U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

UZ Flow, Transport, and Coupled Processes Model Update

Presented to:
Nuclear Waste Technical Review Board

Presented by:

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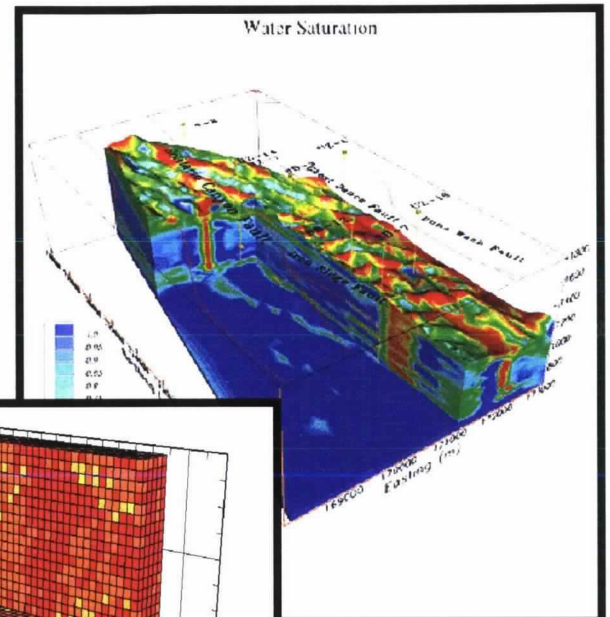
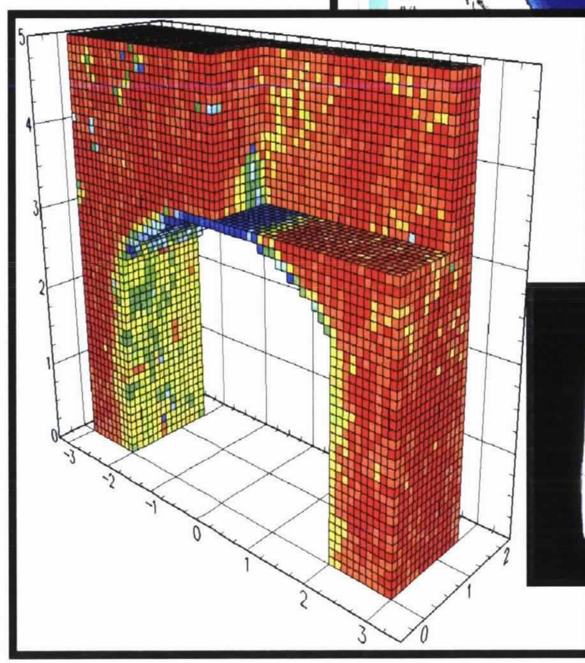
Outline

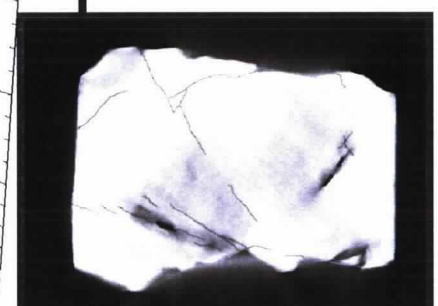
- Role of process modeling
- Unsaturated Zone (UZ) issues considered in this presentation
- Progress on resolution of issues
- Concluding remarks

Role of Process Modeling in Yucca Mountain Project

- Process understanding
- Test design
- Data analysis/
  site characterization
- Predictive modeling
- Sensitivity analysis/
  uncertainty analysis
- Basis for abstraction
- Basis for Total System
  Performance Assessment





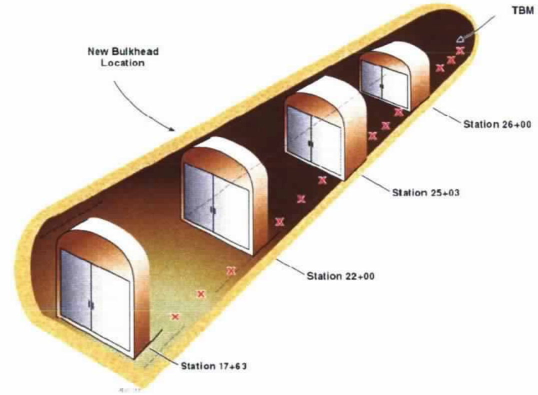


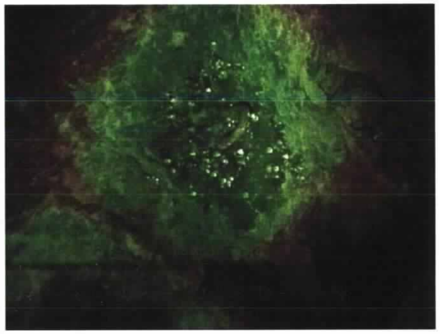
UZ Issues Considered in this Presentation

