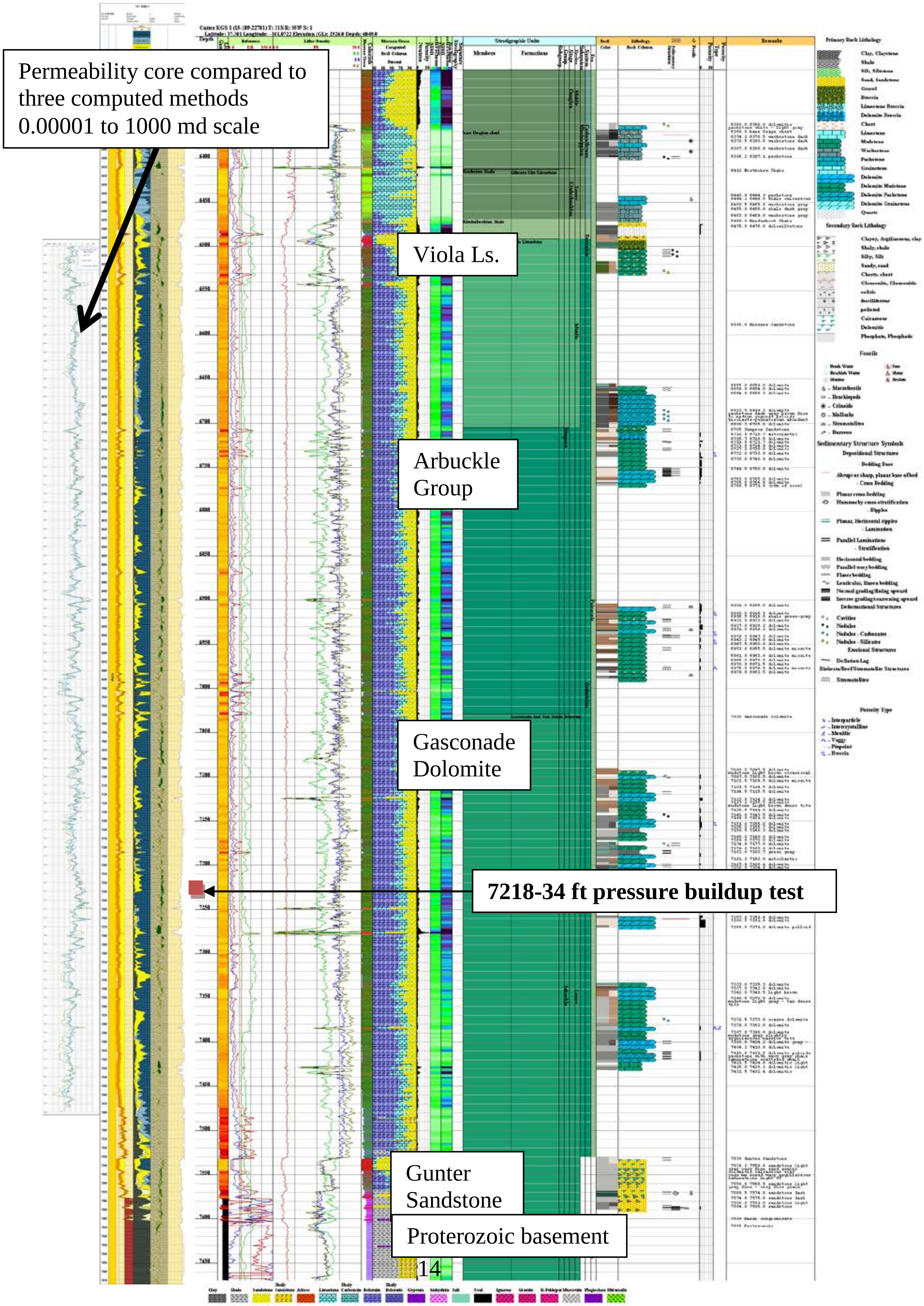
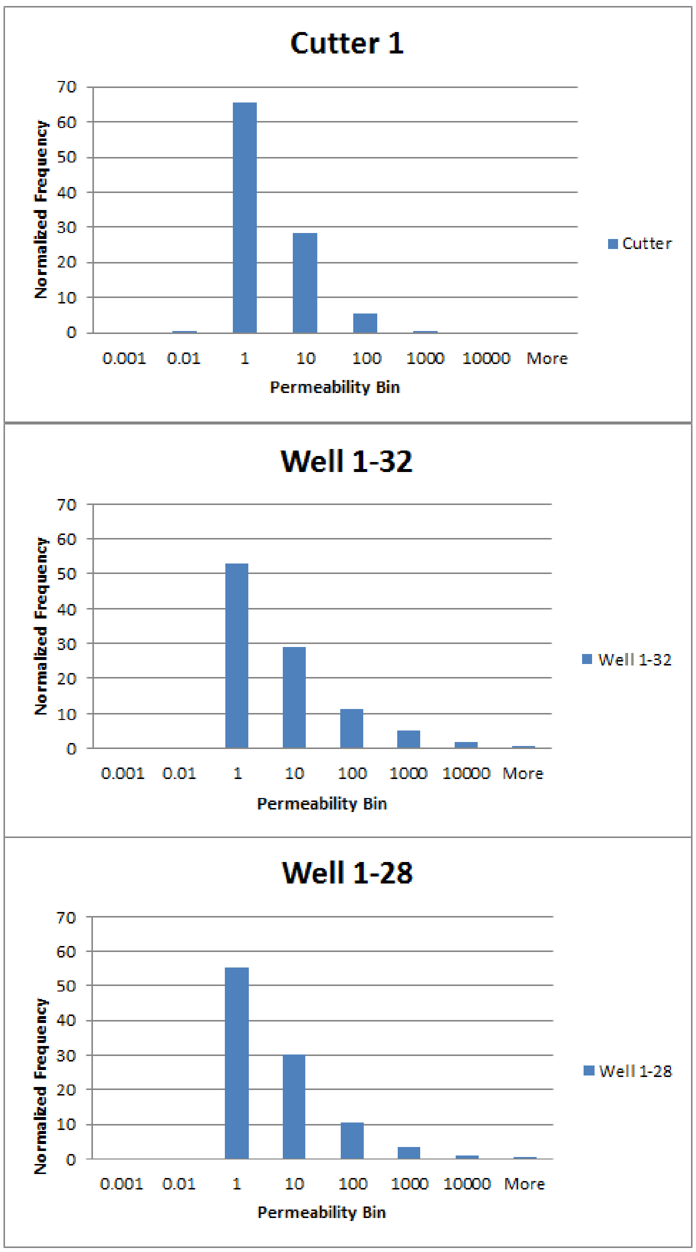

Permeability core compared to three computed methods 0.00001 to 1000 md scale
Viola Ls.
Arbuckle Group
Gasconade Dolomite
7218-34 ft pressure buildup test
Gunter Sandstone
Proterozoic basement

Figure 6. Cored interval with the addition of the computed permeability curve on left side. Interval in the upper Gasconade Dolomite is highlight that we perforated and subjected to a pressure buildup #2 test. Computed and permeability measured from this test are comparable with the test indicating approximately 350 md.

A preliminary comparison of permeability distribution in the Arbuckle Group for the Cutter KGS #1 and the two wells in Wellington Field, indicate that the permeability in the Cutter well is less than the #1-32 and #1-28 at Wellington Field (**Figure 7**). The frequency of the low permeability, 1-10 millidarcies, is higher in Cutter while the permeability over 1 Darcy, while small in wells at Wellington Field, is also lower.



The differences in permeability may require that the petrophysical models will differ between their use between these calibration sites. While lithofacies are similar,corelations with log properties may vary. This will be the next step in the analysis. The explanation may lie in the depositional fabric, diagenesis, or structure.

Figure 7. Permeability histograms for each of the new wells drilled in this study, Cutter 1 in Cutter Field, Well #1-32 and #1-28 from Wellington Field.

Task 18. Update Geomodels and Conduct Simulation Studies

1) Static and dynamic modeling of Eubank, Shuck, and Cutter fields

The characterization of the Morrow sandstone reservoir at Cutter Field has begun and simulation continues for the Chester sandstone reservoir at Eubank Field. Similation of the Chester reservoir at Pleasant Prairie South has been completed with results indicating that CO2-EOR will result in 1.95 million barrels of additional oil with a net utilization of CO2 of 5 mcf/bbl of oil (**Figure 8**). The oil recovered using CO2 represents nearly what was recovered in each phase of primary and secondary production attesting to the effectiveness of the CO2.

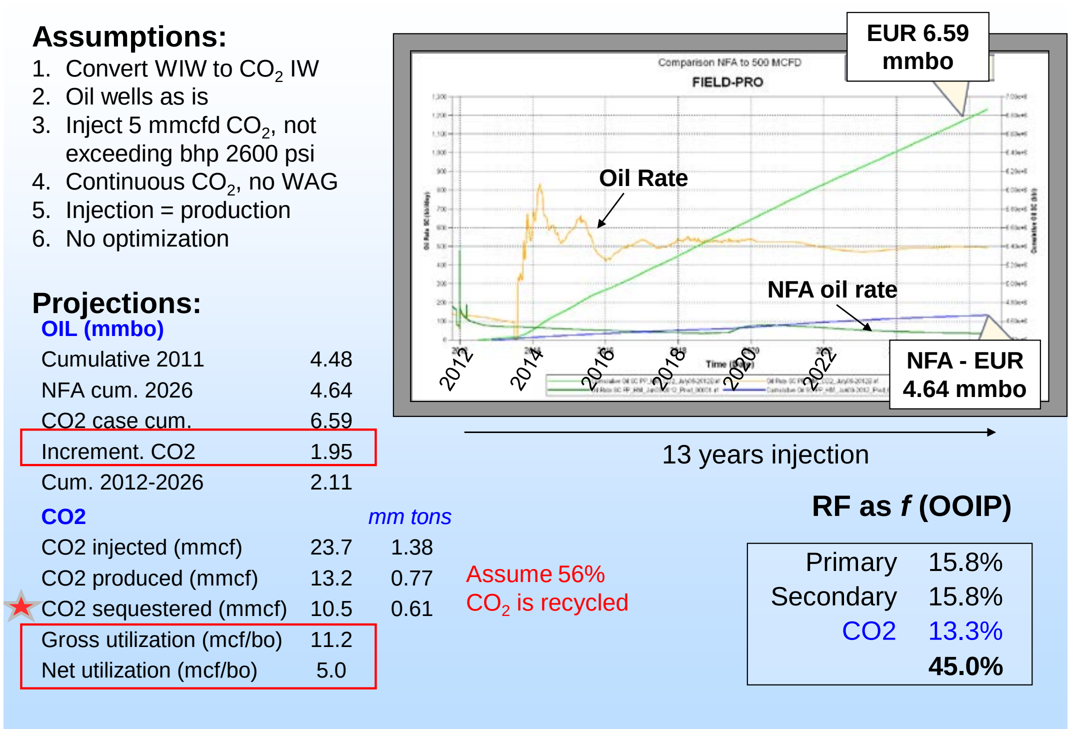


Figure 8. CO2-EOR projections for simulation from Pleasant Prairie South Field that is part of the SW CO2-EOR Initiative.

The basis for the geomodel development in the Chester and Morrow sandstone reservoirs are lithofacies defined from core but are distinguishable on well logs. Lithofacies are predicted using a neural network (**Figures 9 and 10**).

Simulation of the Chester sandstone reservoir is being completed at Eubank and when competed Schuck and Cutter will be modeled.

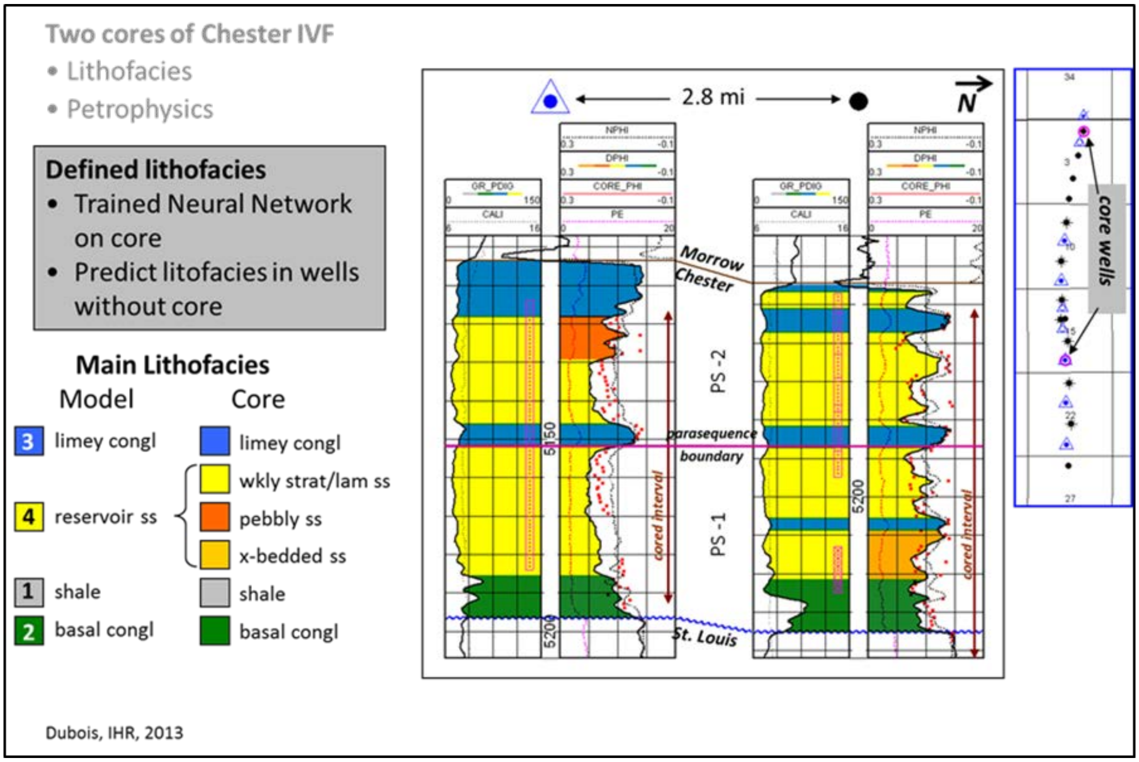


Figure 9. Illusration of two cored wells illustrating the correlation of lithofacies and well log properties.

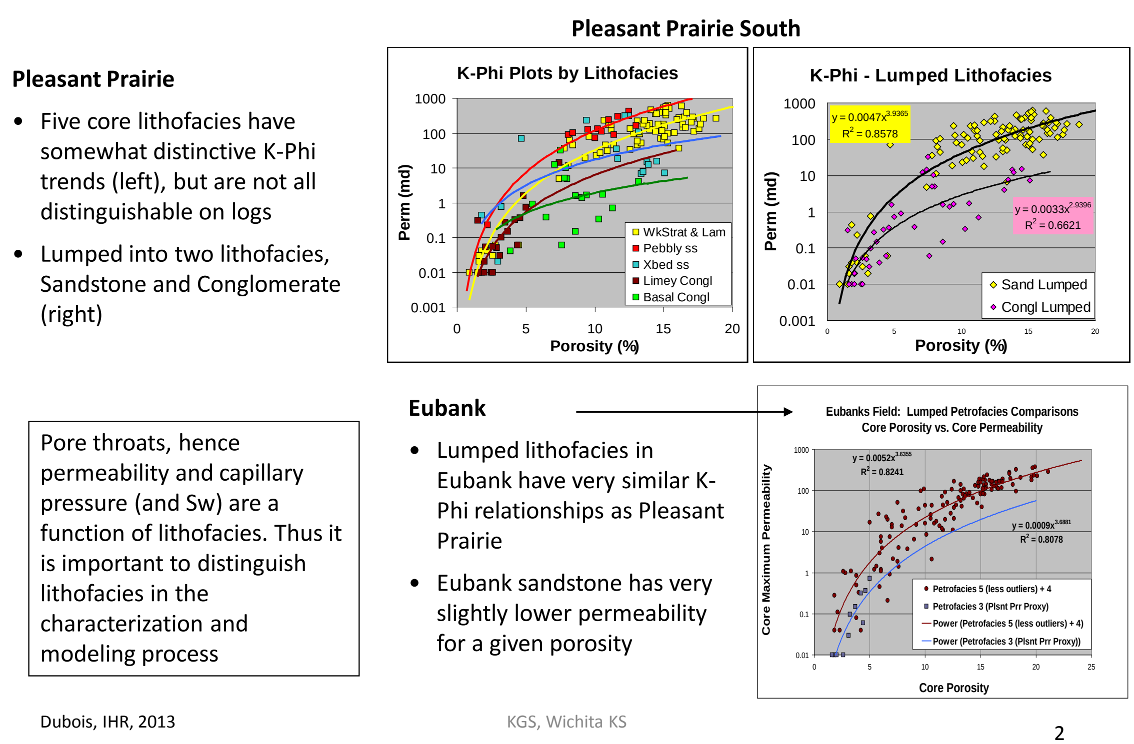


Figure 10. Illustration showing relationships between pore throats, permeability, and water saturation and lithofacies.

Task 12. Regional CO2 Sequestration Potential in OPAS - 17 Counties

1) Calibration of Arbuckle rock properties with well logs and large scale, coarse grid static and dynamic modeling of regional sites to refine estimates of carbon storage potential

The core analysis for the Cutter KGS #1 continues to be made available as it has been analyzed by Weatherford over the past months. The Cutter well is the western calibration point for the regional assessment and is one of the 9 sites that will be simulated using a coarse grid model each covering multiple townships (Figure 11).

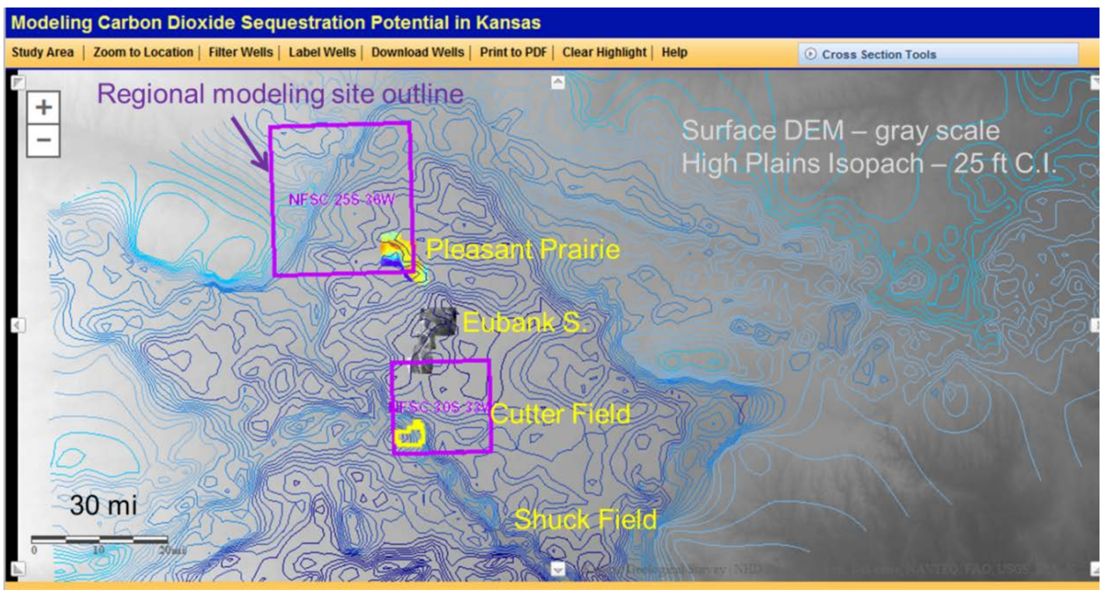


Figure 12. Isopach of the High Plains Aquifer in southwest Kansas with the location of two of the modeling sites for coarse grid simulation of CO2 injection of the Arbuckle. One includes Cutter field and the other Pleasant Prairie Field.

