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Sandia National Laboratories

# Geological Investigations for Development of Nuclear Waste Repository

## *Nuclear Waste Management Organization of Japan (NUMO)*

*Moo Y. Lee, September 26, 2016*

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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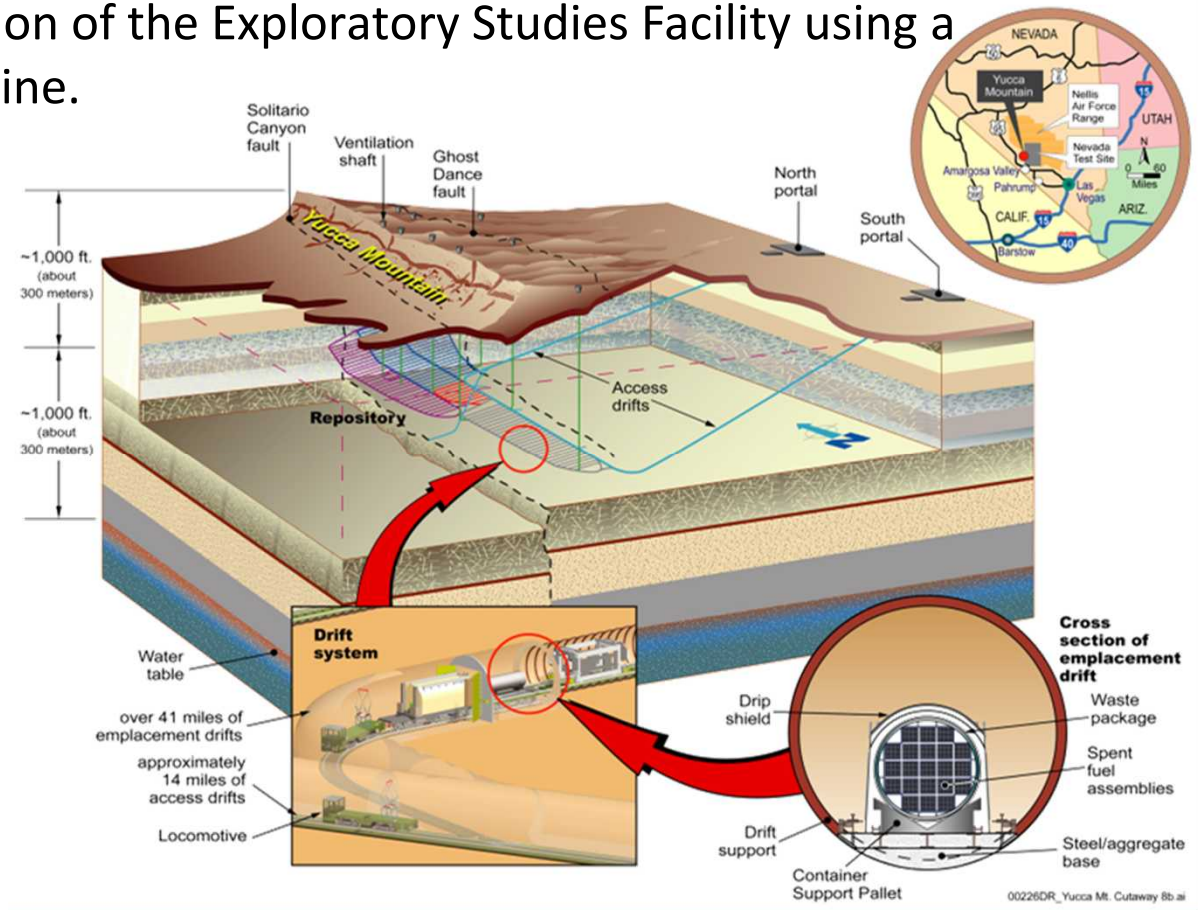
# Stages of Repository Science

