

Synthesis, Technology Transfer, Future Research Priorities

Claire R. Tiedeman
Allen M. Shapiro



Objectives of Toxics Program Research on Contamination in Fractured Rocks

- Advance understanding of physical, chemical, and microbiological **processes and properties** affecting contaminant fate and transport in fractured rocks.
- Investigate processes of **contaminant remediation** and methods for **monitoring** remediation.
- Develop a **hierarchy of quantitative tools** to help synthesize results and improve understanding of processes.
- **Transfer** findings, insight, and methods.

Wide Variety of Field & Lab Methods Used to Achieve Research Objectives



Geology

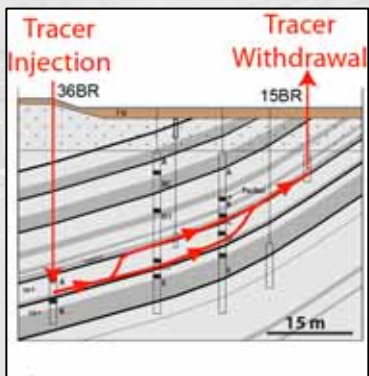
Geochemistry

Contaminant
Delineation

Dissolution Fractures



Water-Rock
Interaction

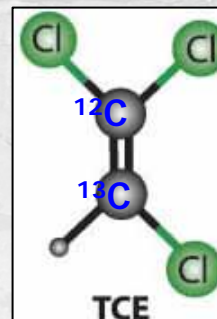


Aquifer &
Tracer Testing

Geophysics



Micro-
biology

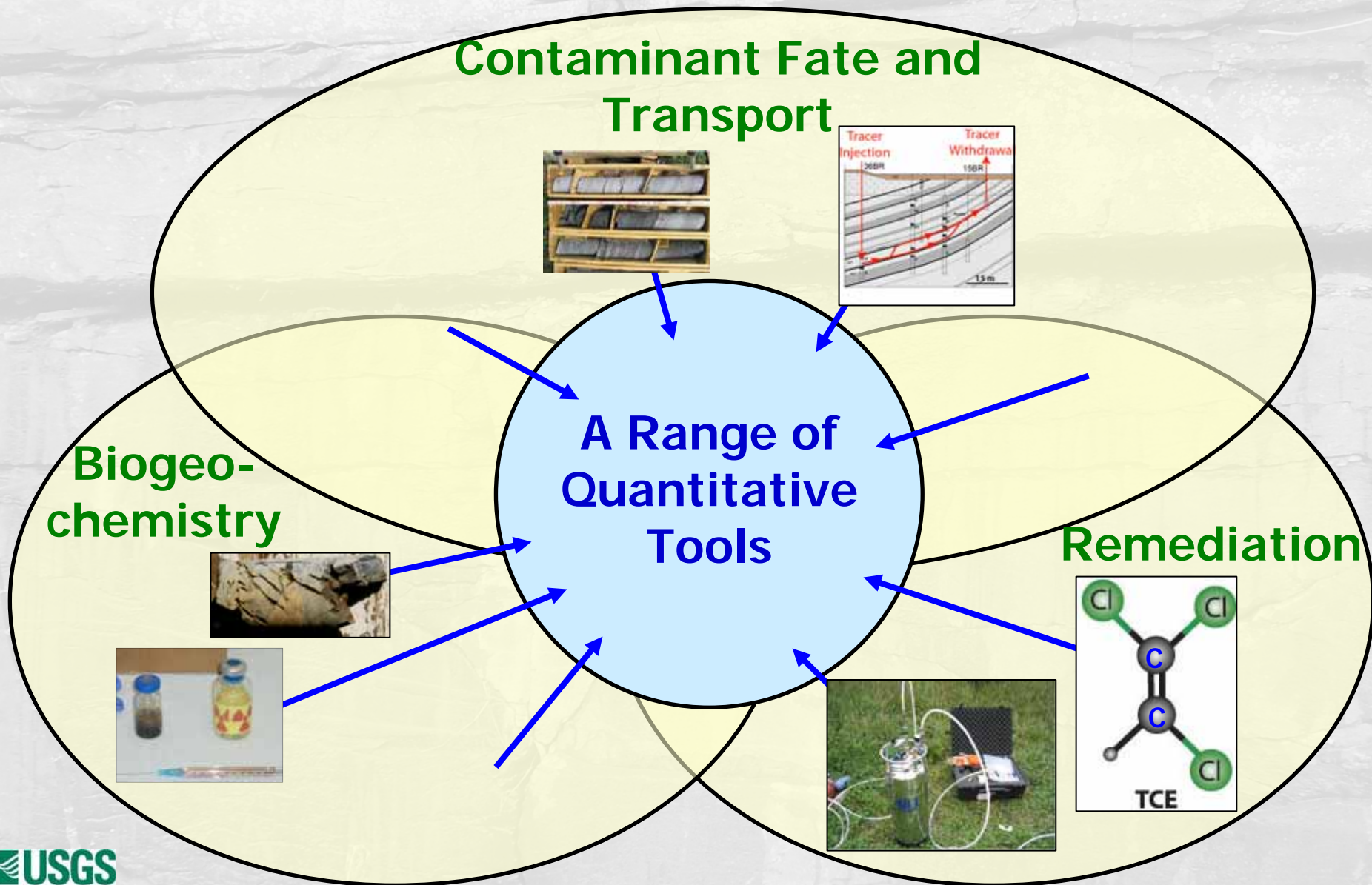


Carbon
Isotope
Analysis



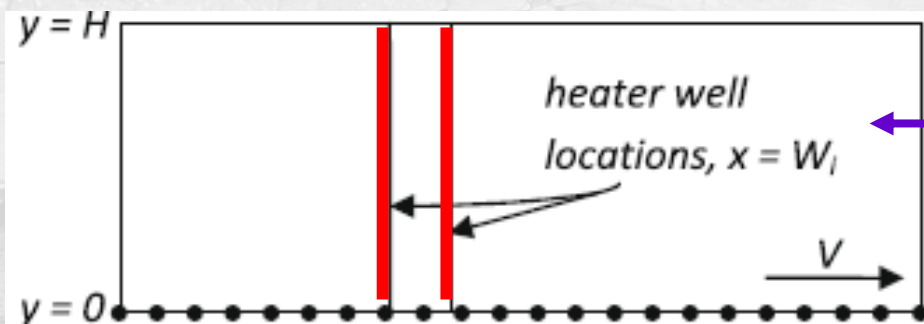
Bioaugmentation

Quantitative Tools: A Key Component of Research on Fractured Rock Contamination



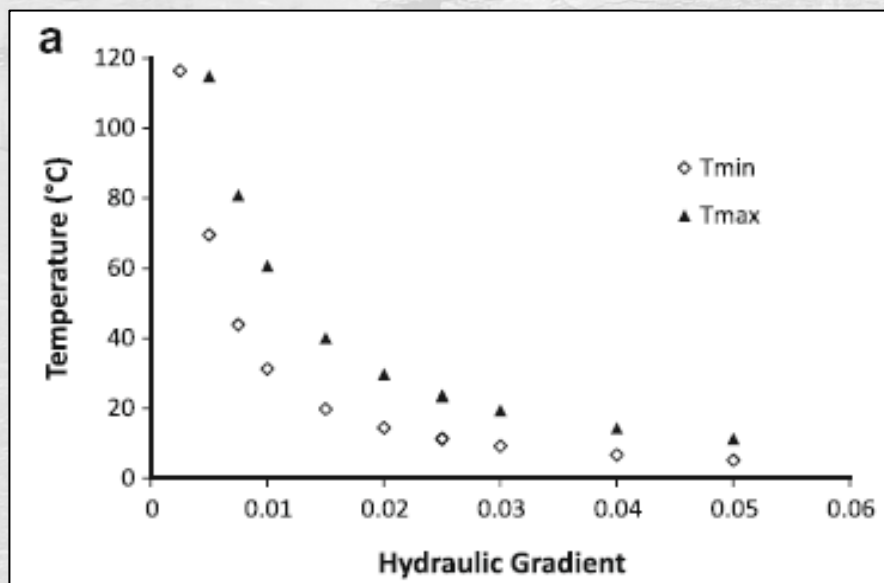
Simple Quantitative Tool: Screening Method for Assessing Effect of GW Flux on Thermal Conductive Heating

