Addressing the Complexities of Contamination and Remediation in Fractured Rock Aquifers

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Federal Remediation Technologies Roundtable
November 9, 2010

Characteristics and Complexities of Fractured Rock

Granite and Schist,
Grafton County, NH

Sykesville Gneiss,
Washington, DC

Silurian Dolomite,
Argonne, IL

Madison Limestone,
Rapid City, SD

Georgetown Intrusive - Tonalite
Washington, DC

Lockatong Mudstone,
West Trenton, NJ

Biscayne Limestone,
Ft. Lauderdale, FL

- *Groundwater moves through discrete discontinuities. . .*
- *Fracturing is not uniform. . .*
- *Complex connectivity of fractures, joints, vugs, etc., . . .*

USGS

Characteristics and Complexities of Fractured Rock

Madison Limestone, Rapid City, SD

Granite and Schist, Grafton County, NH

•*Discontinuities in the rock occur at different scales. . .*

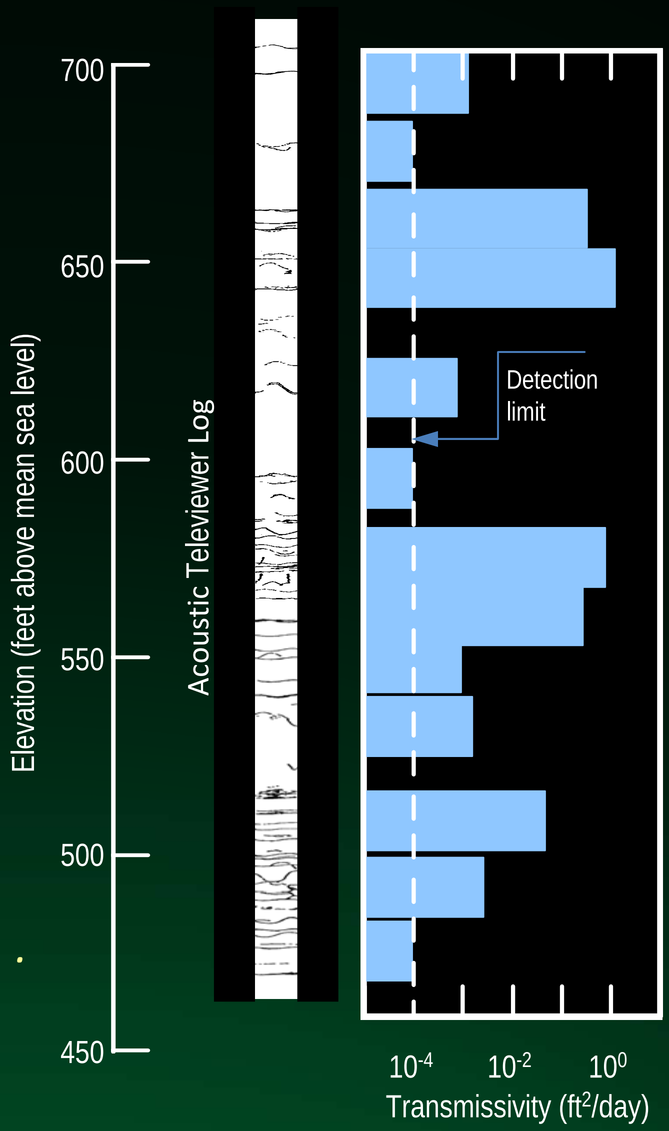
Characteristics and Complexities of Fractured Rock

Granite and Schist,
Grafton County, NH

- *Hydraulic properties of fractures, conduits, vugs, etc., vary over orders of magnitude. . .*

- *Abrupt spatial changes in hydraulic properties*

- *Highly transmissive features aren't necessarily correlated with fracture density. . .*



