Effect of cyclic, sporadic, or episodic processes on evolution of environments in a repository in Yucca Mountain

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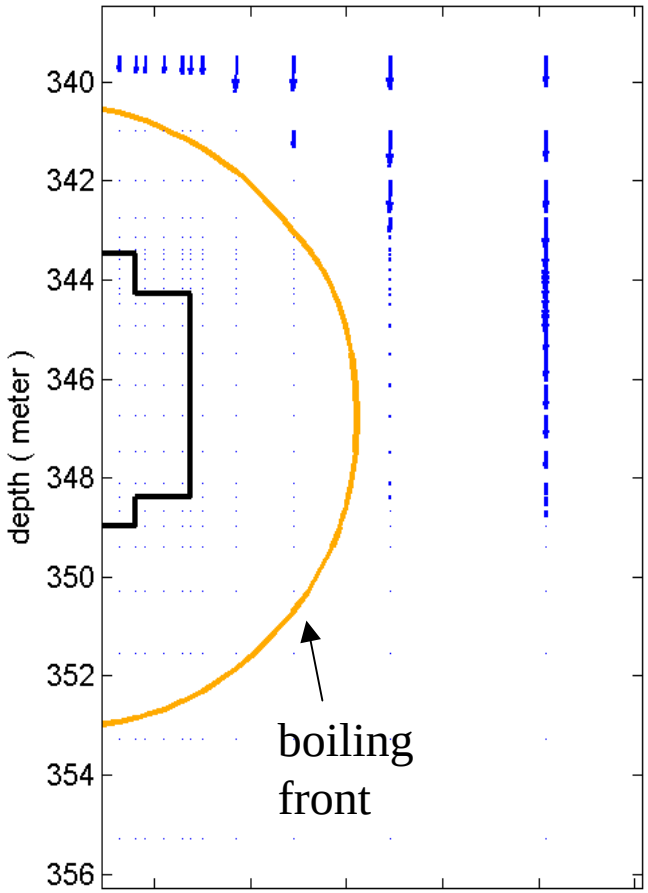
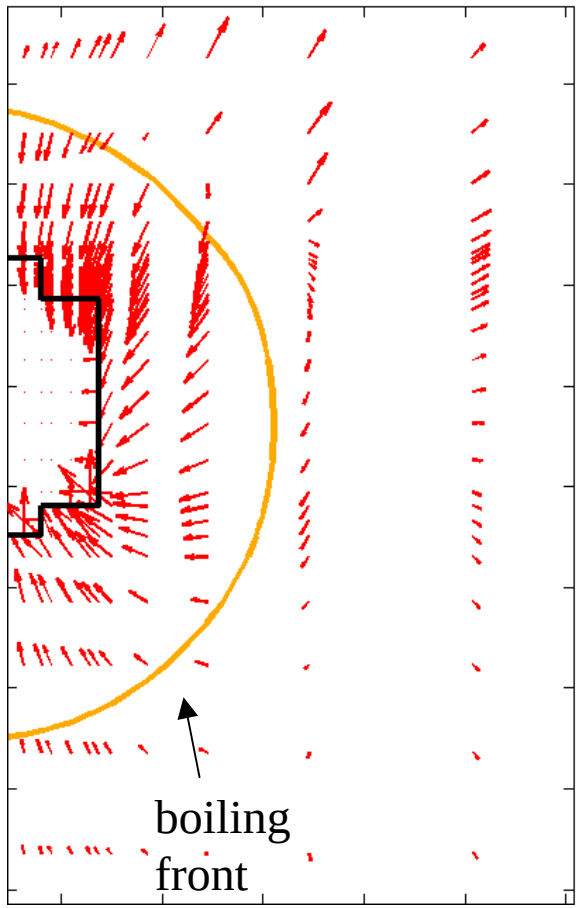
Multiflux Predictions

- Multiflux: developed by G. Danko, applied by Nye County
- Vapor transport dominates near field during thermal period
- Vapor in near field moves predominantly toward drifts
- Evaporation in hot drift sections and condensation at ends moves water towards cold edges
- Three time periods:
  - Drift Attractor (vapor transport toward drifts)
  - Transition
  - Lateral Diversion (drift shadow)