The coarse grid models such as that illustrated in **Fugure 13** will be constructed in 10 sites. A methodology called fuzzy logic was chosen to estimate permeability and other petrophysical properties of the rock using modern log suites (GR, N-D porosity, resistivity, photoelectric curve) and lithologic information based on sample descriptions obtained in georeports (**Figure 14**). Cored wells at Cutter and Wellington fields that were logged with an extensive set of tools provide the basis to develop correlations to permeability.

The basis of the petrophysical correlations has been previously described, quantifying the reservoir quality by pore type and lithofacies. Moreover, this classification has been related to the stratigraphic intervals of the Arbuckle where certain lithofacies appear to dominate. The influence imposed by stratigraphy is being evaluated using the new data obtained from the Cutter well. The constraint of stratigraphy will be factored into the fuzzy logic approach.

Methodology for fuzzy logic prediction of permeability and related reservoir properties --

1.Classify zones in Arbuckle wells as to whether they belong to :

- Low permeability (<0.5 md), micropore, mud-supported petrofacies
- Intermediate permeability (0.5 – 25 md), mesopore, grain-supported petrofacies
- High permeability (>25 md), megapore, vuggy petrofacies

2. Following classification, assign a numerical value of permeability

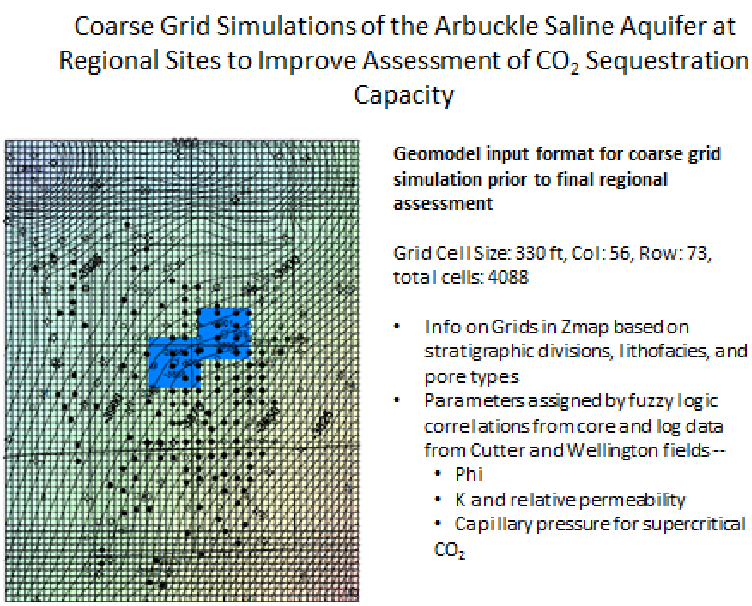


Figure 13. Coarse grid simulation framework to be used at 10 regional sites.

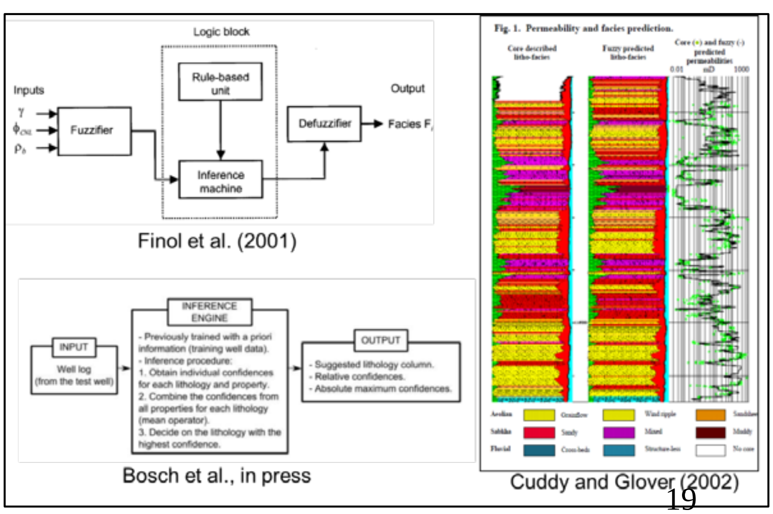


Figure 14. Fuzzy logic approach to permeability prediction.

2) Vetting of type logs and finalizing project interactive mapper

The type log web application was introduced to the community in a presentation at the Mid-Continent AAPG Meeting by Paul Gerlach. Next step is a webinar to engage the committee to review and offer refinements in the stratigraphic correlations.

The interactive mapper and carbon storage assessment will be finalized for the NATCARB and Carbon Storage Atlas by end of calendar year 2013 to meet deadlines on those activities.

3) Timing structural activity encompassing southwest Kansas
The structural evolution of the southwestern Kansas and particularly the timing of the major tectonism in the Mid-continent is an important topic for understanding the development of primary structures as it affects the storage of CO2, namely closure and containment of the CO2, evaluating the integrity of seals and caprocks, providing context on the migration of fluids in the subsurface. This activity was pursued with the regional mapping team (Bittersweet), the team working on the SW CO2-EOR Initiative, and continued collaboration with the USGS and their activity – resource assessment of the Anadarko Basin. The work is described below in the regional mapping since the work has broader ramifications for the regional mapping.

Task 19. Integrate results with larger 17+ county OPAS project

1) Validate structural, stratigraphic, and well based analysis using regional 3D seismic, gravity-magnetics, and remote sensing

The description here focused on an analysis of the structural timing based on synthesis to date of geologic and geophysical information assembled for the regional study and the evaluation of seismic and well data from the study of Chester and Morrow fields in southwest Kansas.

Overview --

The Anadarko Basin the product of Proterozoic (Precambrian) extension that set up the lithologic and structural framework that we refer to as the basement. The structural extension was contininent wide leading to rifting events and basin creation including the the Oklahoma aulocogen and pull-apart basin (**Figure 15**). Concurent with the activity in Oklahoma, the Midcontinent Rift System was active that led to the development of a deep failed rift basin that bisects the state of Kansas from northeast to southwest.

Predominant orientation of the rifting events is northwest and northeasterly. The rifting occurred along existing crustal weaknesses but also cut across older basement trends recognized in the examination of gravity and magnetic maps coupled with age dating of basement rock obtained from drill cuttings and core. Phanerozoic (Cambrian to Recent) deformation from dominated by compression, a distinct reversal in the stress field of the Proterozoic basement (**Figure 16).** This led to reactivation of older weak structures including the Oklahoma aulocogen forming the Amarillo-Wichita uplift and the Mid-Continent Rift System that led to formation of the Nemaha uplift in Kansas. The Hugoton Embayment was formed as a 10,000 km2 structural extension of the newly formed Anadarko Basin.

The primary tectonic stress originated from the convergence and collision of two tectonic plates forming a mountain chain that extended from the Appalachians, Ouchita, and the Marathon range that borders the southern portion of U.S. Tectonic forces noted as σ_1, major compressional stress vector, was believed to be oriented perpendicular to the axis of plate convergence, radiating away from the mountain front as it meandered through the southern part of the craton. The compressional stress extended northward large distances (100s of miles) leading to both uplift and subsidence (**Figure 16**).

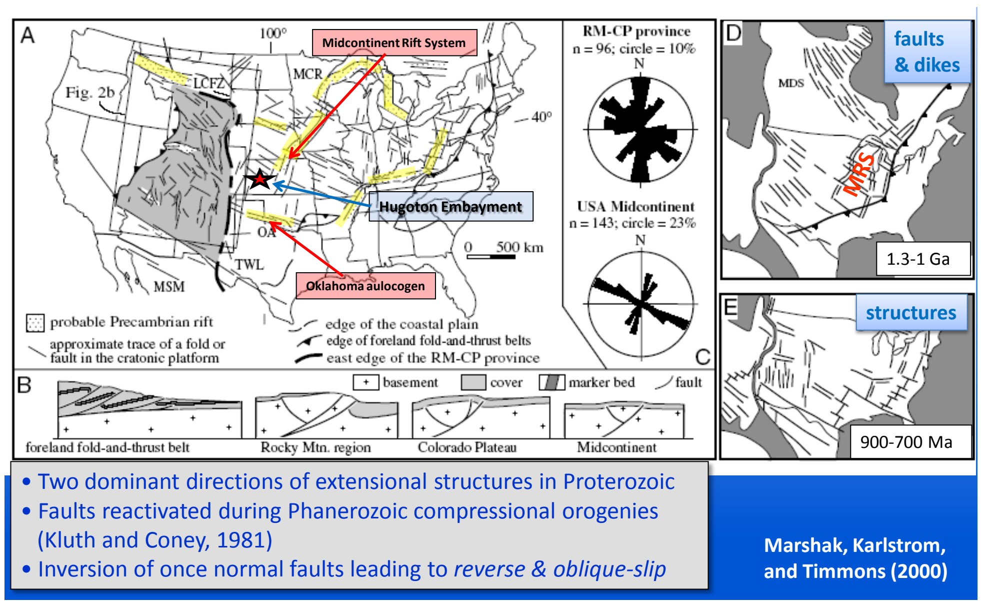


Figure 15. Extensional faults and folds dominate the late Precambrian (Proterozoic) basement of the U.S.

The peak tectonism in the southern Kansas and the Hugoton Embayment region occurred during the lower and middle Pennsylvanian (**Figures 17 and 18**). This is noted by the large sediment accommodation space and clastic sediment infilling of the Anadarko and adjoining Hugoton Embayment. The Atokan Thirteen Finger Limestone consists of a succession of thin dark carbonates and black to dark gray radioactive (elevated gamma ray) shales. This formation is limited to the lower reaches of the Hugoton Embayment and Anadarko Basin and is interpreted as a sediment starved, lower oxygen deposit resulting from a combination of sea level rise and subsidence in these area leading essentially to the drowning of the craton. Areas in the eastern Hugoton Embayment have normal shallow water carbonates, while immediately to the west, the strata are condensed (**Figure 19**). Sedimentary cycles that are deeper water deposits onlap onto the basal

Pennsylvanian unconformity along the higher reaches of the shelf along the western edge of the Central Kansas Uplift (**Figures 19 and 20**).

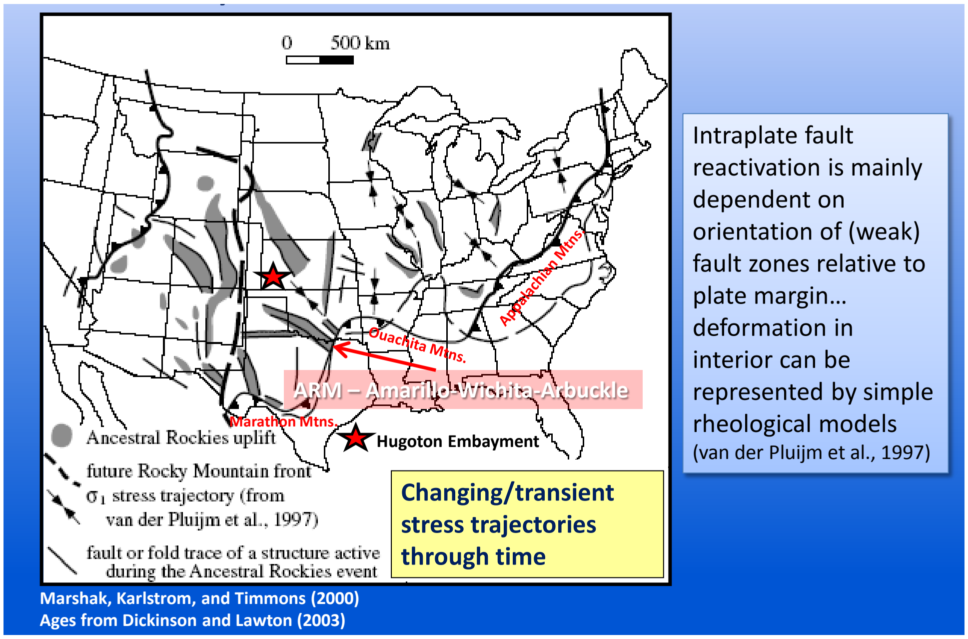


Figure 16. Late Paleozoic tectonism ranged in age from Chesterian to late Leonardian.

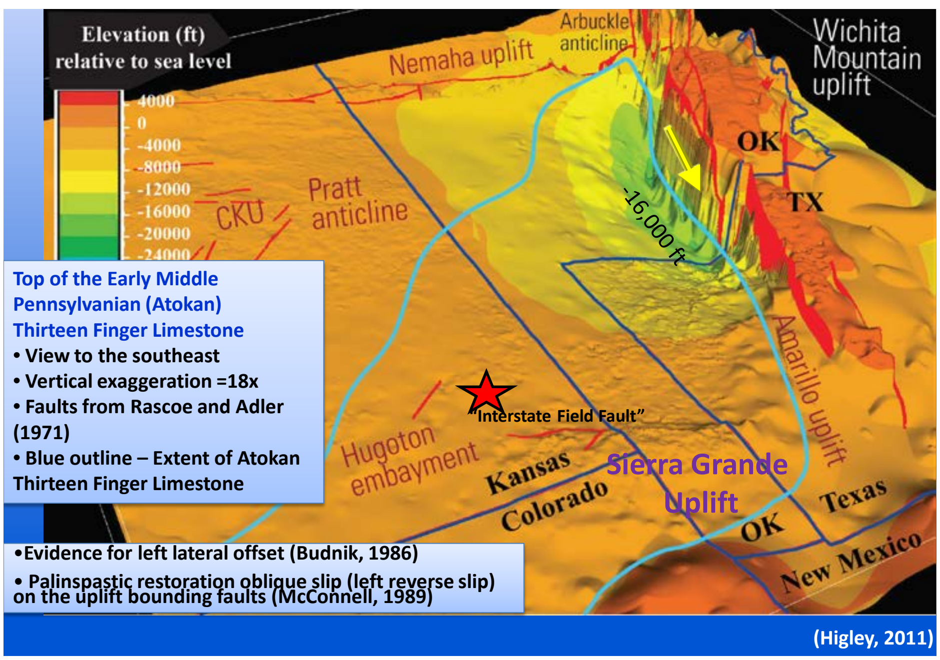


Figure 17. Three dimensional view of the surface on top of the Early Middle Pennsylvanian (Atokan) Thirteen Finger Limestone in southern Kansas and northern Oklahoma.

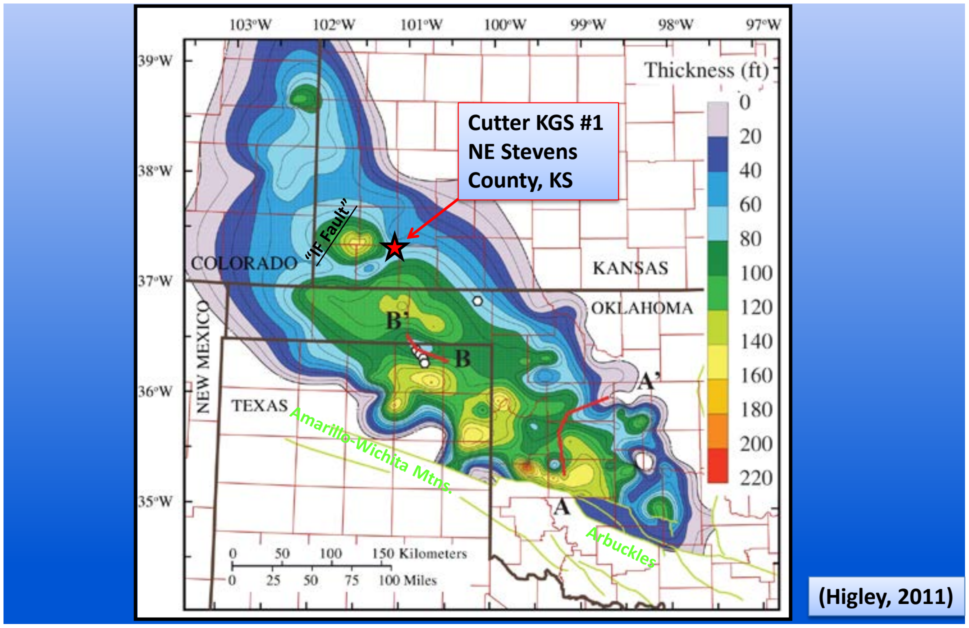


Figure 18. Isopachous map of the Thirteen Finger Limestone in southwest Kansas, Texas panhandle, and western Oklahoma.

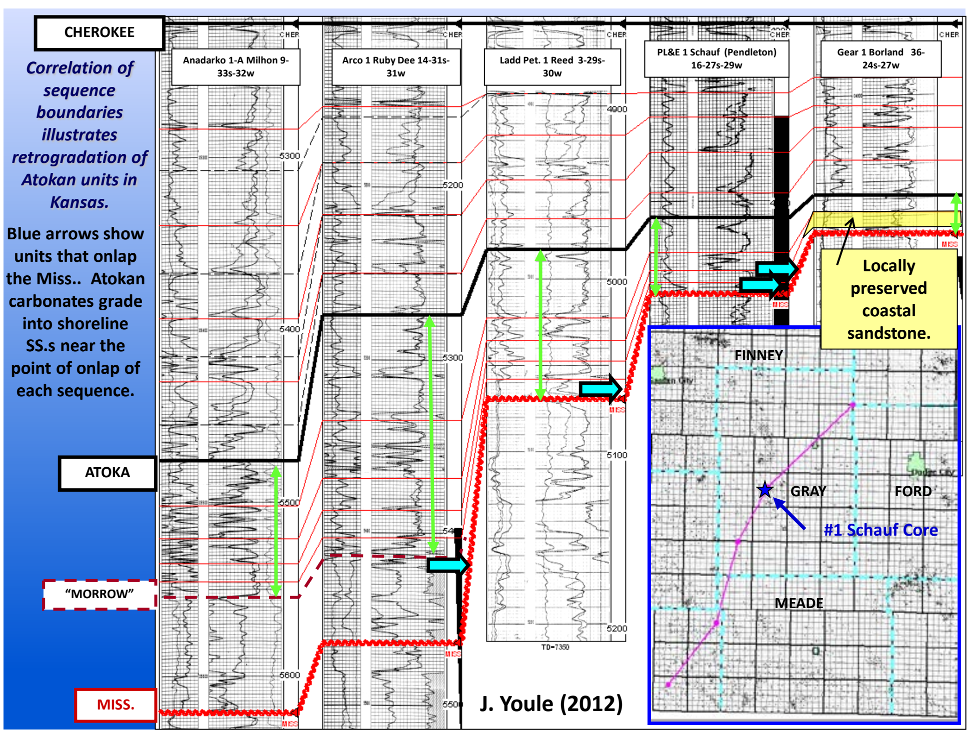


Figure 19. Stratigraphic cross section datum on the top of the middle Pennsylvanian Cherokee Group. Section extends from southwest corner of Kansas toward the northeast along the eastern margin of the Hugoton Embayment.