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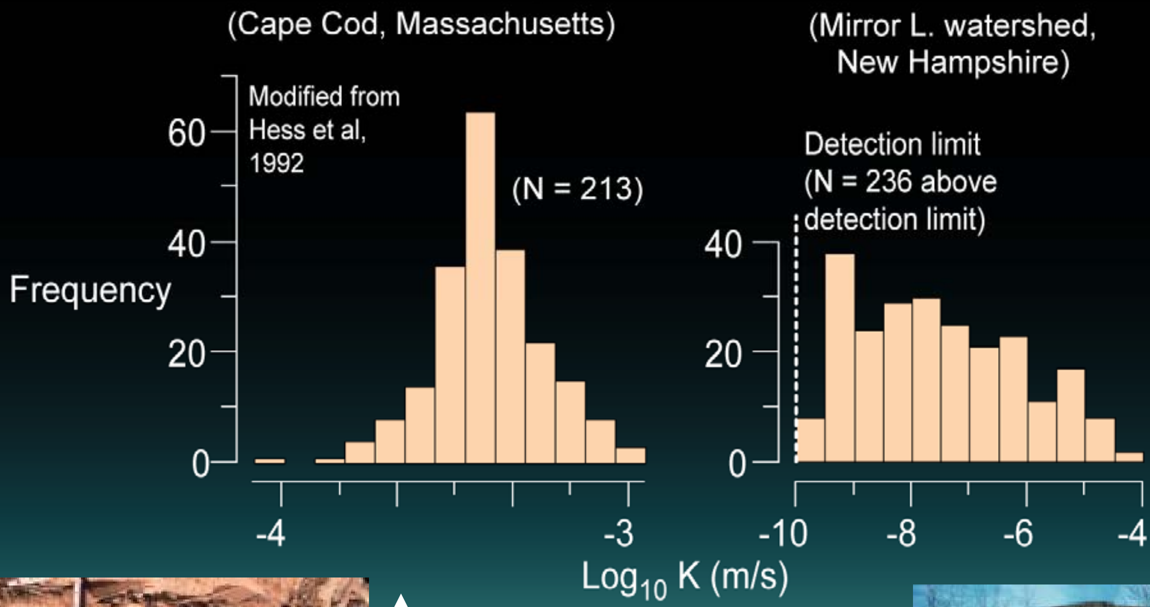
Characteristics and Complexities of Fractured Rock

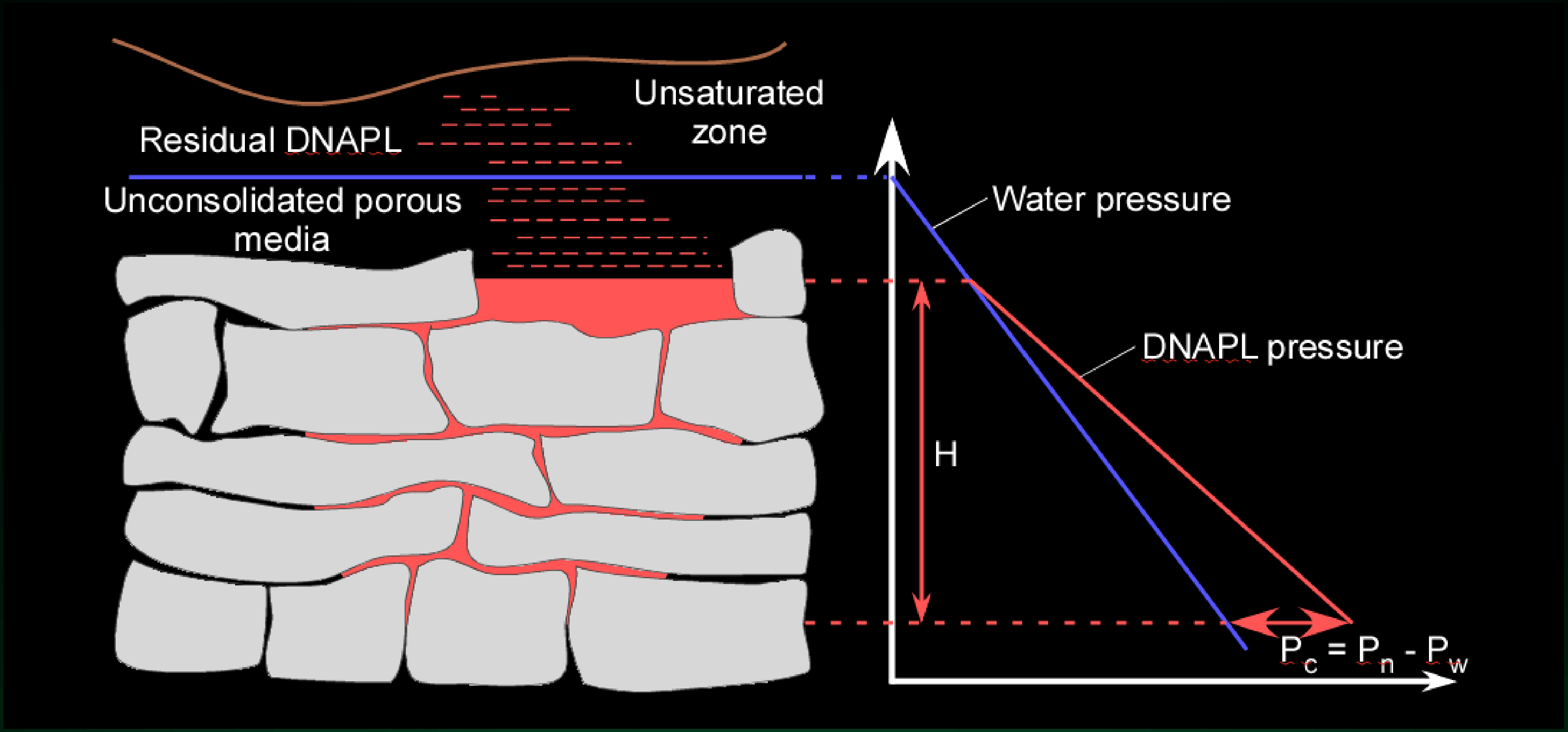
Hydraulic conductivity – Comparison between Unconsolidated Porous Media and Fractured Rock



