

CO₂ Gradient Affects the Microbial Ecology of a Potential Sequestration Site*

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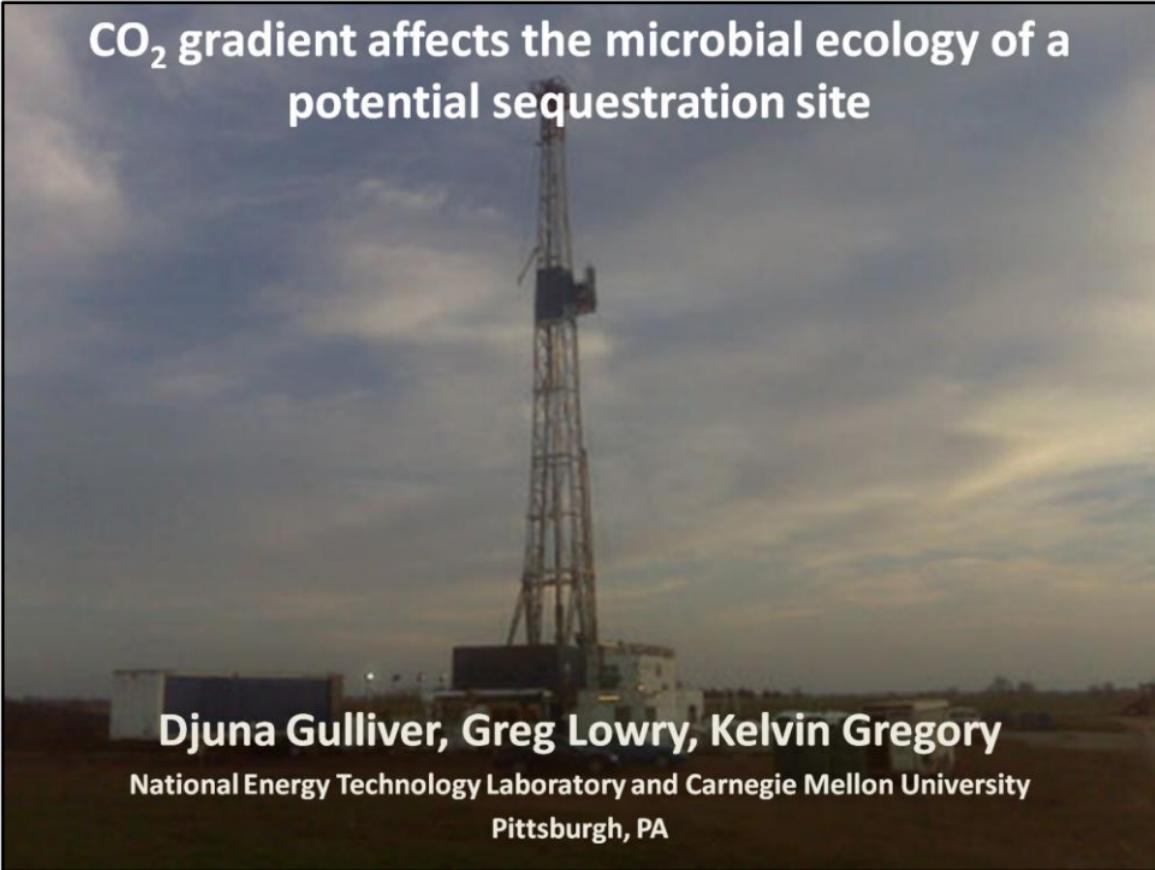
Abstract

Geological carbon sequestration is likely to be part of a comprehensive strategy to minimize the release of greenhouse gasses into the atmosphere. Reservoir storage capacities and long-term security of geologic carbon sequestration will be dependent on the trapping mechanisms and mineral transformation in the deep subsurface. A critical need exists to understand the evolution of microbial populations that influence the biogeochemistry in these reservoirs. As the CO₂ front moves through the storage aquifer, microbial communities may reside in residual brine left behind in cracks, dead flow zones, and upstream to the front; this brine will have a gradient of dissolved CO₂ concentration.

