Colloid Transport and Retention in Fractured Media

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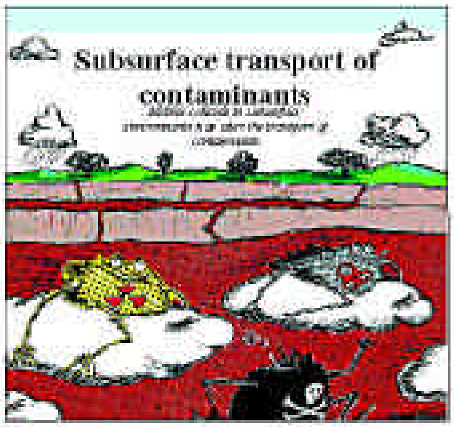
Motivation for the Research:

Mobile colloids may enhance transport of contaminants in groundwater

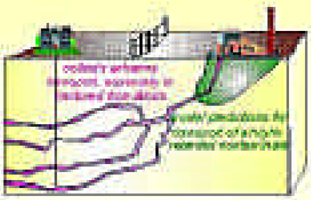
Research Objective:

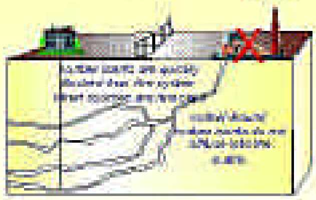
Understand and predict the transport and retention of colloids in fractured formations

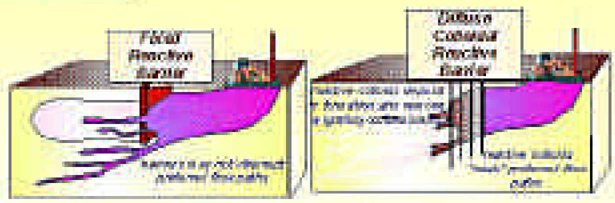


Colloids are submicron-sized inorganic particles or organic macromolecules

The Opportunities







Site Assessment
Correctly predict contaminant migration

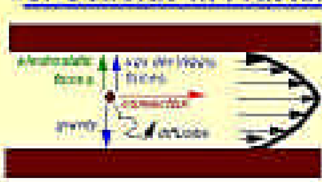
Remedial Alternatives
Source control is a feasible option

Potential New Technologies
Diffuse reactive barriers using colloids

The Approach

Target Multiple Scales to Refine and Test Models of Colloid Transport in Fracture Networks

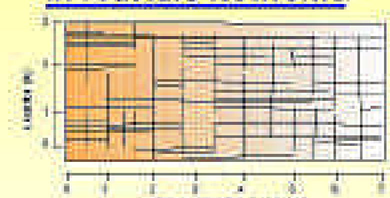
1. **Theoretical Description of Colloids in Fractures**



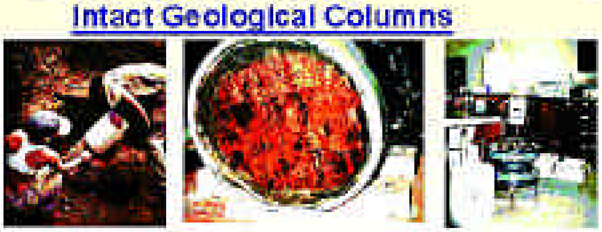
Predict Colloid-Facilitated Contaminant Transport

Evaluate Novel Remedial Strategies

4. **Modeling Colloids in Fracture Networks**



2. **Colloid Transport in Intact Geological Columns**



3. **Field Transport Using Colloidal Tracers**

Research Results

Colloid Transport Studies

Colloid Transport in Intact Geological Columns

Rationale:

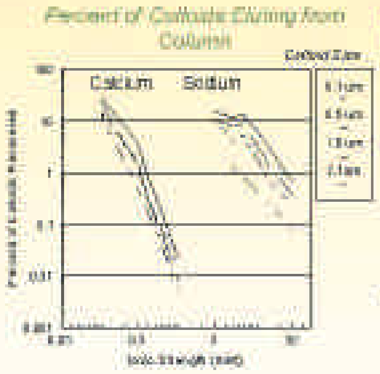
- Natural complexity, but experimental control
  - *flow rate, colloid size, ionic composition*

Objective:

- Processes controlling transport
  - *chemistry (electrostatics)*
  - *physics (influence of flow velocity and colloid diameter)*

Implications:

- Electrostatics dominate transport
  - *water chemistry appears critical to transport*
  - *storm events may exert a large control on colloid mobility*



Results:

- Retention related to flow velocity
- Transport decreased with increasing ionic strength
  - *divalent cations (Ca) much more effective than monovalent (Na)*
- Optimum size for transport
  - *larger particles settle*
  - *smaller diffuse and attach*

Field Transport Using Colloidal Tracers

Rationale:

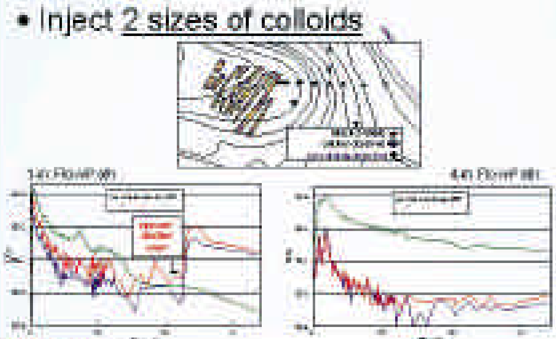
- Realistic scale of fracture connectivity
- Compare lab and model predictions with field-scale transport

