Evaluate CO$_2$ sequestration potential in Ozark Plateau Aquifer System (OPAS) in south-central KS - depleted oil fields and the deep saline Arbuckle aquifer

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Relevance of CO$_2$ Sequestration in Kansas

- Coal-fired power plants to produce for years
  - Need to address problem of CO$_2$ emissions
- DOE efforts to develop carbon capture and storage (CCS) infrastructure
- Initiatives of the Midwestern Governors Association
- CO$_2$-EOR – proven & reliable technology
  - Potential applications in many depleted KS fields
- Deep saline aquifers – has potential to sequester large volumes of CO$_2$
  - Arbuckle saline aquifer in KS
    - Is deep and thick
    - Underlies a large area in south-central KS
- Kansas centrally located to major CO$_2$ emitting states and cities
- With right incentives and government support CO$_2$ sequestration has the potential of becoming a major industry in KS
Geologic Sequestration of CO$_2$

Industry participation in infrastructure development possible if CO$_2$-EOR is viable

Global annual CO$_2$ emissions – $8 \times 10^9$ tons

*Bachu, 2003*

<table>
<thead>
<tr>
<th>Formation Type</th>
<th>$10^9$ Metric Tons</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saline Aquifers</td>
<td>3,297 – 12,618</td>
<td>91.8 – 97.5</td>
</tr>
<tr>
<td>Unmineable Coal Seams</td>
<td>157 – 178</td>
<td>4.4 – 1.4</td>
</tr>
<tr>
<td>Mature Oil &amp; Gas Reservoirs</td>
<td>138</td>
<td>3.8 – 1.1</td>
</tr>
<tr>
<td>Total Capacity</td>
<td>3,592 – 12,934</td>
<td>100.0</td>
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Potential Sequestration of CO2 in Saline Aquifers

http://www.natcarb.org/Atlas/ims_map.html
American Recovery & Reinvestment Act

DOE share: $4,974,352
Cost match by KGS and partners: $1,251,422

Principal Investigators: Dr. Lynn Watney & Saibal Bhattacharya

Duration: December 8, 2009 to December 7, 2012
Project Study Area
Wellington Field (Sumner County) + 17 Counties

Sunflower Electric, Holcomb (Garden City)
Arbuckle Core - TX World Op (disposal well)
Mississippian Chat Fields
Arbuckle Core - Occidental Chemical (brine injection)
Arbuckle Core - Frontier Refinery (El Dorado field)
Wellington Field (BEREXCO, INC.)
Project Objectives

- Build 3 geomodels
  - *Mississippian oil reservoir at Wellington field (Sumner County)* - depleted
  - *Arbuckle saline aquifer underlying Wellington field*
  - *Regional Arbuckle saline aquifer system over 17+ counties*

- Conduct simulation studies to estimate CO₂ sequestration potential in
  - *Arbuckle saline aquifer underlying Wellington field*
    - *Miscible CO₂ flood in Wellington field (along with incremental oil recovery)*

- Identify potential sites for CO₂ sequestration in Arbuckle saline aquifer - 17+ county area

- Estimated CO₂ sequestration potential of Arbuckle saline aquifer – 17+ county area

- Risk analysis related to CO₂ sequestration

- Technology transfer

*No CO₂ will be injected in this project*
Subjects Outside the Purview of this Project

- CO₂ capture from point sources
- CO₂ transmission – from source to injection sites

Other DOE projects, ongoing and future, relate to CO₂ capture and transportation.

KS companies are working on proposals including demonstration projects related to CO₂ sequestration by CO₂-EOR and injection into underlying saline aquifers.
Wellington field, Sumner CO

- Discovered in 1922 (134+ total wells)
- 44 active wells, 20.5 MM bbls (oil)
- Field owned by BEREXCO – unitized
- Excellent waterflood performance (no gas) – great CO$_2$-EOR candidate
- Arbuckle aquifer – 1050 ft thick (Mississippian top ~ 3650 ft, Arbuckle top ~ 4150 ft, Granite wash ~ 5100 ft)
- Considered for CO$_2$-EOR using CO$_2$ from Coffeyville plant
- Anson and Bates - 6 MM bbls oil (Mississippian Chat), 3D seismic donated by Noble Energy Corp
- All three fields together could sequester ~ 30 MM tons of CO$_2$
Data Collection & Analysis

- Geophysical surveys at Wellington field
  - 3D, Gravity/Magnetic, 2D shear

- Drill, core, log, and test Well #1 to basement – Wellington field
  - Collect water samples from different Arbuckle intervals

- Drill, log, and test Well #2 to basement – Wellington field
  - Collect water samples from different Arbuckle intervals

- Analyze Mississippian and Arbuckle core (Well #1) & PVT
  - Integrate core data with previously taken cores

- Geochemical studies on Arbuckle water – KSU Geology Dept.