- Site Selection
  - Identification of potentially suitable geologic media and evaluation/screening of candidate sites
- Site Characterization
  - Experimental and field test programs to characterize long-term performance of engineered and natural components of the system
- Site Evaluation
  - Modeling of future performance under a range of conditions at component and full-system level with uncertainty
- Licensing

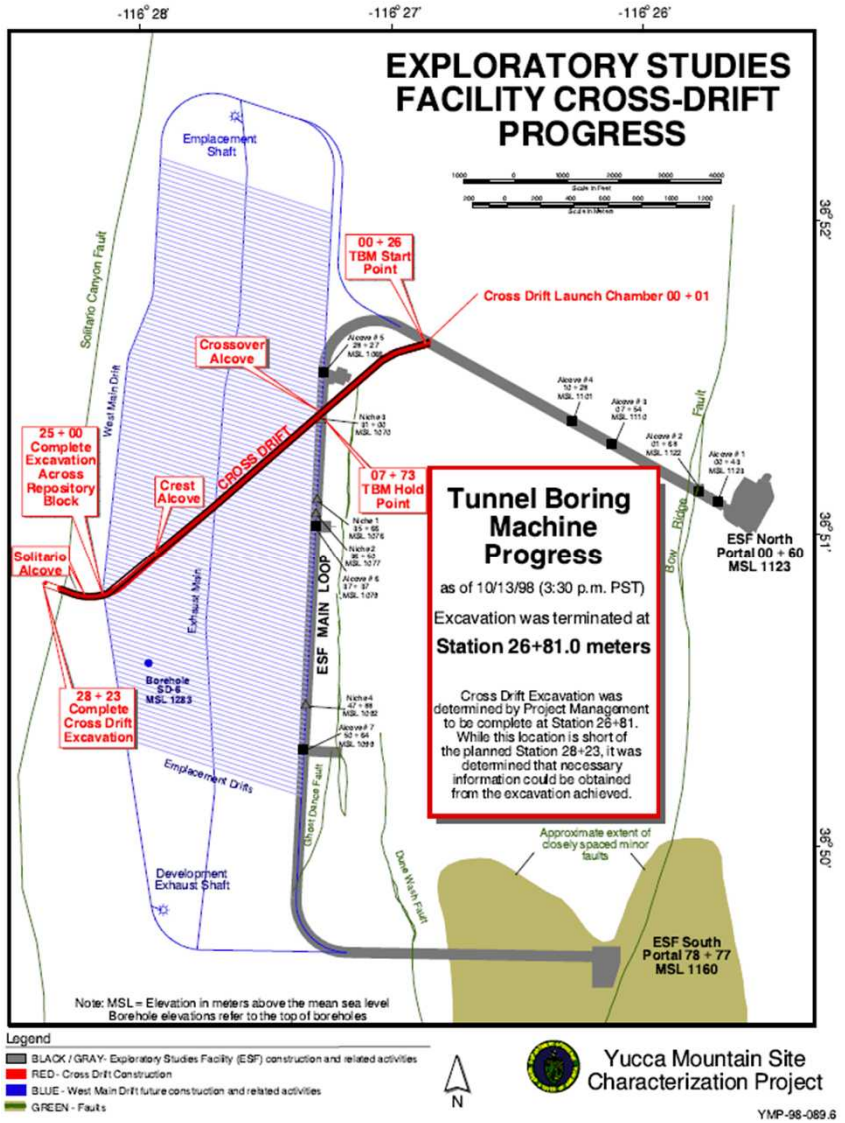
# Yucca Mountain Project

- **1987:** NWPAA designated Yucca Mountain as the only site to be characterized for a permanent nuclear waste repository.
- **1988:** DOE Yucca Mt. Site Characterization Plan
- **1994:** DOE began excavation of the Exploratory Studies Facility using a tunnel boring machine.
- **1997:** ESF main tunnel (8m in diameter and 8km long) was completed.
- **2008:** DOE submitted a license application to NRC to construct HLW repository at Yucca Mountain



# Site Characterization

- 10CFR § 60.15 Site characterization
- Unless the Commission determines with respect to the site described in the application that it is not necessary, **site characterization shall include a program of in situ exploration and testing at the depths that wastes would be emplaced**.
- Investigations to obtain the required information shall be conducted in such a manner as to limit adverse effects on the long-term performance of the geologic repository to the extent practical.