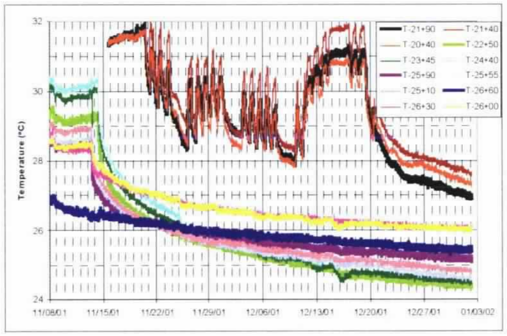
- **Moisture condensation in the Enhanced Characterization of the Repository Block (ECRB)**
- **Model validation issues**
  - Radon data for property validation
  - Seepage in lower lithophysal (Niche 5/Systematic testing)
  - Matrix diffusion (Alcove 8/Niche 3)
- **Radionuclide transport issues**
  - DCPT/FEHM particle transport
  - Radionuclide transport below the drifts (shadow zone)
- **Coupled Processes Issues**
  - Drift-Scale Test (DST) cool-down started
  - Thermal/Hydrologic/Chemical (THC) effects on fracture sealing

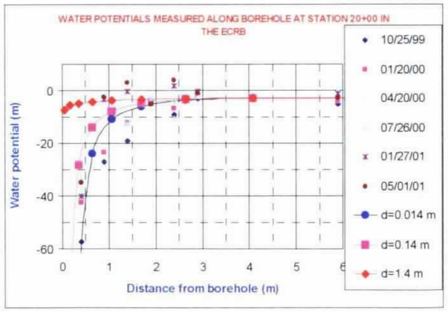
ECRB Moisture Condensation

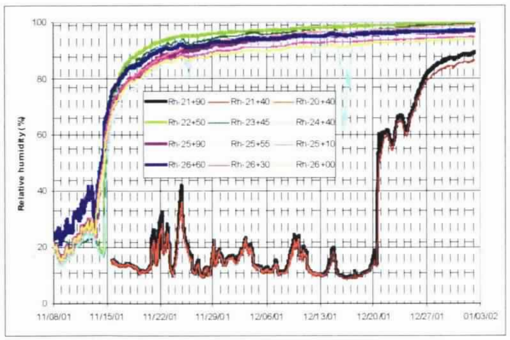
- **Modeling Approach**
  - Ventilation induced drying to match borehole data
  - Moisture flux from the rock to interpret the humidity rise after bulkhead closure
  - Cross Drift simulations to determine condensate origin
- **Results**
  - Water potential data matched
  - Moisture condensation from hot to cold regions identified as the likely mechanism
  - Geothermal feed zones identified as analogs for moist-air in-flow along drifts
  - Drifts along temperature isotherms suggested





