

# **Contamination in Fractured-Rock Aquifers: National Issues, Research Challenges, Overview of NAWC Site**

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# Acknowledgements



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**Technology  
Innovation  
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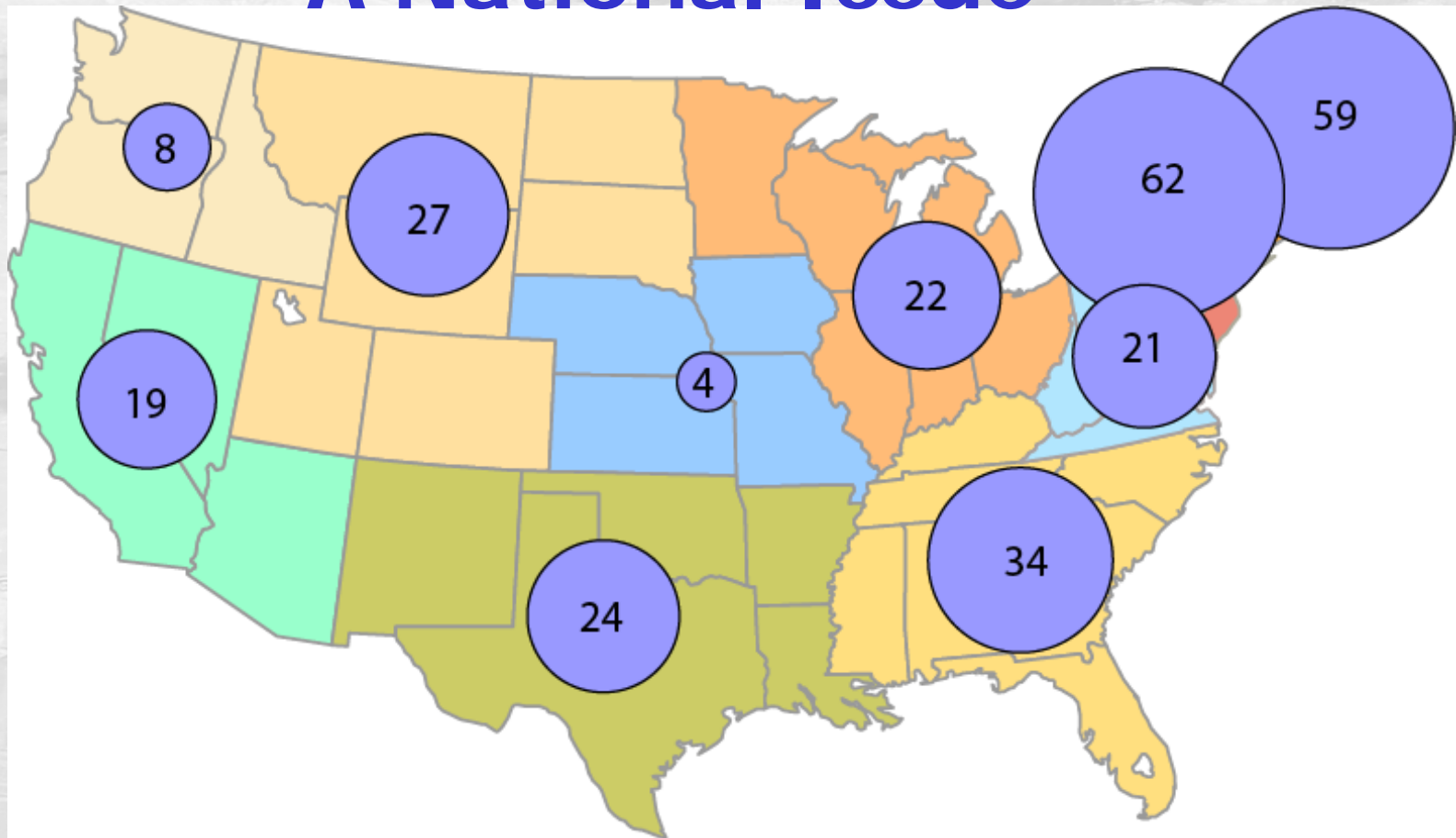


**Naval  
Facilities  
Engineering  
Command**



**Environmental  
Restoration**

# Contamination in Fractured Rocks: A National Issue



Hits for "Fractured Rock" on  
EPA Regional Superfund Web Sites.

# Challenges to Characterizing and Remediating Contamination in Fractured Rocks

- **Extreme heterogeneities...**
  - **Physical** Heterogeneity
  - **Contaminant Distribution** Heterogeneity
  - **Biogeochemical** Heterogeneity
- ...Coupled with complex fate and transport processes

# Challenges to Characterizing and Remediating Contamination in Fractured Rocks

- **Heterogeneity** together with
- **High cost** of subsurface investigations (e.g., drilling) lead to
- **Uncertainty** in contaminant transport properties and processes that is typically larger than in unconsolidated formations.

