THE UNIVERSITY OF TEXAS AT AUSTIN

WHAT STARTS HERE CHANGES THE WORLD

US Potential for CCS and CCUS Progress has been made

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BUREAU OF ECONOMIC GEOLOGY

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www.gulfcoastcarbon.org

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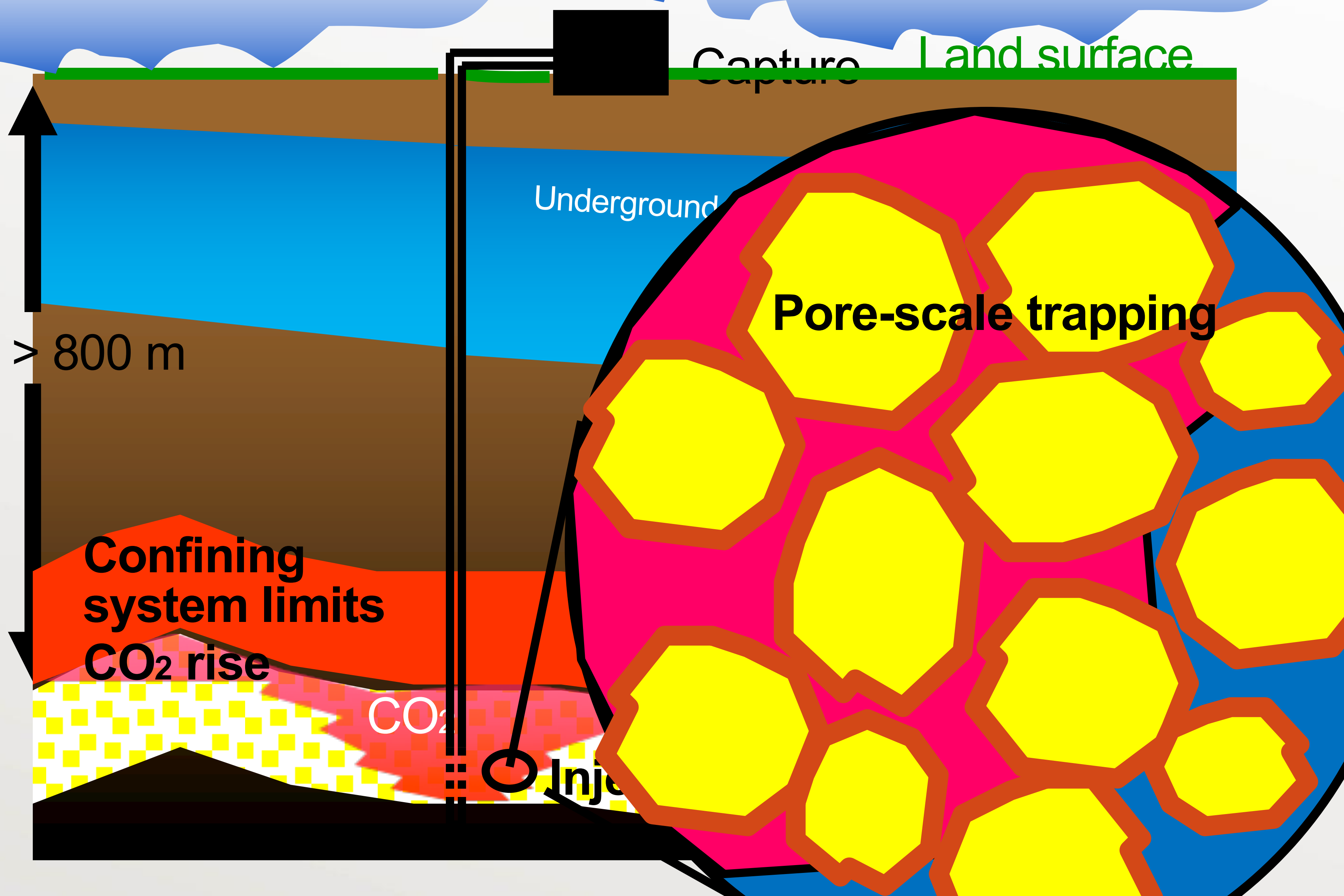
UT- DoGS
UT- LBJ school
BEG- CEE
JSG – EER
Univ. Edinburgh
Univ. Durham
RITE
CO2-CRC

Department of Energy, United States of America
SECARB Southeast Regional Carbon Sequestration Partnership
EDF Environmental Defense Fund, Finding the ways that work
STORE sequestration training, outreach, research & education
Southern States Energy Board

Major Take-a-ways

- Status of geologic storage in porous media: mature, successfully underway and ready for large scale implementation
- Challenges: convincing key stakeholders this is true
- Capacity is large but unevenly distributed

