SAND2011-8843C

Variation in hydraulic conductivity with decreasing pH in biologically-clogged porous medium

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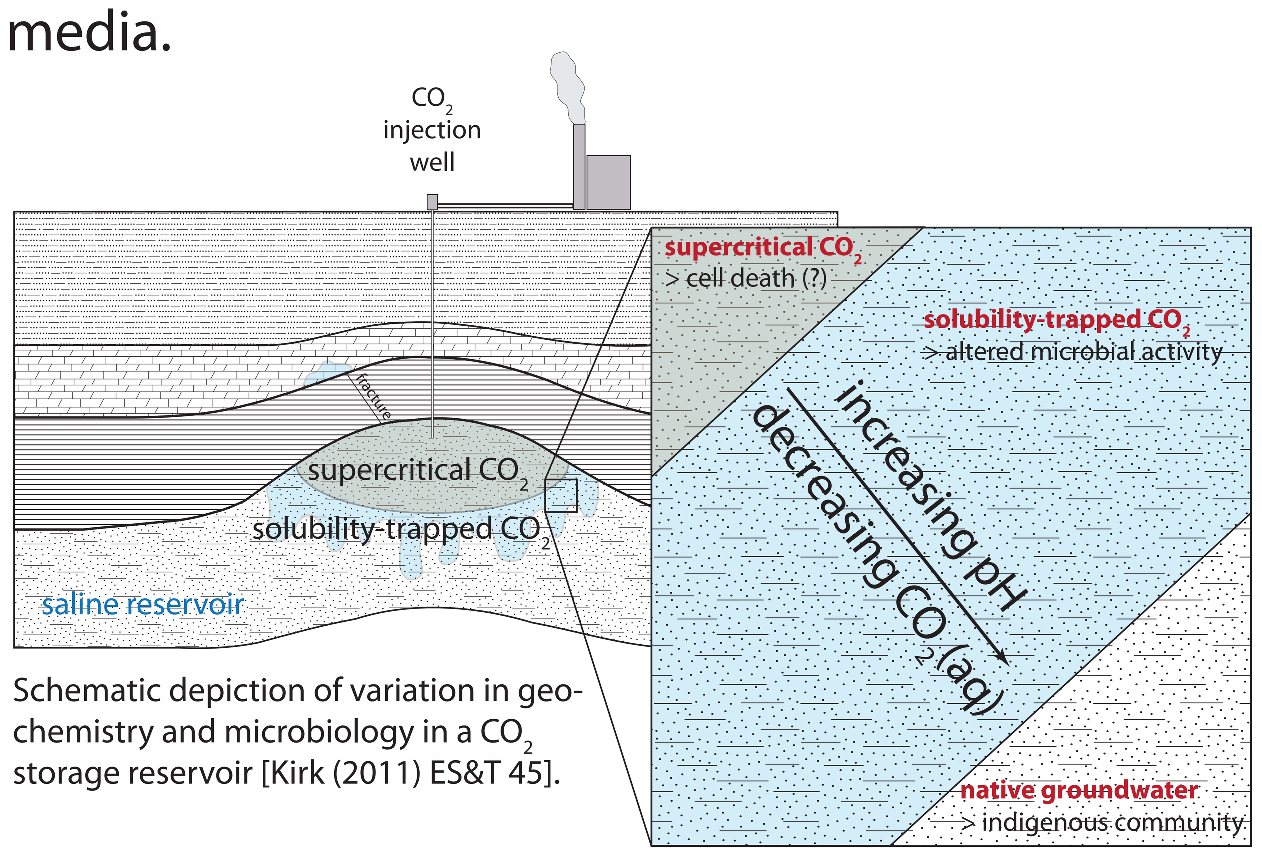
Introduction

Microbial activity can have a considerable influence on the chemical and physical properties of the subsurface. Interaction between subsurface microbes and injected CO_2, therefore, could influence CO_2 trapping and the environmental impact of CO_2 injection. We considered how decreasing pH, a geochemical change caused by CO_2 injection, will affect the stability of bioclogging in porous media.



Schematic depiction of variation in geochemistry and microbiology in a CO_2 storage reservoir [Kirk (2011) ES&T 45].

