Understanding the Impact of CO_2 Injection on the Subsurface Microbial Community in an Illinois Basin CCS Reservoir: Integrated Student Training in Geoscience and Geomicrobiology

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Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the Infrastructure for CO_2 Storage

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Presentation Outline

- Benefit to the Program
- Technical status
- Results and discussion
- Summary
- Appendix

Benefit to the Program

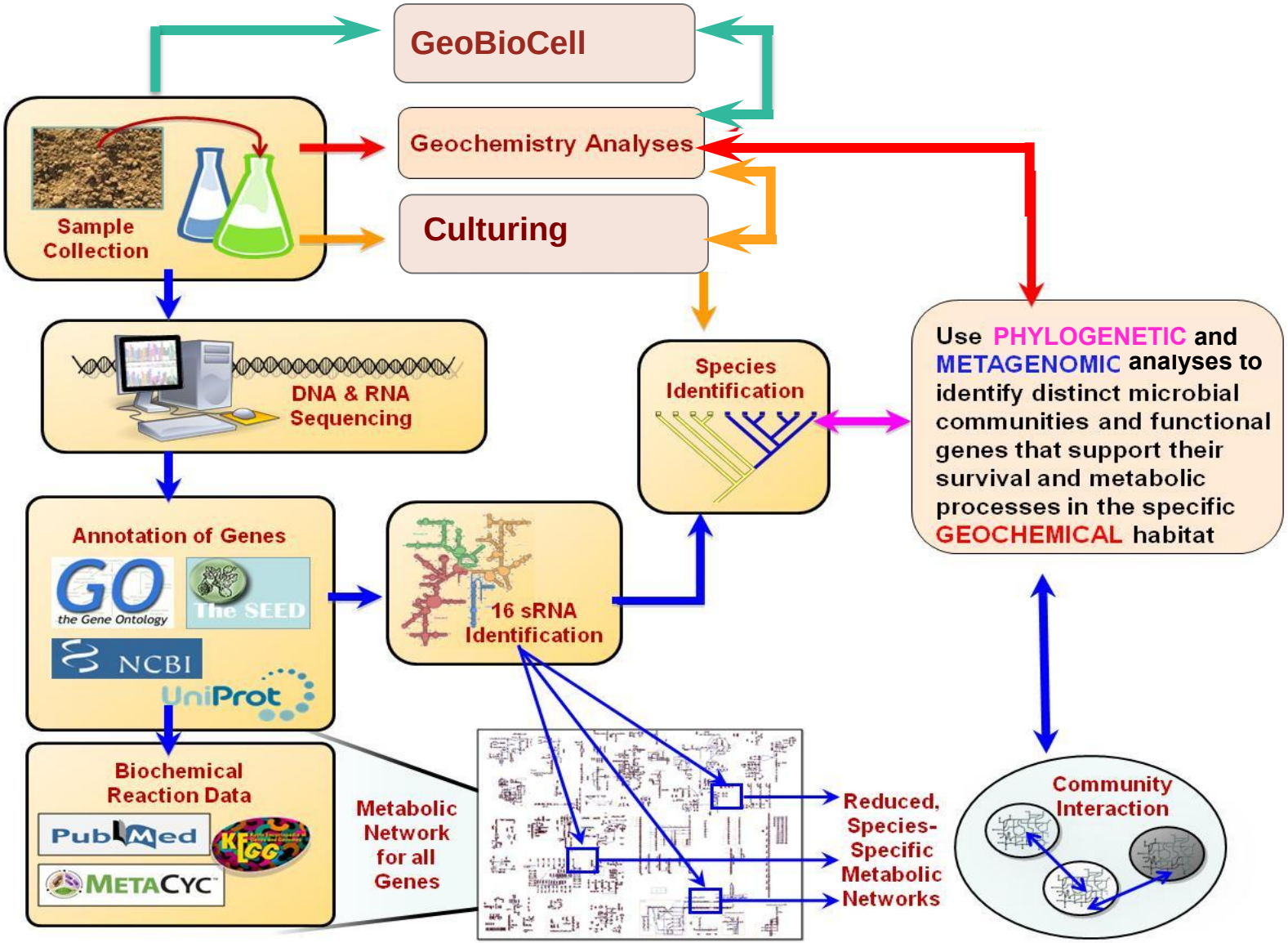
This research project has developed scientific, technical and institutional collaborations for the development of commercial-scale carbon capture and storage (CCS)

- Collaborate with MGSC-ISGS to advance scientific understanding of the Illinois Basin - Decatur Project (IBDP)
- Establish molecular, culturing and microscopic techniques, as well as micro-model systems (e.g., GeoBioCell)
- The education and training activity has enabled students to understand CCS geological and geomicrobiological skill

