Structural Kinematics and Mechanical Stratigraphy of the Pre-Pennsylvanian: Carbonate Research Opportunities to Augment DOE-funded Activities CO$_2$-Enhanced Oil Recovery (EOR) and Saline Aquifer Carbon Storage

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STATUS: Long-term DOE-funded project on carbon sequestration and EOR. Completing funded project by RPSEA on planning and evaluation horizontal drilling to revitalize mature field.
TIMING: Significant results currently available to membership on Mississippian horizontal drilling play and enhanced recovery with CO2-EOR and characterizing Lower Ordovician Arbuckle Group for brine and CO2 disposal.
FUNDING: Extend current DOE funding to topics of interest to membership

Purpose
New projects are invited from KICC membership to leverage a large and growing set of well and seismic data and findings being generated through the DOE-funded (DE-FE0002056) project titled, “Modeling CO$_2$ Sequestration in Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO$_2$ Sequestration Potential of the Western Interior Plains Aquifer System (WIPAS), South-Central Kansas and contract DE-FE0006821 “Small Scale Field Test Demonstrating CO$_2$ Sequestration in Arbuckle Saline Aquifer and by CO$_2$-EOR at Wellington Field, Sumner County, Kansas”. The WIPAS includes the thick (100s meters) and deeply buried (~1500m) Arbuckle Group and the overlying Mississippian siliceous carbonates and sandstones that contain large oil and gas reservoirs in southern and southwestern Kansas. These strata are also the focus of horizontal drilling in the same area and adjoining areas or Oklahoma in the Anadarko and Arkoma basins. Two pilot scale CO$_2$ injections are also slated for Wellington Field beginning in late summer 2015 and will be used to test reservoir models.

Background to DOE Projects -- The DOE study (DE-FE0002056) initiated in 2009 and extending through August 2014 is focused on defining the carbon sequestration capacity of the WIPAS (see above) in southern Kansas, an area encompassing in excess of > 25,000 mi$^2$. Six separate studies of oil fields are serving as sites to prove up for CO$_2$-EOR, as well as serving sites to calibrate the estimates of regional CO$_2$ sequestration through construction of detailed geomodels and fluid flow simulations. These field studies are acquiring an exhaustive sampling of rock and fluid data from long cores (two fields), accompanied by modern suite of wireline logs, reprocessing of large of amounts of existing seismic (>100 mi$^2$), and acquisition of two new 10mi$^2$ 3D multicomponent 3D seismic surveys. These data are complemented by regional and local remote sensing (Landsat) interpretation and reprocessed new and existing gravity and magnetic data to aid in developing an integrated geomodel of rock volume from the basement to surface.
Results are being used to evaluate physical, chemical, and biological properties of the CO₂ injection zones and overlying caprocks to establish optimum CO₂ injection rates and volumes, chemical reactions, and assessment of traps and seals to quantitatively model the short and long-term evolution of the CO₂ plume.

The pilot scale CO₂ injection at Wellington Field (Contract DE-FE0006821) will be used to advance the science and practice of carbon management by refining characterization and modeling and evaluating best practices for monitoring the performance of CO₂ injection.

**Project Description**

Newly assembled geologic and geophysical information from the DOE studies provide the basis for possible new regional and local research directed toward improved understanding of several high priority topics of interest to the petroleum industry. The rich datasets can serve as the basis for further research to better understand geologic controls that impact petroleum reservoirs. Studies could influence concepts that could lead to drilling models for use in other analogous areas.

**Structural kinematics and mechanical stratigraphy of the pre-Pennsylvanian**

To understand the systematics and significance of inherited structures (Figures 1, 2) as a means to forecast remaining petroleum plays, design of horizontal wells, and improve prediction of reservoir models.

_Hypothesis: The structural development during the pre-Pennsylvanian time has been documented to strongly impact the deposition and diagenesis of the pre-Pennsylvanian reservoirs, but the effects of pre-Pennsylvanian fractures, faults, and folds also imposed important controls on the latest structures that further influenced reservoir development. These structural complexities impose significant heterogeneity to carbonate reservoirs and will be applied to refining the reservoir model in Wellington Field._

Results from studies of the Kansas dataset clearly show episodically activated structural framework that needs systematic analysis in order to reconstruct events that have important implications from petroleum systems, reservoir play delineation, and reservoir management. A refined understanding of structural history will be applied to refining the reservoir model at Wellington Field to be tested with injection of CO₂ for improved recovery.

**Deliverables**

**Structural kinematics and mechanical stratigraphy of the pre-Pennsylvanian**

Regional digital well log data, available seismic data, newly re-processed state-wide gravity and magnetic data, and remote sensing in southern Kansas have been used to construct a basic structural and stratigraphic framework using conventional mapping and 3D modeling using Petrel. A collaboration with USGS staff and their modeling of the structural and stratigraphic petroleum system in the Anadarko Basin will be included as part of the synthesis. New studies to be defined by student and staff interest will focus on aspects of the systematic reconstruction and dynamic modeling of southern Kansas and northern Oklahoma. Details would also be established by areas of interest of participating companies.
Application of regional structural synthesis to aid in evaluating the influence of structure on the performance of pilot-scale CO2 injections at Wellington Field.

Results of structural modeling at Wellington will be evaluated during the CO2 injection. Monitoring methods will be used to evaluate the level of structural control vs. matrix controlled fluid flow.

**Selected References**


![Diagram](image)

**Figure 1.** Major Proterozoic rift-related and extensional faults that were affected by compressional tectonism during the Phanerozoic in the U.S.

Kansas Interdisciplinary Carbonates Consortium Prospectus – June 2015
Figure 2. Total magnetic field map of Kansas (upper right), isopach of Arbuckle Group annotated with study area in southern Kansas (right bottom), and digital log image profile of the lower Paleozoic stratigraphy in Wellington Field, Sumner County, KS.