Geological Sequestration of Carbon Dioxide

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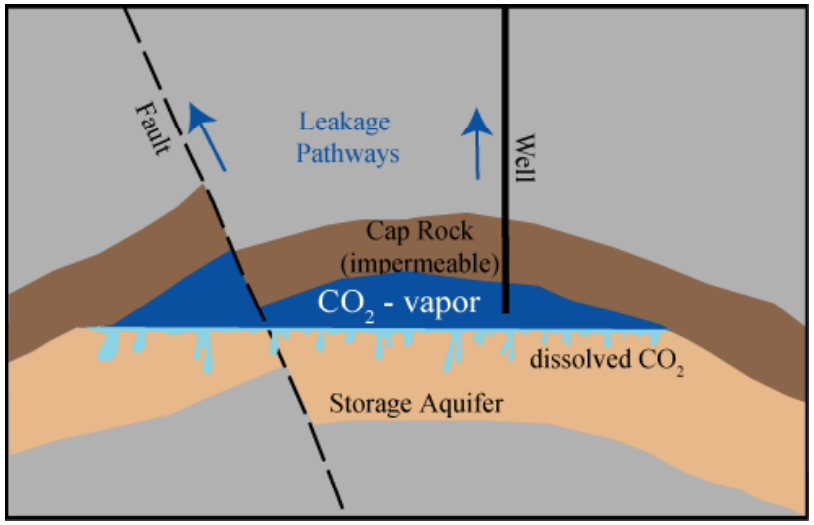
What is CCS?

- CCS is an AC for the Earth:
  - Global warming: anthropogenic or natural?
    - A mute question
  - The question should be whether we can do something to lessen its effects
  - Hot summer is natural! But we invented AC to cool down the temperature to a comfortable level
- CCS is an Insurance Policy against global warming
  - Insurance is costly and no return before cashing in it
  - The question is the cost vs. the benefit
  - Whether one can afford it

Basic Research Questions

- The science of geological sequestration is just starting
- Many R &D questions remain:
  - Capacity
  - Injectivity
  - Impact to reservoir
  - Caprock integrity
  - Leakage pathway and rate
  - Monitoring
  - Performance assessment
  - Risk assessment

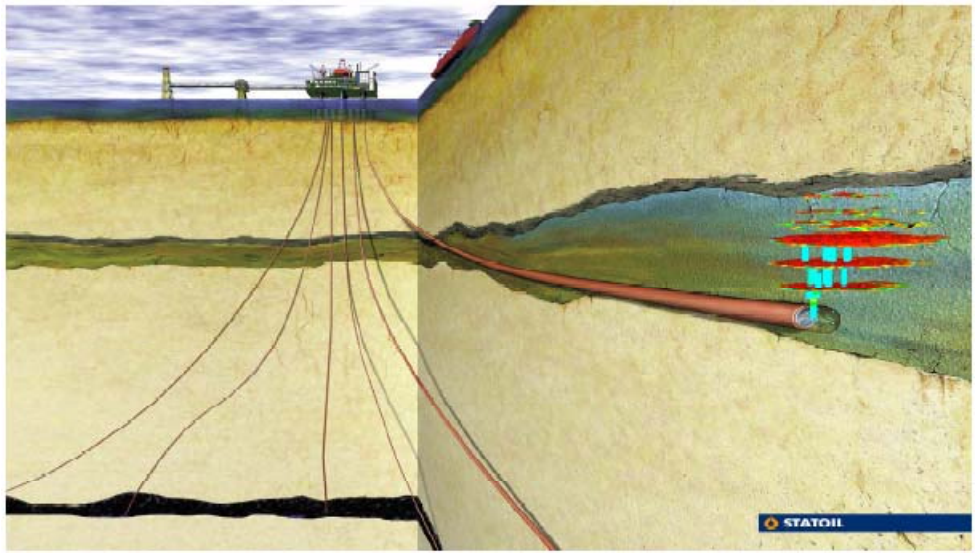


Saline Aquifers

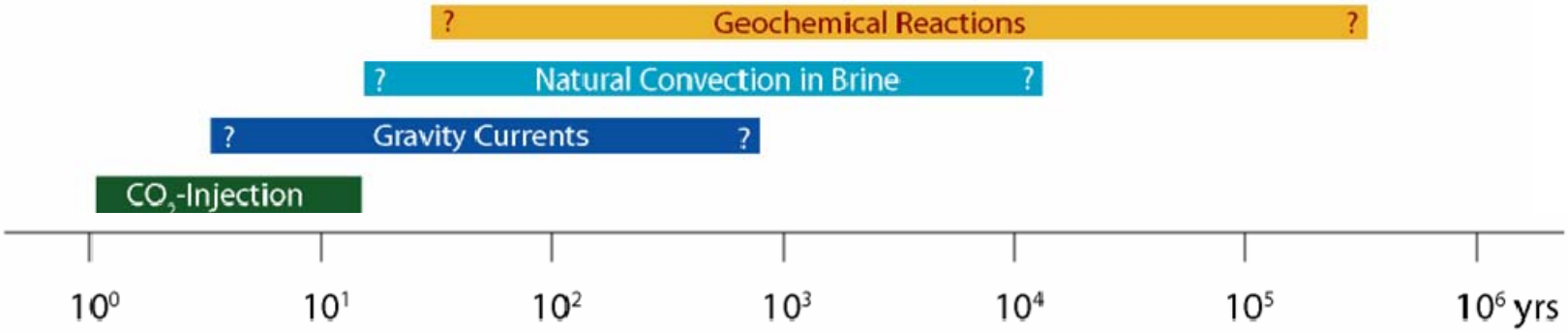
Features:

