
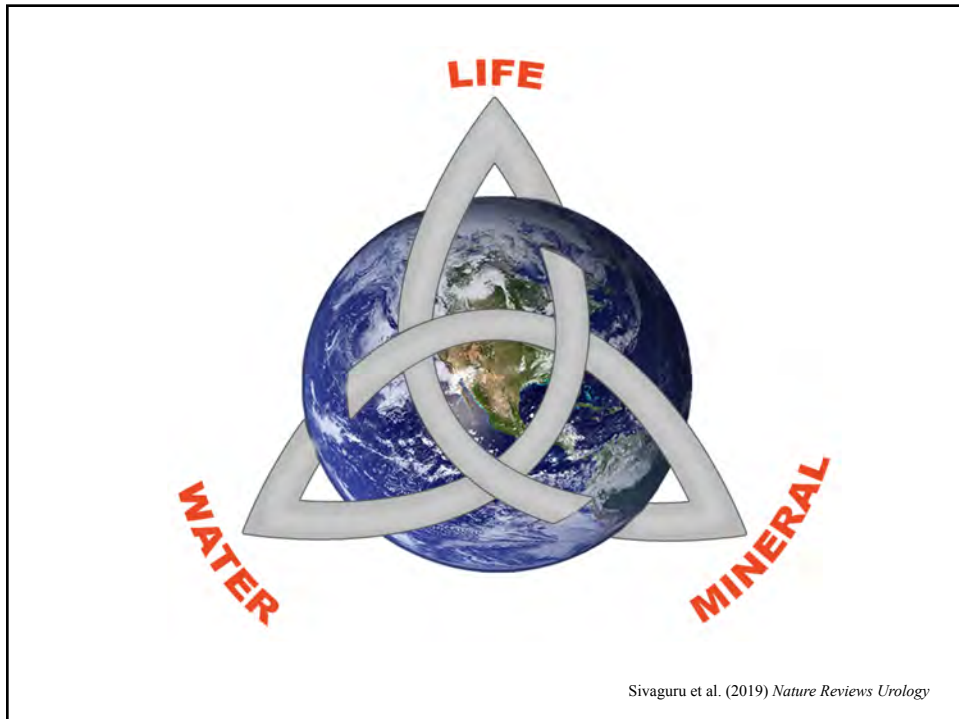


# Life Make Rock: 4 Billion Years of Biomineralization

Bruce W. Fouke

 Director Roy J. Carver Biotechnology Center  
Professor of Geology and Microbiology  
Carl R. Woese Institute for Genomic Biology



## Oil Field Geobiology

CO<sub>2</sub> Sequestration  
Biosouring  
Shale Fracking



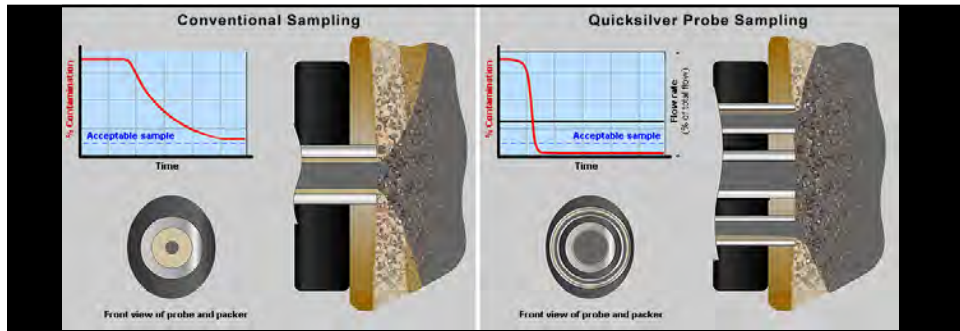
### From Bacteria to Barrels: Microbiology Having an Impact on Oil Fields

Stephen Rassenfoss, JPT/JPT Online Staff Writer



### Decatur, IL USA CO<sub>2</sub> Sequestration Well



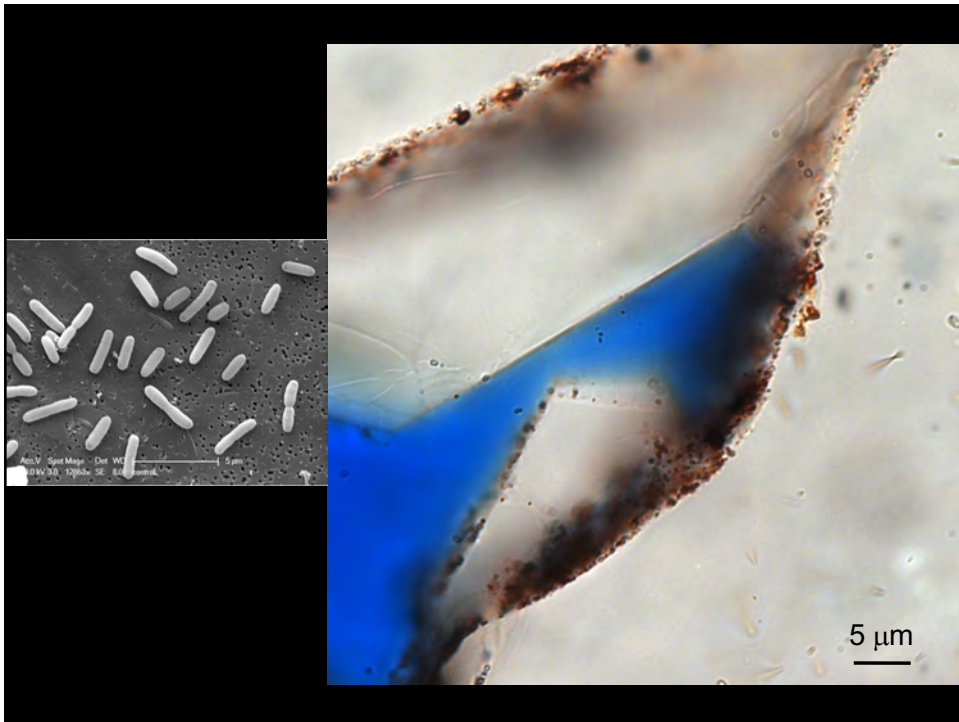
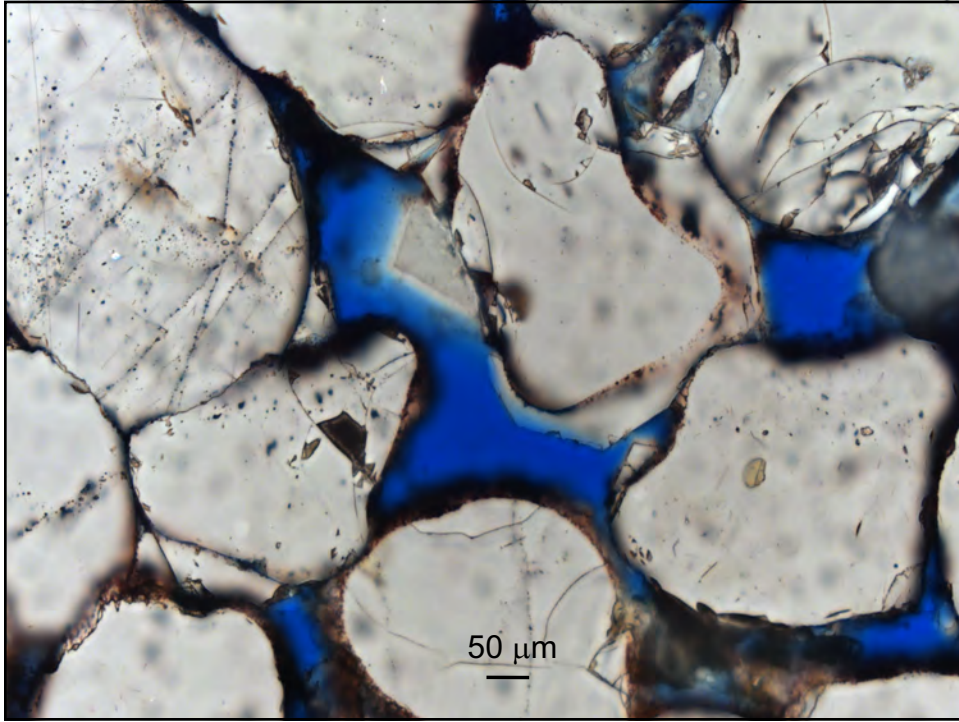


