CONTINUATION APPLICATION AND FUNDING

"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"

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WORK PERFORMED UNDER AGREEMENT

DE-FE0002056

SUBMITTED BY

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Executive Summary

The objectives of 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" include: a) characterization of the Paleozoic-age Ozark Plateau Aquifer System (OPAS) consisting of the Arbuckle Group Saline Aquifer and the overlying Mississippian carbonate reservoirs in south-central Kansas, and b) modeling studies to evaluate the CO_2 sequestration capacity of the Arbuckle Group Saline Aquifer and by CO_2-EOR operations in overlying depleted Mississippian oil fields. This project focuses locally on the Mississippian reservoir and the underlying Arbuckle Group Saline Aquifer at the Wellington Field area, Sumner County, Kansas, encompassing approximately 10 square miles, and regionally on the Arbuckle Group Saline Aquifer extending over a 20,000+ square mile area across 17+ counties in southern Kansas.

The regional study is progressing as per plans with completion of the following tasks: a) review of 14,000+ wells to identify 90 Super Type wells (> 400' Arbuckle penetration and with a modern log suite) and ~ 1400 Type wells (some Arbuckle penetration and wireline log data), b) collection of ~ 4000 Arbuckle DST data, c) cataloging of available Arbuckle water chemistry and (bottom hole) temperature data, d) acquiring available core analysis, geo-reports, and sample descriptions pertinent to the Arbuckle. About 50% of the Super-Type wells have been acquired, scanned, and digitized while the remaining logs from Super-Type and Type wells are being scanned after acquisition. Based on previously scanned Super-Type well logs, regional Arbuckle structure, thickness, and 3rd order trend residual have been mapped along with major stratigraphic units within the Arbuckle to define the lateral extent of cap rocks and aquitards (low permeability zones). Pressure, salinity, and temperature data have been mapped, with the pressure distribution map revealing that the Arbuckle Group Saline Aquifer is an open system connected to its outcrop along the Missouri River near Jefferson City, Missouri. Over the regional study area, gravity and magnetic data has been reprocessed, while remote sensing data has been analyzed and comparative study of surface lineaments/faults is in progress. Currently, the basement structure maps from gravity/magnetic analysis is being compared with Arbuckle structural maps and remote sensing analysis to characterize fault/fracture in the Arbuckle Group Saline Aquifer. A flow-unit based geomodel has been constructed, using depth-constrained cluster analysis of petrophysical data, over a 9-Township area around the Plant Site Disposal Well #10, Sedgwick County, Kansas, and initial simulation studies show that aquitards within the Arbuckle prevent vertical migration of the CO_2 plume towards the primary cap rock.

At the Wellington field study area, the following tasks have been completed: a) collect and digitize all available wireline logs including those from the adjacent Anson-Bates field, b) catalog all available core analyses data, c) acquisition and processing (P-wave) of a new multi-component 3D seismic survey (12 mi^2) and its merging with the donated 3D volume from the adjacent Anson-Bates field, and d) acquisition of high resolution gravity data at the seismic shot points. An initial 3D geocellular model for the Wellington field Mississippian reservoir has been completed showing mapping structure, thickness, and porosity. The geocellular model and Mississippian time structure and amplitude

maps were used to identify the location of the two test boreholes to be drilled to the basement within Wellington field as part of this project. Boreholes are located on structural highs with thick and stable sections of Mississippian and Arbuckle for successful retrieval of representative cores from the above mentioned formations and their cap rocks. Tasks in progress include: a) inventory of well completion and production histories, b) interpretation of merged P-wave seismic volume, c) volumetric coherency attribute analysis, and d) permitting for drilling of test borehole #1.

Processing of newly collected 3D seismic survey and interpretation of the P-wave volume took a couple of months longer than planned because problems related to the complex field geology and processing techniques required more time to resolve than anticipated. This delay in processing the 3D (P-wave) volume resulted in a delay in site selection for the test boreholes #1 and 2. Thus, test borehole #1 is now scheduled to be drilled in late November, 2010. Because of the delay in drilling the test borehole #1, the following budget period 1 (BP-1) tasks will be rescheduled to BP-2: a) special and routine core analysis of Mississippian and Arbuckle cores retrieved from test borehole #1, b) PVT analysis of fluid samples collected from test borehole #1, c) 2D shear-wave survey, data processing and interpretation at Wellington field, d) drilling of and data collection from test borehole #2, e) thin section preparation from cores retrieved from test borehole #1, and f) high resolution magnetic survey at Wellington field. Other BP-1 tasks that will be completed in BP-2 include: a) completion of log digitization in the regional study area, and b) reservoir simulation studies of CO_2 sequestration in the Arbuckle Group Saline Aquifer after obtaining flow-unit specific petrophysical data and geochemistry from core and fluid samples recovered from test borehole #1. Based on contracts signed with vendors/sub-contractors, no additional costs, beyond the already budgeted amounts, will be incurred to complete the above mentioned BP-1 tasks in early part of BP-2.

Results of Work

(Summarize work completed to date on each Task; Include Tables and Illustrations as appropriate)

Task 1: Program Management and Reporting (PMP)
The Recipient has tracked project planning, budgeting, subcontracting, milestones and achievements throughout the duration of the project in accordance with the Federal Assistance Reporting Checklist. The Recipient has participated in an annual project review meeting with the DOE.

The enclosed (Figure 1) schedule pertaining to the drilling of the test borehole #1 includes estimated completion dates for test borehole permit, drill site selection, drilling, completion, data collection, and well abandonment.

Task 2: Characterize the Ozark Plateau Aquifer System (OPAS) in South-Central Kansas
The Recipient has reviewed data from 14,000+ wells drilled in the regional study area, i.e., a 17+ county area (~ 20,000 mi^2) in southern Kansas to identify wells with penetrations into the OPAS which consists of the Mississippian reservoirs and the Arbuckle Group Saline Aquifer.

Subtask 2.1: Choose Subcontractor for performing Data Acquisition within OPAS – *Completion deadline Dec 2009 (refer Gantt Chart)*
The Recipient has selected subcontractors to conduct the following tasks:

i) Reprocess and analyze donated 3D seismic surveys - COMPLETED
ii) Obtain geologic data such as wireline log, core, DST, geo-reports, and brine analysis from the study area - COMPLETED

Subtask 2.2. Acquire geologic, seismic, and engineering data for Ozark Plateau Aquifer System (OPAS) – *Completion deadline Jun 2012 (refer Gantt Chart)*

Status of the Subtask 2.2 tasks given below:

i) Obtained gravity survey over the 17+ county regional study area - COMPLETED
ii) Obtained magnetic survey over the 17+ county regional study area - COMPLETED
iii) Scanned an inventory of 14,000+ wells drilled in the regional study area to identify wells with Arbuckle penetrations and wireline log data – COMPLETED
iv) Identified ~ 90 Super Type wells with modern wireline log data and greater than 400’ of Arbuckle penetration - COMPLETED
v) Identified ~ 1400 Type wells with Arbuckle penetrations and wireline log data including ~ 100 wells with about 200’ Arbuckle penetrations, - COMPLETED

vi) Scanning and digitizing of Super Type well logs – IN PROGRESS (50% COMPLETED)
vii) Scanning and digitizing Type well logs – IN PROGRESS
viii) Obtained DST data from ~ 4000 Arbuckle tests in regional study area – COMPLETED
ix) Obtained available Arbuckle core analysis data covering regional study area – COMPLETED
x) Obtained available Arbuckle salinity data from regional study area – COMPLETED
xi) Uploading selected ASCII-formatted sample logs and geo-reports from key wells including Super Type and Type wells from regional study area – IN PROGRESS
xii) Detailed sample descriptions from key wells acquired and digitized – IN PROGRESS

Subtask 2.3. Develop regional correlation framework and integrated geomodel of the Ozark Plateau Aquifer System (OPAS) – *Completion deadline Jun 2012 (refer Gantt Chart)*

The Recipient has constructed an initial regional geomodel for the Arbuckle Group Saline Aquifer (in OPAS) by integrating available data. The Recipient has correlated and mapped major stratigraphic units including pre-Cambrian basement, and tops of Arbuckle Group Saline Aquifer, Chattanooga Shale (primary cap rock), Mississippian System, Lower Pennsylvanian shales (secondary cap rock), stratigraphic horizons associated with Hutchinson salt (tertiary cap rock), and several internal units within the Arbuckle Group. The Recipient has also mapped Arbuckle structure (Figure 2) and its 3rd order trend residual (Figure 3), gross thickness (Figure 4), DST shut-in pressure (Figure 5), and shut-in pressure less hydrostatic head from surface exposure of Arbuckle (Figure 6).

Status of the Subtask 2.3 tasks given below:

i) Arbuckle structure map along with its 3rd order trend residual over regional study area –COMPLETED
ii) Gross Arbuckle thickness map in regional study area - COMPLETED
iii) Salinity map in the Arbuckle over the regional study area - COMPLETED
iv) Arbuckle pressure distribution map over the regional study area – COMPLETED
v) Geologic cross-section using wireline log, insoluble residue, and sample descriptions – IN PROGRESS
vi) Petrophysical analysis of Super Type logs and establishing flow units and caprocks – IN PROGRESS
vii) Maps and cross sections depicting characteristics of flow units and caprock – IN PROGRESS

Please Note: The above maps will be updated as additional digital log data gets incorporated into the geomodel.