~1m

Characteristics and Complexities of Fractured Rock

Small “pool” heights of DNAPL force DNAPL into small aperture fractures



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•Physical and chemical characteristics of the contaminant and void space architecture affect contaminant distribution. . .

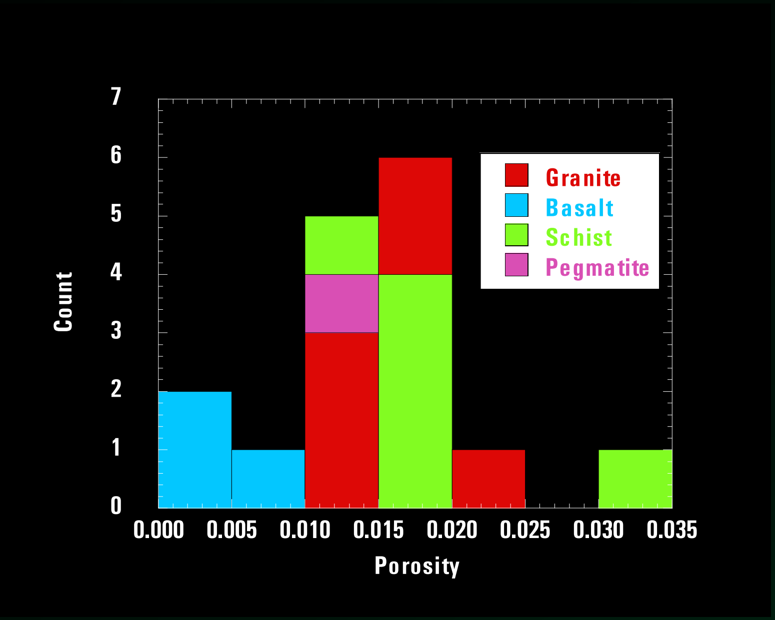
DNAPL detected during coring in fractured rock

Former Naval Air Warfare Center, West Trenton, NJ

Cloth with hydrophobic dye – staining occurs where dye dissolves in NAPL

Sudan IV shake kit – red indicates NAPL

Characteristics and Complexities of Fractured Rock



Granite and Schist, Grafton County, NH

•Chemical diffusion into and out of primary porosity of the rock. . .

