

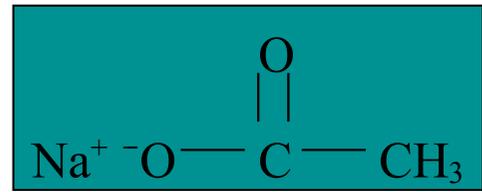
Use of graphite electrodes for quantifying rates of microbial activity



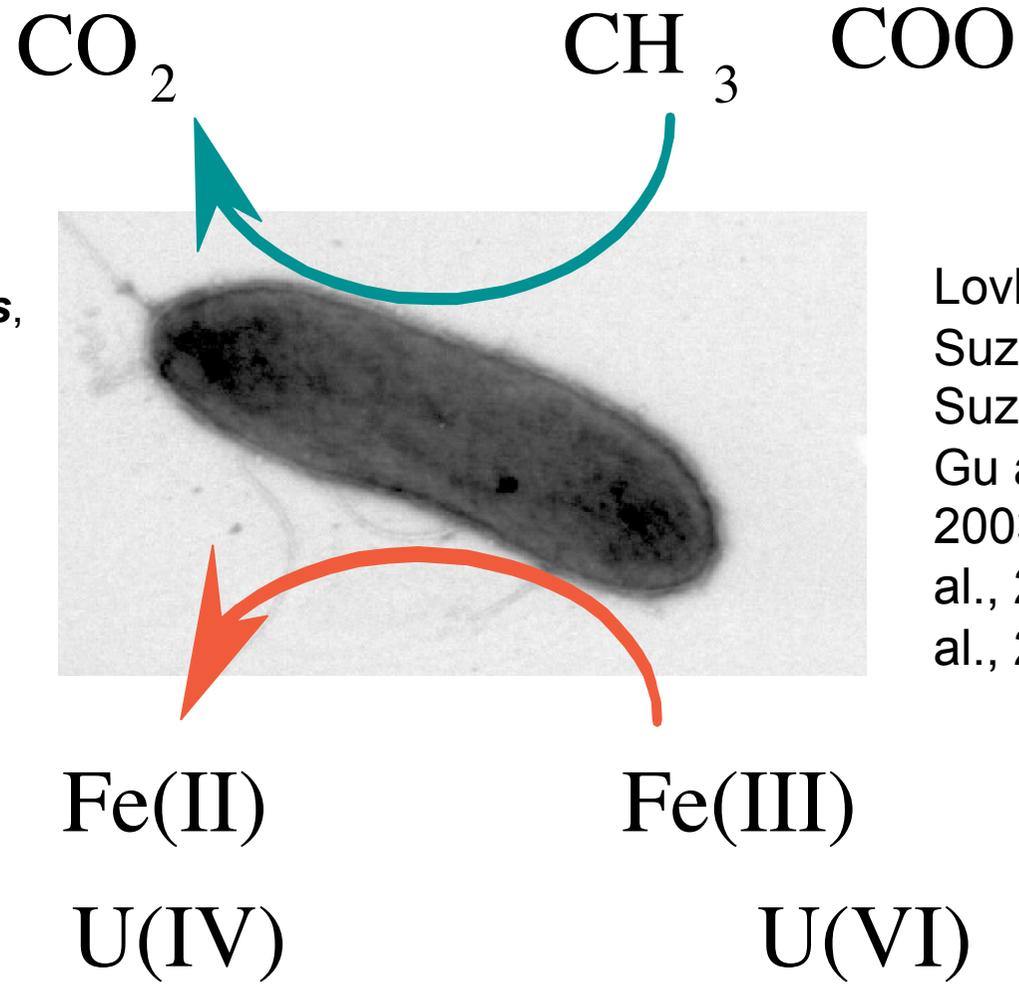
Phil Long, Ken Williams, Derek Lovley
DUSEL Fall Workshop Lead, South Dakota
Friday, October 2, 2009

Metal Reducing Bacteria

Acetate structure



Geobacter uraniireducens,
Isolated from the Rifle Site
and a Member of the
Subsurface Clade I
Geobacter



Lovley et al., 1991;
Suzuki et al., 2002;
Suzuki et al., 2003;
Gu and Chen
2003; Anderson et
al., 2003; Singer et
al., 2007

OUTLINE

1. Rationale for electrodic monitoring

2. Conceptual model - microbial fuel cell analogue

3. Graphite electrode studies at the Rifle IFRC site

- Single (2007) and multi-level (2008) sampling in three wells
- Correlations with geochemical species
- Confocal laser microscopy and microbial community analysis of affixed cells and biofilms
- Future plans to assess naturally bioreduced zones (NBZ's)

4. Proposed Experimental Design for DUSEL

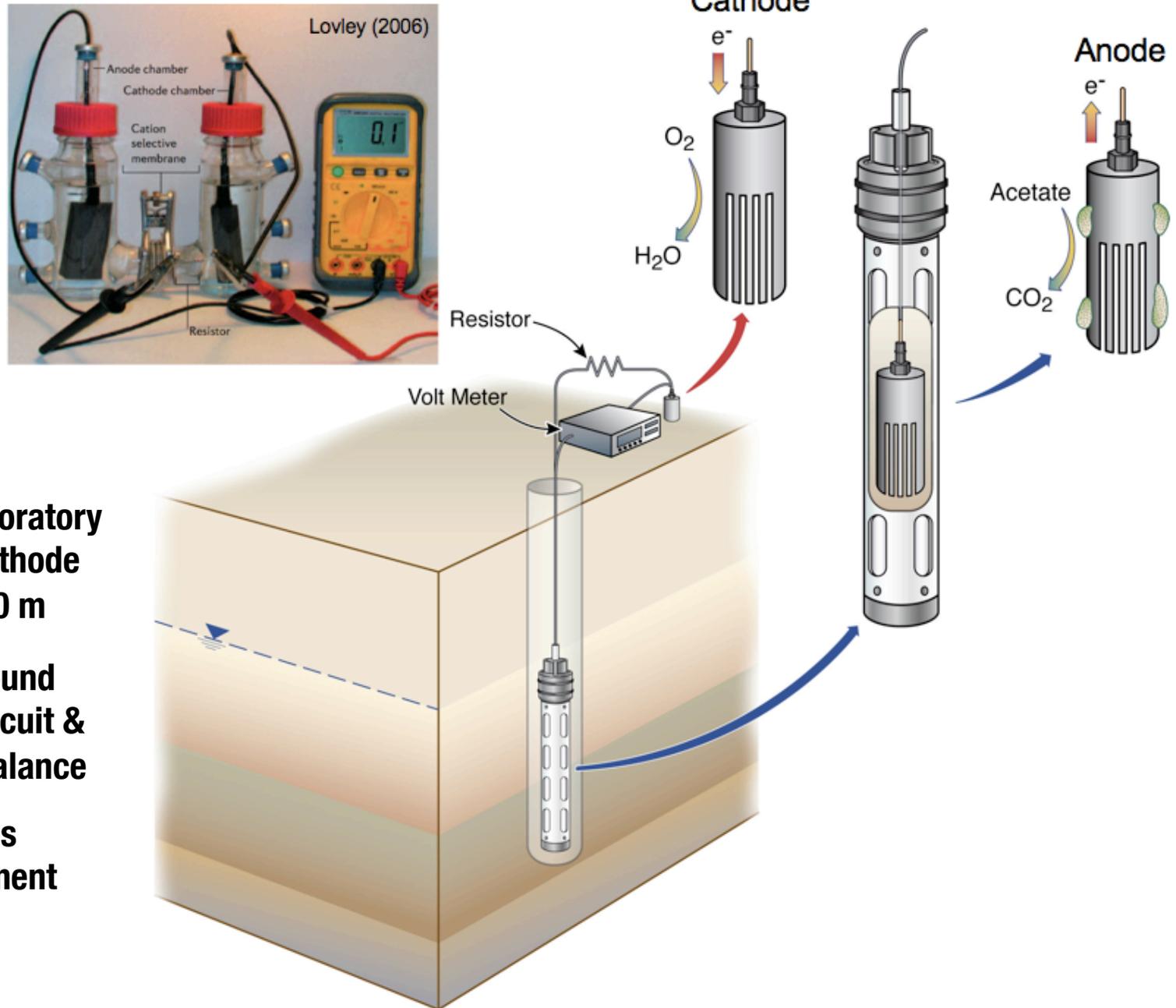
- Deployment outside inflatable packer assembly
- Deployment in packed-off interval
- Electron donor amendment strategies

