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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House Energy and Utilities Committee Meeting
Topeka
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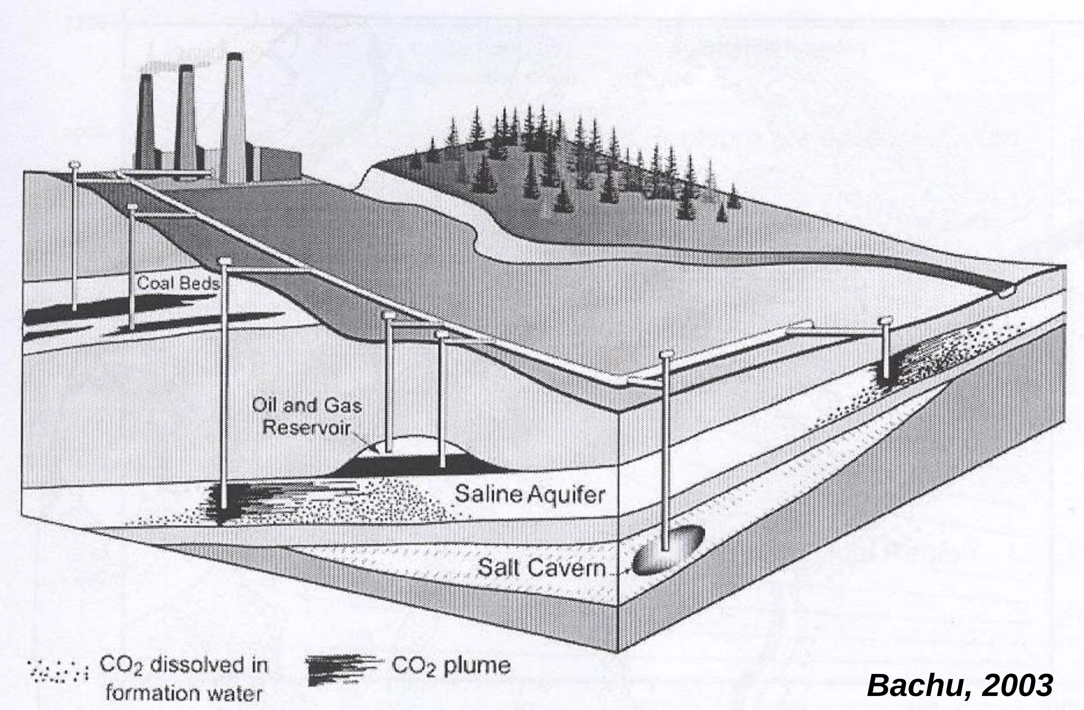
Relevance of CO_2 Sequestration in Kansas

- **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



Bachu, 2003

Industry participation in infrastructure development possible if CO_2-EOR is viable

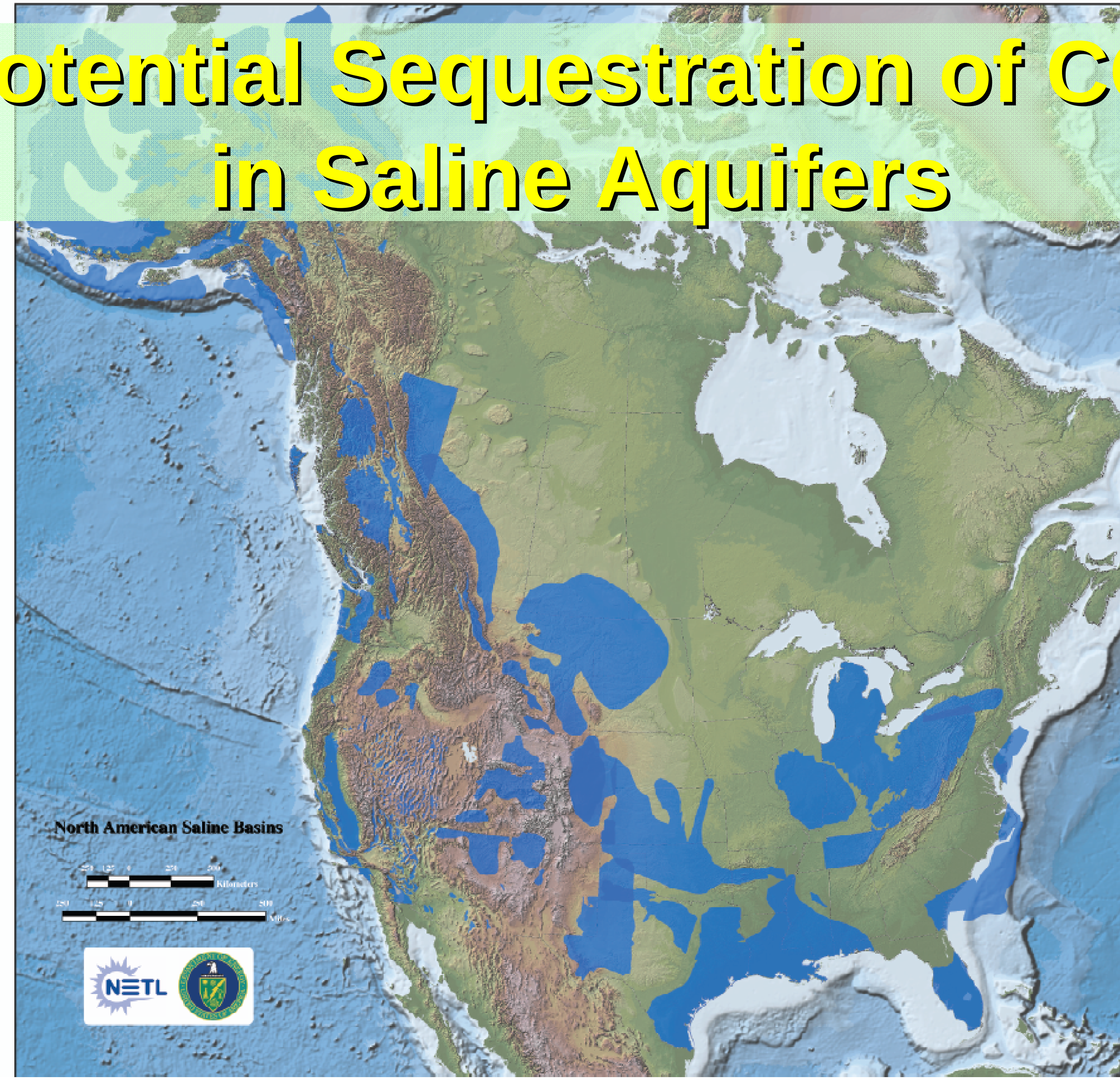
Global annual CO_2 emissions – 8 * 10^9 tons

Earth Policy Institute

Formation Type	10^9 Metric Tons	%
Saline Aquifers	3,297 – 12,618	91.8 – 97.5
Unmineable Coal Seams	157 – 178	4.4 – 1.4
Mature Oil & Gas Reservoirs	138	3.8 – 1.1
Total Capacity	3,592 – 12,934	100.0

