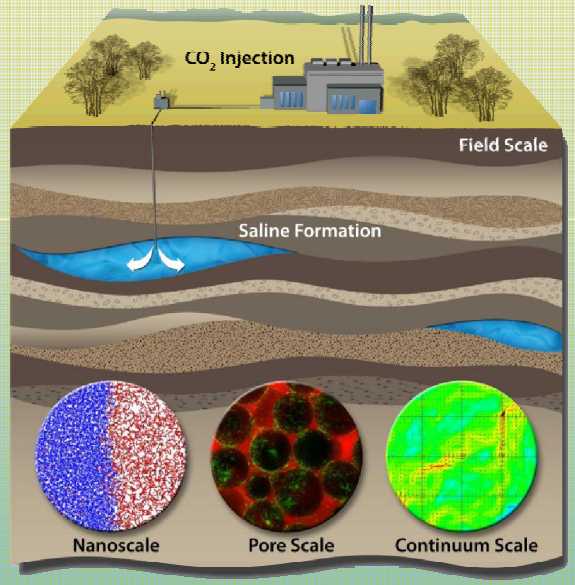
Center for Frontiers of Subsurface Energy Security

SAND2012-0284P

Variation in energy available to subsurface microorganisms



Presenter: Matthew Kirk

Contributors: Eugenio Santillan, Susan Altman, Philip Bennett

EFRC Science Review
Denver, Colorado
January 24, 2012

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY
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TEXAS

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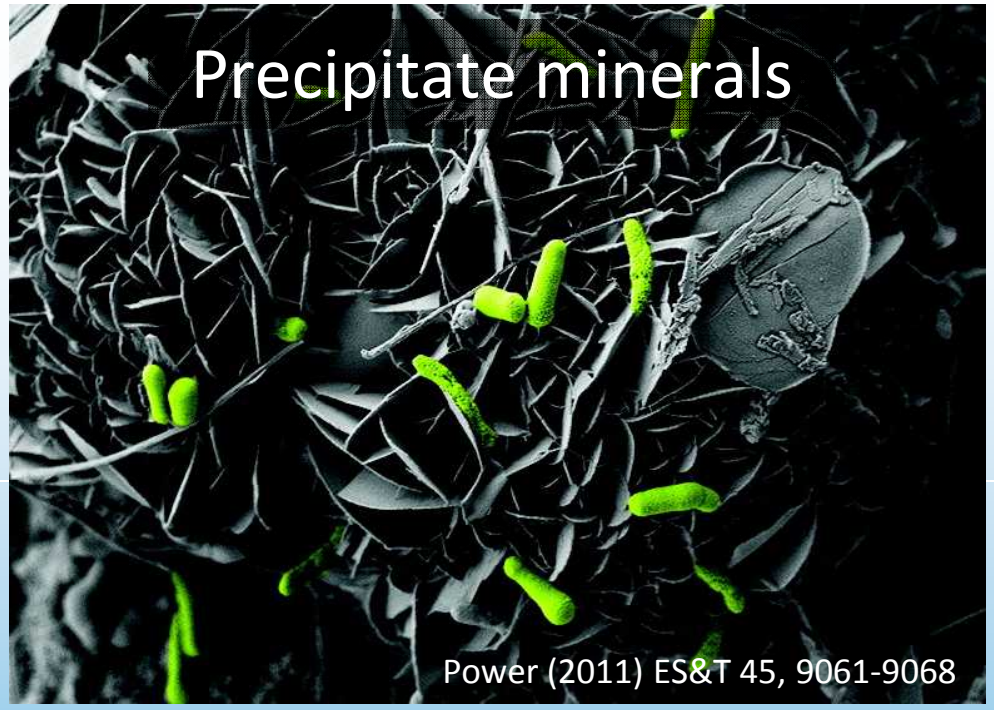
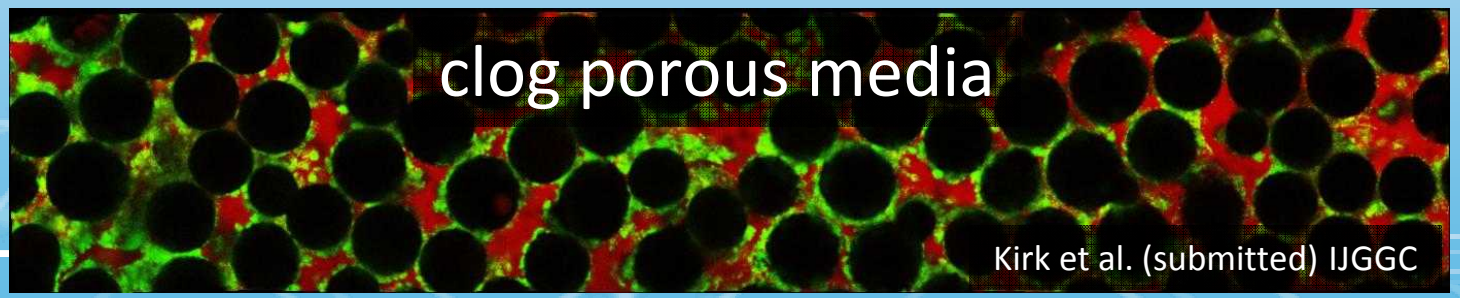
NNSA