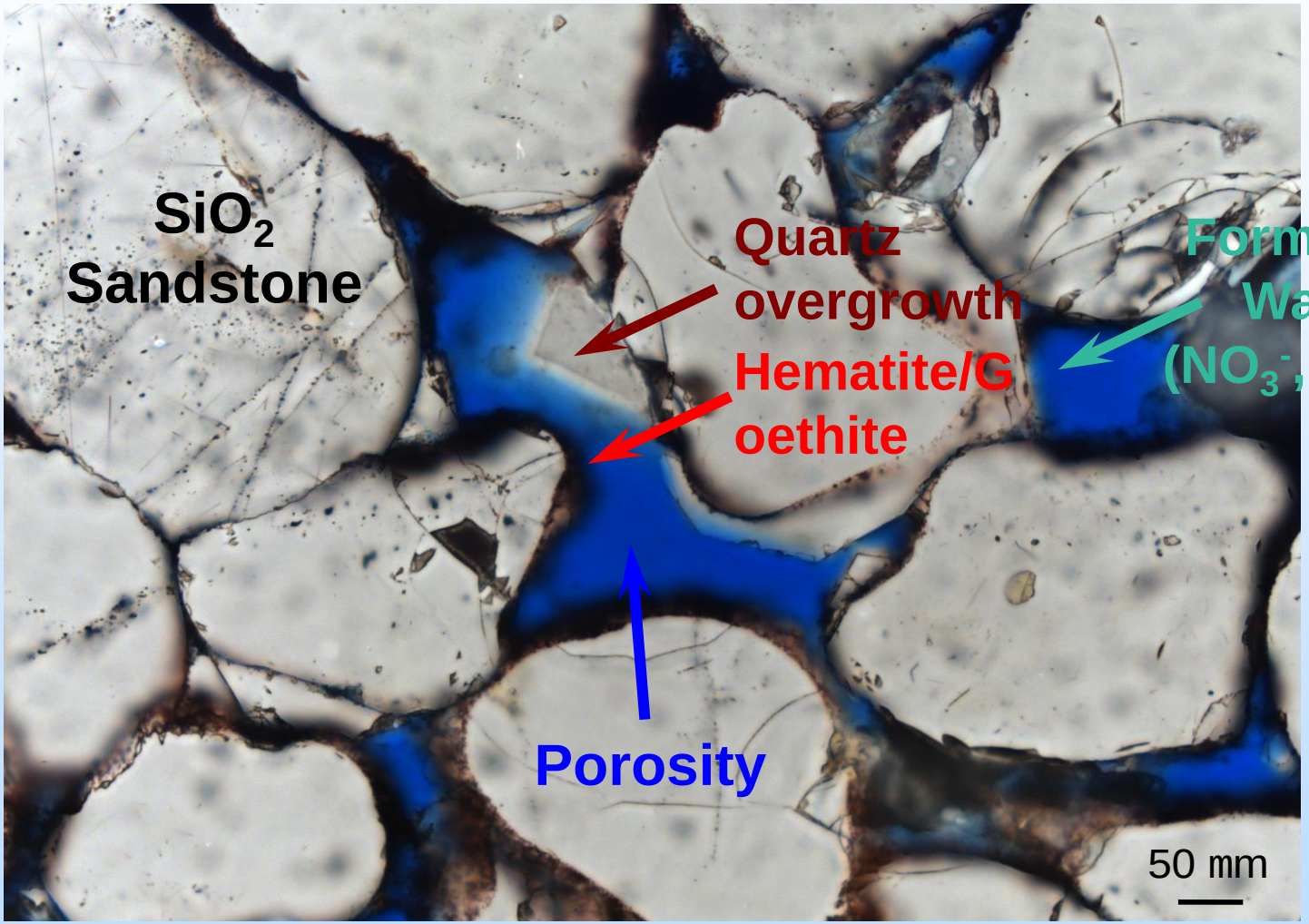
Project Overview: Goals and Objectives

- Identifying microbes to characterize the subsurface biosphere and response to potential CO_2 injection in the IBDP, IL
- Characterizing the paragenesis of the Mt. Simon Sandstone at the IBDP site so as to establish a baseline for future studies of the impact of sequestration on cements and permeability
- Developing a flow cell, called "GeoBioCell", as an experimental apparatus to simulate and study deep subsurface physical and geochemical changes during the CO_2 injection
- Developing undergraduate/graduate-level course materials and seminars that address CCS geological and geomicrobial issues