Rationale:

Develop sensors capable of autonomously monitoring the *in situ* activity of microbial strains involved in contaminant remediation.

Kenneth H. Williams, Kelly P. Nevin, Ashley Franks, Philip E. Long, and Derek R. Lovley, 2009, An electrode-based approach for monitoring *in situ* microbial activity during subsurface bioremediation. ES&T (in revision)

Conceptual Model:



- Analogous to a laboratory MFC, but anode/cathode separations of 8-10 m
- Sediments and ground water complete circuit & maintain charge balance
- Borehole electrodes embedded in sediment implants to hasten colonization

Electrode design:

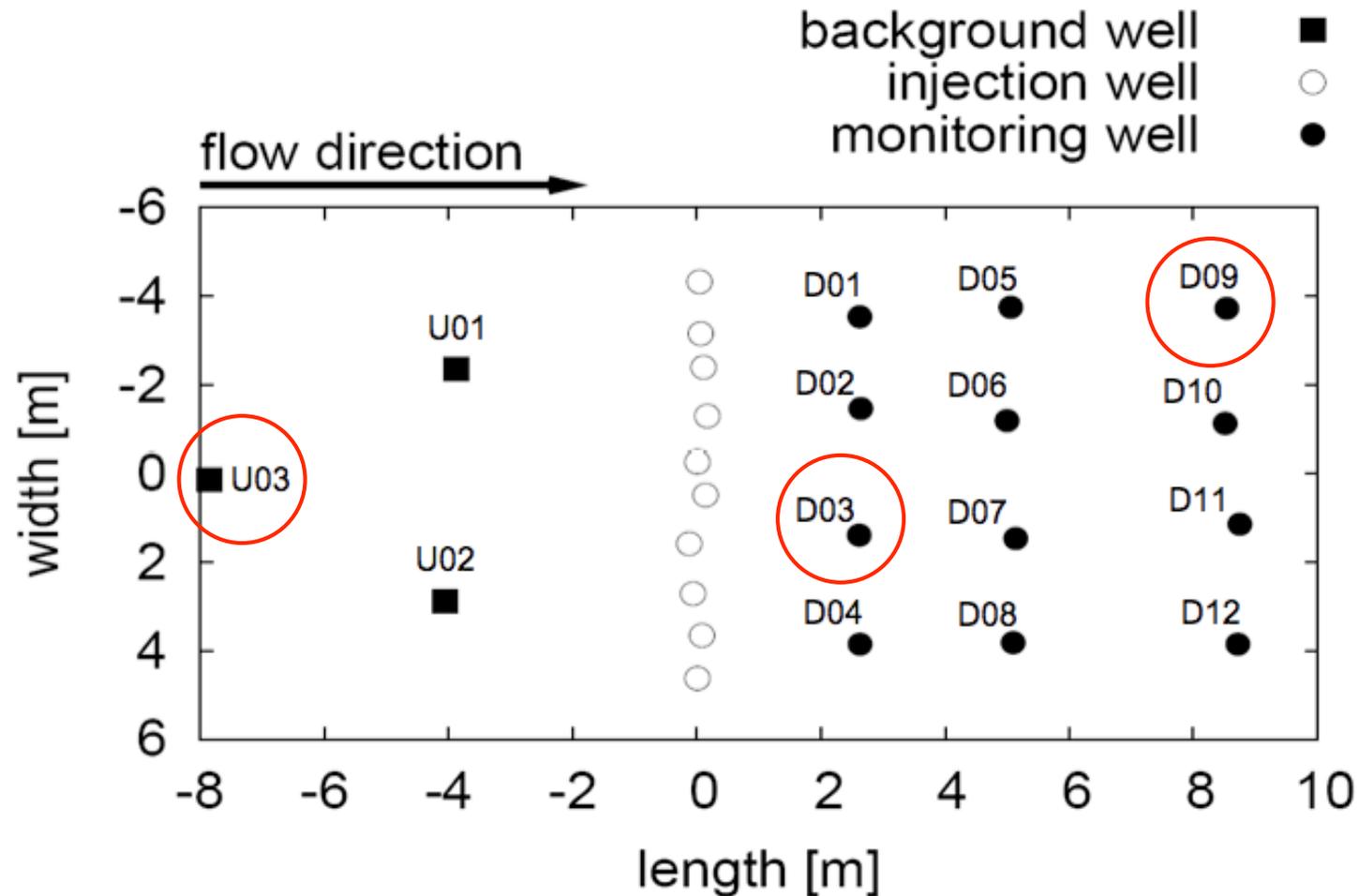


Electrode layout:

- One upgradient control (U-03)
- Two downgradient electrodes:
D-03: 2.5 m
D-09: 8.5 m