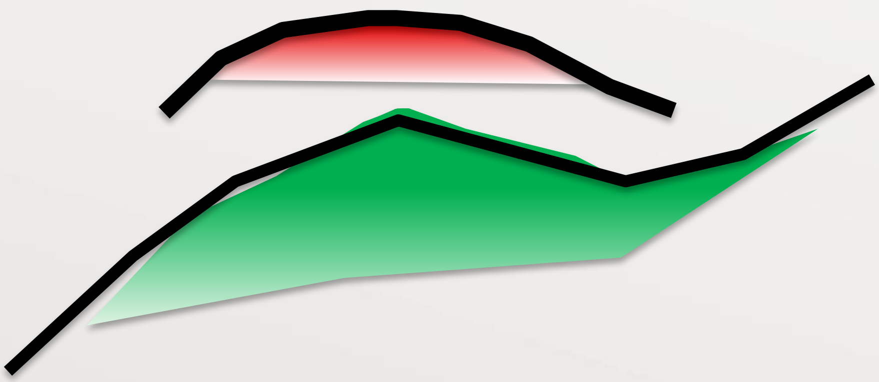
Storage in Porous media



Types of Geologic Storage

Porous media

Stacked CO_2-EOR and Saline



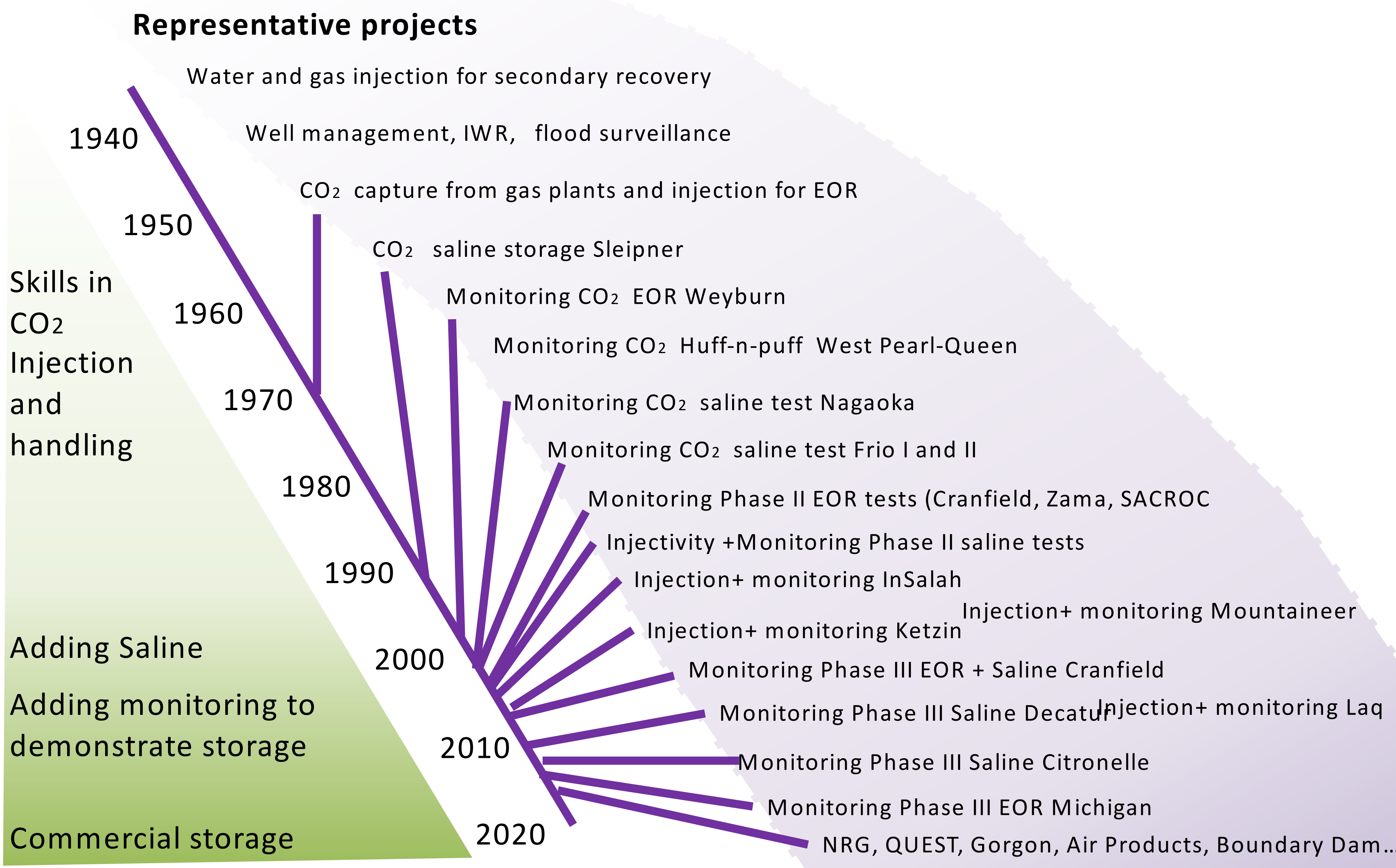
Geochemically-dominated storage

Rock-water-CO_2 reactivity
Mafics and ultramafics

Sorption-dominated
Coal, lignite, organic-rich shales

Fractured rocks

Safe and Effective Injection > 50 years



Examples of Integrated CCS Projects

Capture from / Storage type	Power production	Industry	Gas Separation
For disposal	SECARB- Plant Berry Alabama AEP Mountaineer, West Virginia Aquistore, Sask.	ADM Ethanol, IL Tomakomai-Hokkaido Japan Shell QUEST, Alberta	Sleipner – North Sea Snøvit – Barents Sea Otway Australia
For EOR	Boundary Dam, Saskatchewan NRG/PetraNova-Houston TX	Air Products-Port Arthur TX Yanchang Ordos, China Coffeeville and Enid OK	Many fields in Permian Basin sourced from Val Verde Basin gas, TX Bell Creek, Lost Cabin, WY Multiple midcontinent US projects Lula Field offshore Brazil Uthmaniyah Saudi Arabia

Offshore storage

Completed

Extensive inventory
https://www.globalccsinstitute.com/projects/large-scale-ccs-projects

Questions Stakeholders are asking

- Leakage
  - Impact on humans, ecosystems, water
- Capacity
  - Is there really enough space to accept CO_2
    - In reasonable amounts
    - At reasonable rates 10GT/year
- Seismicity
  - Linked to injection rate via pressure limit

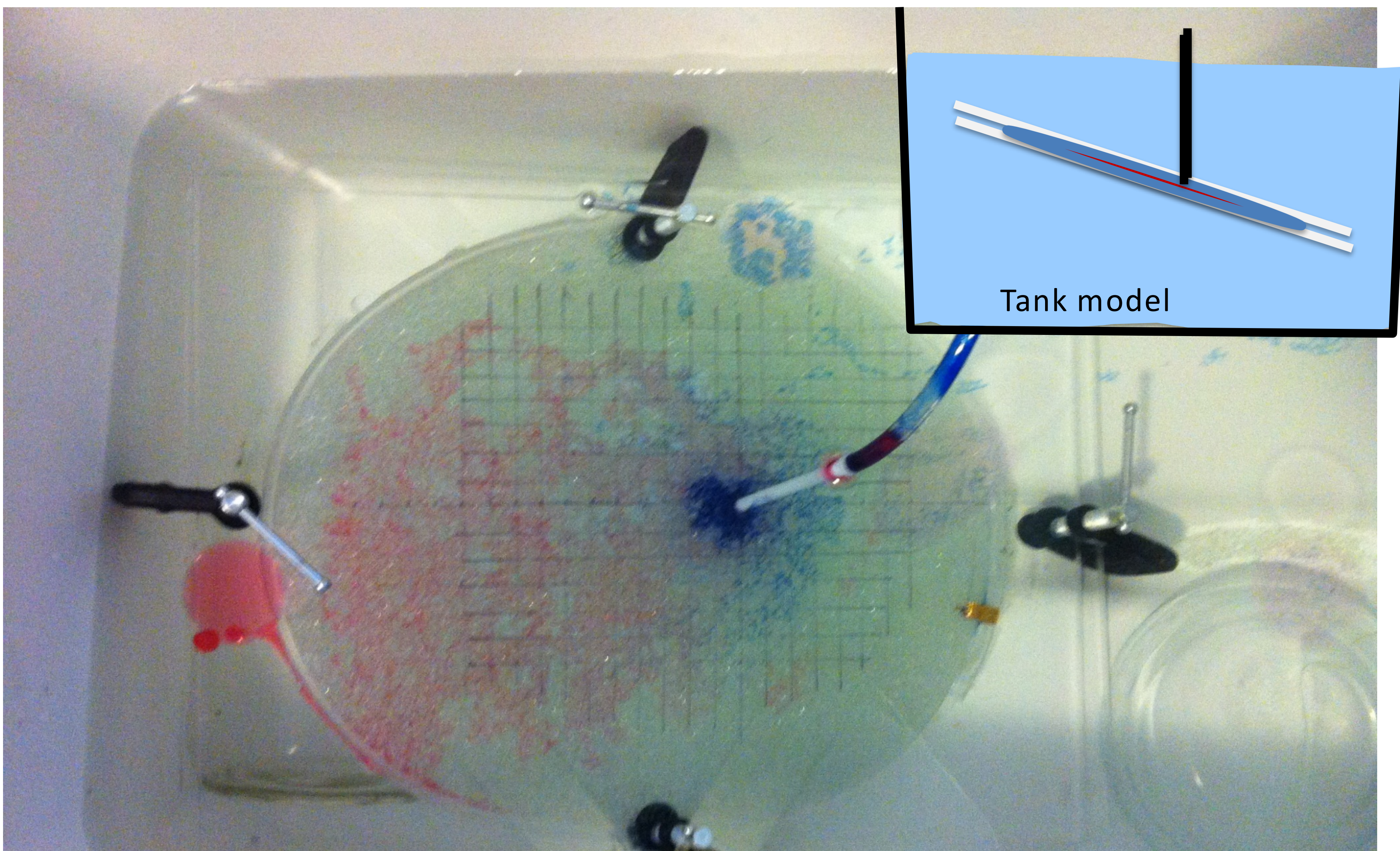
Leakage

- Based on analogs, per IPPC Special Report, a well selected and properly operated site should retain >99% per 1000 years.

Need more designed experiments to experience failures

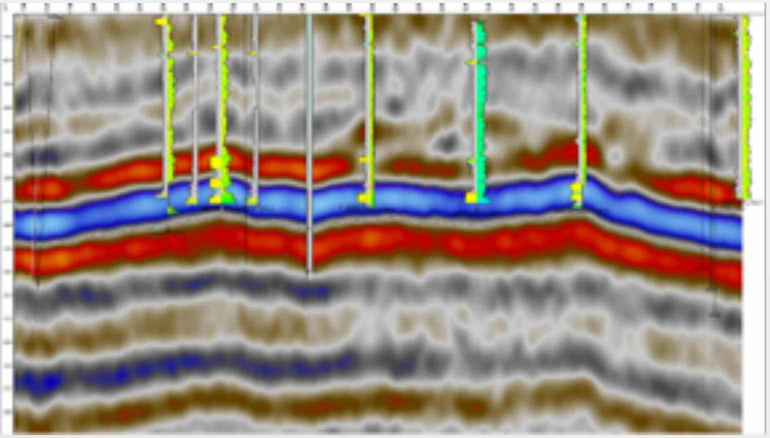
- Based on experience, engineered features (wells) are most likely failure points.