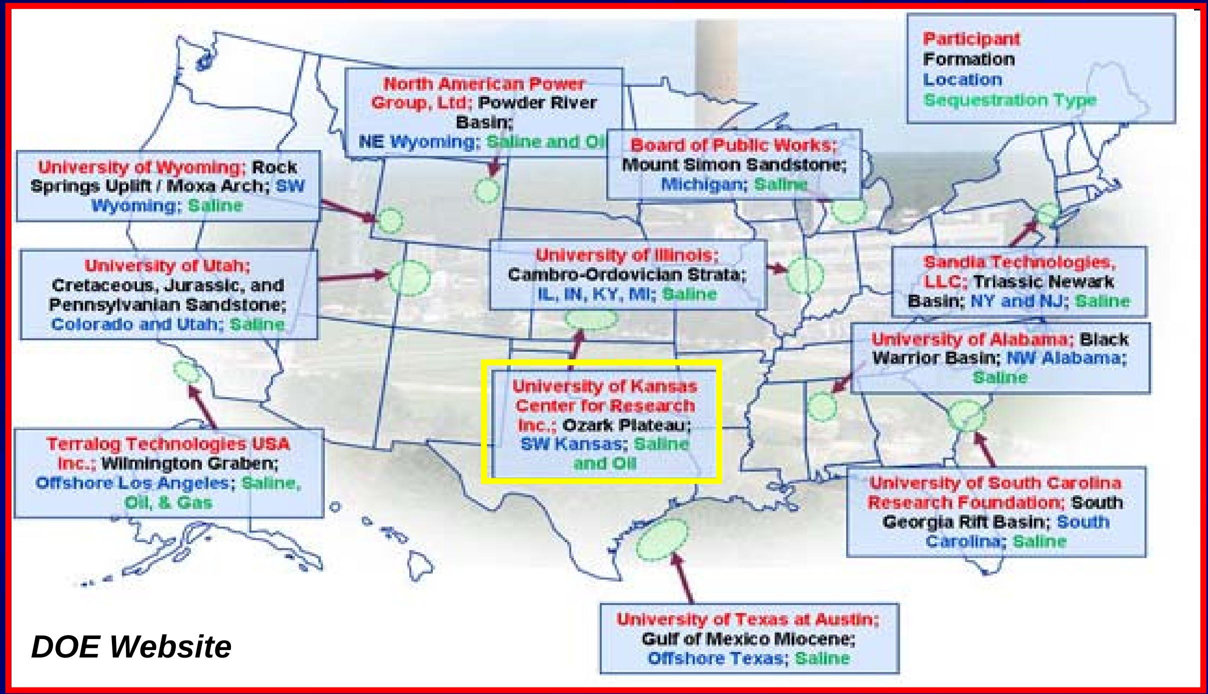
DOE & NETL, "Carbon Sequestration Atlas of the US and Canada", 2008

Potential Sequestration of CO2 in Saline Aquifers



http://www.natcarb.org/Atlas/ims_map.html

American Recovery & Reinvestment Act



DOE Website

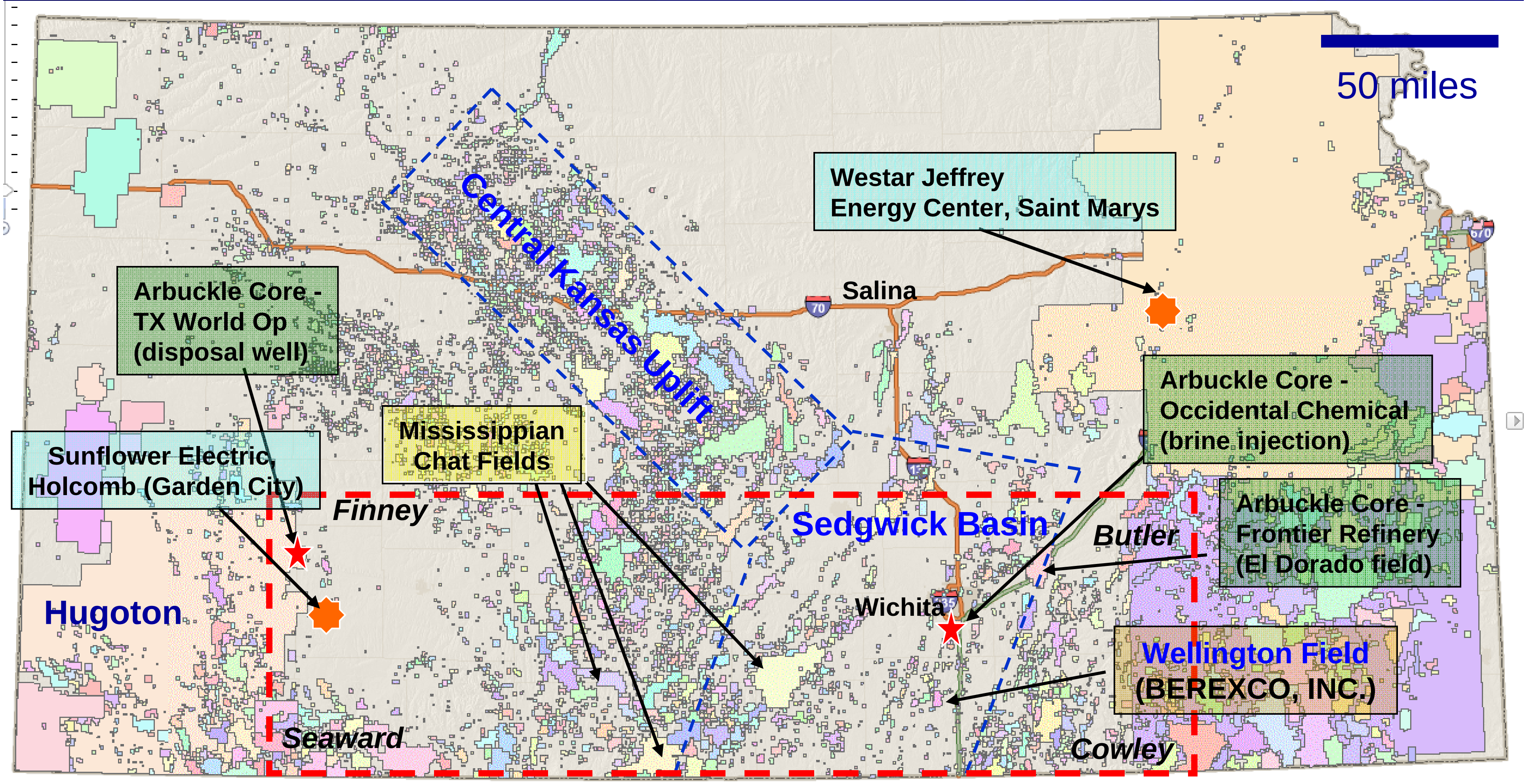
DOE share: $4,974,352
Cost match by KGS and partners: $1,251,422

Principal Investigators: Dr. Lynn Watney & Saibal Bhattacharya

Duration: December 8, 2009 to December 7, 2012

Project Study Area

Wellington Field (Sumner County) + 17 Counties



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 CO_2 sequestration potential in**
  - *Arbuckle saline aquifer underlying Wellington field*
  - *Miscible CO_2 flood in Wellington field (along with incremental oil recovery)*
- **Identify potential sites for CO_2 sequestration in Arbuckle saline aquifer - 17+ county area**
- **Estimated CO_2 sequestration potential of Arbuckle saline aquifer – 17+ county area**
- **Risk analysis related to CO_2 sequestration**
- **Technology transfer**

No CO_2 will be injected in this project

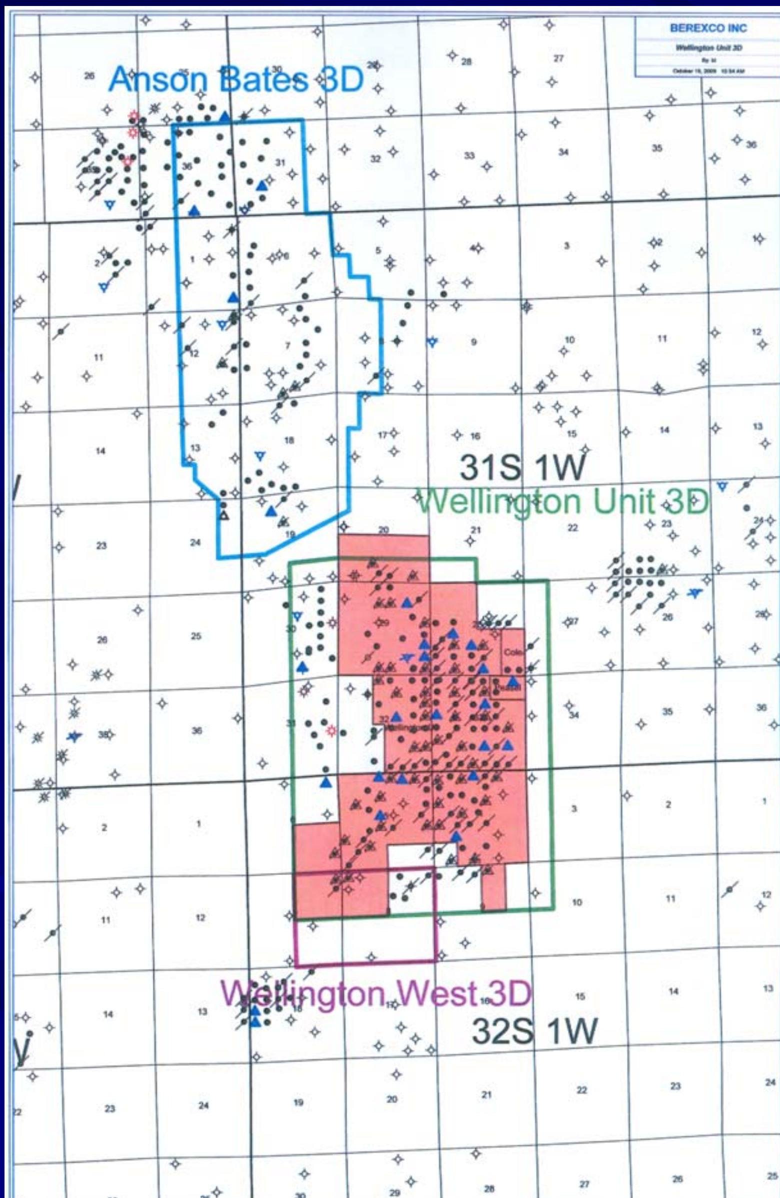
Subjects Outside the Purview of this Project