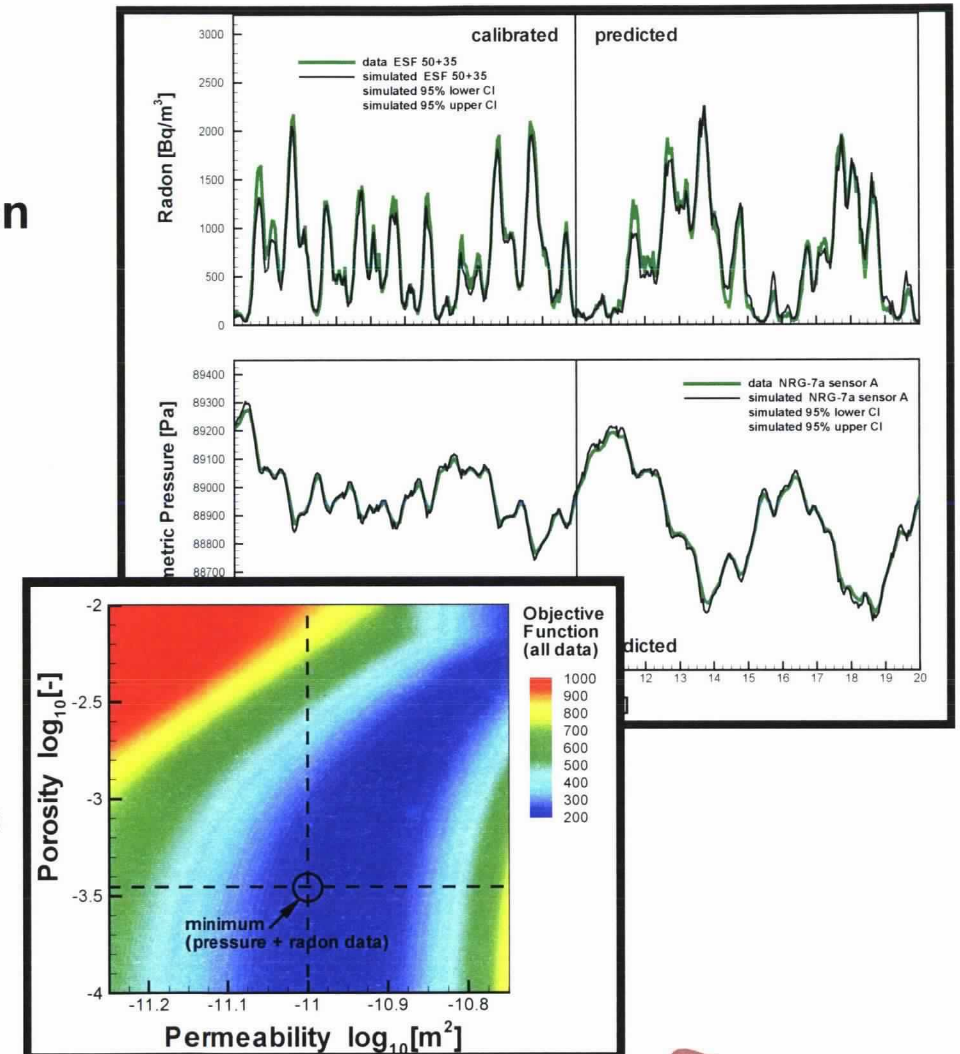






Calibration Against Radon and Pressure Data

- **Modeling Approach**
  - Developed gas flow and radon transport model
  - Performed joint inversion of pressure and radon concentration data
- **Results**
  - Estimated formation parameters and initial and boundary conditions
  - Model accurately reproduces and predicts radon concentrations along Exploratory Studies Facility



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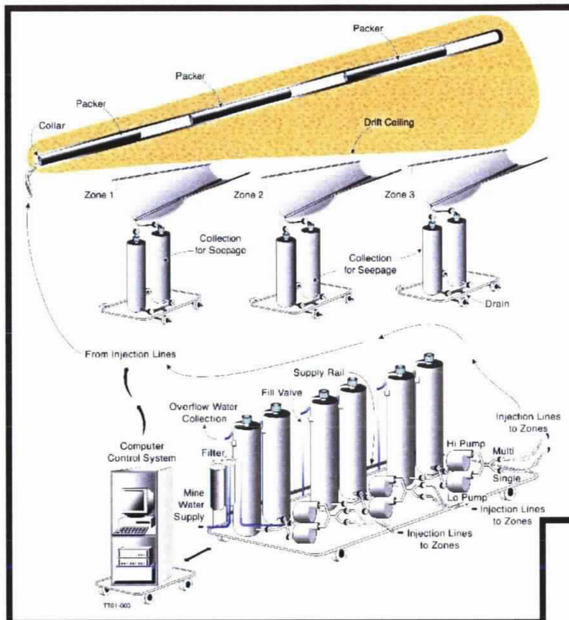
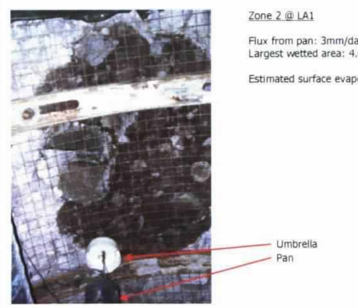
Seepage/Evaporation Analysis