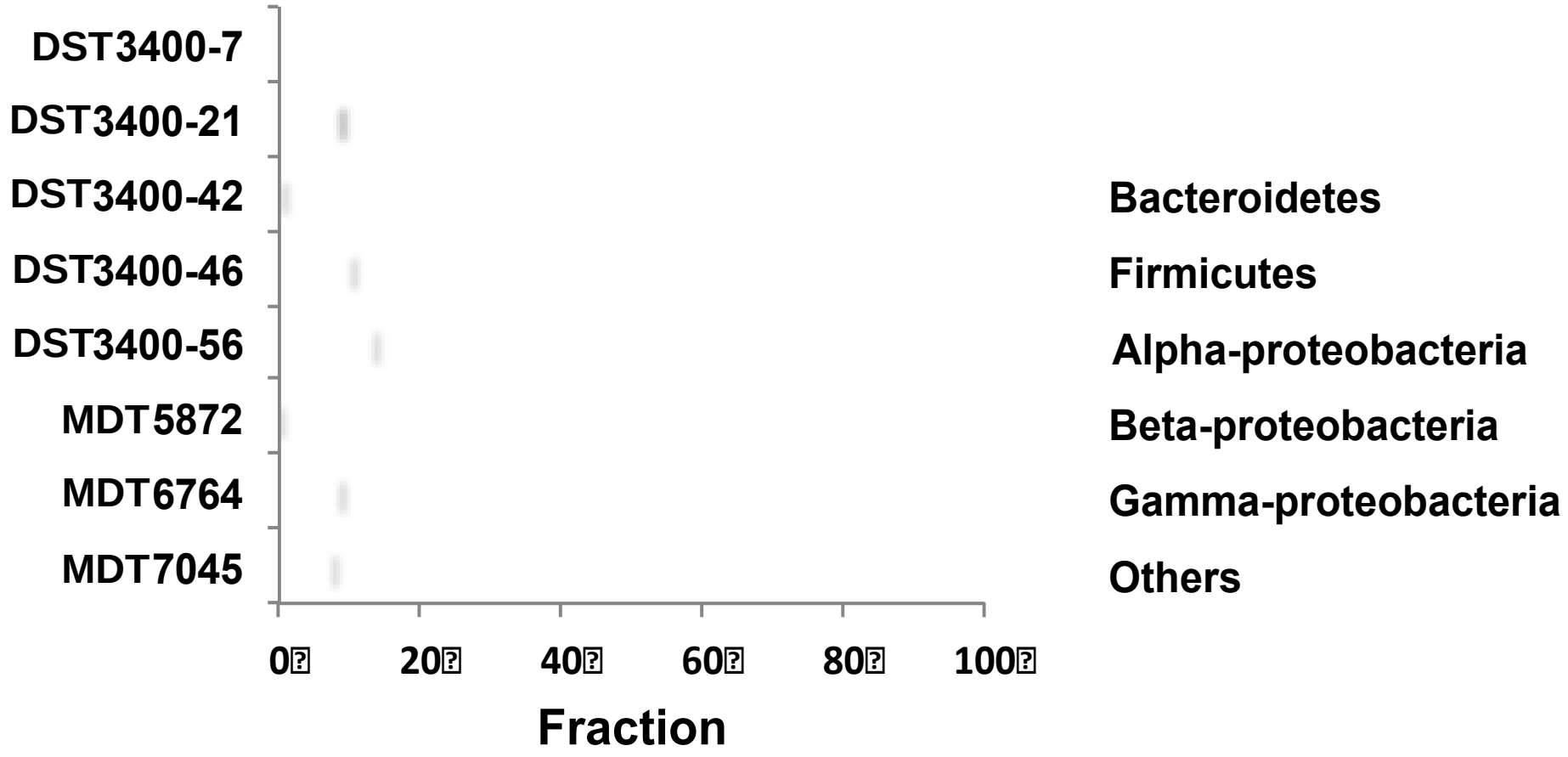
Experimental Setup



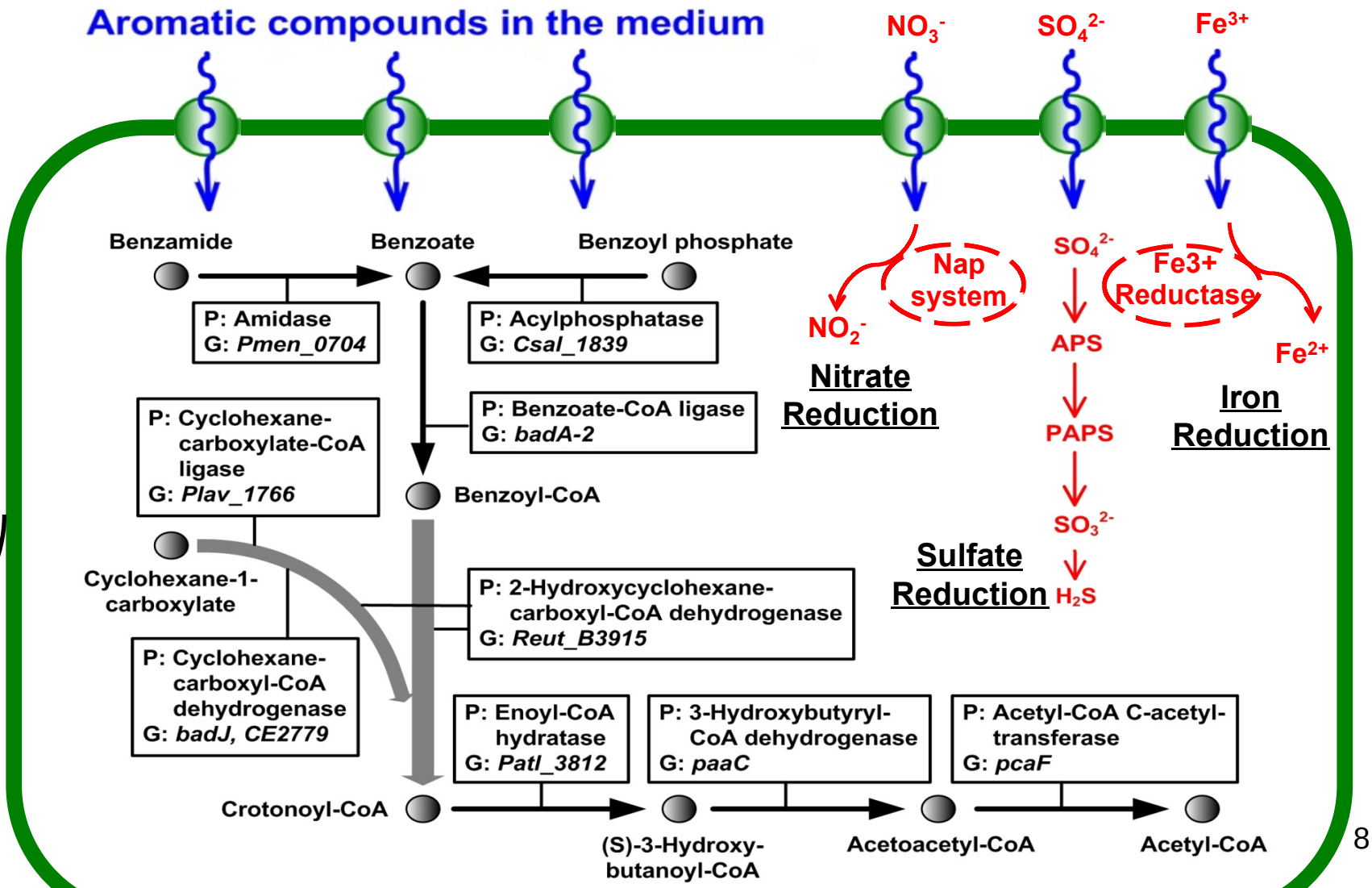
Petrographic and Geochemical Analyses



Heterogeneity of Mt. Simon Microbial Communities

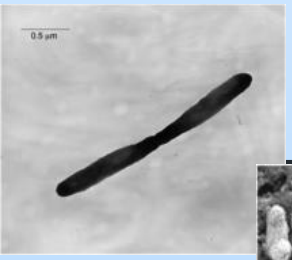


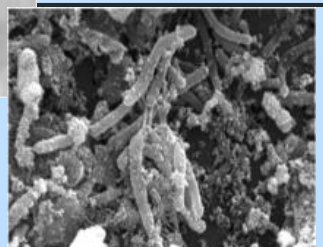
Indigenous Bacterial Metabolic Pathways

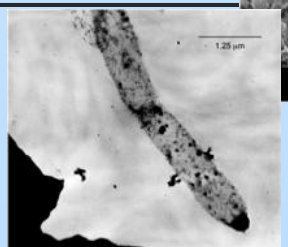


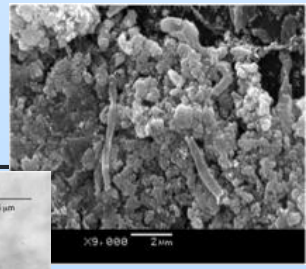
Bacteria Isolated from 1.5-2 km Mt. Simon Formation

	IBDP5655	IBDP6634
Closest type strain	*Vulcanibacillus modesticaldus*[1]	*Orenia marismortui*[2]
16S rRNA identity	96 %	95 %
Aerobic/Anaerobic	Anaerobic	Anaerobic
Morphology (W×L, µm)	Rod (0.3×3-10)	Rod (0.5×2-20)
T (°C) (optimal)	20-60 (30-40)	20-60 (36-45)
pH (optimal)	5.2-8 (5.2-5.8)	6-9 (6-7)
Salt (%) (optimal)	1-5 (2)	1-20 (3-12)
Appendage	Flagella[b]	Pili
Nutrient Source	Fatty acids, sugars, nitrate, Fe(III)-citrate and iron minerals, metals	Fatty acids, sugars, glycerol, Fe(III)-citrate and iron minerals, metals