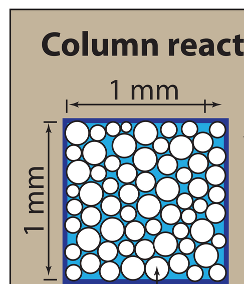
Column Experiments

Pseudomonas fluorescens biofilms were grown for 4 days in column reactors with pH 7.2 medium prior to exposure to pH 4 or 5.7 medium. Green fluorescent protein (GFP) in the bacteria and rhodamine in the aqueous medium allowed cells and pores to be visualized with confocal laser scanning microscopy. Pressure was measured adjacent to the columns using pressure sensors. Cell discharge from the columns was monitored by plating and direct cell counts.

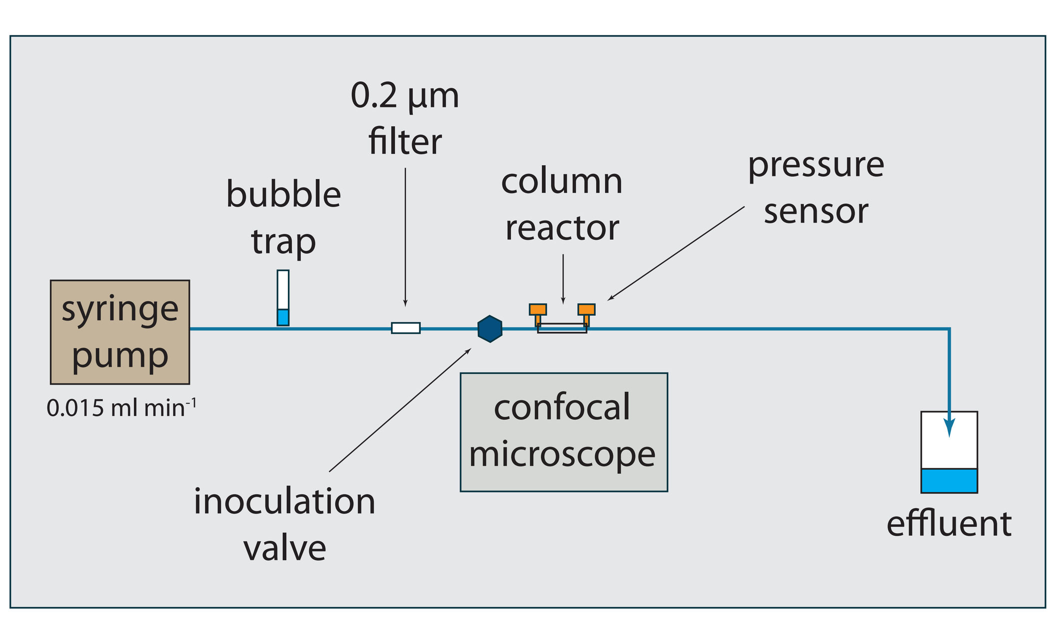
Aqueous medium

Ingredient	*mM*
glucose	1.0
KH_2PO_4	0.05
NH_4Cl	0.5
KNO_3	0.25
$NaHCO_3$	4.0
$CaCl_2$*$2H_2O$	0.5
$MgSO_4$*$7H_2O$	0.25
rhodamine WT	0.0035
at pH 7.2	
alkalinity as HCO_3^-	3.3
TDS (mg L^{-1})	500