Experiments: Long term plume stabilization
Wrong imbibition curve: plume migrates too far

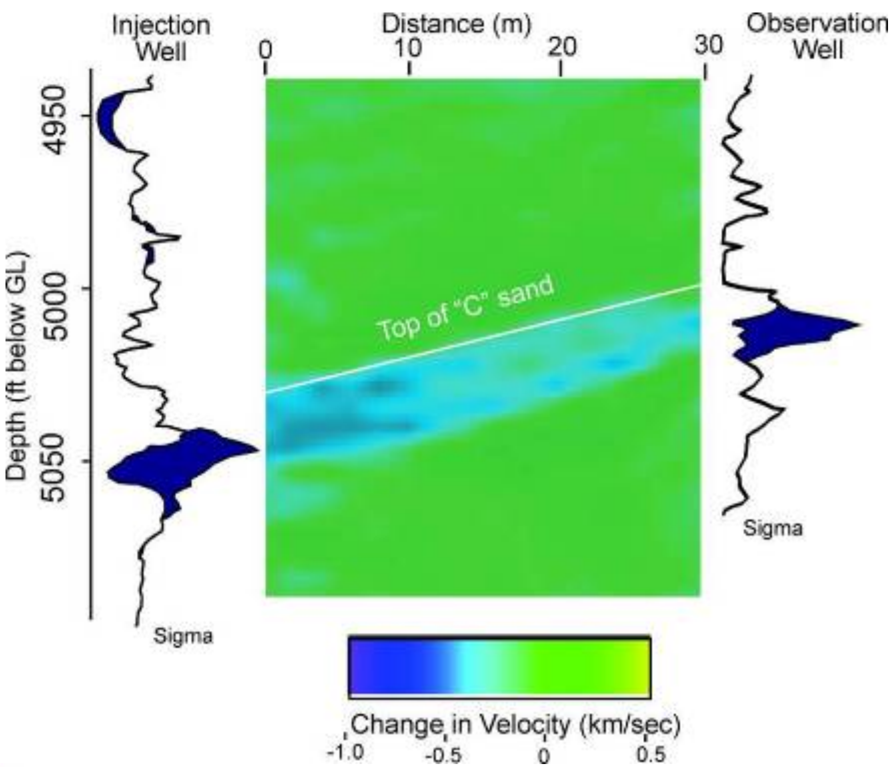


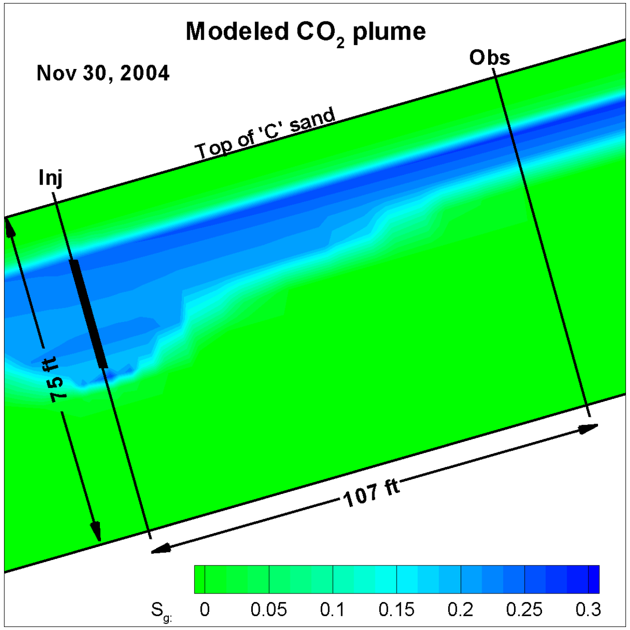
Robustness of geologic systems

- Depth – storage below and isolated from fresh water, dense phase >1 km.
- Multi-layered system
  - Low permeability zones (shales and evaporites), high permeability zones.
- Residual trapping



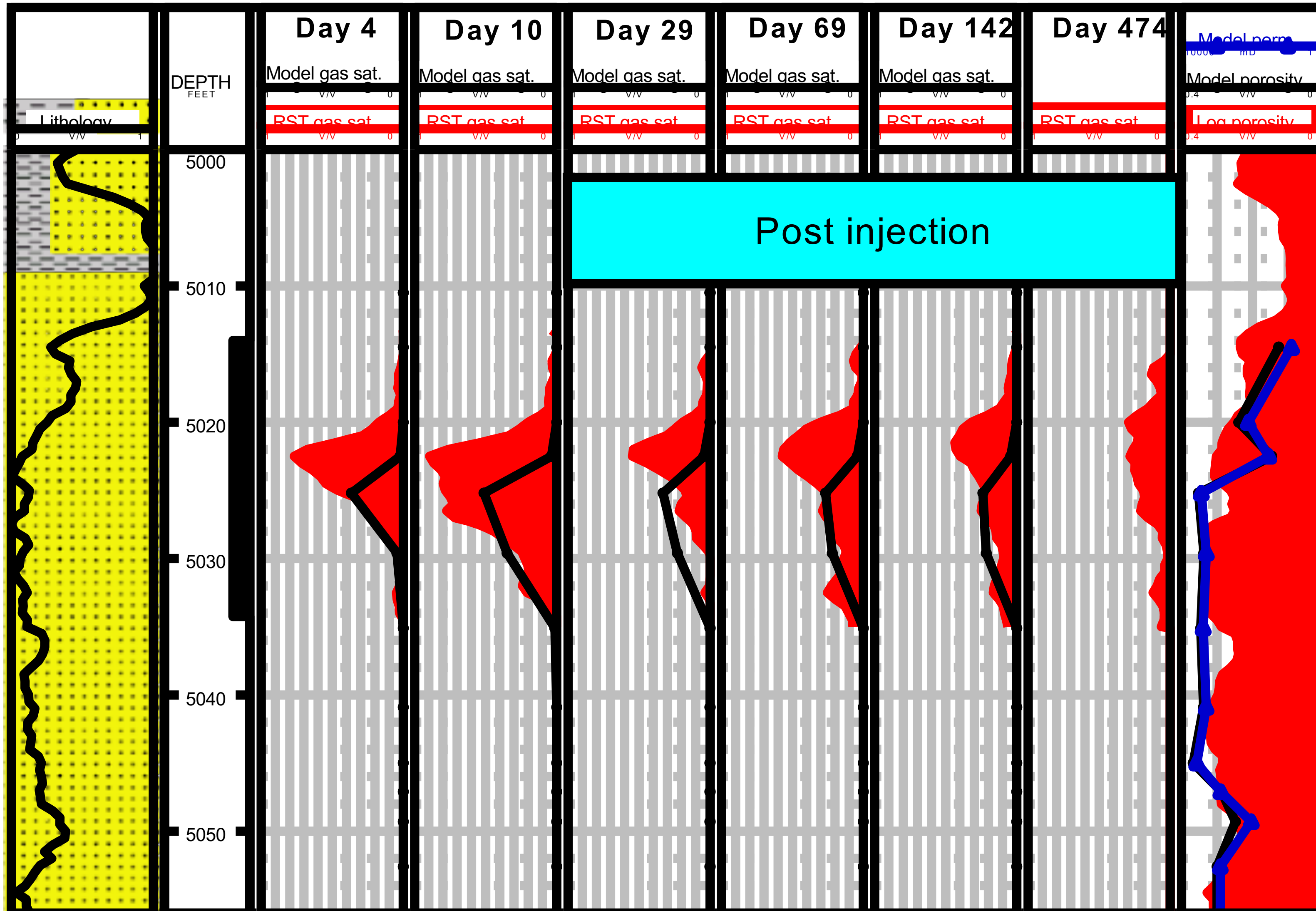
First test: Post injection CO_2 Saturation Observed with Cross-well Seismic Tomography vs. Modeled