Subtask 2.4. Subsurface Fluid Chemistry and Flow Regime Analysis – *Completion deadline Jun 2012 (refer Gantt Chart)*

The Recipient has mapped Arbuckle DST shut-in pressures over the 17+ county regional study area to demonstrate the hydraulic connectivity with the Arbuckle exposure along the Missouri River near Jefferson City, Missouri (Figure 6) assuming a hydrostatic gradient of 0.435 psi/ft which has been reported in published studies to establish hydraulic communication of the Hugoton field to its outcrop. This exercise:

a) provides evidence supporting established observation of minimal to no increase in pressure in the vicinity of 1000s of Arbuckle injection wells disposing produced brine for decades,
b) provides an explanation why the Arbuckle Group Saline Aquifer has sub hydrostatic pressure in the regional study area,
c) shows that there is negligible surface recharge (fluid communication) and that the Arbuckle Group Saline Aquifer is hydraulically isolated from shallower zones,
d) provides evidence for modeling the Arbuckle Group Saline Aquifer in Kansas as an open system communicating with surface exposure in central Missouri located over 200 miles to northeast, and
e) explains that the scatter noticed on DST pressure vs. depth plot is not a result of incomplete stabilization of the DST due to short shut-in times and/or low permeability but because the datum for calculating the hydrostatic head was incorrectly assumed to be the surface elevation rather than that of the base of the outcrop along the Missouri River.

The Recipient has mapped major stratigraphic units within the Arbuckle to: a) define the lateral extent (distribution) of aquitards (flow barriers with low permeability), and b) identify hydrodynamic traps, and has a developed flow-unit based geomodel (Figure 7) covering a 9-Township area around the Plant Site Disposal #10 well (Sedgwick County, Kansas) for initial simulation studies to evaluate the ability of aquitards to prevent vertical migration of the CO_2 plume and to estimate the CO_2 injectivity and capacity.

<u>Status of the Subtask 2.4 tasks given below:</u>

i) Map showing minimal (zero) differences between DST shut-in pressure and the estimated hydraulic head (pressure) at the base of the DST interval assuming that the base for the calculating the pressure is the Arbuckle

exposure along Missouri River near Jefferson City, Missouri (elevation ~ 450') - COMPLETED

ii) Correlation between salinity and depth in Arbuckle Saline Aquifer developed – COMPLETED

iii) Initial flow-unit based geomodel using depth-constrained cluster analysis on wireline log data developed for a multi-township area centered on Plant Site Disposal #10 well – COMPLETED

iv) Initial simulation studies to evaluate the capability of low-permeability aquitards to prevent vertical migration of CO_2 plume - COMPLETED

v) Initial simulation studies to estimate CO_2 injectivity and storage capacity in model area around Plant Site Disposal #10 well – IN PROGRESS

vi) Digitizing data (wireline log, core and test analysis) from Class 1 disposal wells (penetrating Arbuckle) in Kansas – IN PREOGRESS

Subtask 2.5. Analysis of KGS's gravity and magnetic data – *Completion deadline Dec 2011 (refer Gantt Chart)*

The Recipient has reprocessed gravity (Figure 8) and magnetic (Figure 9) data collected over the regional study area, and is currently comparing features visible from the field analysis with structural mapping and analysis of remote sensing data from KGS to map basement structure and characterize the fault/fracture systems.

Status of the Subtask 2.5 tasks given below:

i) Reprocess gravity data over regional study area – COMPLETED

ii) Reprocess magnetic data over regional study area – COMPLETED

iii) Mapping of basement structure – IN PROGESS

iv) Overlaying and comparing remote sensing analysis on Arbuckle structural mapping and gravity/magnetic analysis to characterize fault/fracture systems in the Arbuckle Group Saline Aquifer – IN PROGRESS

Subtask 2.6. Remote sensing analysis – *Completion deadline Dec 2011 (refer Gantt Chart)*

The Recipient has interpreted available remote sensing data to map surface lineaments and potential fracture systems and faults in the regional study area (Figure 9).

Status of the Subtask 2.6 tasks given below:

i) Interpretation of remote sensing data over regional study area including local, medium, and regional lineaments, oval, tonal, and karst features – COMPLETED

ii) Upload interpreted data as layers in Project's web-based interactive map – COMPLETED

iii) Comparative study of surface lineaments/faults with those observed in structural maps and field (gravity/magnetic) analysis – IN PROGRESS

Task 3: Develop a Geomodel of the Mississippian Chat and Arbuckle Group in Wellington Field

The Recipient has acquired 12 mi^2 of multi-component 3D data along with high resolution gravity survey over the same area at Wellington Field, Sumner County, Kansas. The Recipient has completed collection, scanning, and digitizing of available wireline data in and around the Wellington Field. Engineering data, including production, injection, and pressure testing, is ongoing. The Recipient plans to develop an initial geomodel for the Mississippian (chat) reservoir and the underlying Arbuckle Group saline aquifer in Wellington Field by integrating seismic, geologic, and engineering data.

Subtask 3.1. Collect geologic and engineering data – *Completion deadline Jun 2010 (refer Gantt Chart)*

The Recipient has collected wireline logs, core analyses (from Wellington and adjacent Anson-Bates fields), and geo-reports from the Wellington field, and is currently tabulating primary and secondary production, and production and pressure test data. The Recipient is also collecting (similar) data from Class 1 disposal wells penetrating the Mississippian and the Arbuckle Group saline aquifer in the vicinity of the Wellington field.

Status of the Subtask 3.1 tasks given below:

i) Available wireline logs from Wellington field scanned and digitized – COMPLETED
ii) Available wireline logs from adjacent Anson-Bates fields scanned and digitized – COMPLETED
iii) Available Mississippian core analyses from Wellington and Anson-Bates fields digitized for calibration with wireline logs – COMPLETED
iv) Inventory of well completion and production/injection histories – IN PROGRESS

Subtask 3.2. Collect 3D seismic survey data – *Completion deadline Mar 2010 (refer Gantt Chart)*

The Recipient has acquired 3D P-wave survey data over approximately a 12 mi^2 area over the Wellington Field.

Status of the Subtask 3.2 tasks given below:

i) Acquisition of multi-component 3D seismic survey over Wellington field - COMPLETED

Subtask 3.3. Process 3D seismic survey data – *Completion deadline Jun 2010 (refer Gantt Chart)*

The Recipient has completed processing the newly collected 3D seismic data and has merged it with the existing 3D seismic data from adjacent Anson-Bates field.

Status of the Subtask 3.3 tasks given below:

i) Processing of P-wave seismic data collected over Wellington field – COMPLETED
ii) Merging Wellington 3D volume with donated 3D volume from adjacent Anson-Bates field – COMPLETED
iii) Interpretation of merged P-wave seismic volume – IN PROGRESS

Subtask 3.4 Collect gravity and magnetic survey data – *Completion deadline Mar 2010 (refer Gantt Chart)*

The Recipient has collected high resolution (80 stations per mi^2) gravity data at the seismic shot points. Magnetic data could not be collected at the time of the gravity survey due to equipment failure, and is scheduled to be collected after the drilling of the test borehole #1, i.e., in early part of 2011.

Status of the Subtask 3.4 tasks given below:

i) High resolution gravity survey at Wellington field – COMPLETED
ii) Magnetic survey at Wellington field – TO BE COMPLETED AFTER DRILLING TEST BOREHOLE#1 (EARLY 2011)

Subtask 3.5. Interpret seismic, gravimetric, and magnetic data – *Completion deadline Jun 2010 (refer Gantt Chart)*

The Recipient has completed the initial analysis of seismic P-wave data by integrating available wireline log data, and has started work on curvature analysis using newly acquired seismic data.

Status of the Subtask 3.5 tasks given below:

i) Mississippian time structure map at Wellington field – COMPLETED
ii) Mississippian amplitude map at Wellington field – COMPLETED
iii) Correlation of other significant seismic reflectors – IN PROGRESS
iv) Volumetric coherency attribute analysis – IN PROGRESS

Subtask 3.6. Develop initial geomodel for the Wellington Field – *Completion deadline Jul 2010 (refer Gantt Chart)*

The Recipient has build fine-scale geomodels for the Mississippian (Chat) reservoir (Figure 10) by integrating seismic with wireline log data.

Status of the Subtask 3.5 tasks given below:

i) Initial 3D geocellular models of Mississippian structure, thickness, and porosity– COMPLETED
ii) Structural mapping of underlying Arbuckle aquifer – IN PROGRESS
iii) Cross-section and flow-unit identification within the Mississippian and the Arbuckle Group Saline Aquifer – IN PROGRESS

Task 4: Preparation, Drilling, Data Collection and Analysis – Test Borehole #1

The Recipient has selected the location of the Test Borehole #1 based on seismic analysis (Figure 11) such that the expected Mississippian penetration is relatively high on the structure with the underlying Arbuckle appearing as a stable zone for successful drilling and coring.

Subtask 4.1. Locate Test Borehole #1 – *Completion deadline Jul 2010 (refer Gantt Chart)*

The Recipient, in consultation with industry partner (BEREXCO), has selected a structural high as the site for Test Borehole #1. Based on seismic analysis, the well is expected to penetrate thick sections of Mississippian and Arbuckle strata so that representative cores can be obtained for majority of the flow units. Also, the Arbuckle zone appears stable on the seismic analysis and should be suitable for retrieving representative cores.

Status of the Subtask 4.1 tasks given below:

i) Site selection for Test Borehole #1 – COMPLETED

Subtask 4.2. Permitting for Test Borehole #1 – *Completion deadline Jul 2010 (refer Gantt Chart)*

The industry partner has applied for permits (including agreements with land owner(s)) necessary to drill Test Borehole #1.

Status of the Subtask 4.2 tasks given below:

i) Application for drilling permits – IN PROGRESS

Task 9: Characterize leakage pathways – Risk assessment area

The Recipient has started to gather well completion information about all wells within the Wellington field and for all wells penetrating the primary seal for the

Arbuckle Group Saline Aquifer in the risk assessment area – a 10 sq. mi area around the Wellington field. This data inventory will be used by an expert to classify quality of well integrity.

Subtask 9.4. Inventory well status – *Completion deadline Jun 2012 (refer Gantt Chart)*

The Recipient is collecting completion records for all wells drilled within the Wellington field and for wells that have penetrated the primary seal of the Arbuckle Group Saline Aquifer within the risk assessment area around the Wellington field.

