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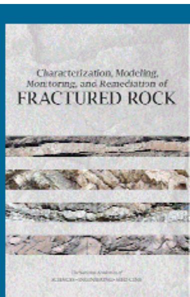

Characterization, Modeling, Monitoring, and Remediation of Fractured Rock

A New Academies Report

December 2, 2015
Sammantha Magsino

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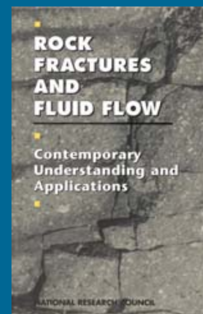

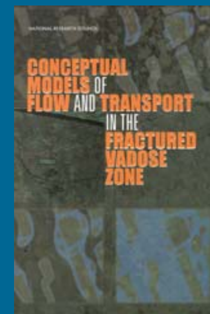

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Statement of Task

Address issues related to flow and transport in fractured rock for lifecycle of infrastructure


Photo: USGS

- Fracture/matrix characterization, conceptual modeling
- Detection of pathways/travel times
- Thermal, hydrological, chemical, mechanical, and coupled processes
- Remediation and monitoring
- Decision making

RECOMMENDATIONS

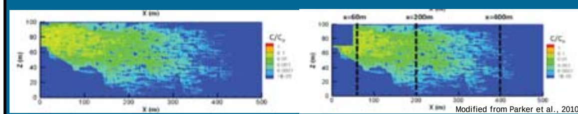
(two types)


Photo: Sent ne R dge L

- Ways to improve engineering practice given today's tools and knowledge
- Suggestions for R&D to improve future practice

Develop and communicate realistic expectations related to remediation effectiveness

Effective characterization and parameterization, and explicit understanding of matrix diffusion → realistic and achievable remediation goals



No Source Remediation — With Source Remediation

Honesty is the *only* policy…

The technical community needs to document failures as well as successes

Existing resources (e.g., Clu-in) provide access to vast amounts of data and studies, however there are significant gaps in communication of remediation

Monitoring programs need to be comprehensive from spatial, analyte, process, and temporal standpoints to help us believe

Take an *interdisciplinary* approach to engineering in fractured rock

use site geologic, geophysical, geomechanical, hydrologic, and biogeochemical information

conceptualize

- transport pathways
- storage porosities
- Fate/transport mechanisms
- coupled processes that control rock fracture-matrix interactions.

Use observational methods and adaptive approaches to inform engineering decisions

Conceptualization is Key

- What types of transport pathways may exist?
- What boundary conditions may exist?
- What storage porosities need to be considered?
- What fate/transport mechanisms need to be considered?
- Which coupled processes need to be estimated or considered explicitly?

Estimate the potential for contaminant transport into and back out of rock matrix over time.

- Interactions between fracture and matrix are rapid and powerful!

- Fick's First Law:

$$J_m = -\phi D_e \frac{\partial C}{\partial x}$$

Porosity; Diffusive Flux; Diffusion Coefficient; Concentration Gradient

Quantify contaminant in mobile and immobile zones

Monitoring wells provide limited information about where contaminant is, but can tell you where it is going

Core section analysis needs to be a fundamental component of any site investigation

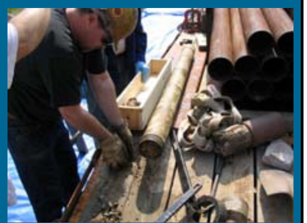


Photo: USGS

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Develop *appropriate* hydrostructural conceptual models for fracture and rock matrix geometries and properties

Perform preliminary calculations (e.g., analytic or simple numerical) to better inform and allocate resources for site characterization, modeling, and remediation

Photo: L. Lau

Photo: USGS

Photo: T. Enge der

Photo: R. Ke er

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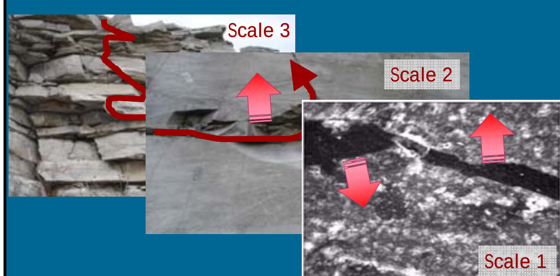
Recognize processes and their scales



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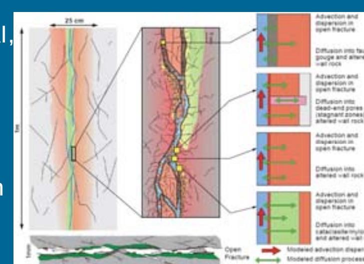
Characterize processes at the appropriate scales

Chem, bio, thermal, mechanical, hydraulic

Coupling of processes and conditions that can lead to coupling



Adapted from Winberg, et a 2003

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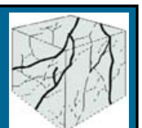
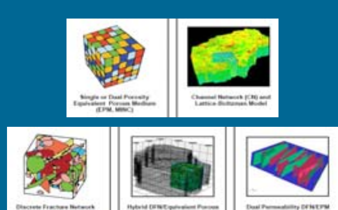
Base numerical models on an appropriate hydrostructural model





Courtesy of B. Dershow tz

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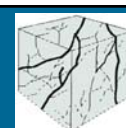
1

- Number/connectivity of mobile (advective) and immobile (diffusion, sorption) porosities
- Geometry/reactive surface area of transport pathways (e.g., streamline vs branching)
- Matrix/fracture interaction (Sigma factor, flow wetted surface)
- Infilling, coatings, matrix
- Geochemical and geobiologic processes (solution/precipitation, filtering, colloid transport)



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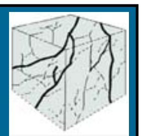
Error, bias, and uncertainty introduced by simplification and upscaling



- Equivalent continuum models
  are they equivalent?
- Upscaling for flow
  vs upscaling for transport
  vs upscaling for geomechanics
- Discrete models
  are they over or underconnected?

Courtesy of B Dershow tz

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1

Incorporate long-term behavior into monitoring system design.

Planning for change means less changes in plan

Understand most of the action starts in the fractures
but not all fractures are active
and the action shifts from where it started

Base design on understood discrete pathways, matrix contaminant storage, and issues of geologic heterogeneity and anisotropy when using point source concentration measurements

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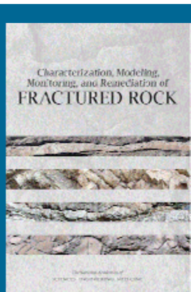

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2