Tom Daley and Christine Doughty LBNL

Measurement at a Well:
Saturation logging (RST) Observation well to measure changes in CO_2 saturation – match to model



Shinichi Sakurai, Jeff Kane, Christine Doughty

Risk to Humans, Ecosystem, Water, Ocean from Storage Failure is Low

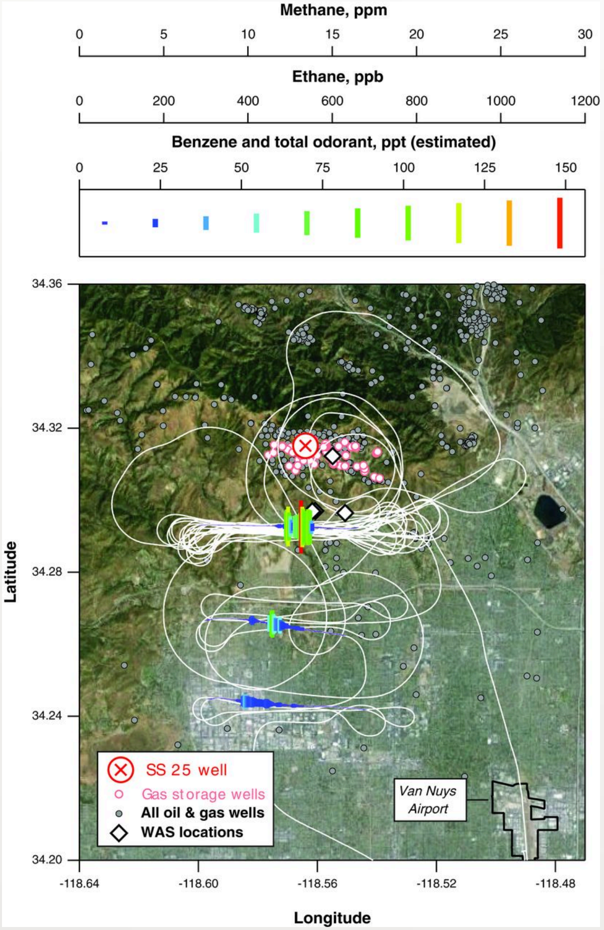
- Available past practices = low rate of failure and low consequences
  - 80MMT stored at SACROC field, Scurry County TX
    - No detection of CO_2 in groundwater
  - 20 MMT stored at Sleipner field North Sea
    - No detection of loss by British Geologic survey
    - Well failure studies Kell 2011; Porse, Wade, Hovorka,
- Controlled release experiments
  - What would happen if CO_2 leaked to air, water, soil, ocean
    - Small but detectible impacts. No massive damage.

Health and Safety

- Impact from failure of surface infrastructure and wells

Analog study: Aliso Canyon gas storage facility -- well failure

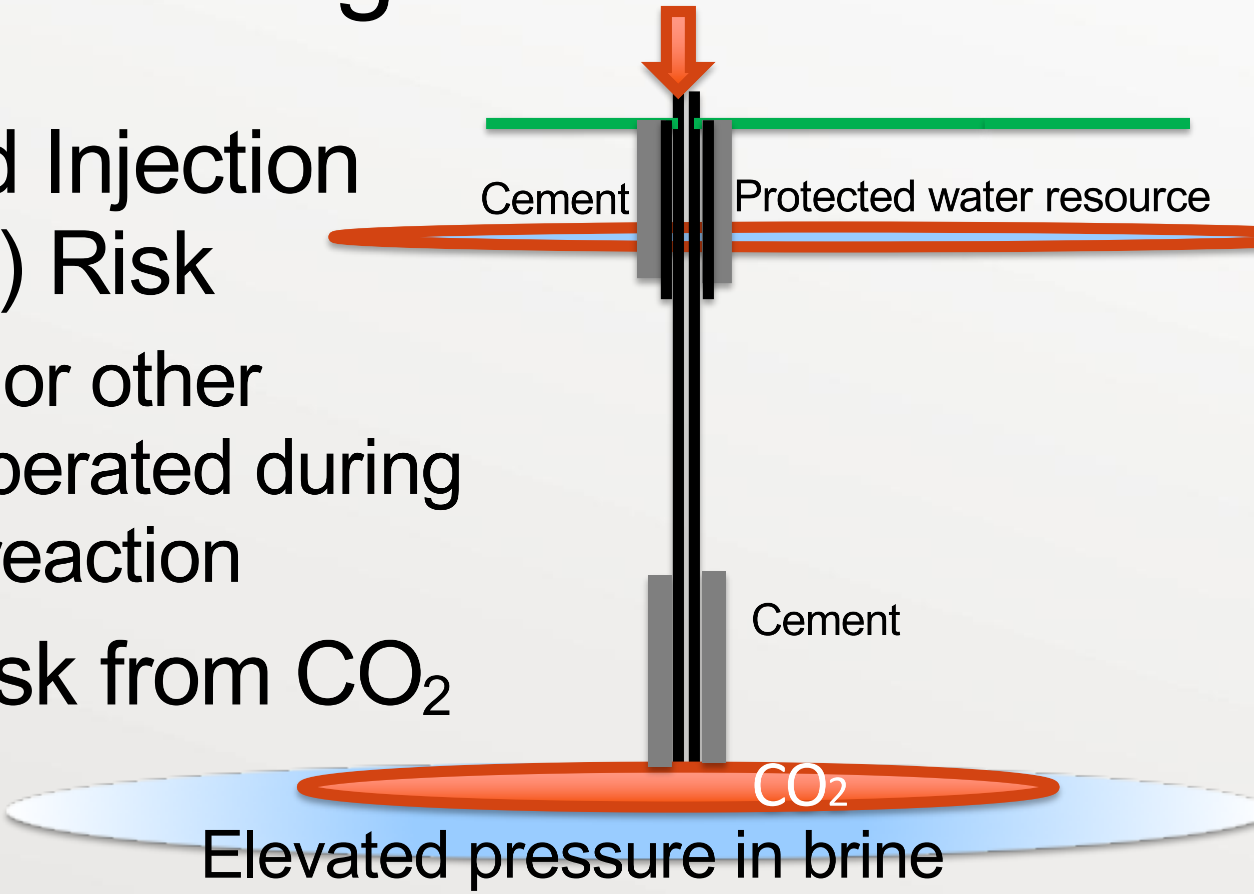
- Geologic failure – any flow will be retarded by tortuous flow paths – more relevant to long term benefit reduction than H&S