Status of Subtask 9.4 tasks given below:

i) Cataloging well completion files for all wells in Wellington field – IN PROGRESS

Task 14. Technology Transfer

As part of technology transfer, the Recipient has developed a project web site which is updated to include presentations made to the public, legislators, regulators, and oil and gas industry professionals. Various web-based data display tools and working prototypes have been developed to, a) view and overlay geo-referenced map layers such as structure, remote sensing analysis, basement maps, b) wireline log analysis for petrophysical calculations and depth constrained cluster analysis to determine flow-units, c) create cross sections detailing lateral continuity of stratigraphic units.

Subtask 14.1. Build and maintain project website – *Completion deadline Dec 2012 (refer Gantt Chart)*

i) Project Website – CREATED & UPDATED REGULARLY

Subtask 14.2. Link project web-site to DOE database - *Completion deadline Dec 2012 (refer Gantt Chart)*

i) Project website address provided to DOE – COMPLETED
ii) Data transfer using DOE format – WAITING FOR DOE GUIDANCE

Subtask 14.3. Publish project results – *Start date Jun 2011 & Completion deadline Dec 2012*

i) Abstract submission to AAPG 2011 Annual Conference, Houston (Appendix A) - COMPLETED

Papers, Publications, Patents, etc. *(include other products such as computer programs, models, etc.)*

1. Submitted abstract to AAPG 2011 – (see attached Appendix A)
2. Developed software tools including
    a. Prototype working versions of Web-based tools include: WELLPROFILE, CROSS-SECTION, DEPTH-CONSTRAINED CLUSTER ANALYSIS
    b. Interactive MAP VIEWER to display and interact with well locations and maps using Google-type map format
3. Developed initial 7-layer flow-unit based geomodel for a 9-township area around Plant Site Disposal #10 (Sedgwick County, KS), and conducted initial simulation studies to estimate injectivity and CO_2 sequestration capacity using approximate petrophysical properties.
4. Development of regional geomodel include:
    a. DST SIP map demonstrating hydraulic communication of Arbuckle Saline Aquifer with its outcrop along the Missouri river located at the northern edge of the Ozark Uplift in central Missouri
    b. Salinity (TDS) vs. depth profile in Arbuckle
    c. BHT vs. depth profile in Arbuckle
    d. Mapping of structural residuals
    e. Potential fields mapping - reprocessed maps of gravity and magnetic data
    f. LANDSAT imagery analysis to identify lineaments (lines and ovals), tonal changes, and karst distribution.
5. Development of geomodels around the Wellington field area
    a. Initial P-wave interpretation of the pre-stack time migration of the merged 3D seismic volume including surveys (~ 20 mi^2) over Wellington and adjoining Anson-Bates fields
    b. Initial 3D geocellular models of Mississippian structure, thickness, and porosity

Summary of Current Technical Status (~1-2 pages) - Gantt Chart, Milestone Status

The focus areas for the 1st year of the project includes: a) developing a regional geomodel for the Arbuckle Group Saline Aquifer over a 17+ county area (~ 20,000 sq. miles) in southern Kansas, and b) developing a detailed geomodel of the Mississippian reservoir and the underlying Arbuckle Saline Aquifer at the Wellington field, Sumner County, Kansas.

As part of the regional study, an inventory of 14,000+ wells was screened to identify wells that penetrate the Arbuckle and have modern suite of logs. As a result of this audit, 90 Super-Type wells were identified to have greater than 400 ft of Arbuckle penetration and with a post-1980 suite of wireline logs. Also identified were 1400 Type wells with Arbuckle penetration and limited wireline log data, and out of which about 100 wells were found to have less than 200 ft Arbuckle penetration. About 50% of the Super-Type well logs have been scanned and digitized, while the digitization of the remaining 50% are expected to be completed soon. Acquisition, scanning, and digitization of the Type well logs are in progress and are expected to be completed by the end of 2010. All available DST (~ 4000+ records), salinity, and BHT (bottom-hole temperature) data have been acquired and plotted. A software program has been developed to automate the uploading of selected geo-reports and sample descriptions from keys wells in the regional study area. Gravity and magnetic surveys over the regional study area have been retrieved and reprocessed.

Based on current input data, initial regional maps have been constructed for the Arbuckle Group Saline Aquifer for: a) structure and its 3rd order trend residual, b) gross thickness, c) salinity, d) temperature, and e) pressure. Major stratigraphic units that have been regionally correlated and mapped including pre-Cambrian basement, and tops of Arbuckle Group Saline Aquifer, Chattanooga Shale (primary cap rock), Mississippian System, Lower Pennsylvanian shales (secondary cap rock), stratigraphic horizons associated with Hutchinson salt (tertiary cap rock), and several internal units within the Arbuckle Group. Mapping of DST pressures revealed that the Arbuckle Group Saline Aquifer system is hydraulically connected to the Arbuckle exposure along the Missouri River near Jefferson City, Missouri, and that there is negligible surface recharge. Such hydraulic connectivity with the outcrop across 100s of miles indicates that the Arbuckle Saline Aquifer can be modeled as an open system in reservoir simulation studies. Lack of back pressure in this saline aquifer after disposal of huge volumes of produced brines for over 50 years supports the open system model of the Arbuckle. Salinity-depth plots indicate increasing salinity with depth in the Arbuckle Group Saline Aquifer. Depth constrained cluster analysis was conducted on petrophysical data from the Plant Disposal #10 well, in Sedgwick County, Kansas, to identify flow units in the Arbuckle Group Saline Aquifer. Based on these flow-units, a 9-layer reservoir model was constructed for a 9-Township area centered on the Plant Disposal #10 well. Initial simulation studies were conducted using estimated properties, and these demonstrated that low permeability (~ 0.001 md) shaly aquitards were capable of thwarting vertical migration of the CO_2 plume by deflecting it laterally along the updip direction, thus preventing accumulation of free-phase CO_2 under pressure under the primary cap rock. Regional gravity and

magnetic data has been processed and mapping of the basement structure is in progress. Remote sensing data from over 17+ counties have been analyzed and surface lineaments/faults have been mapped. Currently, gravity and magnetic analysis is being overlaid by structural mapping and remote sensing analysis to identify fault/fracture trends that may serve as conduits for sub-surface fluid movement to the surface or shallower horizons.

As part of the Wellington field study, all available wireline logs from Wellington field and adjacent Anson-Bates field have been acquired, scanned, and digitized. All available core analysis data from the above fields have been acquired and digitized for calibration with the wireline log data. Inventory of well completion histories along with production/injection data from Wellington field is 70% complete. Efforts are ongoing to find production/injection data for missing periods. Difficulty in reconstructing production/injection histories is common for fields such as Wellington which has changed ownership through time. Approximately 12 mi^2 of 3D multi-component seismic survey has been acquired over Wellington field, and the collected data has been processed.

Initial 3D geocellular models of Mississippian structure, thickness, and porosity have been completed, while structural mapping of the underlying Arbuckle and identification and correlation of constituent flow-units within Mississippian and Arbuckle are in progress. The newly collected 3D data at Wellington field has been successfully merged with existing (donated) 3D data from adjacent Anson-Bates field, and initial processing of P-wave seismic data at Wellington field has been completed. Interpretation of the merged P-wave seismic volume is currently in progress while the Mississippian time-structure and amplitude maps have been completed. Work on volumetric coherency attribute analysis has started. The initial geomodel and the P-wave interpretation were used to select two locations for drilling test boreholes #1 and #2 such that representative sections of both the Mississippian and the Arbuckle along with their respective cap rocks are available for coring. Based on the seismic interpretation, the Arbuckle zone appears stable at both selected locations, and this is expected to minimize core recovery problems.

At present, the industry partner (BEREXCO, Inc.) is completing legal formalities with landowners and obtaining permits to start drilling the 1st test borehole. The BEREXCO rig is scheduled to move into location in the 3rd week of November, 2010 and will stay in Wellington field for the next 3 months to complete drilling of both test boreholes.

Gantt Chart – Enclosed (Appendix B).

Milestone Chart for 2010

KGS Milestone 1.1: Hire geology consultants for OPAS modeling

Planned completion date: 3/31/2010

Actual completion date: 3/31/2010

Validation: Completed

KGS Milestone 1.2: Acquire/analyze seismic, geologic and engineering data - Wellington field

***Planned completion date*:** 6/30/2010

Actual completion date: Ongoing

Validation: 90% Completed (Geologic data acquired. Seismic data acquired and analysis in progress. Discovery of production/injection data in progress)

KGS Milestone 1.3: Develop initial geomodel for Wellington field

Planned completion date: 9/30/2010

Actual completion date: 9/30/2010

Validation: Completed

Summary of Current Financial Status

Planned vs. Actual - DOE Expenditures

Qtr	Planned DOE	Actual DOE
Dec-09	**$1,273.10**	**$4,019.93**
Mar-10	**$330,271.41**	**$84,603.97**
Jun-10	**$330,271.41**	**$494,428.37**
Sep-10	**$1,302,953.72**	**$111,405.52**

Planned vs. Actual - non-DOE cost match

As of Oct 20, 2010:

Budgeted Cost Match	Actual Cost Match
$1,109,043	$84,564

Note: KUCR calculates cost-match bi-annually. The above figures are current as of Oct 20, 2010 and will be revised at the end of the BP-1.

