Fourth Annual Conference on Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

Sequestration of Carbon Emissions in Geologic Formations

Microbially Enhanced Geologic Sequestration of Supercritical CO_2

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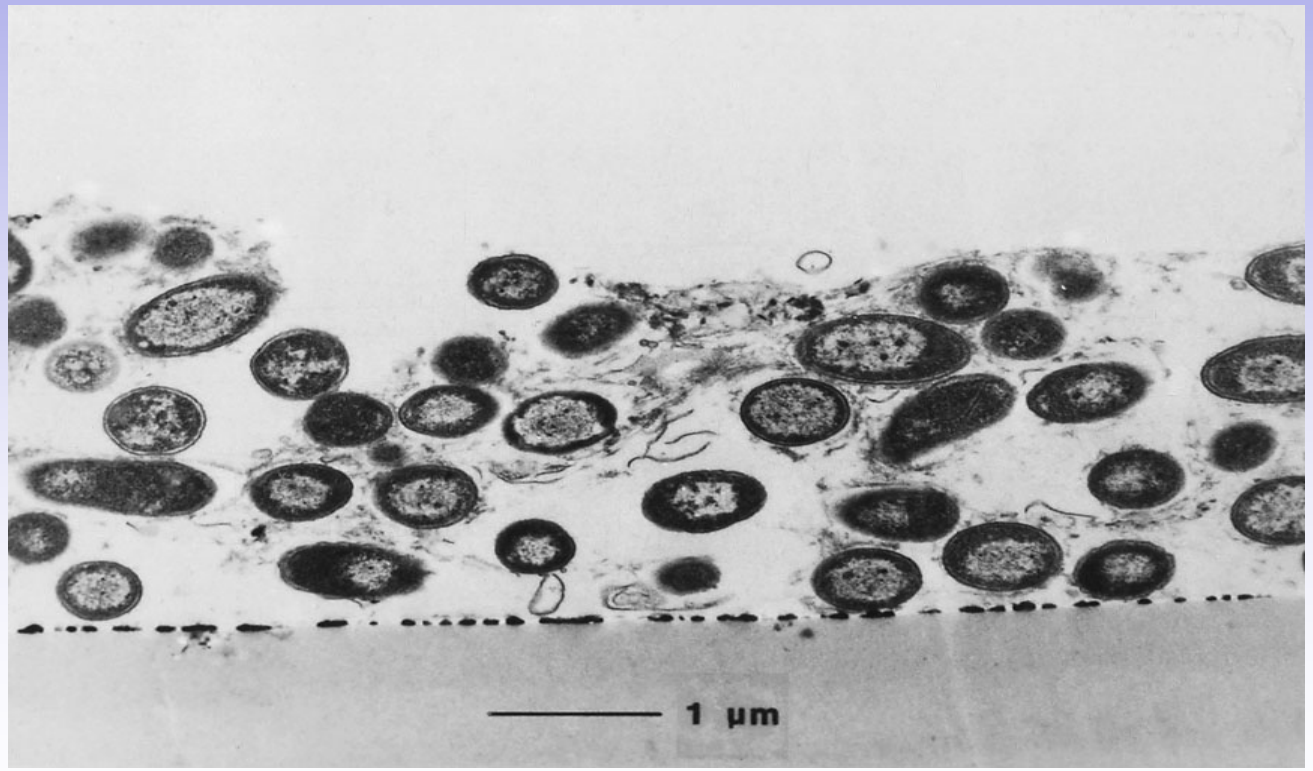
May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia

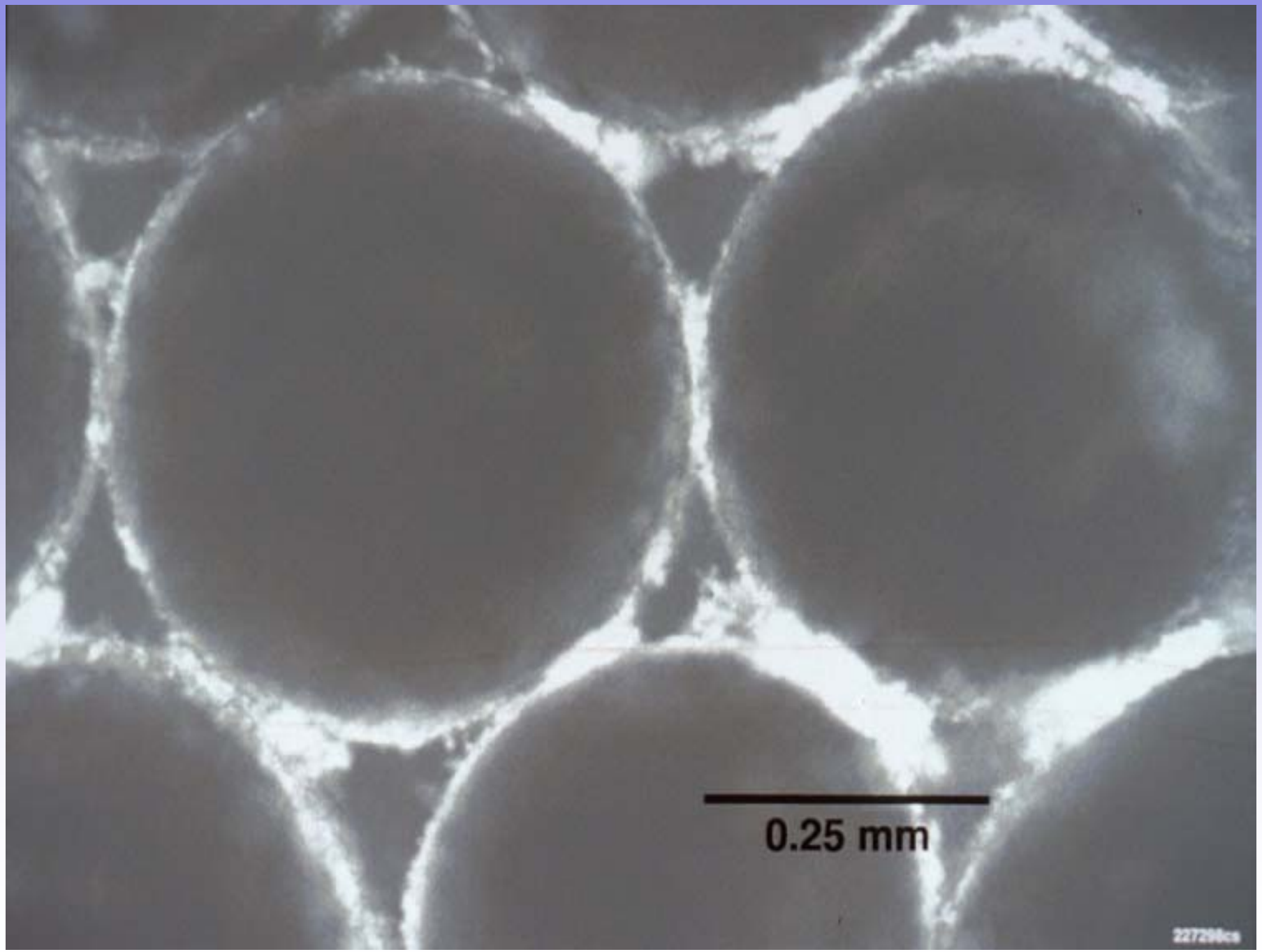
CENTER FOR BIOFILM ENGINEERING



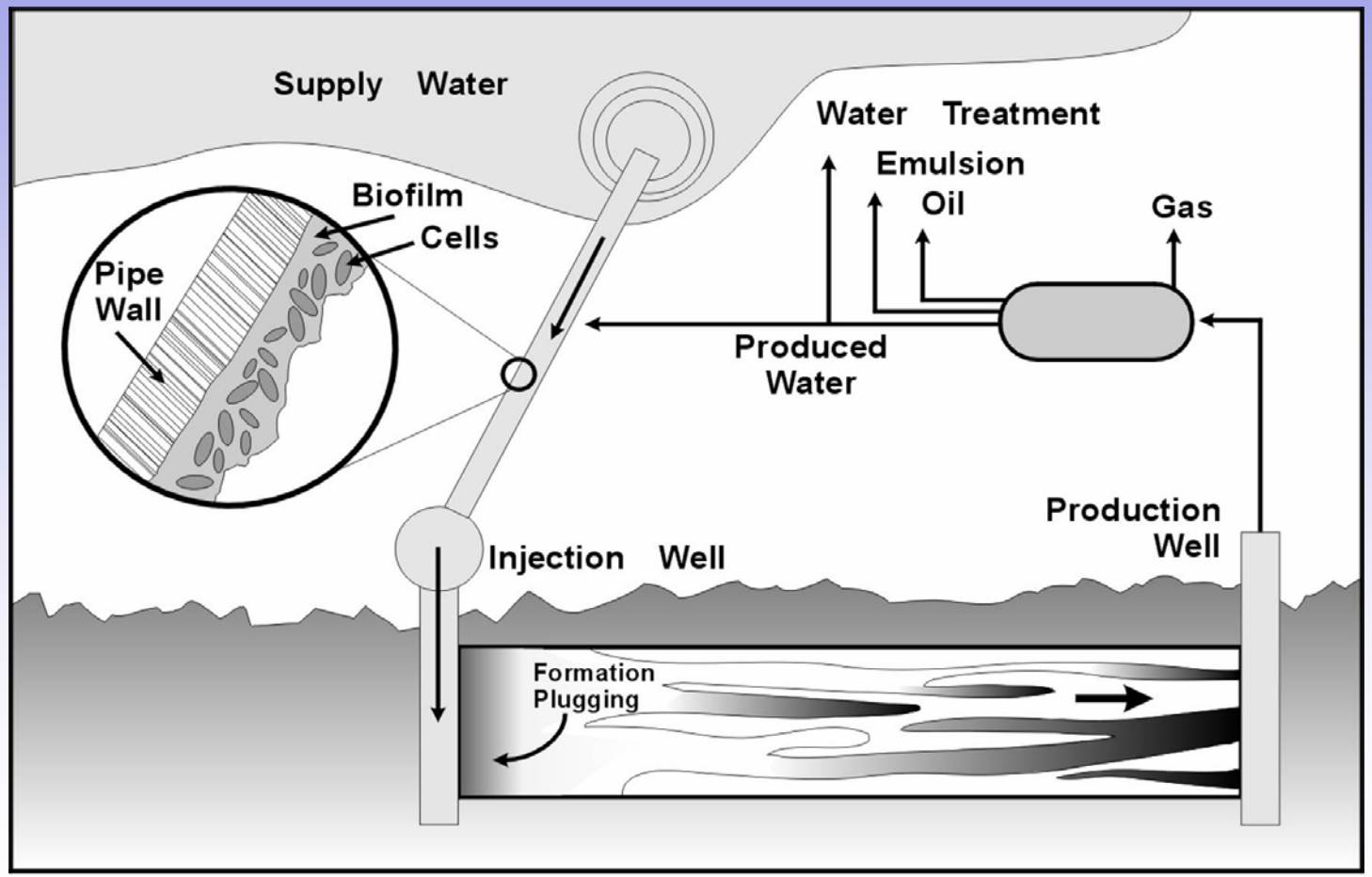
A National Science Foundation Engineering Research Center

BIOFILMS IN POROUS MEDIA

Injection of fluids and nutrients into subsurface formations can cause the formation of thick microbial biofilms which plug free pore space and reduce porosity and permeability.


0.25 mm

Formation Plugging during EOR Water Flood



OILWELL.CDR

FORMATION PLUGGING

PROBLEMS:

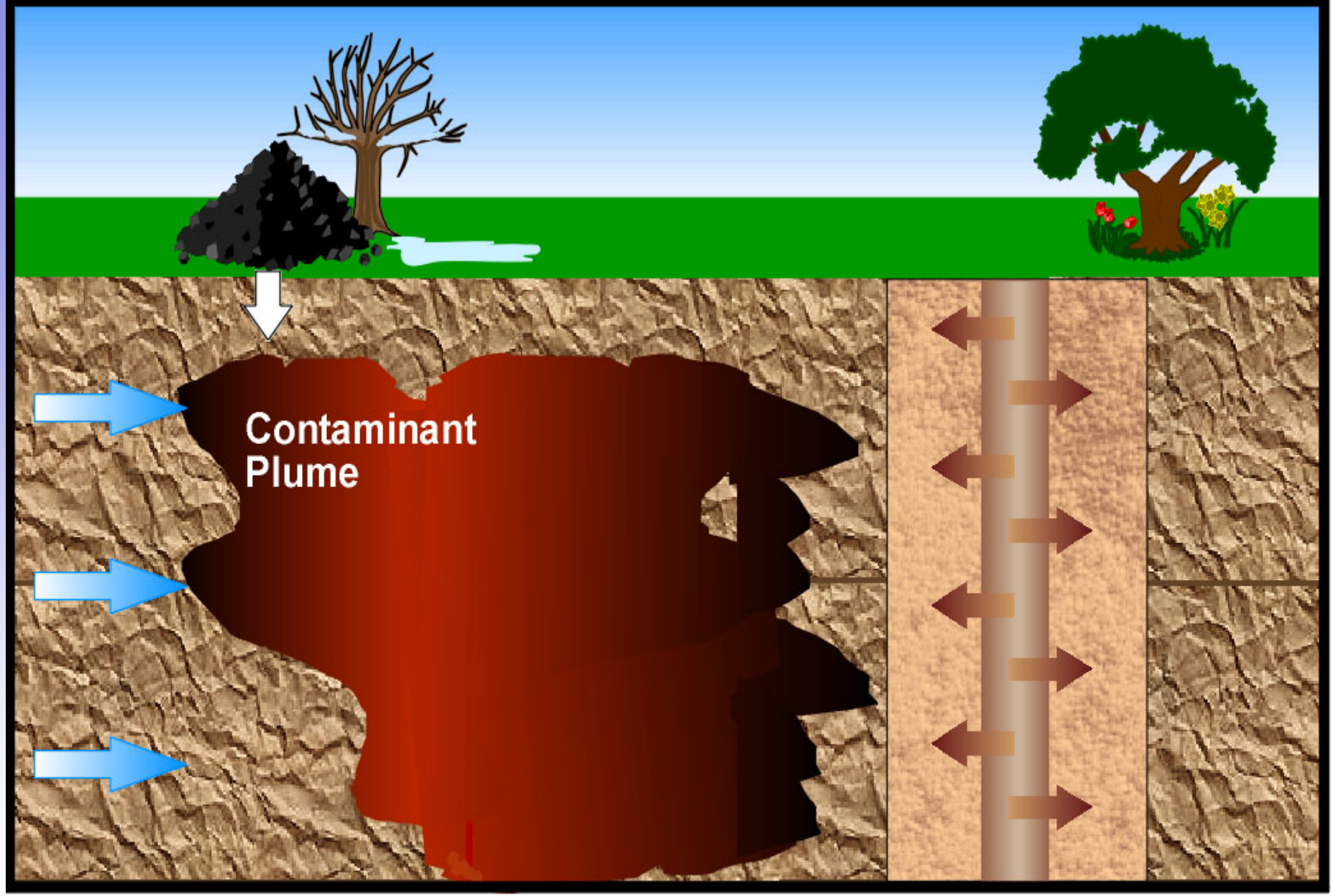
Formation plugging near injection well (EOR).