- CO_2 capture from point sources
- CO_2 transmission – from source to injection sites

Other DOE projects, ongoing and future, relate to CO_2 capture and transportation.

KS companies are working on proposals including demonstration projects related to CO_2 sequestration by CO_2-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.

Project Time Line

	Year 1	Year 2	Year 3
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 underlying 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			

Data Collection

CO_2-Seq Potential - Wellington

CO_2 Seq Potential - Arbuckle 17+ Counties

No CO_2 injection will take place in this project

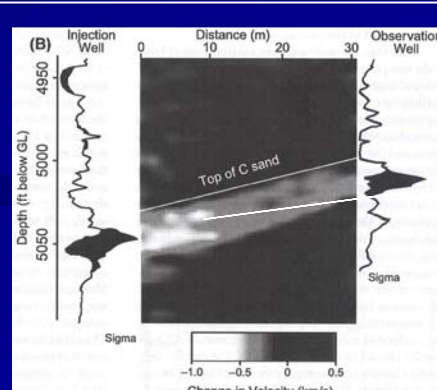
What happens when super-critical CO_2 is injected into a saline aquifer?

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)*

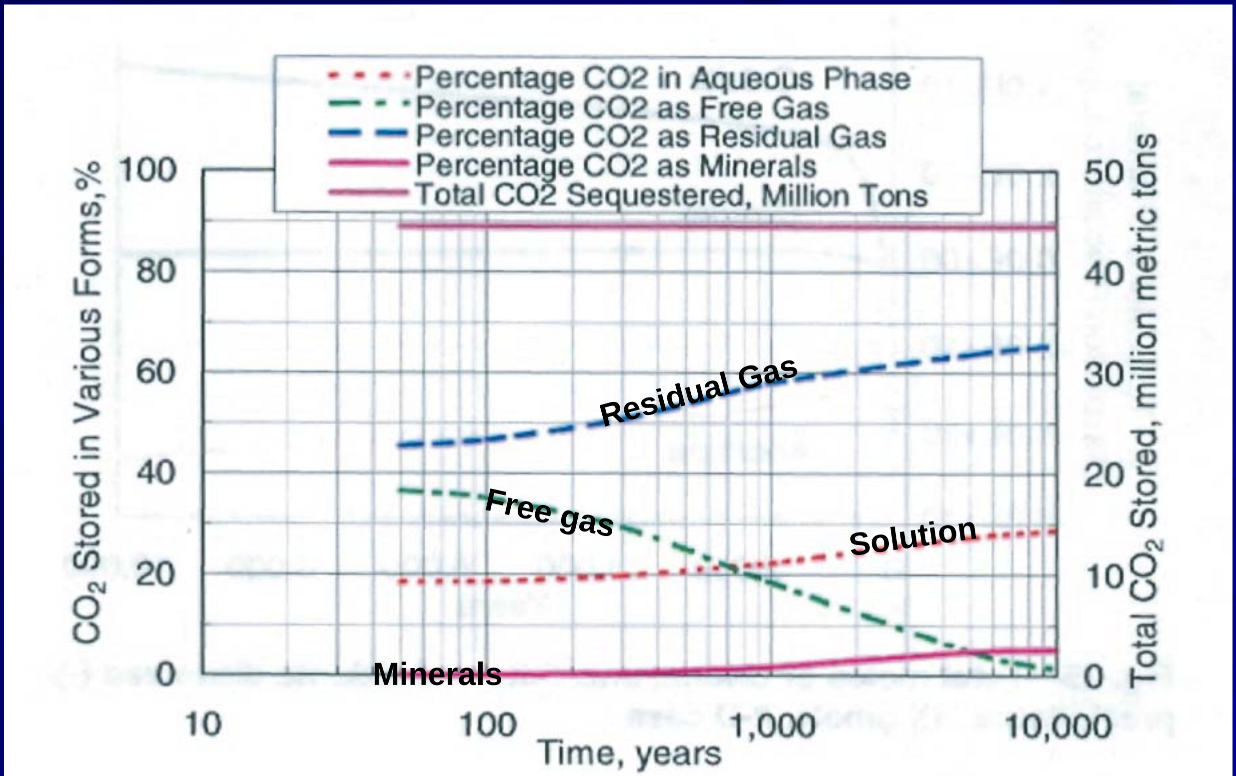
3. As free-phase (gas) CO_2 rises, additional CO_2 gets trapped in fine pores in the rock – **residual gas saturation**
4. Natural movement of water in the aquifer **dilutes** CO_2 in solution and in free phase
5. Over long term (100s and 1000s of years), some of the injected CO_2 gets trapped as **mineral precipitates** in the aquifer

Frio Pilot CO_2 injection Project, Texas



CO_2 plume visualized by cross-well seismic tomogram

In situ entrapment of injected CO_2



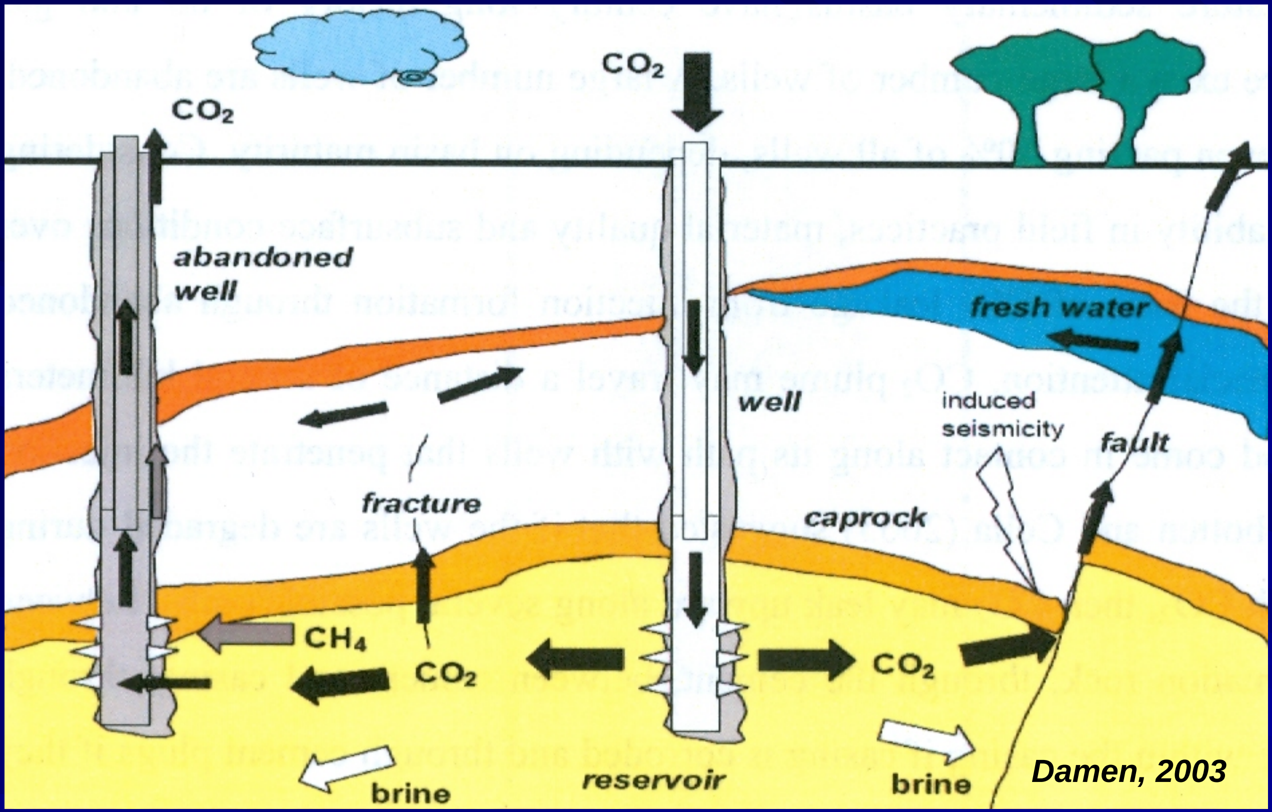
Ozah, 2005 – In situ CO_2 distribution after 50 years of injection