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The "Reality" at Sites of Groundwater Contamination in Fractured Rock

•*Anticipate being engaged in long-term stewardship at fractured rock sites having groundwater contamination. . .*

•*Develop strategies for deciding if it is financially prudent to implement aggressive remediation technologies. . .if so, where, when, and for what duration. . .to accomplish specific objectives. . .recognizing contaminant mass will still remain in the subsurface. . .*

•*Look to reduce long-term operational and monitoring costs. . .*

Former Naval Air Warfare Center, West Trenton, NJ

Managing Sites of Groundwater Contamination in Fractured Rock

Granite and Schist,
Grafton County, NH

In recognition of the "realities" at fractured rock sites. . .

- *Enhanced characterization to minimize monitoring locations and reduce long-term costs. . . robust conceptual models. . .*

- *Better understanding of in situ physical, chemical, thermal, and microbial processes that affect fate and transport. . .*

- *Synthesizing lessons learned in different geologic settings and at different scales. . .*

- *Develop innovative methods of monitoring biogeochemical processes to reduce long-term costs. . .*

Madison Limestone,
Rapid City, SD

Silurian Dolomite,
Argonne, IL

Lockatong Mudstone,
West Trenton, NJ

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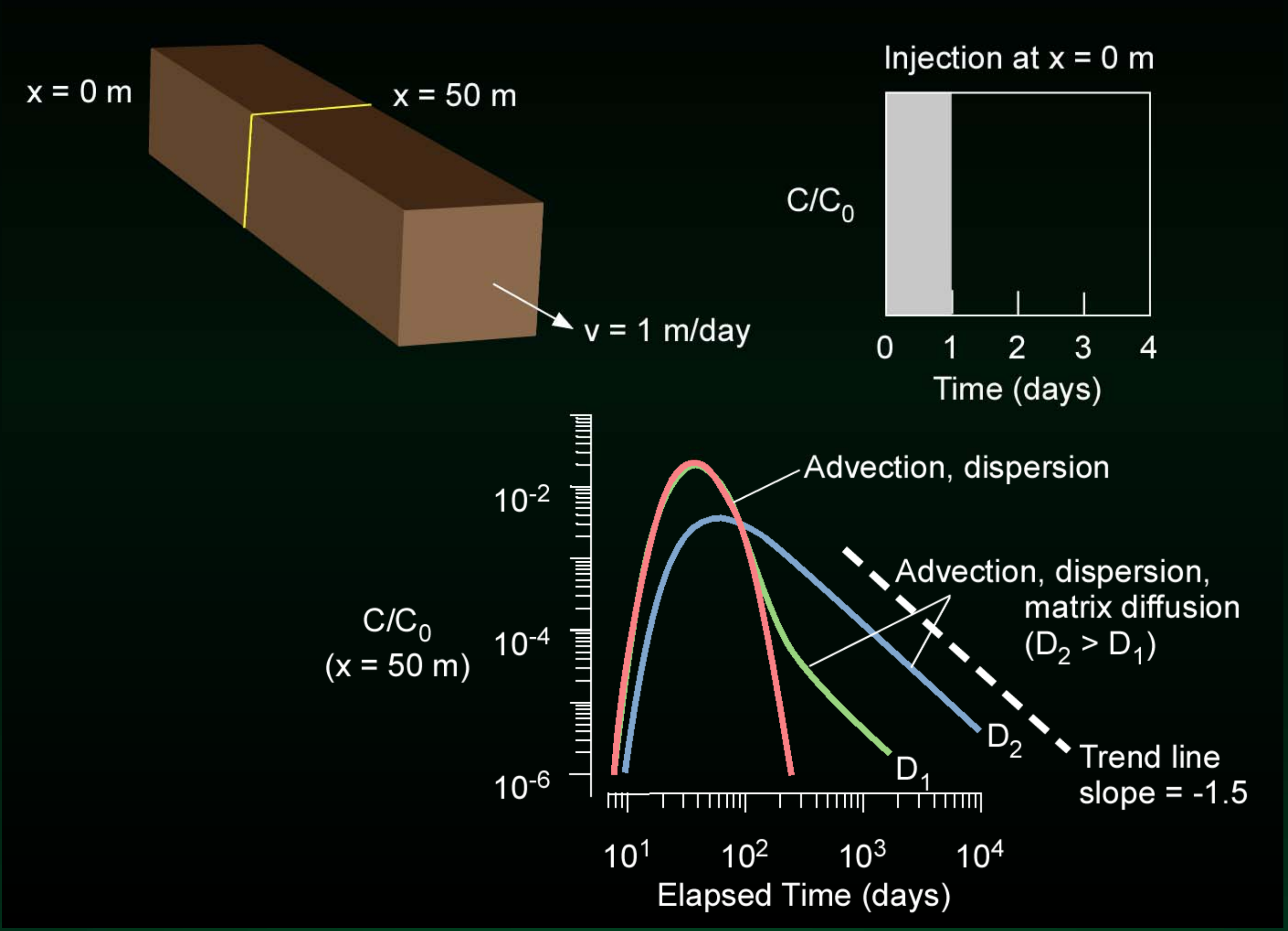
Understanding In Situ Processes