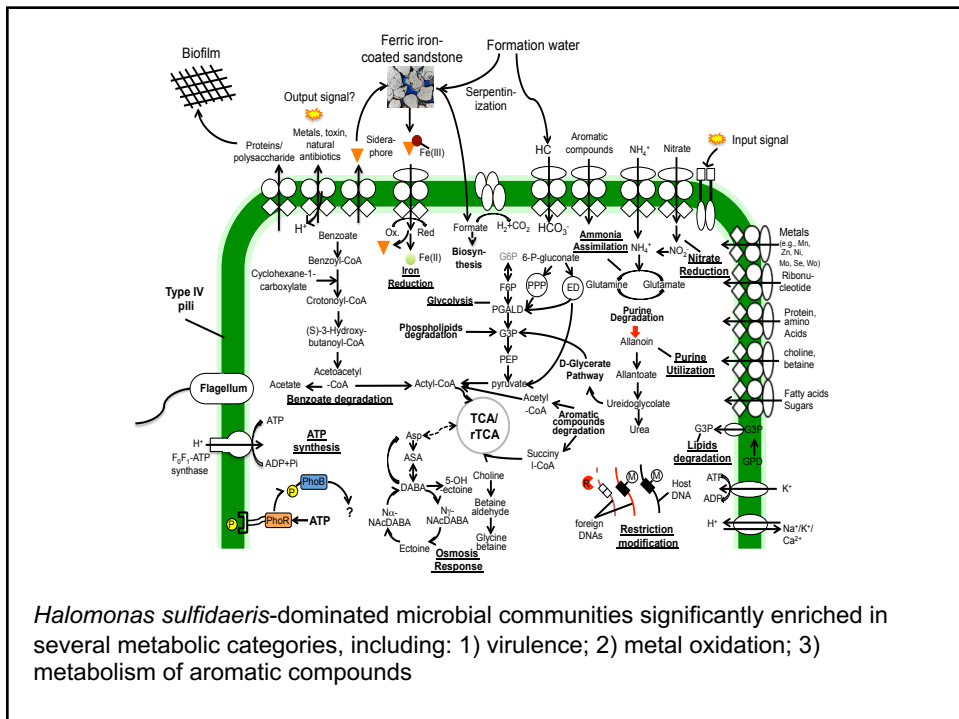
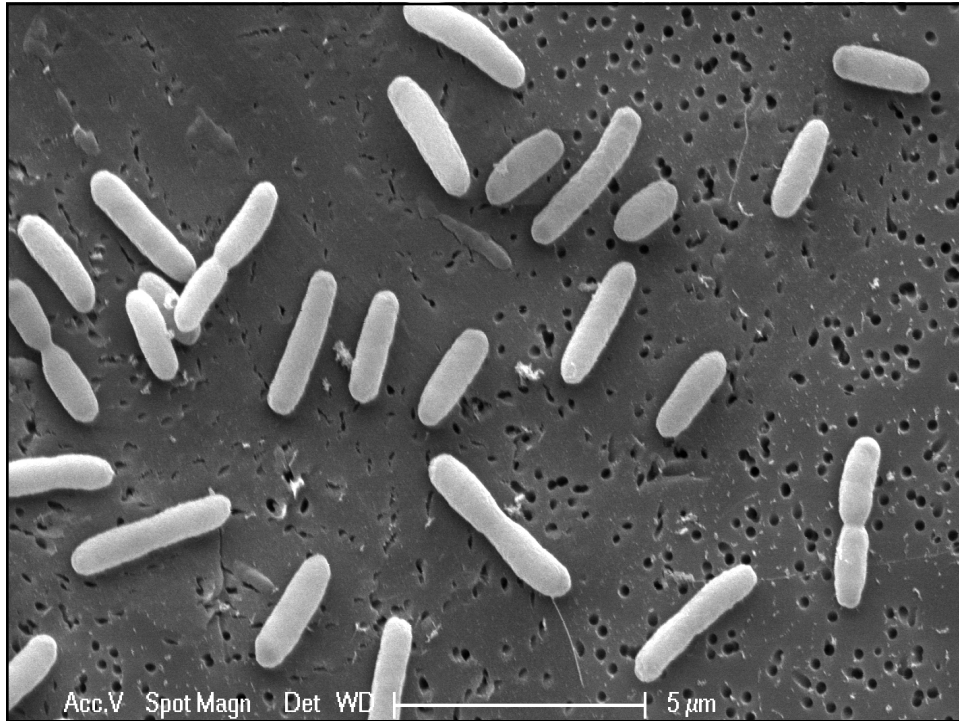
**Schlumberger Quicksilver Probe**





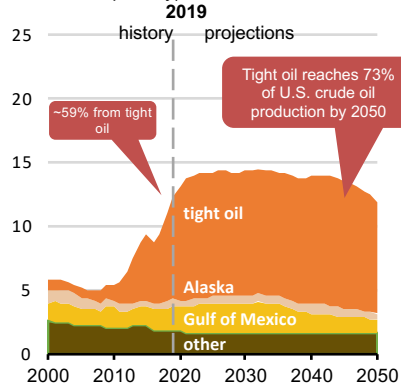




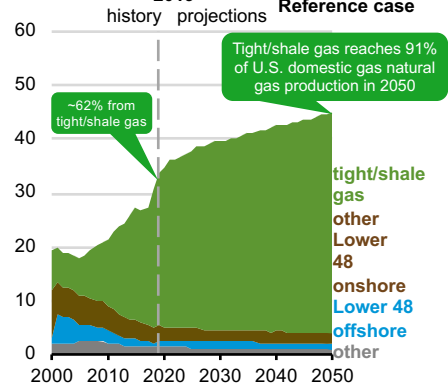


## Unconventional Tight/Shale Oil Gas Production Driver of U.S. Crude Oil and Natural Gas Production

AEO2020 crude oil production  
(million barrels per day)



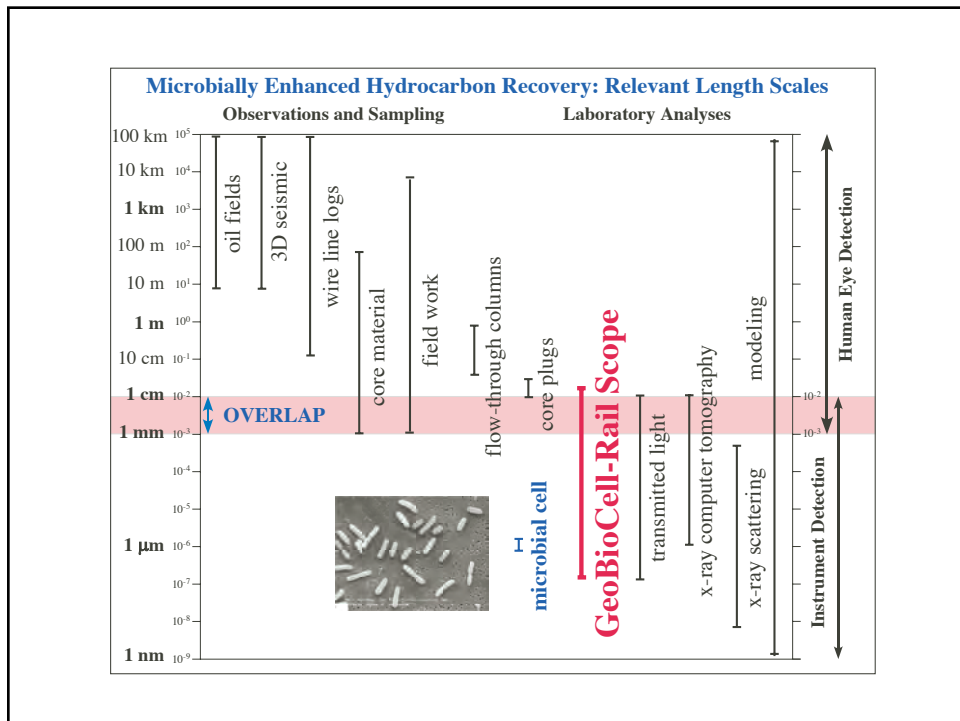
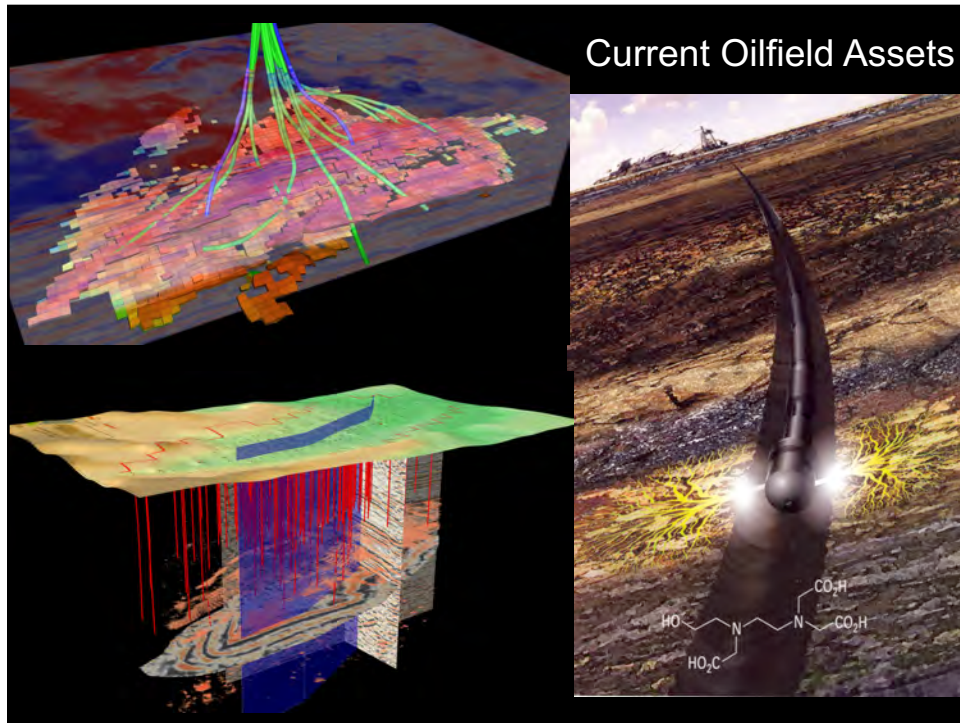
AEO2020 dry natural gas production by type  
trillion cubic feet 2019