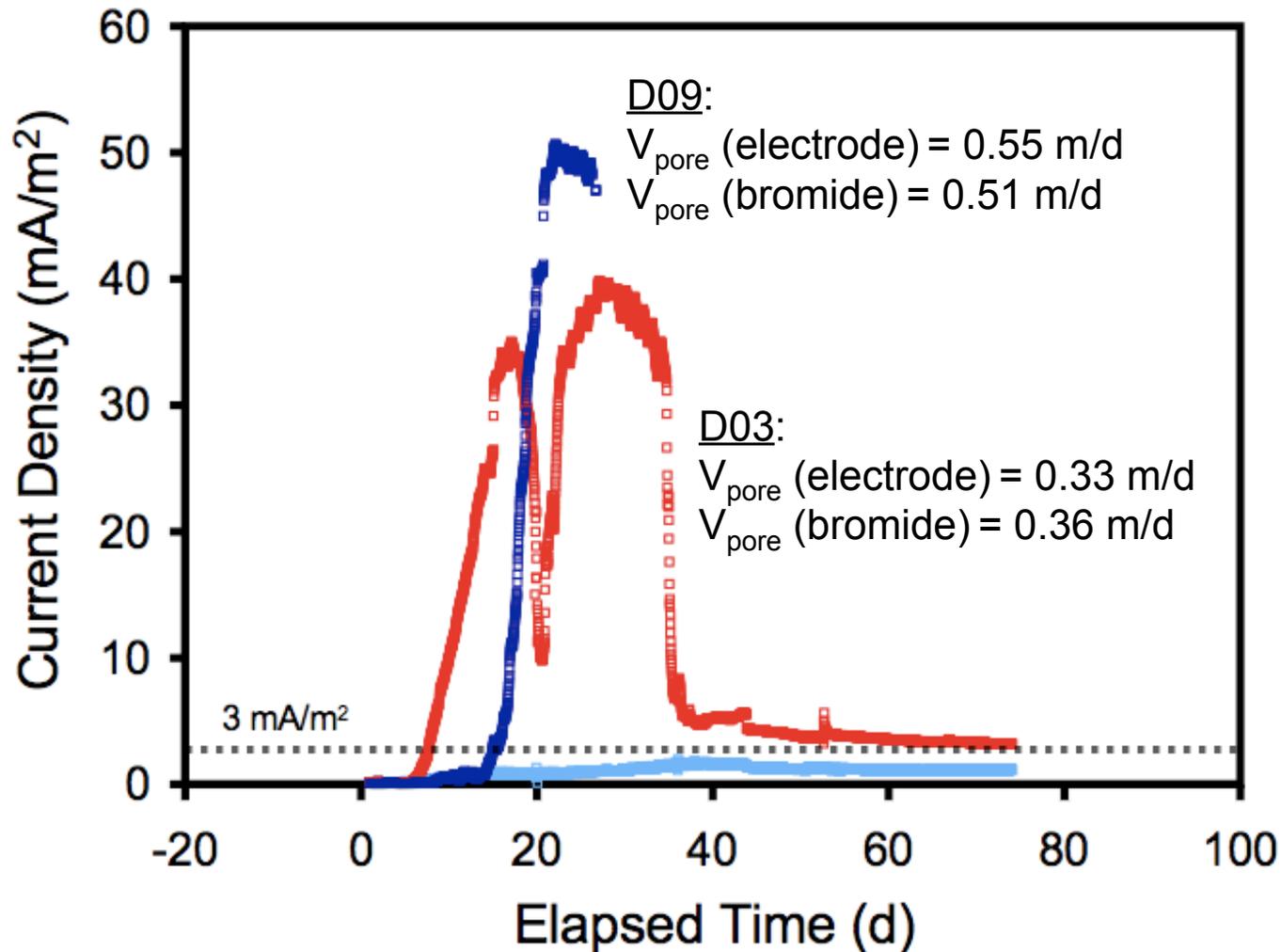
2007: 21-day acetate injection

2008: 106-day acetate injection

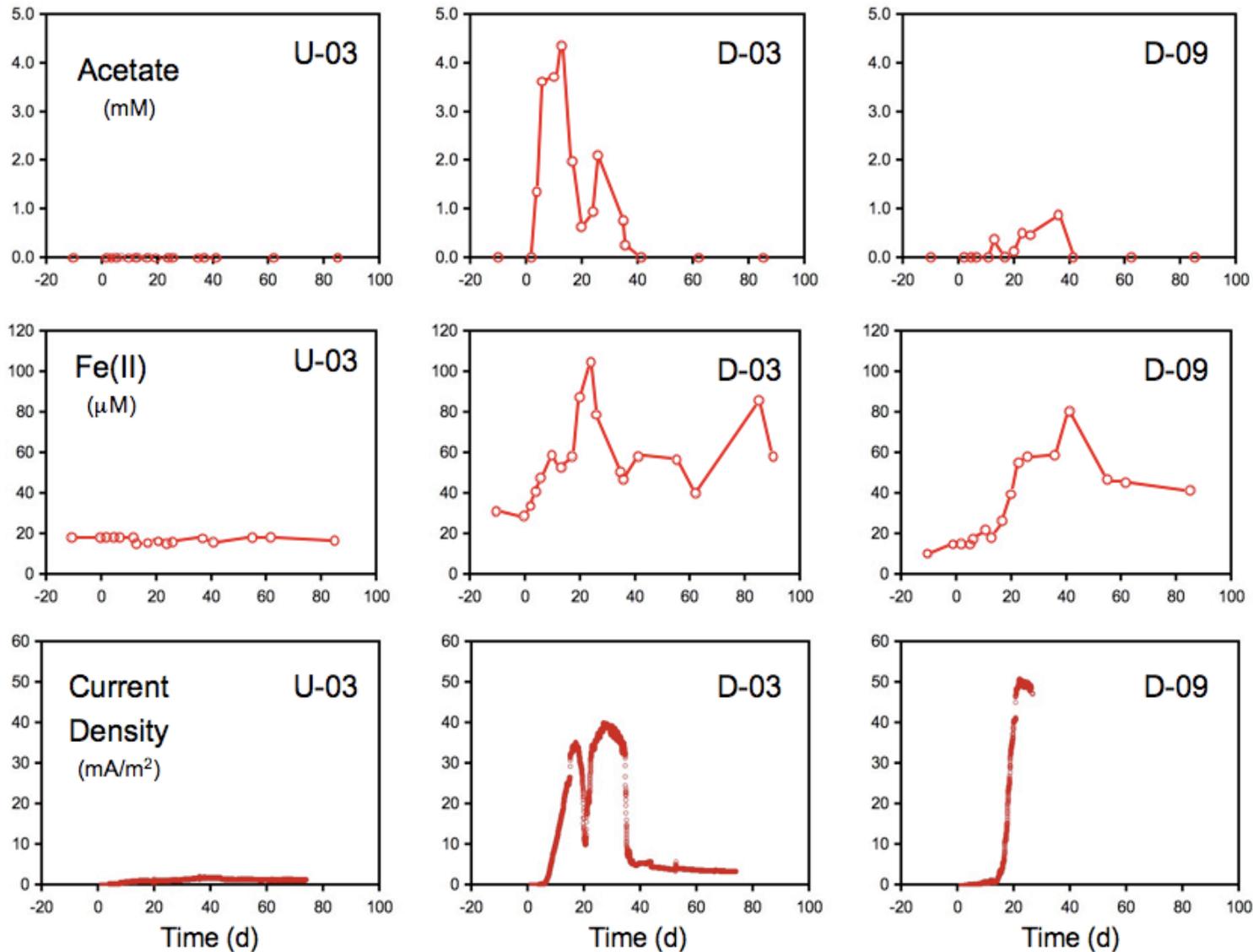


Electrode response (2007):