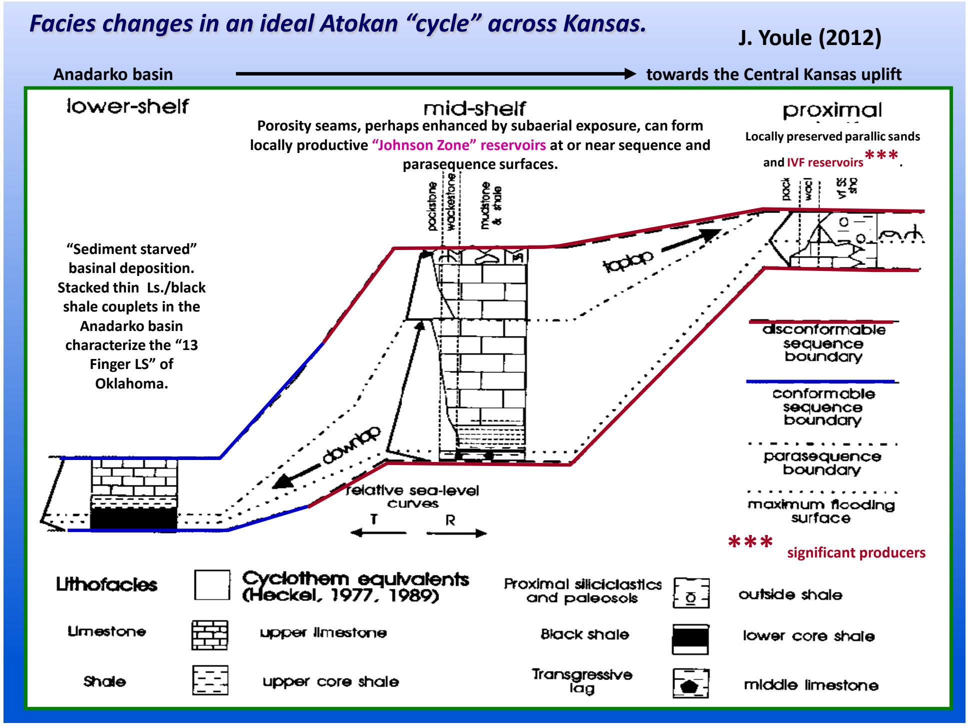


Figure 20. Cycle of sedimentation for the Atokan extending from SW to NE across the Hugton Embayment unto the west flank of the Central Kansas Uplift (Youle, 2012).

Additional work by the USGS Andarko Basin study identifies shale dominated intervals that have anomalously low resisitivity that together with burial history and depositional setting strongly suggest undercompaction and paleopressure extended into southwest Kansas in the Morrowan age strata (**Figure 21**, Nelson and Gianoutos, 2011). This is explained by rapid burial of shale rich strata that did not sufficiently dewater due the limited permeability.

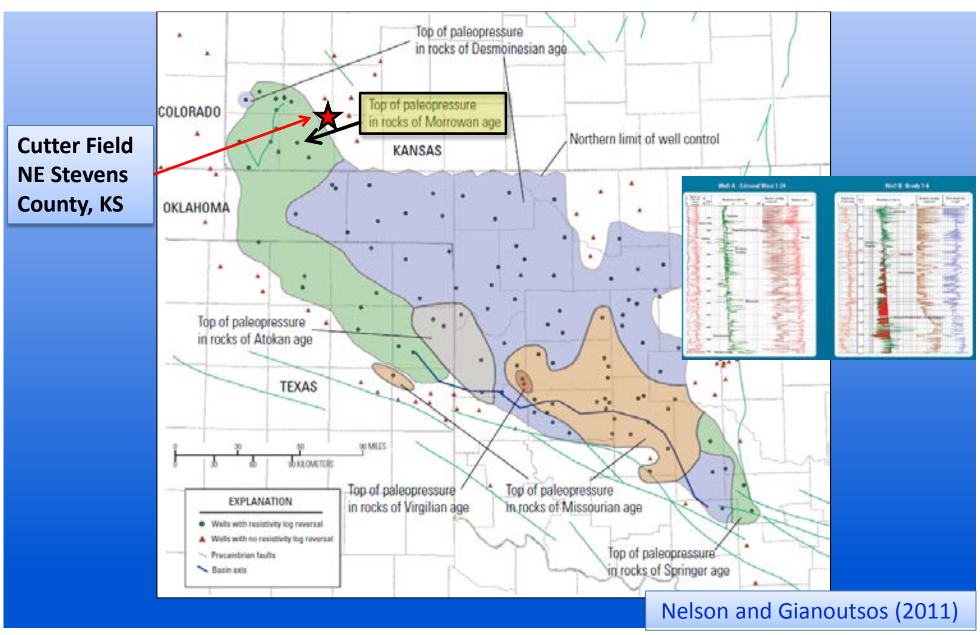


Figure 21. Map of paleopore pressure in the Anadarko basin and southern reaches of the Hugoton Embayment.

The Hugoton Embayment was clearly structurally active during the Morrow and Atokan time and the strata distribution and composition reflect the rapid subsidence of this area. The series of oil fields being examined in southwest Kansas are located in the south-central part of the Hugoton Embayment with reservoirs including the Chester age incised valley fill sandstone in Pleasant Prairie, Eubank, and Shuck fields, and the Upper Morrow fluvial-dominated channel sandstone at Cutter Field. The location of the fields in a map of the magnetic field intensity and the contours of the top of the Precambrian shows the relationship of the fields in relationship to large magnetic lineaments, several delimited in the map (**Figure 22**). The primary trend of the lineaments is northeast and northwest trending. However, it is not clear at this scale and of map what controls the location of the fields other than the location of the incised valley system of the Chester.

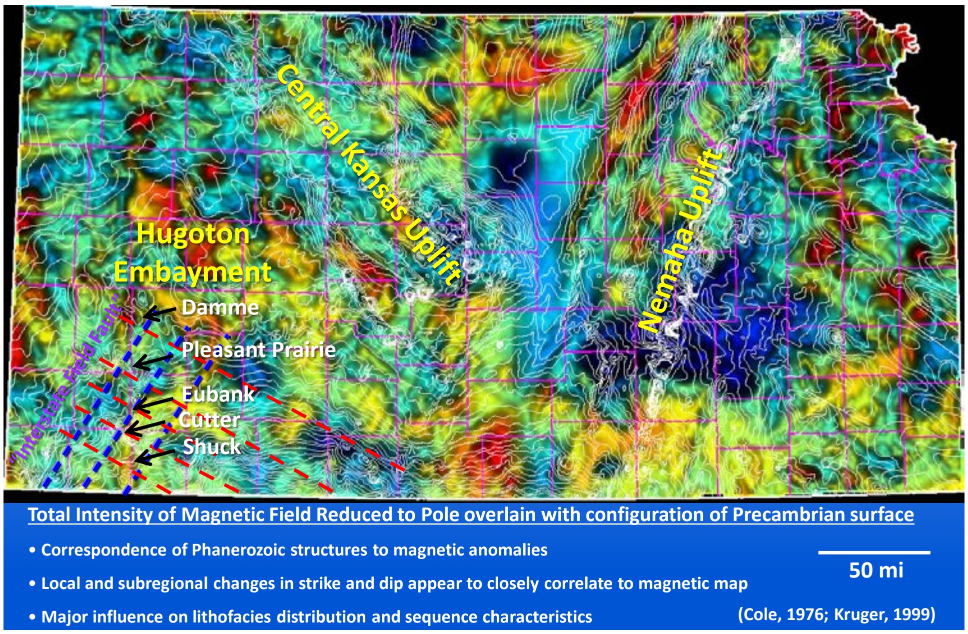


Figure 22. Total magnetic field reduced to pole overlain by the configuration of the Precambrian surface.

The geophysical limits of the Proterozoic Mid-continent Rift System were interpreted by Kruger (1997) who noted that the western boundary extended into the Hugoton Embayment and eastward to encompass the entire DOE study area in southern Kansas (**Figure 23**). The key deep well control used in the mapping of the Arbuckle used in the carbon storage assessment penetrated 600 ft of coarse grained arkosic strata in Seward County, the location of Shuck Field. This could be an isolated outlier, but in general the rift south of the terrane boundary that it crosses in central Kansas is only locally distinguished with arkosic sediment and is primarily represented by structural lineaments or more deep seated material such as magnetic bearing granite and basic igneous intrusives.

Further indications of the northeast and northwest trending lineaments is demonstrated again with a magnetic map, but this time total magnetic reduced to pole with a 2-10 mile filter to emphasize higher frequency events. This map is overlain with a tilt angle processed magnetics emphasizing local contrasts in magnetic intensity (**Figure 24**).

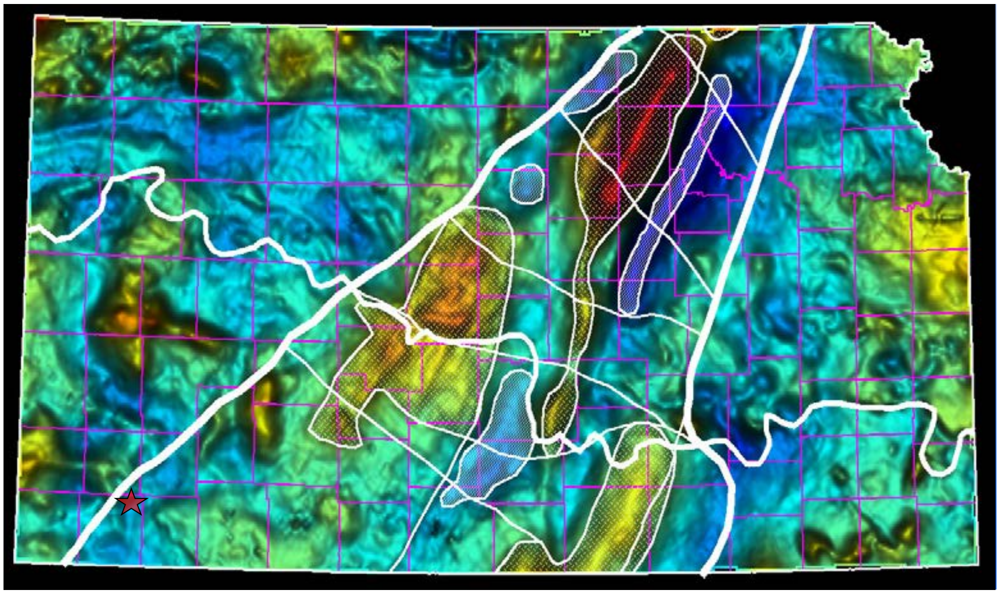


Figure 23. Gravity map of Kansas overlain with outlines of the Mid-continent rift system (northeast trending), which cross cuts the older Proterozoic accretionary terrane that trends northwesterly, cutting diagonally through the state.

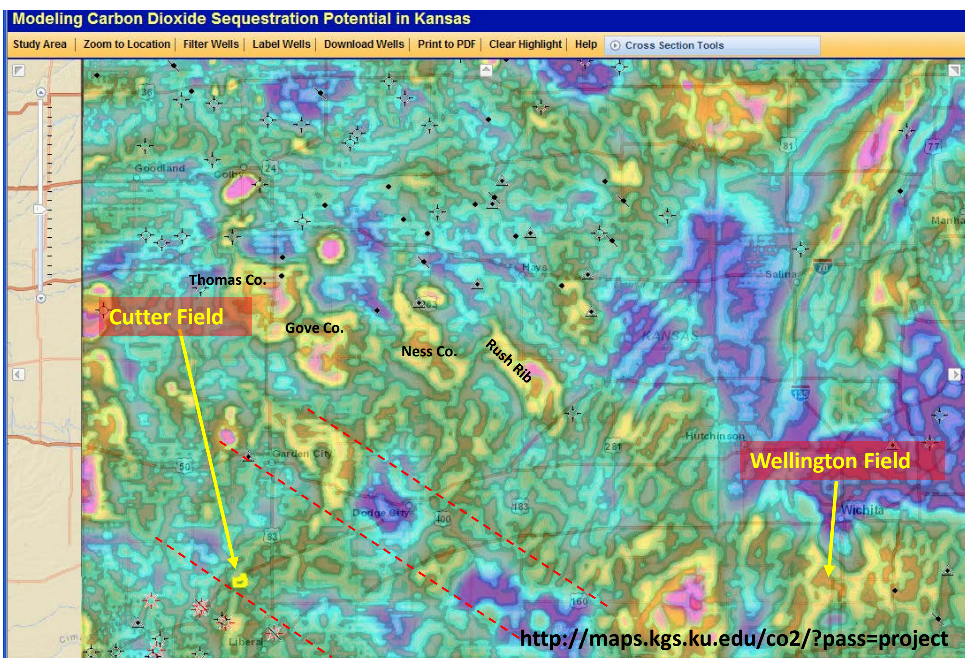


Figure 24.Total magnetic field intensity, reduced to pole (910 m) with 2-10 mile filter overlain with tilt angle emphasizing contrasts in the magnetic intensity. Area is western 2/3rd of Kansas.

The top of Chester Isopach map in southwestern Kansas provides a set of lineaments that are used in subsequent maps, used to outline the major structural fabric. In the case of the Chester Isopach, the south sides of the lineaments abruptly thicken compared to the north sides (**Figure 25**). The Chester is thickest in the southeast edge of the map along the Kansas-Oklahoma border.

The fields being studies with the exception of Damme are identified. The each field is associated with a structural high located near the junction of one or more of the lineaments. The Chester incised valley system trends more than 100 miles from north to south and is incised along the east side of each of these structures. Yet, the incised valley cuts through significant portions of the uplift suggesting that the valley formed prior to the uplift. Also, the Chester valley is incised at an angle to the lineaments but drains down the axis of the thickest Chester, which thickens abruptly across the lineaments. This suggests that the structure responsible for the thickening pattern of the Chester and the initial incision of the valley were subtle compared to the main tectonic activity that was to follow.

The current day structure on the top of the Mermec Mississippian is the erosional surface into which the Chester valley is incised (**Figure 26**). The northeast and northwest lineaments carried over from the Chester Isopach in **Figure 25** are included. Interestingly, the locations of abrupt changes in the structure map correspond to segments of the previously defined lineaments and are similarly oriented both northeasterly and northwesterly. Each of the oil fields corresponds with a domal uplift with a structurally steep or faulted west-southwest flank and a more gentle downwarped on the east side. Seismic evidence shown later confirms the faulting and the dome being a horst feature.

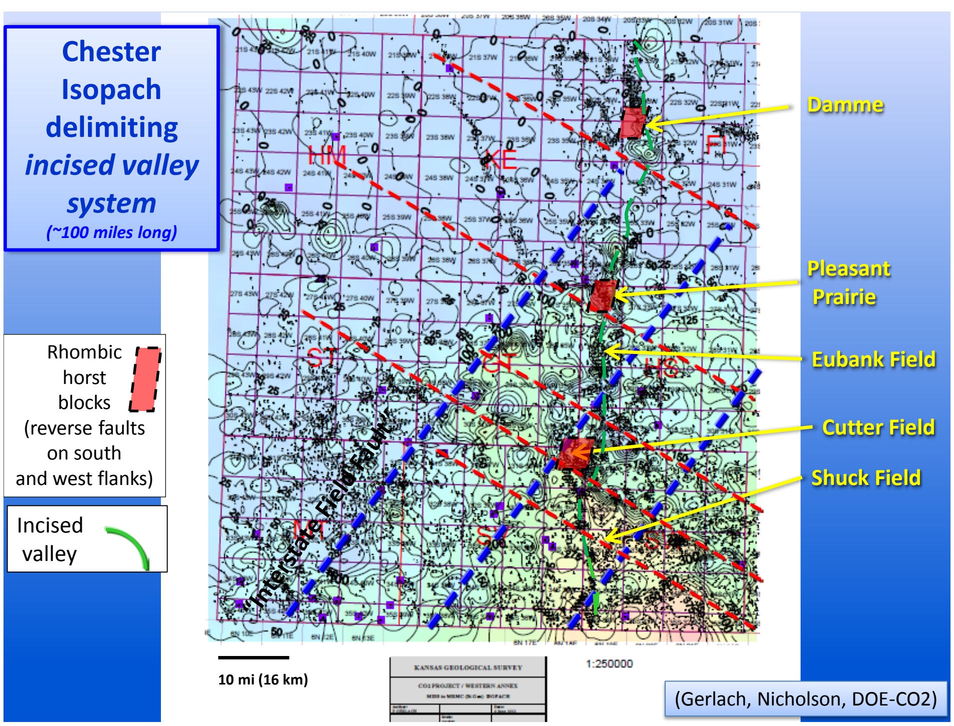


Figure 25. Isopachous map of the Chester strata.

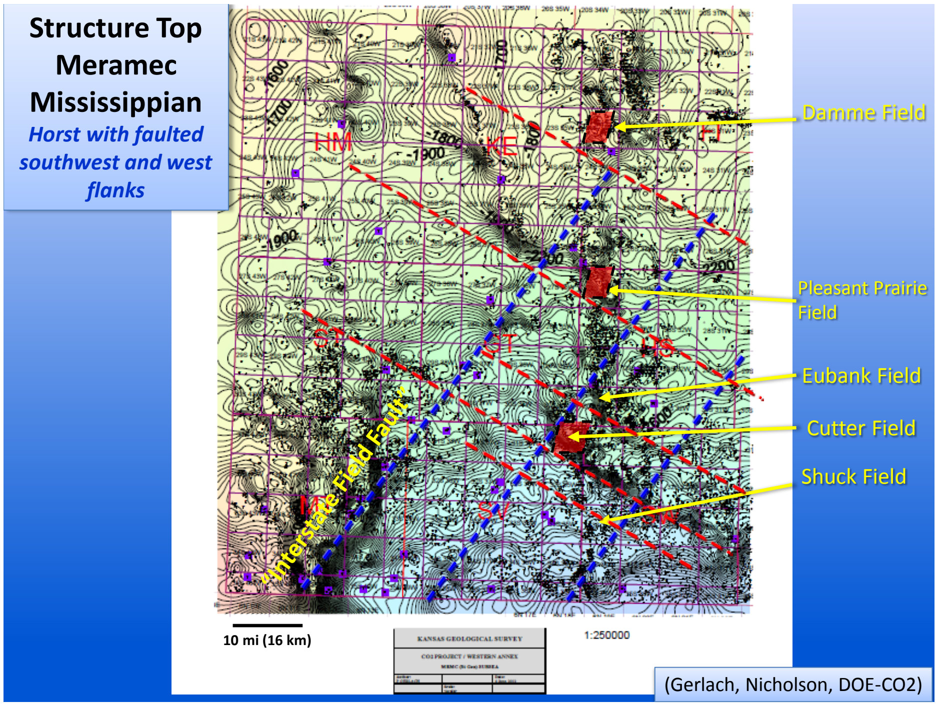


Figure 26. Stucture map, Top Meramec Mississippian.