Plans for Upcoming Budget Period (~ 1-2 pages) (Summarize work to be completed in the next Budget Period from both a technical and management perspective)

BP-1 tasks to be completed by end of BP-1:

Task 4: Preparation, Drilling, Data Collection and Analysis – Test borehole #1

Subtask 4.3. Drill, core, DST
Subtask 4.4. Log
Subtask 4.5. Completion
Subtask 4.6. Log analysis
Subtask 4.7. Perf, test, and sample fluids

BP-1 tasks to be completed during BP-2:

Task 4. Preparation, Drilling, Data Collection and Analysis – Test borehole #1

Subtask 4.8. Analyze Arbuckle core
Subtask 4.9. Analyze Mississippian core
Subtask 4.10. PVT - oil & water
Subtask 4.11. Geochemical analysis of water samples
Subtask 4.12. Microbiological studies on produced water
Subtask 4.15. 2D shear wave survey
Subtask 4.16. Process & interpret 2D shear

Task 5. Preparation, Drilling, Data Collection and Analysis – Test borehole #2

Subtask 5.1. Locate (confirm based on test borehole #1 log/core)
Subtask 5.2. Permit
Subtask 5.3. Drill & DST
Subtask 5.4. Log
Subtask 5.5. Case, cement, perforate, test and sample fluids
Subtask 5.6. Analyze log

BP-2 tasks to be completed during BP-2

Task 2. Characterize the OPAS

Subtask 2.5. Gather and interpret KGS's gravity and magnetic data
Subtask 2.6. Remote sensing analysis for lineaments

Task 6: Update Geomodels

Subtask 6.1. Hydrogeologic studies

Subtask 6.2. Revise 3D seismic interpretation
Subtask 6.3. Update geomodel - Arbuckle & Mississippian

Task 7: Evaluate CO_2 Sequestration Potential in Arbuckle Group Saline Aquifer

Subtask 7.1. CO_2 sequestration potential
Subtask 7.2. Long-term effectiveness of cap rock
Subtask 7.3. CO_2 sequestered in brine
Subtask 7.4. CO_2 sequestered as residual gas
Subtask 7.5. CO_2 sequestered by mineralization
Subtask 7.6. Field management - max CO_2 entrapment
Subtask 7.7. Monte Carlo - total CO_2 sequestration capacity

Task 8. Evaluate CO_2 Sequestration Potential in Depleted Wellington field

Subtask 8.1. CO_2-EOR potential
Subtask 8.2. Long-term effectiveness of cap rock
Subtask 8.3. CO_2 sequestered in brine and residual gas
Subtask 8.4. CO_2 sequestered by mineralization

Funds from BP-1 to be used in BP-2 and the reasons for delay

Subtask 2.2: **Log digitizing – $32,493**
Only $5,507 of the $38,000 allocated to digitize wireline logs of key wells was used in BP-1. The remaining $32,493 will be used in BP-2 to complete the digitizing. This task includes defining key wells, scanning, organizing transmittal instructions and lists of scans to be digitized, and proofing, merging, and adding header information to each new digital file. This took several more months to complete, in addition to the actually digitizing, because of difficultly obtaining the paper logs for a large number of wells.

Subtask 3.4: **Collect gravity and magnetic data - $24,120**
The high resolution gravity data has been acquired at the Wellington field in BP-1. The magnetic survey could not be completed at the time of the gravity survey because of tool failure. The magnetic survey is therefore scheduled to be completed, along with the 2D shear survey, in early 2011, after drilling of the test boreholes. This same vendor used for acquiring the gravity survey and the 2D shear will carry out the magnetic survey to address surface velocity variations.

Task 4: Preparation, Drilling, data collection and analysis of test borehole #1 - $1,399,740
The test borehole #1 is scheduled to be drilled in late November, 2010, and industry partner BEREXCO has already reserved their rig for this task. The drilling and coring is expected to take about 40 days, and thus the invoices related to this activity will be processed in BP-2. Drilling of test borehole #1 was delayed because of extra time required to complete the processing and interpretation of the

newly acquired 3D seismic survey at Wellington field in order to successfully resolve questions related to complex geology.

Subtasks 4.8, 4.9, 4.10, 4.11: Analyze Arbuckle and Mississippian cores, PVT of oil & water samples - $365,873

The above mentioned subtasks can be carried out only after test borehole #1 has been drilled, cored, and sampled for fluids. The drilling of the test borehole #1 has been delayed from the original July to September, 2010 window to late November, 2010 because the processing of newly acquired 3D seismic volume took more time than expected due to reservoir complexity. Thus, the above tasks are rescheduled to be completed during early part of 2011.

Subtasks 4.15 and 4.16: 2D shear wave survey, and process & interpret 2D shear - $86,170

The 2D shear wave survey is dependent on the location of the two test boreholes. These subtasks have been delayed due to delay in identifying the locations for the test boreholes. This survey will therefore be carried out after the drilling of test borehole #1 and is therefore scheduled for completion in early 2011.

Task 5. Preparation, Drilling, data collection and analysis of test borehole #2 (Subtasks 5.1 to 5.6) - $739,395

This task has been delayed due to the delay in drilling the test borehole #1. The same rig will be used to drill both test boreholes #1 & #2 to reduce mobilization and de-mobilization costs. Industry partner has scheduled their rig to move on to location of test bore-hole #1 in late November 2010, and thus the test bore-hole #2 is scheduled for drilling in early 2011.

Reservoir Simulation: CMG simulator rental and consulting - $89,952

Some initial reservoir simulation studies were scheduled for BP-1 after obtaining wireline log data for the Arbuckle Group Saline Aquifer from test boreholes #1 and #2. However, these simulation studies have been rescheduled to BP-2 because of the delay in drilling of the above mentioned test boreholes.

Thin section preparation - $ 5,000

Funds allocated in BP-1 to prepare thin sections will be used in BP-2 after acquiring cores from the test borehole #1.

LIST OF FIGURES

obtained from remote sensing analysis using Landsat imagery.

Figure 10. Initial 3D Petrel geomodel showing porosity distribution in the Mississippian oil reservoir at Wellington Field that is the focus of evaluation for carbon dioxide enhanced oil recovery.

Figure 11. (on left) Arbitrary seismic profile through main portion of Wellington Field identifying main seismic reflectors and location of Test Borehole #1 and #2. Test boreholes are in structurally high positions for both the Mississippian and Arbuckle in areas with more continuous seismic reflectors. (on right) Seismic time section on the top of Mississippian seismic reflector showing location of arbitrary seismic profile shown on the left and the location to Test Borehole #1 and #2. Hachured green lines depict area with common dual reflectors in the upper Mississippian suggesting a more homogeneous porous reservoir, also indicated by the 3D Petrel porosity geomodel shown in Figure 10.

APPENDIX A

CONTROL ID: 986344

TITLE: Evaluation of CO2 Sequestration Potential in Ozark Plateau Aquifer System (OPAS) in southern Kansas – Initial Studies

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5. Department of Geology, Wichita State University, Wichita, KS, United States.
6. Department of Geology, Kansas State University, Manhattan , KS, United States.
7. Hedke-Saenger Geoscience, Ltd., Wichita, KS, United States.
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10. Geological Consultant, Houston, TX, United States.

ABSTRACT BODY: The Paleozoic-age Ozark Plateau Aquifer System (OPAS) in southern Kansas is centrally located to multiple major point sources of CO2 emissions and is considered a prime candidate for CO2 sequestration. The OPAS consists of the thick (>800 ft) and deeply buried (>3500 ft) Arbuckle Group saline aquifer and overlying Mississippian carbonate reservoirs, such as Wellington field (Sumner County), many of which are in various stages of depletion. The Arbuckle saline aquifer consists of siliceous dolomite with interbedded shales, and appears to be well suited for supercritical CO2 sequestration because multiple regional caprocks isolate it from shallow freshwater aquifers. Demonstration of CO2-EOR potential in depleted Mississippian fields should spur infrastructure development for commercial scale CO2 sequestration in the OPAS.

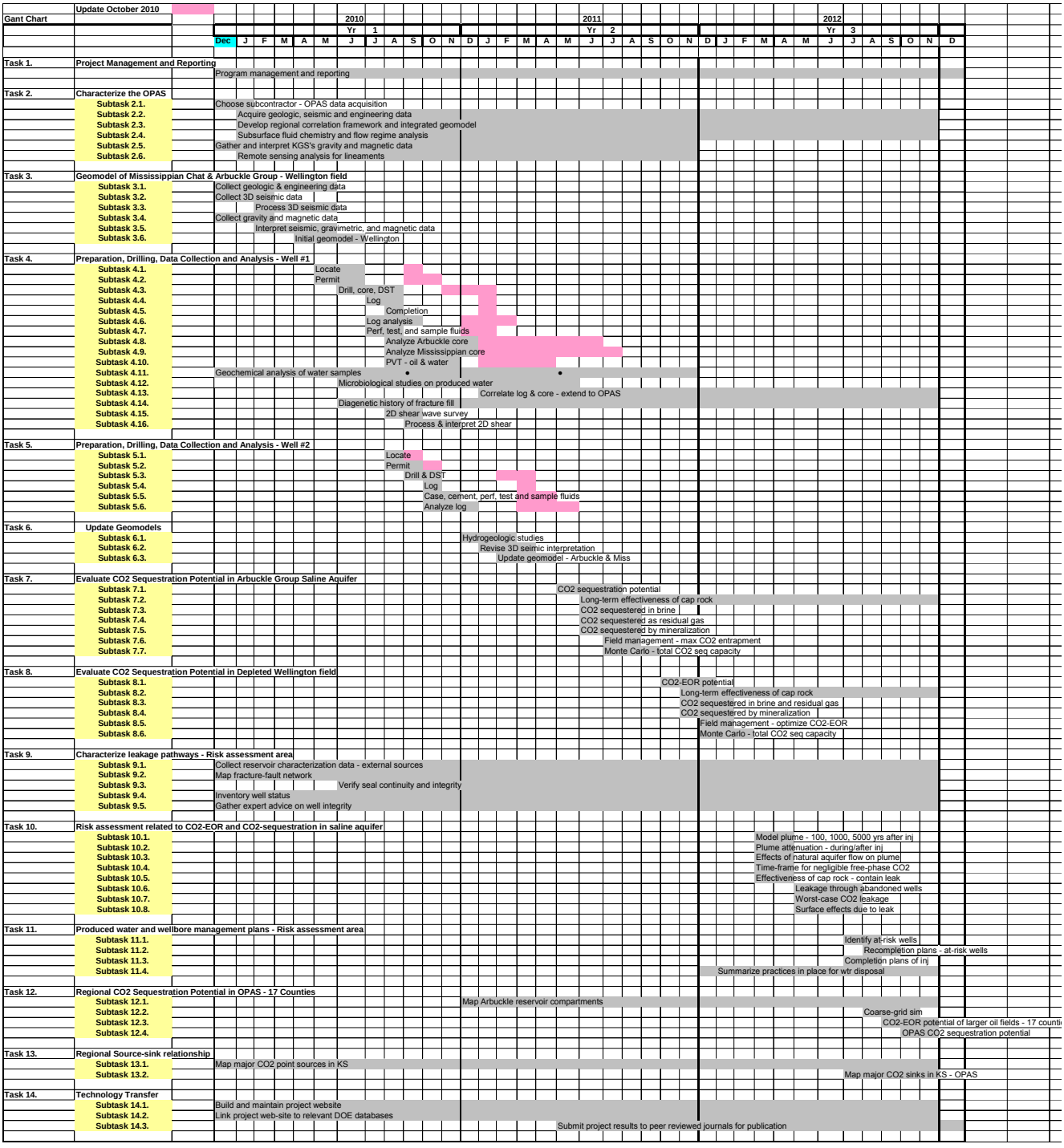
This study focuses on 1) developing a regional (≈ 20,000 mi2) geomodel for the Arbuckle saline aquifer, 2) constructing a local geomodel of the Mississippian reservoir and the underlying Arbuckle saline aquifer at Wellington field, 3) estimating the CO2 sequestration capacity of the OPAS, and 4) evaluating CO2-EOR potential of Wellington field. The regional Arbuckle geomodel was constructed utilizing wireline logs from 95 type wells and 1400 key wells, 5 cores, DSTs, and gravity/magnetic and remote sensing data. The detailed Wellington geomodel integrates existing geologic and engineering data with newly acquired data: multi-component 3D seismic survey (10 mi2), gravity/magnetic surveys, and core and wireline logs from 2 wells drilled to basement.