Column reactor details

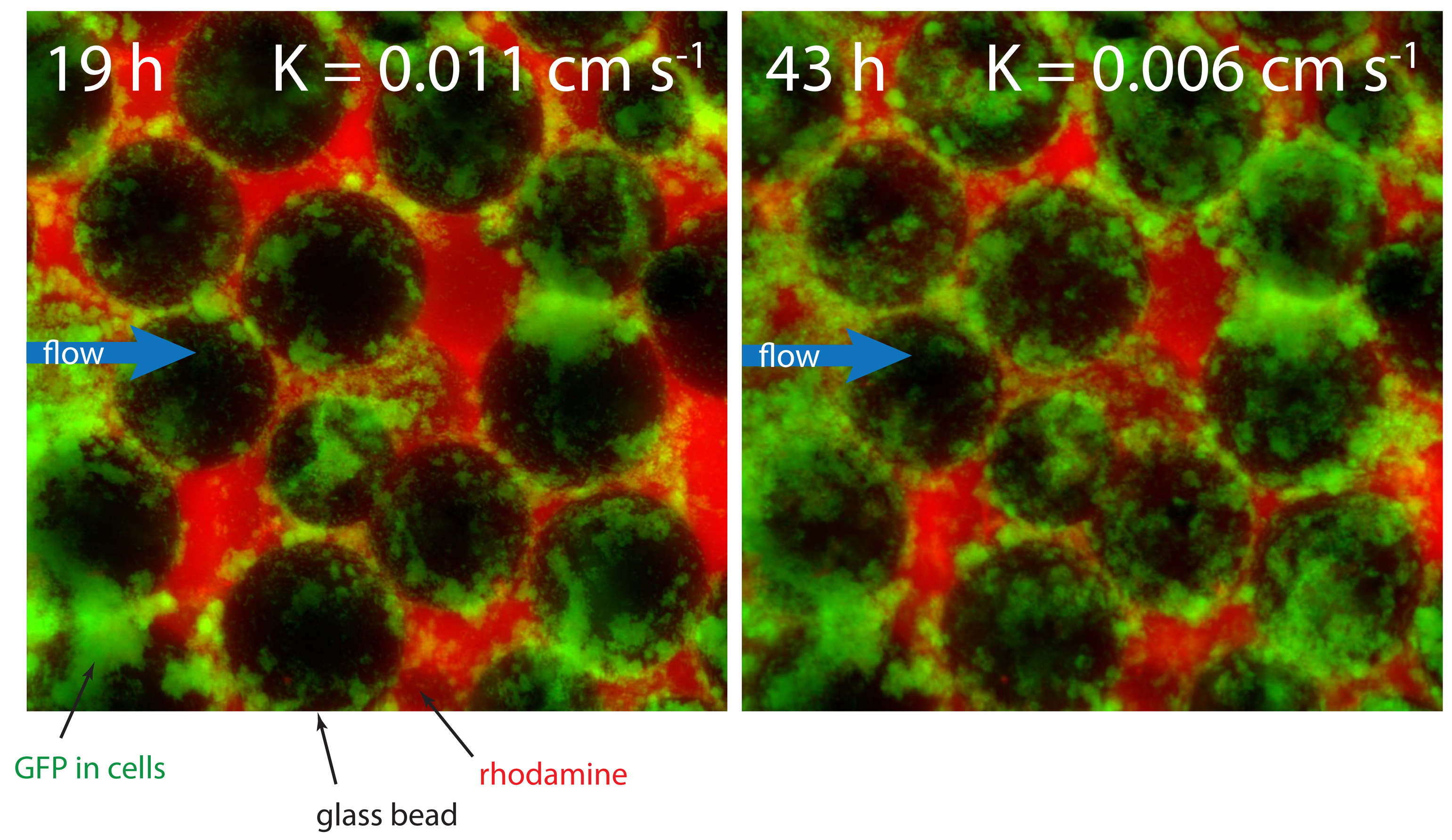


10 cm long dimension
0.15 mm wall



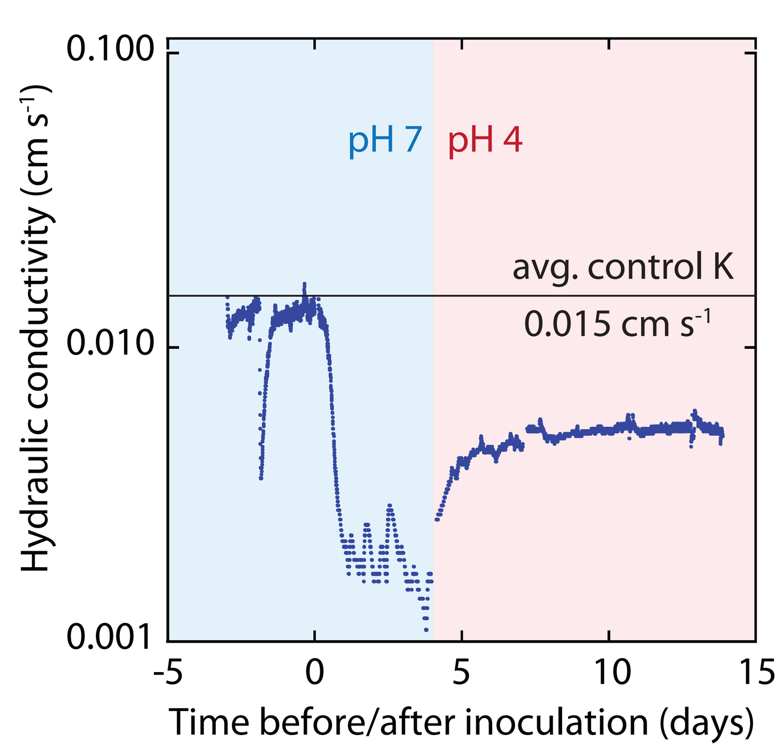
Bioclogging

Growth for 4 days at pH 7.2 caused hydraulic conductivity (K) to decrease 9X on average.