Baston and
Kueper,
Adv. Water
Res., 2008



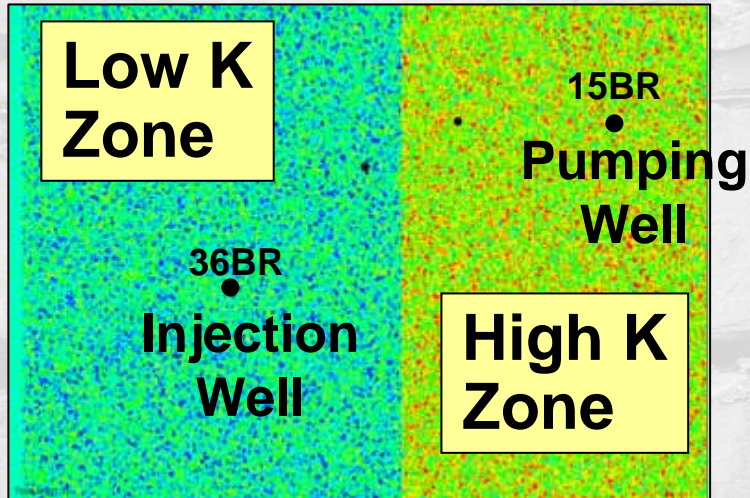
Matrix

Fracture with
flowing
groundwater



Effect of hydraulic
gradient on
temperature
between the two
heating wells

Fairly Simple Tool: Model for Designing Injection of Bioaugmentation Amendments

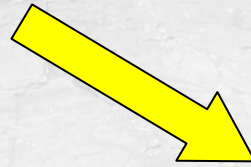


2D flow model with very simple heterogeneity representation

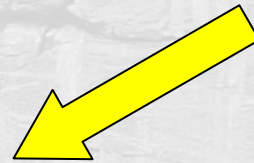
Particle tracking simulation:
Inject amendments then flush well

Migration of amendments
toward pumping well

More Complex Quantitative Tools



**Site-scale 3-D GW flow
model calibrated to aquifer
test data and heads**



**2-D solute transport
model simulates forced-
gradient tracer test**

**2-D reactive transport model
simulates biodegradation**

**Process Understanding
Uncertainty Analyses**

Technology Transfer

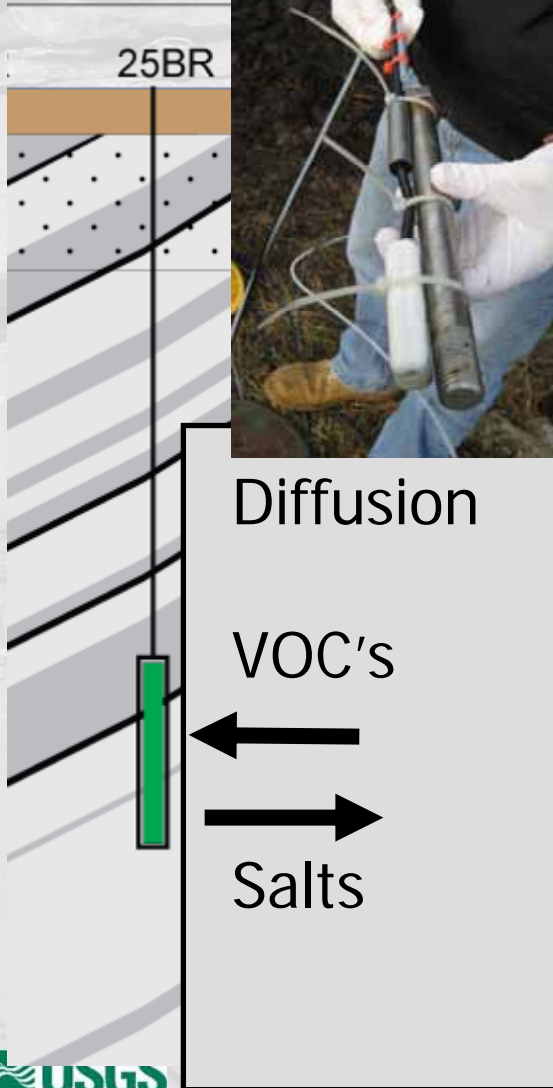
- Transfer of new **methods**
- Guidance on **which characterization activities are most important** to conduct, for:
 - Making informed decisions about remediation strategies
 - Monitoring remediation
- **Generalization of results and insight** from NAWC, to guide activities and help understand processes at other sites.