Our study will estimate the amount of CO_2 (tons) that will sequestered in various states using site-specific geology, rock, and water properties

Majority of injected CO_2 gets trapped as residual gas saturation followed by CO_2 dissolved in brine solution.

CO_2 mineralization is a slow process.

Risk Analysis – Potential leakage pathways

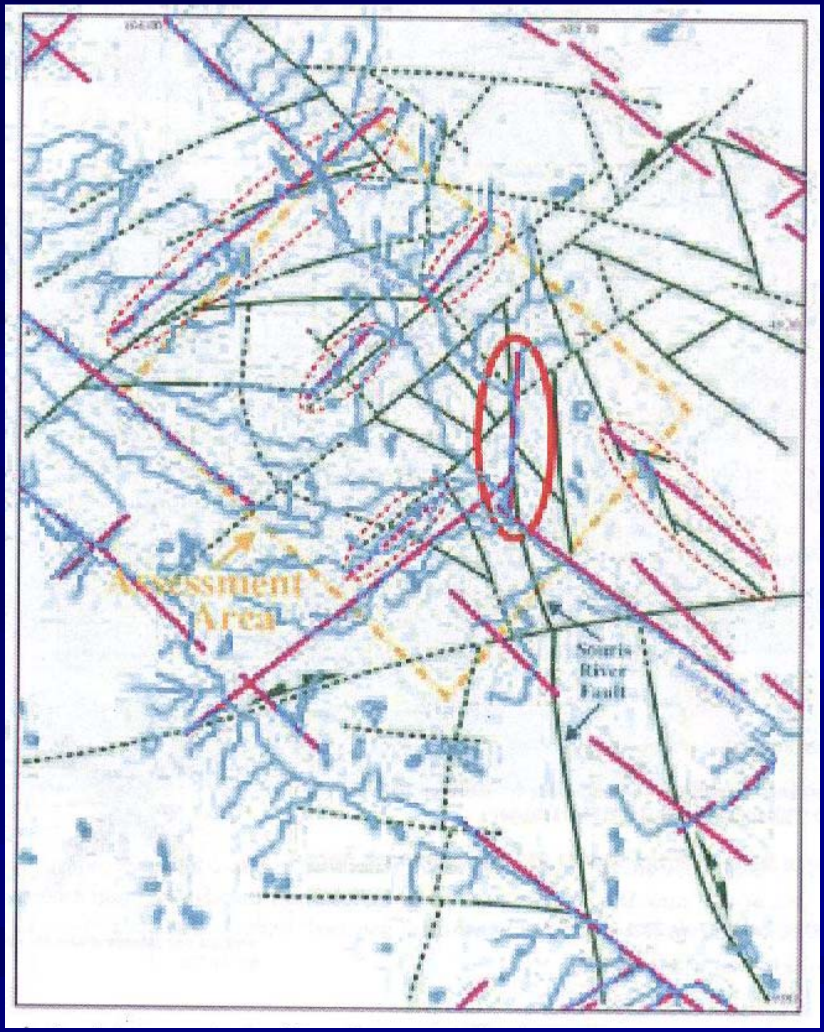


Faults and fractures will be mapped in the 17+ county study area:

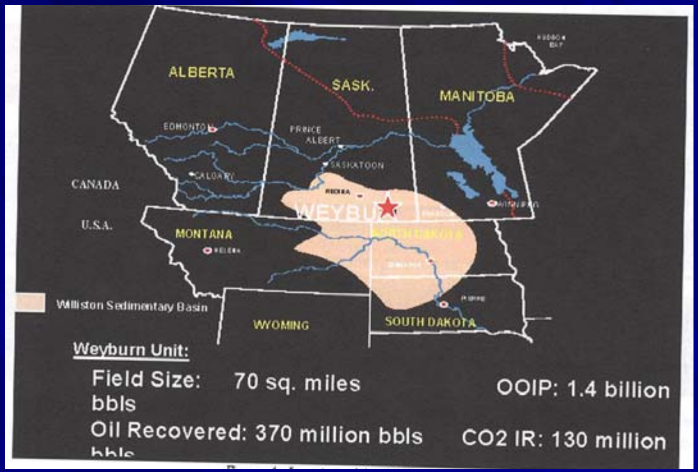
1. Satellite imagery
2. Gravity/Magnetic
3. Structure maps

Site selection critical to minimize risks associated with CO_2 injection
Not all fractures/faults reach the surface – some do and need to be identified
Inventory of all plugged wells critical – REPLUG if needed.

Weyburn CO_2-EOR - Canada



IEA GHG Weyburn Summary Report 2000-04



Solid Green* – *fault trends from seismic & HRAM

Broken Green* – *trends from HRAM

Purple* – *surface lineaments

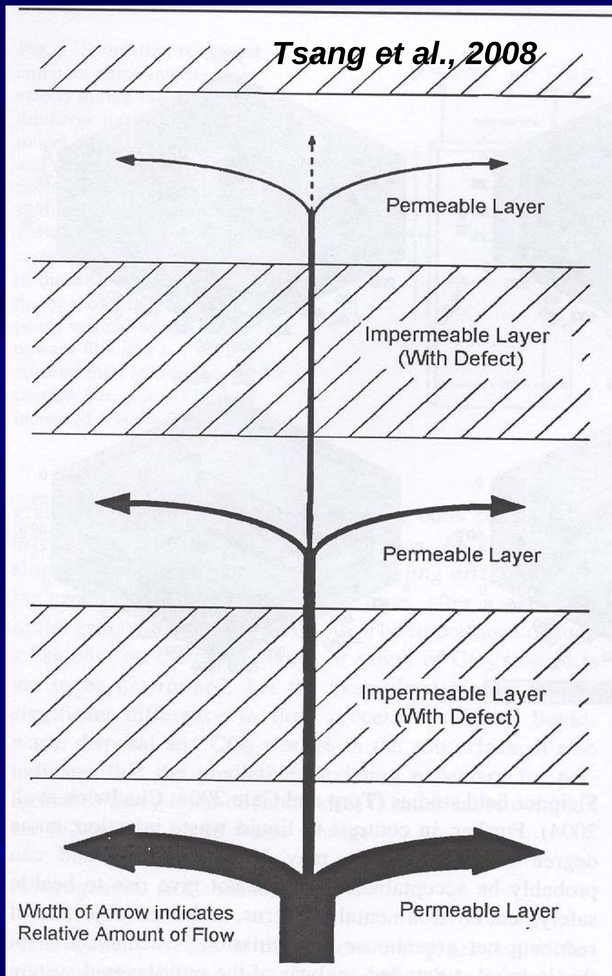
Red oval* – *Souris Valley fault (fault identified by seismic and HRAM coincide)