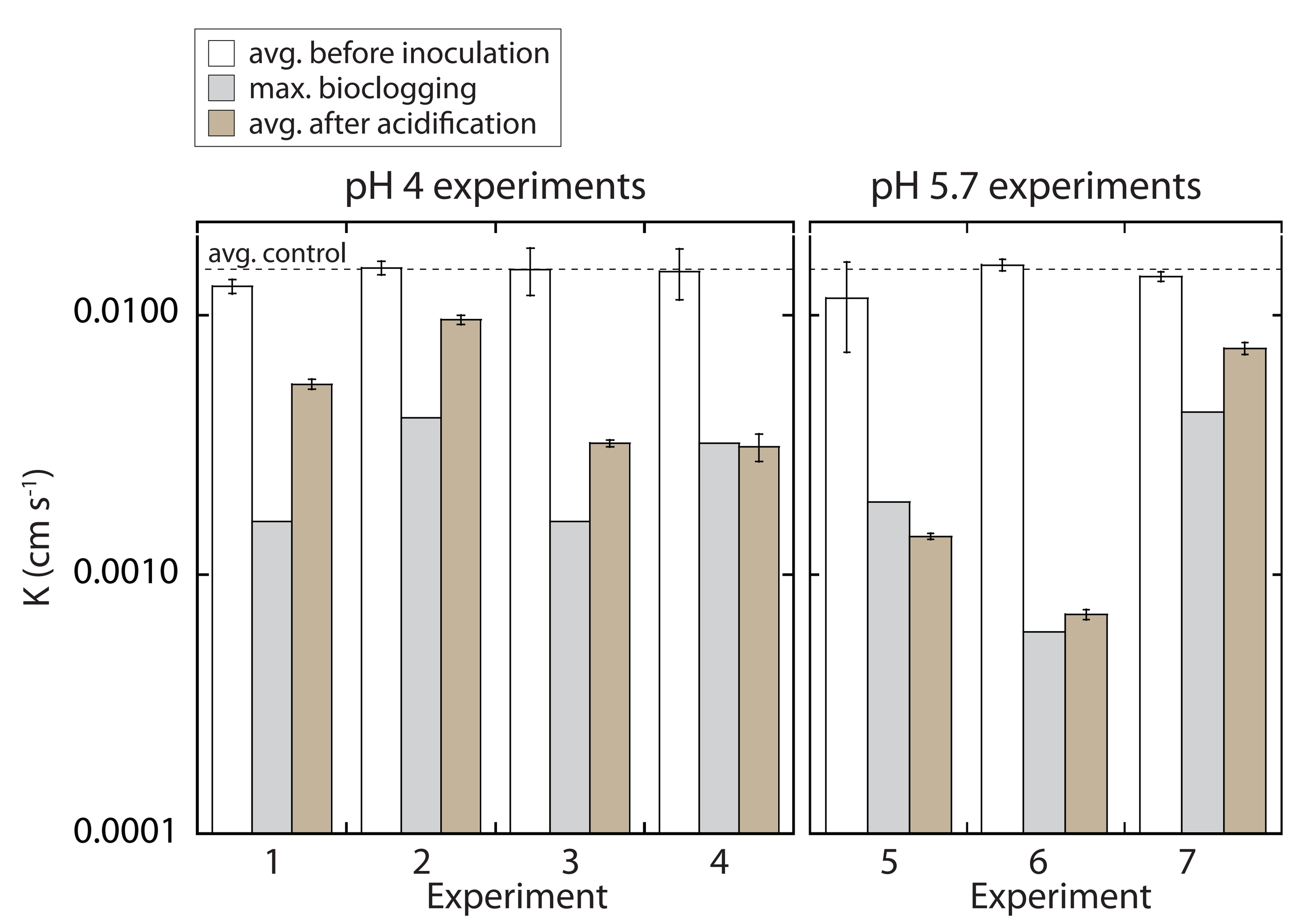


Variation in K with acidification

K increased following acidification in most experiments. However, the the ***columns remained largely clogged*** because most biomass remained intact.



