U.S. Department of Energy
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Development of Multiple Lines of Evidence for SSPA

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YUCCA MOUNTAIN PROJECT

Working Definition of Multiple Lines of Evidence for SSPA

- **Independent reasoning used to demonstrate how well a system, sub-system, or process is understood. These can be :**
  - **Natural analogs**
  - **Simple calculations**
  - **Sensitivity analyses**
  - **Observations from site characterization**
  - **Observations from lab and field experiments**
  - **Independent modeling studies**

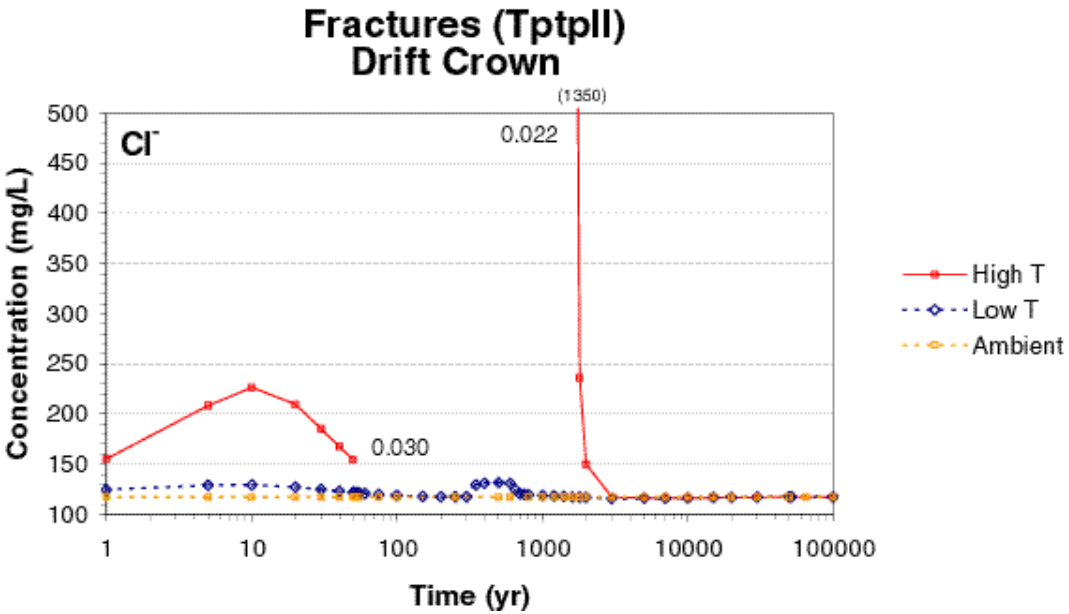
Sequence in Development of Multiple Lines of Evidence for SSPA

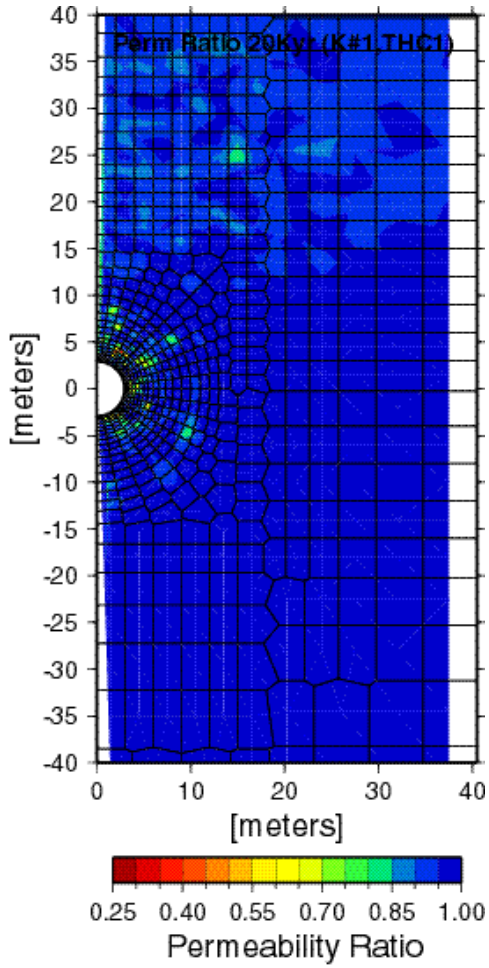
- **Focused on areas of uncertainty, particularly with respect to operation of the process over long spatial and temporal scales**
- **A list of potential multiple lines of evidence (MLEs) was compiled and a small team worked to develop them for each SSPA section**
- **Benefits of both quantitative and qualitative MLEs**
- **Weight of evidence from MLEs varied widely from one process model to another (e.g., MLEs for percolation flux were extensive and woven together; less convincing for lateral diversion in PTn)**
- **Sometimes if a model demonstrated no effect due to a process (e.g., THC effects on transport), it was difficult to find MLEs**