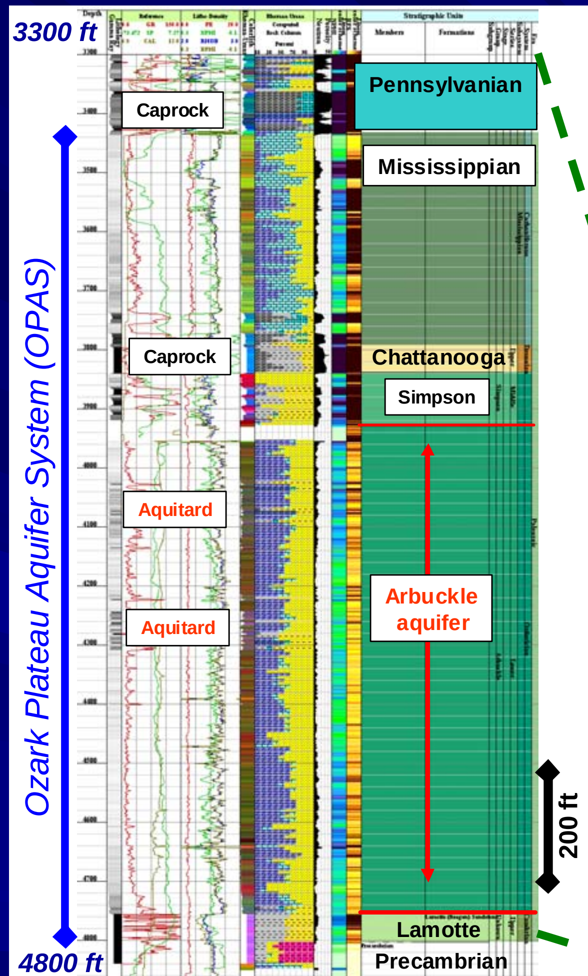
Broken Red* – *weak correlations between data sets

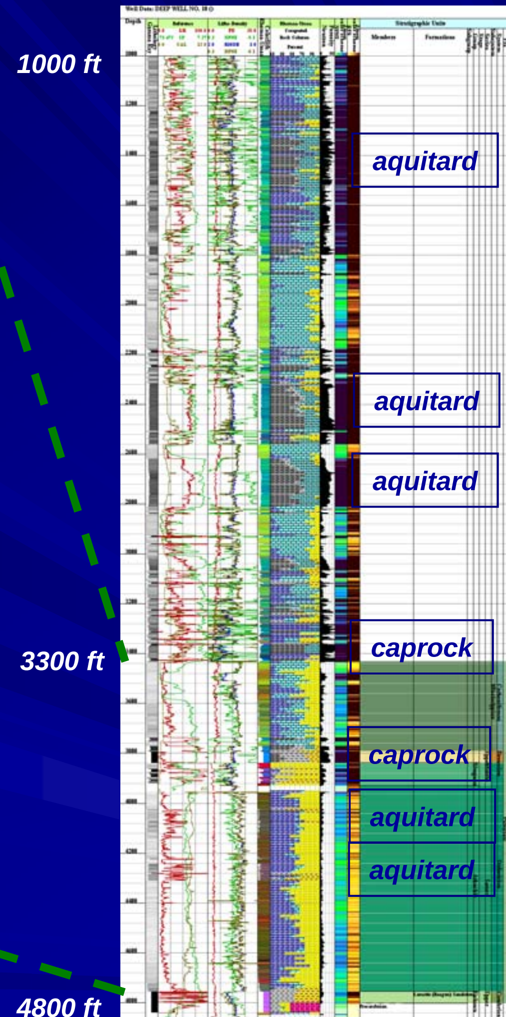
Not all Sub-surface faults/fractures reach the surface

Risk Analysis

Leakage Retardation – Multiple Caprocks & Aquitards

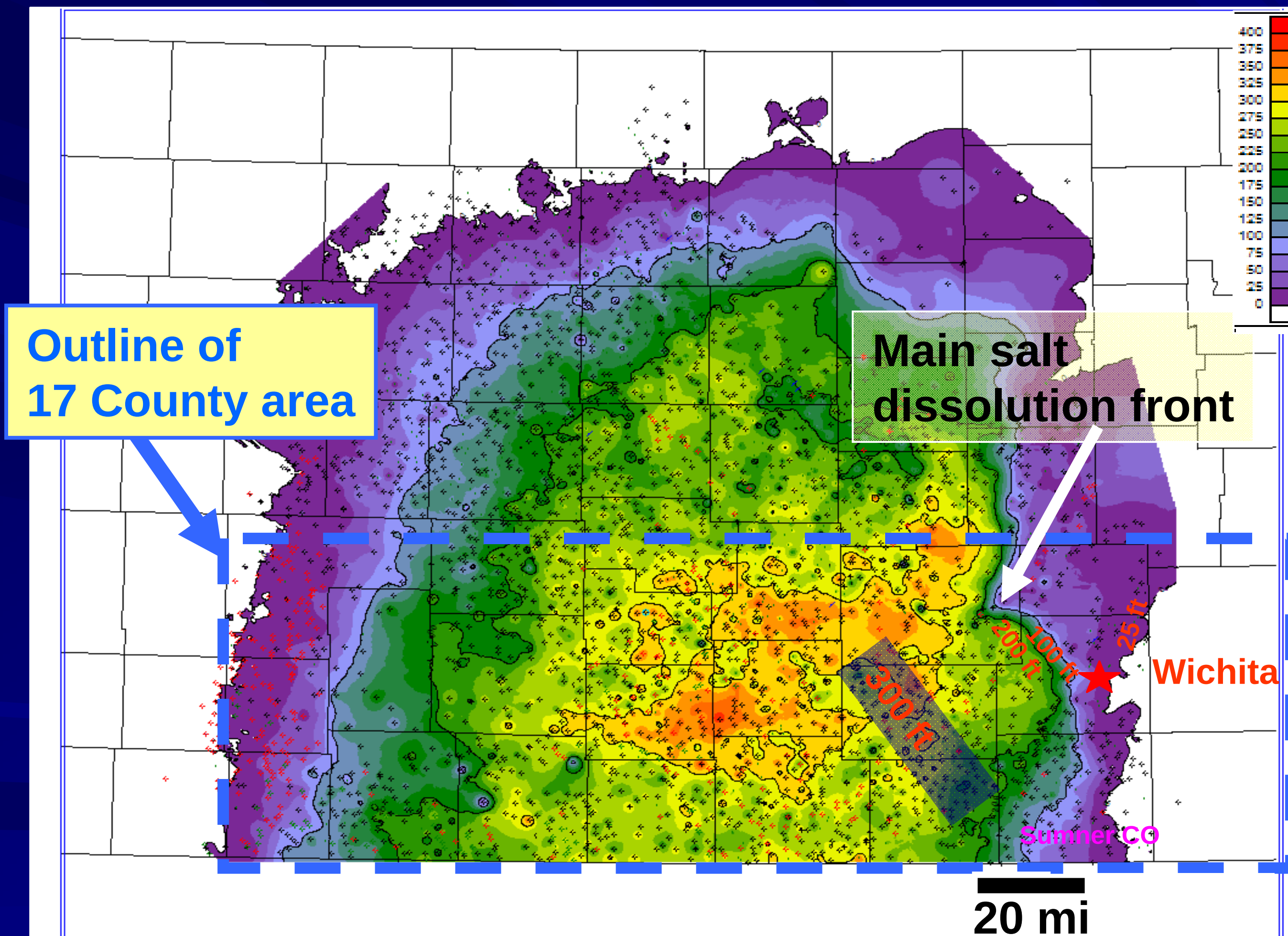






CO_2 plume undergoes pressure reduction and is trapped in the fine pores of caprocks and/or aquitards.