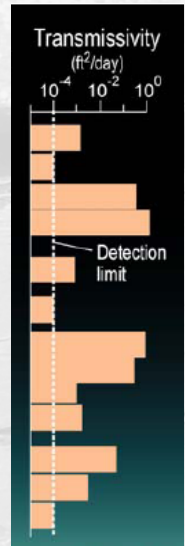
# Physical Heterogeneity

**Geologic Complexity**



**Extreme variation in hydraulic properties over short distances**

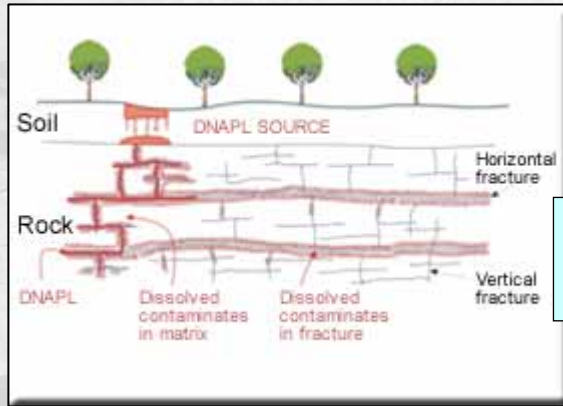
Modified from Shapiro et al., 2007, article in Hyndman et al., eds., AGU Geophysical Monograph Series, v. 171.



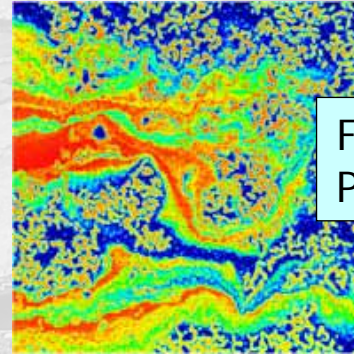
**Primary (rock matrix) and secondary (fractures) porosities with greatly different flow and transport properties**



# Contaminant Distribution Heterogeneity



Site Scale



Fracture Plane

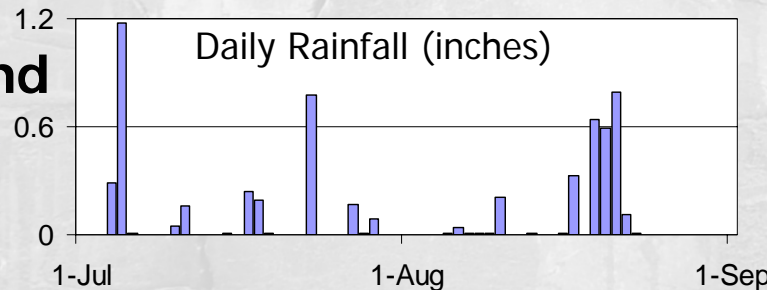
Rock Matrix

Caused by Physical Heterogeneity together with:

Complex spatial and temporal history of aqueous-phase and NAPL contaminant spills



Complex spatial and temporal recharge distribution





# Biogeochemical Heterogeneity

Geochemical  
Constituents

Microbiological  
Populations

**Caused by physical heterogeneity, contaminant distribution heterogeneity and its causes, together with:**

**Complex  
subsurface  
geochemical  
reactions**

# Past 20 Years: Significant Progress in Coping with Heterogeneities!

- **Methods for identifying flow and transport paths and properties**

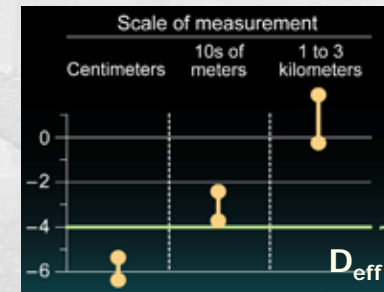
- Borehole flow logging
- Aquifer and tracer testing in packed-off borehole intervals
- Characterizing contaminants in rock matrix



- **Understanding of flow and transport processes**

- Variation of flow and transport properties with scale
- Matrix diffusion versus slow advection

- **But, challenges remain...**

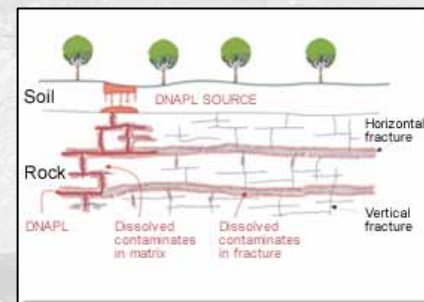


Modified from Shapiro et al., 2007, article in Hyndman et al., eds., AGU Geophysical Monograph Series, v. 171.