# Rock Mass Classifications

- Identify significant parameters influencing the behavior of a rock mass and relating those parameters to engineering applications based on experience
- Enable effective communication for the conditions of rock
  - **RQD** (Rock Quality Designation) by Deere

    % of good (>10 cm) rock  vP, P, F, G, E
  - **Q** (Rock Tunneling Quality) system by Barton

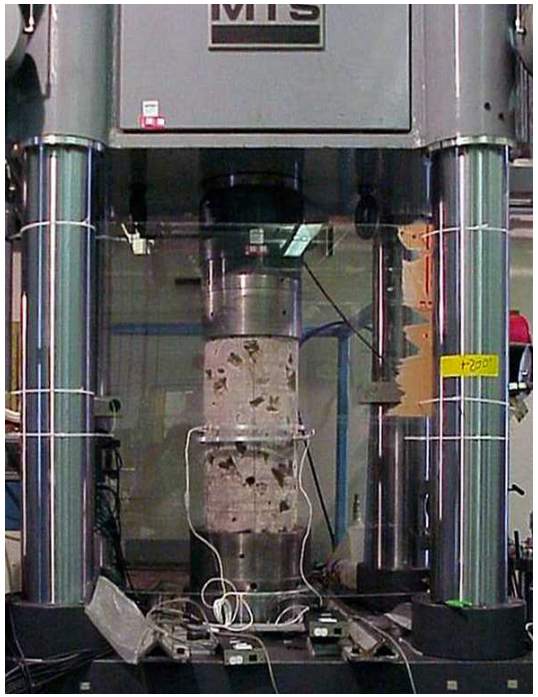
    $$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$  vP, P, F, G, vG
  - **RMR** (Rock Mass Rating) by Bieniawski

    $\sum P_{i=1 \text{ to } 6}$  I-vG, II-G, III-F, IV-P, V-vP


Rock-mass classification of candidate repository units at Yucca Mountain, Langkopf and Gnirk, SAND82-2034

# Laboratory Experiments

- Determine basic T-H-M-C properties and variabilities of rock
- Attempt to understand deformation and failure mechanisms
- Provide baseline data for extrapolation of laboratory to repository scale T-H-M-C properties



Mechanical and bulk properties in support of ESF design issues, HLWMC1994 by Price et. al.