S. Conley et al. Science 2016;351:1317-1320

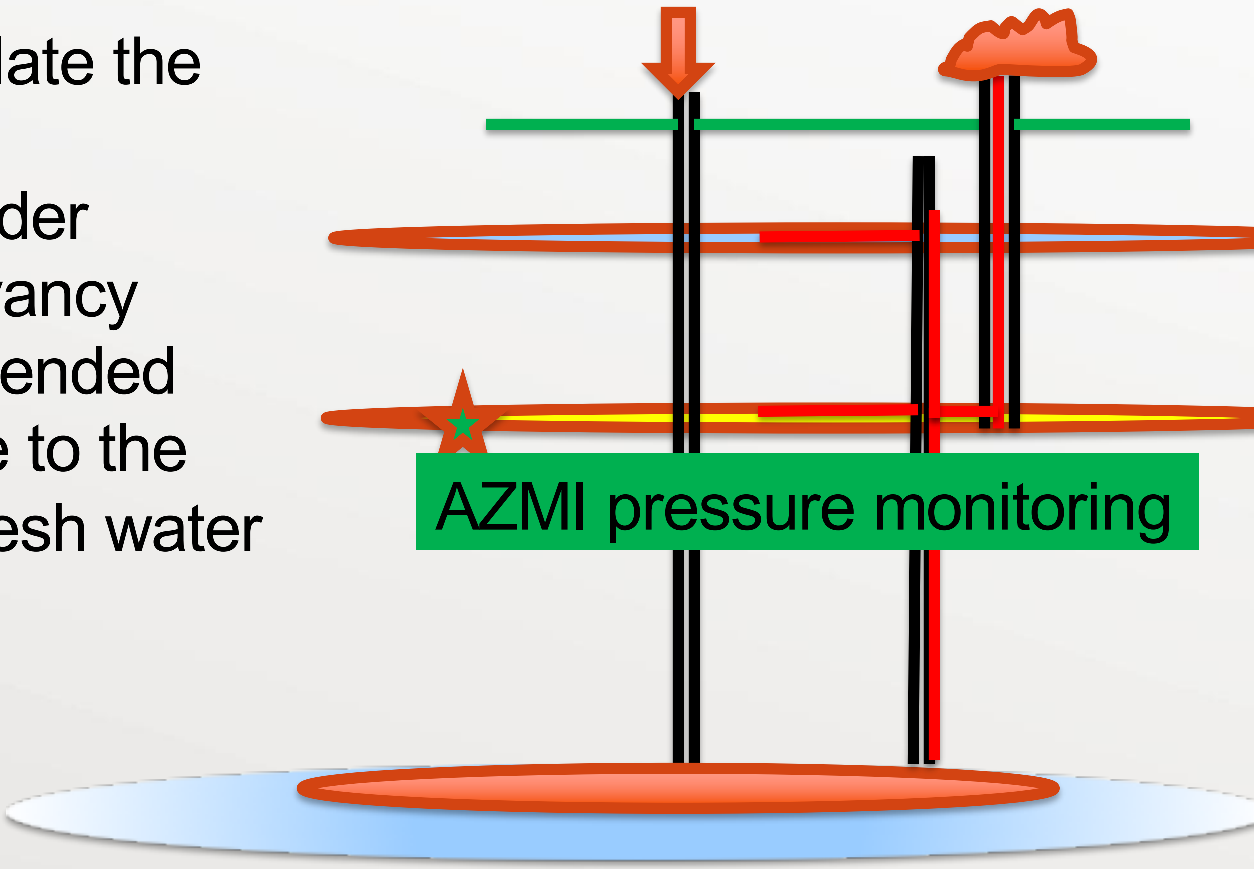
Protection of Underground Sources of Drinking Water

- Well-known Underground Injection Control (UIC) Risk
  - Brine, CO_2, or other impurities liberated during rock-water reaction
- No special risk from CO_2



Containment Failure Scenario

- A well fails to isolate the injection zone.
- Fluids , either under pressure or buoyancy Migrate out of intended zone and escape to the surface or into fresh water



CO_2 Controlled Release Experiments

ZERT experiment:
https://water.usgs.gov/nrp/proj.bib/Publications/2010/spangler_dobeck_etal_2010.pdf

Brackenridge and SECARB experiments
Changbing Yang -- BEG

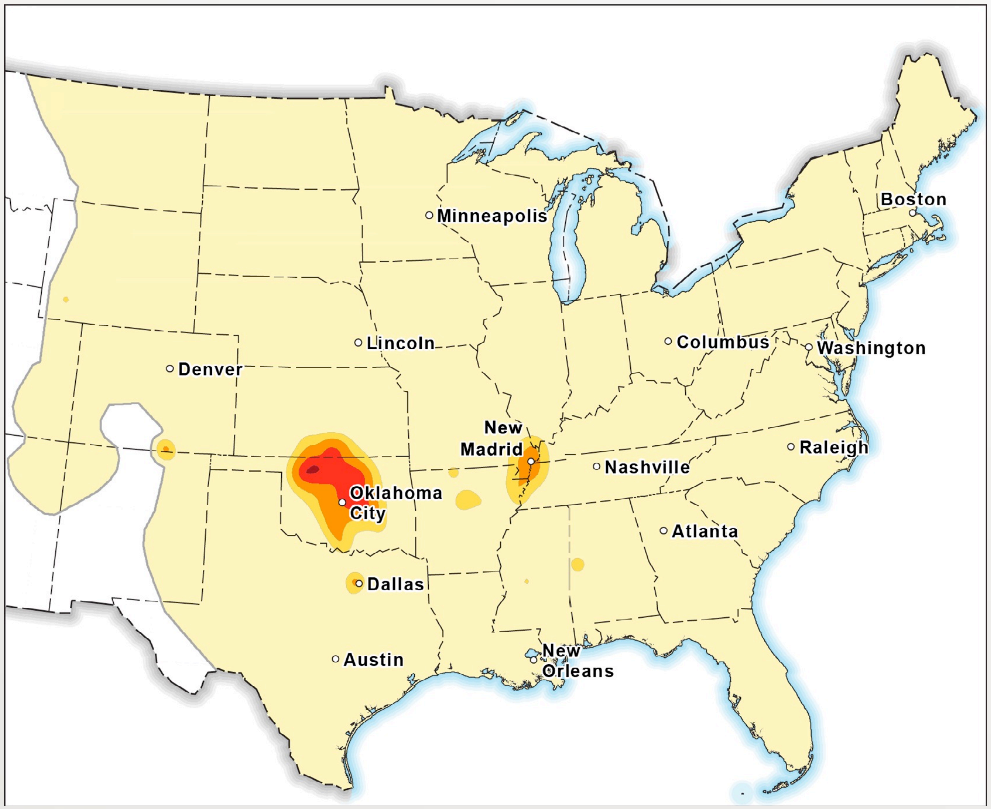
Ginninderra
http://www.ieaghg.org/docs/General_Docs/1_Comb_Mon_EnvRes/3_GinnCRFSEC.pdf

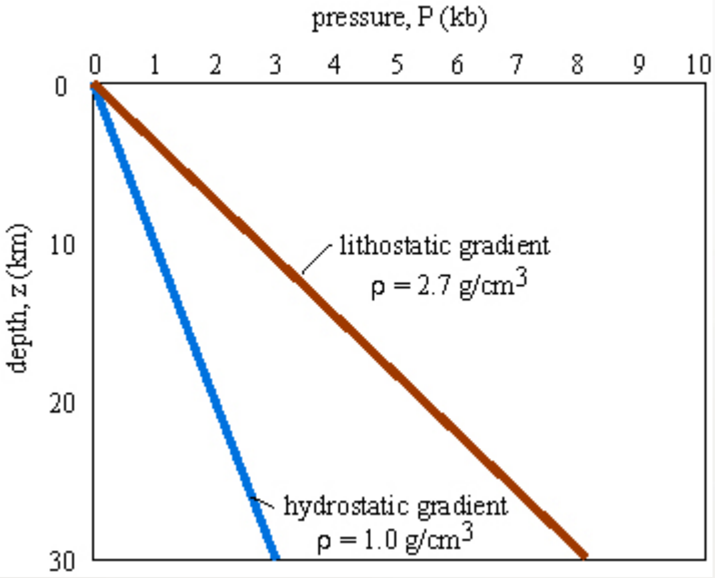
http://www.pml.ac.uk/News/CCS_controlled_leak_results