# Examples of Key Research Questions

- **How to delineate the contamination?**

- Because of heterogeneity and convoluted transport paths, it can be very difficult to determine the contaminant distribution



- **What are the important microbial processes?**

- Degradation potential in fractured rocks
- Different roles of attached & mobile microbes



- **How to address contaminant mass in rock matrix and slow/stagnant flow zones?**

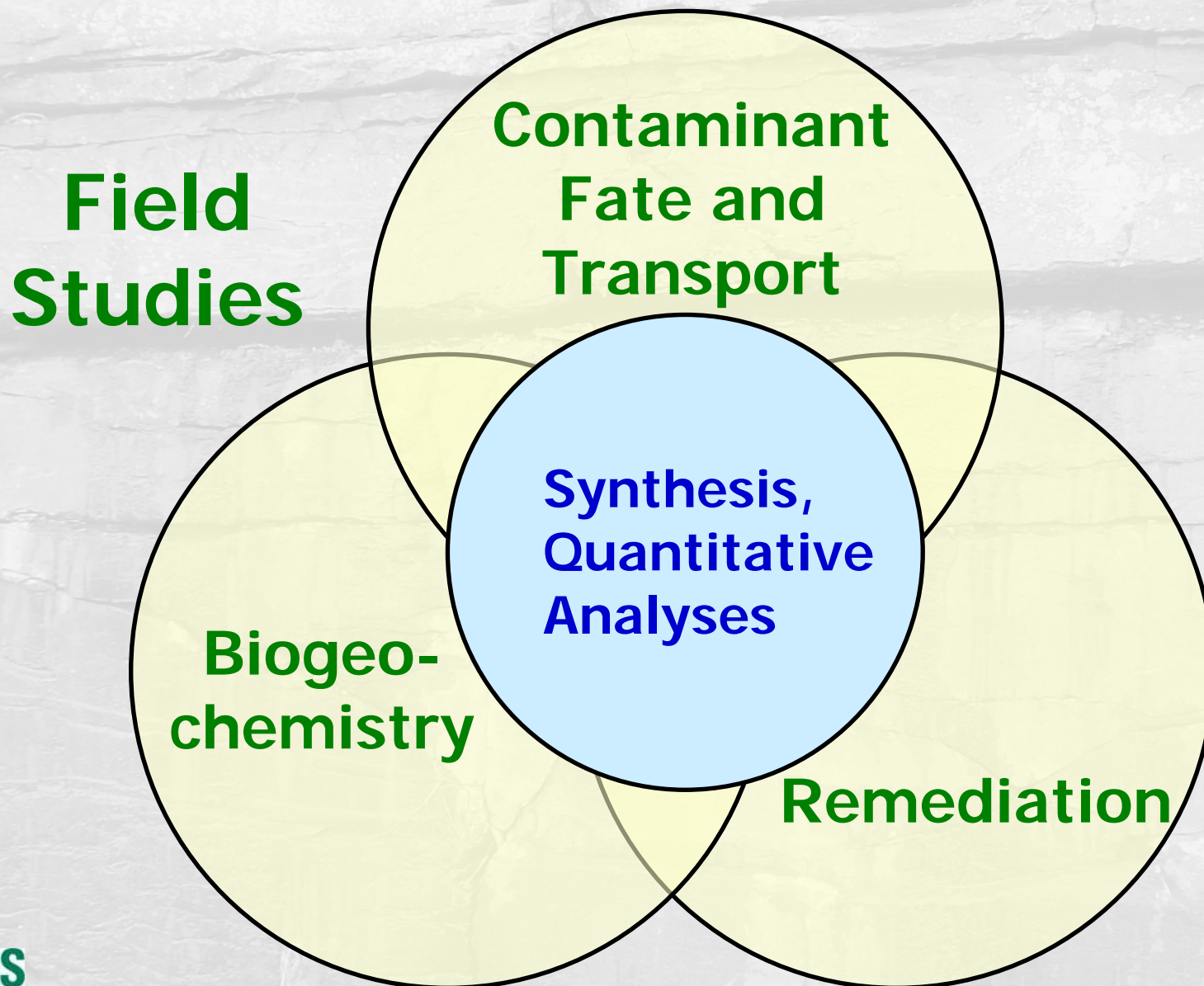
- Contaminant mass in these regions acts as extremely long term secondary source



# 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 cleanup.
- **Develop a hierarchy of quantitative tools** to help synthesize results and improve understanding of processes.
- **Transfer** findings, insight, and methods.