The regional Arbuckle geomodel has helped to understand factors, such as lateral continuity of Arbuckle strata including caprocks and shale beds, and relationship between underpressurization and hydraulic connectivity to the outcrop (northwestern flank of Ozark Uplift), critical to modeling sequestration capacity of the OPAS. Arbuckle flow units, indentified by depth-constrained cluster analysis of petrophysical data and mapped over a 9-Township area over a monoclinal structure, were used in simulation studies, with CO2 injected in bottom Arbuckle flow unit, to demonstrate sequestration of significant tonnage of CO2 by solution, residual gas saturation, and mineralization. Intermediate shaly layers in Arbuckle appear to prevent vertical migration of free-phase CO2 to the lowermost caprock. Simultaneous brine injection from shallow Arbuckle flow-units increased residual gas trapping of CO2.

CURRENT THEME: Theme 10: Energy and Environmental Horizons: Creating Growth

CURRENT SUB-CATEGORY: 5) (DEG) CO2 capture and sequestration

APPENDIX B



Gantt Chart of the project including modification to original schedule (pink bars) to acquire test borehole #1 with completion dates for test borehole permit, drill site selection, drilling, completion, data collection, and well abandonment.

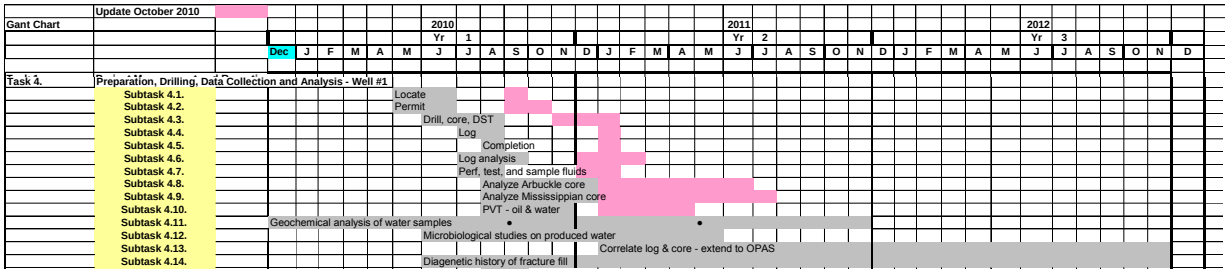


Figure 1 -- Portion of Gantt Chart of project showing modification to original schedule to acquire test borehole #1 with completion dates for test borehole permit, drill site selection, drilling, completion, data collection, and well abandonment.

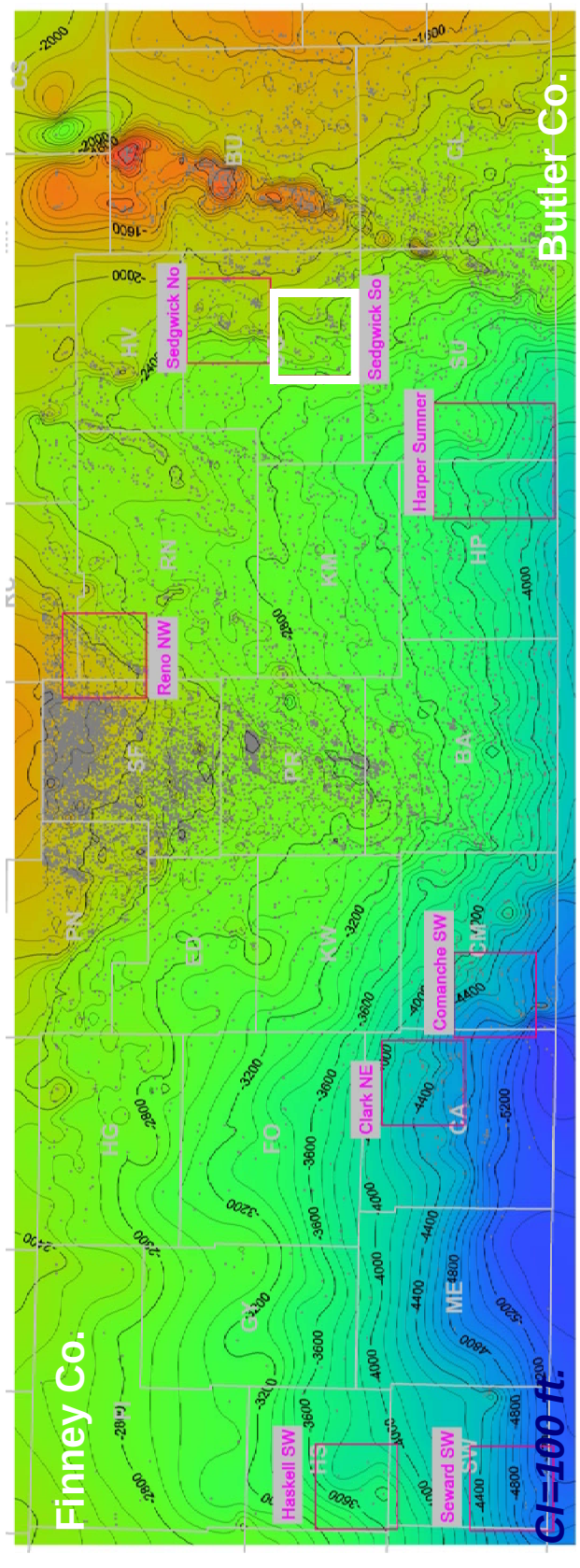
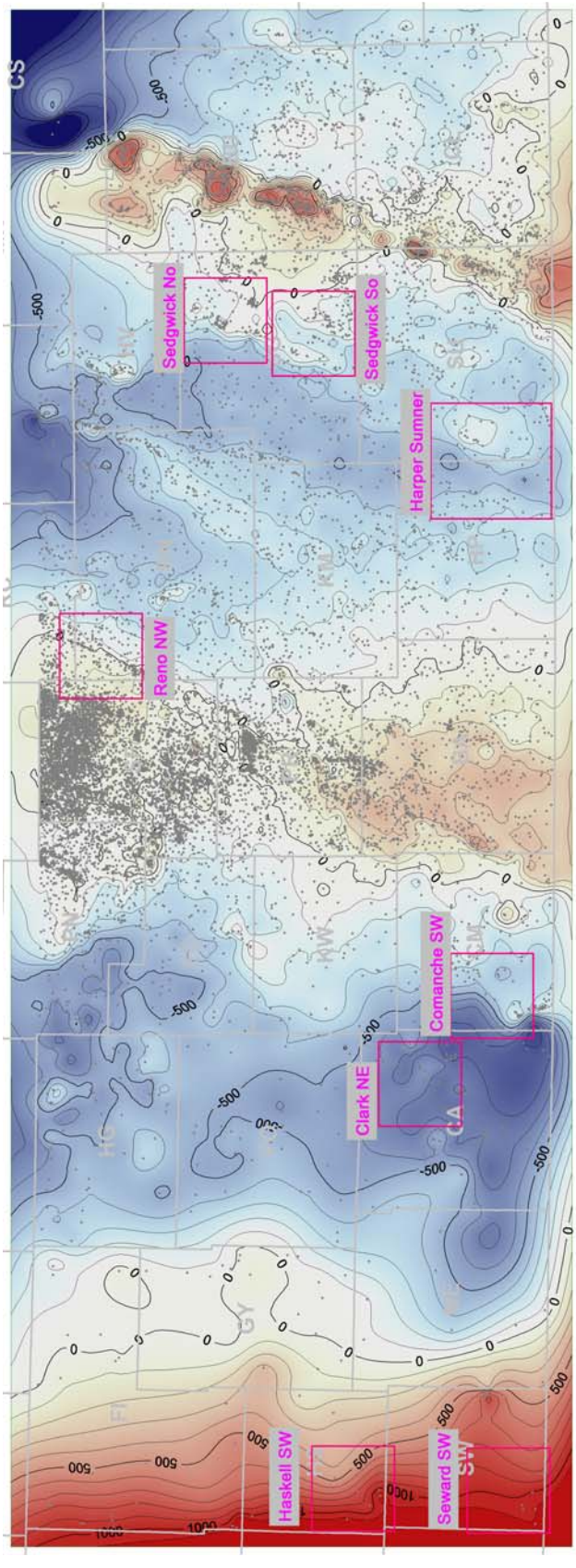