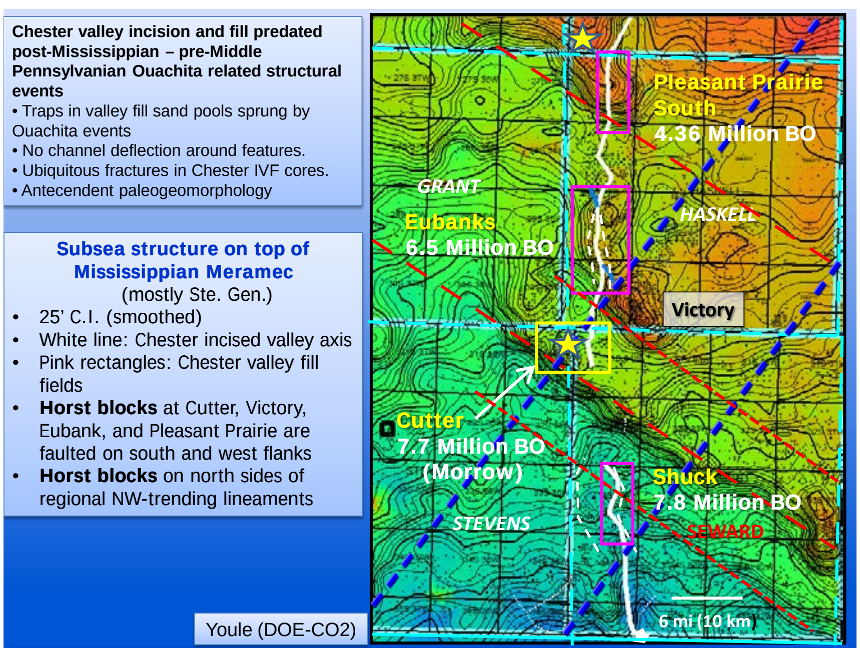


Figure 27. Structure map top of the Meramec Missisippian with Chester and Morrow producing fields that are being studied. Cutter Field with new well and core is highlighted.

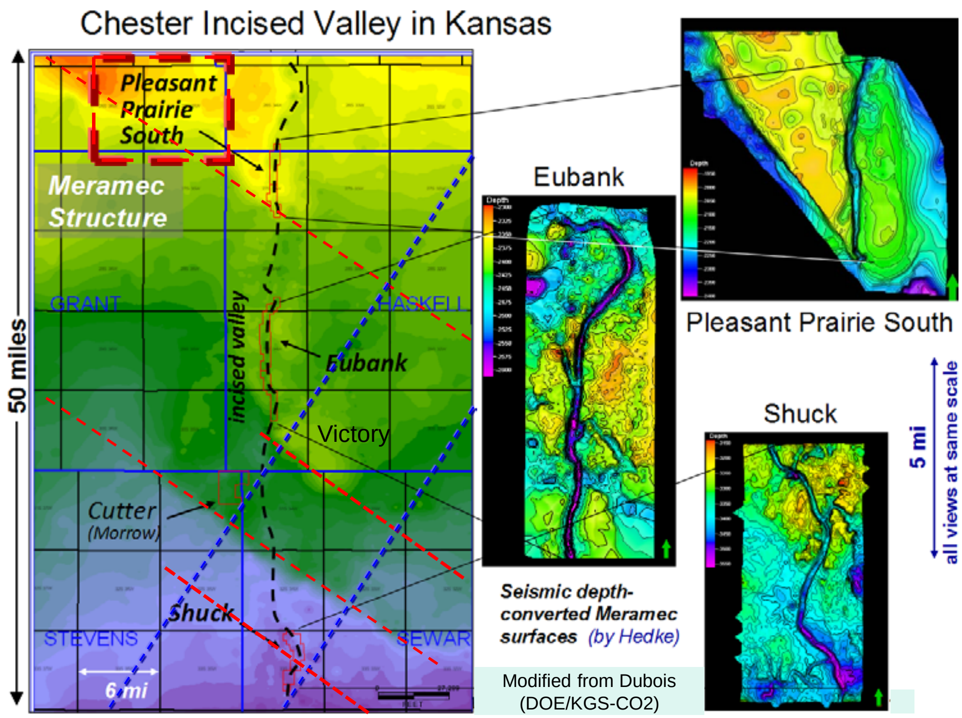
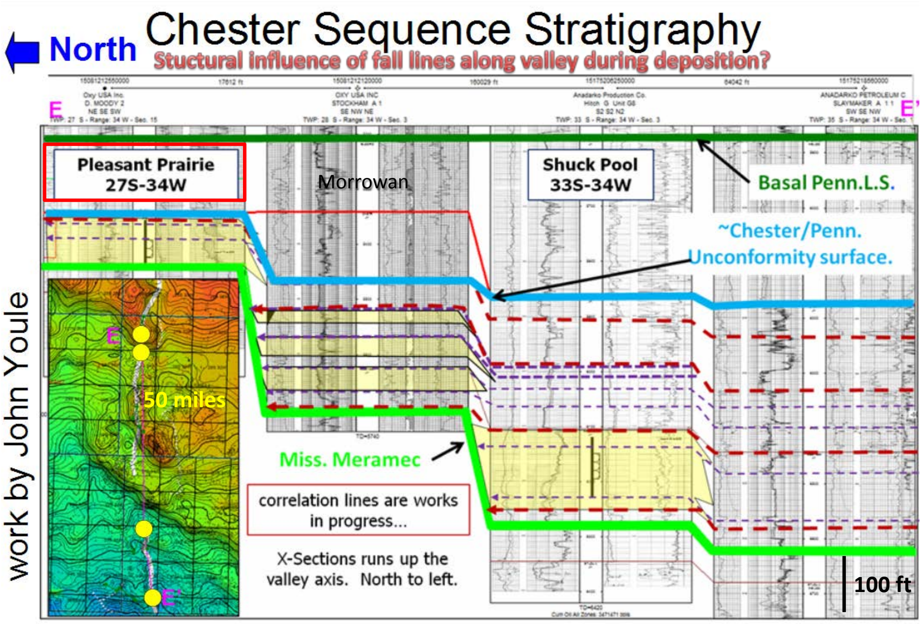


Figure 28. Stucture top of Meramec (left) with regional lineaments and location of Chester and Morrow fields being studied. Seismic time sufaces on the top of Meramec horizon at each field on the right reveal that the incised valley cross cuts the local domal/horst structures.

The importance of the regional lineaments in defining structure and location of these major oil fields is further exemplified in **Figures 27 and 28**. Victory Field of to the east of the Chester incised valley is a nother major oil field in a domal structure that is clearly influenced by the location of the regional lineaments. Multiple stacked oil pays characterize this field on one of the more prominent structures in the area. Figure 28 also provides seismic evidence that the incised valley cuts across the series of domal/horst blocks that define these fields indicating the timing of the major deformation occurred post Chester.



The cyclic retrogradational nature of Chester shoreline advances into Kansas are interpreted to have filled incised valleys with a series of 'back-stepping' stacked estuarine sandstone reservoirs. Red dashed lines are postulated sequence boundaries, and purple lines are possible parasequences. *(Youle)*

Figure 29. Regional north to south stratigraphic cross section in the Chester incised valley hung on a datum at the base of Atokan. Cross section illustrating step-wise stratigraphic thickening and addition of temporally distinct stratal packages that J. Youle refers to as parasequences.

The isopach of the Chester age strata showed the abrupt changes in thickness across each of the regional lineaments (**Figure 25)**. **Figure 29** documents the nature of the internal changes that correspond to the abrupt southward thickening that include 1) progressive, step-wise onlap and thinning of parasequences to the north and 2) varied sandstone stacking patterns that comprise the temporally distinct and time-transgressive nature of a relative sea level rise. The latter inferred rise in sea level led to progressive filling of the incised valley. The link to the regional lineaments indicates that differential subsidence occurred across them that contributed an important part to the increase in sediment accommodation through the Chester succession that filled the incised valley. Also of note is the stepwise increase in the thickness of the Morrow strata to the south paralleling the thickness increases of the Chester (**Figure 29**).

A seismic 3D volume donated for Pleasant Prairie Field provides detail of the domal structure (**Figure 30**). The field located on the map in **Figure 28** is a domal feature that with the 3D seismic reveals complex en echelon faulting, down to the west. Several of the faults are high angle reverse. Accompanying the faulting is apparent thickening of the lower Paleozoic strata on the downthrown side. This is not simple truncation of the strata at the base of the Pennsylvanian since the thickening is progressive in the Arbuckle stratat and post-Arbuckle, pre-Pennsylvanian intervals. This suggests that the structure had a extended history of development during the pre-Pennsylvanian.

The east side of the structure is bounded by a more gentle eastward dip, but the seismic reveals a deep-seated high angle fracture set that lies beneath the location of the Chester incised valley (**Figure 30**). Thus, the fractures may dicate the location of the valley and its linear tract across the structural uplift at Pleasant Prairie Field

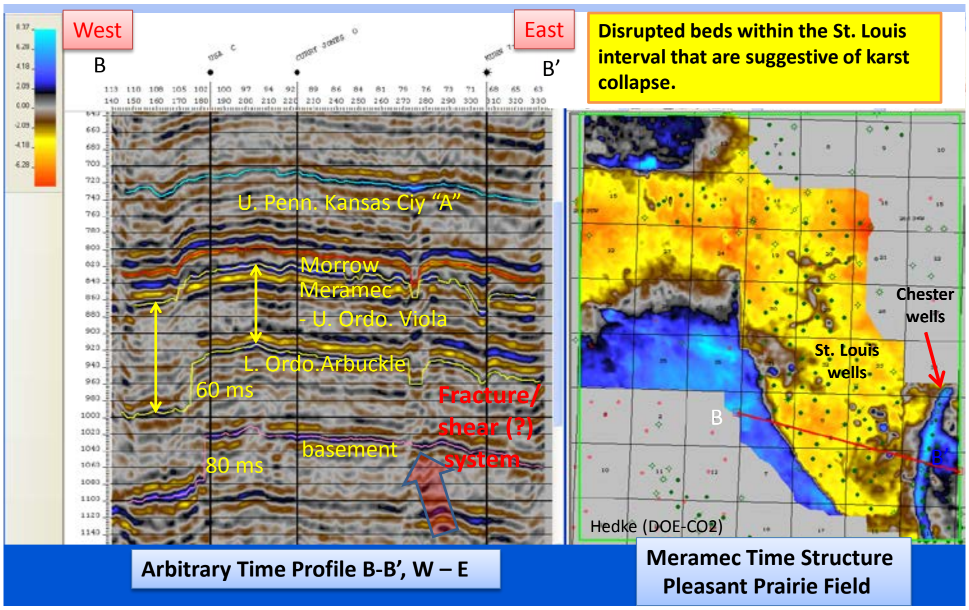


Figure 30. Arbitrary time section and Meramec time structure at Pleasant Prairie Field.

Another seismic profile, this time oriented southwest to northeast crosses the western flank of Pleasant Praire Field, reveals radiating high angle, down to the west-oriented faults (**Figure 32**). The faults are interpreted as a flower structure that is diagnostic of strike-slip faulting (**Figure 33**). While the lateral offset has not been documented, a right-lateral strain is strongly suggested. Accompanying the shear at this location is the shift in the spatial trend of the fault system, making a leftward jog general northward trend of the fault where it crosses the regional northwest trending lineament (**Figure 26**). This offset has the structure form of what is called a restaining bend (**Figure 33**), suggesting translation of the fault along a preexisting weakness (the lineament) leading to localized strain buildup. A horst uplift is a result along with tensional forces along the east side of the block that may be responsible for the fracture set along which the course of the incised valley developed.

The seismic isochron of the interval Morrow to the Proterzoic basement indicates a west-northwest trending lineament is the site of faulting on the west side of Pleasant Prairie while possible karst features extend eastward suggesting that the trend continues as fractures without offset (**Figure 32**).

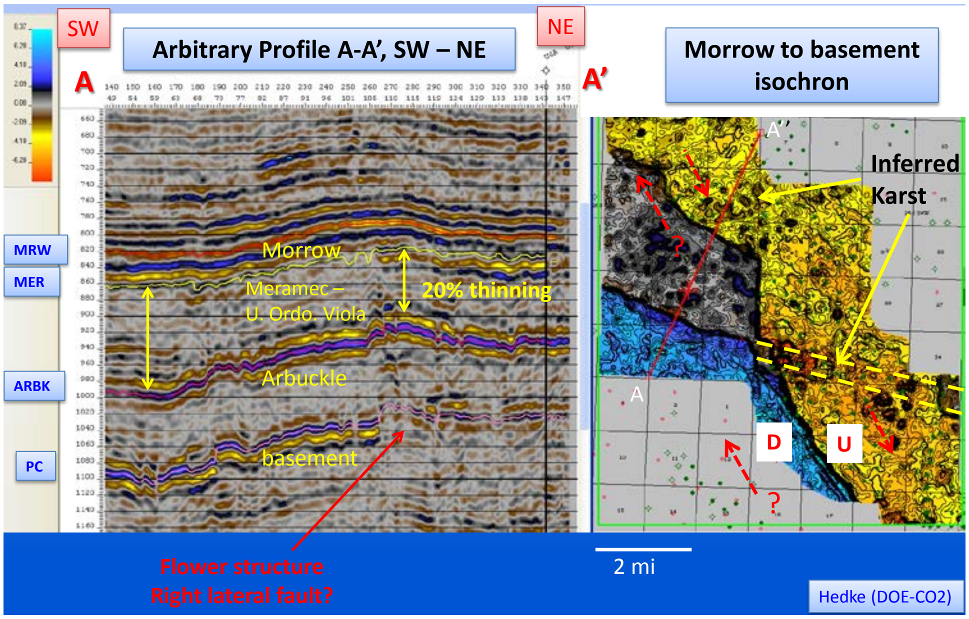


Figure 32. SW to NE arbitrary seismic profile and isochron of the interval from top of Morrow to the Proterozoic basement at Pleasant Prairie Field.

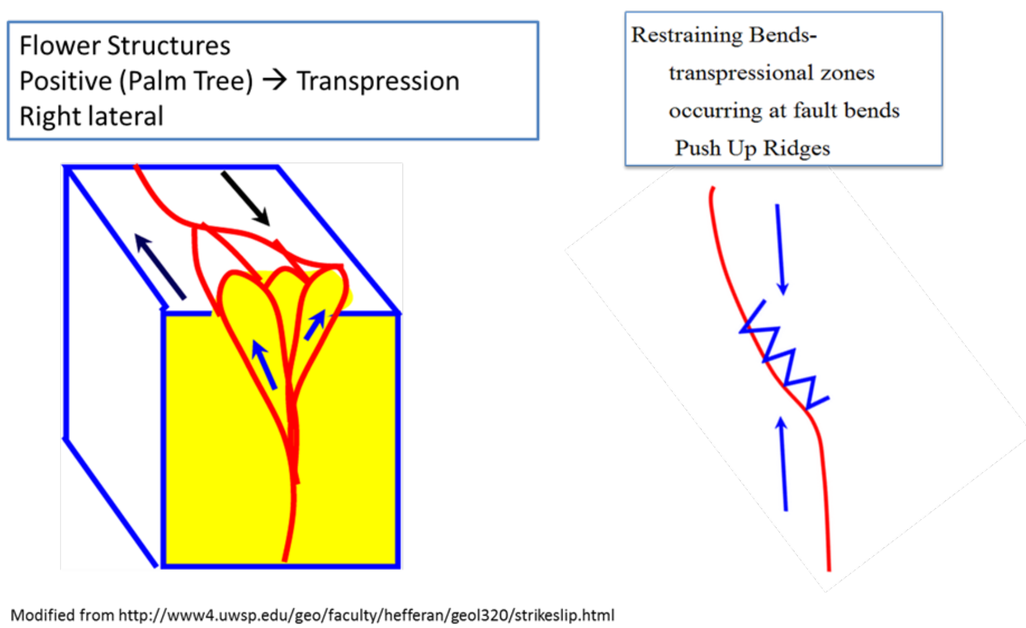


Figure 33. Flower structures and restraining bend are believe key structural components at Pleasant Prairie Field.

The time structure of the Arbuckle on the Pleasant Praire Field indicates that west-northwest trending lineament extends eastward from a fault to a linear trend of karst features developed on the Arbuckle unconformity surface (**Figure 34**). The recognition of apparent structurally influenced karst in the potential carbon storage site is important to understand – 1) is the karsting limited to the Arbuckle or could the karst have extended to shallower horizons if the timing of the collapse is post-Arbuckle?

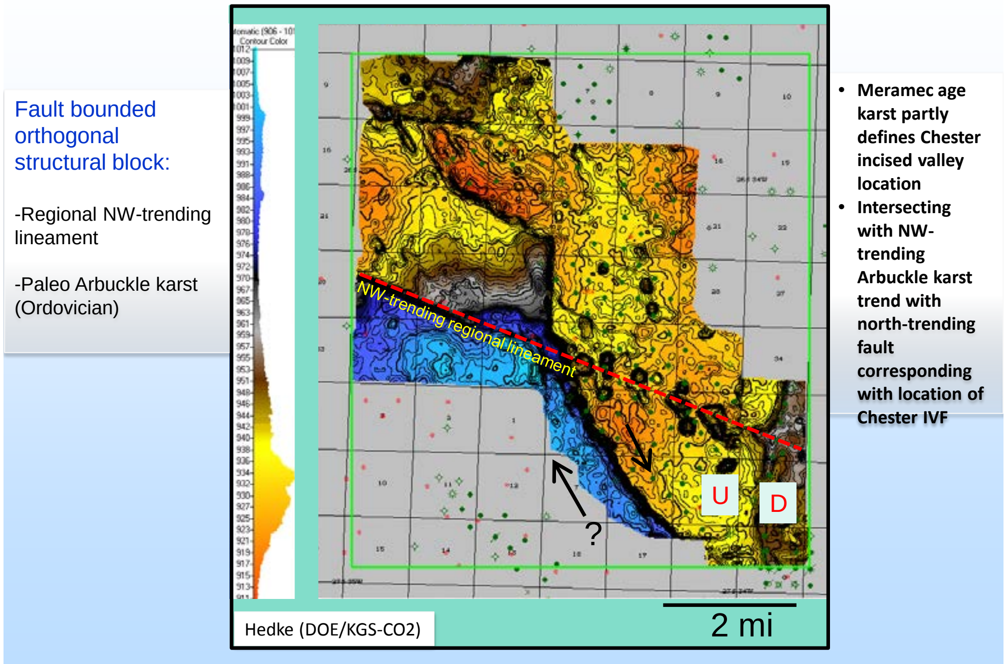


Figure 34. Time structure top of Arbuckle Pleasant Prairie Field.