(Enhanced oil recovery, in situ bioremediation)

OPPORTUNITIES:

Engineered biofilm barriers.

(MEOR, bioremediation, CO_2 sequestration)



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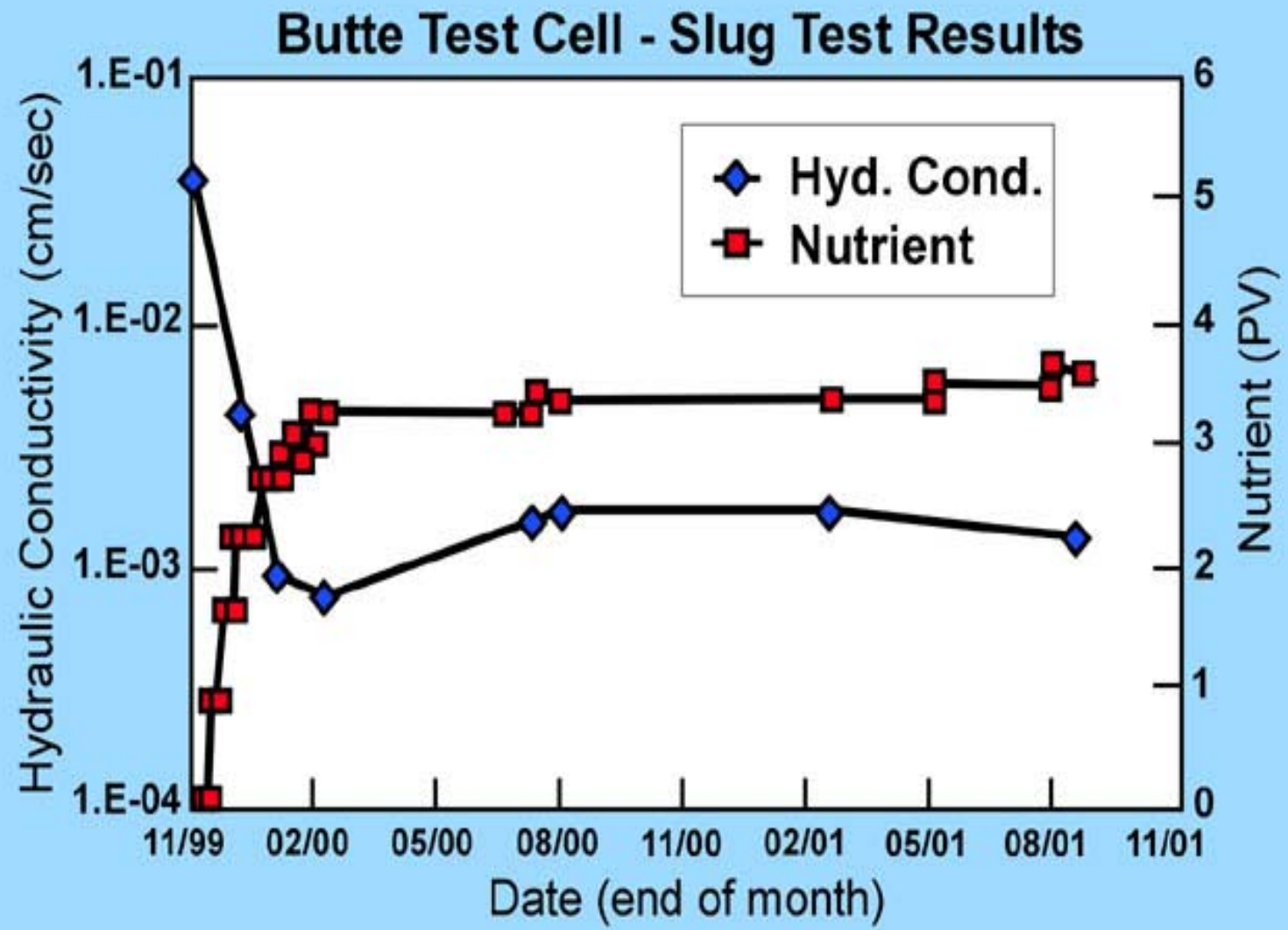


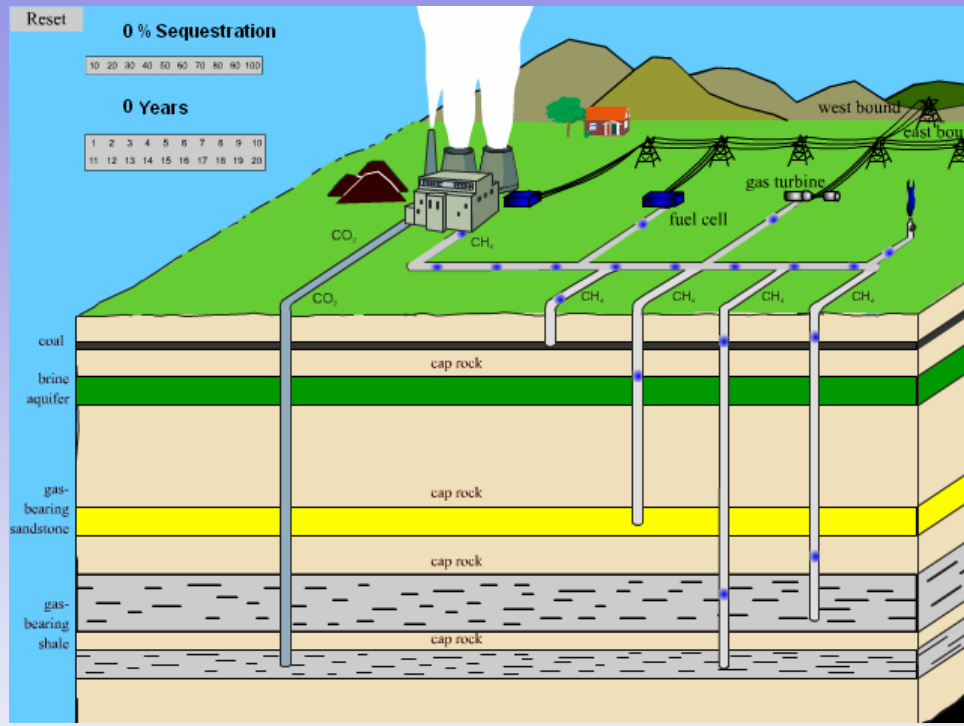
Average test bed hydraulic conductivity and cumulative nutrient addition for 22- month test period