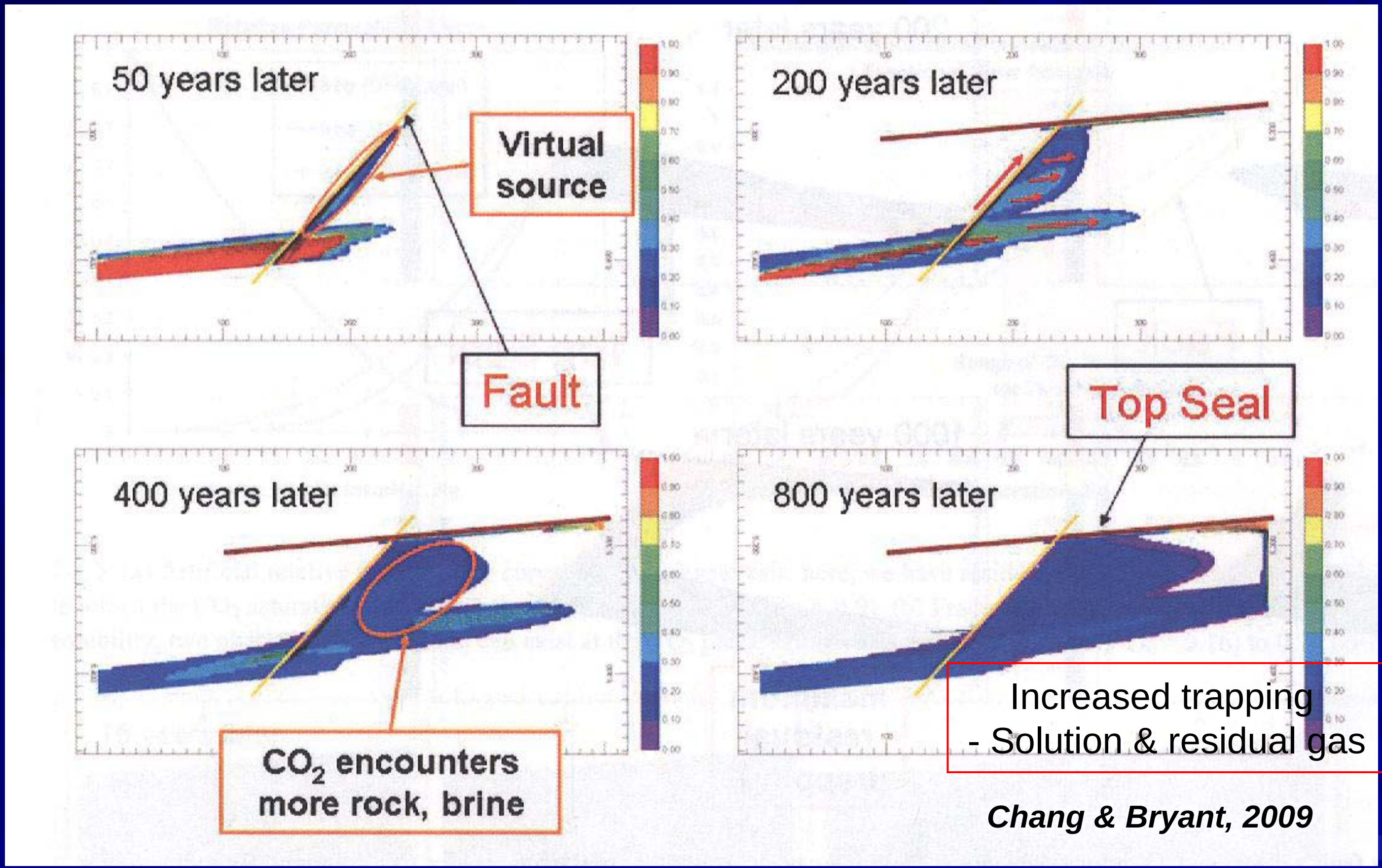
Net Halite (salt) Isopach (thickness)



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



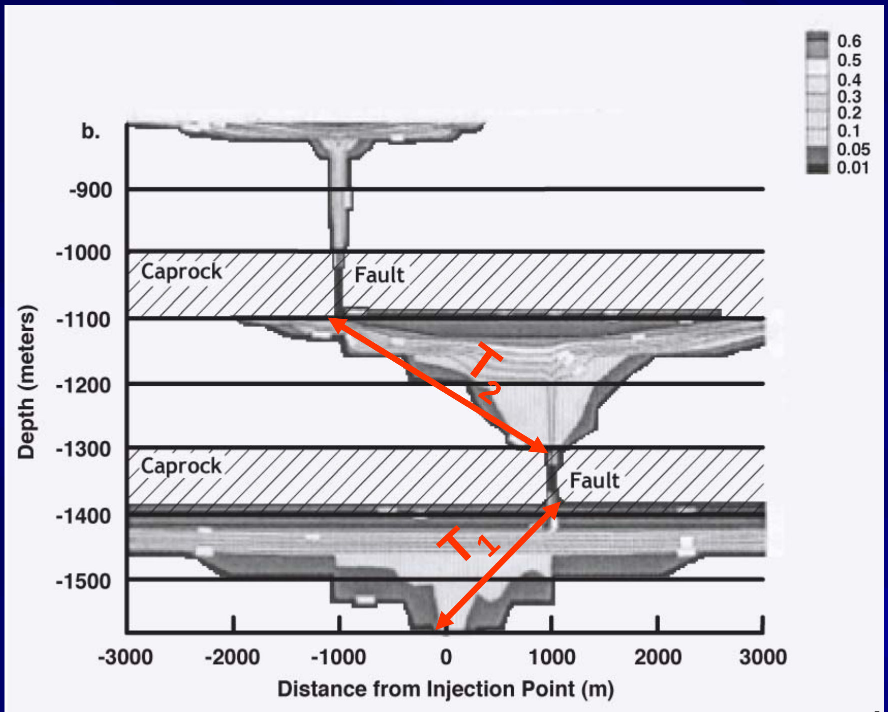
Chang & Bryant, 2009

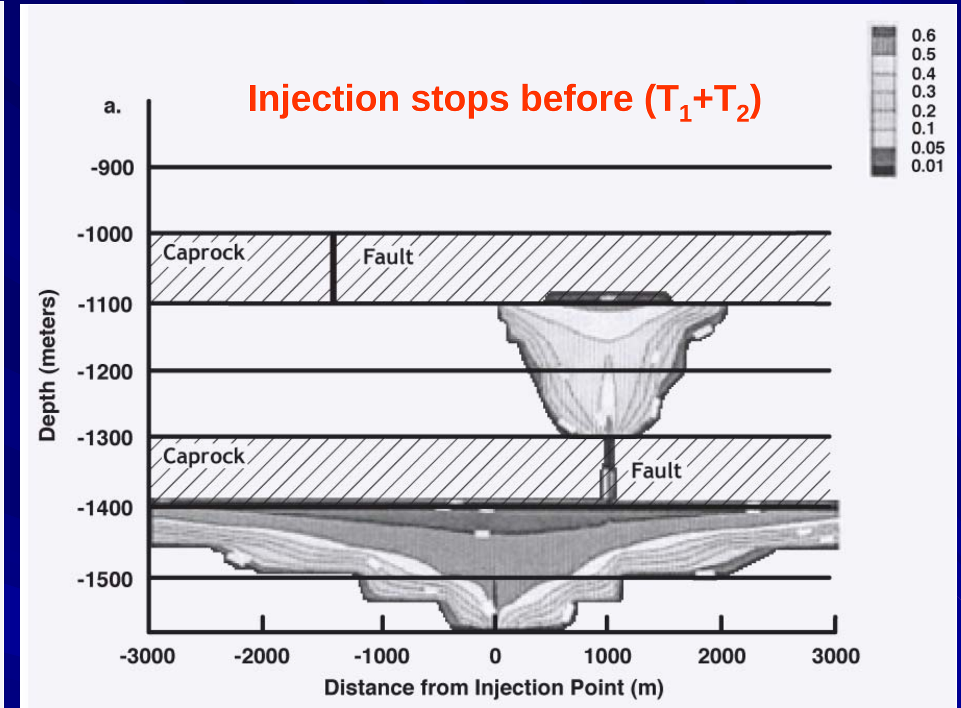
CO_2 leaks into fault and creates a "virtual CO_2 source".