Moving to Cutter Field, a cross section illustrates the subtle changes across a major bounding fault on the southwest side of the structure (**Figure 35**). The active faulting is post Chester and including contemporaneous movement with the deposition of the Morrow strata. The comparison of the wells in the cross section with a datum of the base of the Permian upper Wellington Formation and the structure cross sections indicates that the large down to the south structure was reactivated during the post-Permian to reverse the sense of this fault. The event may well be the Laramide tectonism of the early Tertiary. The major compressional tectonic event several hundreds of miles to the west apparently led to the reactivatiton of this northwest trending lineament and fault.

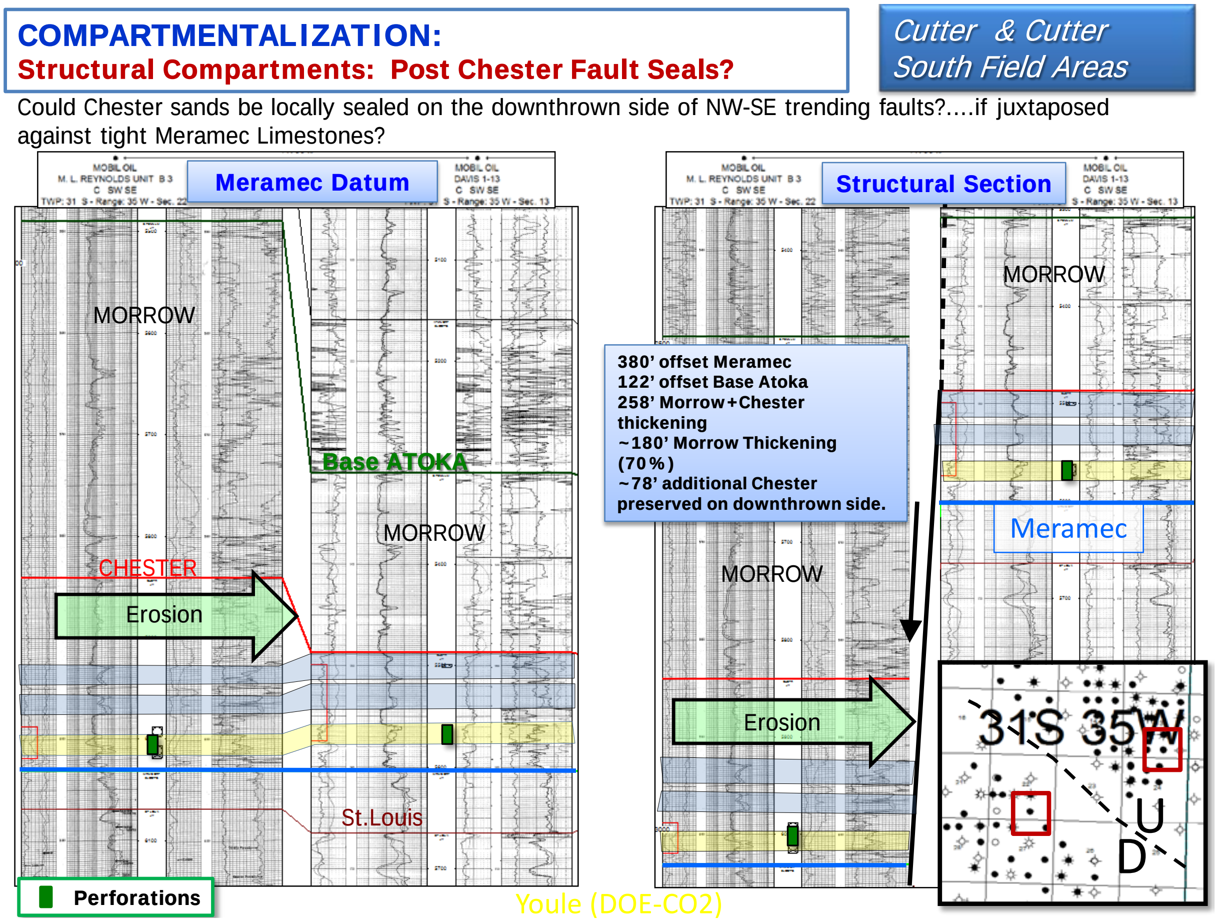


Figure 35. A pair of cross sections with a pair of wells crossing the southeast bounding down to the southwest fault at Cutter Field (Left) Meramec datum showing minor change in sand content and thickness of the Chester, while Morrow has thickness dramatically increases across the fault. (Right) Structural cross section showing offset across the fault with expanded thickness of the Morrow and other changes.

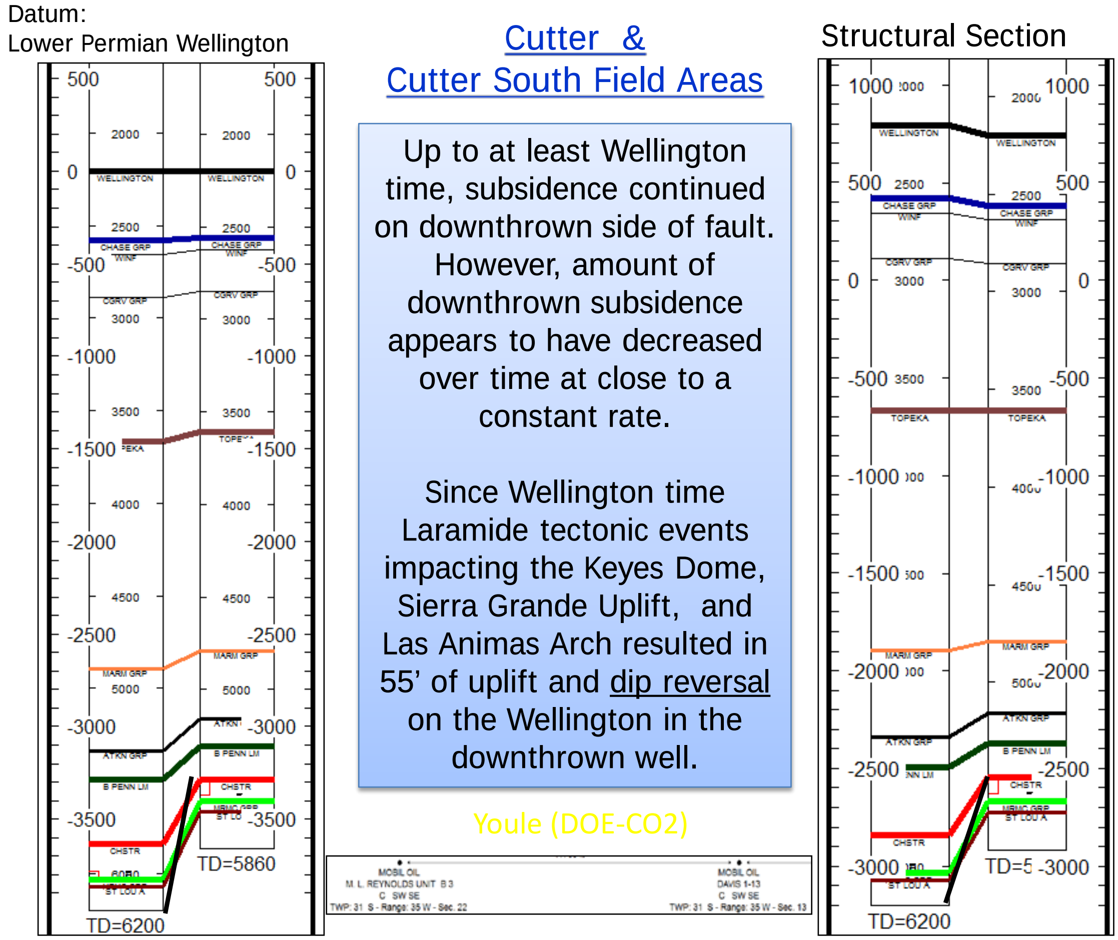


Figure 36. Stratigraphic (datum base of the lower Permian Wellington Fm.) and structural cross sections compared side by side to show the timing of the structure. The wells are the same as those shown in Figure 35.

Shuck Field is the southern most field of this study with a Chester incised valley reservoir that crosses another structural dome formed post Chester time (**Figure 36 and 37**). Shuck Field crosses another northwest trending lineament that affects both the isopach of the Chester and the current structure on top of the Meramec surface into which the Chester valley was incised. The Meramec surface drops abruptly south of dome and the narrow incised valley opens up to become a large estuary bay inferred from the estuarine sediments that fill the valley as described by J. Youle in core (**Figure 38**).

The northwest trending lineament on the south side of Shuck Field corresponds with a fault that is illustrated in **Figure 39**. The stratigraphic datum is the correlable shale called the Notch Flooding Shale that overlies the sandstone reservoir. Note that the sandstone thickens south of the fault by ~30%. This also corresponds with the southward thickening of the Morrow by ~100%. The fault apparently underwent initial movement in the Chester prior to the main tectonic in the Morrow and Atokan. This is supported by previous discussion above.

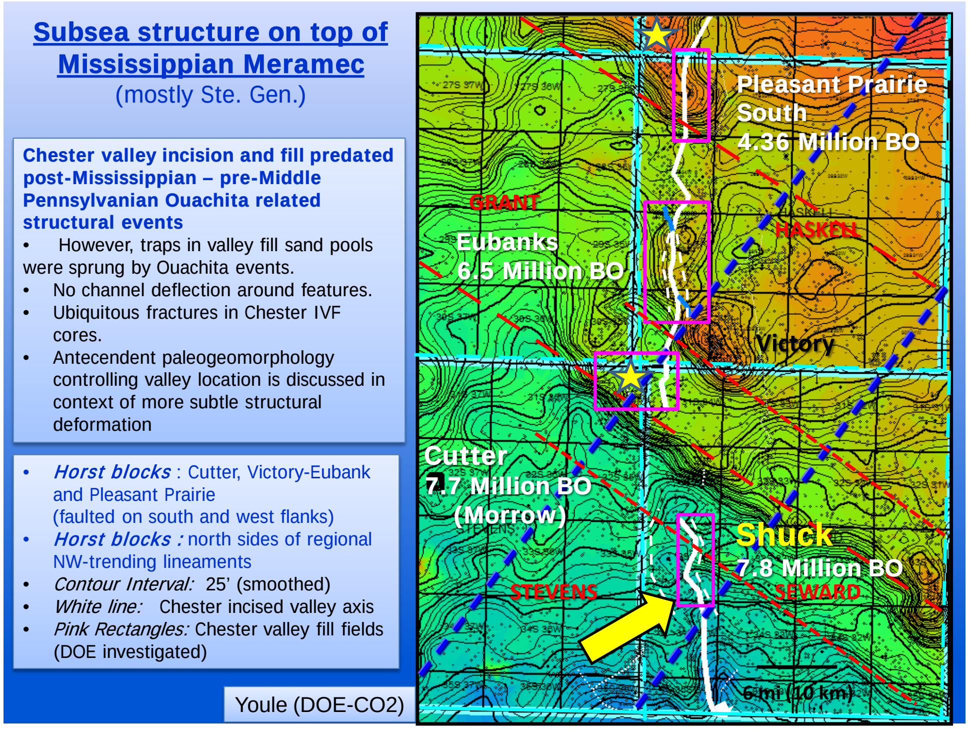


Figure 36. Meramec structure with location of the Shuck Field highlighted.

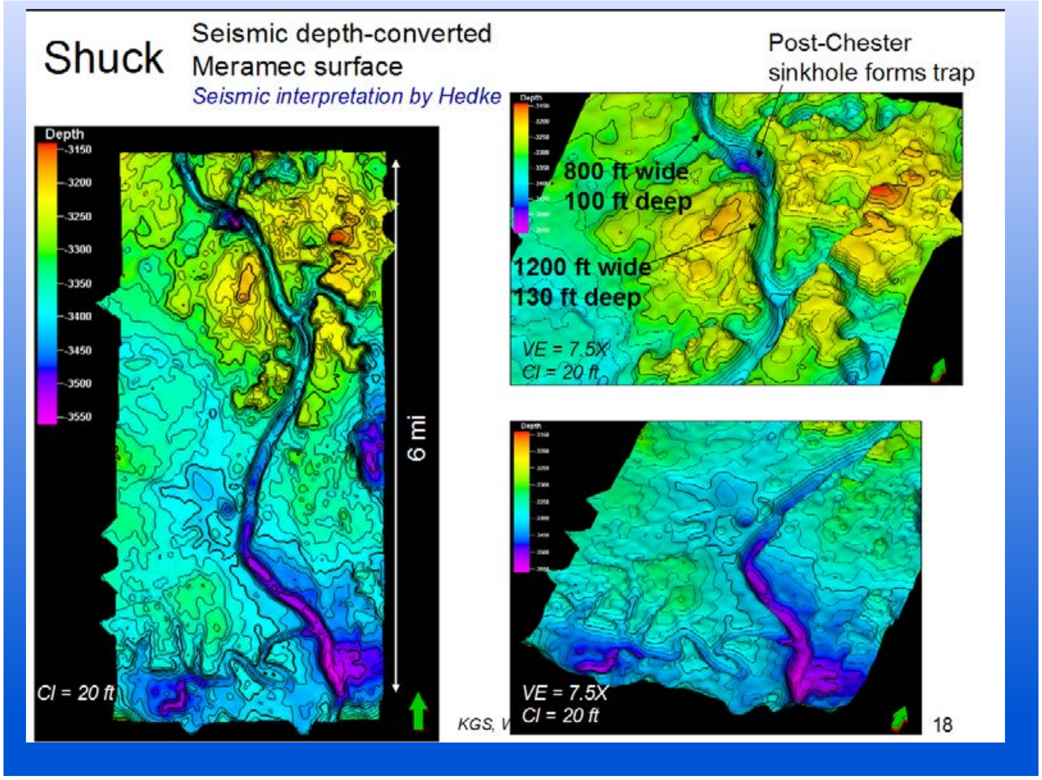


Figure 37. Chester incised valley crossing structure dome of Shuck field. Area south of the dome is structurally quiet on the south side of the regional northwest trending lineament.

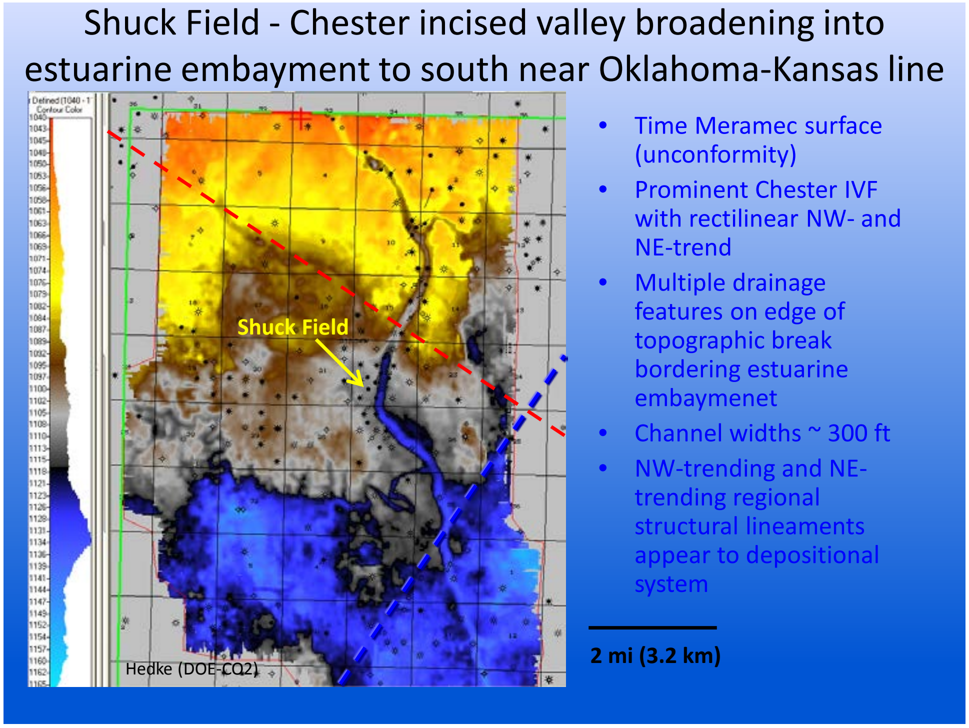


Figure 38. The incised valley opens up to become a large estuary with several drainage systems involved besides the main valley system.

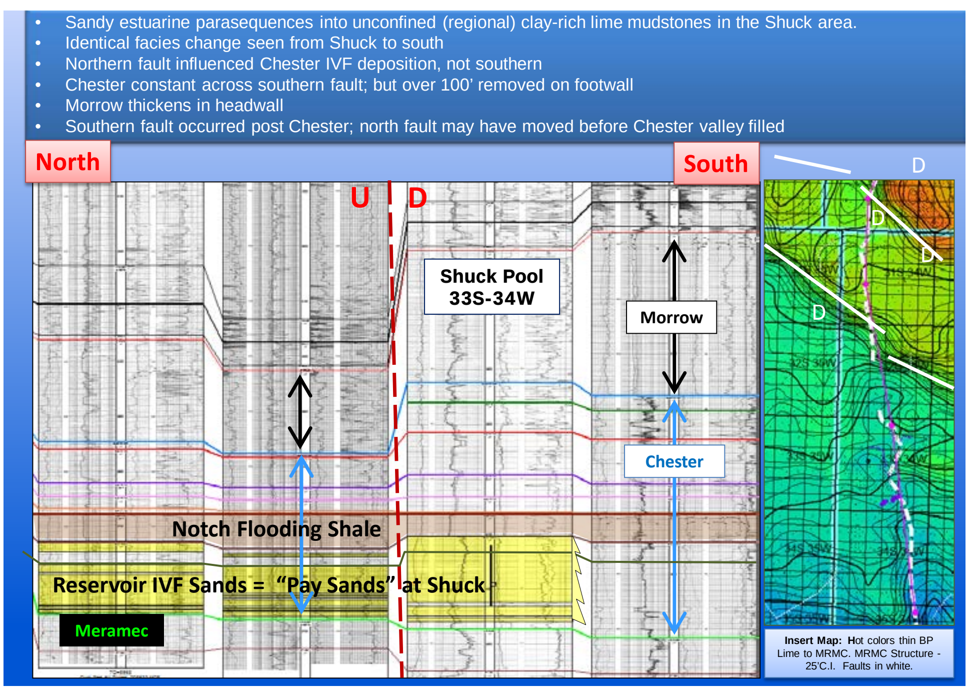


Figure 39. North-south stratigraphic cross section crossing northwest trending down to the south fault at Shuck Field. Datum it top of the Chester age Notch Shale.