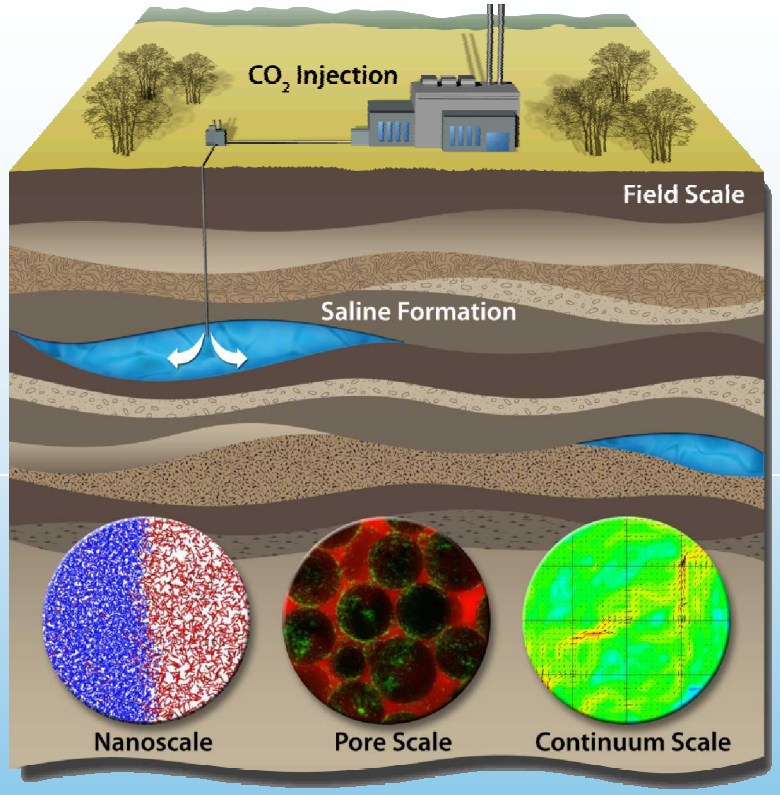
Microbes can influence CO_2 trapping





bacteria water glass beads

Scales Range from Molecular to the Field and Femtoseconds to Millennia



10^3 years (or more)