CURRENT RESEARCH:

Biofilm Barriers for Cap Rock Preparation and CO_2 Leak Mitigation

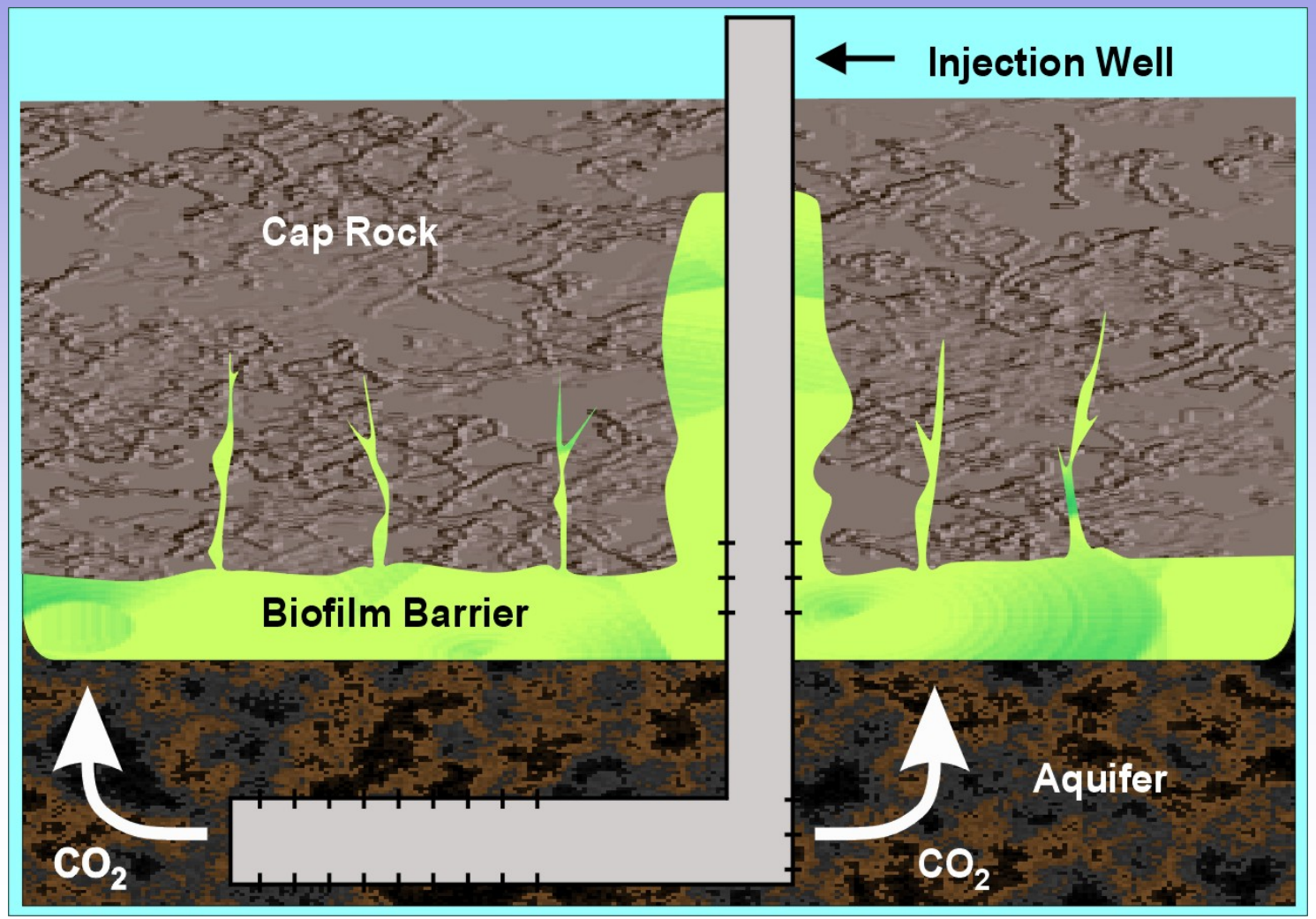
ZERT Zero Emissions Research and Technology

Below Ground Issues



- Reservoir modeling including potential pathways to the biosphere
- Geosciences
- Monitoring technologies (i.e., components)
- Integrated monitoring, measurement, and verification systems
- Testing of monitoring protocols in support of CSLF and other applications
- Leakage countermeasures
- Risk assessment methods