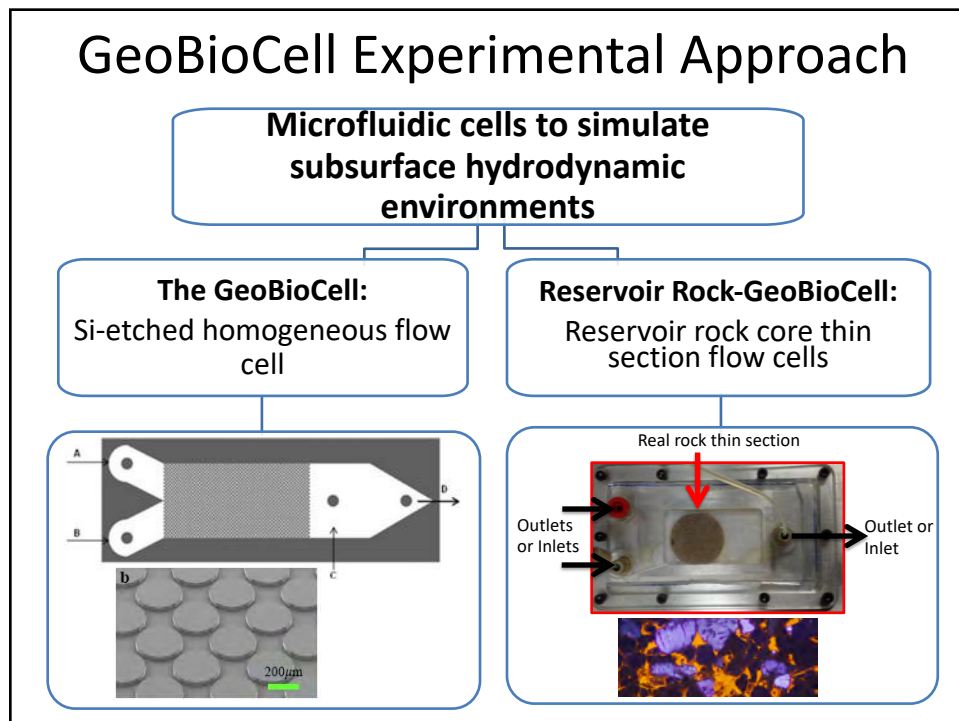
Data from Annual Energy Outlook 2020 infographics

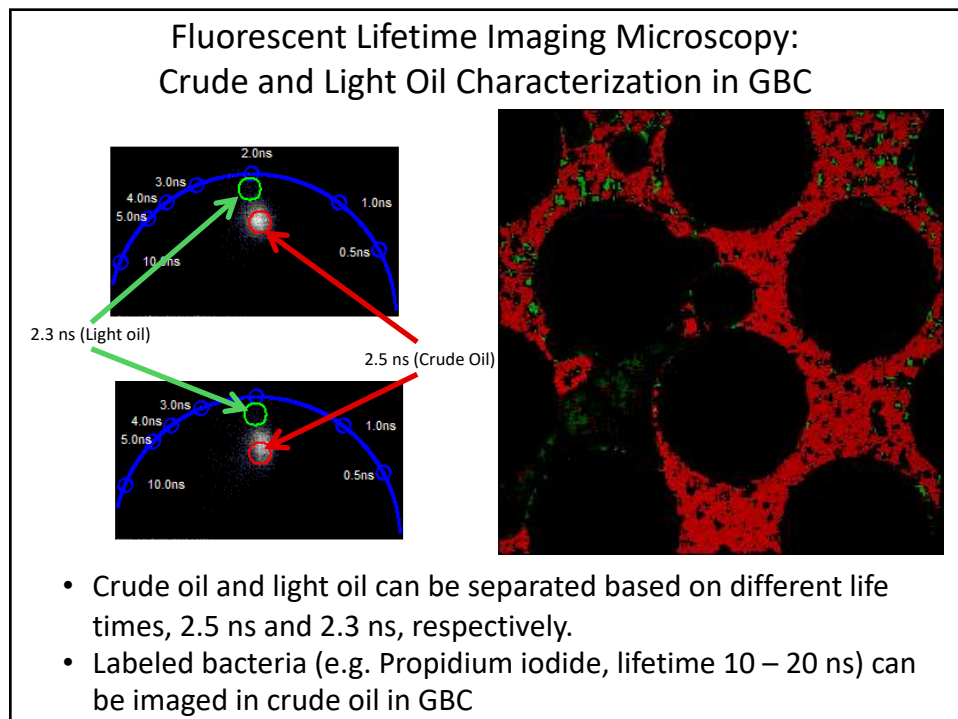
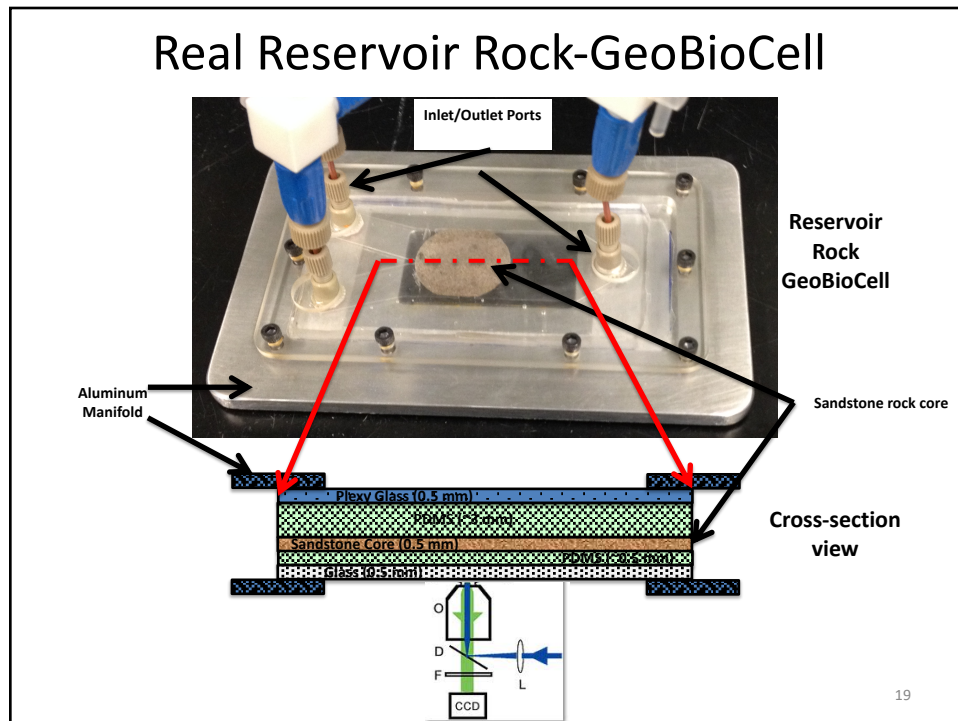