# Hydrofrac In Situ Stress Measurement

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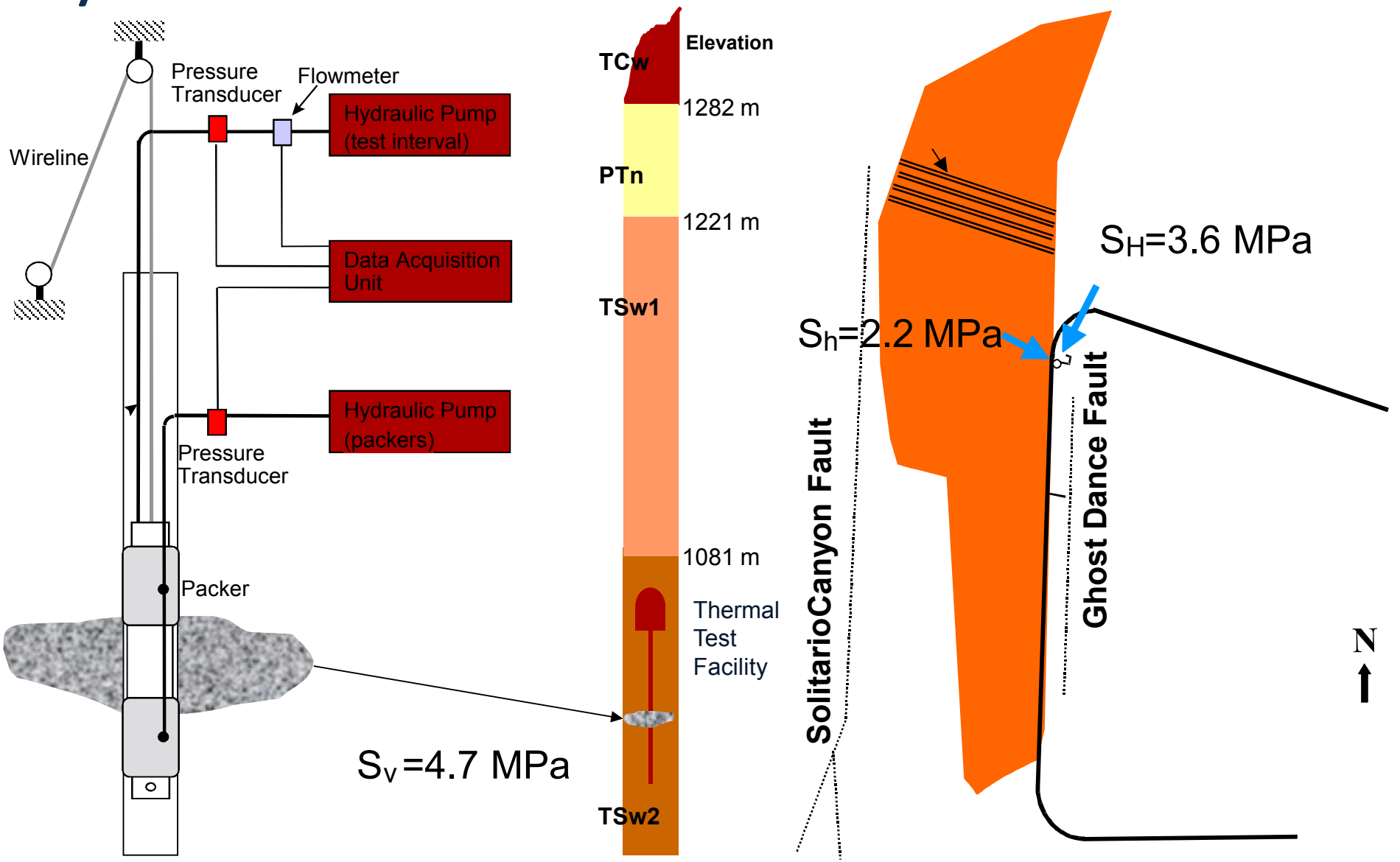
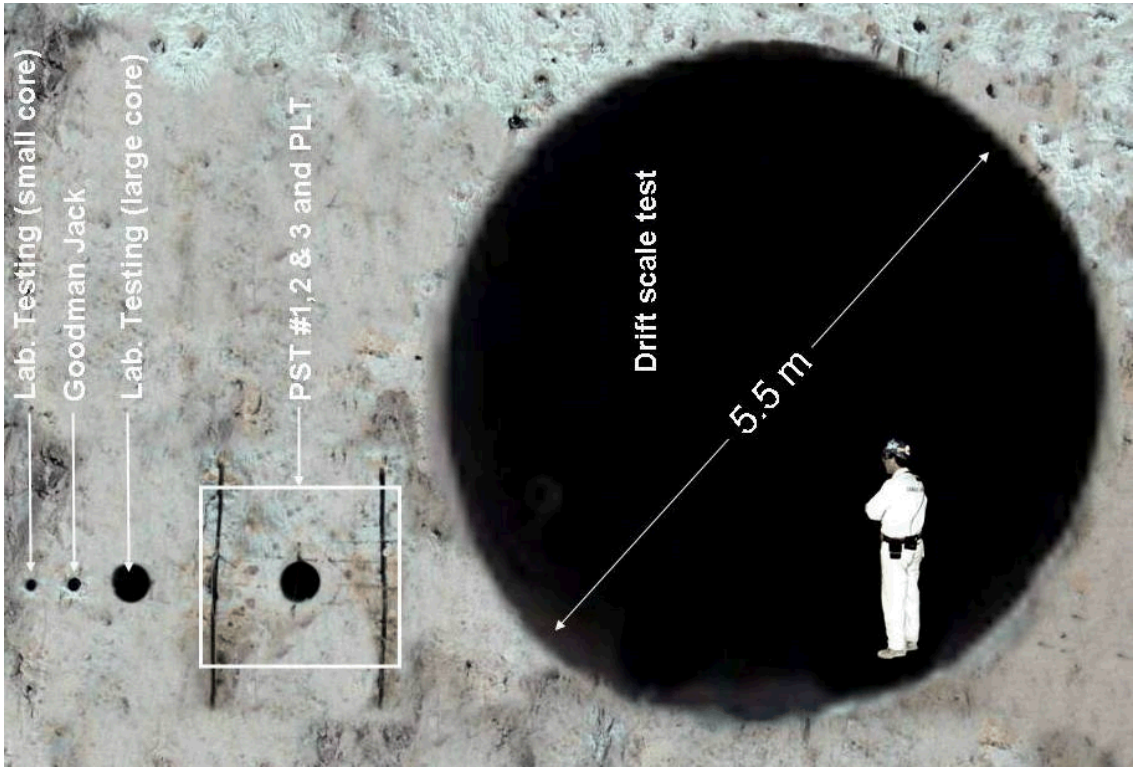
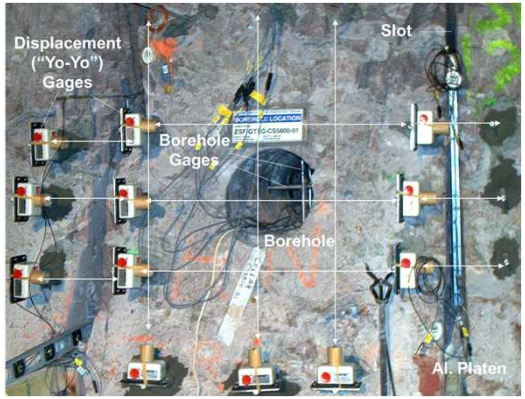