The northwest trending fault at Shuck Field is further analyzed in **Figure 40**. As noted previously, the deformation across the fault is minor but does affect the character and thickness of the Chester sandstone reservoir. **Figure 40** (a) also indicates that the incised valley fill estuarine sandstone pinches out south of the fault as it reaches the wide estuarine bay. **Figure 40** (b) datumed on the Atokan shows the notable thickening in the Morrow and Atokan across the fault further supporting the major tectonism during these intervals. **Figure 40** (c) shows 300 ft of offset of the Atokan datum indicated notable post Atokan tectonic movement.

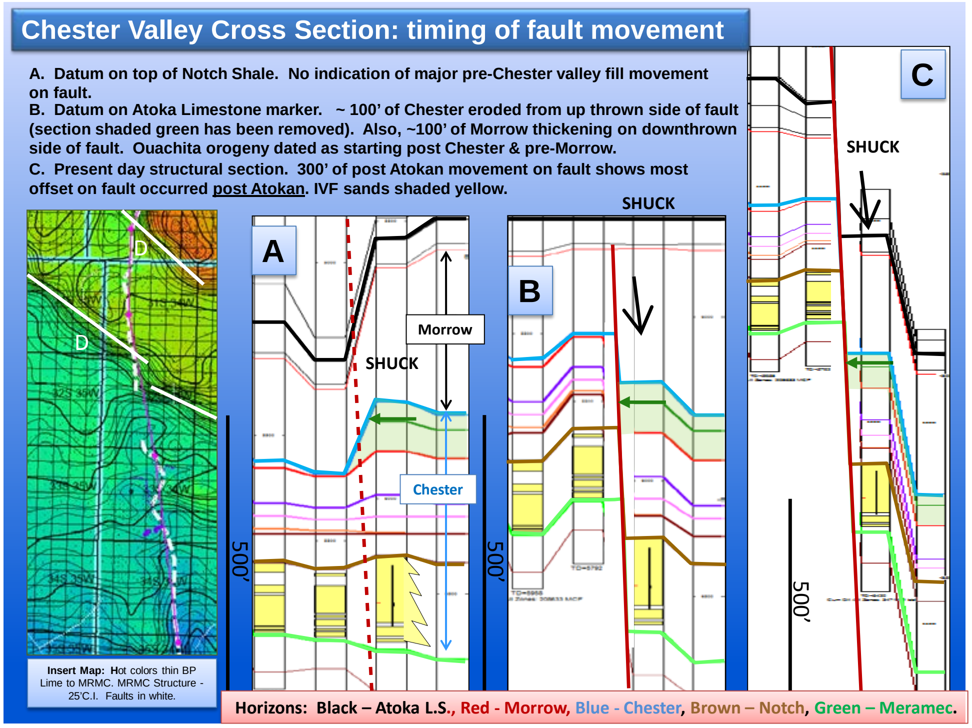


Figure 40. Three north-south cross sections at Shuck Field crossing notable northwest trending fault, (a) datum on the Notch Shale as in Figure 39, (b) datum on the Atokan Limestone, and (c) current day structure.

Seismic that has been examined in this area indicates that the overall deformation above the Atokan diminishing greatly, but is still a factor in the structural configuration and its affect on deoposition. **Figure 41** solidifies this point, showing the Isopach of the lower Permian from the top of the Hutchinson Salt Member to the Neva Limestone in the Council Grove Group. The regional lineaments are again shown and it is clear that the influence on deposition of this much younger interval is sill apparent with stepwise thickening to the southeast. The patterns of thickening have changed, probably as a result of the changing stress field as the Ouachita based tectonism migrated to the Marathon orogeny in south Texas.

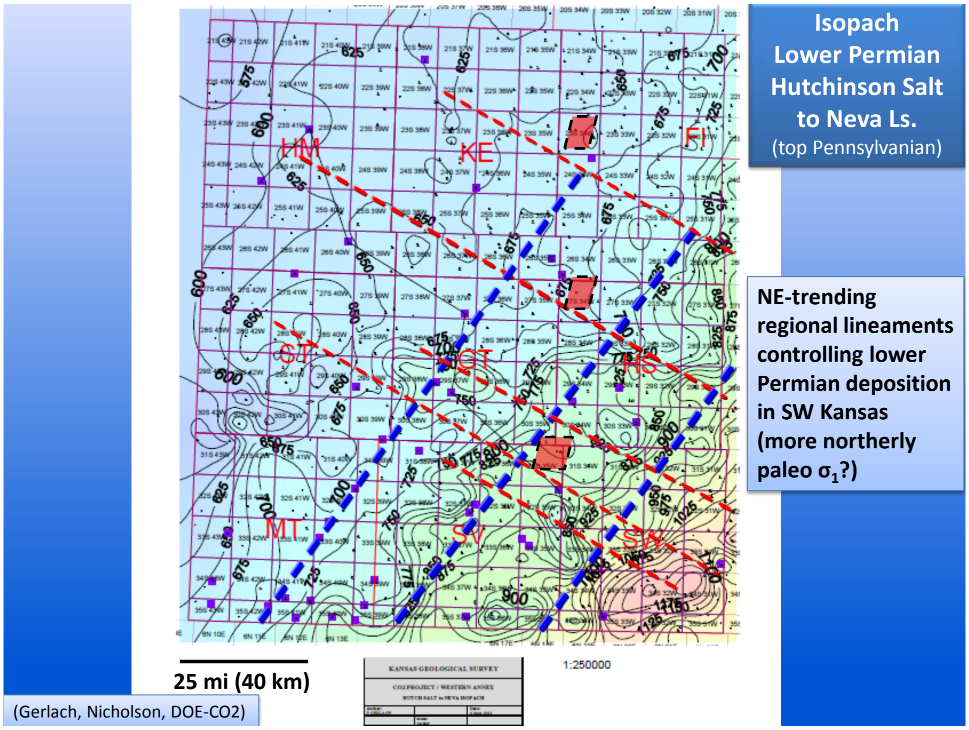


Figure 41. Isopach of the lower Permian Hutchinson salt to Neva Limestone.

The influence of lineaments in much younger deformation is also apparent in the examination of the trends of evaporite dissolution in western Kansas in the area discussed above.The isopach of the halite bearing Blaine Formation reveals a dissolution zone that forms a clear linear northeastern trend (**Figure 42**).The dissolution front also corresponds closely to the location of the western edge of the regionally thick High Plains Aquifer. The edge of the salt dissolution is also is expressed at the surface by a topographic escarpment. The coincidence strongly suggests cause and effect. The dissolution front is also the location of recent sinkholes.

The saturated thickness of the High Plains Aquifer and the thickness of the Blaine Formation closely correspond suggesting that the sediment accommodation for the aquifer originated with the dissolution of the halite (**Figure 43**). The rectilinear distribution on both maps also suggest that structural lineaments influence the processes leading to this development.

Importantly, their have been no indications of contamination of water in the High Plains Aquifer from the communication with brines from the pre-Permian. Rather these is local saltwater intrusion from the dissolution of Permian halite. This suggests that the structural control may be represented from preferred joint patterns that may be opened when stress from such features as post-Laramide uplift in the Rockies were active.

A more detailed view of the Blaine Formation structure shows the linear trends of highly gradient slopes that correspond to underlying salt dissolution.

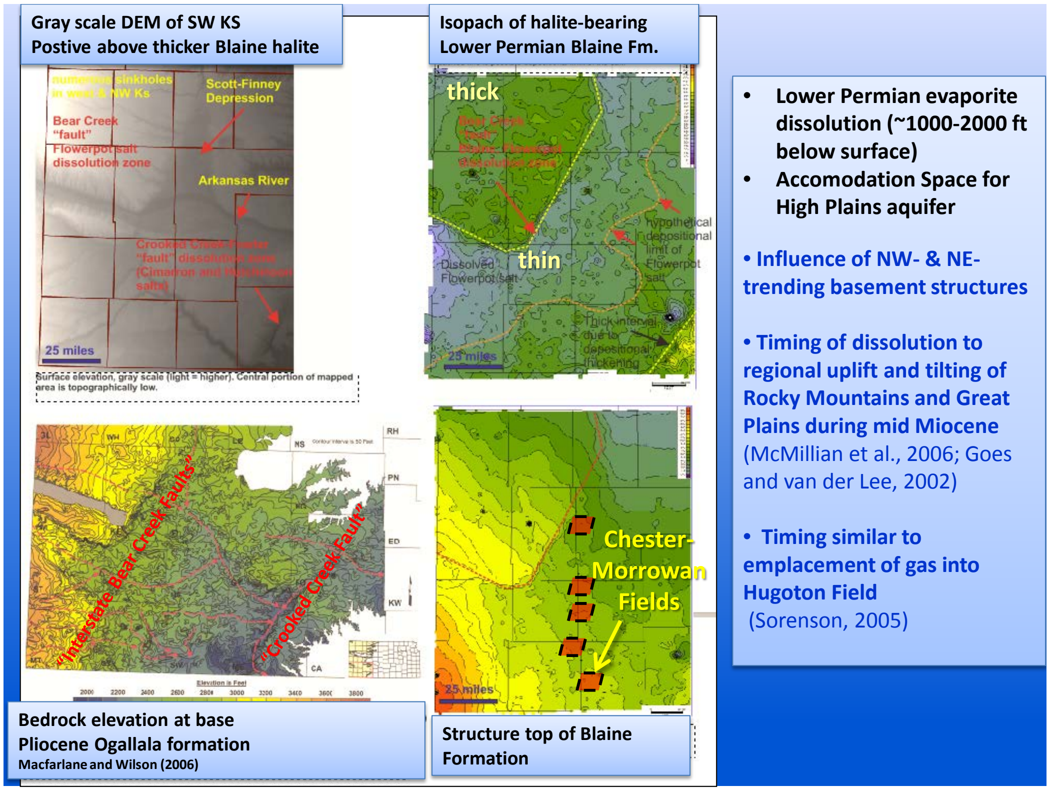


Figure 42. Surface topography (upper left), Isopach of the halite-bearing Blaine Formation (upper right), Bedrock elevation of the High Plains Aquifer (lower left), and structure top of the Blaine Formation (lower right).

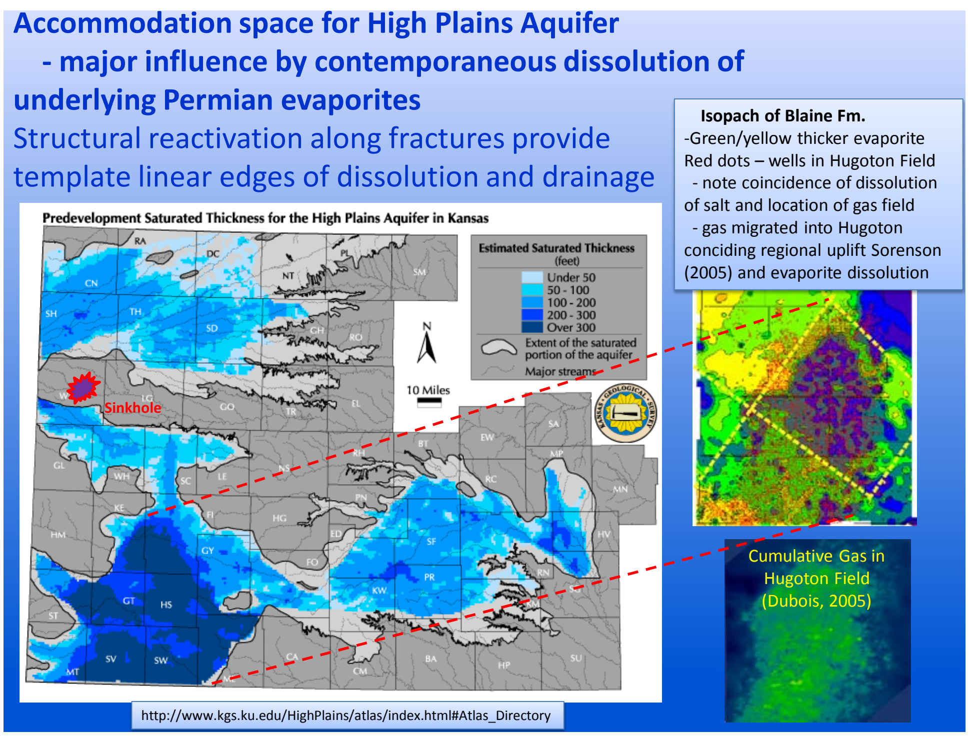


Figure 43. Saturated thickness of the High Plains Aquifer (left) compared to the Isopach of the Blaine Foration (upper right) shows similarity in shape. Lower right is the depiction of the Hugoton Gas Field as cumulative gas production corresponding to the shape and size of the previous maps.

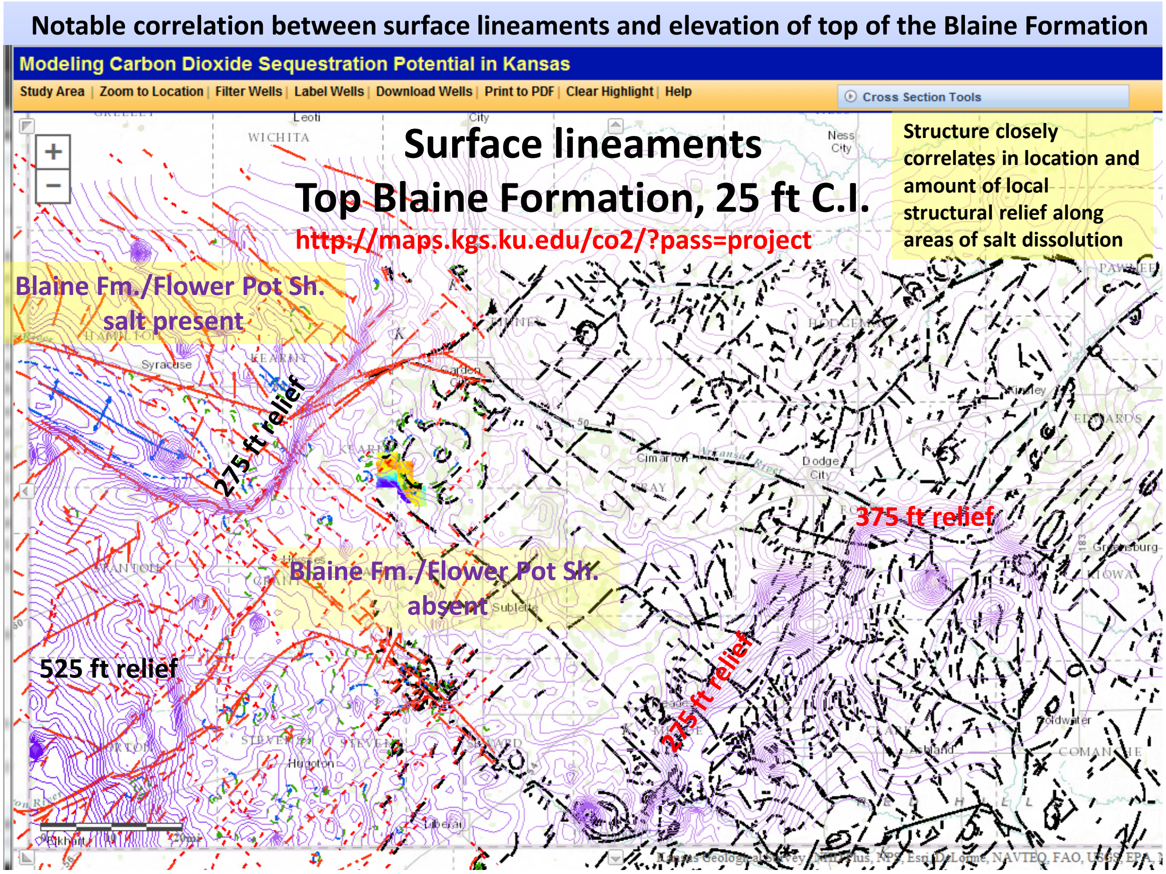


Figure 44. Elevaton on top of the Blaine Formation and identification of the locations of steeper gradients inferred to result from salt dissolution. Area missing salt corresponds to thick High Plains Aquifer. Surface lineaments are also overlain on this map.

Summary

The literature contains considerable evidence for post Laramide structural uplift that affects western Kansas and stream drainages on the high plains (**Figure 45**). Resulting extensional forces related to the uplift may have allowed joints to open and allow percolation of surface waters and contact the halite.

The degree of uplift of the High Plains Aquifer is seen when the attitude (dip azimuth and rate) is compared with the underlying Permian strata. The west to east lithofacies cross section of the High Plains Aquifer along the course of the Cimarron River shows essentially the same dip as the underlying Permian strata including the salt bearing intervals (**Figure 46**). Changes in lithofacies occur in High Plains Aquifer where the underlying underlying Permian section is either faulted or underwent sharp flexture (down to the east along a northeast trending structure). Lithofacies change abruptly from fine grained and clay to more sand rich (upper left of **Figure 46**). This suggests renewed activity along the structural line during deposition of the High Plains Aquifer, but without vertical offset on the deeper seated feature. Finally, similar dip rates of the late Tertiary and Permian suggests that the aquifer is not at depositional dip, but is oversteepened as suggested by some workers (**Figure 45**). The abundance of clay near the western edge of the thick aquifer proximal to the salt dissolution front suggests a local reduction in the depositional gradient at locations where underlying salt underwent dissolution prior to and concurrent with sedimentation.