- Viscous fingering
- Gravity segregation
- Capillary entrapment
- Convective mixing
- Geochemistry

Sleipner CO2 Injection

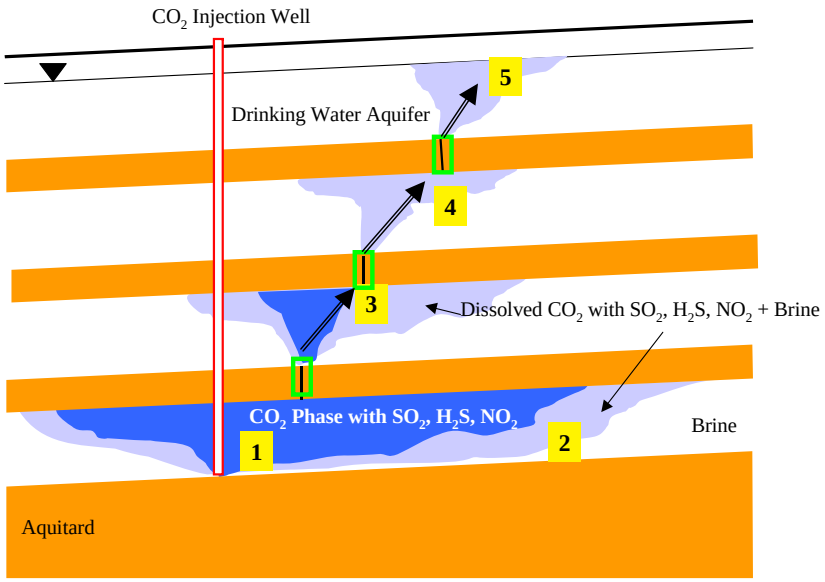


Time scale estimates



Complexities and Uncertainties

- A multiplicity of length scales
  - From atomistic and microscopic, to macroscopic and to field-scale
- Large timescale range of interest
  - From picoseconds to millennia
- Coupled processes
  - Fluid flow, geomechanics, geochemistry, and heat transfer
- Various components
  - Reservoir/aquifer, caprock, overburdens, faults, and wells
- Spatial variabilities and poor knowledge of them

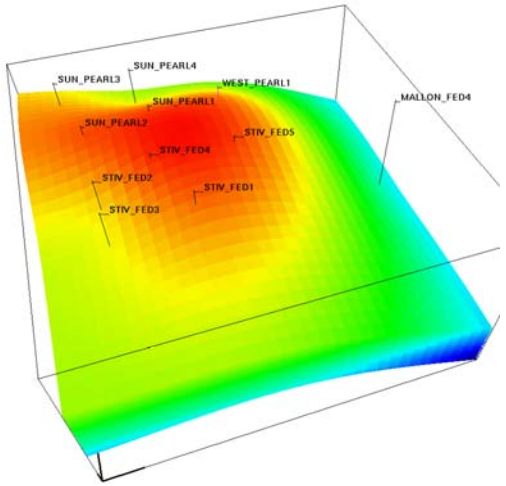


EOR/EGR vs. Sequestration

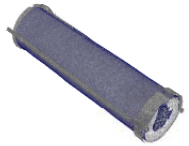
- Although industrial EOR experiences exist, there are major differences between EOR and Sequestration:
  - The current EOR minimizes the amount of CO_2 used while the goal of seq. is to store as much CO_2 as possible
  - EOR is a short term process (of several years) while seq. is at the scale of 100s to 1000s years
  - Long term performance assessment required for sequestration --- EOR has an industrial experience of 40 years (still a short timeframe for seq.)
  - Higher-confidence predictive and monitoring tools are needed for sequestration
- New EOR strategies are needed if sequestration is the goal

Our Past and Ongoing Research on GCS (1)

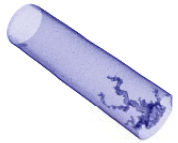
- Los Alamos National Lab (LANL):
  - DOE: A comprehensive modeling and site monitoring project (USD 3.515M, 2000-2004).
  - LANL: Science of Geological Carbon Sequestration: Integration of Experimentation and Simulation (USD 3.0M, 2004-2006).