- **Analysis Approach**
  - Partition of flow paths by travel times and volumes in series of seepage tests
  - Evaporation estimates by pan measurements
  - Wetted area evolution on the drift/niche ceiling
- **Results**
  - Evaporation alone can not account of difference between injection and seepage, further validating threshold concept
  - Lower lithophysal tuff has large storage capacities to suppress seepage and enhance seepage threshold, based on Niche 5 and systematic testing results to be used in Seepage Calibration model



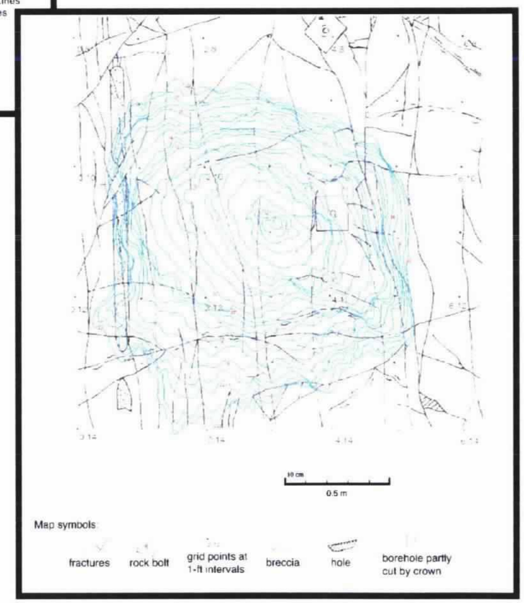
Evaporation estimate (surface)



Zone 2 @ LA1

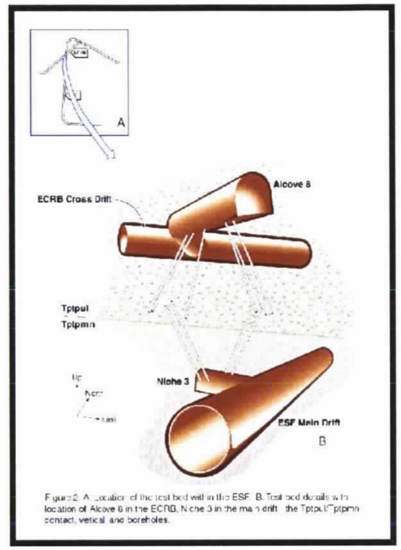
Flux from pan: 3mm/day
Largest wetted area: 4.6 m^2

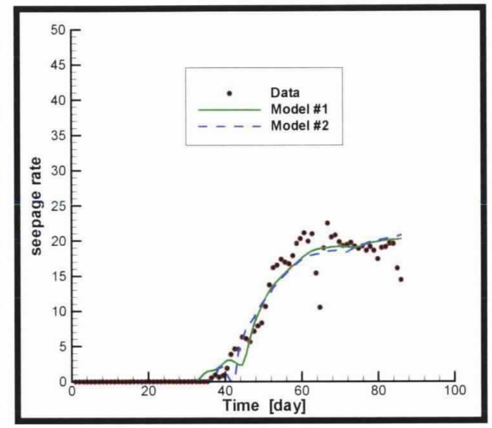
Estimated surface evaporation rate: 9.5 ml/min