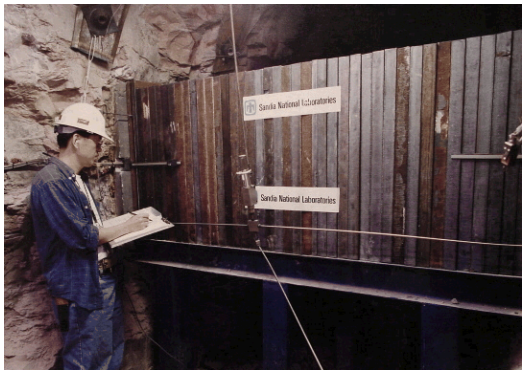

Initial stress measurements in the Exploratory Studies Facility Yucca Mountain, Lee and Haimson,1999

# In Situ Rock Mass Deformability Measurements

- Goodman Jack
- Pressurized Slot Testing (PST)
- Plate Loading Test (PLT)



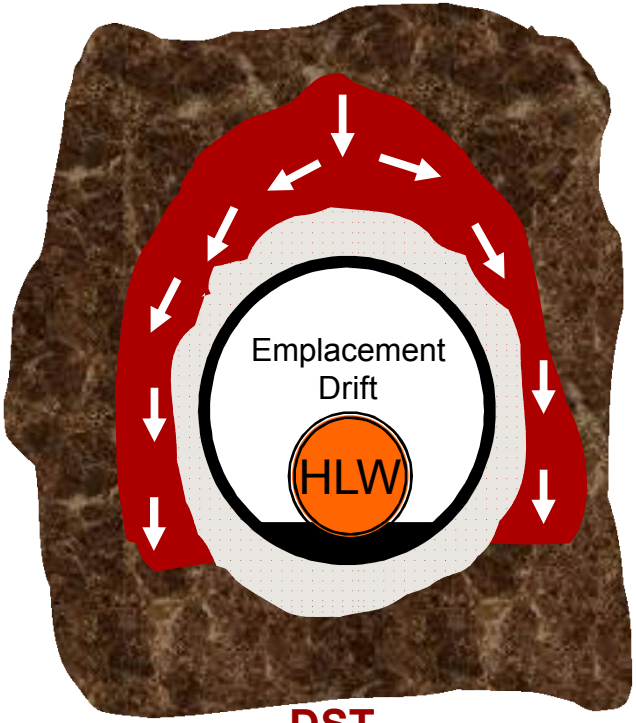



Rock-mass deformation modulus testing at YMP in lithophysal stratigraphic units, USRM 2003 by Howard et. al.

# Heater Tests

- Evaluation of coupled **T-H-M-C** behaviors surrounding the emplacement drift
  - Vaporization barrier created by boiling water prevents water from seeping into the drift
  - Diversion of water around the drift reduces seepage onto the waste package
  - Thermal stress creates slab failures in the crown area of the drift at high temperature