The evolution of microbial ecology along this CO₂ concentration gradient was investigated using fluid-slurry samples obtained from a proposed carbon sequestration site. The native species of these samples were investigated with varying pCO₂ from 0% to 100% under reservoir temperature and pressure for up to 56 days. Microbial growth occurred with 0% and 1% pCO₂, while microbial population decreased by four orders of magnitude with 10% and 100% pCO₂. This suggests that any biological processes that may have been involved in the security of the reservoir pre-CO₂-injection will be hindered near the CO₂ plume, but may be important where CO₂ is attenuated. Batch reactors with 0% pCO₂, but lowered pH had increased microbial population by one order of magnitude, suggesting that microbial shifts will occur even in highly buffered reservoirs due to exposure to CO₂. Halotolerant microorganisms *Halomonas* and *Marinobacter* were the most tolerant to the conditions that would follow CO₂ injection. Findings provide insight into the populations that may survive in the deep subsurface following the supercritical fronts. These populations will eventually give rise to the community that will impact the trapping mechanisms, storage capacities, and long-term security of the CO₂ deposits. Knowledge of the surviving microbial populations will enable improved models for predicting the fate of CO₂ following injection and lead to better strategies for ensuring the security of CO₂ in the subsurface.

Reference Cited

Rackley, S.A., 2010, Carbon capture and storage: Butterworth-Heinemann/Elsevier, Burlington, MA, 392 p.

A tall, slender industrial structure, likely a drilling rig or wellhead, stands prominently in the center of the frame. It is constructed from a lattice of metal and has a small platform or cabin near the top. The structure is set against a backdrop of a cloudy sky with soft, diffused light, suggesting an overcast day. In the foreground, there are some lower-level industrial buildings and equipment, but they are less distinct than the tall rig.

**CO₂ gradient affects the microbial ecology of a
potential sequestration site**

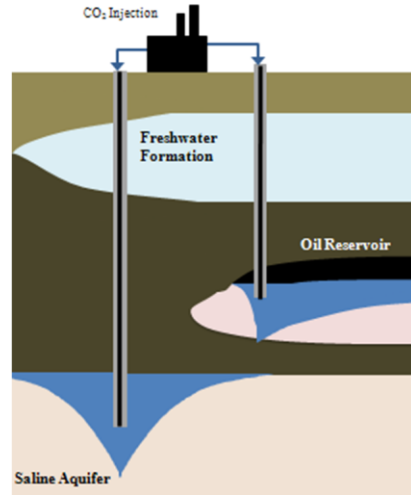
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Background

Geologic carbon storage

- **Main carbon storage concerns:**
 - capacity of CO₂ storage
 - permanence of CO₂ storage
 - reservoir injectivity

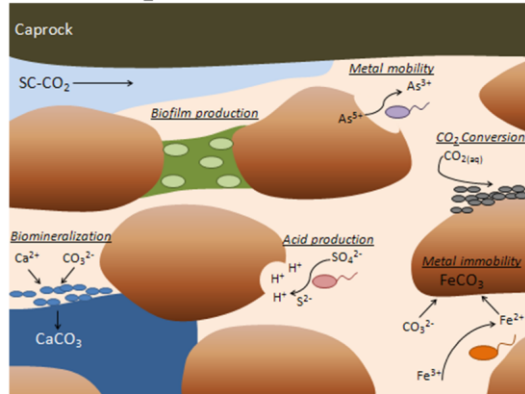


Presenter's notes: Just hit 400 ppm in atmosphere, compared to 368 in 2000 (Rackley, 2010).

Background

Biological processes

- Microbiology may affect geologic CO₂ storage through various biological processes
 - Biomineralization
 - Biofilm production
 - Acid production
 - Metal mobilization
 - Metal immobilization
 - CO₂ conversion

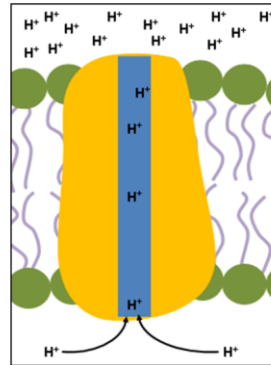
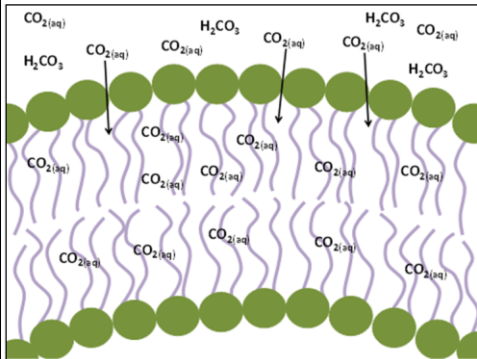


- We need to understand the relevant microbial community before we can begin to investigate bioprocesses that will occur.