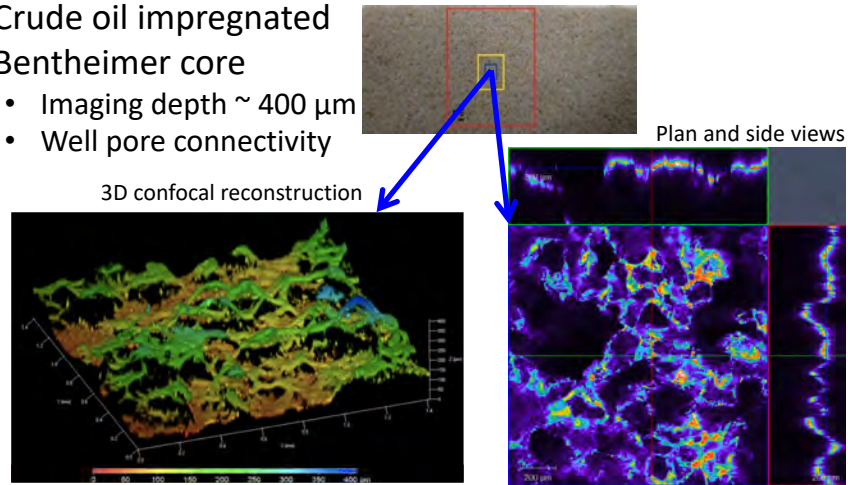




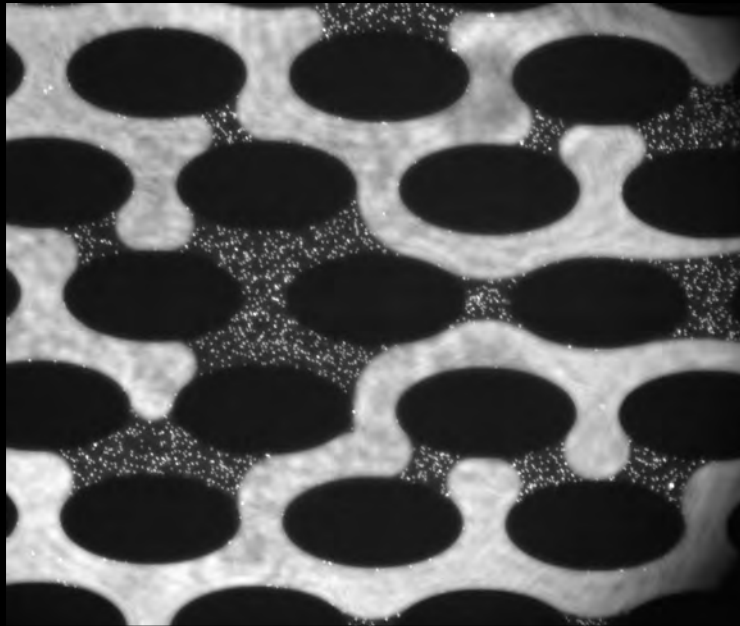
## Thin Sections Impregnated with Oil and Pore Structure Analyzed with Confocal Microscopy

- Crude oil impregnated Bentheimer core

- Imaging depth  $\sim 400 \mu\text{m}$
- Well pore connectivity

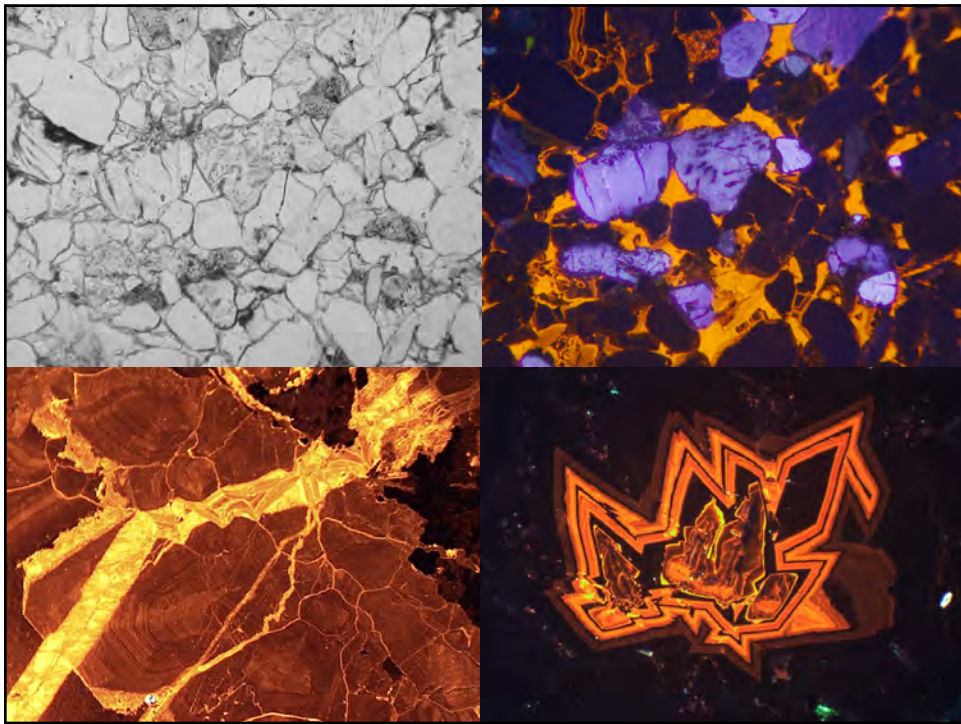
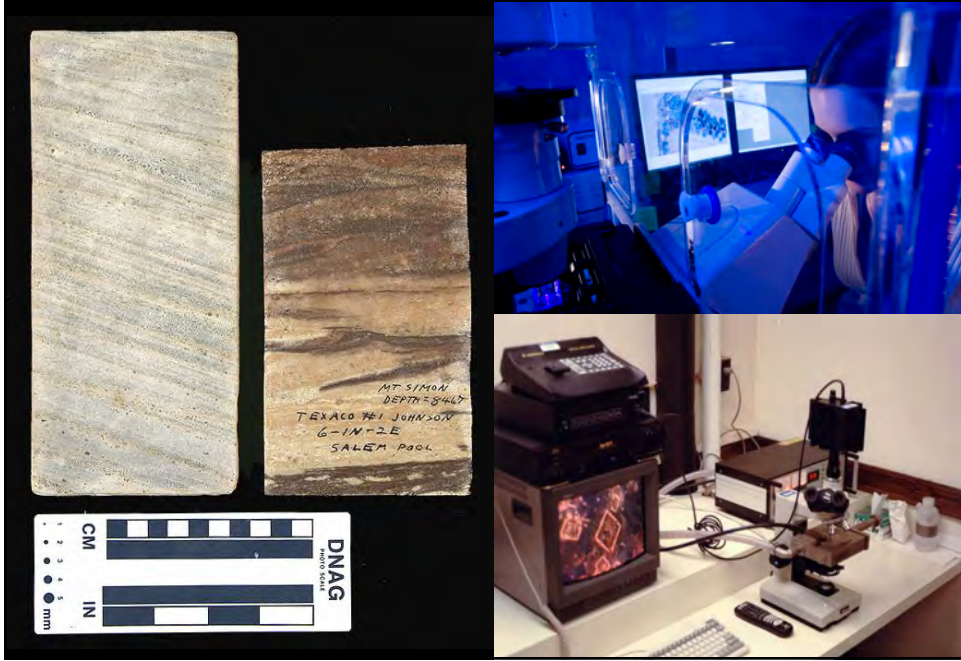


## Particle Image Velocimetry (PIV)





# Mt. Simon Sandstone Reservoir Rock Analyses

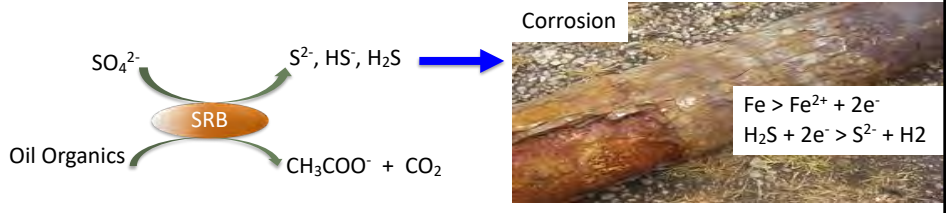


## Training at the Blind Pig



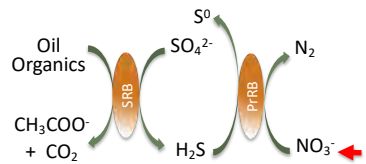
# Mechanisms for Biosouring

- Biological reduction of  $\text{SO}_4^{2-}$  to Sulfides ( $\text{S}^{2-}$ ,  $\text{HS}^-$ , and  $\text{H}_2\text{S}$ ) via sulfate reducing Bacteria (SRB)

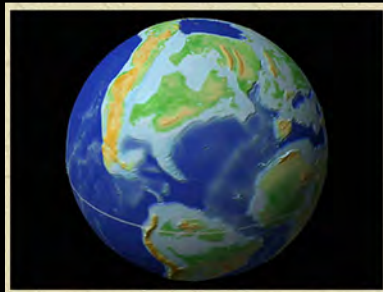


- Prevent biological reduction of  $\text{SO}_4^{2-}$  to Sulfides ( $\text{S}^{2-}$ ,  $\text{HS}^-$ , and  $\text{H}_2\text{S}$ ) by feeding  $\text{NO}_3$  to subsurface bacteria and thus preventing sulfate reducing Bacteria (SRB)