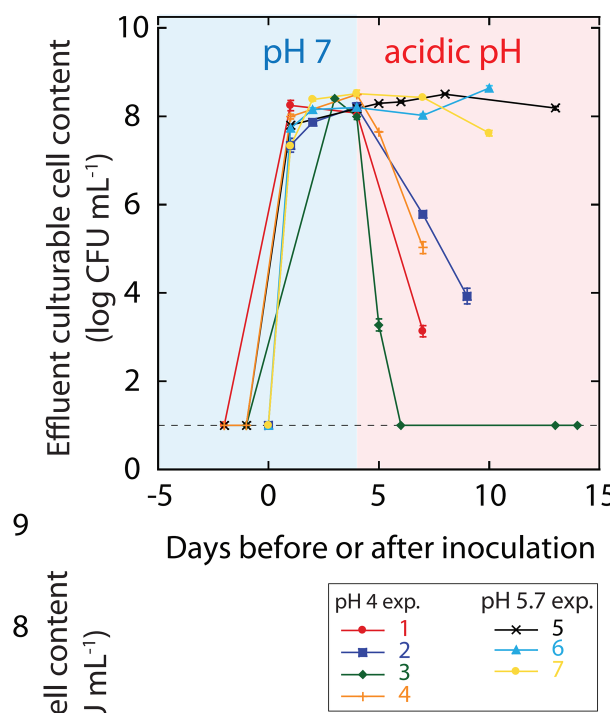
The plot to the left shows typical variation in K during the experiments. The bar chart below summarizes the results from all of the biologically-active experiments. ***Increases in K were greater at pH 4 than pH 5.7.***



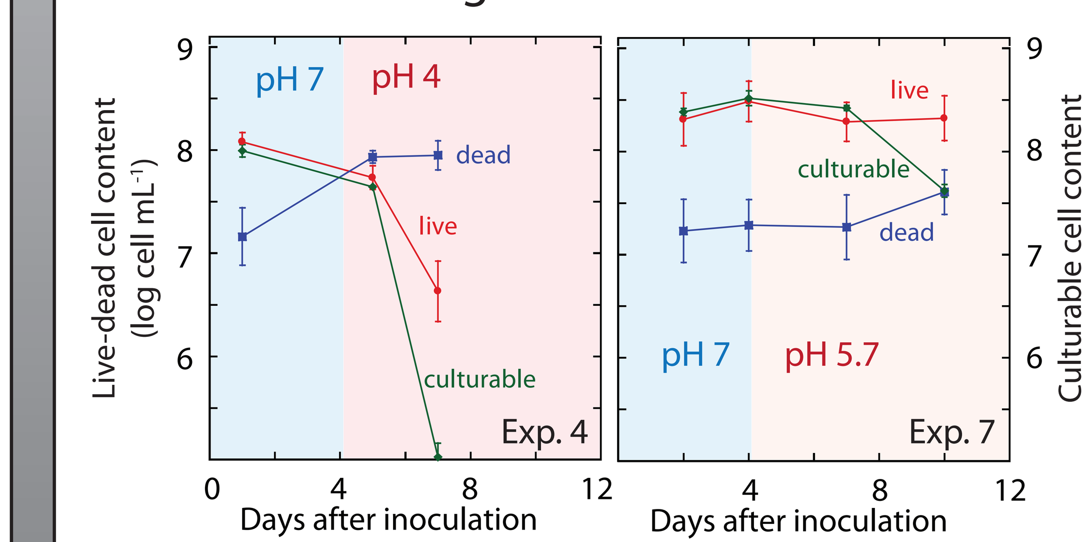
Cell viability

Changes in viability and culturability after acidification may explain differences in bioclogging persistence. ***Cell death and stress was greater at pH 4 than pH 5.7,*** reflecting the pH tolerance of *P. fluorescens*.