Time

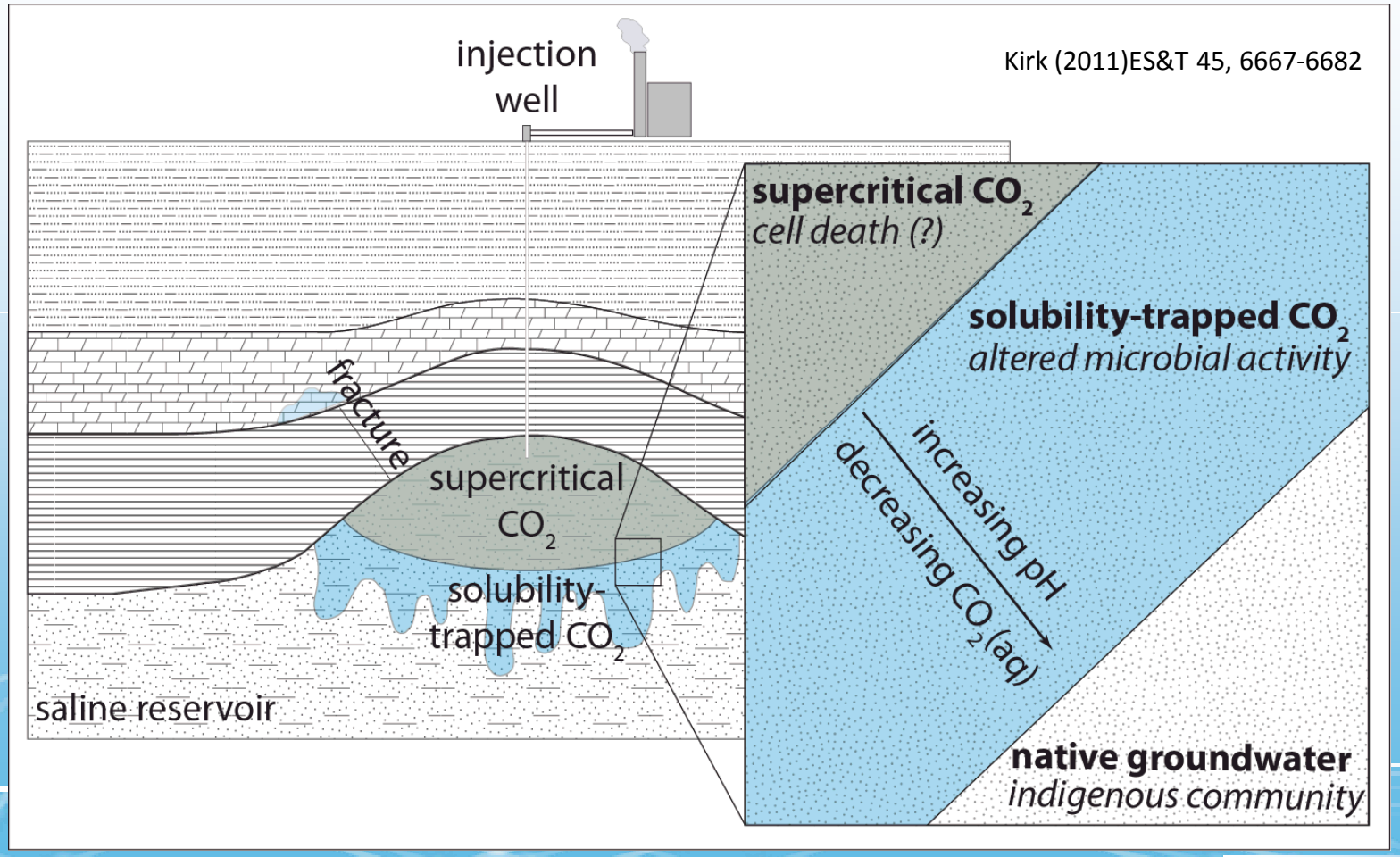
10^{-15} second

10^{-9} m | 10^{-5} m | 10^{-1} m | 10^{2} m

Focus Area 1 | Focus Area 2 | Focus Area 3 | Focus Area 4

Nanoscale | Pore Scale | Continuum Scale | Field Scale

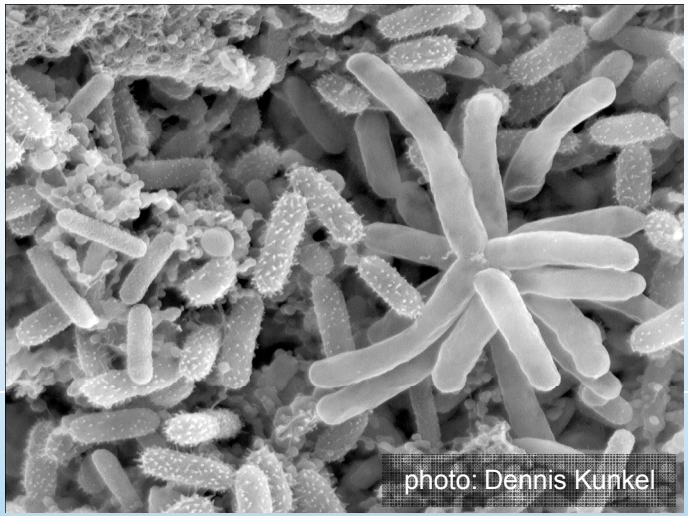
How will changes in water chemistry affect <u>what</u> microbes are doing?



Bioenergetics analysis

CO_2 injection field experiments:

- Frio Formation
- ZERT site



Microorganisms:

- Fe(III) reducers
- SO_4^{2-} reducers
- Methanogens

Calculating energy available (ΔG_A)

ΔG_A = free energy released by metabolic reaction:

$$\Delta G_A = -\Delta G_r = -[\Delta G_T^{\circ} + RT ln Q_r]$$

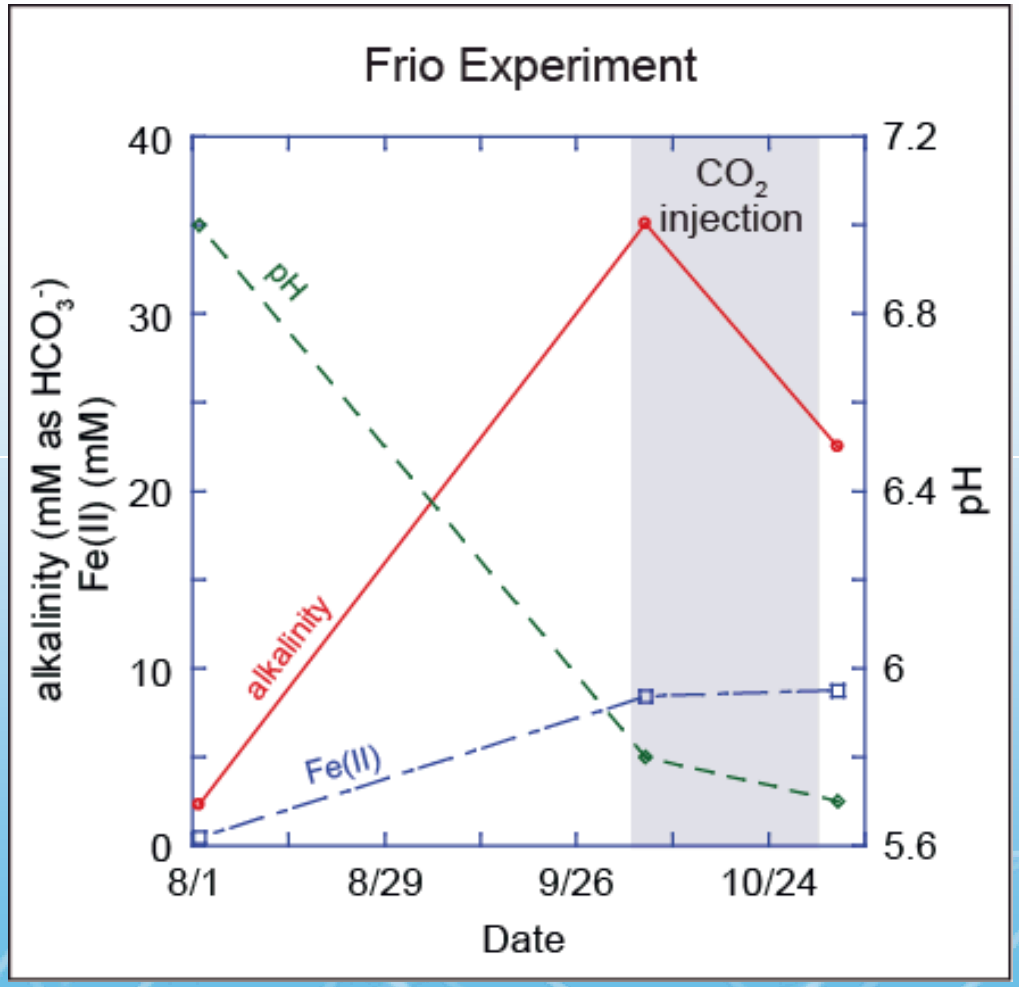
$$Q_r = \prod_i (\gamma_i \times m_i)^{v_i}$$

- v_i: stoichiometric coefficient
- γ_i: activity coefficient
- m_i: molality

Result normalized to conditions prior to CO_2 injection:

$$\Delta G_A^{CO_2} - \Delta G_A^{initial} = \Delta G_A^n$$

CO_2 injection affected pH, alkalinity, and Fe



observation well results

CO_2 injection

1600 tons of CO_2

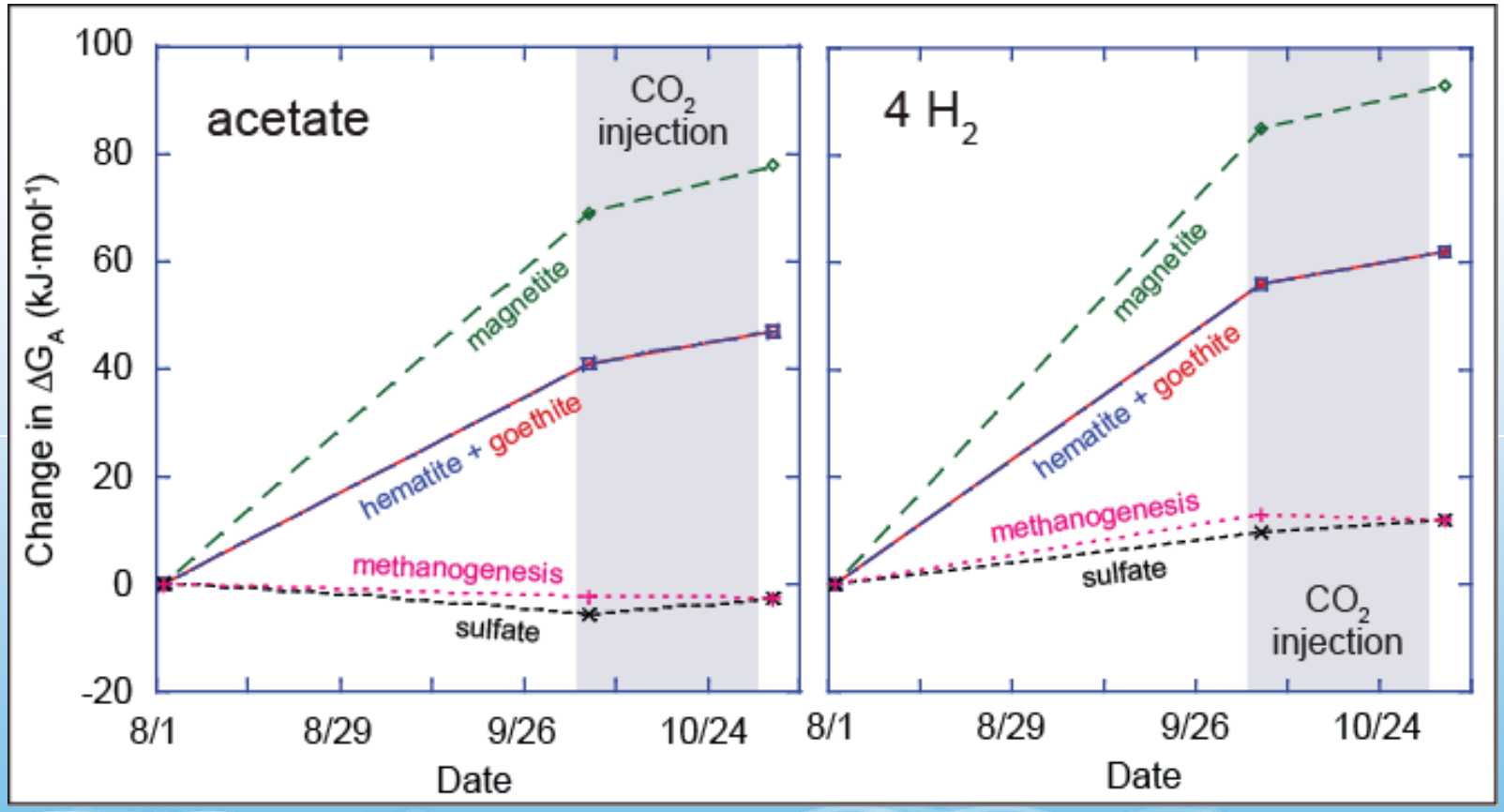
24 m thick sandstone

1500 m depth

Data source – Kharaka et al. (2006) Geology 34

ΔG_A for Fe reduction increased

Kirk (2011)ES&T 45, 6667-6682



Fe(III) reduction 8 Goethite + CH_3COO^- + **17 H^+** → 2 CO_2(aq) + 14 H_2O + 8 Fe^{2+}