Biofilm Barriers for Cap Rock Preparation and CO_2 Leak Mitigation



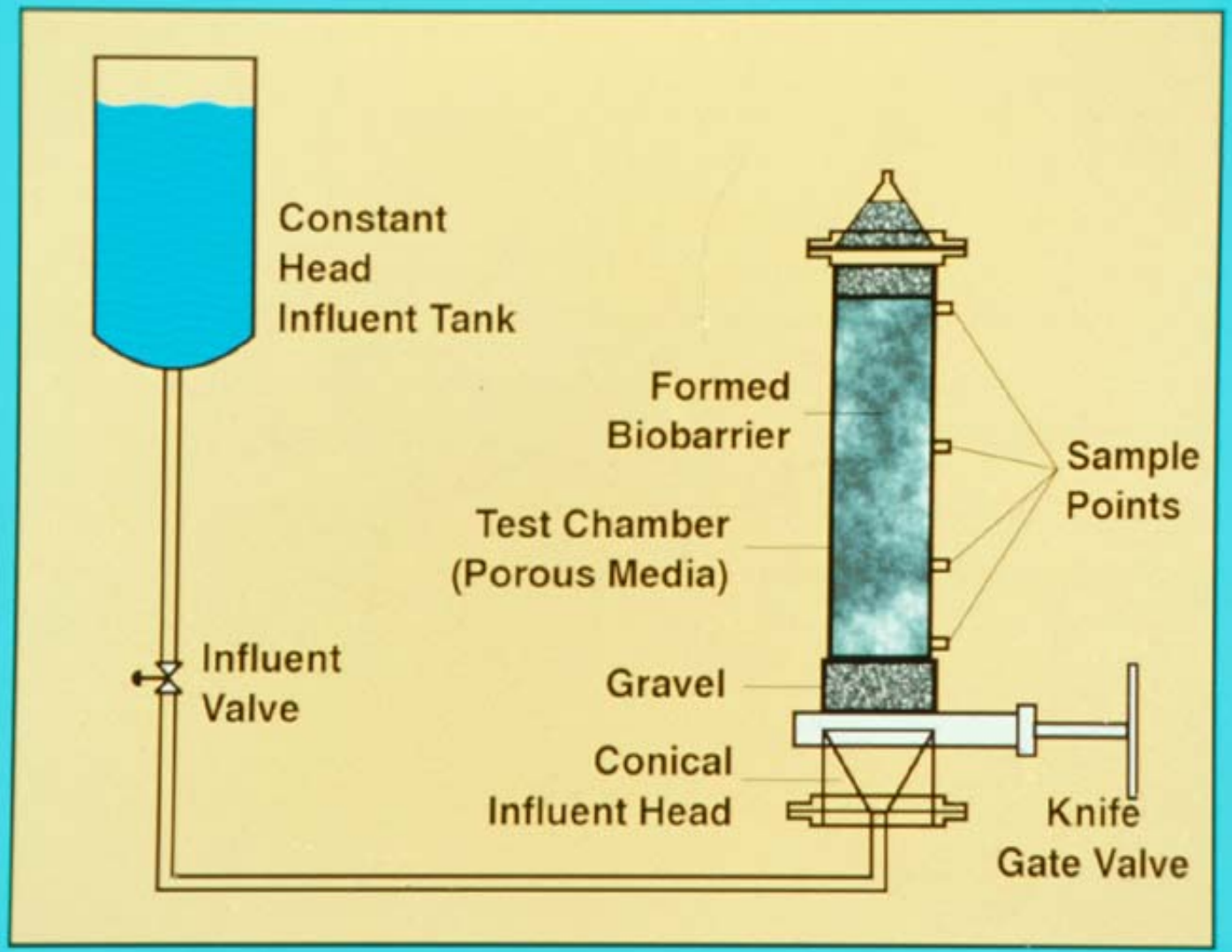
ZERT Research Work plan

1) identification of microorganisms which can serve as inoculum (pressure tolerant, mesophillic, salt tolerant, mucoid).

2) Assess different combinations of inoculum, growth substrate, and electron acceptor to produce biofilms which effectively plug porous media.

3) Conduct biofilm plugging experiments in both packed columns and rock columns to determine the individual response to challenges from high pressure, salinity, and supercritical CO_2.

4) Design a pilot demonstration experiment to test plugging technology at the field scale.



Pilot-scale Test Chamber

EXPERIMENTAL PARAMETERS

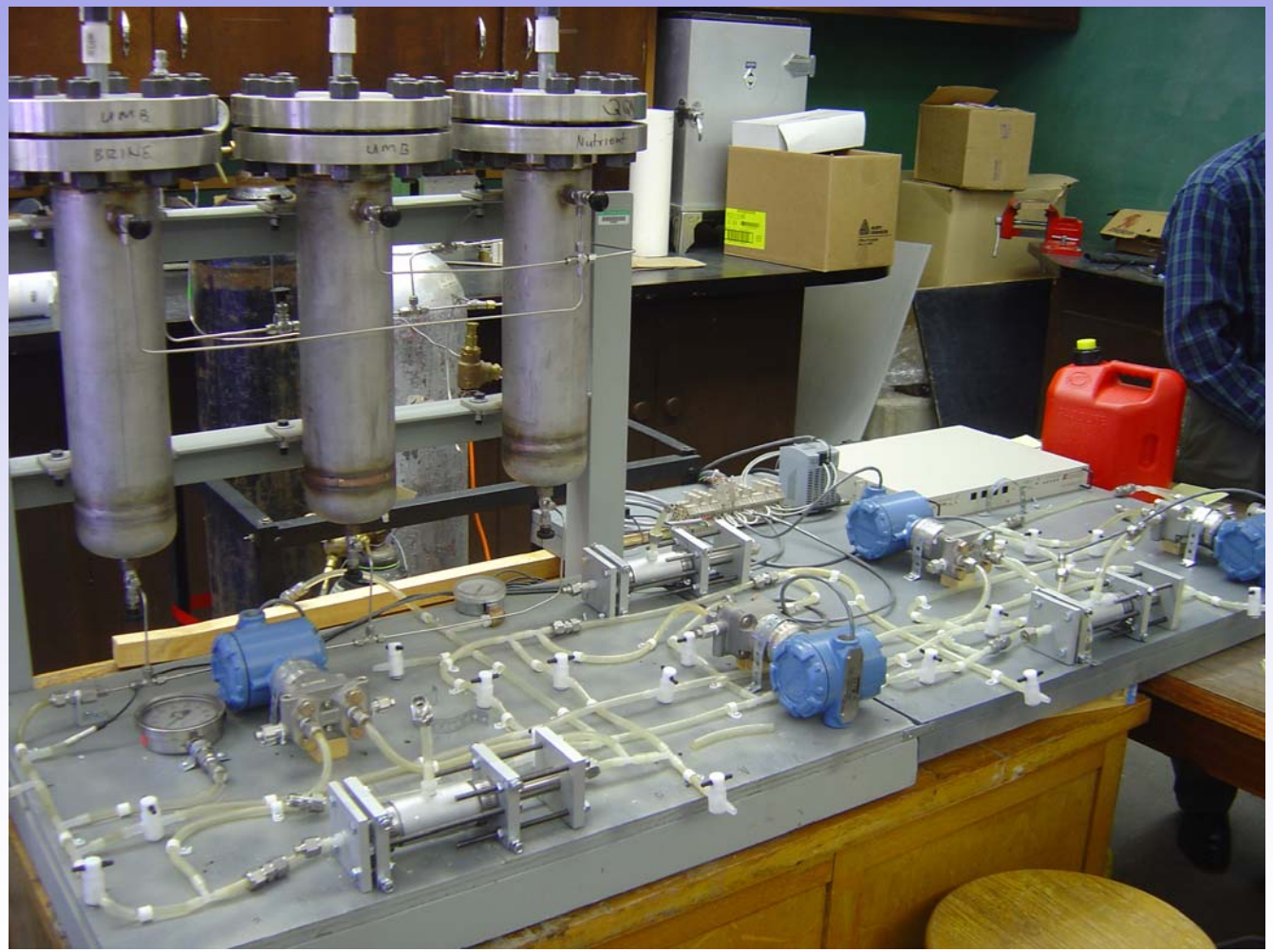
- Measurement:
  - Reduction in permeability (hydraulic conductivity) in Berea sandstone cores due to biofilm accumulation
  - High pressure (450 psig)
  - High salinity (4.0% KCl)
  - Core length 3.5 inches, diameter 1.2 inches
  - Initial Permeabilities: 6.6E-04, 1.2E-03, 3.2E-03 cm^2
  - Initial Permeabilities 67, 125, 468 md
  - 1 md = 9.87 E-06 cm^2
  - 1cm^2 = 9.80 cm/s