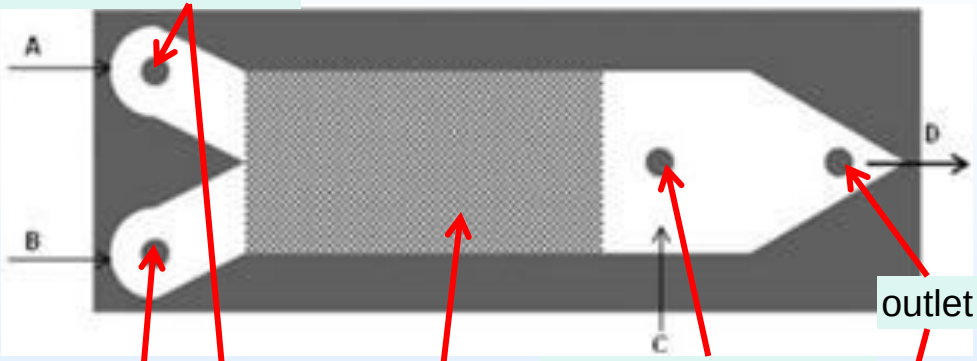




1. L'Haridon et al, 2006; 2. Moune et al., 2000

GeoBioCell as a Micromodel System

Reactant A: i.e $CaCl_2$, electron donor etc.

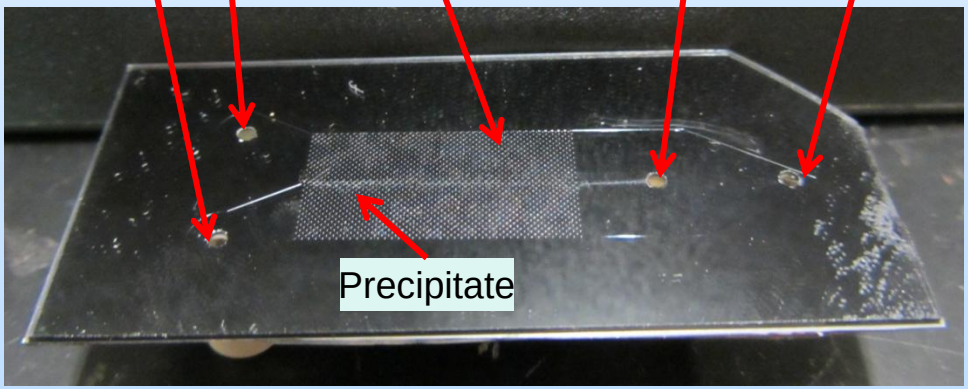


outlet

Reactant B: i.e $NaHCO_3$, Electron acceptor etc.

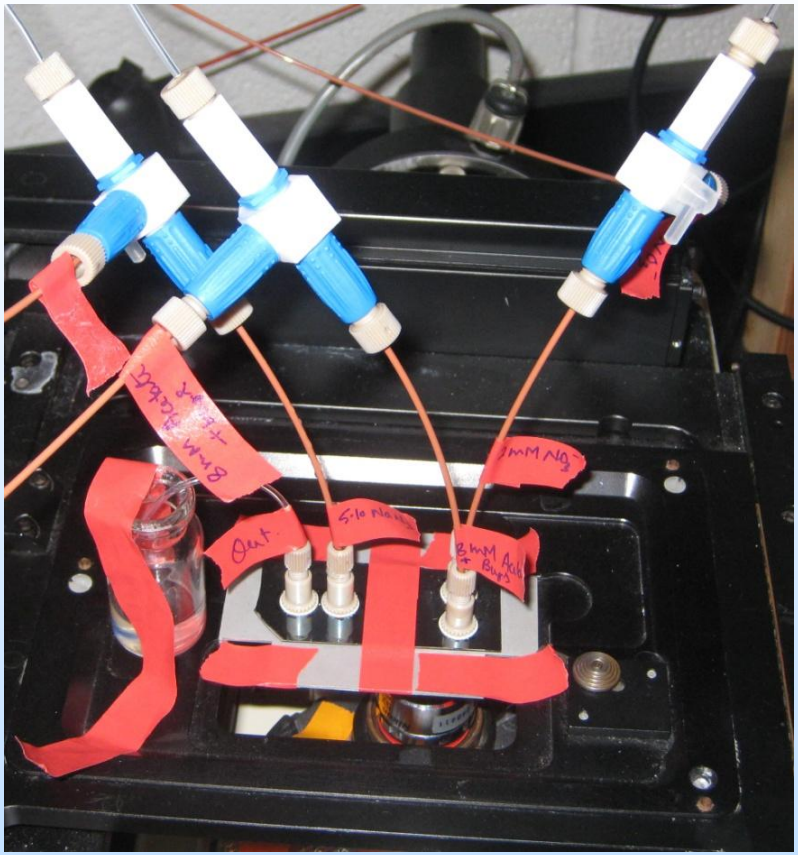
Reactant C: i.e NaN_3, Acidic solution etc.