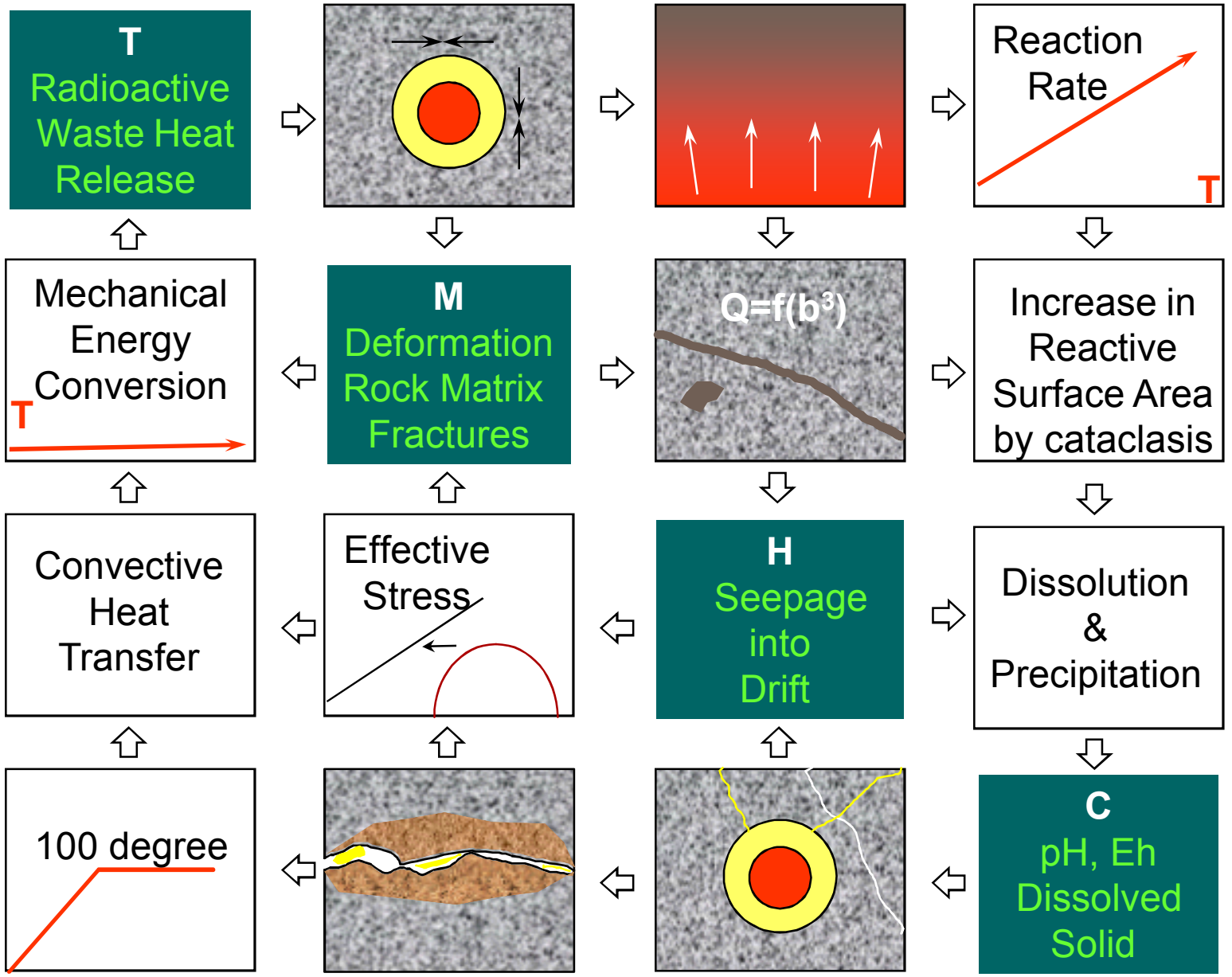

**SHT**

**LBT**

**DST**

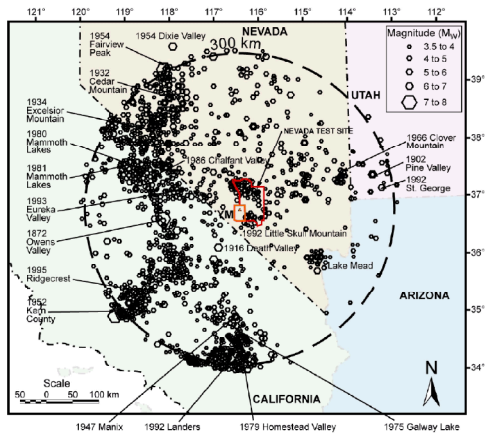
The Yucca Mountain Project Drift Scale Test, USRM 1998 by Finley et. al.

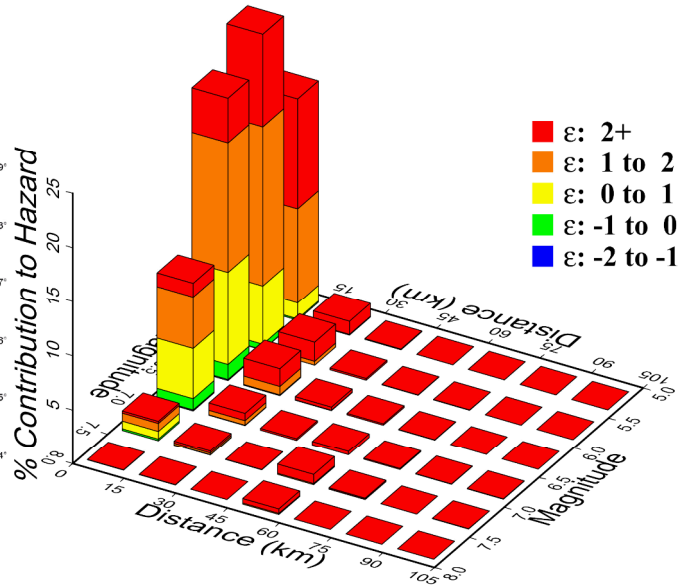
# Coupled T-M-H-C Processes in HLW Repository