THC Effects on Flow and Chemistry

- **Little permanent change during high temperature (T) or low T**
- **Low T chemistry similar to that at ambient T**

courtesy E. Sonnenthal





Example: Effects of Water-Rock Interaction on Fluid Flow

- **Model shows small permanent change within range of fracture permeabilities**
- **Supported by analogs at shallow intrusive and extrusive contacts in UZ, e.g., Banco Bonito obsidian flow, Grants Ridge intrusion**
- **Localized effect of alteration related to intrusion of Papoose Lake Sill, Paiute Ridge**
- **Yellowstone Y-8 core suggests that silica seal may have formed in response to transient boiling events associated with depressurization**

Effects of Water-Rock Interaction at Paiute Ridge

Anastomosing veins of mineral alteration within 8 feet from the intrusive contact of the Papoose Lake sill

Example: Effects of Water-Rock Interaction on Fluid Flow

(Continued)

- **Closed-system hydrothermal flow-through experiments in Topopah Spring and Bullfrog tuffs showed small reduction in permeability at T = 90° to 250°C in absence of boiling**
- **Tuff dissolution and precipitation in a boiling, unsaturated fracture experiment and simulations indicate that localized zones with elevated flux rates within the boiling front would be most susceptible to self-sealing. Small amounts of total porosity reduction are required along sharp, stationary boiling fronts and within narrow apertures to seal a fluid conduit**