Porous network



Precipitate

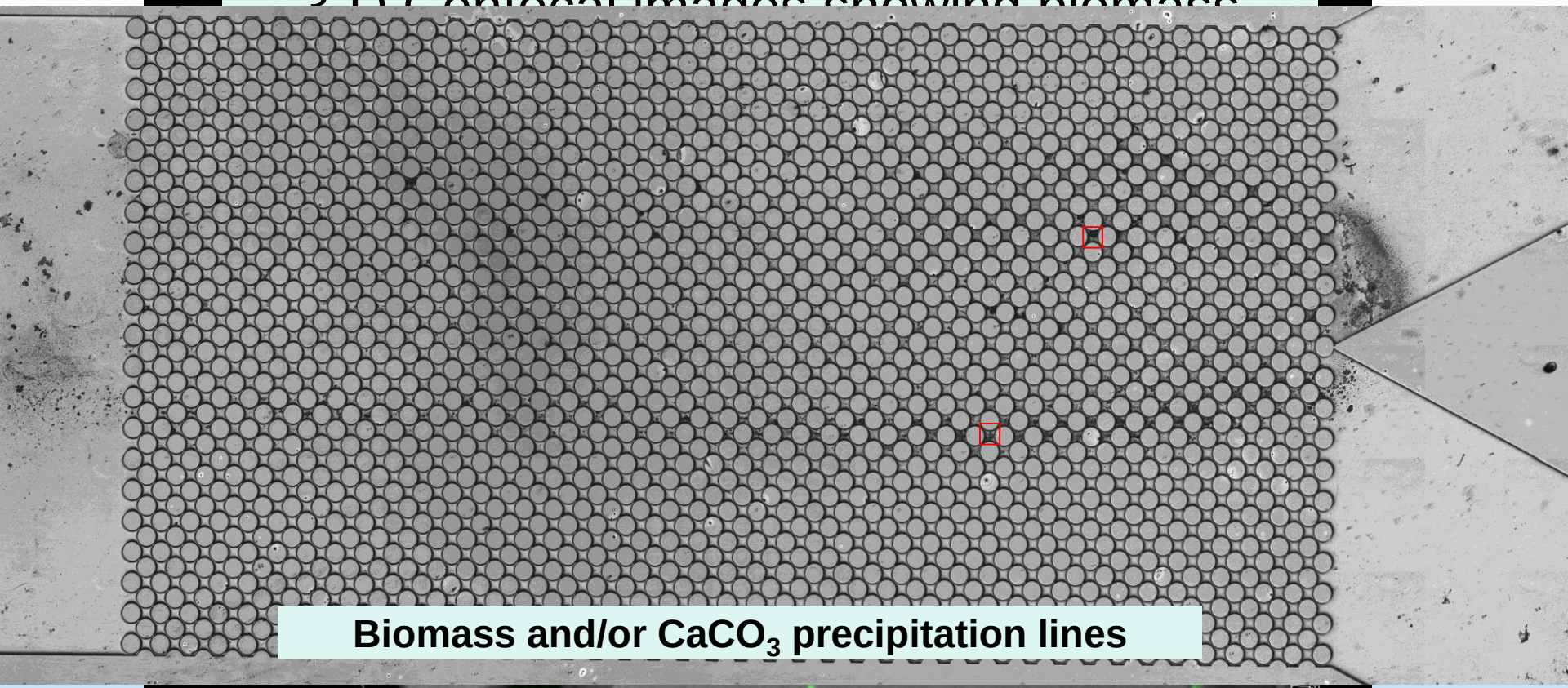
Design and Fabrication of GeoBioCell



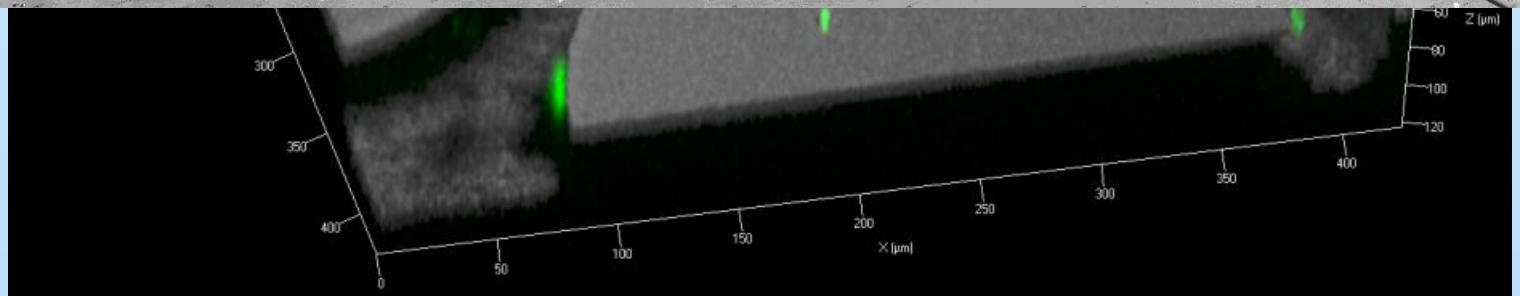
Experimental Set-up: A typical GeoBioCell on microscope stage during biofilm growth experiment.