Background

CO₂ effects on microbiology

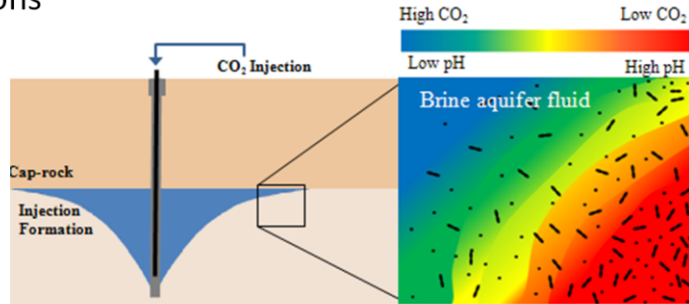
- Affect cytoplasmic enzymes
- Greatly lowers pH
- Membrane infiltration of CO₂



Background

Heterogeneous characterization

- Injection of CO₂ will not lead to a uniform CO₂ concentration
- Varying conditions
 - CO₂ conc.
 - pH
 - Ion conc.



- Microbial ecology will adjust to varying condition

Objectives

- Characterize the native microbial community of the Arbuckle Aquifer, Wellington, KS
- Characterize Arbuckle Aquifer microbial community changes with various CO₂ concentration

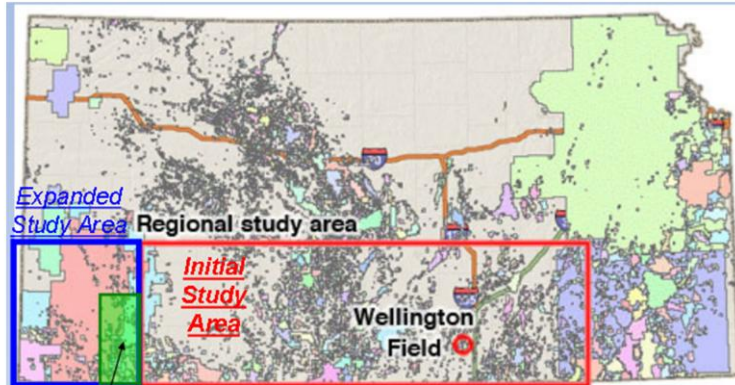
Materials and Methods

Sampling Site

Depth of 4175-4390 ft

Formation consists of dolomite with lenses of shale

Pressure of 14 MPa, Temperature of 40 °C, pH of 7.8



http://www.jgs.ku.edu/PRS/Ozark/Reports/2012/Watney_KGS_tech_mtg_3-6-12.pdf

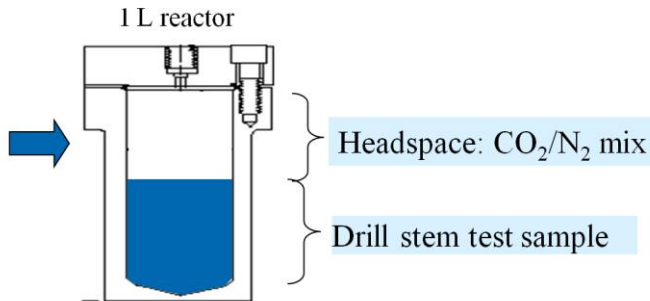


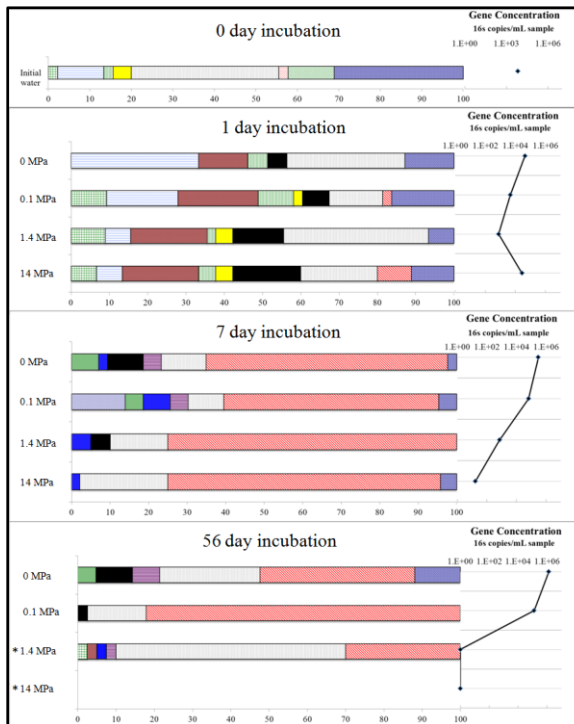
Presenter's notes: Drill stem test at depths of 4175-4190 ft and 4280-4390 ft