STEMM-CCS

http://www.stemm-ccs.eu/

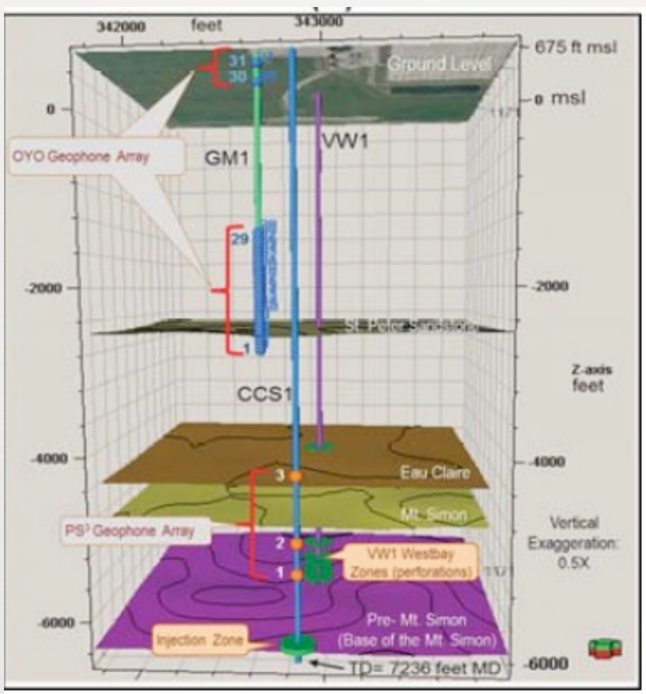
Induced Seismicity

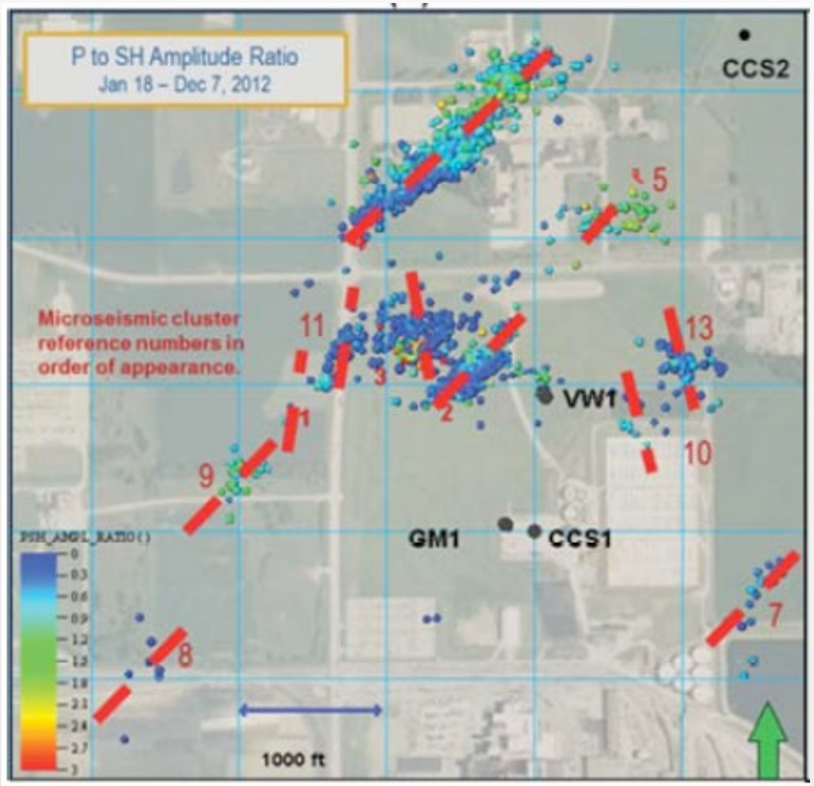




USGS Pedersen, 2016 http://pubs.usgs.gov/of/2016/1035/ofr20161035ver1_1.pdf

Microseismicity for tracking pressure elevation



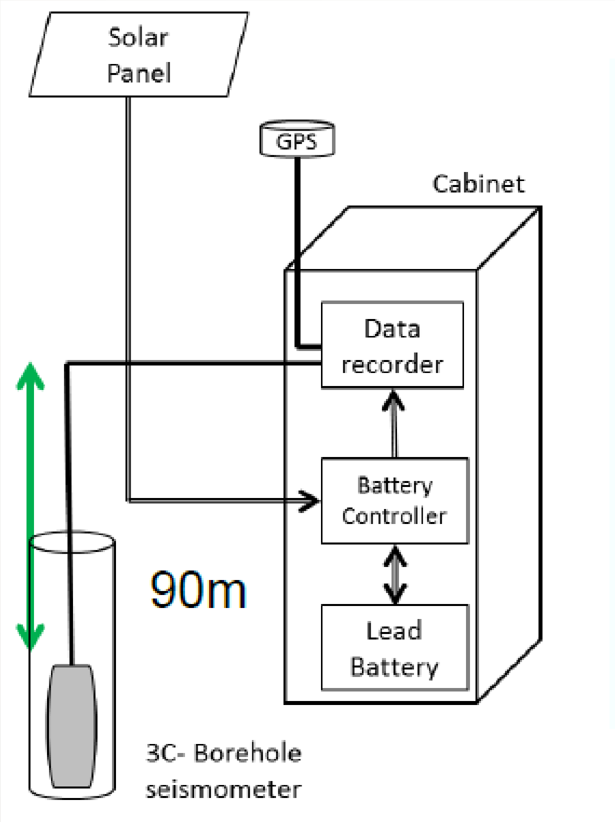


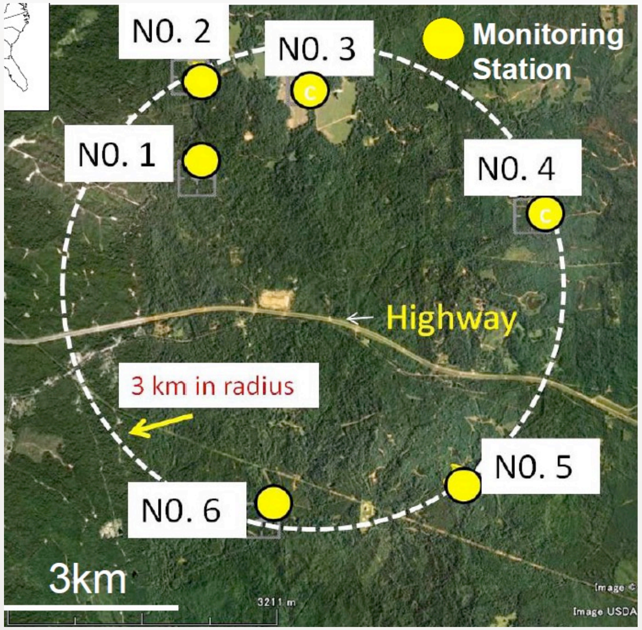
Illinois Basin Decatur Project, Lee et al, 2014