Butler Co.
Finney Co.
CI=100 ft.
Sedgwick No
Sedgwick So
Harper Sumner
Reno NW
Comanche SW
Clark NE
Haskell SW
Seward SW

Figure 2.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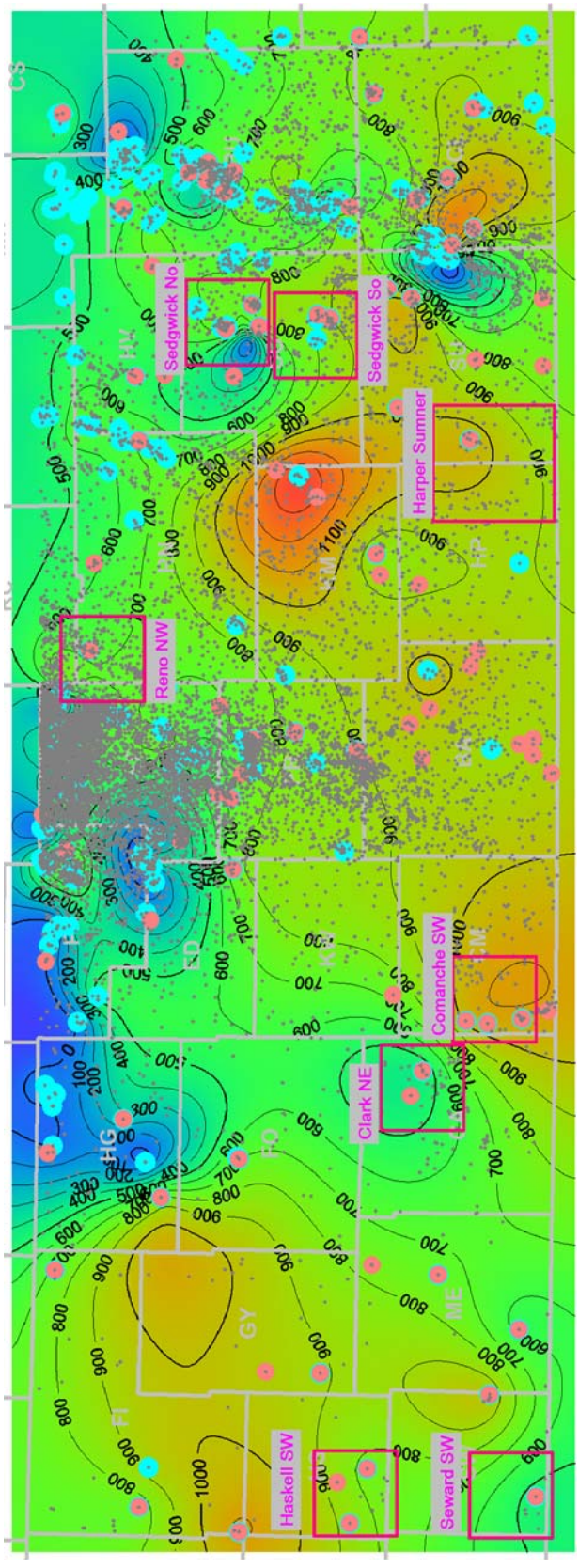
Sedgwick So
Harper Sumner
Reno NW
Comanche SW
Clark NE
Haskell SW
Seward SW

Figure 3.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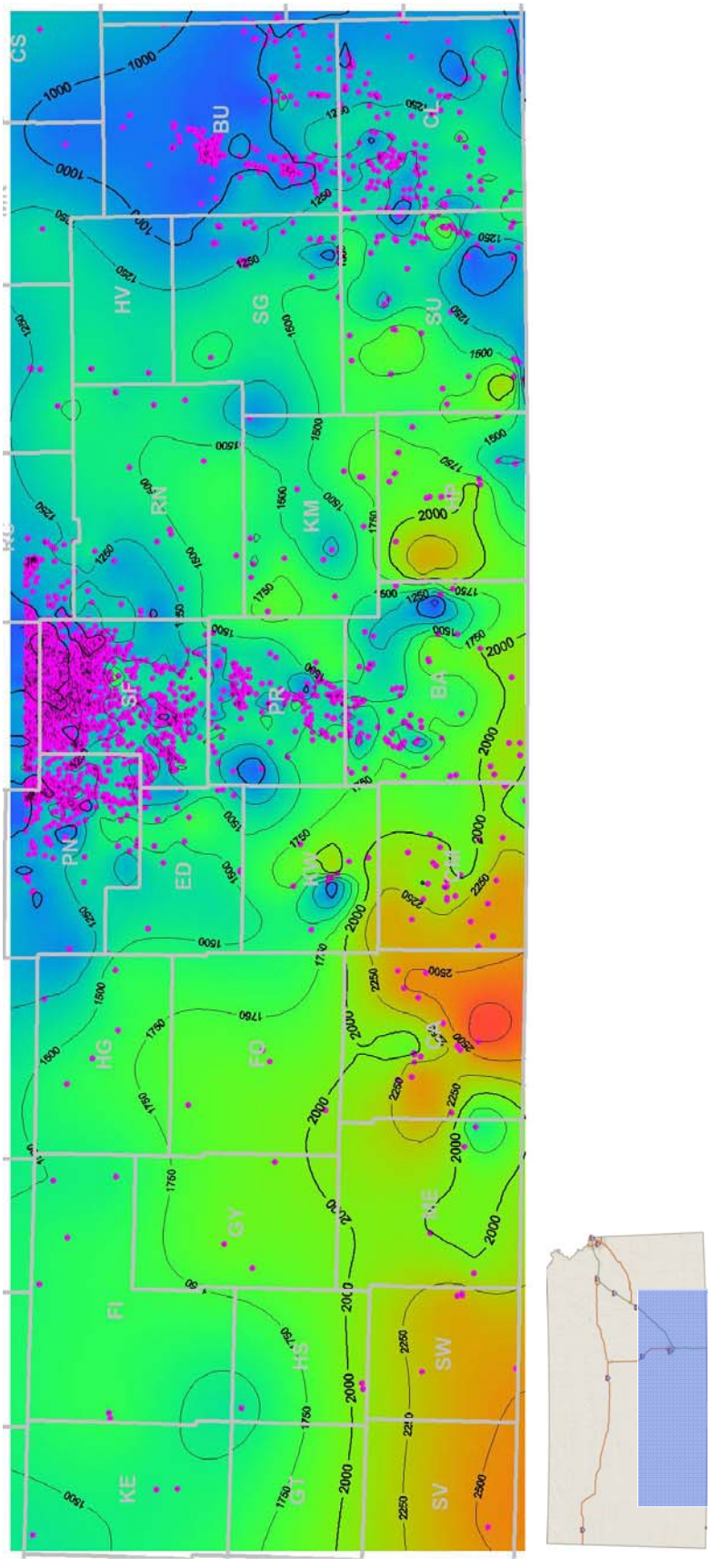
Sedgwick So
Harper Sumner
Reno NW
Comanche SW
Clark NE
Haskell SW
Seward SW

Figure 4.