8 Goethite + 4 H_2(aq) + **16 H^+** → 16 H_2O + 8 Fe^{2+}

Increase in ΔG_A for Fe reducers favors more rapid Fe reduction

Microbial reaction kinetics

$$r \propto [X] F_D F_A F_T$$

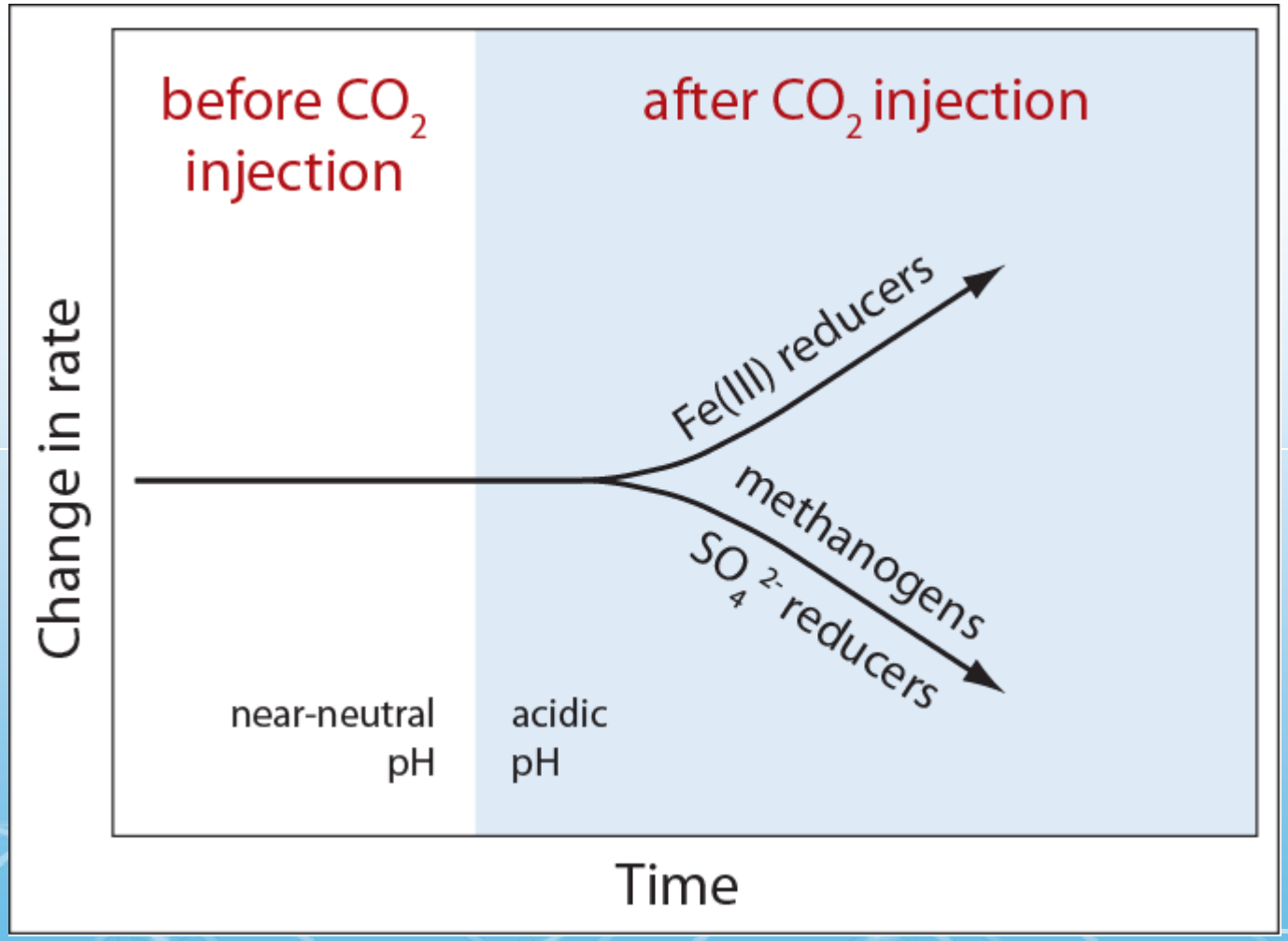
biomass

electron donation

electron acceptance

thermodynamic drive

Conclusions



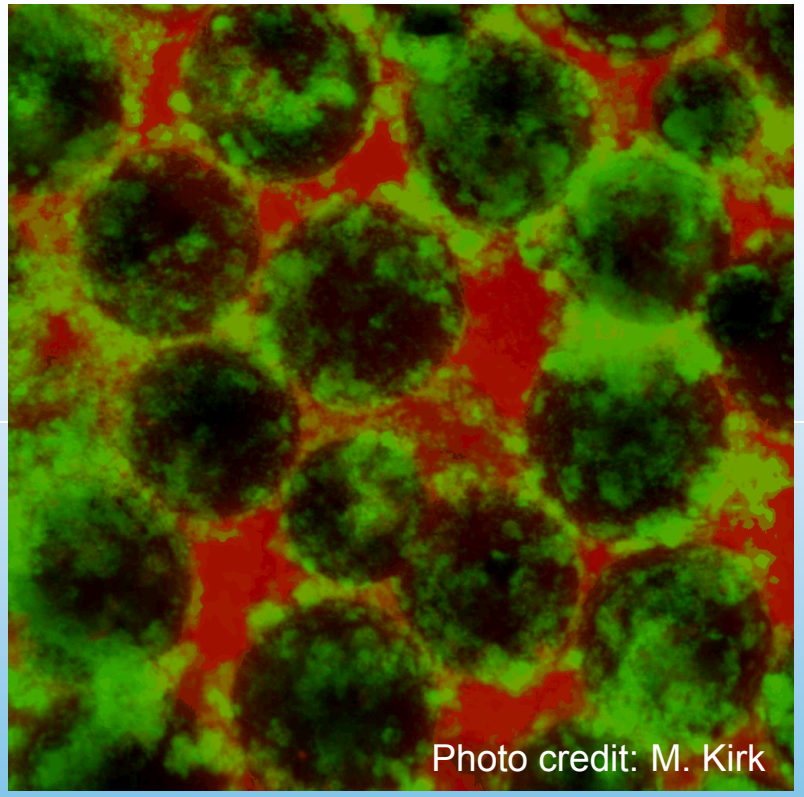
Kirk (2011)ES&T 45, 6667-6682

Implications

Geochemistry changes:

- pH
- oxidation state of Fe
- trace element mobility

Biologically enhanced trapping



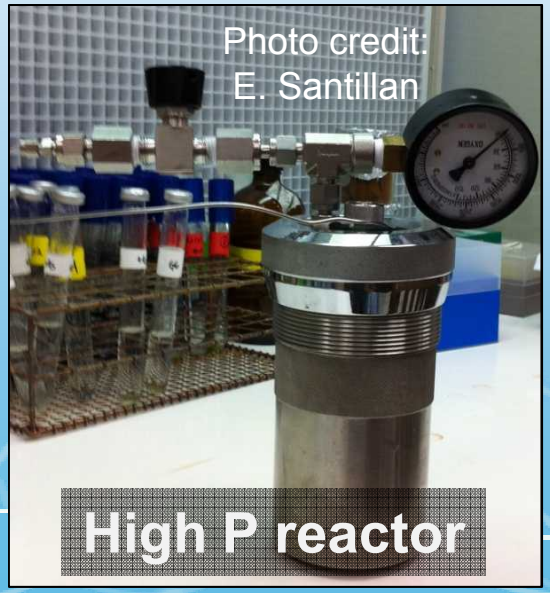
"bioclogging"