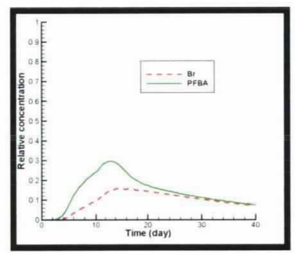


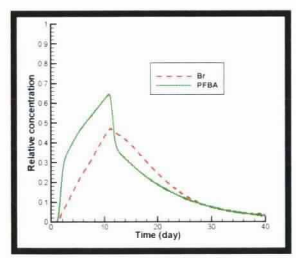
Alcove 8 / Niche 3 Matrix Diffusion

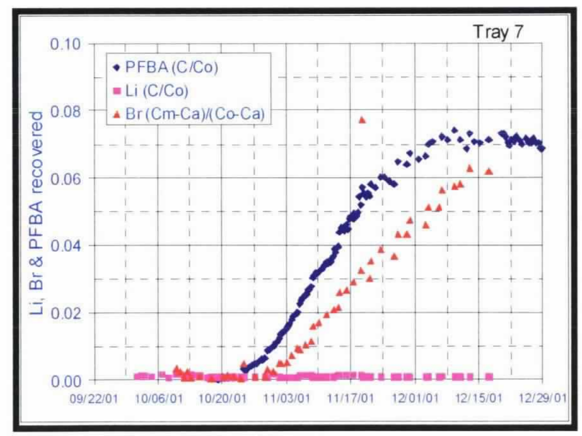
- **Modeling Approach**
  - Dual-permeability models for the fault connected to fracture network (Model #1) or with fracture network ignored (Model #2)
- **Results**
  - Models matched the seepage data well
  - Different predictions were made for tracer breakthroughs from two models, due to differences in the matrix diffusion contributions of the fracture network