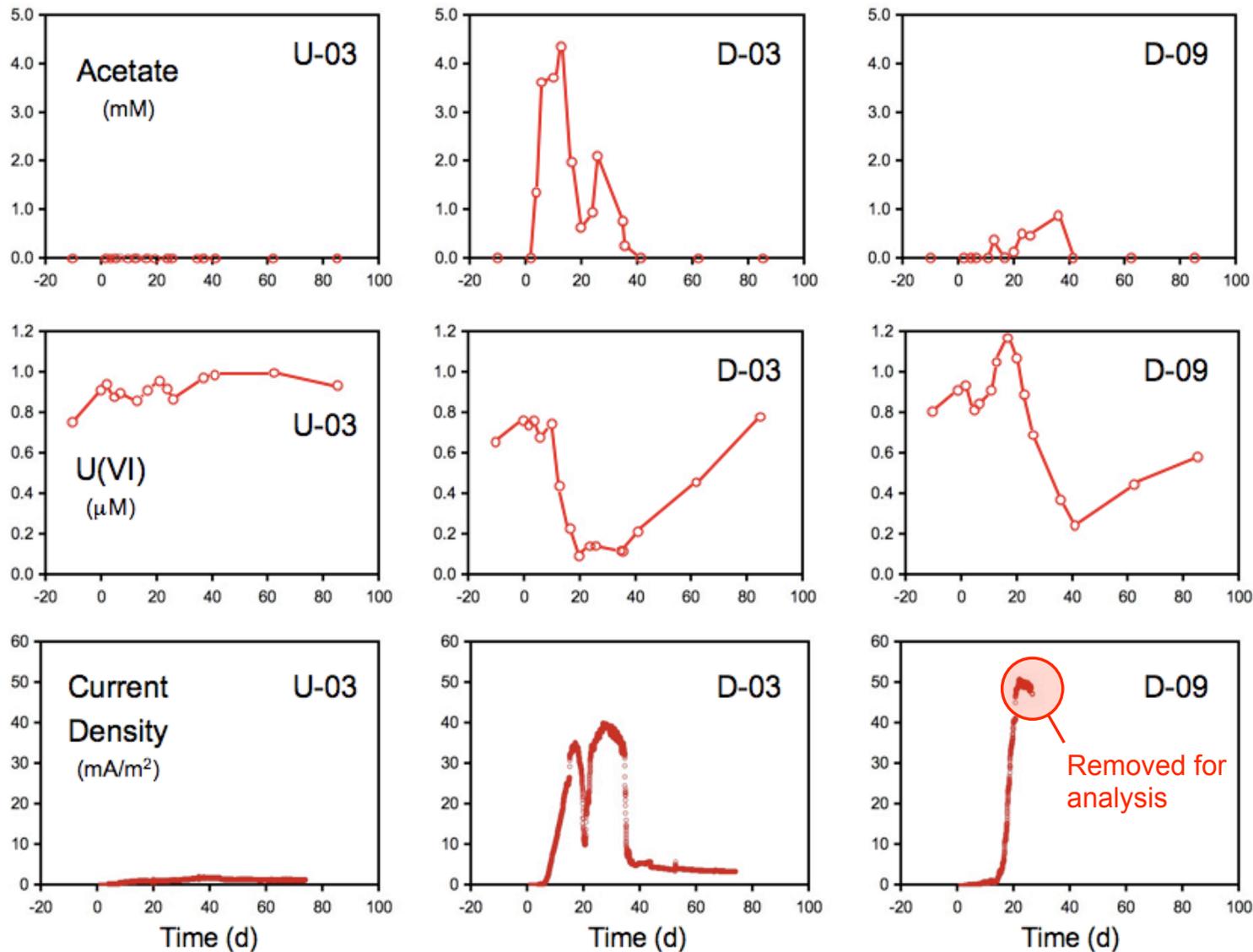
- Delay in onset of current flow related to distance from injection
- Can use onset of current flow to estimate hydraulic information (e.g. pore water velocity)



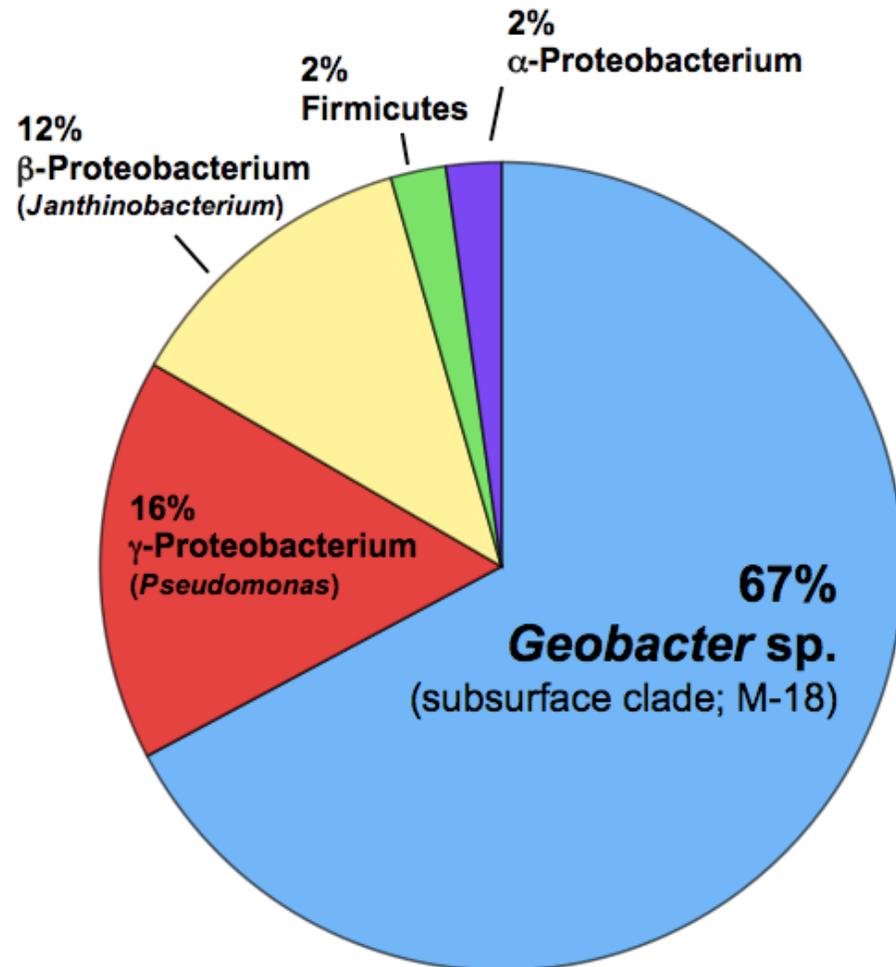
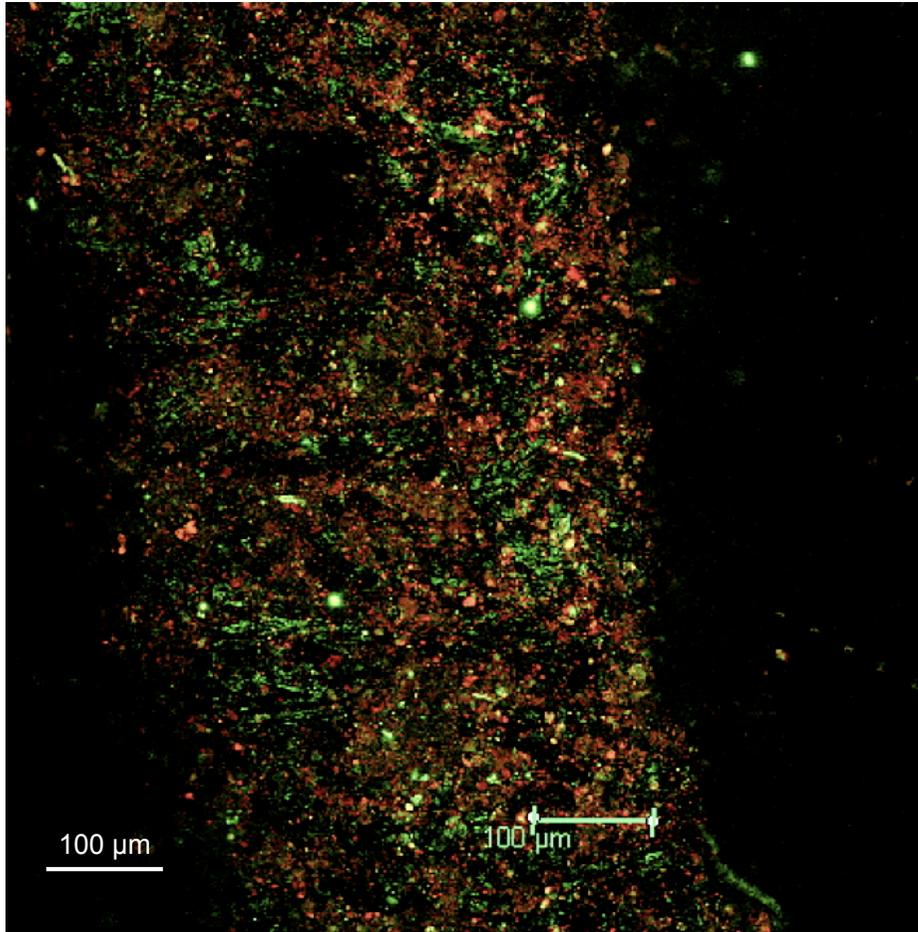
Electrode response (2007): Correlation with acetate and Fe(II) production