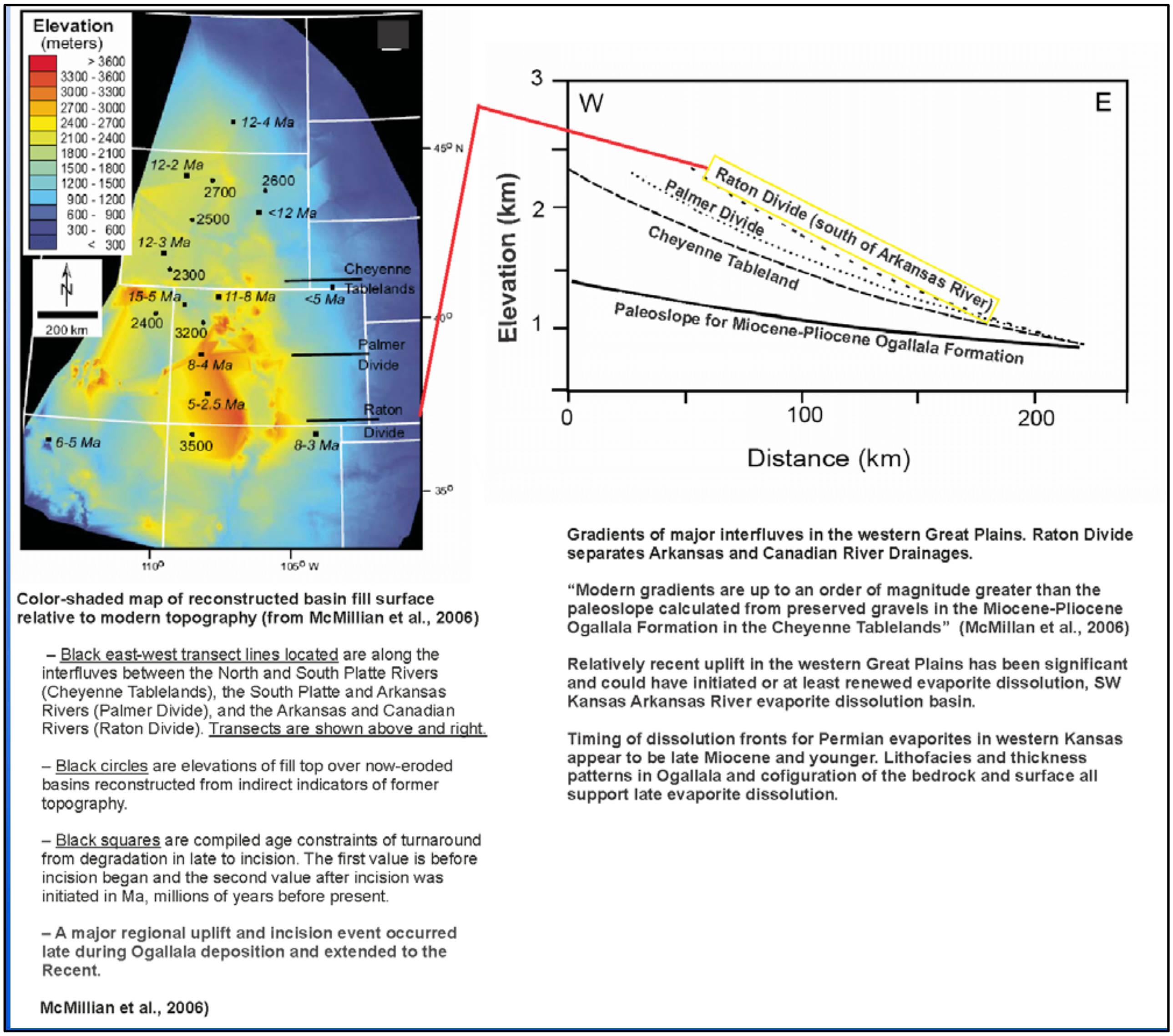


Figure 45. Post Laramide uplift of the central Rocky Mountains has been documented.

A recent sinkhole formed in early August 2013 (**Figure 47**) rekindled interest in this subsidence in this area that has occurred episodically in the historical past. Vestiges of previous sinkholes are clustered in the vicinity of this recent sink (**Figure 48**). It has been surmised by some that that the source of the subsidence is shallow such as karst in the immediately underlying Niobrara Chalk. But, the area is also the site of salt dissolution based on these observations – 1) the immediate area underlain by halite in the Flower Pot Shale where ~220 ft of salt is locally missing (**Figures 50 and 51**); 2) the potentiometric surface of the formation water in the Permian is ~1650 ft below ground level (**Figure 49**) suggesting the potential for meteoroic water to perculate to depths of the salt-bearing strata, and 3) the recent sinkhole and the earlier sinkholes occur along an area of mapped northwesterly thinning of the halite that might be related to a regional lineament system as previously discussed.

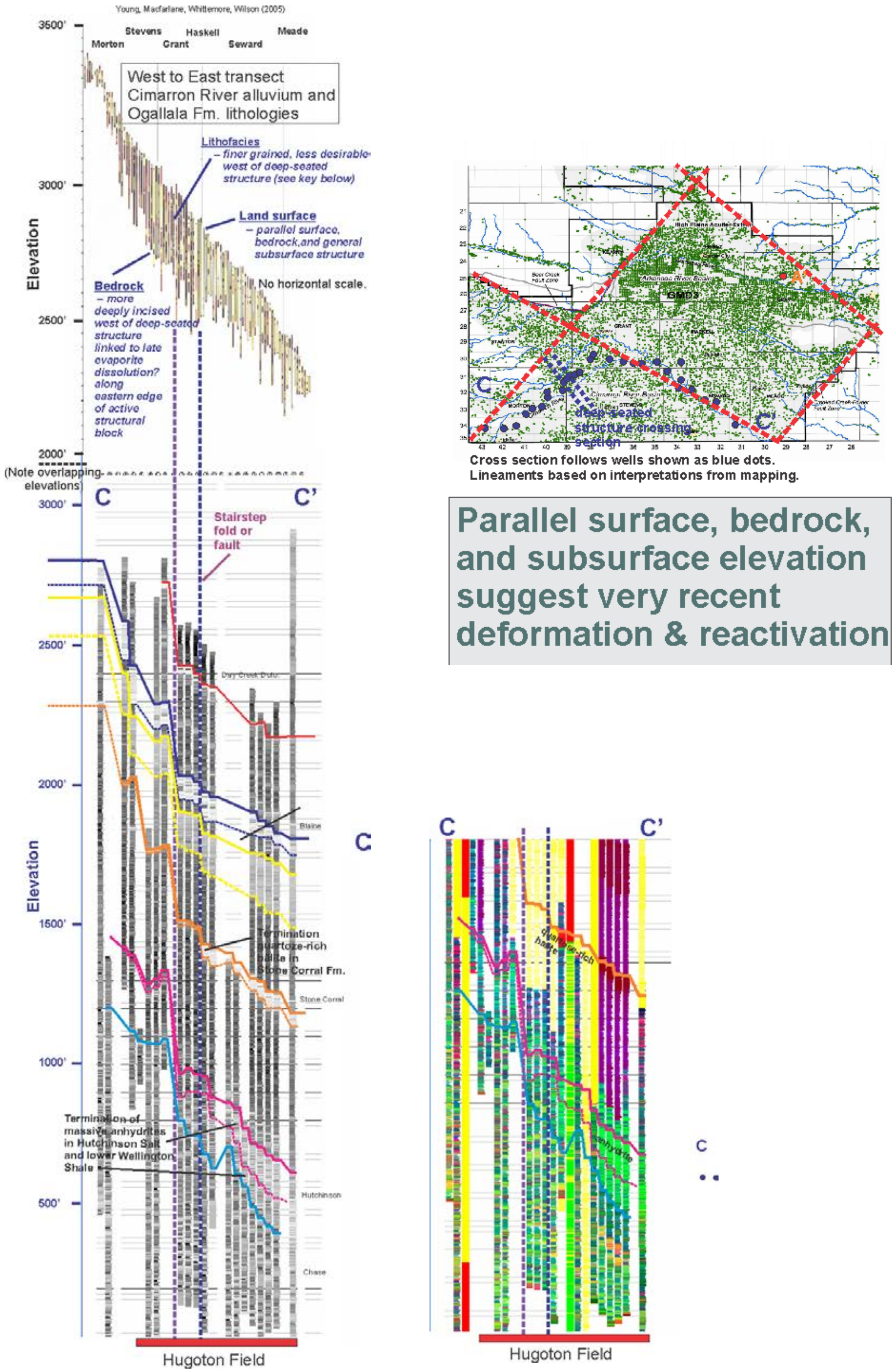


Figure 46. West to east structural cross section from ground surface into the lower Permian strata along a transect following the Cimarron River in the SW corner of Kasnas

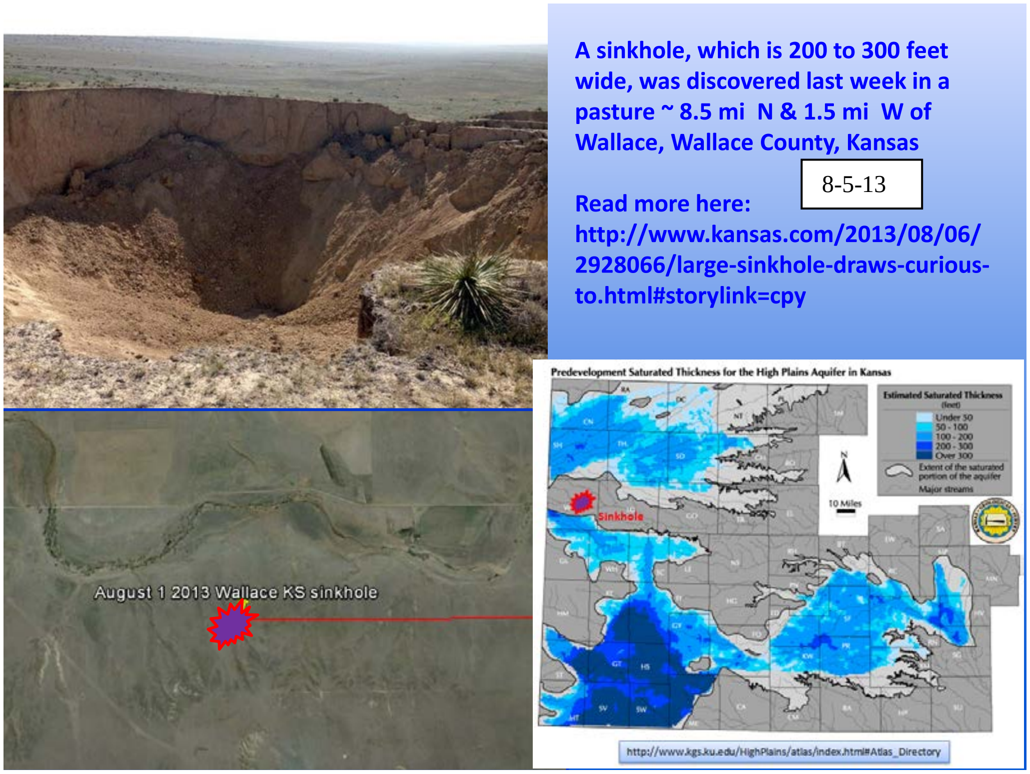


Figure 47. Recent sinkhole developed in western Kansas in area with the Blaine Formation halite is or has recently undergone dissolution.

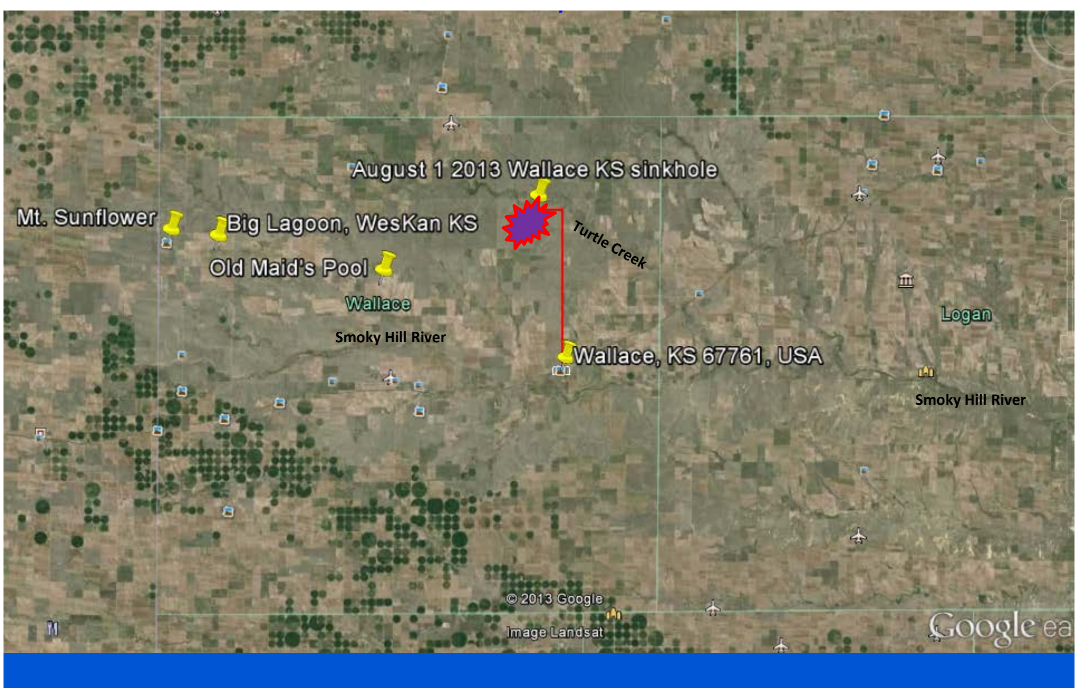


Figure 48. Recent sinkhole and those nearby along the headwaters of the Smokey Hill River.

The potentiometric surface is near the elevation of the salt (~1500 ft above sea level) so gravity flow of meteroric water could theoretically intercept the salt bed (**Figures 49, 50, and 51**).

Large cavities could develop in the salt and then eventually collapse, which could extend toward the ground surface via stopping. The process may be delayed over millennia as roof rock stabilizes the upward stopping and allows the cavern to widen.

In all of this discussion of possible structural controls and reactivation of basement lineaments, the salt dissolution appears to be driven my meteoroic water coming from above, not below. One of the largest gas fields in North America, Hugoton-Panoma Gas Area, accumulated below the salt beds and other less soluble evaporites beneath them. Natural gas has not leaked to the surface, nor is there any recorded leakage of formation brines from below the evaporite interval into the High Plains Aquifer. The potentiometric surface of the Permian has also remained considerably below that of a hydrostatic water column attesting in general to the general isolation of surface and deeper subsurface aquifer systems.

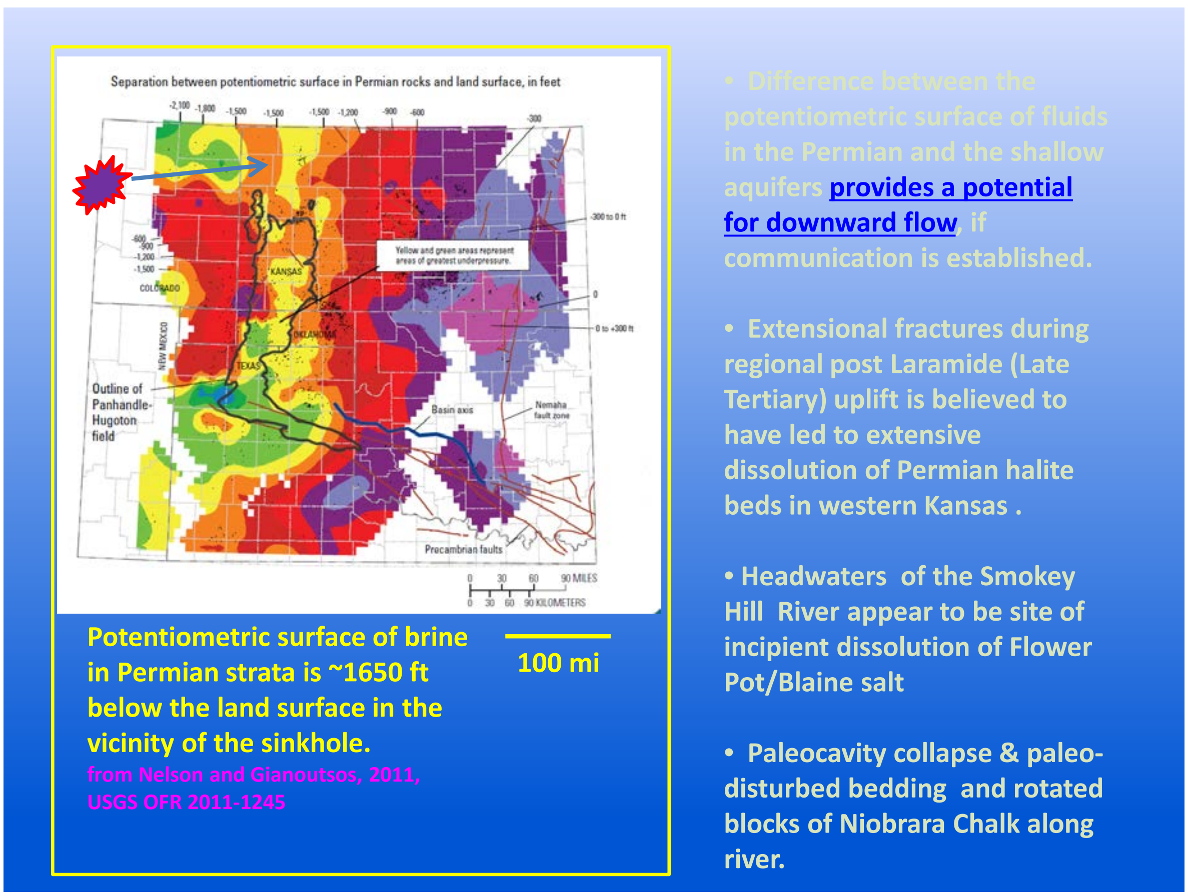


Figure 49. The potentiometric surface of the formation water in the Permian strata is approximately 1650 ft below the land surface at the location of the sinkholes noted in Figure 48.

The Hugoton Gas Area has also underwent fracture stimulation since the late 1950s when the technology was first deployed in the U.S. Besides the natural episodic structural movement, some quite recent, and the man-made fractures in the gas reservoir, the integrity of the Permian evaporites attests to the effectiveness as a caprock.

While the region has underwent a dynamic structural evolution, some subtle and episodic and others distinct and notable, the suitability of the area to commercial scale carbon storage in sites being studied appear to be favorable and continue to be evaluated relying on the wide range of observations from the microscopic scale to the regional level.

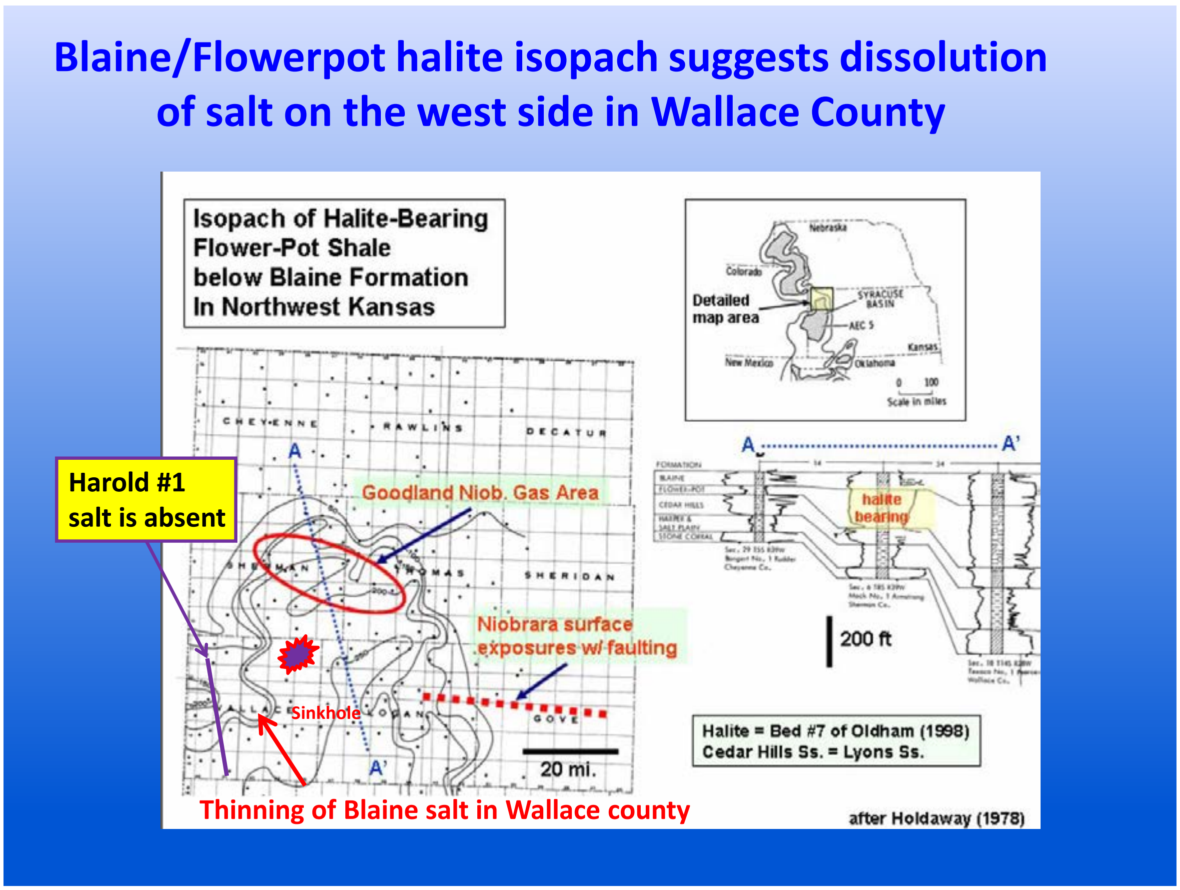


Figure 50. Isopach of halite bearing Flower Pot Shale showing location of the Harold #1 where the halite is absent (Figure 51).