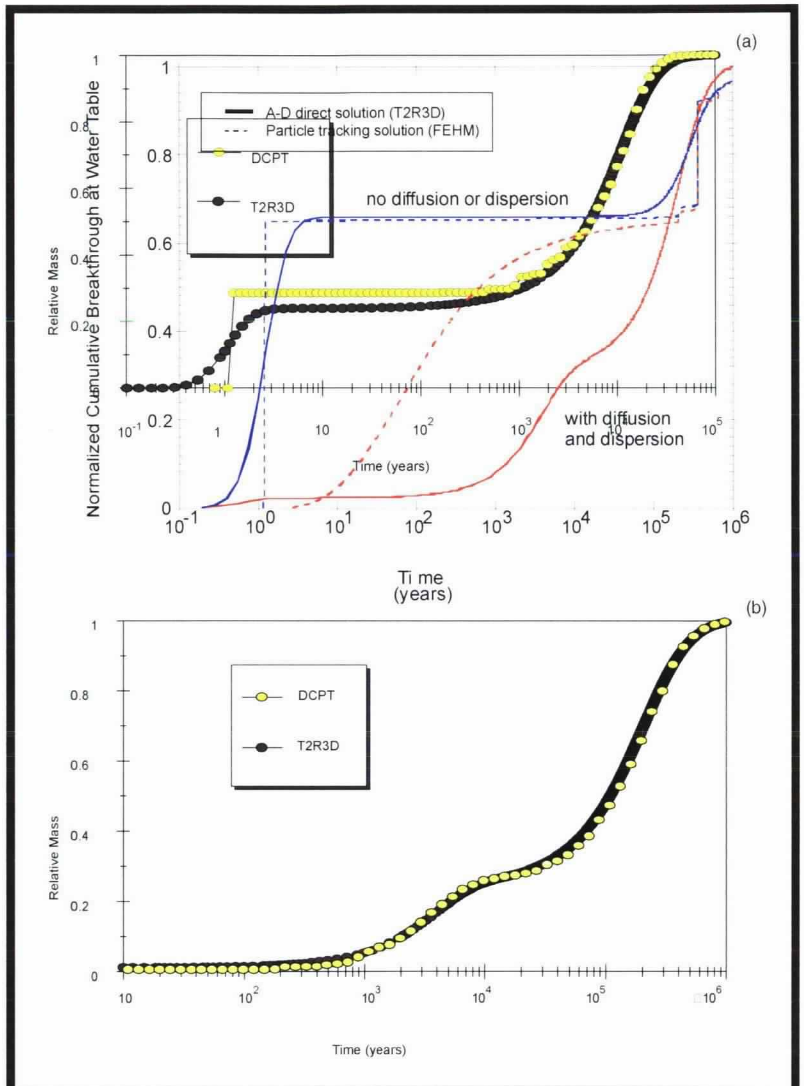






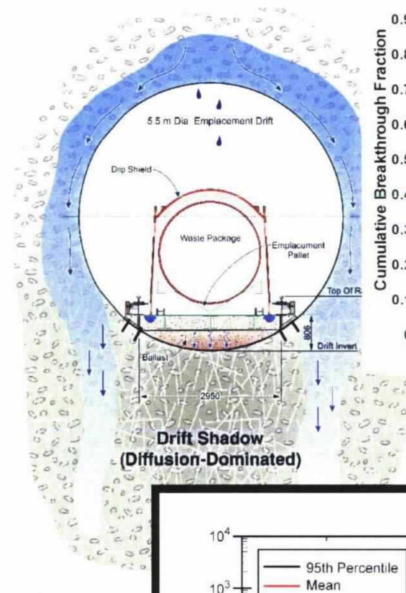
DCPT/FEHM Particle Transport

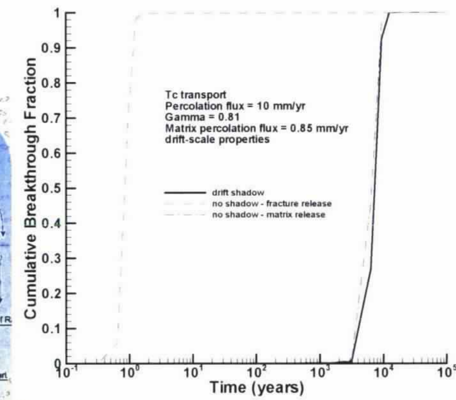
- **Modeling Approach**
  - FEHM uses dual-porosity matrix-diffusion model
  - DCPT uses random-walk particle method for a dual-continuum-particle-tracker
- **Results**
  - FEHM may be non-conservative at early- and late-times, conservative at mid-breakthroughs
  - DCPT matched T2R3D dual-K results (Water Resources Res. accepted 2002)
  - Currently we are evaluating a path forward with a realistic transport model for Performance Assessment

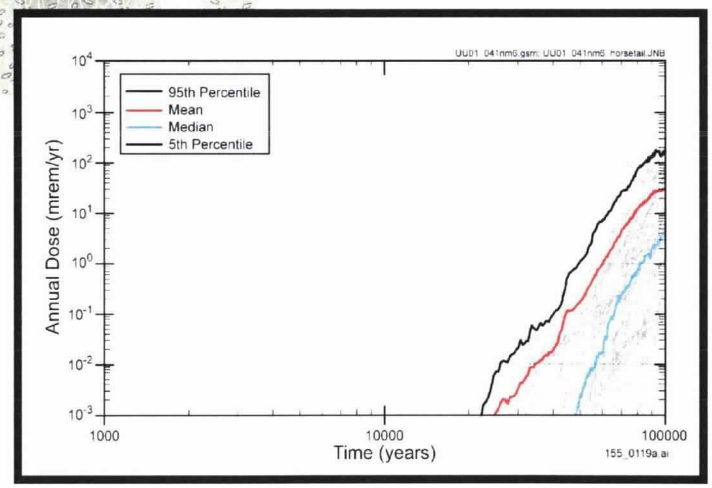


Radionuclide Transport from the Emplacement Drifts (Shadow Zone)

- Drift shadow zone formed by seepage diversion
- Matrix flow below drift for seepage-free drifts
- Delays transport by 10,000 years or more from base case
- This performance enhancement needs verification



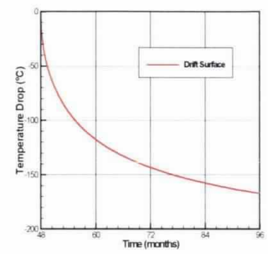


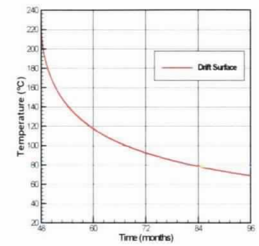


Drift Scale Test Cool-Down

- **Modeling Approach**
  - DST model calibrated with four-year heating phase data
  - Predictions will be compared during the cool-down phase
- **Results**
  - After two years of cooling, all locations are predicted to decline below 100°C
  - After over one year of cooling, fracture saturations in the air-K test zones are predicted to return to ambient values
  - Matrix saturations (geophysical measurements) are predicted to remain almost unchanged through the cooling cycle (4 years)