Electrode response (2007): Correlation with acetate and U(IV) removal



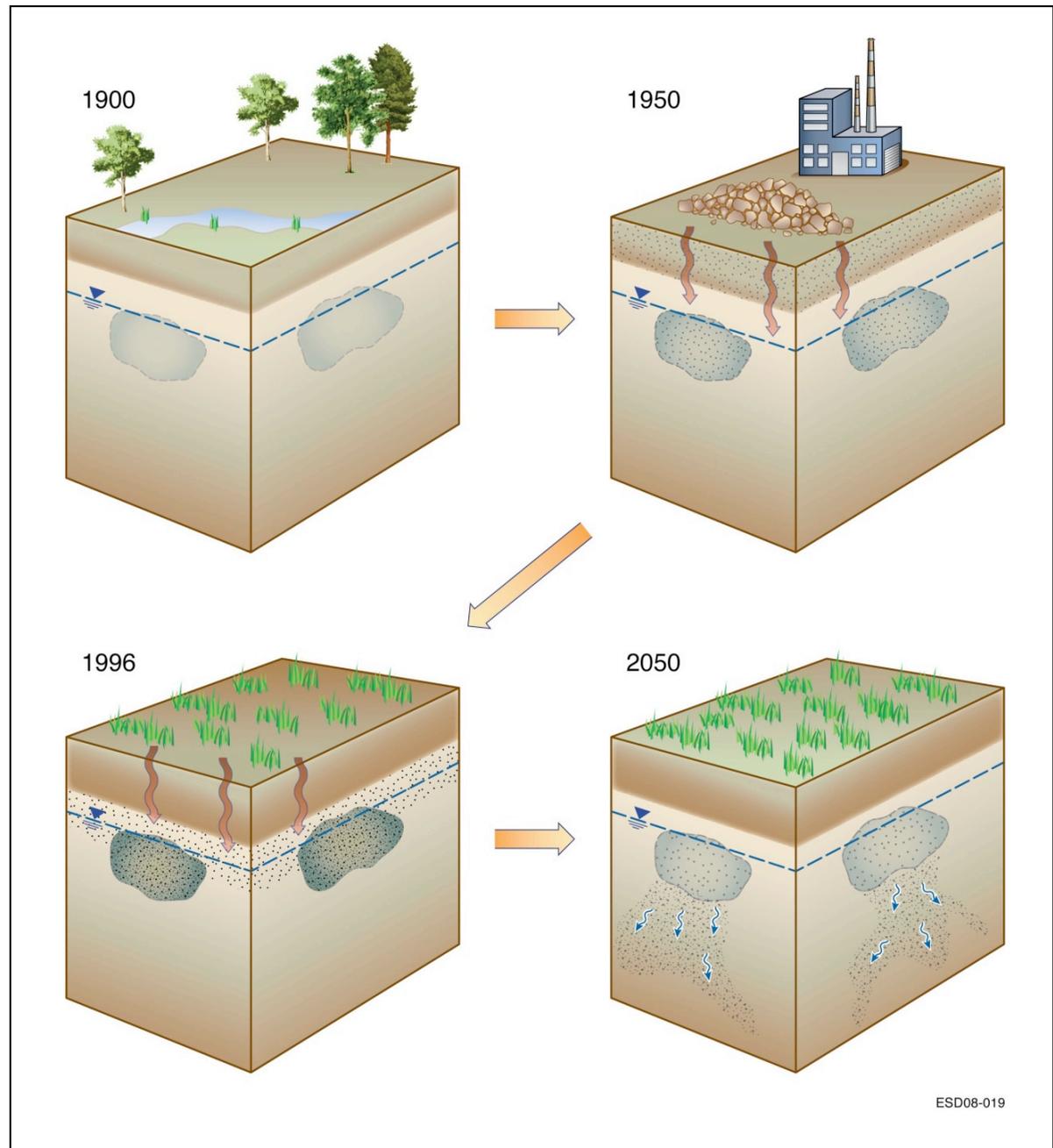
Electrode response (2007): Surface-associated biomass



16S microbial community analysis - D09 (dominated by *Geobacter* sp. with closest match a Rifle site-isolate)