Theoretical interpretation of diffusion and "back" diffusion. . .



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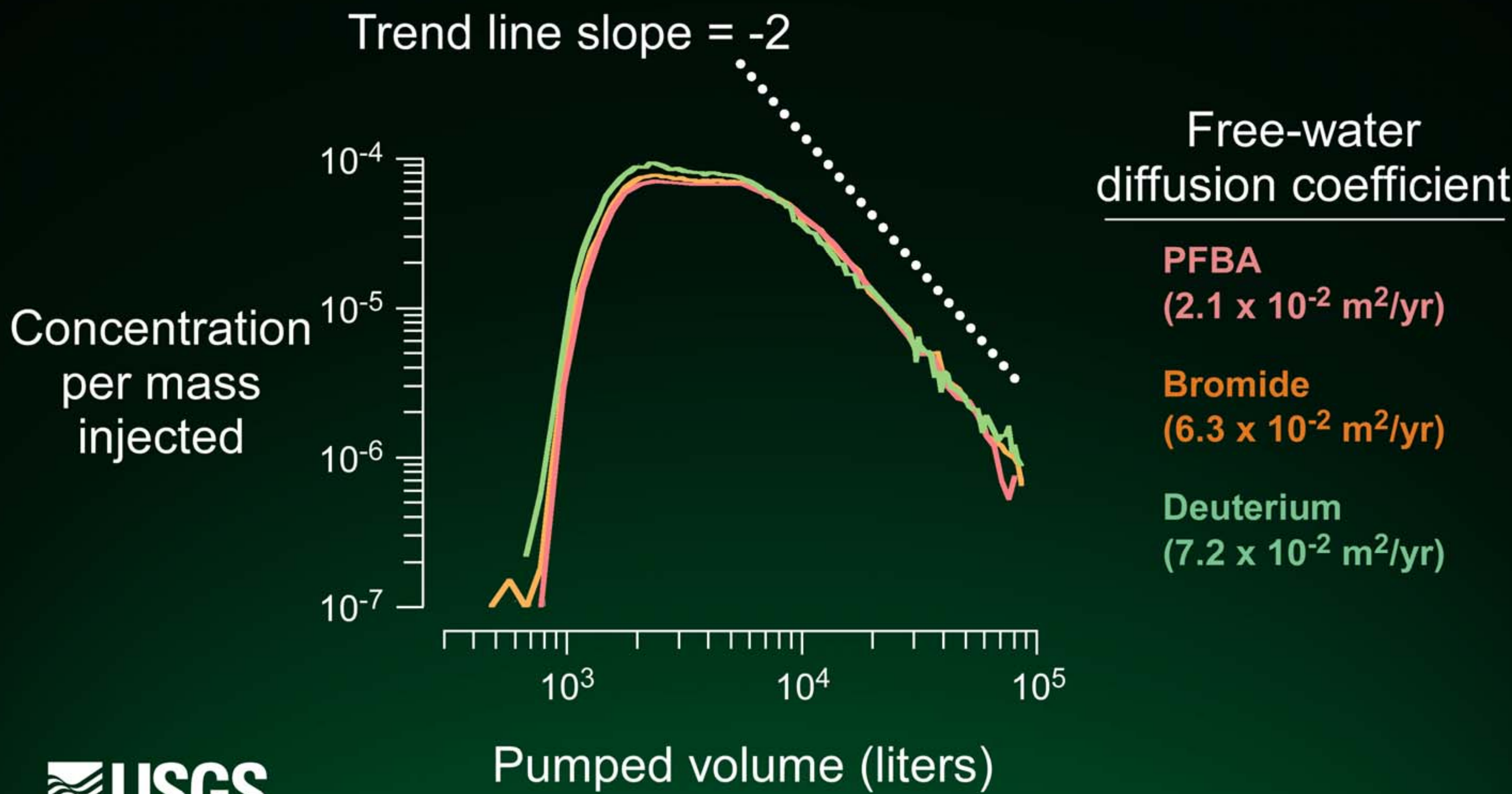
Granite and schist, Mirror Lake, NH