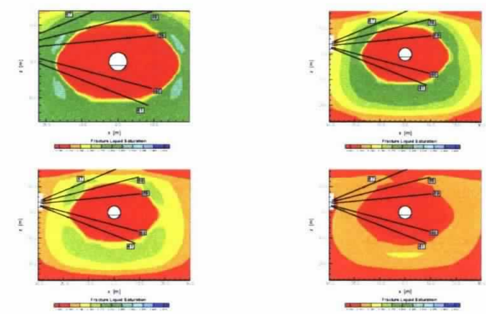
Temperature Decline





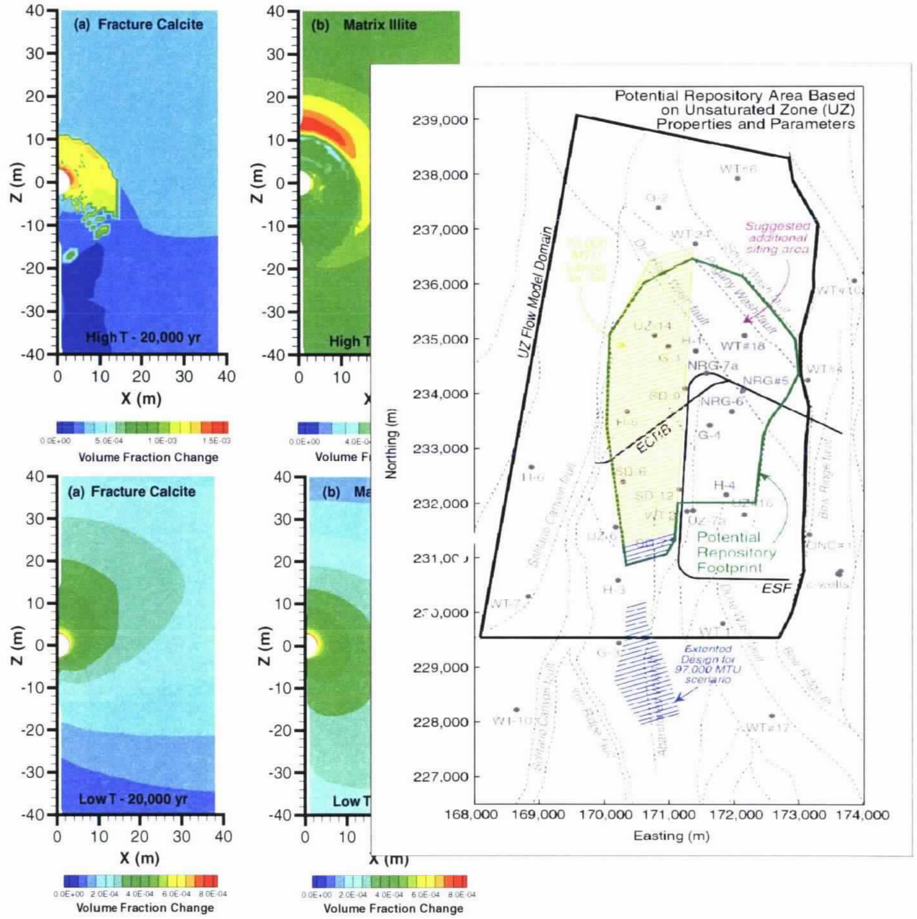
- After one year of cooling, drift surface temperature drops by 120°C, after two years the drop is 140°C.

Fracture Liquid Saturations During Cooling: 48 (Top Left), 51 (Top Right), 54 (Bottom Left) and 60 m (Bottom Right)



High- and Low-Temperature (T) Comparison

- **Modeling Approach**
  - Detailed THC model for seepage chemistry and in-drift Waste Package/Engineered Barrier System conditions
- **Results**
  - Both high-T and low-T cases have no extreme pH or salinity values, and small porosity changes
  - High-T has low probability of seepage during thermal period
  - Low-T has less thermal-hydrologic, THC uncertainties, higher probability of seepage, and needs larger repository footprint
  - THC sealing in multiple fractures is uncertain



Concluding Remarks

- The approach of testing and associated modeling is key element in realistically assessing the Yucca Mountain performance
- Moisture redistribution by temperature variation is shown to be an important process affecting drift conditions
- Radon evolution by barometric pumping validates bulk k estimate
- Seepage suppression by ventilation is being quantified for testing in lower lithophysal unit
- Matrix diffusion, matrix-matrix interaction, and drift shadow greatly delay transport through the UZ
- Coupled processes continue to be evaluated with the DST; THC sealing effects will be evaluated for multiple fractures