Neutron Tomography of Limestone After Stage 1 Flooding

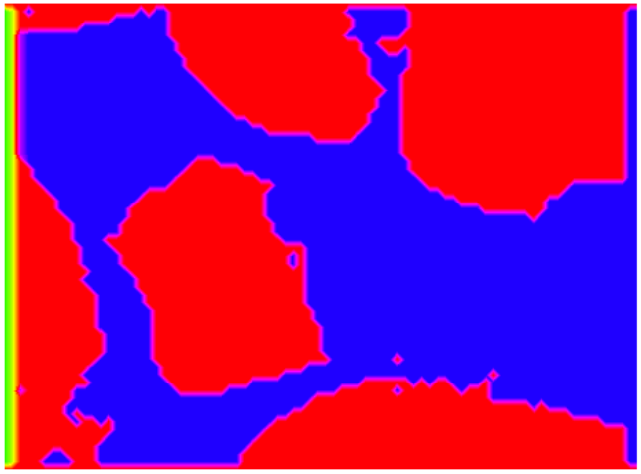


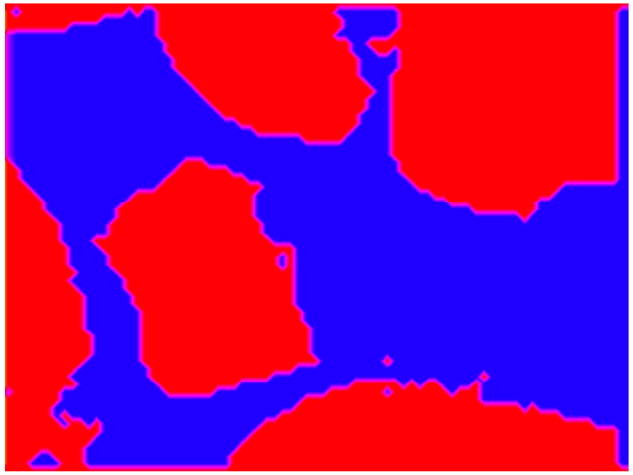
Outer Surface of Core



3-D Wormhole View

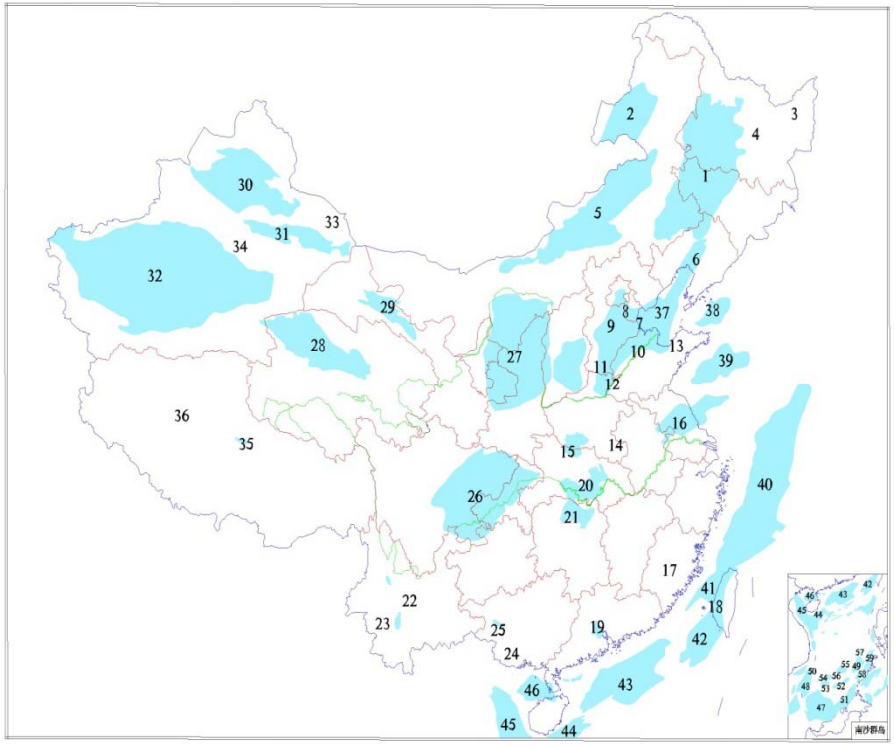
2-D Slice





Our Past and Ongoing Research on GCS (2)

- Peking (Beijing) University:
  - 973 Project – Geological Carbon Storage with Enhanced Oil Recovery, PI: SHEN Pingping, 2006-2011. (Topic #3: D. Zhang)
  - Stanford GCEP Project: Collaborative Research on Carbon Sequestration in Saline Aquifers in China, PKU-CUG-USC (USD 2.0M)



General Conclusion

- Geological sequestration presents an **immediate, low-cost** option for carbon management.
- Carbon sequestration is an important measure for sustaining fossil fuel based economy.
- In spite of past experiences, many fundamental R&D issues are outstanding:
  - Prediction under uncertainties: Development, validation, and verification
  - Monitoring and verification technologies
  - Performance and risk assessment
  - Public awareness and acceptance
- The field of carbon sequestration is still in its infancy --- providing ample research opportunities

CCS Technical Workshop

Berkeley-Stanford-Beijing
U.S.-China Workshop on Carbon Dioxide Capture and Storage

Beijing University, November 11-12, 2009

Workshop Chairs
Donald J. DePaolo (UCB, LBNL)
Dongxiao Zhang (PKU)