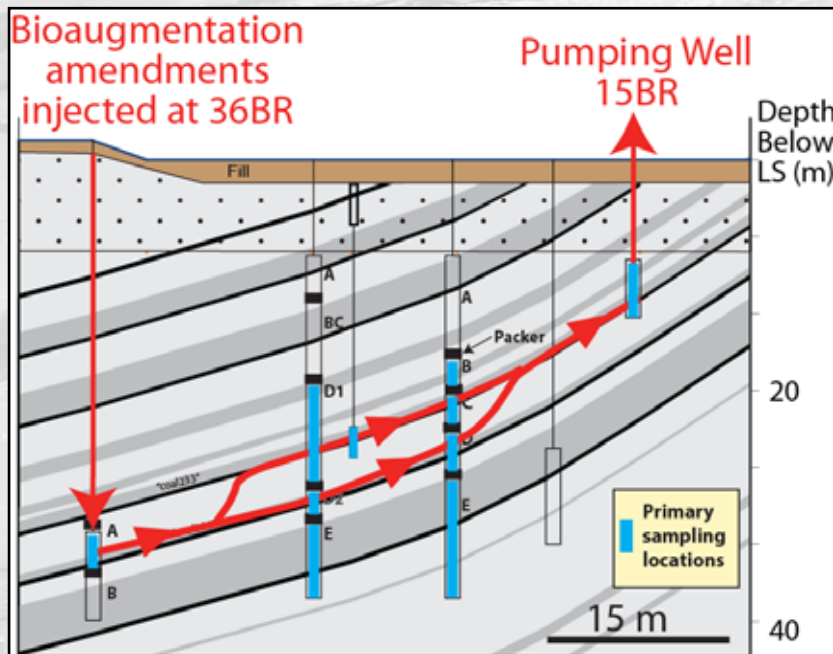
Technology Transfer: In Situ Diffusion Test at NAWC



- Has promise as a **cheaper alternative method to coring** for estimating **contaminant concentrations in rock matrix.**



Technology Transfer: Bioaugmentation Experiment at NAWC



Analytes:

Field parameters (O_2 , pH, SC, turbidity)
Dissolved anions, cations, nutrients
Metals
VOCs
Dissolved gases
Volatile fatty acids
Microbial DNA
Dissolved hydrogen
Isotopes of VOCs
Isotopes of DOC, DIC



- Identify subset of analytes most useful for understanding effects of bioaugmentation, to help streamline monitoring at other sites.
- Insight gained about designing and monitoring bioaugmentation: Applicable to other sites.

Looking To The Future: Examples of Research Priorities

Contaminant Fate and Transport



Fracture surface area in contact with transported contaminants

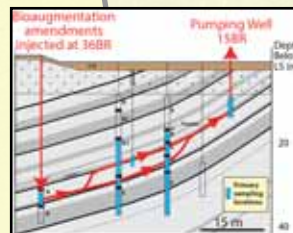
Biogeochemistry



Role of microbes in rock matrix



Remediation



Effective monitoring methods

Acknowledgements



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