Multiple tracers (with different free water diffusion coefficients) injected



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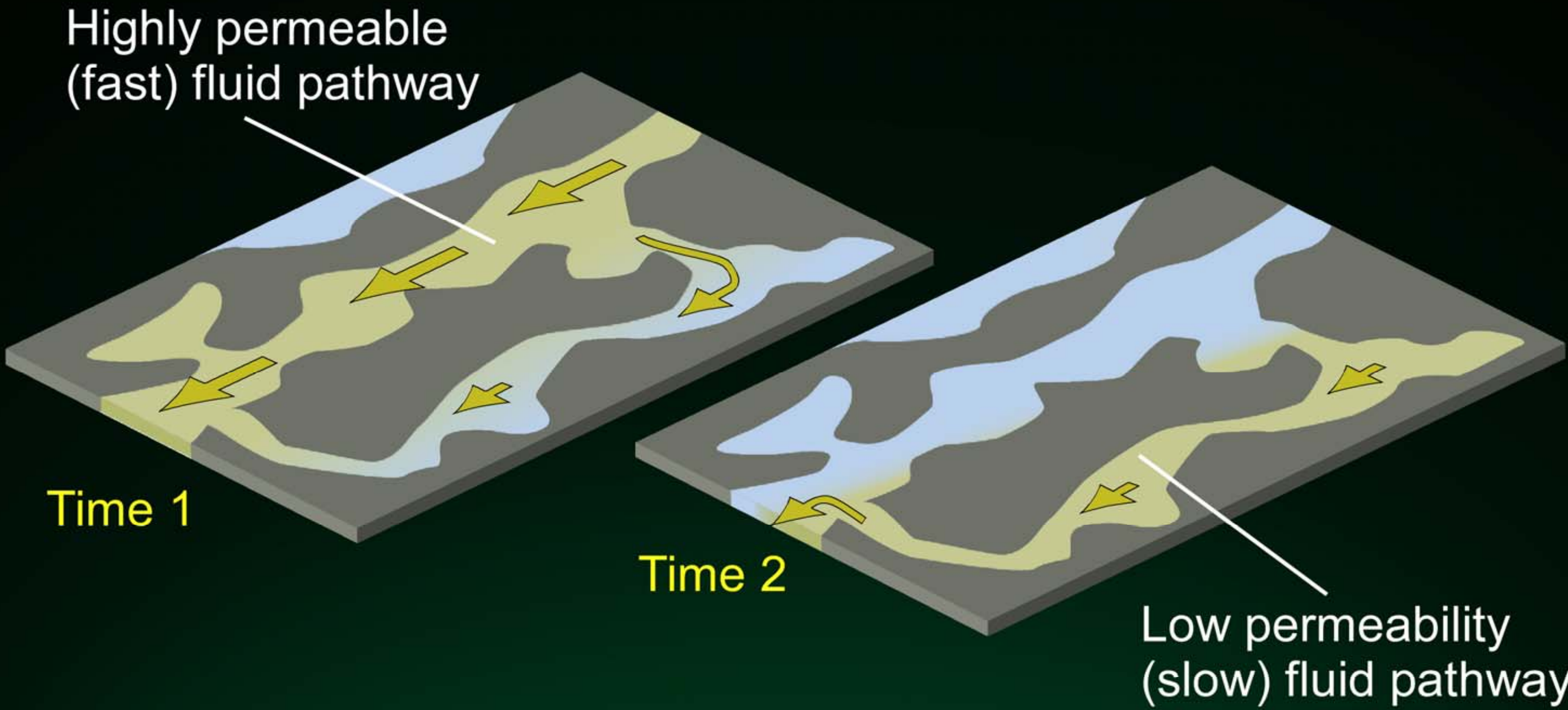
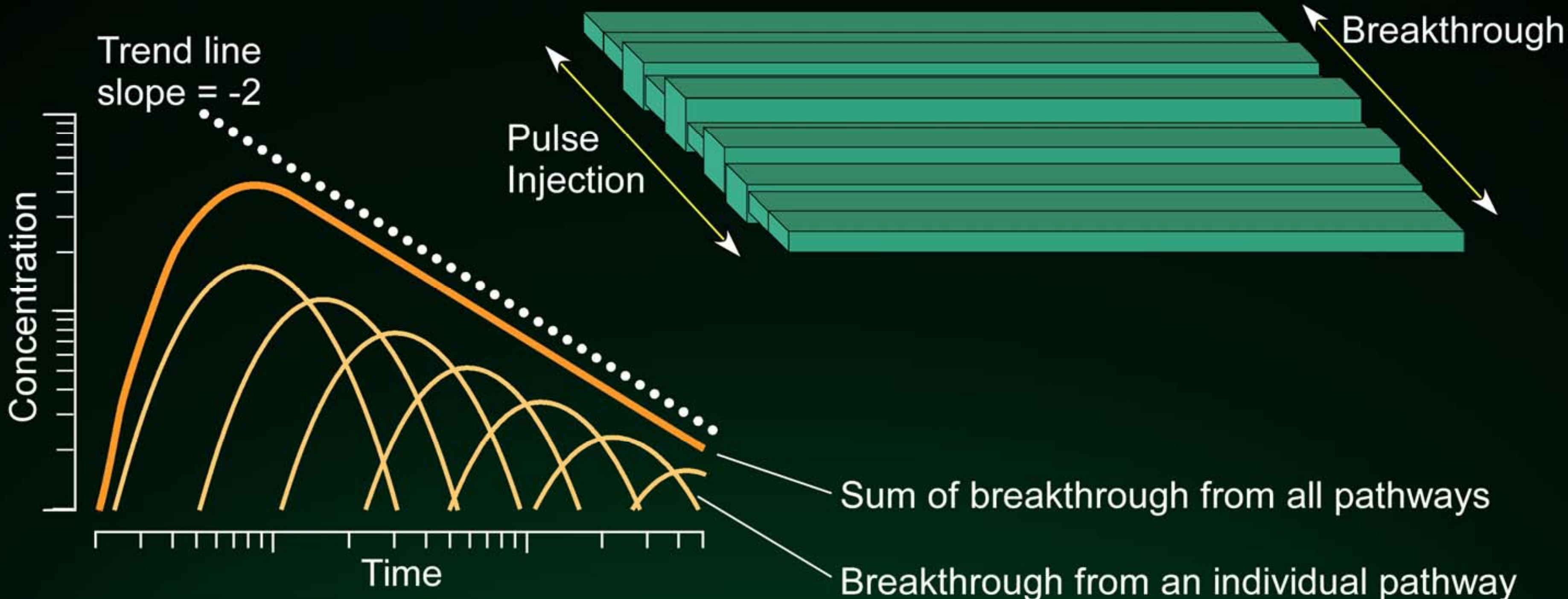
Improved Understanding of Chemical Transport in Fractured Rock



Breakthrough curves from a tracer test as the summation of transport along multiple pathways. . .



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Addressing the Complexities of Fractured Rock:

•Recognizing our limitations. . .hydrogeologic complexities translate into the long-term presence of contaminant mass. . . accepting the "reality" of long-term stewardship. . .

•Managing long-term commitments through . . .

(1)Advanced hydrogeologic characterization. . .
(2)Better understanding of in situ processes. . .
(3)Synthesizing lessons learned. . .
(4)Innovative monitoring of biogeochemical processes. . .

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