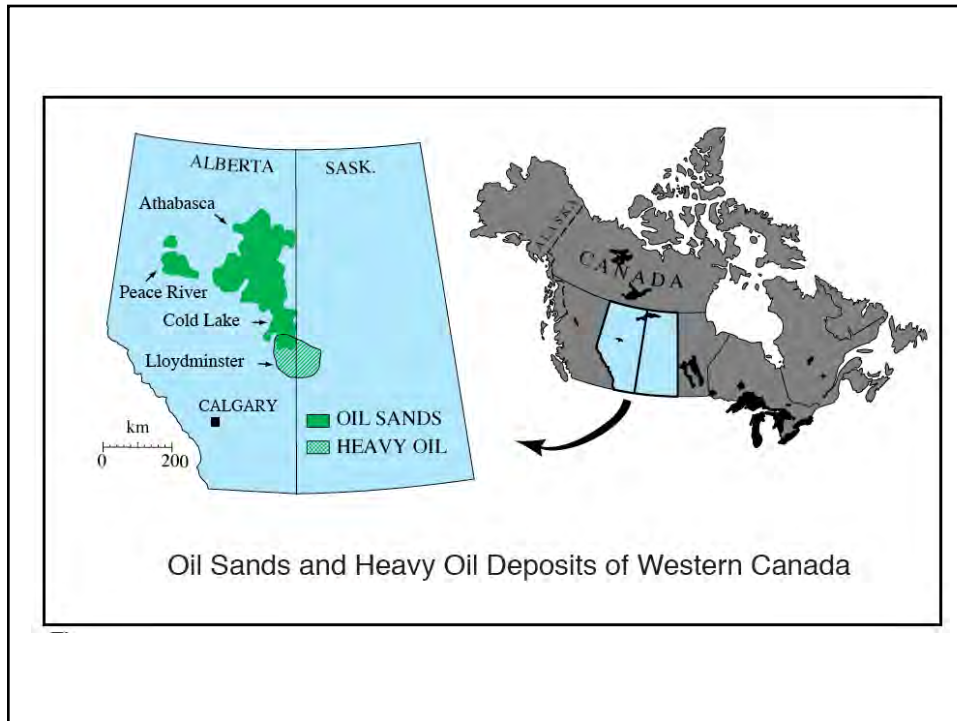
## $\text{NO}_3$ Injection



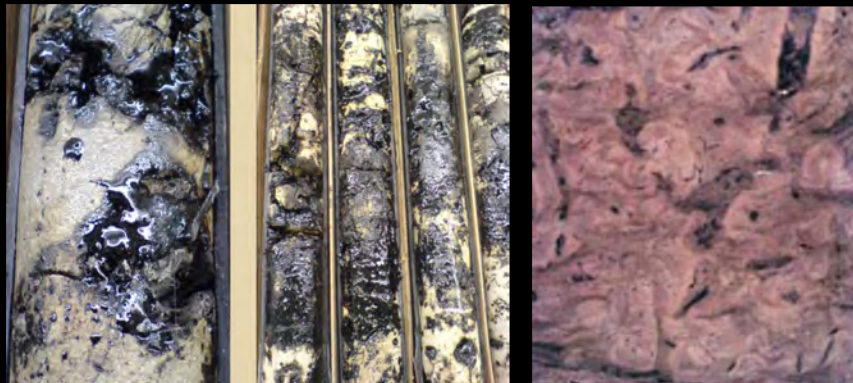
# Cretaceous Western Interior Seaway







**Upper Devonian Grosmont Limestone Reservoir**  
Unconventional Bitumen and Heavy Oil Reservoir  
>318 Billion BBL (perhaps 400-500 Billion BBL total)



**Core to Pore**











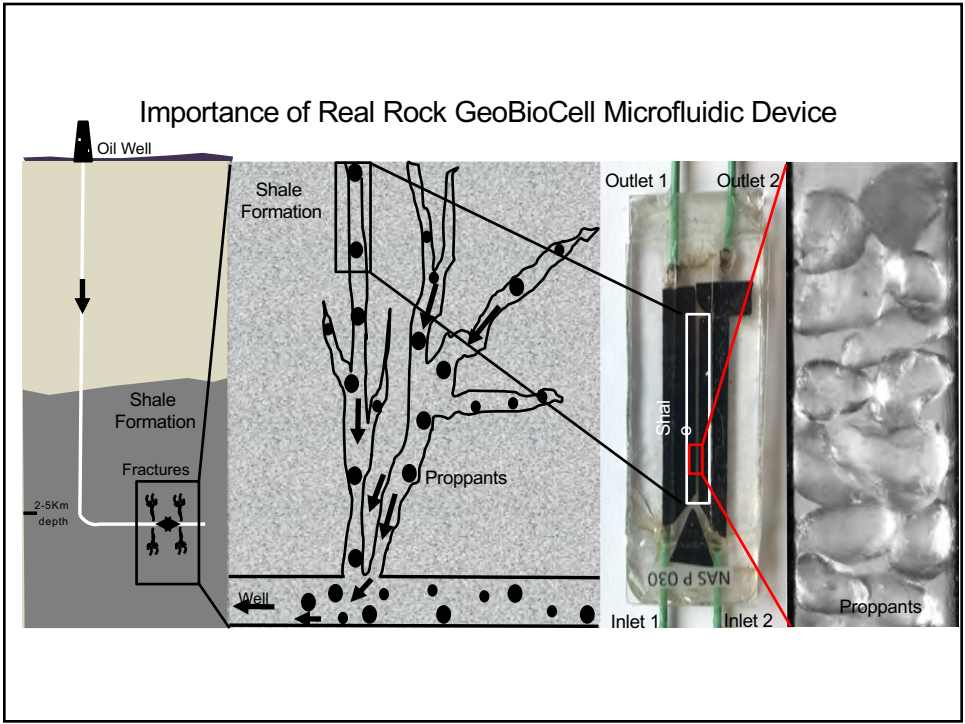
Deep Subsurface Microbial Biosphere, Heavy Oil, North Slope Alaska





**Marathon Oil Company  
Animation of Hydraulic Fracturing (Fracking)**

<https://www.youtube.com/watch?v=VY34PQUiwOQ&feature=youtu.be>



### Sulfate Reducing Bacteria (SRB) Culturing

**SRB Enrichment**

- Enriched from produced formation waters at 1-1.5km depth.
- Cultured in media formulated to simulate 45°C subsurface conditions.

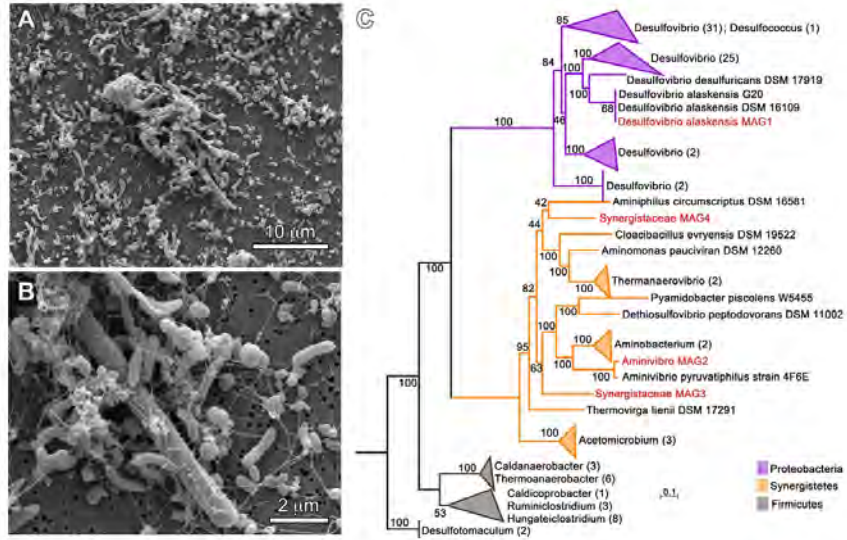
Selective media containing volatile fatty acids (VFA) and vitamins

1. Acetate (13mM)
2. Formate (15mM)
3. Butyrate (1.2mM)
4. Propionate (1.4mM)

Control      SRB enrichment

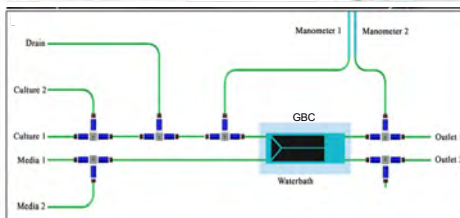


## Ecology, Physiology and Metabolism of the Subsurface Biosphere Inhabiting Fracked Shale

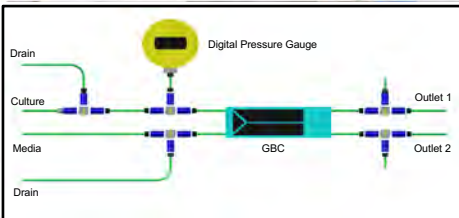
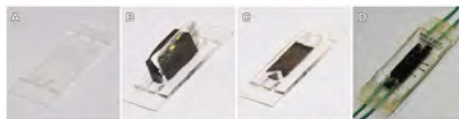