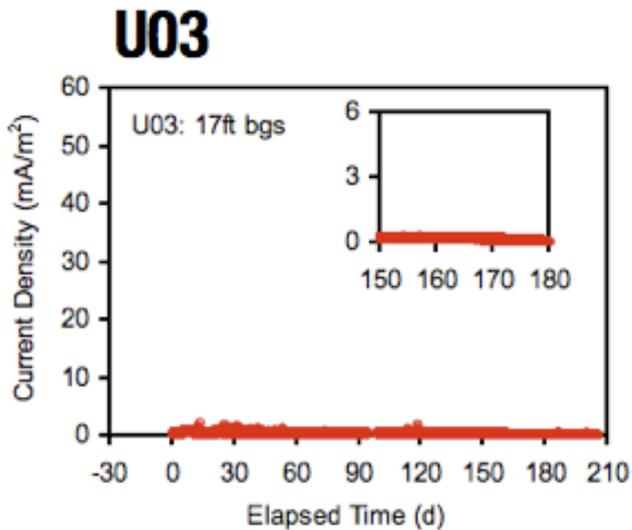
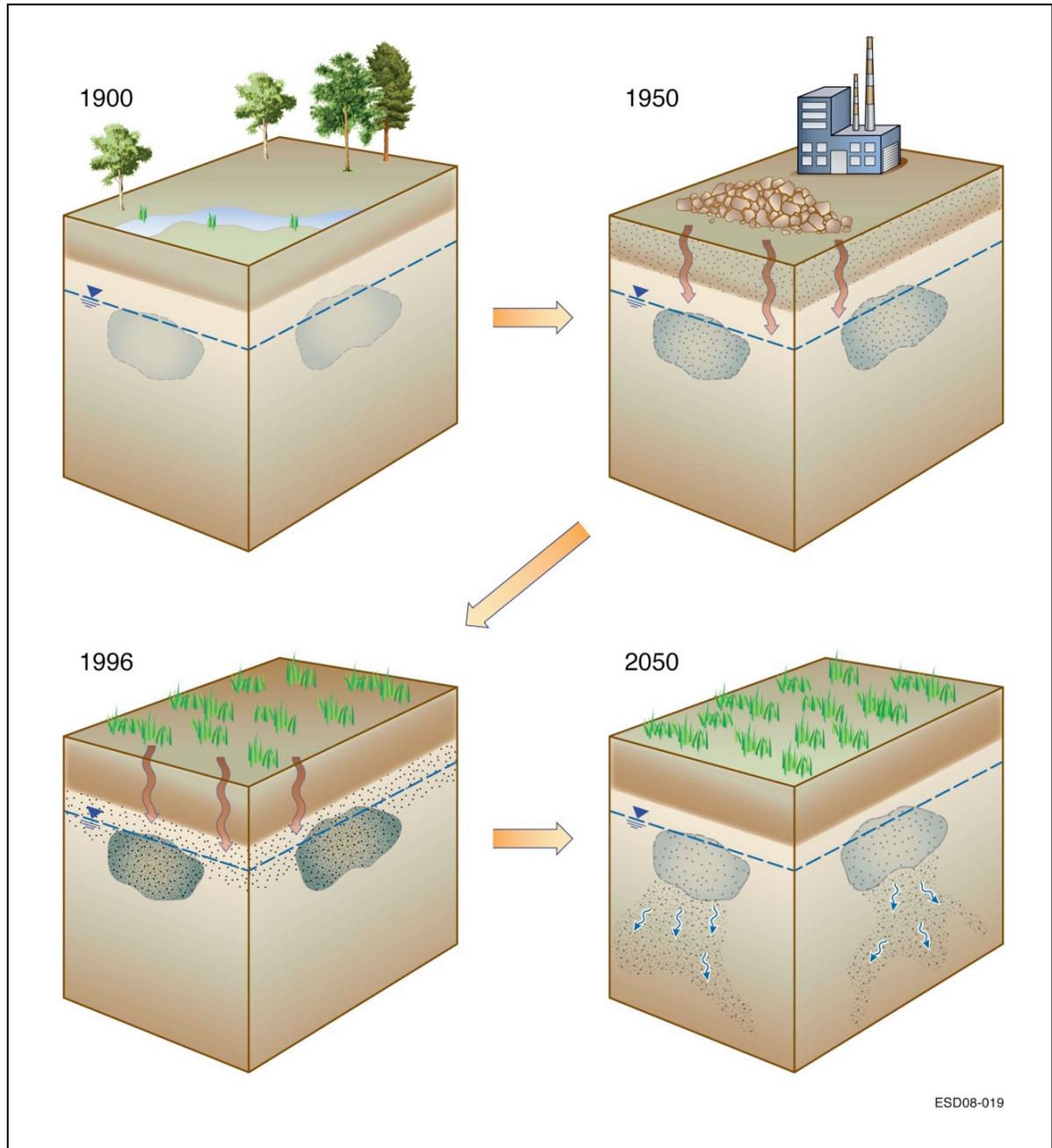
Conceptual Model of Naturally Bioreduced Zones

- ▶ A conceptual model that includes naturally bioreduced zones may dramatically change estimates of uranium plume persistence
- ▶ In 2050 will these zones be sources or sinks for U(VI)?



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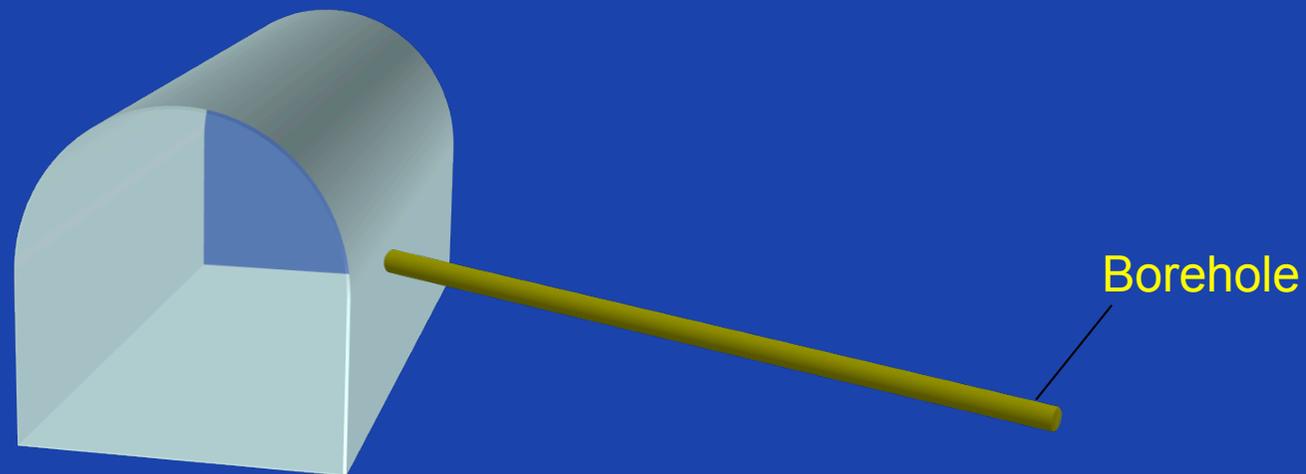
ESD08-019

Technical issues with graphite electrodes

- ▶ Abiotic electron production by reduced species (e.g. Fe(II))
- ▶ Different microbial species may have different intrinsic rates of electron production
- ▶ Not a one-to-one relationship between acetate concentration and electron production
- ▶ Don't know how well this will work at very low rates of microbial activity