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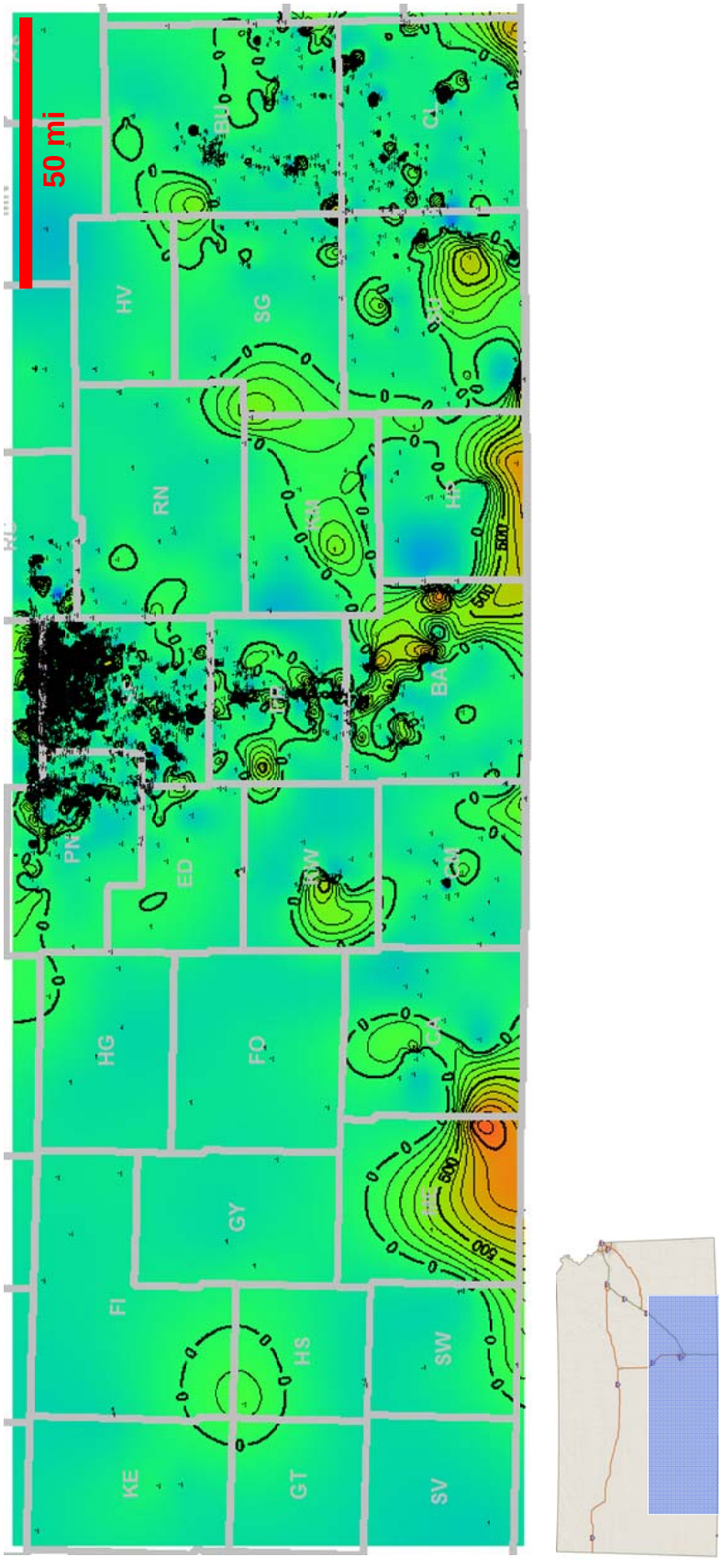
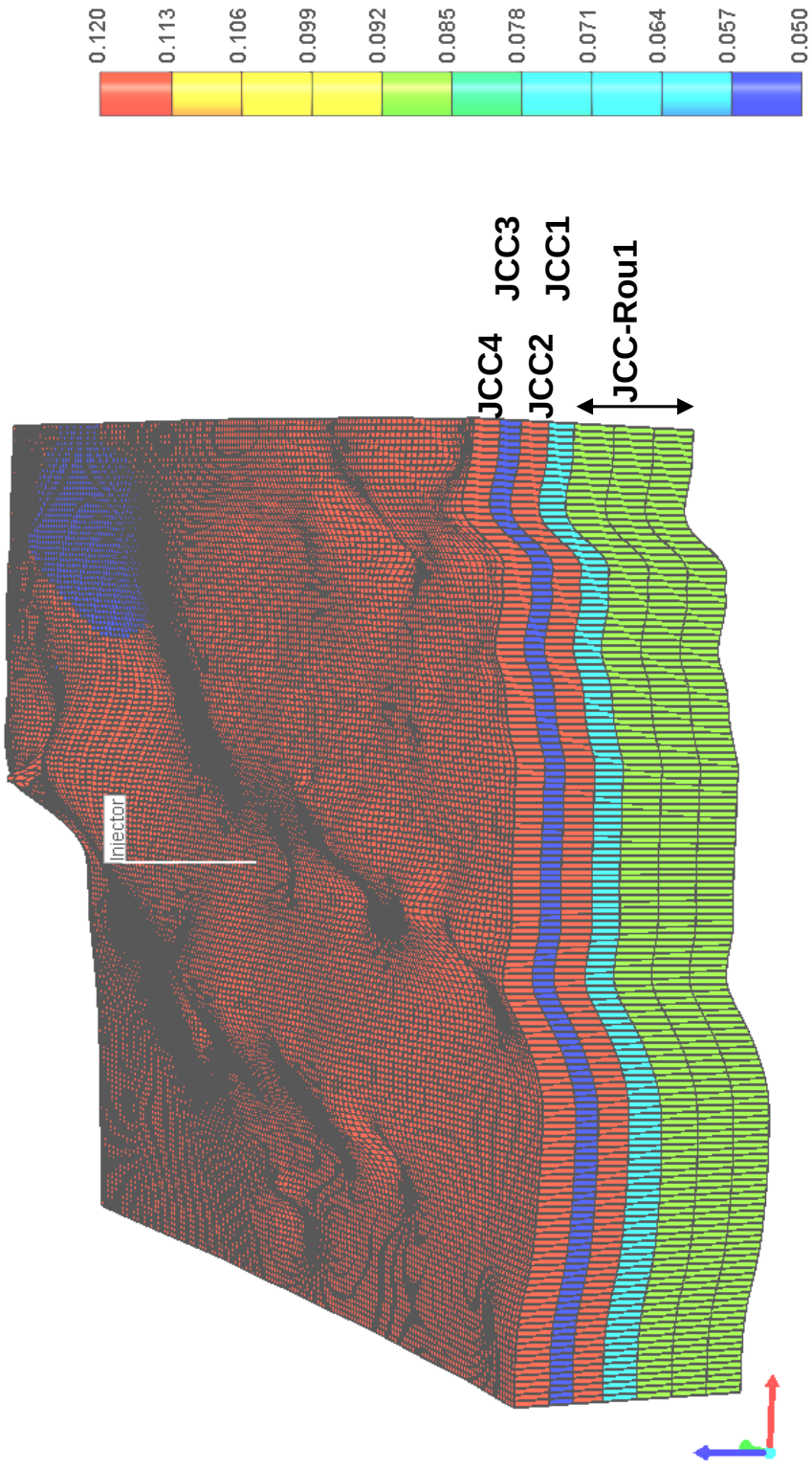


Figure 6.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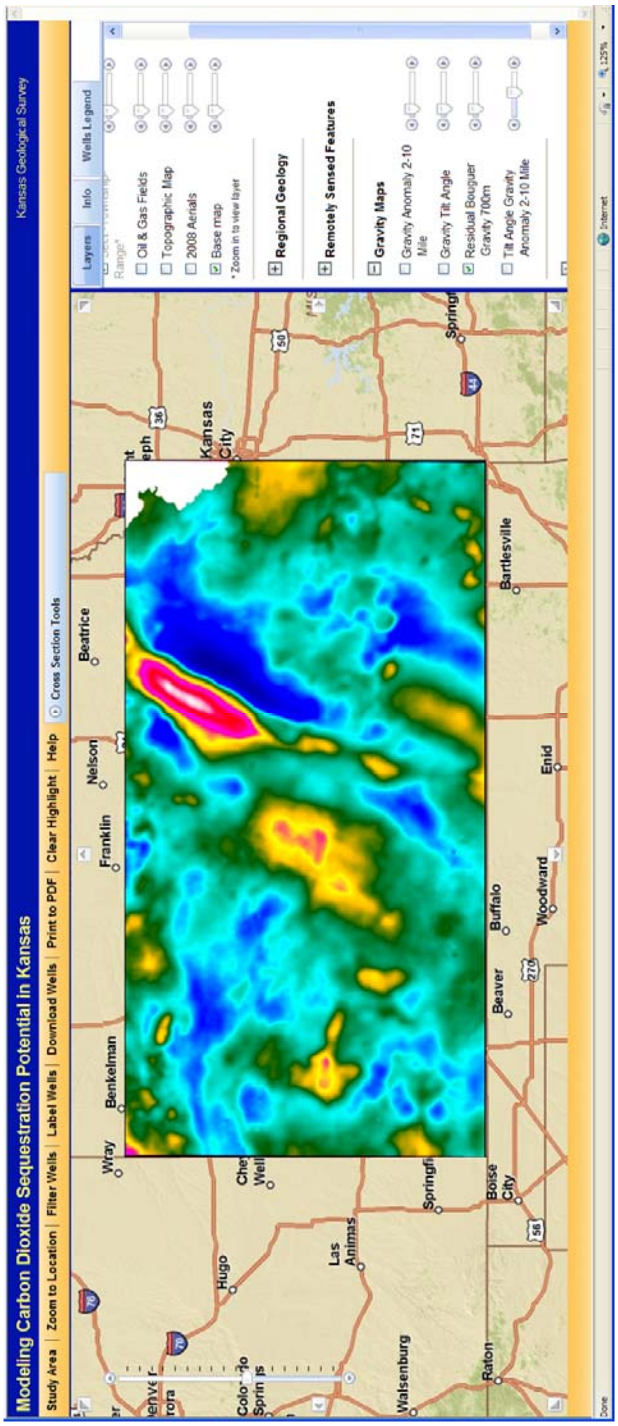
0.113
0.106
0.099
0.092
0.085
0.078
0.071
0.064
0.057
0.050
JCC4
JCC3
JCC2
JCC1
JCC-Rou1
Injector

Figure 7.


Modeling Carbon Dioxide Sequestration Potential in Kansas
Kansas Geological Survey
Study Area | Zoom to Location | Filter Wells | Label Wells | Download Wells | Print to PDF | Clear Highlight | Help
Cross Section Tools
Layers
Info
Wells Legend
Oil & Gas Fields
Topographic Map
2008 Aerials
Base map
Regional Geology
Remotely Sensed Features
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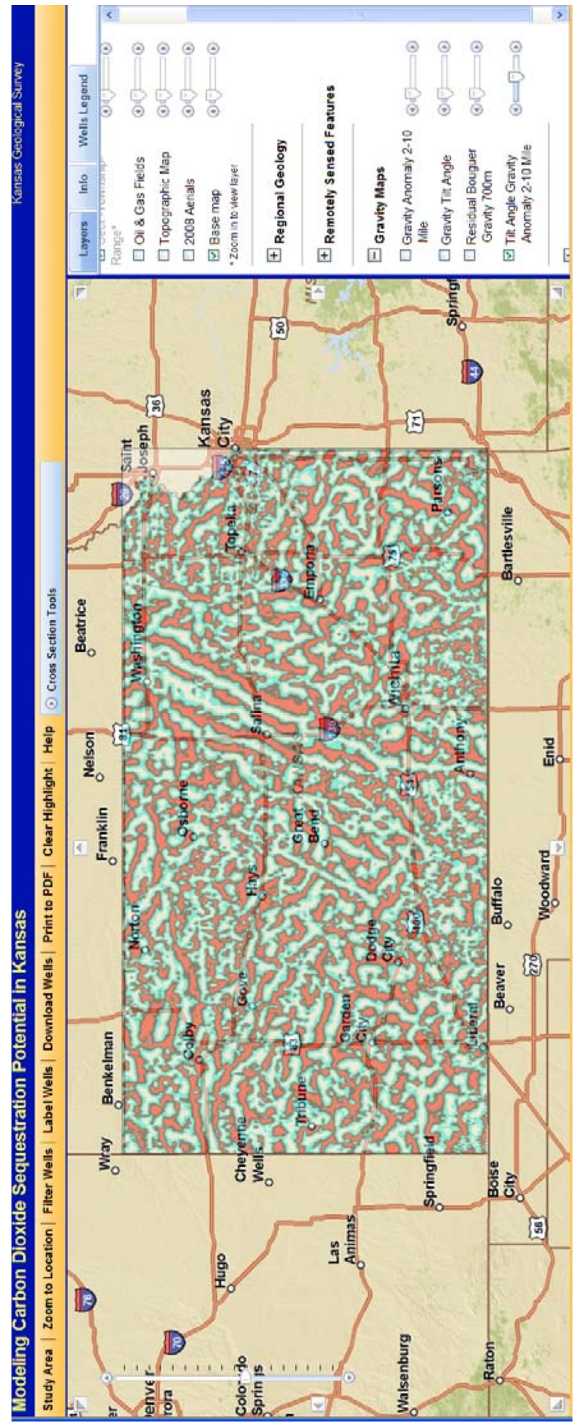
Gravity Anomaly 2-10 Mile
Gravity Tilt Angle
Residual Bouguer Gravity 700m
Tilt Angle Gravity Anomaly 2-10 Mile