Materials and Methods

Pressurized vessel

- Place drill stem test samples under in situ temperature (40 °C) and total pressure (14 MPa)
- Vary partial pressure of CO₂ of 0 MPa pCO₂, 0.1 MPa pCO₂, 1.4 MPa pCO₂, and 14 MPa pCO₂
- Vary incubation time of 1 day, 7 days, and 56 days to detect adapting ecology
- Characterized change in microbial community with 16S rRNA clone libraries and qPCR





Results

Microbial phylotypes (genus)

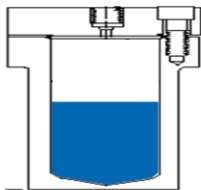
- Xylanimonas*
- Marinilabilia*
- Psychromonas*
- Clostridium*
- Geoalkalibacter*
- Pelobacter*
- Bacillus*
- Pseudomonas*
- Desulfovibrio*
- Desulfuromonas*
- Halomonas*
- Marinobacter*
- Alkaliflexus*
- Cyclobacteriaceae*
- Other*

* Used nested PCR methods

Materials and Methods

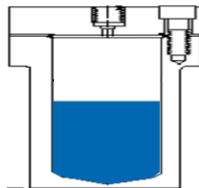
Pressurized vessel

Vessel 1



0 MPa CO₂, pH=4.4

Vessel 2



1.4 MPa CO₂

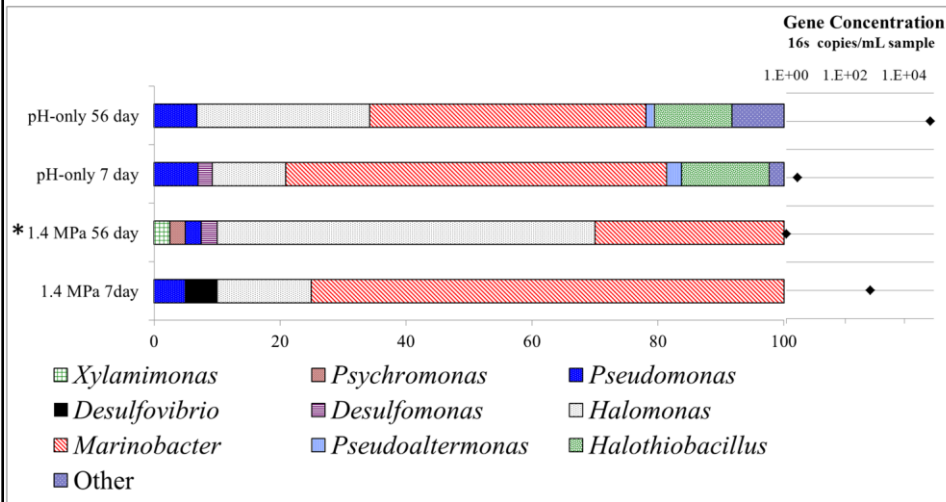
Liquid: Arbuckle Drill Stem Test

Temperature: 40 °C

Run time: 7 days, 56 days

Results

Changes in microbial community during carbon storage



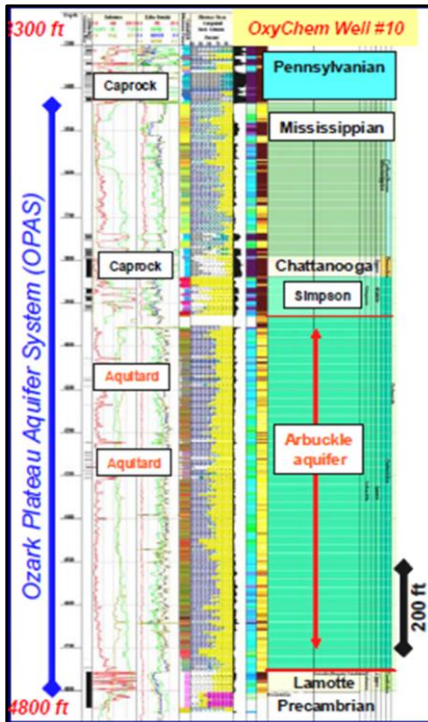
Summary

Changes in microbial community during carbon storage

- CO₂ exposure as low as 0.1 MPa will inhibit microbial growth
- CO₂ exposure as low as 1.4 MPa will exterminate microbial growth
- Highly diverse samples after 1 day evolved to limited diversity after 7 days and 56 days of CO₂ exposure
- Halotolerant microorganisms *Halomonas* and *Marinobacter* appeared to be the most resilient to CO₂
- Microbial processes will not be of importance near the CO₂ front, but may be important at a distance where CO₂ will be attenuated