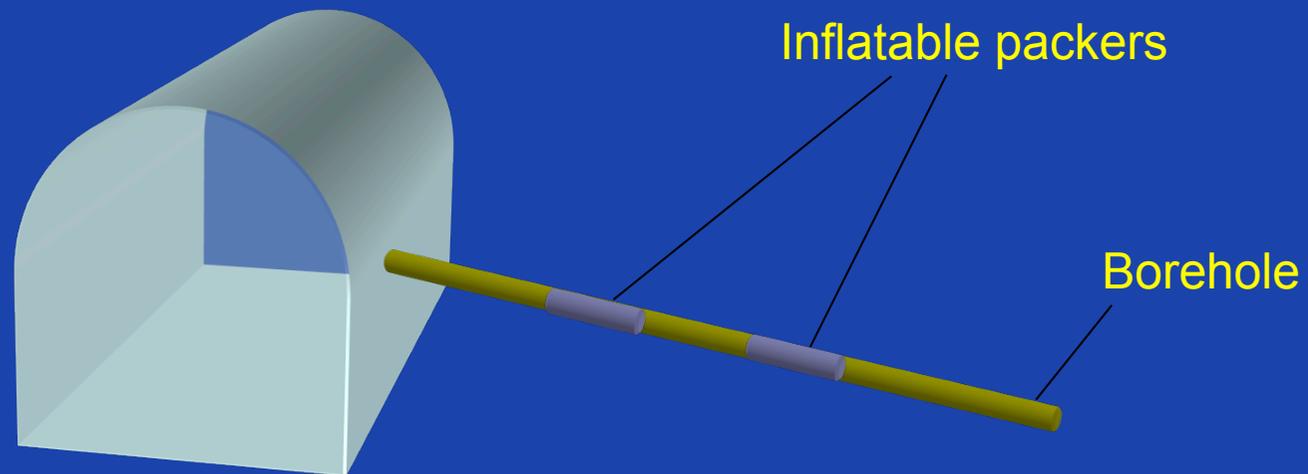
Proposed Experimental Design for DUSEL

Overall concept



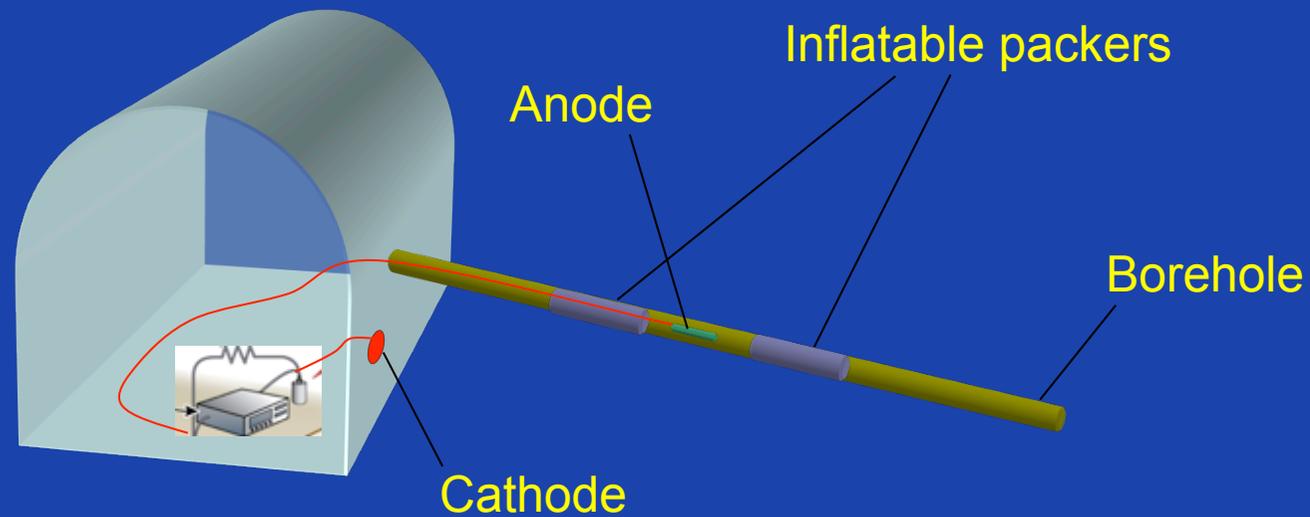
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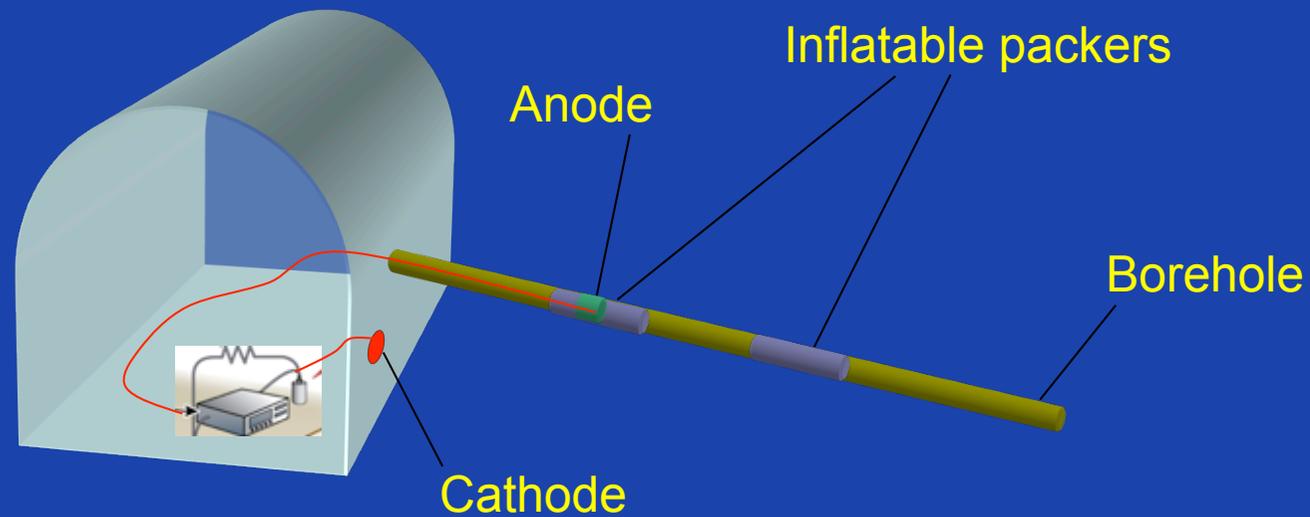
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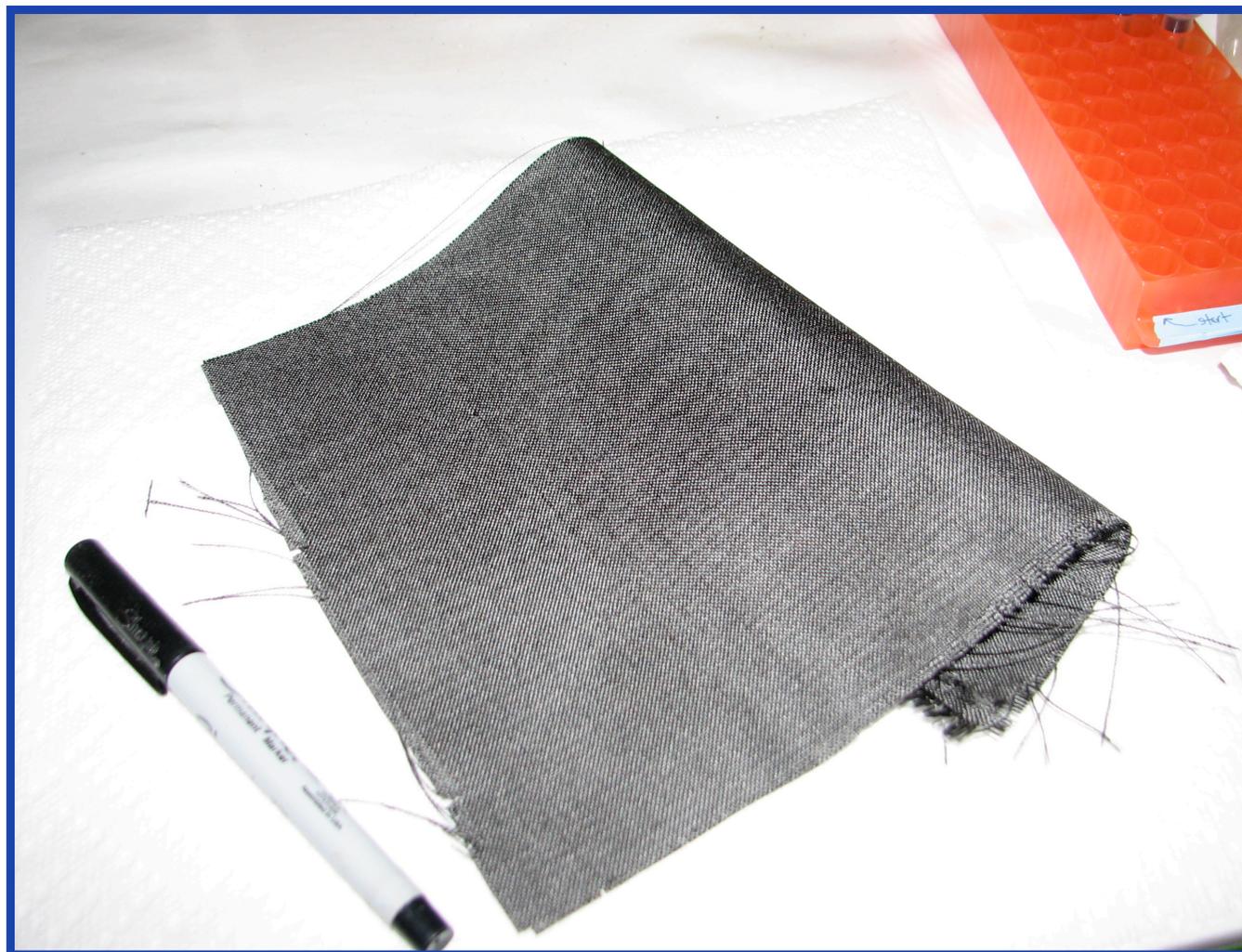