Culturability results

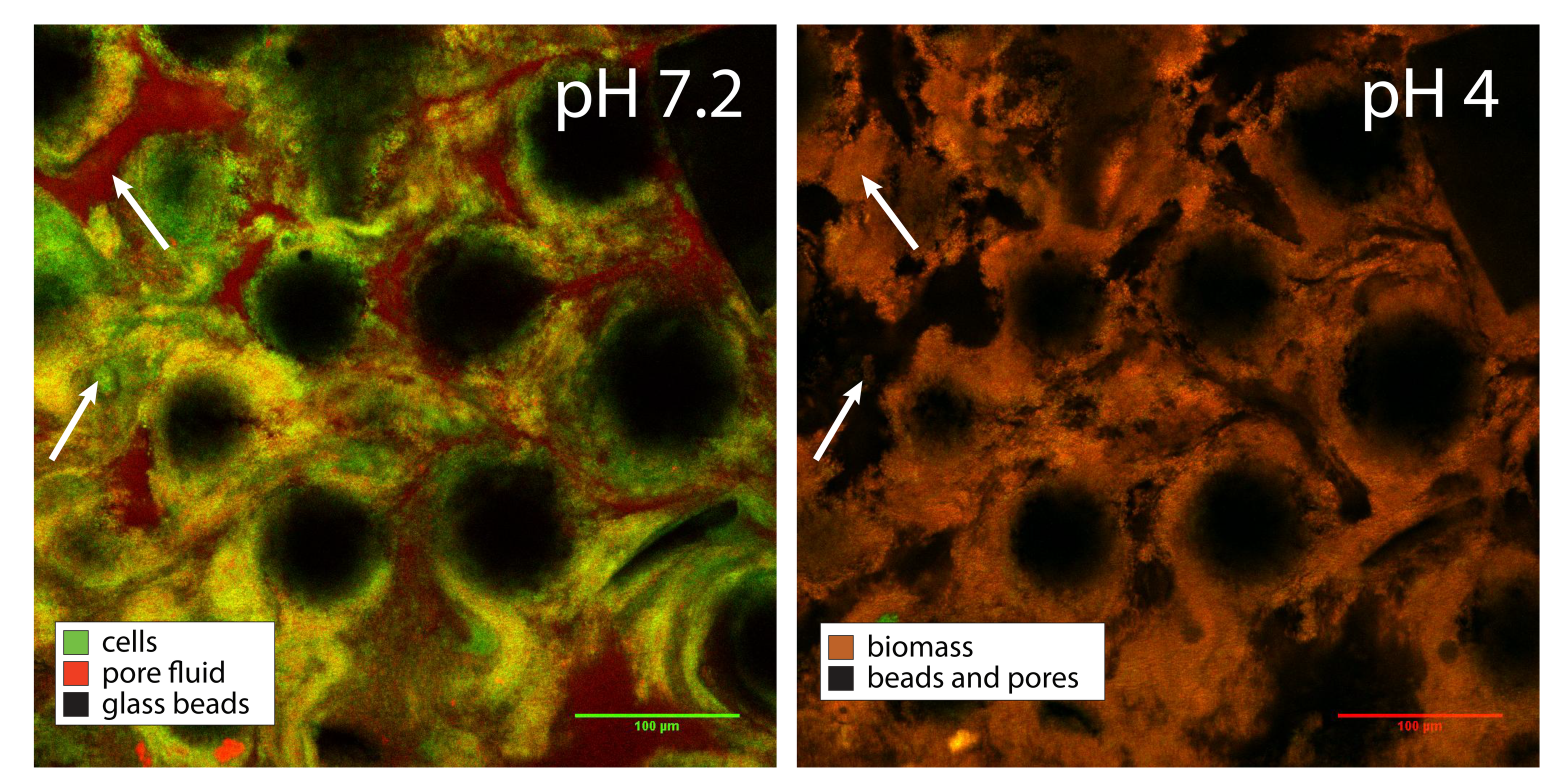


Live/dead staining results



Biomass distribution

Acidification caused shifts in biomass distribution to occur (e.g., arrows in images below), potentially contributing to the increase in K.



Conclusions and implications

We conclude that:

- Bioclogging can remain largely intact after acidification.
- Bioclogging stability reflects species pH tolerance.
- Shifts in biomass distribution with pH likely impact clogging persistence.

These results imply that bioclogging to limit leakage pathways in caprocks will remain intact in acidic water.

Acknowledgements

This material is based upon work supported as part of the Center for Frontiers of Subsurface Energy Security, and Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Award Number DE-SC0001114.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.