CO_2 migrates updip and gets attenuated – additional trapping in solution and as residual gas

Risk Analysis

Plume Intersects Inclined Conductive Fault





Tsang et al., 2008

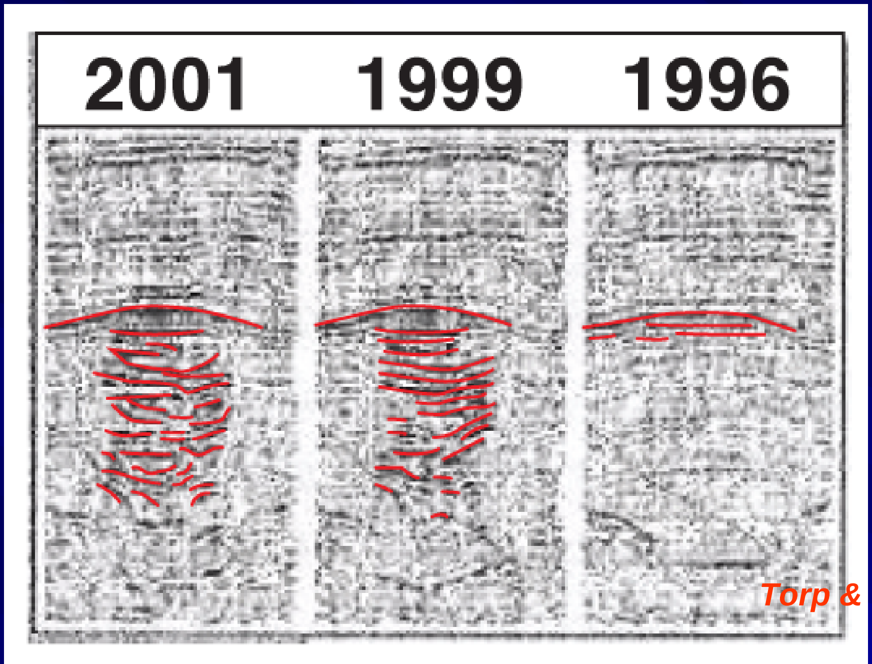
If injection stops before plume reaches fault – then no leakage occurs.

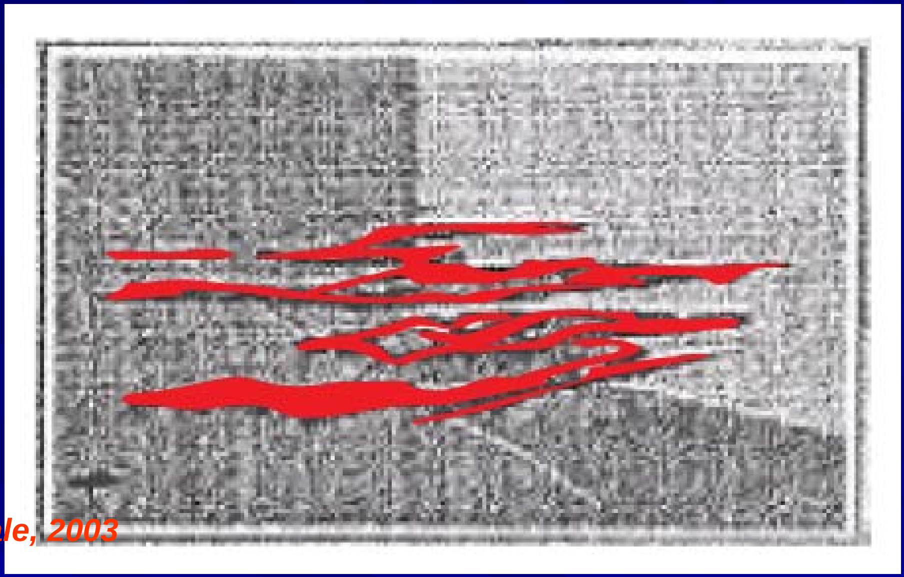
How much CO_2 can be sequestered before plume reaches fault?

Is CO_2 sequestration tonnage economic?

Risk Analysis

Seismic Monitoring Results - Sleipner field (North Sea)





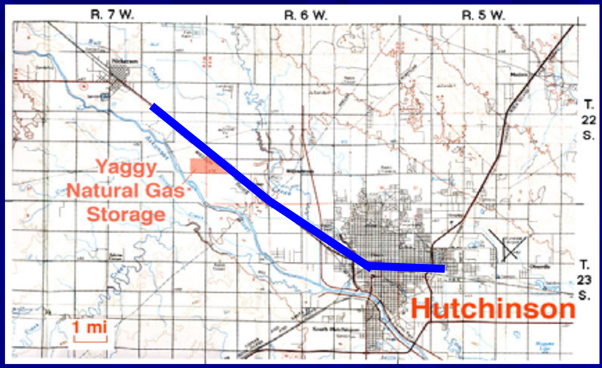
Torp & Gale, 2003

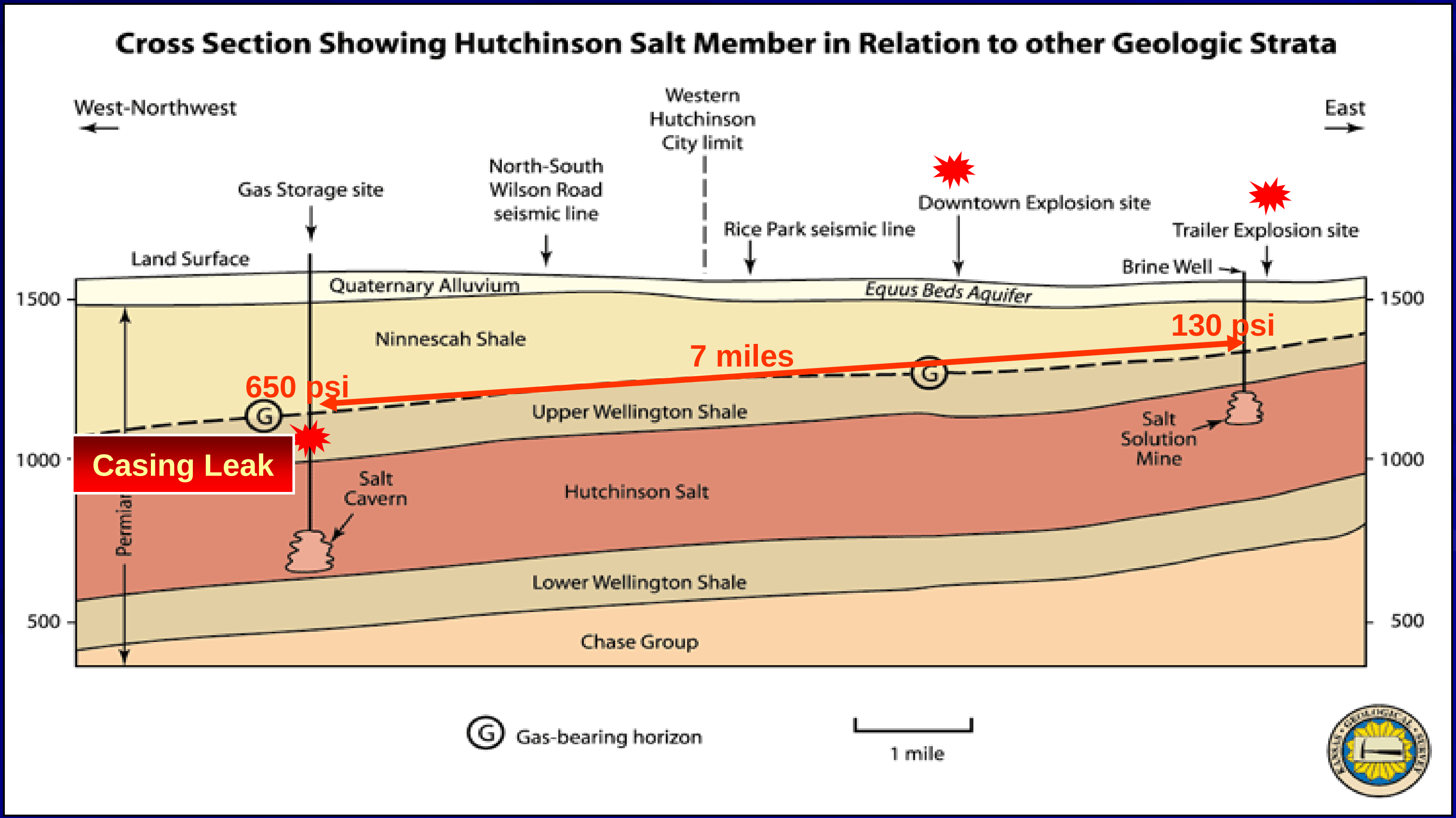
Every time the CO_2 plume met a thin shale layer, it spread out laterally. This lateral dispersion resulted in CO_2 dissolving into brine and getting trapped in fine pores of the rock.

Presence of similar thin shale layer (stratification) and aquitards are expected to be present in the Arbuckle aquifer system.