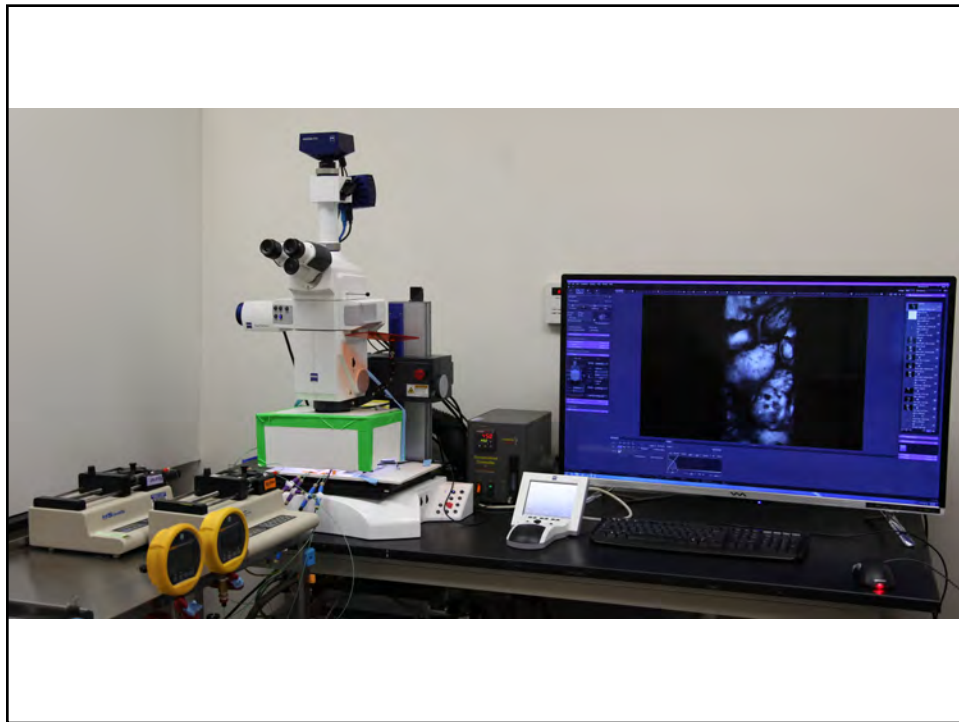
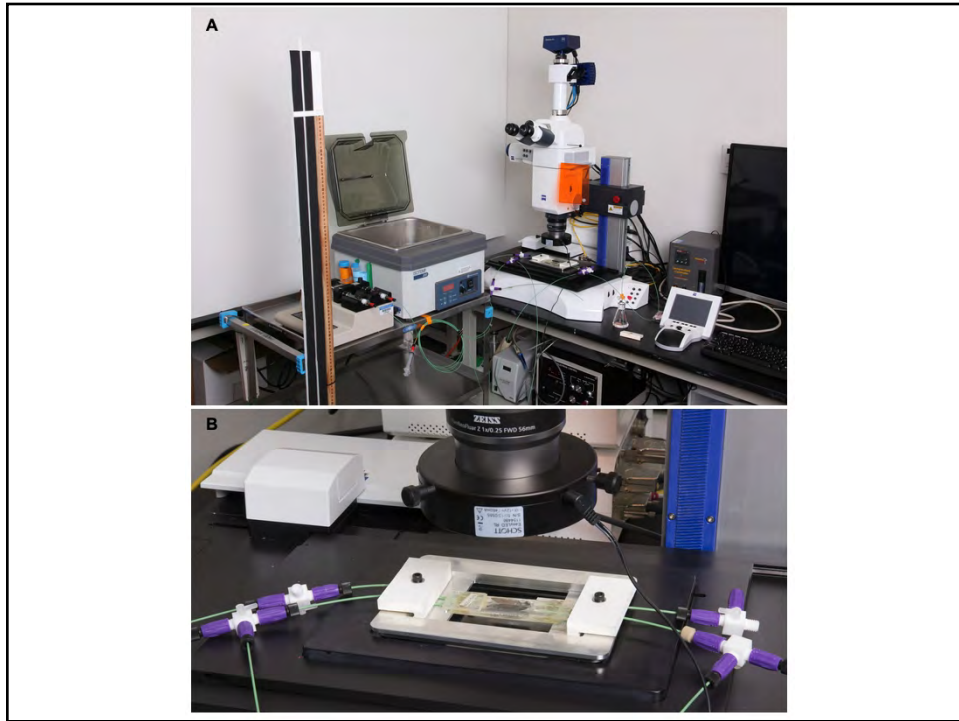
## Real-Rock Shale GeoBioCell Construction and Operation

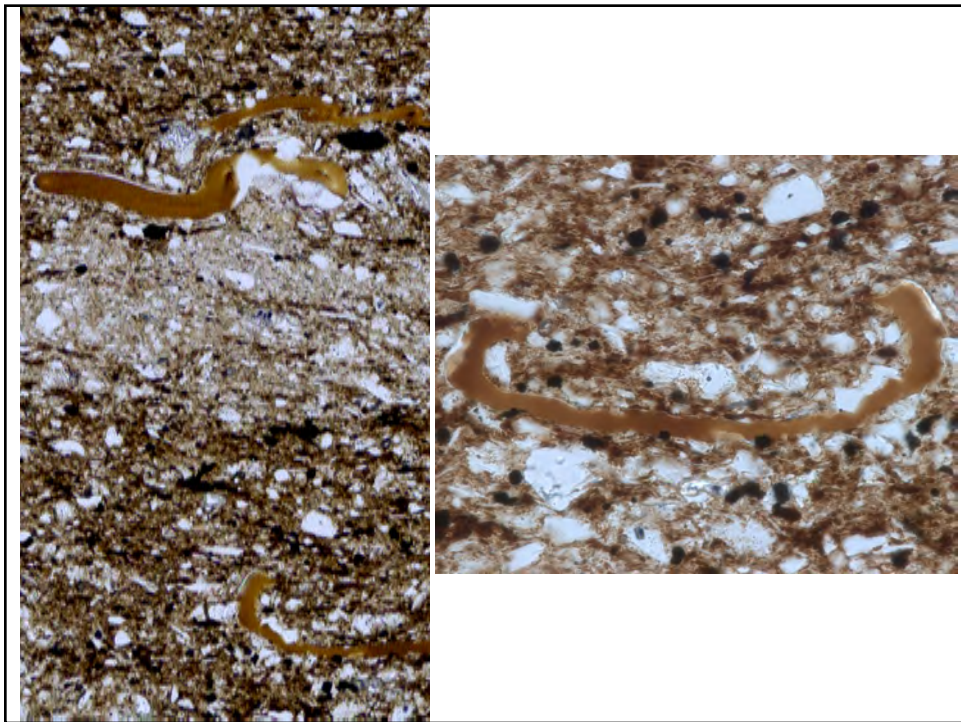
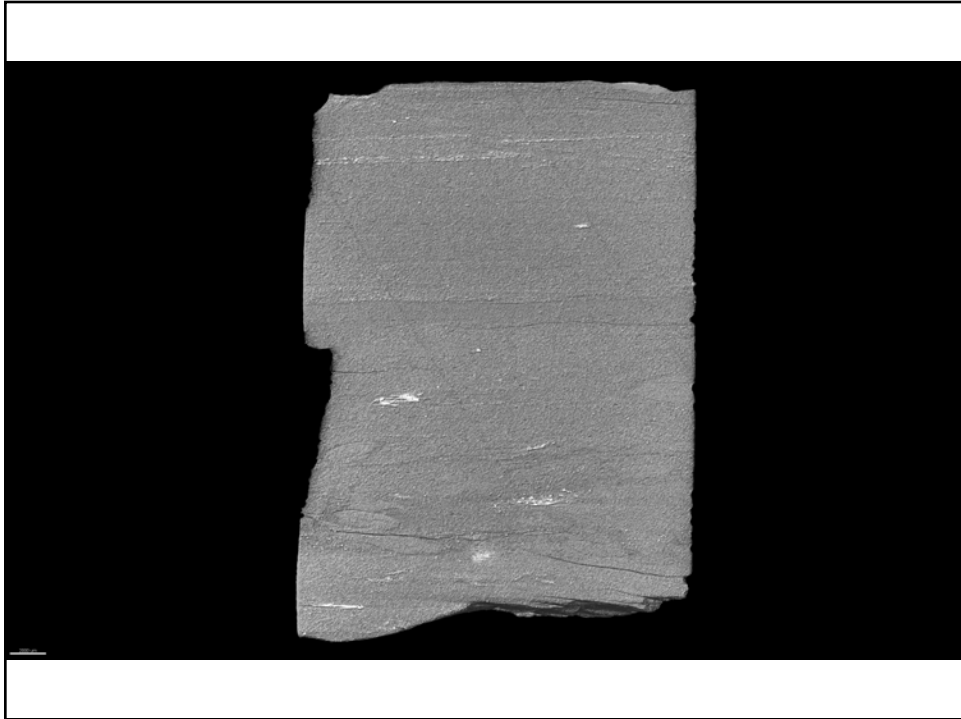
Shale GBC