Objective

- Effect of ionic strength and fracture network
  - sites with differing chemistry
  - contrasting lithologies within a site

Waste Area Group-5 North, ORNL

- Transuranic storage trenches
- Inject 2 sizes of colloids



Results:

- Very limited transport (*high Ca [3 mM]*)
- Colloid size not very important
- Decreased ionic strength mobilized colloids

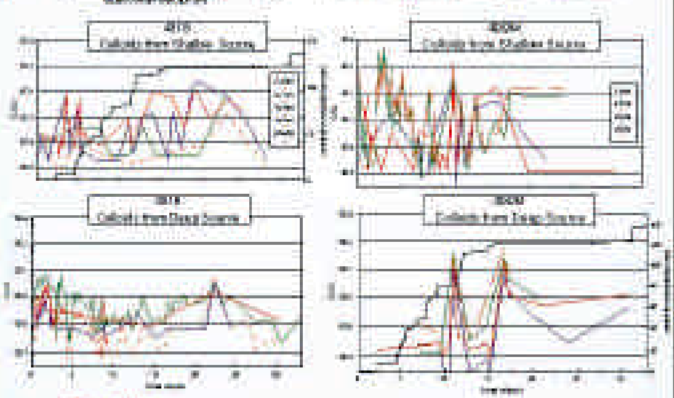
Implications of the Two Field Studies:

- Confirms importance of water chemistry
  - *transport varied with Ca concentration*
- Field-scale fracture connections reduces importance of colloid size
- Lowered ionic strength mobilizes colloids
  - *storm events can mobilize colloids*

West Bear Creek Valley

- Inject 4 sizes of colloids in 2 lithologies

- **shallow saprolite** *(dense, small aperture fracture network)*
- **deeper weathered bedrock** *(widely-spaced, larger fractures)*



Results:

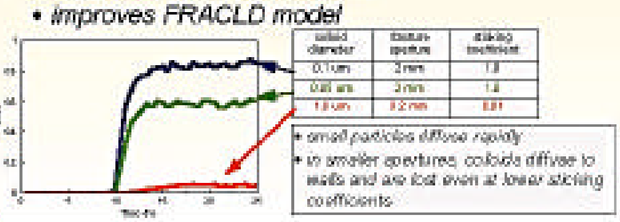
- Very rapid transport over >30-m
  - *due to lower Ca (1 mM)*
- Transport promoted by storms
- size unimportant in large fractures

Research Results

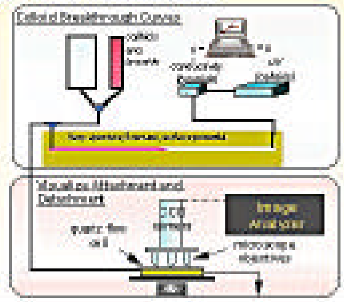
Theoretical Description and Transport Modeling

Theoretical Description of Colloids in Fractures

- Extend porous media concepts to fracture geometry
  - *particle tracking model*
  - *particle diffusion, sedimentation, and electrostatics*
- Derived an analytical solution
  - *improves FRACLD model*



- Test theory in a 1-D, parallel-plate "artificial fracture"
  - *vary aperture, flow rate, particle size and colloid-wall interactions*



Modeling Colloids in Fracture Networks

- FRACLD: 2-D numerical model
  - *developed for colloid-facilitated transport in fractured media*
  - *complex fracture networks, variable flow rates, diffusion into microfractures*

Objective:

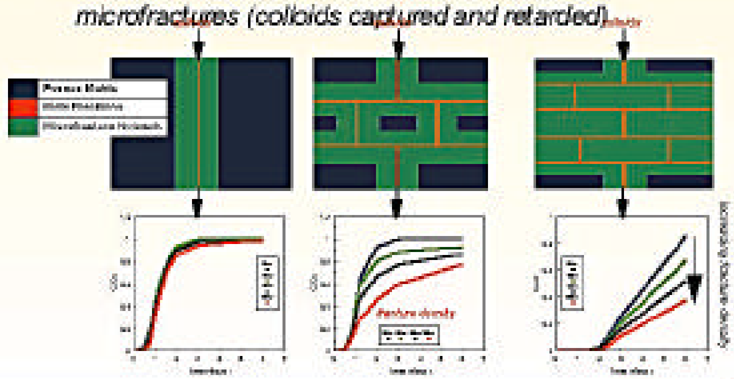
- Examine importance of fracture geometry on transport
- Simulation of column studies
- Tool to predict facilitated transport and potential remediation

Implications:

- Physical structure of fractured formation is important
  - *will be exploring role of electrostatics*
- Theoretical descriptions of colloid retention *(above)* being incorporated for improved predictions
- Computational improvements will permit larger field-scale simulations

Results:

- Modifying code
  - *add colloidal diffusion into fine pores*
  - *dramatic increase in computational efficiency*
- Importance of fracture geometry and density
  - *fracture junctions increase dispersion into microfractures (colloids captured and retarded)*



On the Subject of Colloid-Facilitated Transport....

Natural Organic Macromolecules Enhance Radionuclide Transport

WAG-5N, ORNL

- Transuranics (TRU) migrate rapidly
  - *mobile TRU is complexed with NOM*
  - McCarthy et al. *J. Contam. Hydrol* 30:49-77 (1998)
- Field tracer study
  - *lanthanide (Nd(III)) injected as surrogate for actinides*
  - *almost unretarded migration as an NOM complex*