Carbonate Precipitation in GeoBioCell

3-D Confocal images showing biomass



Biomass and/or $CaCO_3$ precipitation lines



Accomplishments to Date

- Technique development in collaboration with the MGSC-ISGS
- Deep subsurface formation samples were collected from Mt. Simon of the Illinois Basin (1.5-2.1 km) of the IBDP
- Petrographic analyses of Mt. Simon formation side cores
- Indigenous microbial communities inhabiting different horizons of the Mt. Simon Sandstones were identified
- Active enrichment cultures were developed and isolated pure cultures were obtained
- Successful fabrication of the GeoBioCell and biofilm growth in the simulated porous space. Effect of biofilm growth on $CaCO_3$ precipitation is being studied

Accomplishments to Date

- A seminar course “Geology and Microbiology of Carbon Sequestration” was open to all UI students in 2010
- A semester of seminar on geology and geomicrobiology was opened in spring 2011 (invited speakers included: Dr. Kenneth Nealson (USC) and Dr. Michael McInerney (OU))
- A group of U of I undergraduate and graduate students have obtained CCS field and laboratory fundamental research training since 2009

Summary

- **Key Findings**
  - Stratigraphic heterogeneity of microbial ecosystems exists within the deep subsurface of the Illinois Basin
  - Metagenomic reconstruction of the indigenous microbial communities reveals adaptive evolution of indigenous microorganisms within the subsurface environments
  - GeoBioCell analyses suggest enhanced carbonate precipitation in the presence of microorganisms
- **Lessons Learned**
  - Importance and difficulty in differentiating indigenous microorganisms from drilling mud contamination
- **Future work**
  - Post-CO_2 injection microbial ecosystems and their response to changes in geochemistry