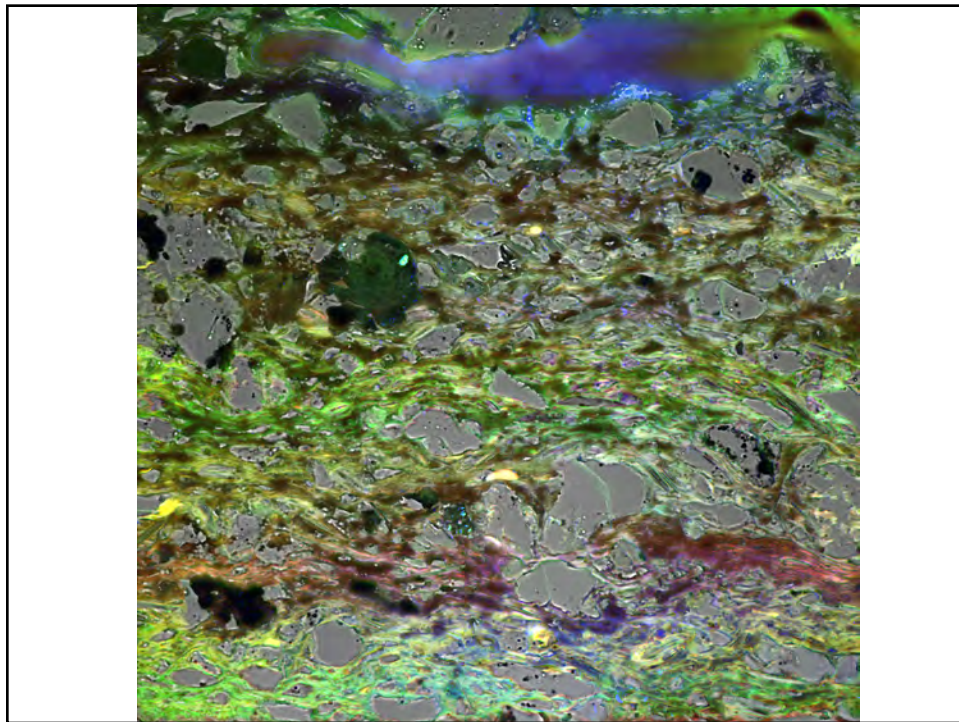
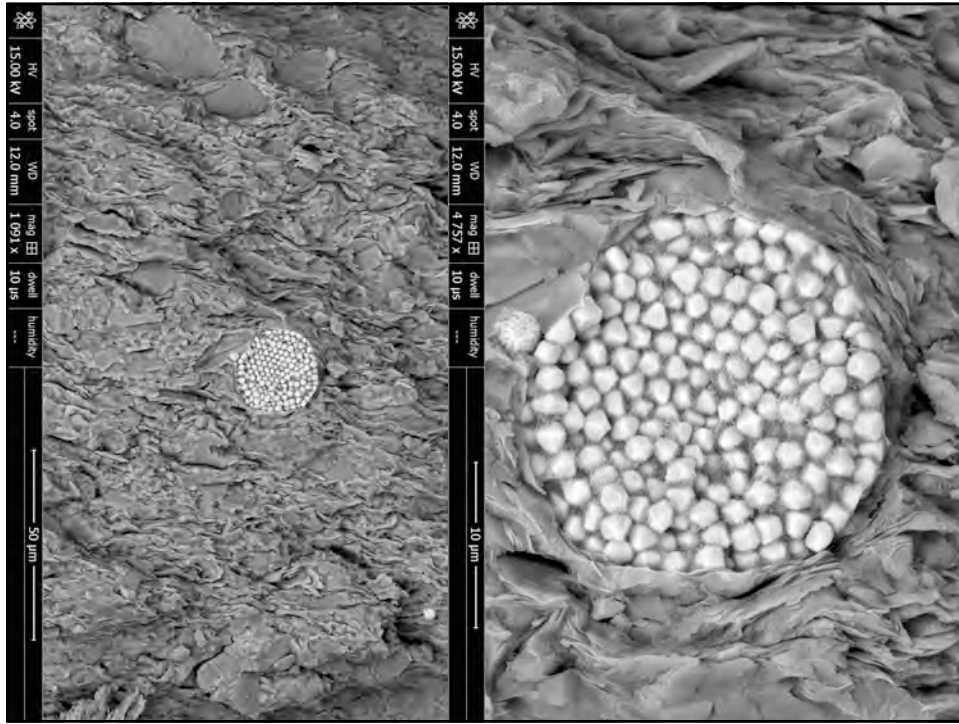
Shale GBC with proppants

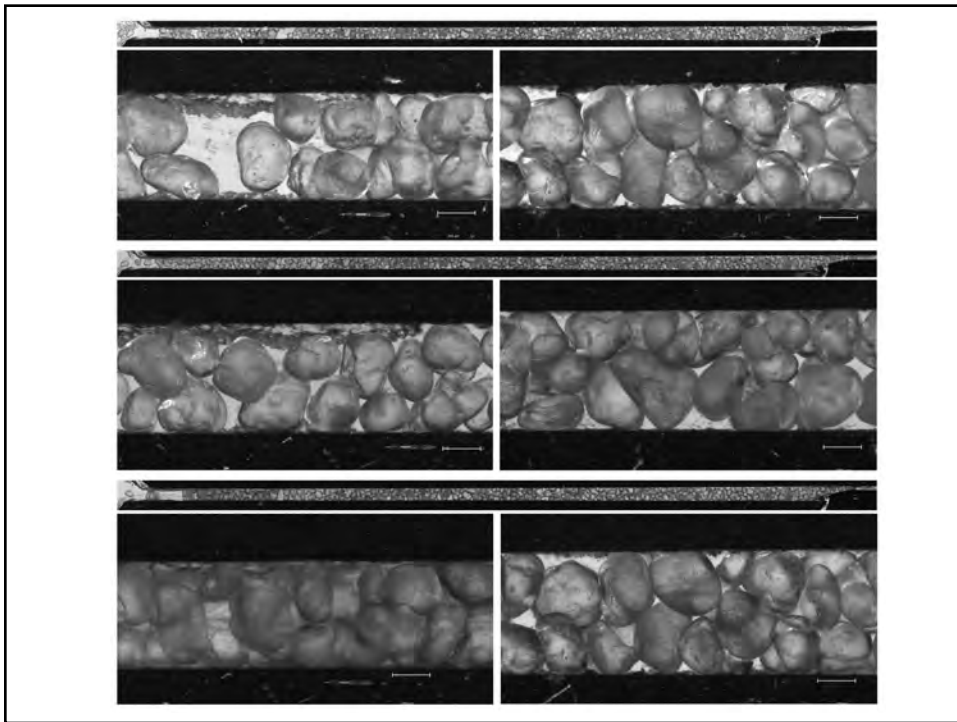
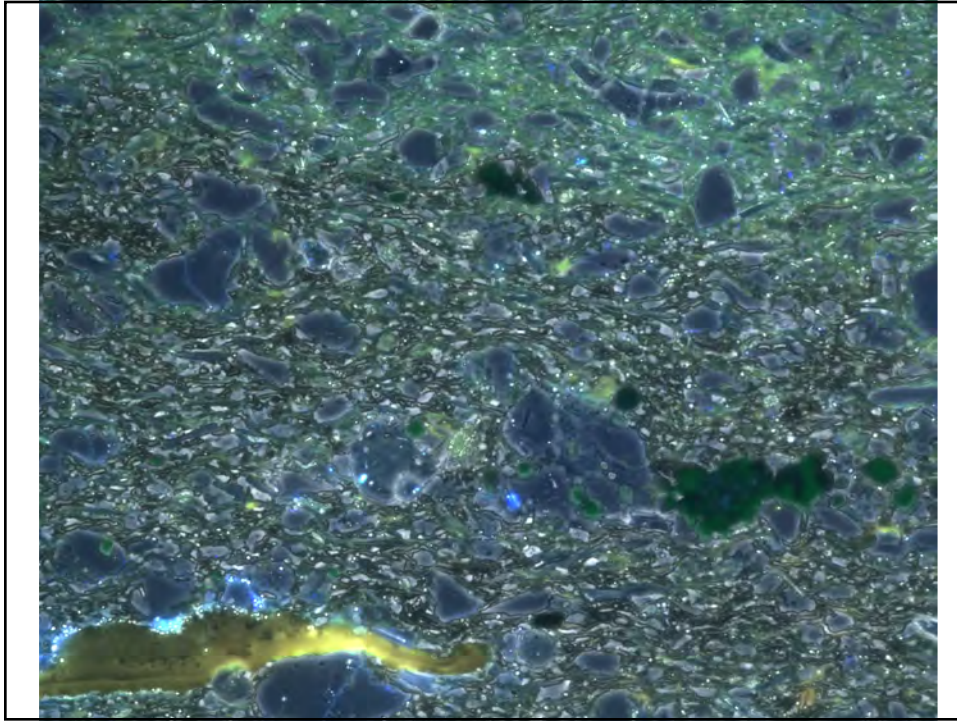