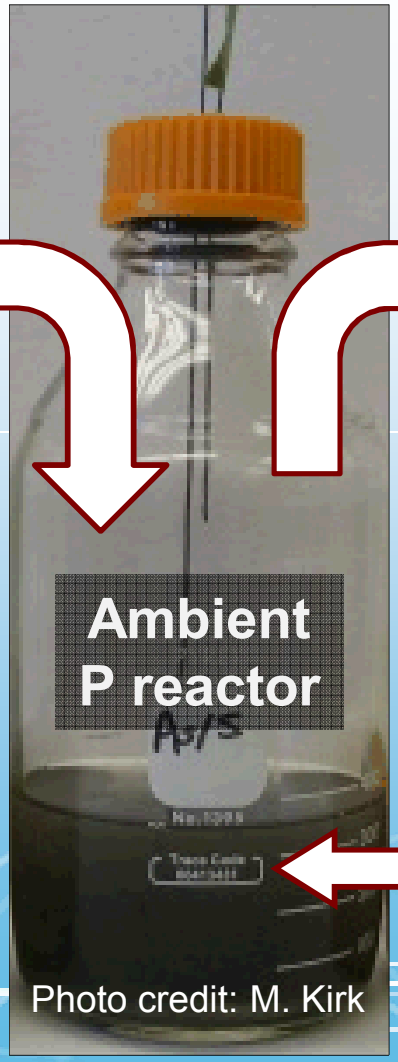
Future work: Bioreactor experiments!