Acknowledgement

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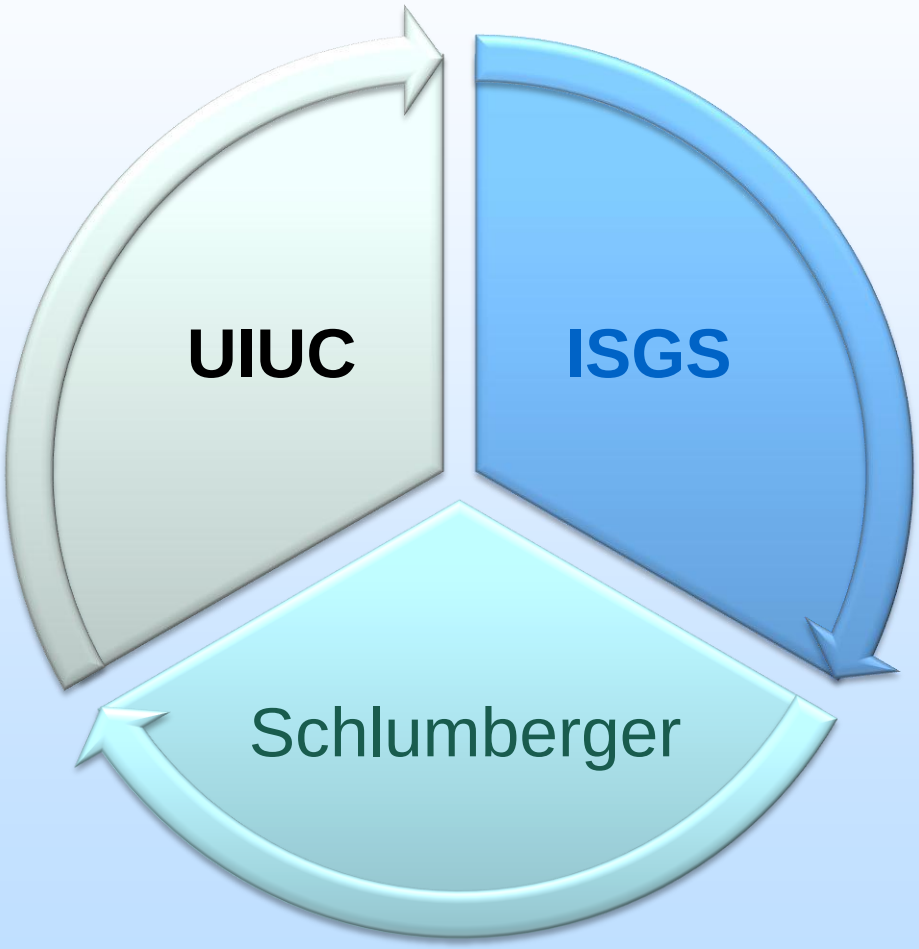
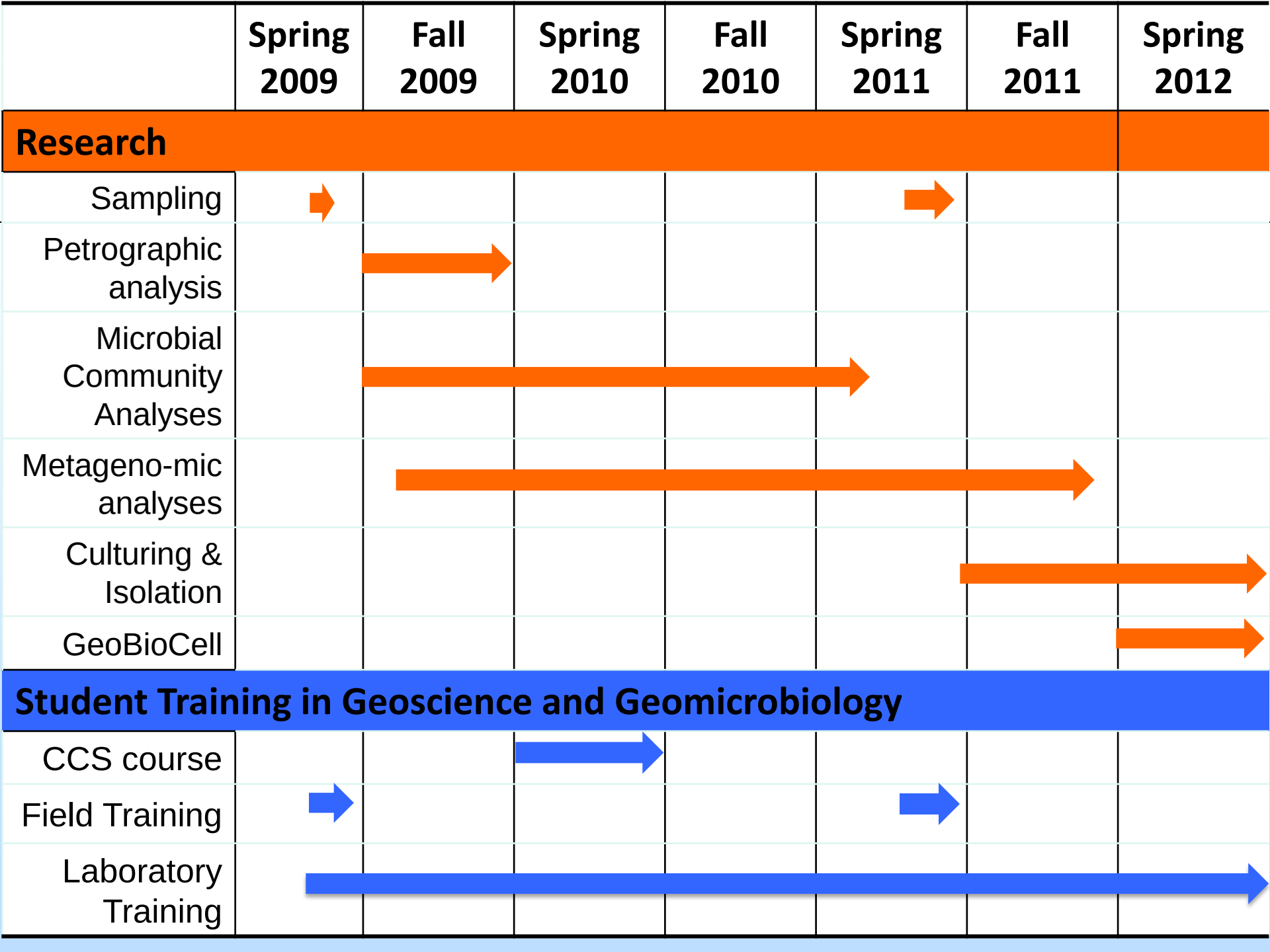
- Schlumberger Carbon Services
- Institute for Genomic Biology, University of Illinois Urbana-Champaign (UIUC)
- UIUC Carver Biotechnology Center and other on-campus collaborators
- Fouke group

Appendix

Organization Chart




Spring 2009
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Research
Sampling
Petrographic analysis
Microbial Community Analyses
Metageno-mic analyses
Culturing & Isolation
GeoBioCell
Student Training in Geoscience and Geomicrobiology
CCS course
Field Training
Laboratory Training

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