- Analysis over 17 county area – Regional geomodel of Arbuckle system
  - Satellite imagery
  - Gravity and magnetic

- Cap rock integrity and micro-biological studies – KU Geology Dept.
Regional geomodel development of Arbuckle saline aquifer
Collect, process, interpret 3D seismic data - Wellington field
Collect, process, interpret gravity and magnetic data - Wellington field
Drill, core, log, and test - Well #1
Collect, process, and interpret 2D shear wave survey - Well #1
Analyze Mississippian and Arbuckle core
PVT - oil and water
Geochemical analysis of Arbuckle water
Cap rock diagenesis and microbiology
Drill, log, and test - Well #2
Complete Wellington geomodels - Arbuckle and Mississippian reservoirs
Evaluate CO2 sequestration potential in Arbuckle underlyiing Wellington
Evaluate CO2 sequestration potential in CO2-EOR in Wellington field
Risk assessment - in and around Wellington field
Regional CO2 sequestration potential in Arbuckle aquifer - 17+ counties
Technology transfer

No CO2 injection will take place in this project
What happens when super-critical CO$_2$ is injected into a saline aquifer?

1. Part of the injected CO$_2$ dissolves in the surrounding brine under pressure - **solution**

2. Part of injected CO$_2$ remains as **free-phase (gas) CO$_2$**
   - *Free-phase (gas) CO$_2$ rises to the top of the formation (being lighter)*

3. As free-phase (gas) CO$_2$ rises, additional CO$_2$ gets trapped in fine pores in the rock – **residual gas saturation**

4. Natural movement of water in the aquifer **dilutes** CO$_2$ in solution and in free phase

5. Over long term (100s and 1000s of years), some of the injected CO$_2$ gets trapped as **mineral precipitates** in the aquifer

Frio Pilot CO$_2$ injection Project, Texas
**In situ entrapment of injected CO₂**

Majority of injected CO₂ gets trapped as residual gas saturation followed by CO₂ dissolved in brine solution.

Our study will estimate the amount of CO₂ (tons) that will sequestered in various states using site-specific geology, rock, and water properties.

CO₂ mineralization is a slow process.

*Ozah, 2005 – In situ CO₂ distribution after 50 years of injection*
Risk Analysis – Potential leakage pathways

Faults and fractures will be mapped in the 17+ county study area:
1. Satellite imagery
2. Gravity/Magnetic
3. Structure maps

Site selection critical to minimize risks associated with CO₂ injection
Not all fractures/faults reach the surface – some do and need to be identified
Inventory of all plugged wells critical – REPLUG if needed.

Damen, 2003
Weyburn CO₂-EOR - Canada

Solid Green – fault trends from seismic & HRAM

Broken Green – trends from HRAM

Purple – surface lineaments

Red oval – Souris Valley fault (fault identified by seismic and HRAM coincide)

Broken Red – weak correlations between data sets

Not all Sub-surface faults/fractures reach the surface
Risk Analysis
Leakage Retardation – Multiple Caprocks & Aquitards

CO₂ plume undergoes pressure reduction and is trapped in the fine pores of caprocks and/or aquitards.
Additionally, KGS maps show that total evaporite thicknesses range from 400 to 2000 ft in south-central KS. These evaporites serve as ideal cap rocks.
Risk Analysis
Plume Intersects Inclined Fault – does not extend to surface

CO₂ leaks into fault and creates a “virtual CO₂ source”.

CO₂ migrates updip and gets attenuated – additional trapping in solution and as residual gas

Chang & Bryant, 2009
Risk Analysis
Plume Intersects Inclined Conductive Fault

If injection stops before plume reaches fault – then no leakage occurs.

How much CO$_2$ can be sequestered before plume reaches fault?

Is CO$_2$ sequestration tonnage economic?

Tsang et al., 2008
Every time the CO$_2$ plume met a thin shale layer, it spread out laterally. This lateral dispersion resulted in CO$_2$ dissolving into brine and getting trapped in fine pores of the rock.

Presence of similar thin shale layer (stratification) and aquitards are expected to be present in the Arbuckle aquifer system.
Yaggy Gas Storage Leak - 2001

Site selection for CO\textsubscript{2} sequestration CRITICAL, because all wells drilled in the area have to be accounted for and properly completed before onset of CO\textsubscript{2} injection.
CO$_2$ Sequestration Projects Worldwide
Deep Saline Aquifers

Michael et al., 2009
Cap CO₂ & Univ. of Utah will submit proposal to DOE for field scale CO₂-EOR in Apr 2010 with KGS as a partner