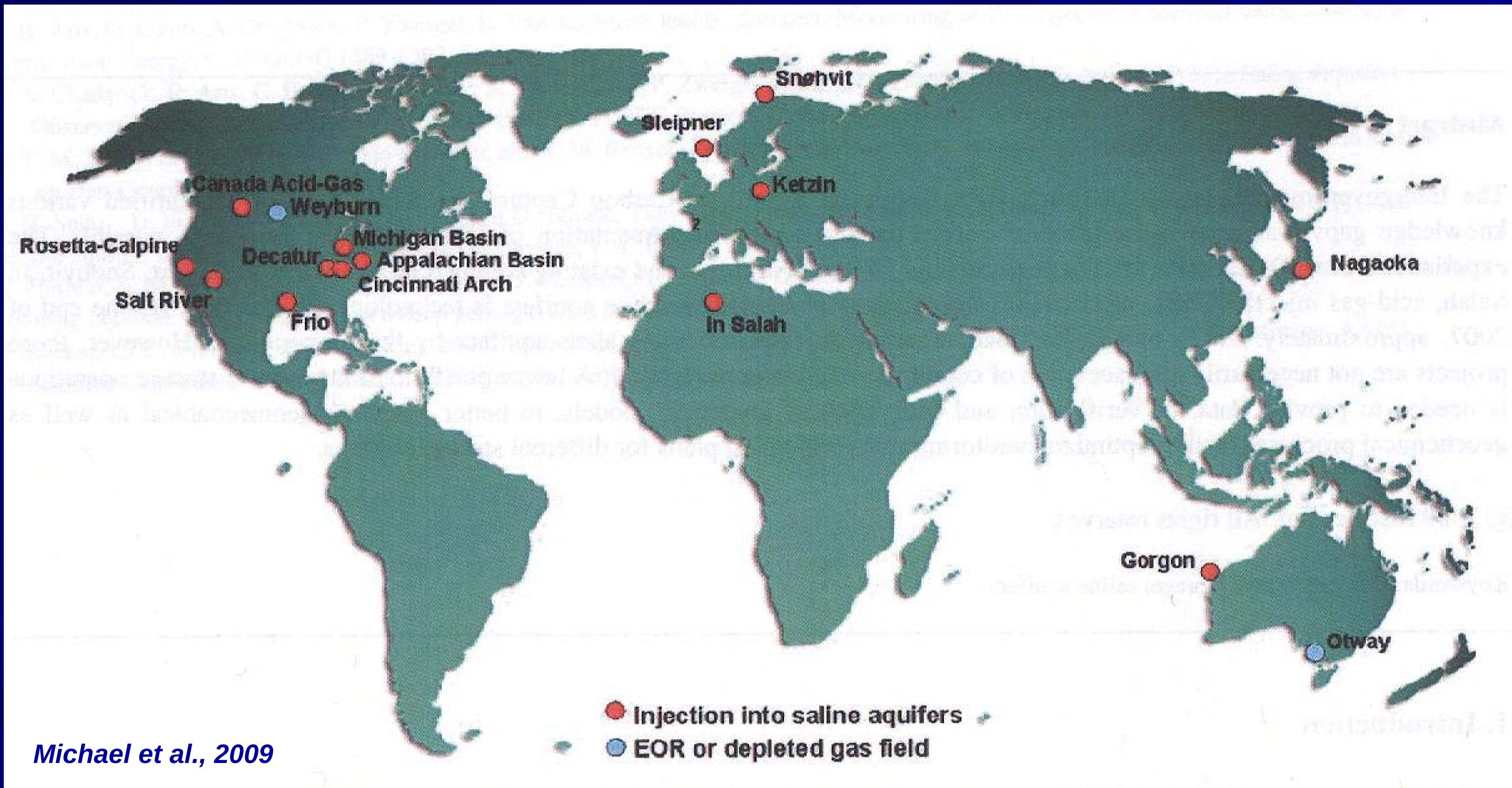
Yaggy Gas Storage Leak - 2001

Site selection for CO_2 sequestration CRITICAL, because all wells drilled in the area have to be accounted for and properly completed before onset of CO_2 injection.



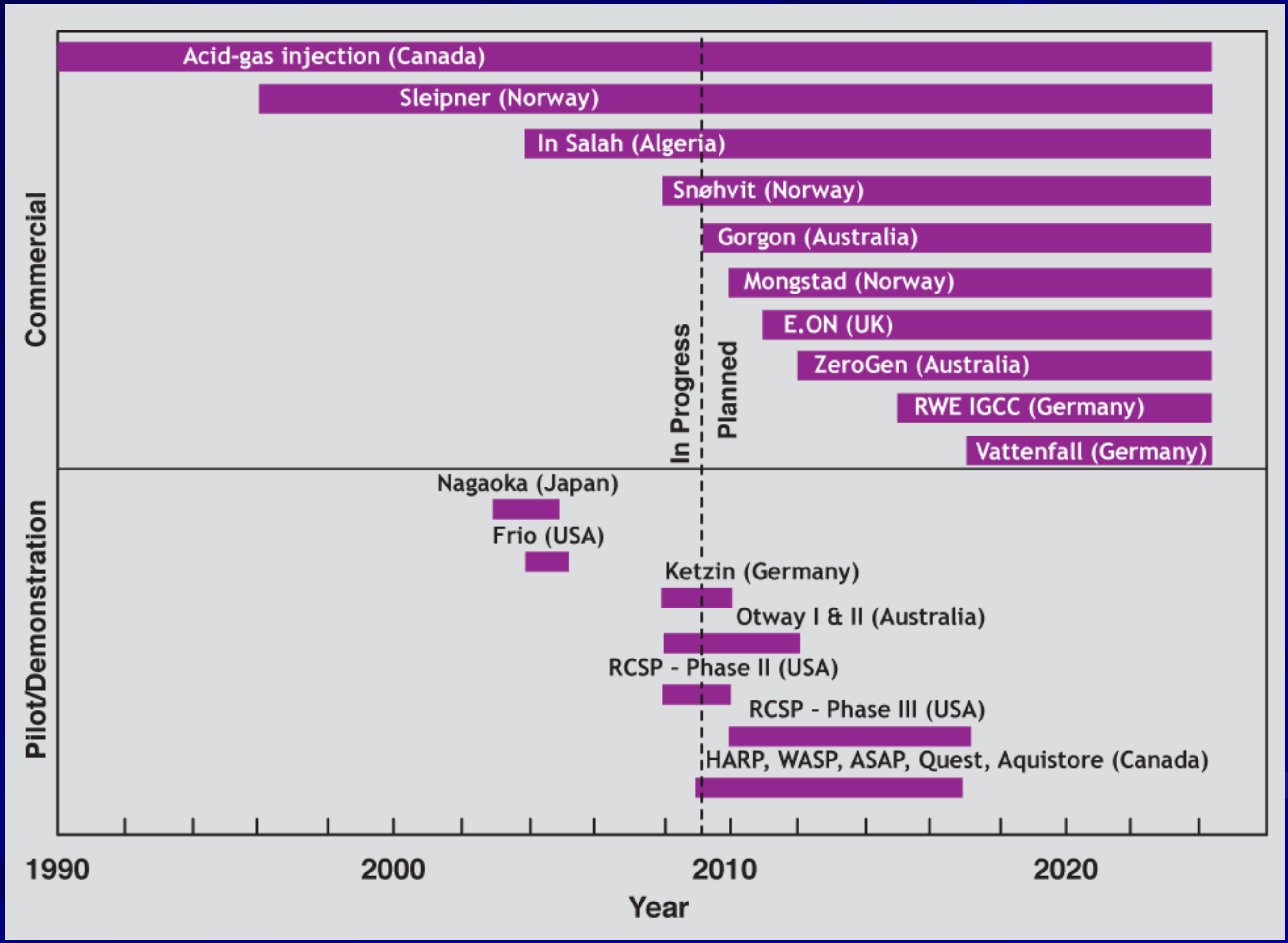


CO_2 Sequestration Projects Worldwide
Deep Saline Aquifers



Michael et al., 2009

CO_2 Sequestration Projects Worldwide
Deep Saline Aquifers



Cap CO_2 & Univ. of Utah will submit proposal to DOE for field scale CO_2-EOR in Apr 2010 with KGS as a partner