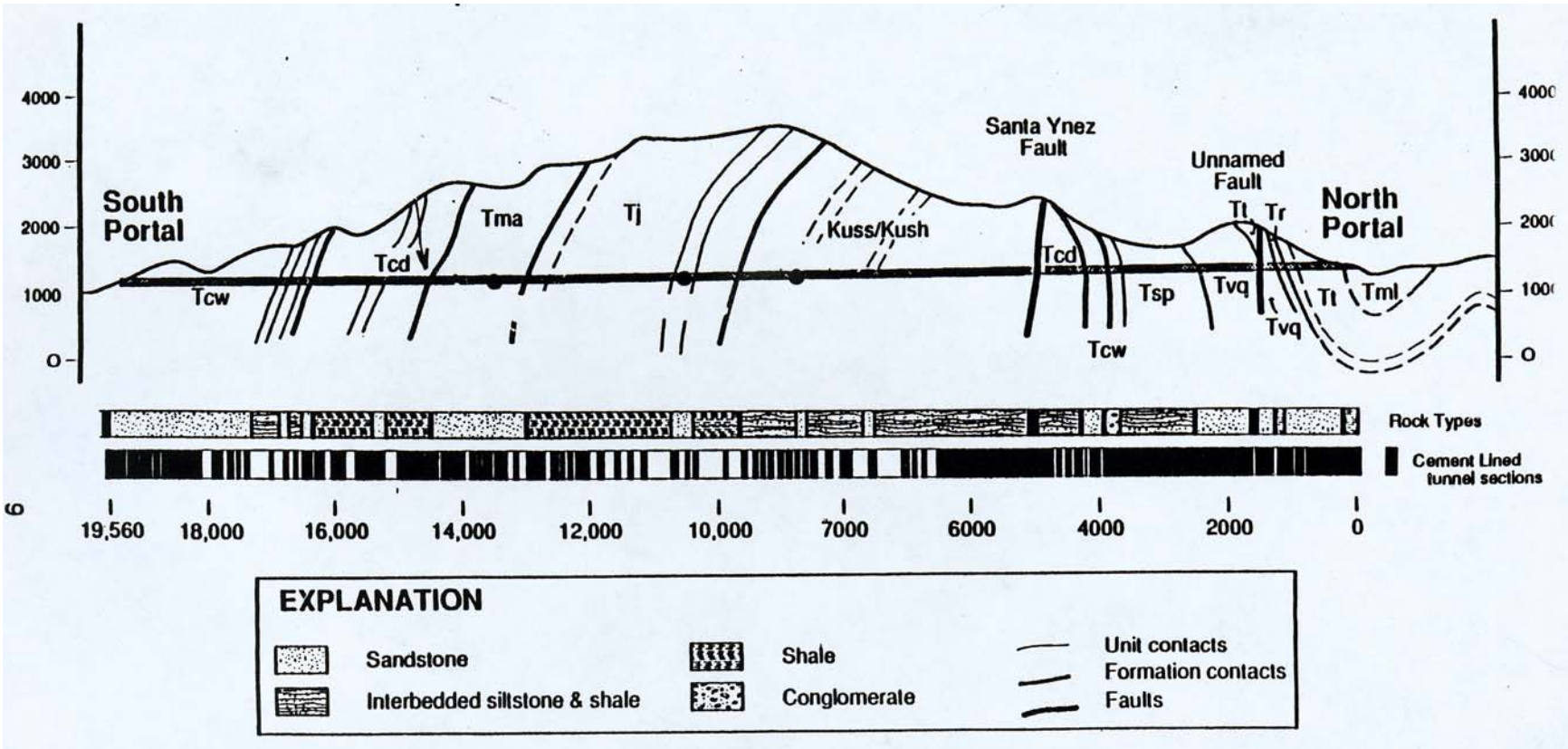
Examples: Absence of Evidence

- **Seepage enhancement resulting from rock bolts**
  - **Counter to observations of occasional dripping at rock bolts in Exploratory Studies Facility (ESF); not enhancement of background percolation seepage**
  - **Seepage enhancement at rock bolts in saturated tunnel does not apply because tunnel is not a capillary barrier**
- **Seepage enhancement from rockfall**
  - **No evidence from Rainier Mesa, Altamira, Mitchell Caverns, sealed segments of ESF and the Cross Drift**

Example: Potential Opposing Evidence

- **Tunnels drilled through the Santa Ynez Mountains for the Santa Barbara Water District in the early 1900's and the 1960's provide a history of water-rock interaction with well constrained flow paths, flow times, precipitation, and seepage amount and composition**
- **Stalactites that have precipitated in the tunnel provide a possible one hundred year climate record**

Geologic Cross-Section of Mission Tunnel



Different Types of MLEs used in SSPA

- **Natural analogs: UZ and saturated zone (SZ) flow and transport**
- **Simple calculations: percolation flux using carbon-14 method**
- **Observations from site characterization: geochemical data corroborating UZ flow focusing; $^{234}U/^{238}U$ anomaly in SZ**
- **Observations from lab and field experiments: Busted Butte, Alluvial Tracer Complex, Stripa, G-Tunnel, radionuclide column experiments**
- **Literature studies: general corrosion over long term, biosphere parameters, microbial uptake of colloids**
- **Independent modeling studies**

What We Learned from MLEs for SSPA

- **Useful in capturing previously reported work in a more connected way as MLEs**
- **Stretched the imagination re analogs and what type of information can be used to corroborate understanding - not always straightforward**
- **Provided a head start on Fiscal Year 2002 planning- identified areas where more effort on MLEs is needed**

Where Do We Go From Here?

- **SSPA was a work in progress. Work will continue on the MLEs we didn't get to. Many of these will be included in the Natural Analog Synthesis Report**
- **Fiscal Year 2002 planning includes natural analog work for every process model. Seeking analogs for drift shadow zone and engineered barrier system processes**
- **Evaluating additional lines of evidence, both supporting and opposing**