A)


Modeling Carbon Dioxide Sequestration Potential in Kansas
Kansas Geological Survey
Study Area | Zoom to Location | Filter Wells | Label Wells | Download Wells | Print to PDF | Clear Highlight | Help
Cross Section Tools
Layers
Info
Wells Legend
Oil & Gas Fields
Topographic Map
2008 Aerials
Base map
Regional Geology
Remotely Sensed Features
Gravity Maps
Gravity Anomaly 2-10 Mile
Gravity Tilt Angle
Residual Bouguer Gravity 700m
Tilt Angle Gravity Anomaly 2-10 Mile

B)

Figure 8.

Southern Kansas – project area
Tilt-angle magnetic + Total magnetic field intensity +
Regional scale lineaments + Structure contour top Mississippian

Wellington Field

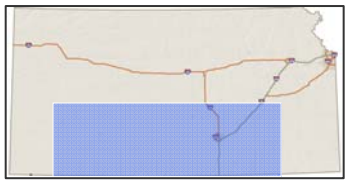


Figure 9.

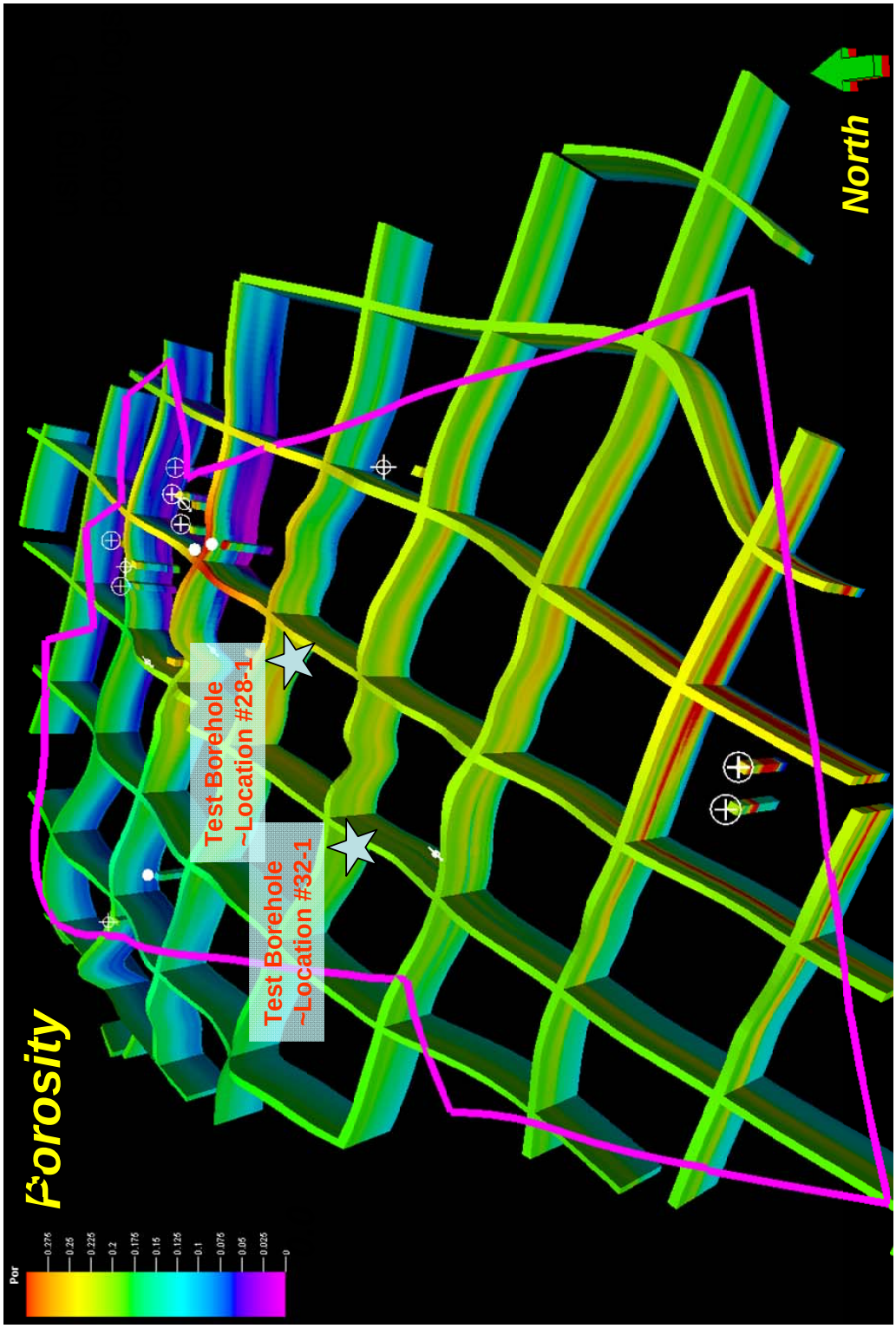

Porosity
Por
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
Test Borehole
~Location #28-1
Test Borehole
~Location #32-1
North

Figure 10.

Arbitrary Profile to Compare Test Borehole Locations

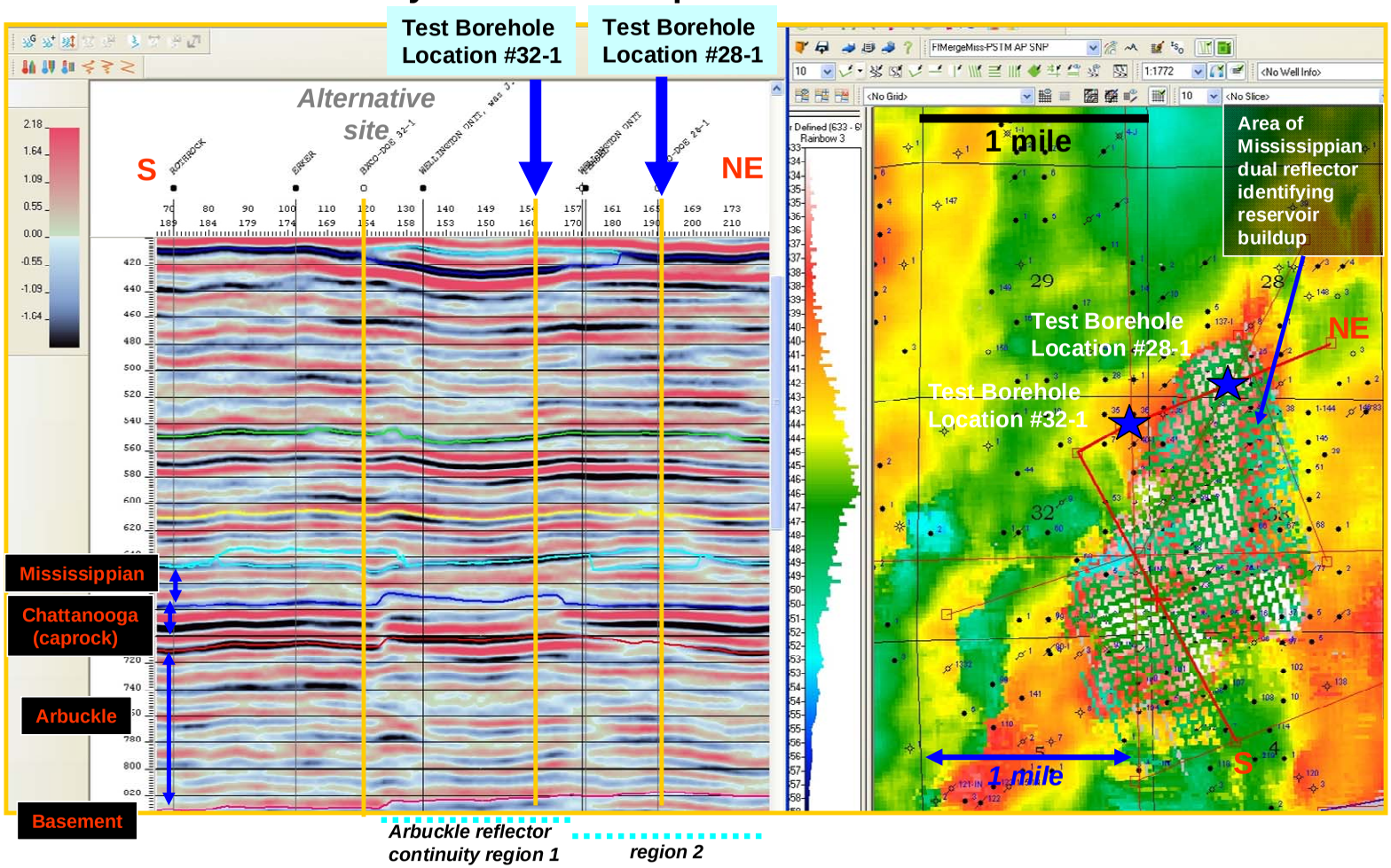


Figure 11.