EXPERIMENTAL PARAMETERS

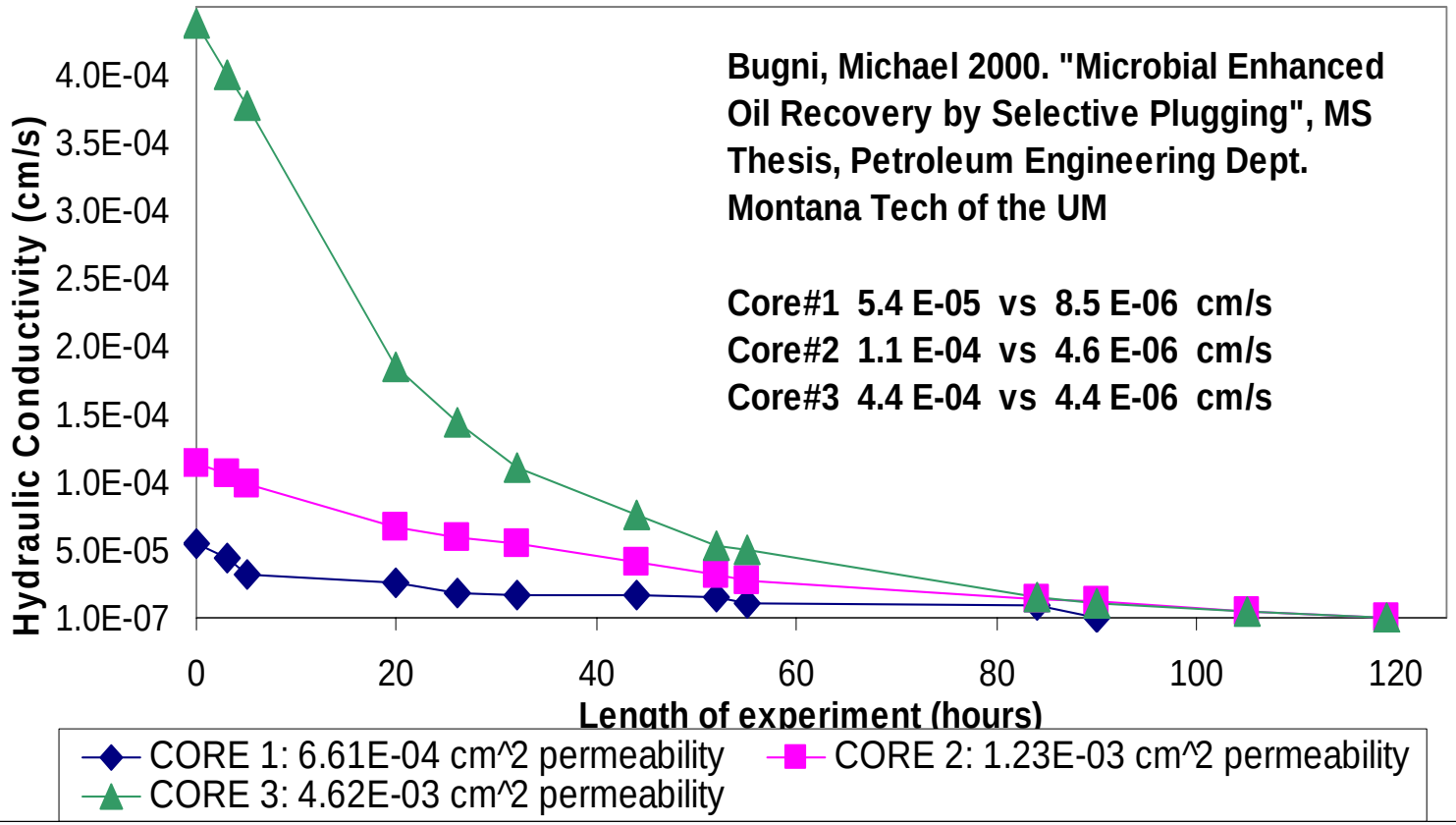
- Inoculum: *Shewanella frigidimarina*
  - Isolated from an existing oil reservoir
  - Facultative bacterial strain
    - Aerobic metabolism (Unlikely)
    - Anaerobic metabolism (Nitrate-based)

  - Molasses Nutrient Recipe
    - H_2O 1 Liter
    - K_2HPO_4 1.23 grams
    - KH_2PO_4 0.40 grams
    - NaCl 40.0 grams
    - $NaNO_3$ 2.95 grams
    - Molasses 10.0 grams

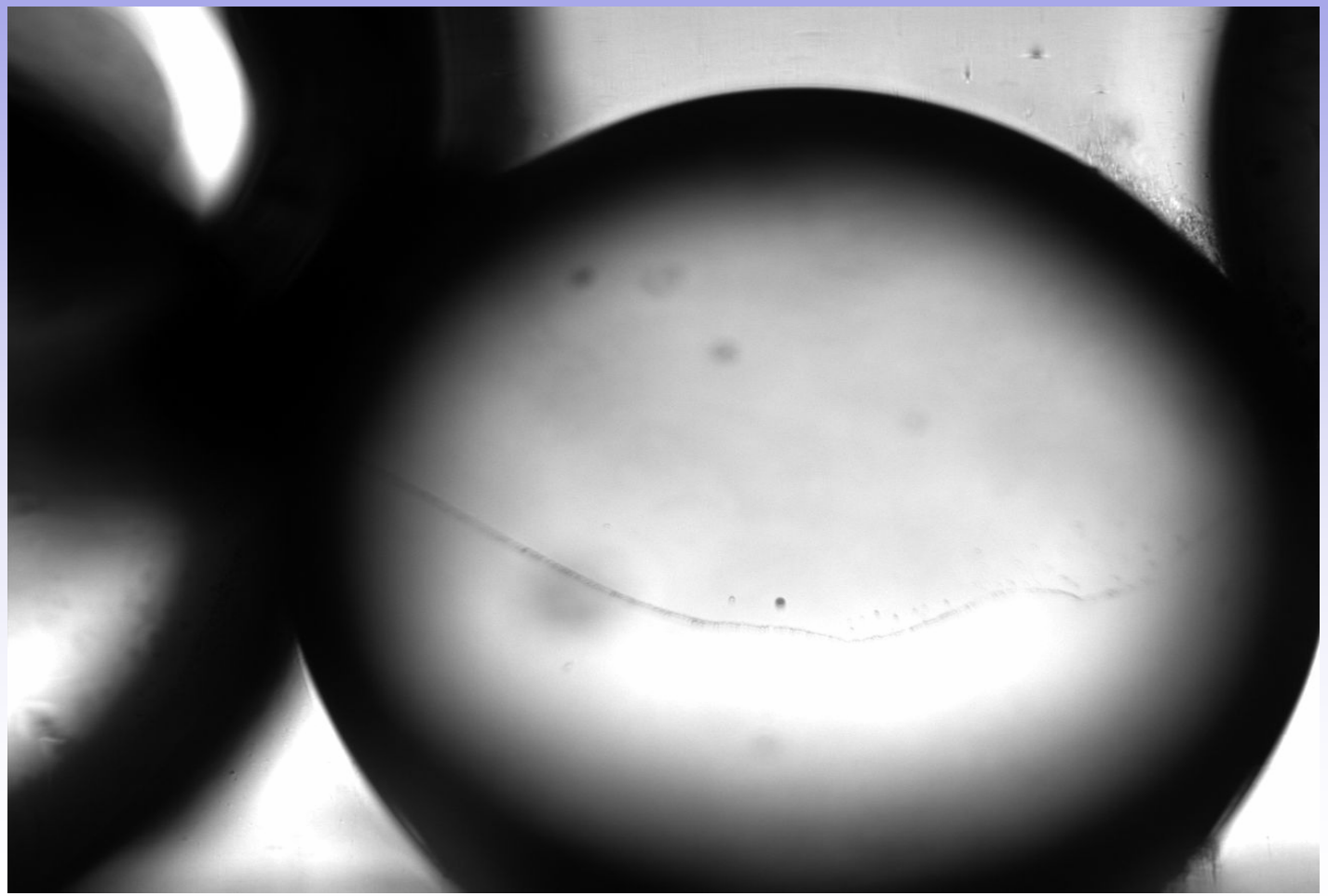
High Pressure Biofilm Core testing System