Proposed Experimental Design for DUSEL

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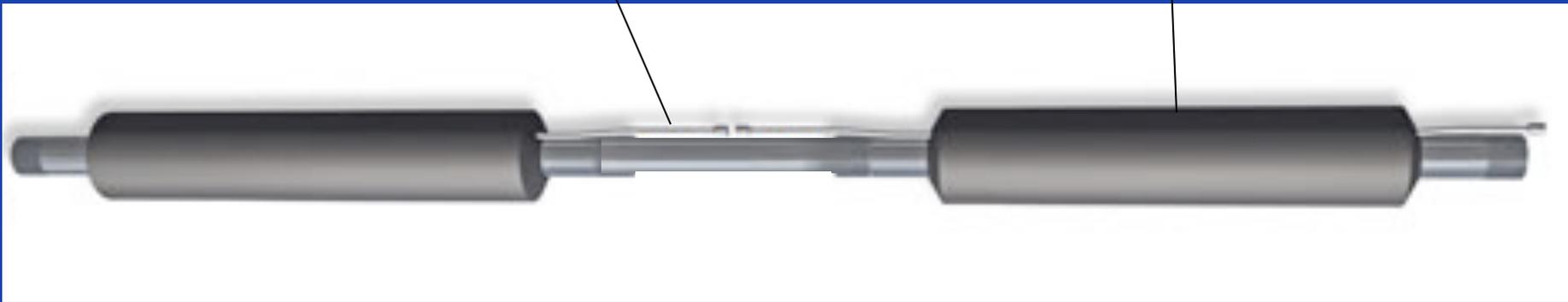
Graphite Fiber Cloth: new approach to graphite electrodes



Miniature Graphite Electrode



Dual packer set up

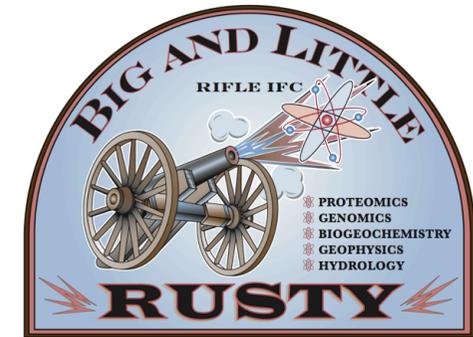
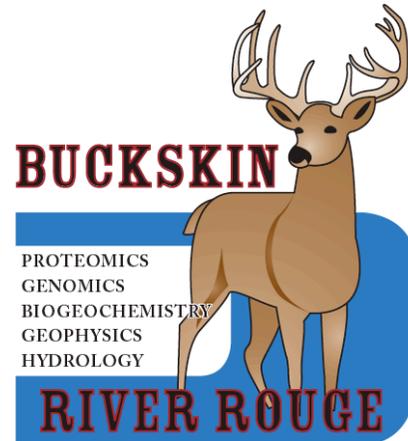
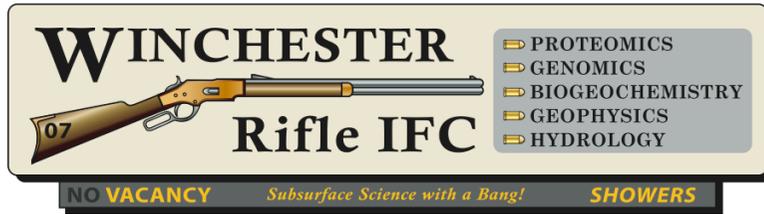


Possible Experimental Strategy

- Characterization (biogeochemistry, microbiology, hydrology, 2 months?)
- Initial monitoring phase with graphite electrodes and other sensors (6 months?)
- Electron donor amendment (variable concentration, simple to complex, e.g. acetate $[\text{CH}_3\text{COO}]$ to propionate $[\text{CH}_3\text{CH}_2\text{COO}]$, 2 years?)

Issues for discussion...

- Do we need a “new” packed-off interval for each electron donor?
- How do we integrate a range of related *in situ* experiments in diamond core holes?
- Others...



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(Long and Williams)**

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(Lovley)**