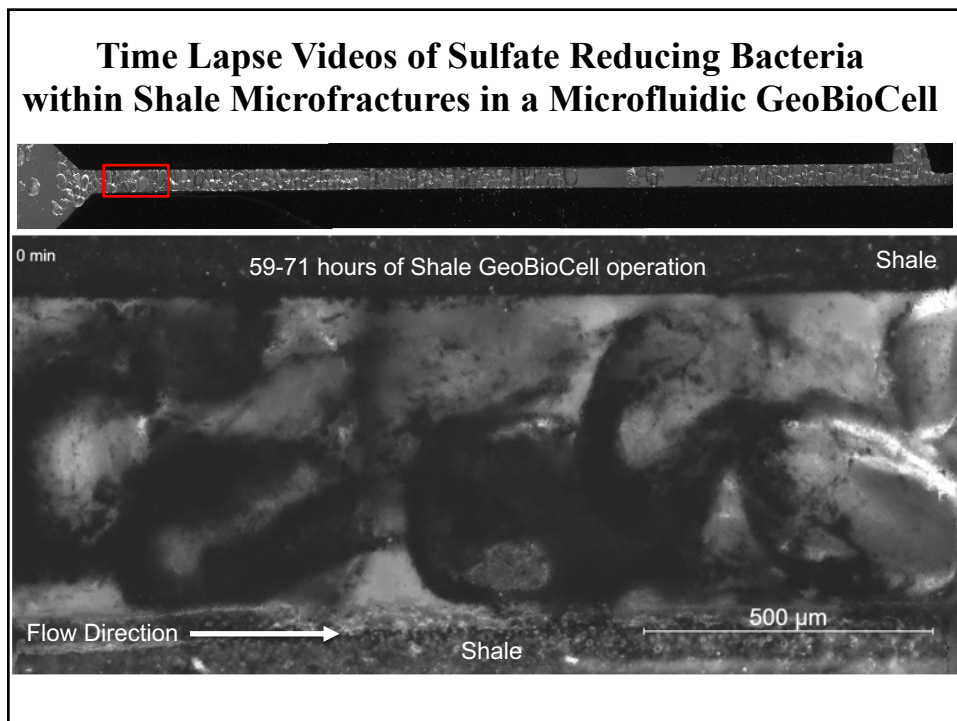
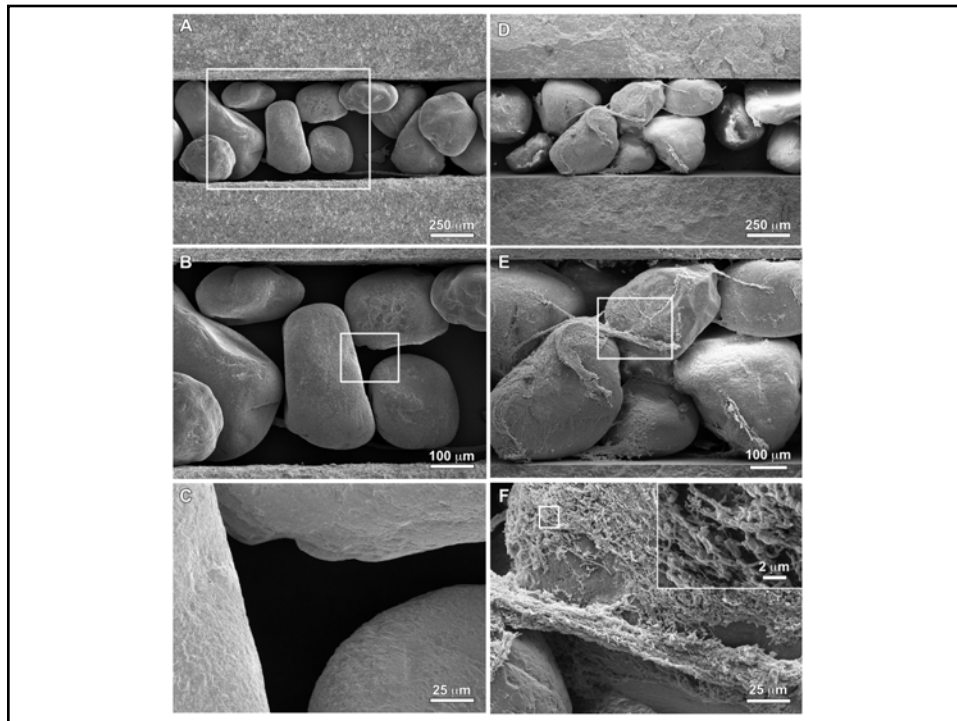




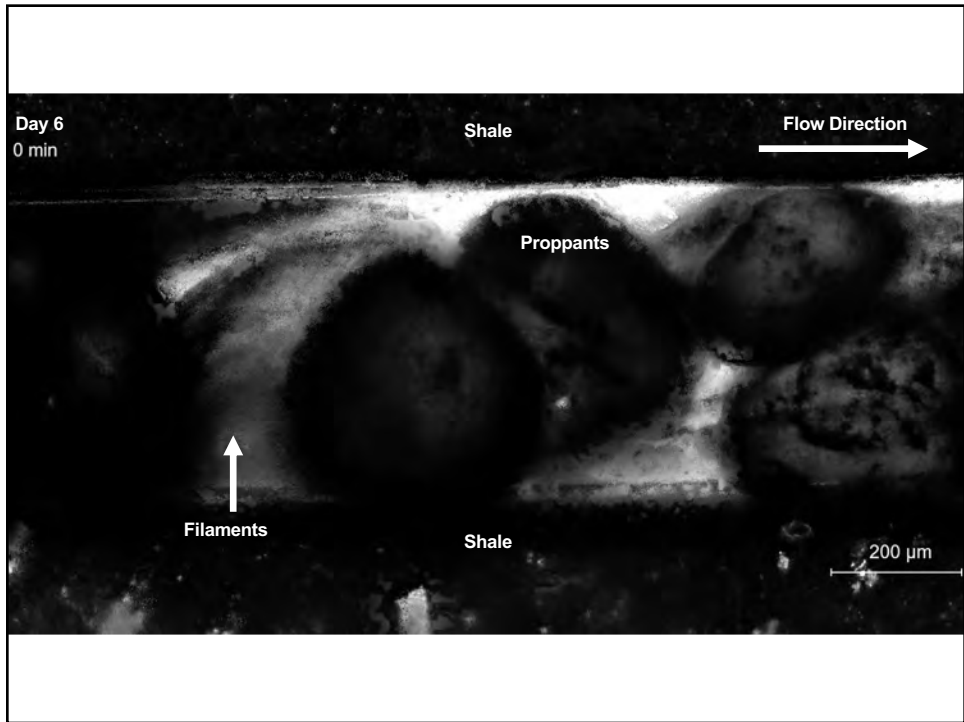
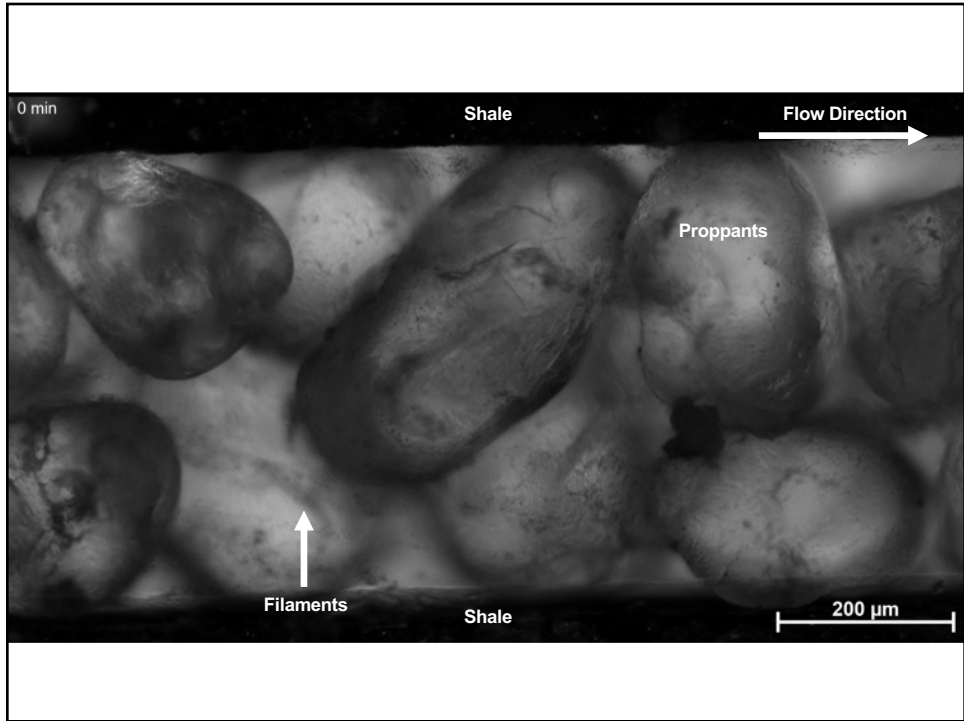












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CO<sub>2</sub> Sequestration

Biosouring

Shale Fracking



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