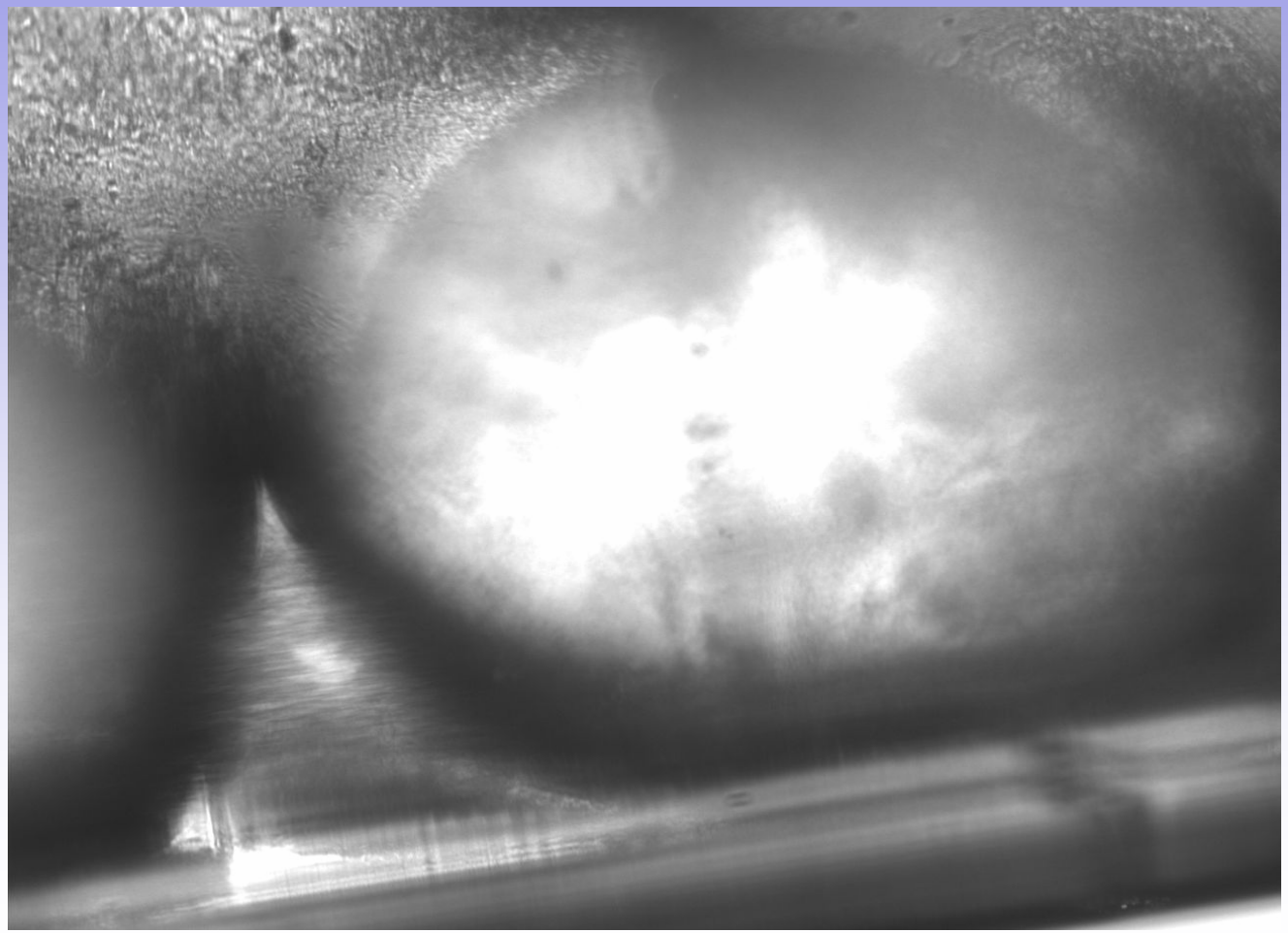
Hydraulic Conductivity Reduction



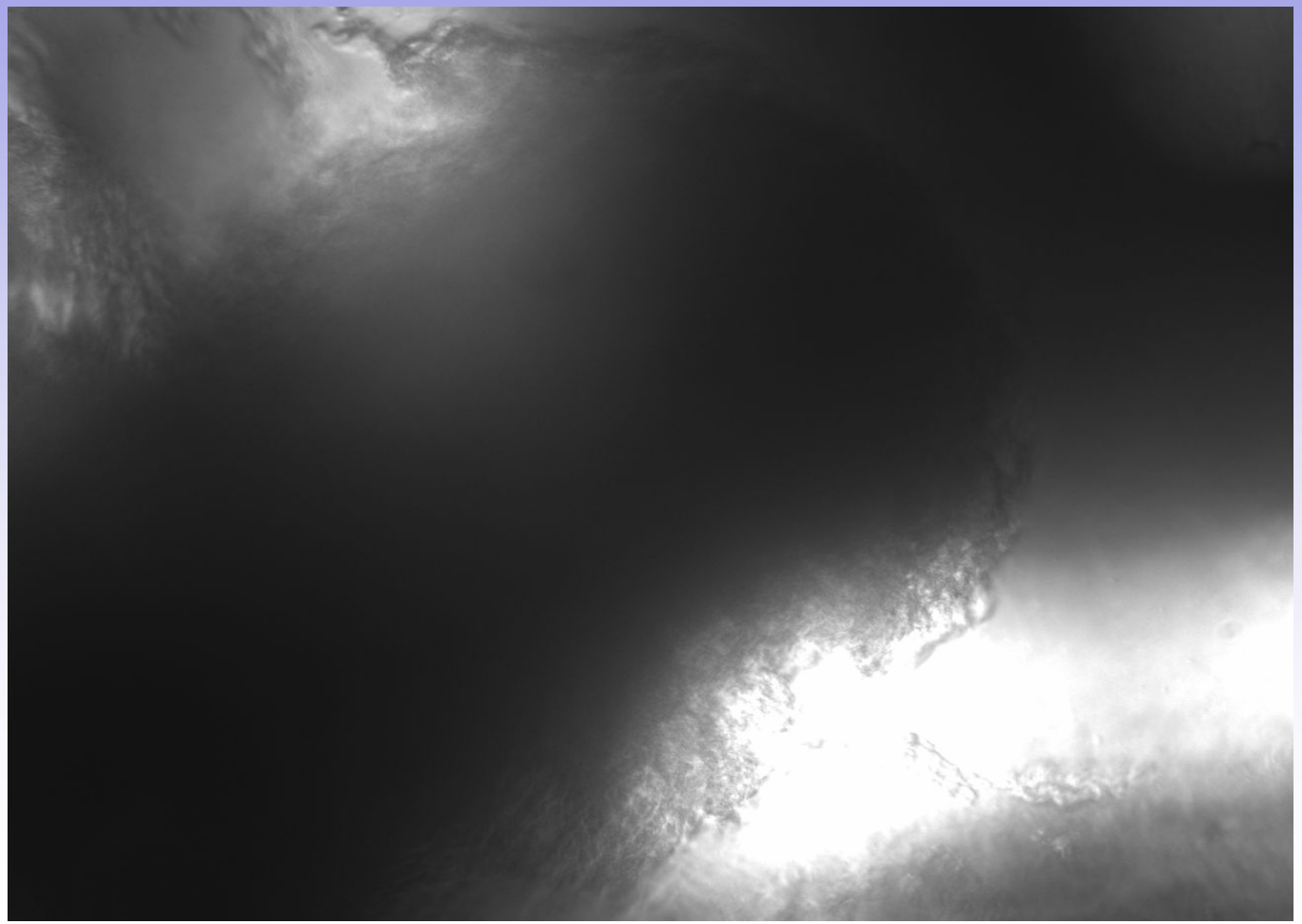
2-day S. frigidimarina biofilm growth on 0.5mm beads