Reactor P, T consistent with reservoir/aquifer conditions

Growth medium

Reacted fluid



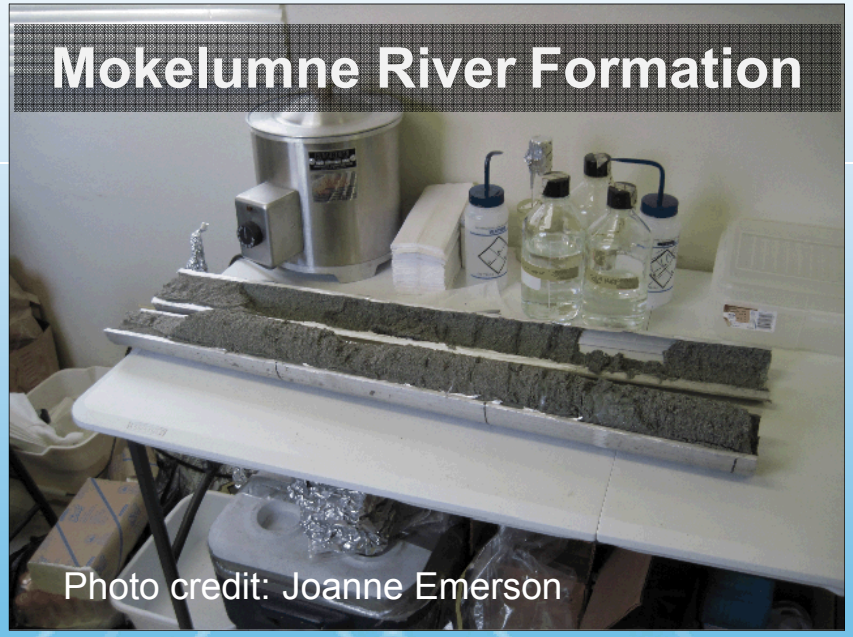


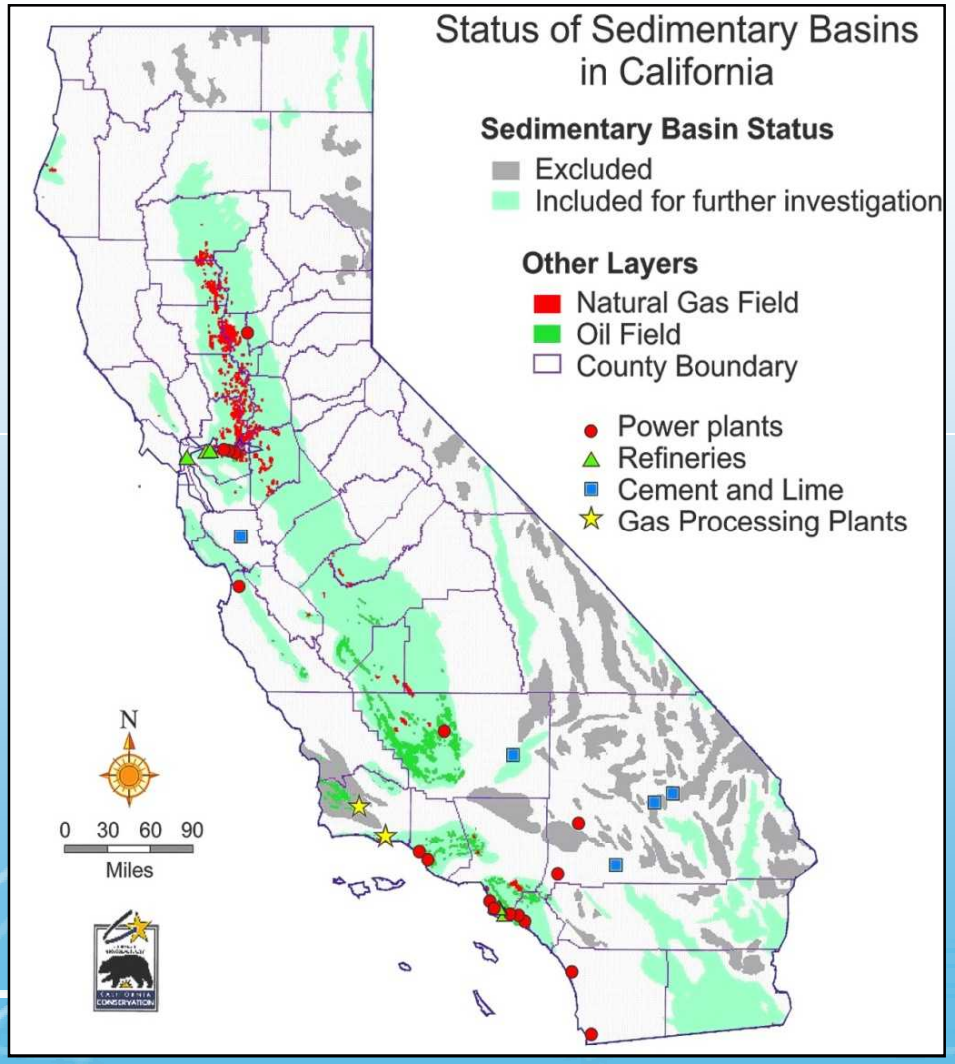
Sediment w/ natural community

Future Work: Deep saline reservoir experiments

NETL

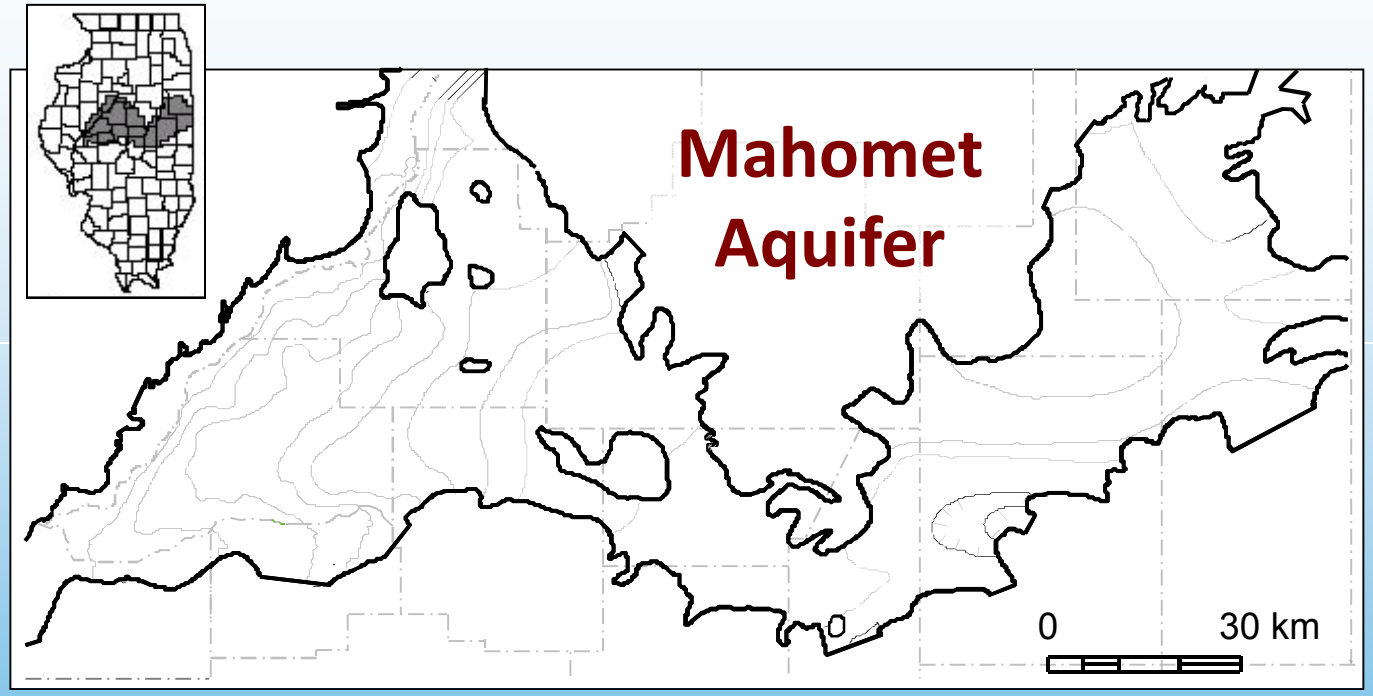
WESTCARB





Future work – Drinking water aquifer experiments

Bug trap



Synergy

WESTCARB core "bioteam"

- SNL + UT
- LBNL
- UC Berkeley
- MIT

UT grad student Eugenio Santillan doing lab work at Sandia

Acknowledgements

We thank Randall Cygan, Qusheng Jin, Hongkyu Yoon, Jay Santillan, Yousif Kharaka, and Susan Hovorka for assisting with this work.

This research is supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences. The Center for Frontiers of Subsurface Energy Security (CFSES) is a DOE Energy Frontier Research Center, under Contract No. DE-SC0001114