Acknowledgements





Additional Information

Site Description

- Depth of 3,500 ft
- Formation thickness of 800 ft
- Overlain by 50 ft Chattanooga shale and Mississippian EOR reservoir
- Formation consists of dolomite with shaley aquitards
- Pressure of 14 MPa
- Temperature of 40 °C

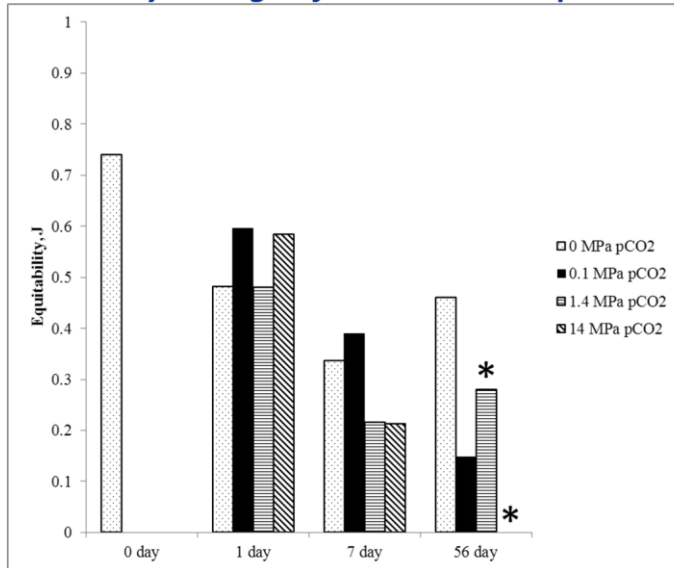
Additional Information

Site Description

- **DOC of 110-170 ppm C**
- **CH₄ of 280-4370 ppm**
- **CO₂ of 0.40-4.0 ppm**
- **TDS of 10,000-250,000 ppm**
- **Salinity of 55,100-57,800 ppm**

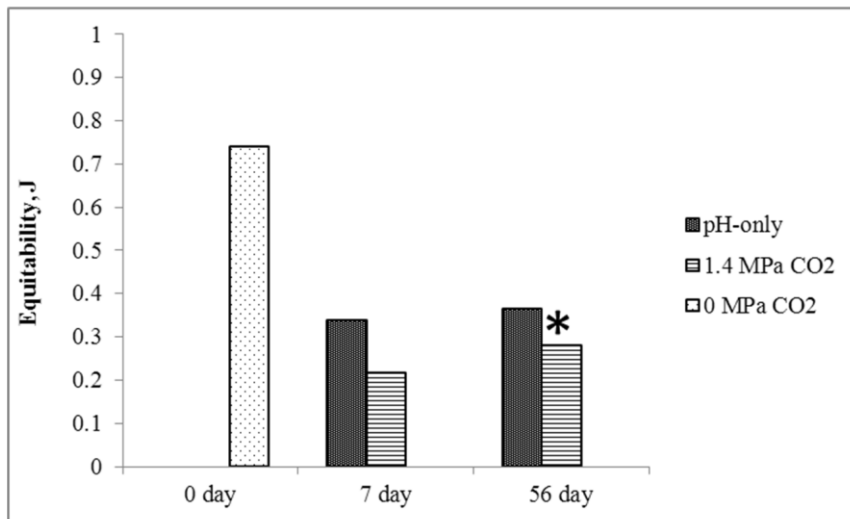
Additional Information

Diversity change of main vessel experiment



Additional Information

Diversity change of pH vessel experiment



Additional Information

Water Chemistry

	Units	Raw	0 MPa CO ₂	0.1 MPa CO ₂	1.4 MPa CO ₂	14 MPa CO ₂
Ca	mg/L	2502.0	2071.0	2186.0	2186.0	2104.0
Fe	mg/L	< DL	< DL	< DL	0.5	2.5
K	mg/L	258.5	251.7	255.9	253.2	256.6
Mg	mg/L	702.4	567.8	578.4	577.1	590.7
Mn	mg/L	0.9	0.7	0.9	0.9	0.9
Na	mg/L	22690.0	18280.0	18440.0	17530.0	17640.0
P	mg/L	1.5	3.4	1.4	2.4	2.0
S	mg/L	631.0	593.9	618.4	601.0	613.1
Si	mg/L	10.0	9.4	10.1	10.8	11.0
Zn	mg/L	0.2	0.1	0.8	1.8	2.4
SO₄²⁻	mg/L	1190.0	369.9	1007.4	953.7	1096.3
Cl⁻	mg/L	31528.2	31992.3	32397.2	31639.1	37757.3
Modeled pH		7.80	7.50	5.50	4.38	2.88