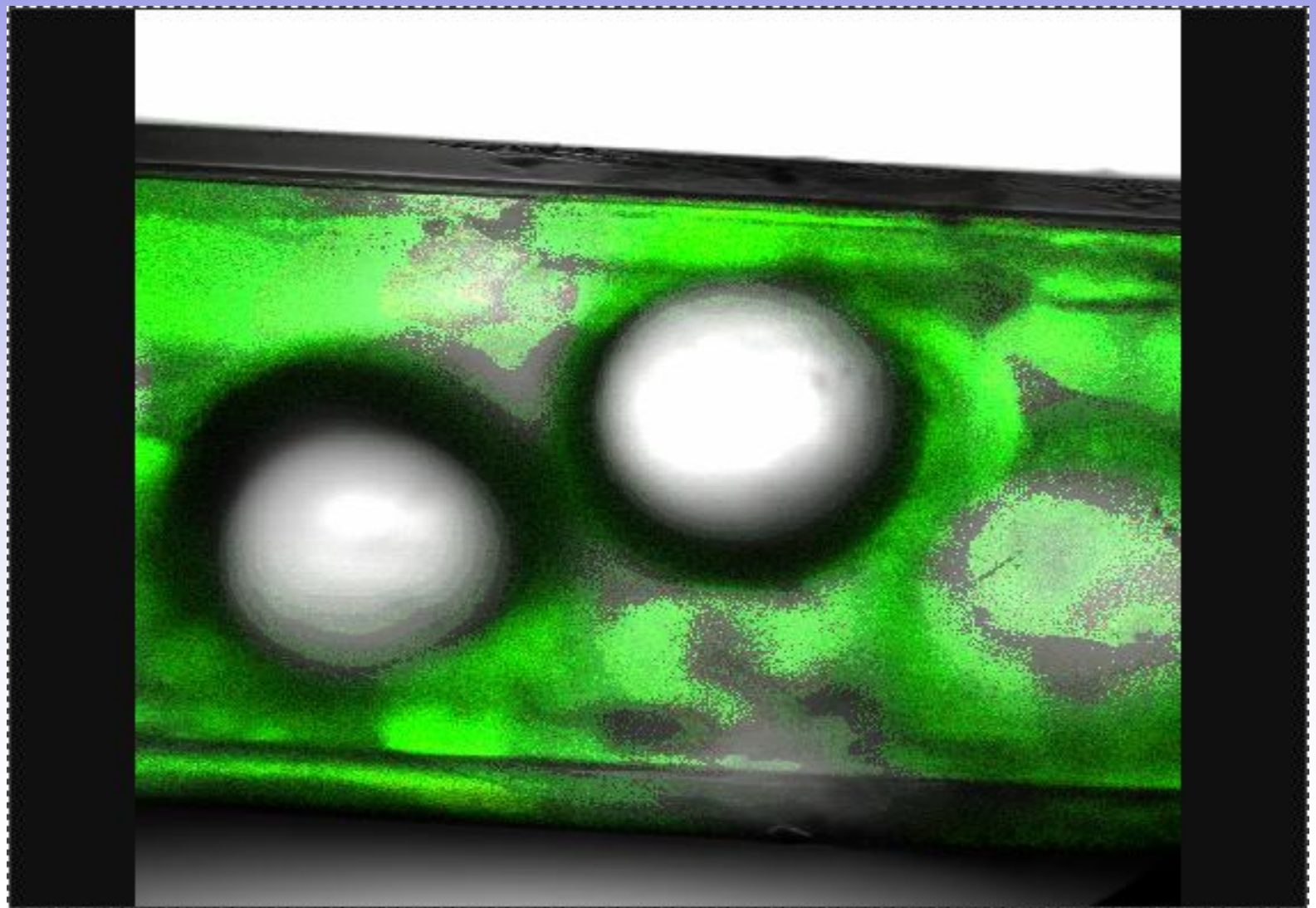
5-day S. frigidimarina biofilm growth on 0.5mm beads



5-day S. frigidimarina biofilm growth on 0.5mm beads



7-day S. frigidimarina biofilm growth on 0.5mm beads, stained with SYTO9 (DNA stain)



Summary

- Previous research demonstrates the potential for use if biofilms barriers in CO_2 sequestration
- Suitable model biofilm forming bacteria have been isolated and tested successfully (i.e. starvation resuscitation)
- Initial tests show biofilm formation and permeability reduction in Berea sandstone cores under high pressure and salinity.

Future Research

- High pressure core test system (1500psi)
- Biofilm formation, high pressure, 30-60 degrees C
- Challenge biofilm barrier with supercritical CO_2, high salinity
- Fractured media
- Bacterial transport (starvation/resuscitation)

ACKNOWLEDGEMENTS

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ZERT Zero Emissions Research and Technology

Subsurface Biofilm Barrier Summary

Field demonstration project for an engineered biofilm barrier designed to simultaneously reduce aquifer hydraulic conductivity and denitrify contaminated ground water has been completed.

Other field applications for subsurface biofilm barriers currently under consideration include:

1) **Isolation and containment of contaminated ground water plumes.**

2) **construction of *in-situ* cut-off walls for reducing salt water intrusion into fresh water aquifers.**

3) **plugging of high permeability zones in oil fields to enhance secondary oil recovery operations.**