Field Measurements of Seismicity

3 year seismic detection project by Makiko Takagish, RITE at Cranfield

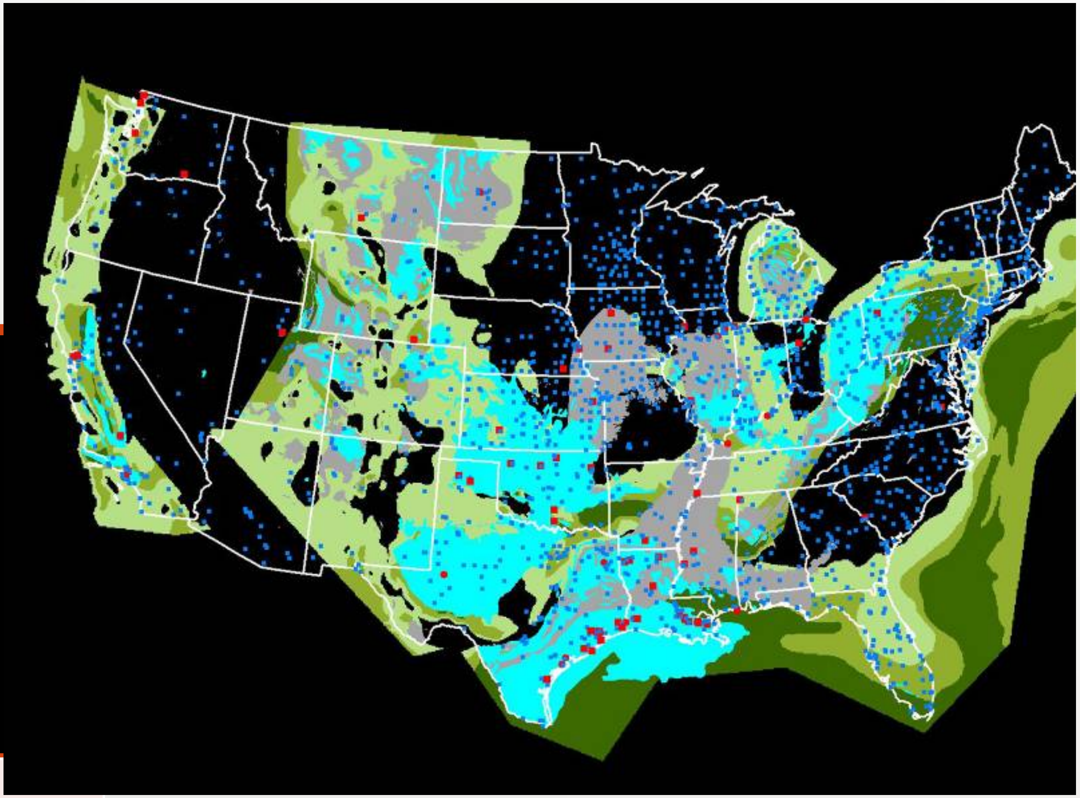
- Injection of >5 MMT Co2 over 5 years.
- Pressure increase 1000 psi at times.
- No local microseismicity detection





Minimum detectable amplitudes at reservoir depth are .4 (horizontal) and 0.7 (vertical)

US Storage Resource



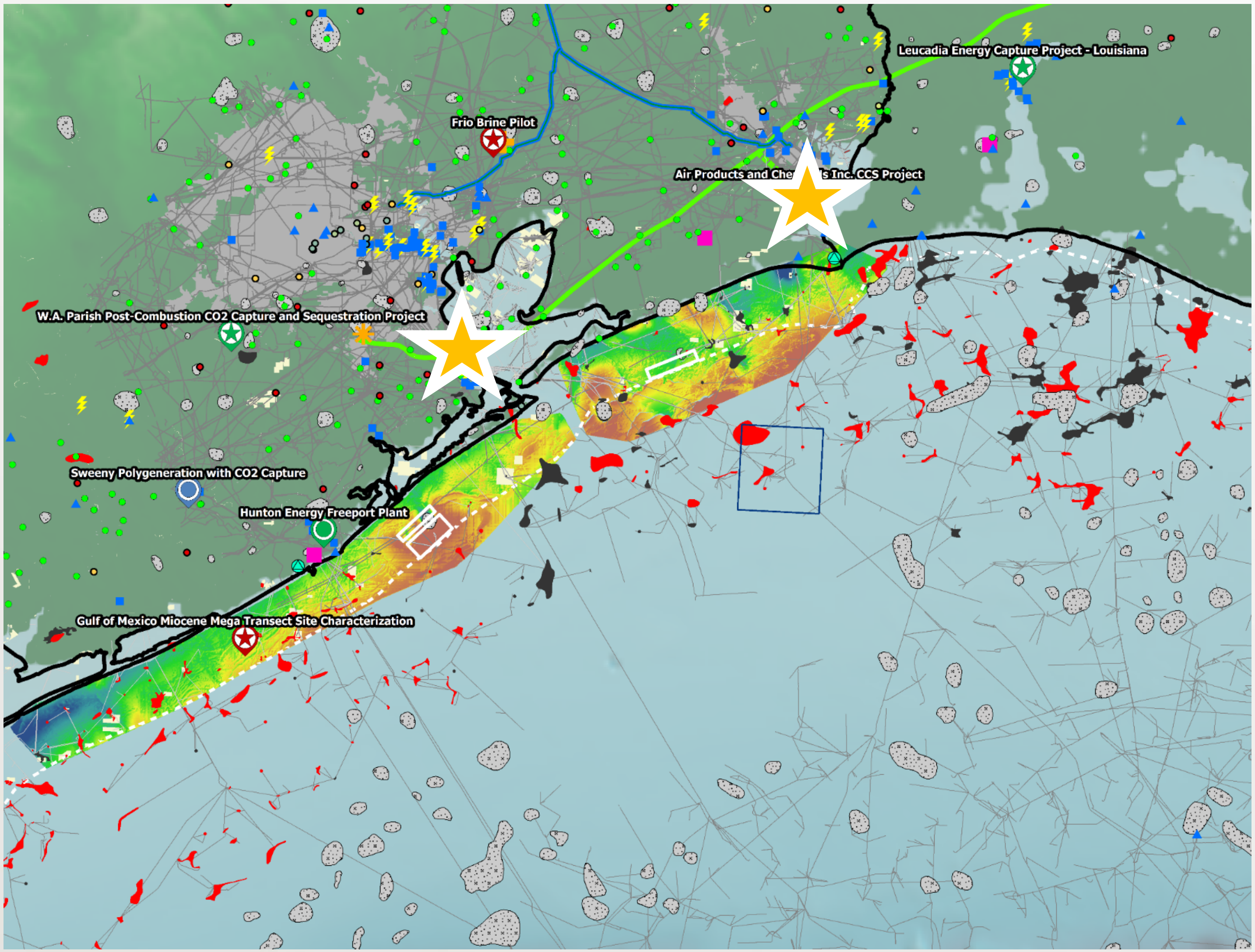
- Power Plants
- Pure CO_2 sources
- Oil and Gas (USGS)
- Coal (USGS)
- Brine Aquifer> 1000m

	Billion Metric tons
NETL Altas V P 10	2,618
NETL Altas V P 90	21,978
USGS	3,000

Compiled 2000 from USGS data

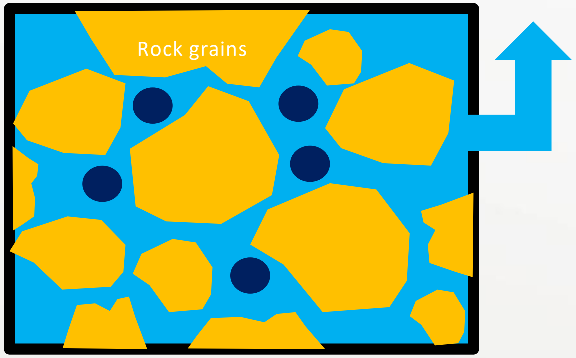
Uncertainty in methods Goodwin 2013 review