# Current Avenues of Research



# Long History of Research on Flow and Transport in Fractured Rock Aquifers



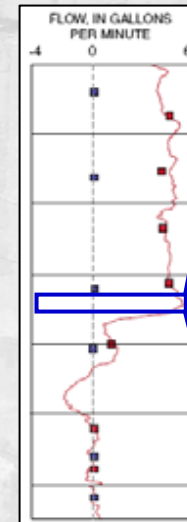
**Mirror Lake Crystalline Rock, NH:** Methods and findings used to understand flow and transport at many other fractured rock sites. (Shapiro, Hsieh, Haeni, and others)



**Illinois Basin Silurian Dolomite Superfund Site:** Tools used to characterize fracture connectivity and transport properties. (Lane, Shapiro, and others)



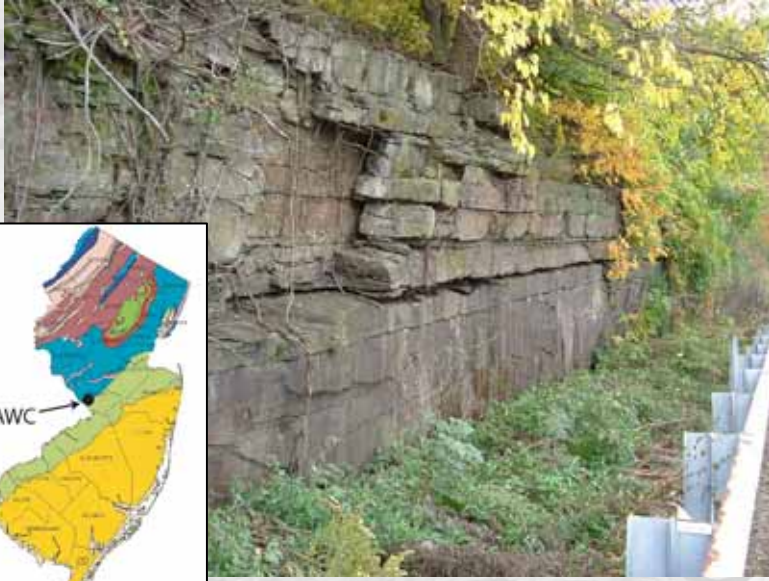
**Biscayne Karst Limestone, FL:** Extending methods to investigate pathogen and chemical transport. (Shapiro, R. Harvey, and others)



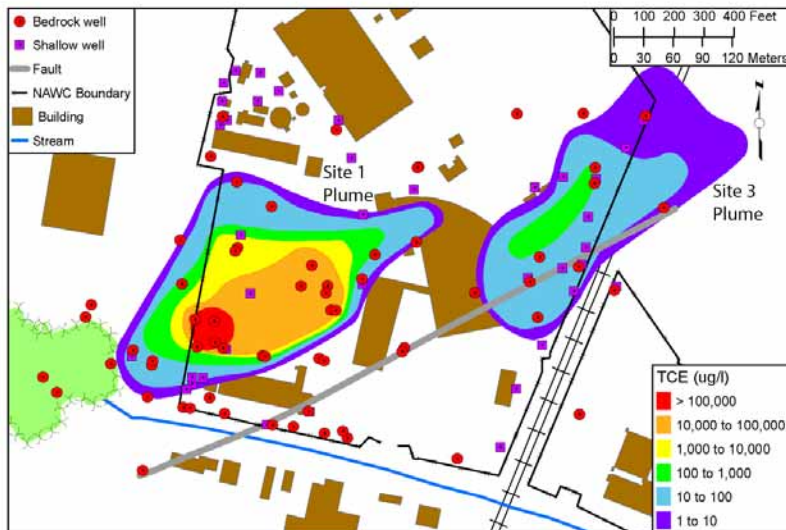
**Contaminated Fractured Sandstone, CA:** Borehole flow logging identifies flow zones important to contaminant transport.

(modified from Williams and others, 2002, USGS WRIR 00-4083)

# Naval Air Warfare Center (NAWC), West Trenton, New Jersey



- **Current focus site** for Toxics Program research on fractured-rock contamination.
- **Sedimentary rocks** of the Newark Basin.
- **Extensive TCE, DCE, VC contamination.**
- Area of focused study: 0.5 x 0.5 km.



# Site History

- Navy jet engine testing facility, 1950's to 1990's
- TCE & jet fuel leaked into subsurface
- Facility was closed in 1998
- Pump & treat since mid-1990's





# NAWC: Multiple Parties with Different Objectives

**USGS, SERDP, ESTCP, Universities:** Research contaminant transport, fate, & remediation; and transfer results.

**U.S. Navy:** Characterize contamination & clean up site quickly and efficiently.

**NJ Dept. of Environmental Protection:** Clean up site and prevent contaminants from spreading.



**Site owner:** Develop retail businesses on site.

# Next Four Talks in This Session

## Contaminant Fate and Transport

Lacombe: Geologic Framework

Goode: Contaminant Persistence

## Biogeochemistry

Bradley: Biodegradation

Shapiro: Remediation