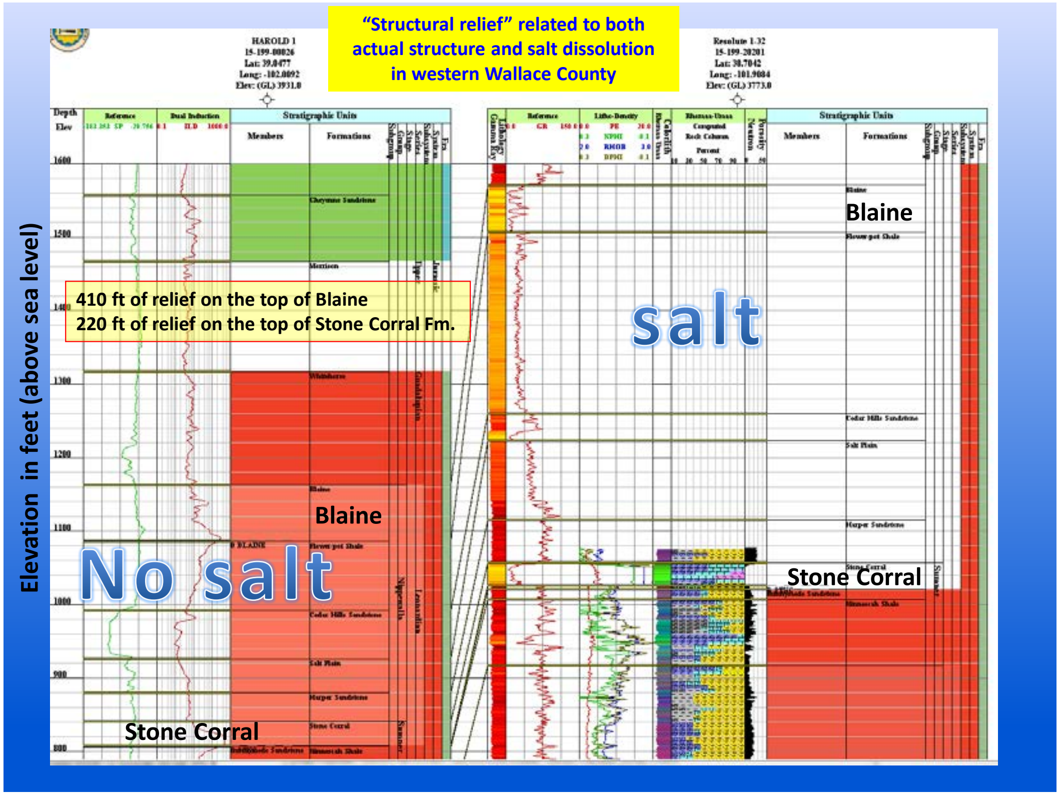


Figure 51. Structural cross section of the Blaine Foramtion to Stone Corral Formation showing two wells, one with halite/salt and one without, the Harold #1.

ONGOING ACTIVITIES - WELLINGTON FIELD –

Task 7. Evaluate CO2 Sequestration Potential in Arbuckle Group Saline Aquifer - Wellington field

New models have been completed for the Arbuckle saline aquifer and Mississippian oil reservoir at Wellington Field.

PRESENTATIONS AND PUBLICATIONS

Next Step Oil and Gas Seminar, Hays, KS

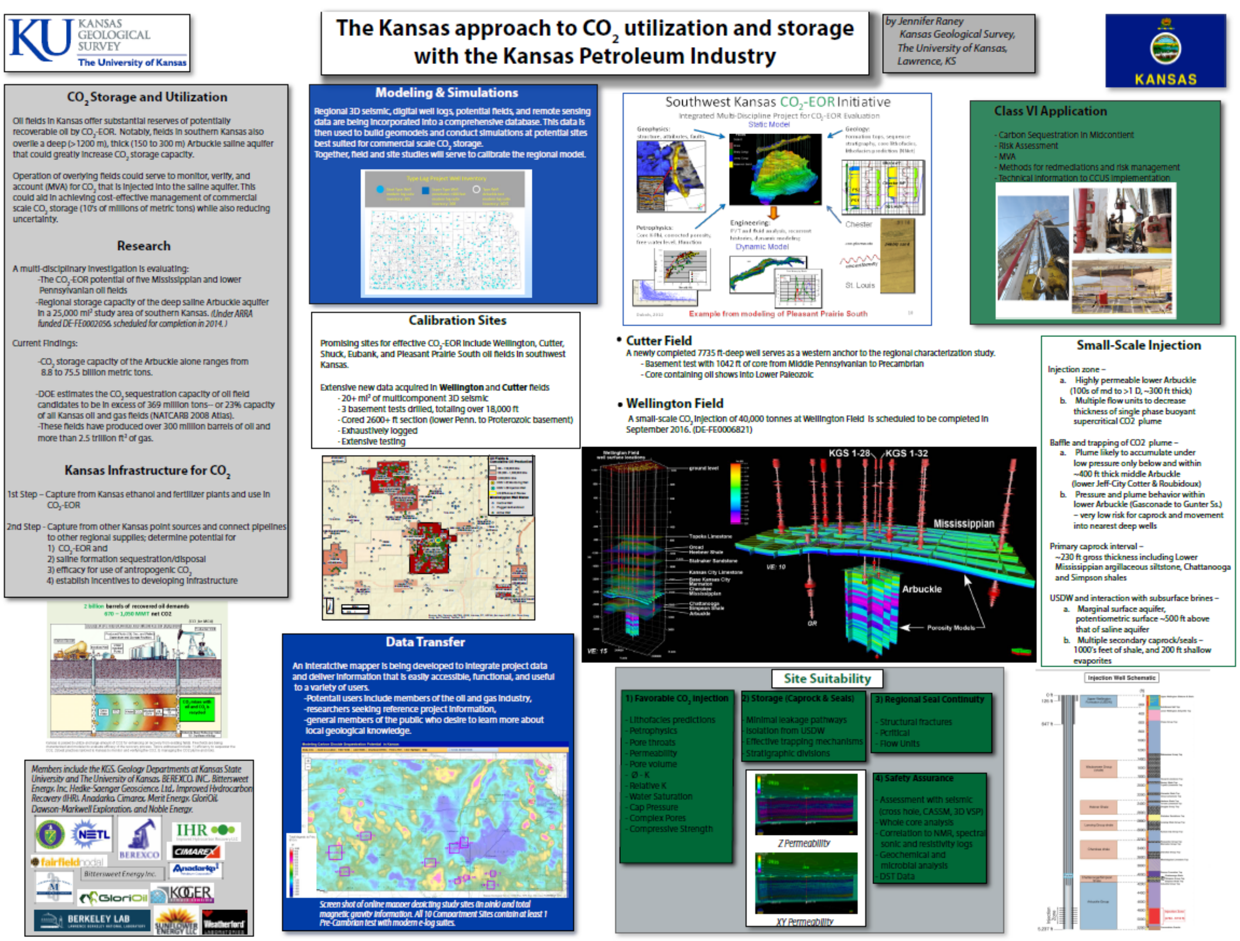
W. Lynn Watney, John Youle, Dennis Hedke, Paul Gerlach, Raymond Sorenson, Martin Dubois, Larry Nicholson, Thomas Hansen, David Koger, Ralph Baker, Jennifer Raney, 2013, *Sedimentologic and Stratigraphic Effects of Episodic Structural Activity During the Phanerozoic in the Hugoton Embayment*, Kansas USA. http://www.kgs.ku.edu/PRS/Ozark/Reports/2013/Structural_analysis_Hugoton_Embayment.pdf

DOE Annual review meeting, August 20 & 21, 2013, Pittsburgh, PA

W. Lynn Watney and Jason Rush, Joint PIs, 2013, *Small scale field test demonstrating CO2 sequestration in Arbuckle saline aquifer and by CO2-EOR at Wellington field, Sumner County, Kansas DE-FE0006821*. http://www.kgs.ku.edu/PRS/Ozark/Reports/2013/Watney_DE-FE0006821_FY13_Carbon_Storage_Review_v3.pdf

W. Lynn Watney and Jason Rush, Joint PIs, 2013, *Modeling CO2 Sequestration in Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO2 Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas Project Number (DE-FE0002056). http://www.kgs.ku.edu/PRS/Ozark/Reports/2013/DE-00002056_FY13_Carbon_Storage_Review.pdf*

Jennifer Raney, 2013, *The Kansas approach to CO2 utilization and storage with the Kansas petroleum industry*. (see below)



Presentations, Midcontinent AAPG

Brent Campbell, 2013, Geochemical assessment of secondary oil recovery, and assessing potential quantification of CO2 sequestration in the underlying saline Arbuckle aquifer, AAPG Mid-Continent Section Meeting, Wichita.

John Doveton, 2013, Pore size and textural analysis of carbonates from nuclear magnetic resonance logging : an Arbuckle case study, AAPG Mid-Continent Section Meeting, Wichita.

Martin Dubois, 2013, CO2 Enhanced oil recovery and CO2 sequestration potential of the Mississippian Chester incised valley reservoir system, Haskell and Seward Counties, Kansas, AAPG Mid-Continent Section Meeting, Wichita.

Paul Gerlach, 2013, The Geologic History of Kansas, 2013 or Updating the Work of a Legend, AAPG Mid-Continent Section Meeting, Wichita.

Paul Gerlach, 2013, Online Development of New Kansas Type Logs, AAPG Mid-Continent Section Meeting, Wichita.

Yevhen Holubnyak, 2013, Reservoir Engineering Aspects of Pilot Scale CO2 EOR Project in Upper Mississippian Formation at Wellington Field in Southern Kansas, AAPG Mid-Continent Section Meeting, Wichita.

Yevhen Holubnyak, 2013, Dynamic Modeling of CO2 Geological Storage in the Arbuckle Saline Aquifer, AAPG Mid-Continent Section Meeting, Wichita.

John Youle, 2013, Depositional history and distribution of reservoir rocks in Chesterian incised valley fill pools: examples from Shuck and Eubank fields in southwestern Kansas, AAPG Mid-Continent Section Meeting, Wichita.

W. Lynn Watney, 2013, Seismic attribute analysis of the Mississippian chert at the Wellington Field, south-central Kansas, AAPG Mid-Continent Section Meeting, Wichita.

W. Lynn Watney, 2013, Systematic and episodic structural deformation in southern Kansas and implications for petroleum systems and CO2 storage, AAPG Mid-Continent Section Meeting, Wichita.

W. Lynn Watney, 2013, Evaluating CO2 Utilization and Storage in Kansas, AAPG Mid-Continent Section Meeting, Wichita.

W. Lynn Watney, 2013, Paleozoic Anchor Core in Southwest Kansas -- Berexco Cutter KGS #1 in Stevens County, AAPG Mid-Continent Section Meeting, Wichita.

W. Lynn Watney, 2013, Paleozoic Anchor Core in South-Central Kansas – Berexco Wellington KGS #1-32, Sumner County, AAPG Mid-Continent Section Meeting, Wichita.

KEY FINDINGS

1. Core analysis in the Cutter well is being used to predict permeability from the well logs. Core data indicates that the permeability ranges 4.5 orders of magnitude compared to porosity and is again closely related to the pore type and lithofacies. Pore space again is fabric selective.
2. Oil shows in the core analysis and shows of oil in the fluid sampling of the Arbuckle at Cutter Field substantiates the presence of oil in the lower Paleozoic strata, occurring in multiple horizons.
3. Preliminary results from the pressure buildup tests conducted during the perforating and swabbing in the Arbuckle of the Cutter well exhibit permeability in the 100s of millidarcies indicating zones are present with sufficient injectivity for CO2. However, these permeability measuremnts are quite a bit larger than measured in whole core analyses. More work needs to be done.
4. CO2-EOR simulation work at Pleasant Prairie oil field suggests a viable site for carbon storage. The analytical techniques are being refined and the results will be useful in building scoping models of CO2-EOR for analogous fields. Simulations from Eubank, Shuck, and Cutter will also be factored into the feasibility assessment and will result in refined scoping models for these types of reservoirs.
5. The fuzzy logic methodology is selected as the optimal method to interpolate properties in the regional assessment of the Arbuckle Group using modern suite of well logs and cuttings descriptions.
6. Anadarko Basin and Hugoton Embayment are structurally coupled system spanning Proterozoic extension to Phanerozoic compression.
7. Major structures in the Hugoton Embayment at serve as traps for the oil reservoirs being studied show prominent evidence of coupled and complex compressional events from far field stresses including diagnostic features such as flower structures and restraining bends developed along reactivated basement lineaments.
8. Episodic structural movement is the norm in the Midcontinent with post tectonic movement affecting sedimentation/stratigraphy throughout Phanerozoic including High Plains Aquifer.
9. Pattern of deformation suggests systematic controls affected by prominent basement weaknesses (the template) as revealed by potential fields and lineament analysis. Basement weaknesses interact with an evolving stress field leading to preferred patterns of deformation.
10. While southern Kansas has underwent a dynamic structural evolution, some subtle and episodic and others distinct and notable, the suitability of the area to commercial scale carbon storage in sites being studied appear to be favorable and continue to be evaluated relying on the wide range of observations from the microscopic scale to the regional level.

PLANS

1. Launch review of the stratigraphic correlations via the type log project and web application.
2. Complete carbon isotopic analysis of the Arbuckle Group at Wellington Field to aid in confirming physical stratigraphic correlations.
3. Complete assessment of the carbon storage volume in the Arbuckle for southern Kansas using new methodologies that have been established.
4. The interactive mapper and carbon storage assessment will be finalized for the NATCARB and Carbon Storage Atlas by end of calendar year 2013 to meet deadlines on those activities.
5. Continue to obtain core and fluid analyses from the Cutter well to understand communication between hydrostratigraphic units and relationship to the hydrocarbon shows.

SPENDING PLAN

See next page.

COST PLAN/STATUS

	BP 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	$43,980.04	$40,584.78	$13,195.88	$526,210.30	$35,887.34	$414,511.02	$20,247.24
Total Incurred Costs-Quarterly (Federal and Non-Federal)	$4,019.93	$84,603.97	$535,013.15	$124,601.40	$764,886.27	$1,938,823.89	$1,040,364.19	$296,001.74
Cumulative Incurred Costs	$4,019.93	$88,623.90	$623,637.05	$748,238.45	$1,513,124.72	$3,451,948.61	$4,492,312.80	$4,788,314.54
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	$233,280.71	$236,675.97	$264,064.87	-$526,210.30	-$35,887.34	-$414,511.02	$282,935.51
Total Variance-Quarterly Federal and Non-Federal)	$1,280,863.57	$1,156,299.49	$749,870.35	$1,160,282.10	-$764,886.27	-$1,938,823.89	-$1,040,364.19	$1,176,724.01
Cumulative Variance	**$1,280,863.57**	**$2,437,163.06**	**$3,187,033.41**	**$4,347,315.51**	**$3,582,429.24**	**$1,643,605.35**	**$603,241.16**	**$1,779,965.17**

			BP3 Starts 8/8/12	Ends 2/7/14					
10/1/11 - 12/31/11	1/1/12 - 3/31/12	4/1/12 - 6/30/12	7/1/12 - 9/30/12	10/1/12 - 12/31/12	1/1/13 - 3/31/13	4/1/13 - 6/30/13	7/1/13 - 9/30/13	10/1/13 - 12/31/13	1/1/14 - 2/7/14
Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
$1,169,543.00	$1,169,543.00	$1,169,543.00	$316,409.00	$316,409.00	$316,409.00	$316,409.00	$0.00	$0.00	$0.00
$303,182.75	$303,182.75	$303,182.75	$81,854.50	$81,854.50	$81,854.50	$81,854.50	$0.00	$0.00	$0.00
$1,472,725.75	$1,472,725.75	$1,472,725.75	$398,263.50	$398,263.50	$398,263.50	$398,263.50	$0.00	$0.00	$0.00
$8,084,985.50	$9,557,711.25	$11,030,437.00	$11,428,700.50	$11,826,964.00	$12,225,227.50	$12,623,491.00	$12,623,491.00	$12,623,491.00	$12,623,491.00
$523,196.12	$453,026.11	$238,793.52	$1,282,545.00	$1,314,156.54	$395,319.33	$299,454.96	$465,714.15		
$16,687.00	$61,683.20	$150,646.51	$221,053.41	$121,637.40	-$65,989.76	$23,362.67	$34,263.50		
$539,883.12	$514,709.31	$389,440.03	$1,503,598.41	$1,435,793.94	$329,329.57	$322,817.63	$499,977.65		
$5,328,197.66	$5,842,906.97	$6,232,347.00	$7,735,945.41	$9,171,739.35	$9,501,068.92	$9,823,886.55	$10,323,864.20		
$646,346.88	$716,516.89	$930,749.48	-$966,136.00	-$997,747.54	-$78,910.33	$16,954.04	-$465,714.15		
$286,495.75	$241,499.55	$152,536.24	-$139,198.91	-$39,782.90	$147,844.26	$58,491.83	-$34,263.50		
$932,842.63	$958,016.44	$1,083,285.72	-$1,105,334.91	-$1,037,530.44	$68,933.93	$75,445.87	-$499,977.65		
$2,712,807.80	**$3,670,824.24**	**$4,754,109.96**	**$3,648,775.05**	**$2,611,244.61**	**$2,680,178.54**	**$2,755,624.41**	**$2,255,646.76**		