I. Integrated Sequence Stratigraphy and Bio- and Chemo-
Stratigraphy of the Late Devonian-Mississippian strata – II.
Structural Kinematics and Mechanical Stratigraphy of the Pre-
Pennsylvanian: Carbonate Research Opportunities to Augment DOE-
funded Activities CO2-Enhanced Oil Recovery (EOR) and Saline Aquifer
Sequestration

W. Lynn Watney, John Doveton, Mina Fazelalavi, Eugene Holubnyak, Dave Newell, Jason
Rush, Ross Black, Evan Franseen, David Fowle, Robert Goldstein, Gene Rankey, Jennifer
Roberts, Mike Taylor, George Tsofilias

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, characterizing Lower Ordovician Arbuckle Group, and re-drilling Unger Field,
Marion Co., KS with horizontal well.
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 CO2 Sequestration in Saline Aquifer and Depleted Oil Reservoir to
Evaluate Regional CO2 Sequestration Potential of Ozark Plateau Aquifer System, South-
Central Kansas and contract DE-FE0006821 “Small Scale Field Test Demonstrating CO2
Sequestration in Arbuckle Saline Formation and by CO2-EOR at Wellington Field, Sumner
County, Kansas”. The Ozark Plateau Aquifer System (OPAS) is comprised of thick (100s
meters) and deeply buried (~1500m) Arbuckle Group saline aquifer and the overlying
Mississippian tripolitic chert, carbonate, and sandstone that contain large oil and gas
reservoirs in south-central 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. Small-scale injection will include 40,000 metric tons of CO2 into Arbuckle
and 30,000 metric tons into the Mississippian oil reservoir at Wellington Field, with detailed
dynamic modeling and monitoring methods employed.

Background to DOE Projects -- The DOE study (DE-FE0002056) initiated in 2009
and extending through August 2013 is focused on defining the carbon sequestration capacity
of the OPAS (see above) in southern Kansas, an area encompassing in excess of > 25,000
mi². Six separate studies of oil fields are serving as sites to prove up for CO2-EOR, as well
as serving sites to calibrate the estimates of regional CO2 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
mi2), and acquisition of two new 10mi² 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 CO$_2$ injection zones and overlying caprocks to establish optimum CO$_2$ injection rates and volumes, chemical reactions, and assessment of traps and seals to quantitatively model the short and long-term evolution of the CO$_2$ plume.

The small scale CO$_2$ injection project at Wellington Field (Contract DE-FE0006821) will continue through 2015. The project objectives are to advance the science and practice of carbon sequestration in the Midcontinent by refining characterization and modeling; evaluating best practices for monitoring, verification, and accounting; optimize methods for remediation and risk management; and provide technical information and training to enable additional projects.

**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 other analogous areas.

Two general topics are identified that have the highest potential for immediate success:

1) **Integrated sequence stratigraphy and bio- and chemo-stratigraphy of the Late Devonian-Mississippian strata** (Kaskaskia cratonic sequence) to develop predictive regional and local high-resolution correlation and mapping as a basis to refine petroleum plays in the Mississippian strata.

*Hypothesis: The stratal architecture and associated facies of the shale gas and oil and conventional hydrocarbon plays in this stratigraphic interval can be greatly refined with the integration surface and subsurface rocks, seismic data, and use of latest knowledge of bio- and chemo-stratigraphy.*

A new database consisting of digital well log data, sample, core, and cutting samples is being developed for the southern third of Kansas as part of the DOE project. In addition, a biostratigraphic study has recently been funded by KICC to combine prior results from surface exposures with the analysis of the Wellington #1-32 well that was drilled in 2011 for the DOE project. The entire pre-Pennsylvanian interval was cored in Wellington #1-32 serves as a baseline for the new, expanded project.

In addition, the biostratigraphy, well logs, and geochemical information from the KGS-OGS Current #1 core drilled in 2008 at Ada, Oklahoma from the southeastern corner of the Arkoma Basin will be integrated into this study. The core extends continuously from the base of the Pennsylvanian through the Mississippian Caney Shale, and through the Woodford Shale into the Devonian limestone.
2) 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 and aid the design of horizontal wells.

Hypothesis: The structural development during the pre-Pennsylvanian time has been documented to strongly impact the deposition and diagenesis of the pre-Penn reservoirs, but the effects of pre-Pennsylvanian fractures, faults, and folds also imposed important controls on the latest structures that further influenced reservoir development.

Preliminary results from the DOE studies clearly show early structures that were not reactivated at some later time, but were most significant in the development of pre-Pennsylvanian reservoir-quality strata. In contrast, some post Mississippian structures were episodically activated and affected younger reservoirs, seals, and also diagenetic events such as evaporite dissolution. The complex structural history needs to be deciphered in a systematic way and modeled to reconstruct events that have important implications for petroleum systems and remaining reservoir play delineation.

Regional high resolution mapping of logs and use of regional 3D seismic data in the DOE project and the Hugoton Field and related studies in western Kansas conducted by the KGS in the late 1990’s and early 2000’s provide an excellent basis for in-depth research to decipher and document the structures, impacts, and implications for petroleum exploration and development.

Deliverables
1) Integrated sequence stratigraphy and bio- and chemo-stratigraphy of the Late Devonian-Mississippian strata
The analysis of carbon, oxygen, and strontium isotopes is to be obtained on both cores described above to develop a chemo-stratigraphic framework for the Mississippian carbonate shelf margin and its adjoining basinal deposits. A regional correlation grid to be developed will tie the area together. Student and staff interest would define details of this study.

2) 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.

Selected References


**Figure 1.** Major Proterozoic rift-related and extensional faults that were affected by compressional tectonism during the Phanerozoic in the U.S.
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 Ozark Plateau Aquifer System and stratigraphy of key cored well in Sedgwick Basin (left side).