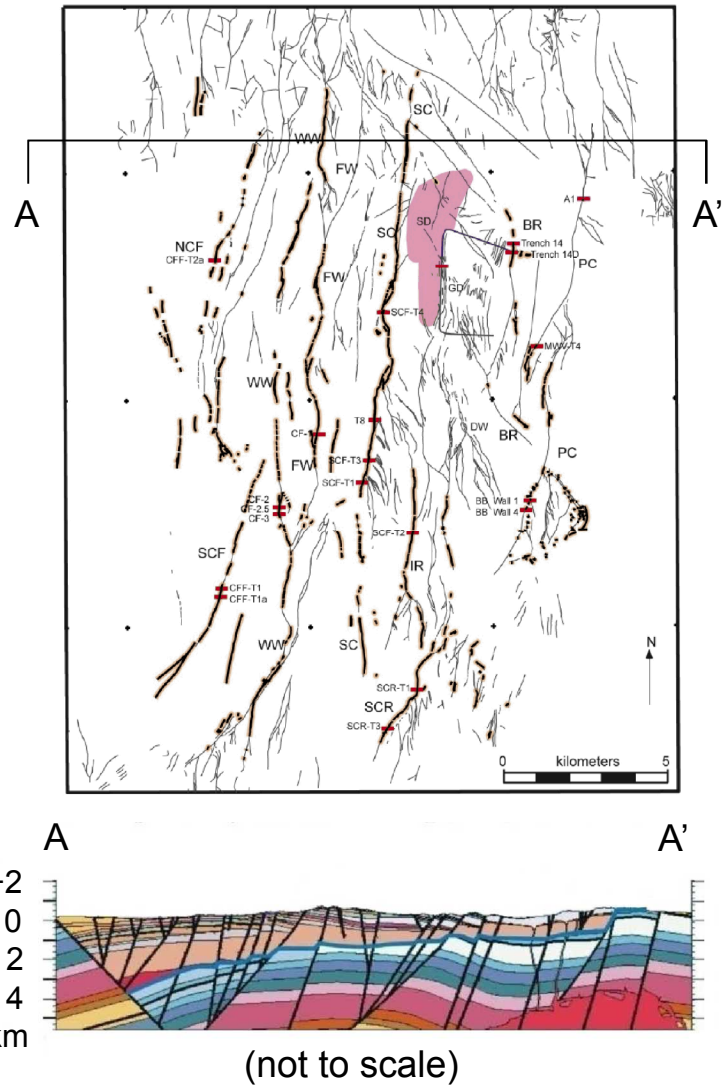


# Seismicity

- Site characterization
- Seismic source characterization
- Ground motion characterization
- Hazard calculation and results
- Deaggregation of hazard results




Probabilistic Analysis of Geologic Hazards, SAND2010-3340P by Quittmeyer

# Summary

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- 10CFR § 60.15 requires in situ exploration and testing be conducted at the depths that wastes would be emplaced
- Laboratory experiments provide baseline data for material properties and failure/deformation mechanisms of rock
- RQD, Q and RMR enable effective communication for the conditions of rock
- Hydraulic fracturing estimates In situ stress at the site
- Goodman Jack, PST, and PLT measure deformability of the rock mass for different scales
- Heater tests (single, large block, drift scale) provide coupled T-H-M-C behaviors unique to the HLW repository project.

# Repository Science Consortium

**Repository Science Consortium**

- Annual Training → Repository Science
- Staff Exchange → On site collaboration
- Information Share → WIPP & YMP Publications; Repository Data & Models; Experience
- Collaborative R&D → SNL Laboratories; SNL Computing Facilities; Universities → Publications; SAND Reports; NUMO-TR
- Annual Workshop → Evaluation and Planning → Publications; SAND Reports; NUMO-TR

The central goal of the RSC is to develop solutions and provide innovative technology advancements in the repository sciences in order to meet nuclear waste management challenges throughout the world. By fostering an international collaborative environment, the Repository Science Consortium will be able to undertake activities beyond the capabilities of its individual members.