Gulf of Mexico Partnership - GoMCarb



Use of CO_2 for enhanced oil recovery (EOR) process

Residual oil will not move to production wells

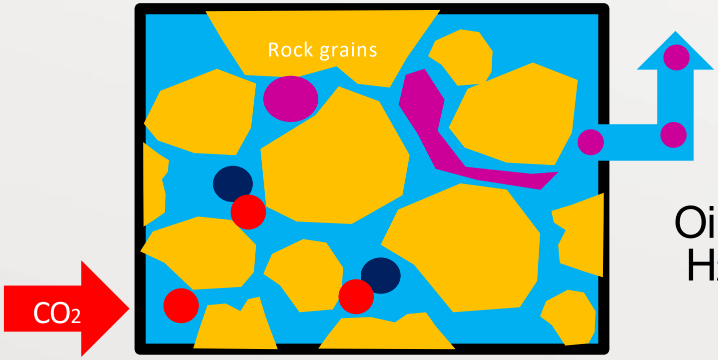


30% Remaining oil is residual, immobile

At reservoir pressure, CO_2 is miscible with oil

- Viscosity decrease
- Volume increase

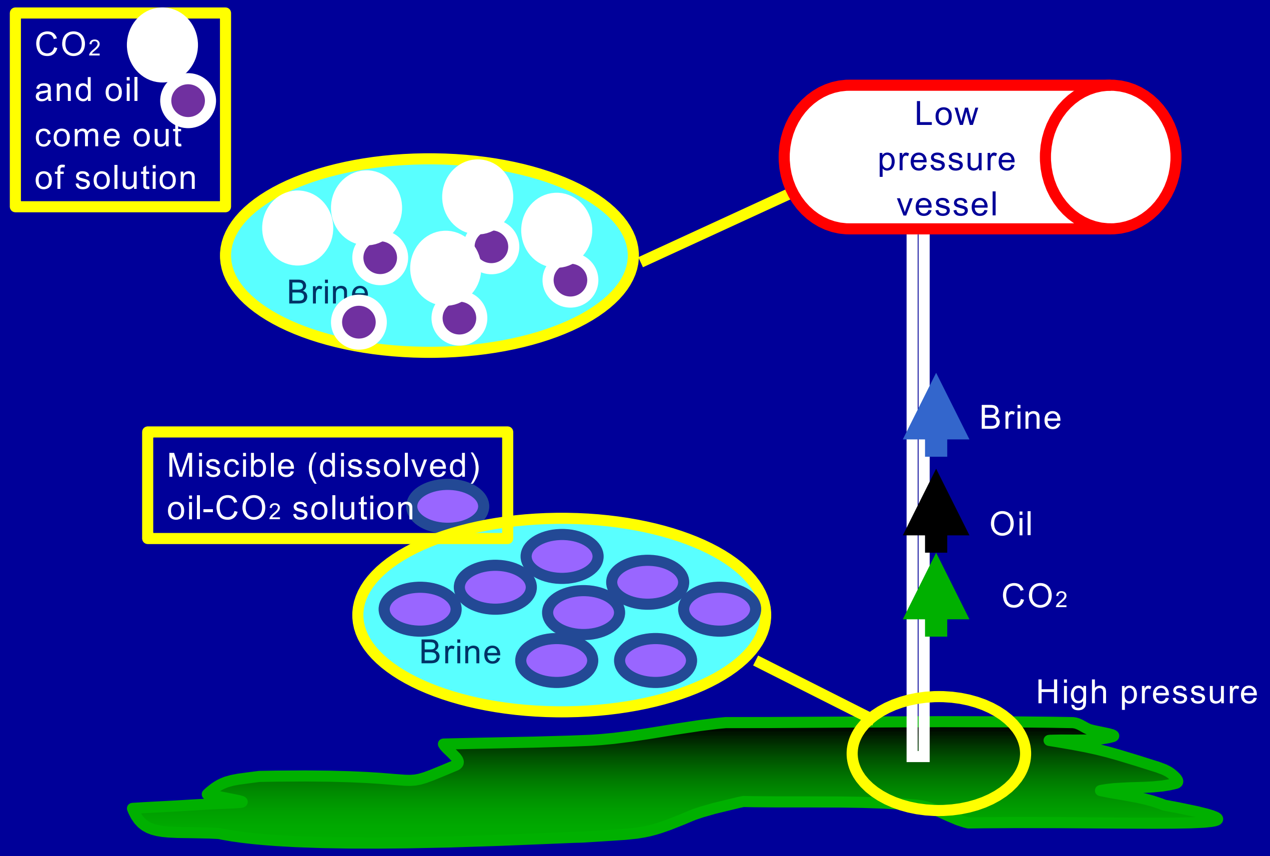
Oil-CO_2 phase can migrate to production wells



Oil, CO_2, and H_2O produced

Note: Many other EOR techniques compete with CO_2

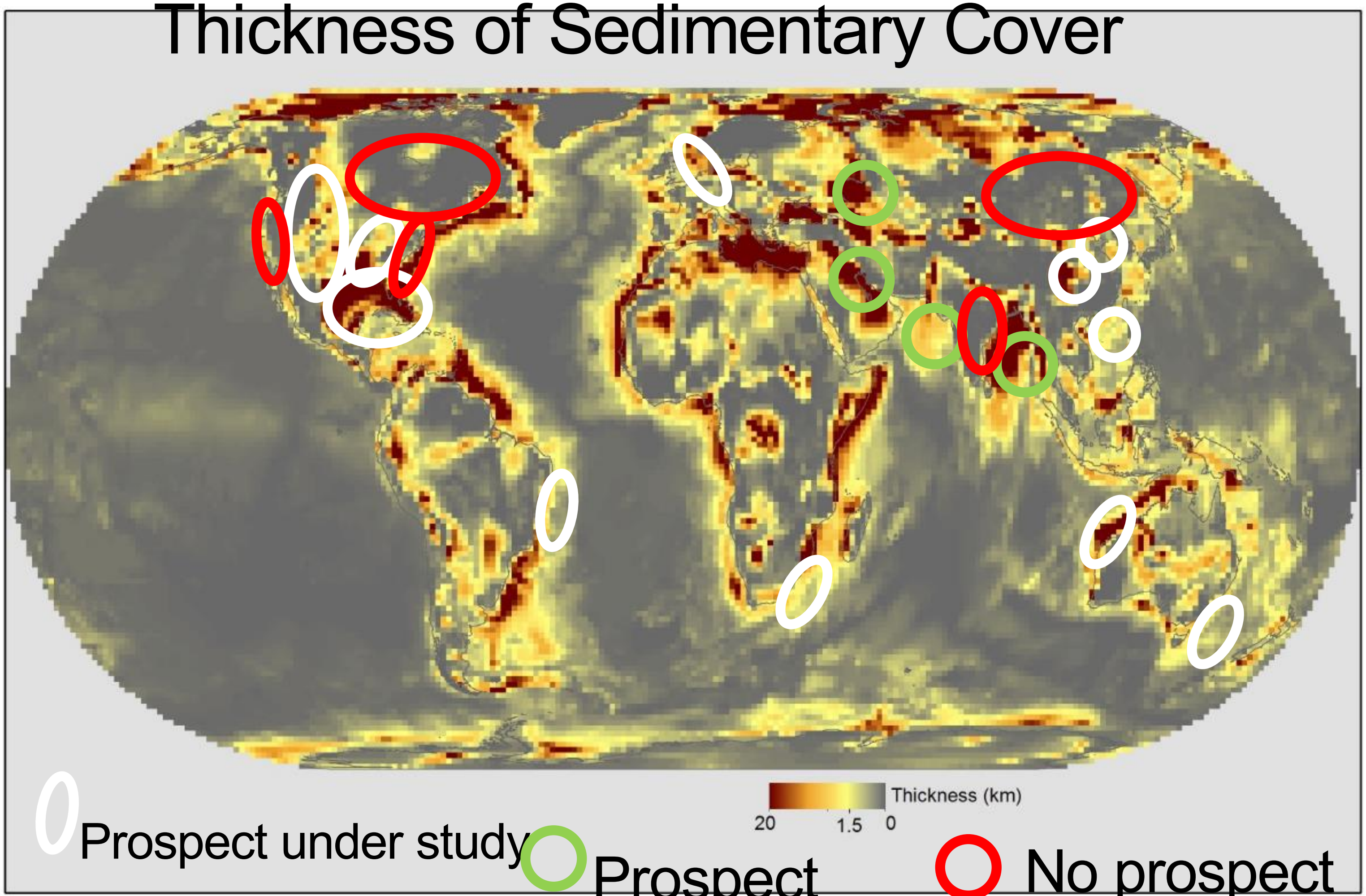
Overview of CO_2 Recycle



Conclusions

- Status of geologic storage in porous media: mature, successfully underway and ready for large scale implementation
- Challenges: convincing key stakeholders this is true
- Capacity is large but unevenly distributed
- Methods for dealing with questions
  - Failure is rare: Need more experience via experiments

Where can storage occur:
Thickness of Sedimentary Cover



G. Laske and G. Masters, A Global Digital Map of Sediment Thickness, EOS Trans. AGU, 78, F483, 1997
GIS by Ruth Costly, BEG