Radial Flux at 600 Years

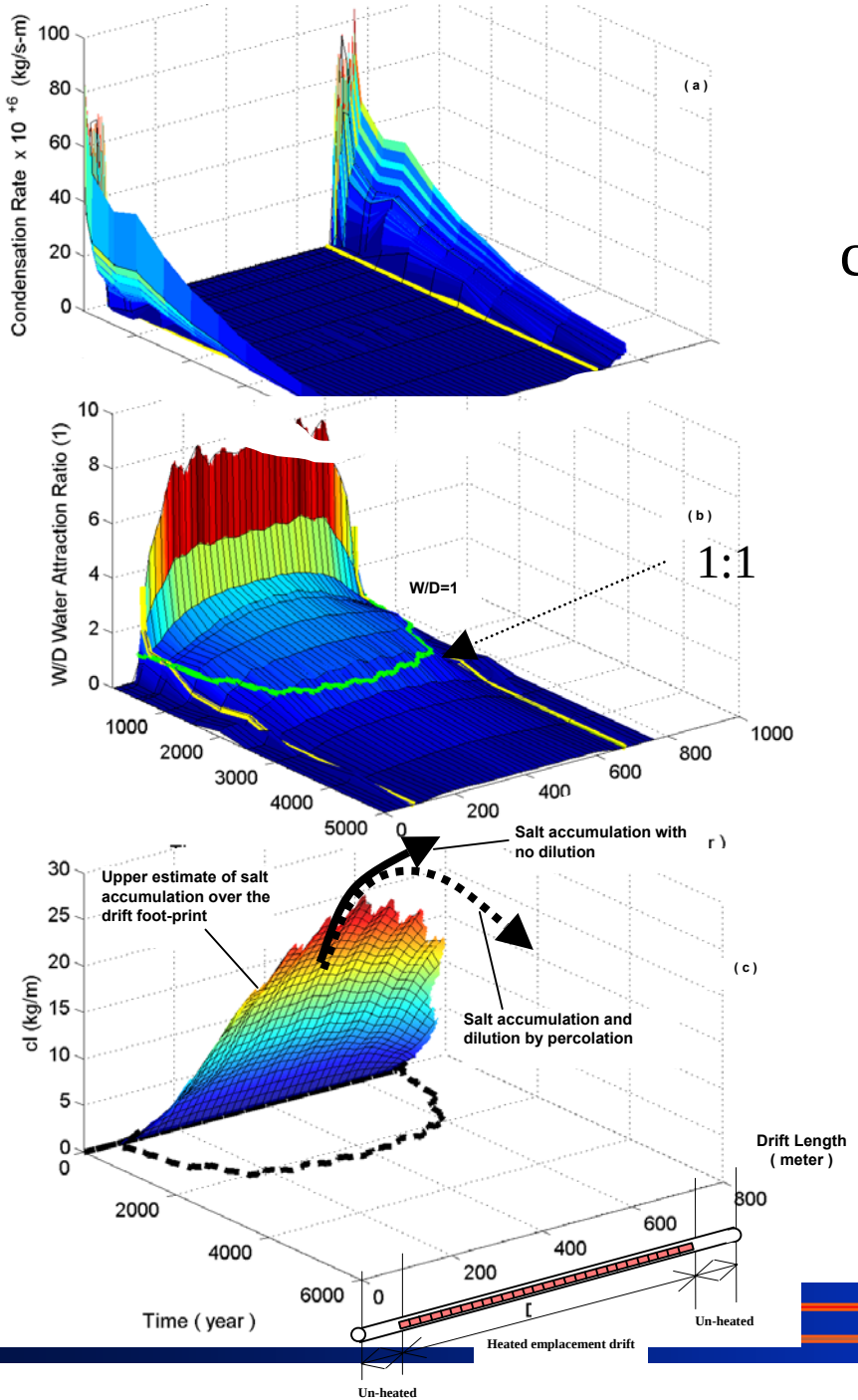


liquid



vapor

preliminary figures, for informational purposes only



condensation

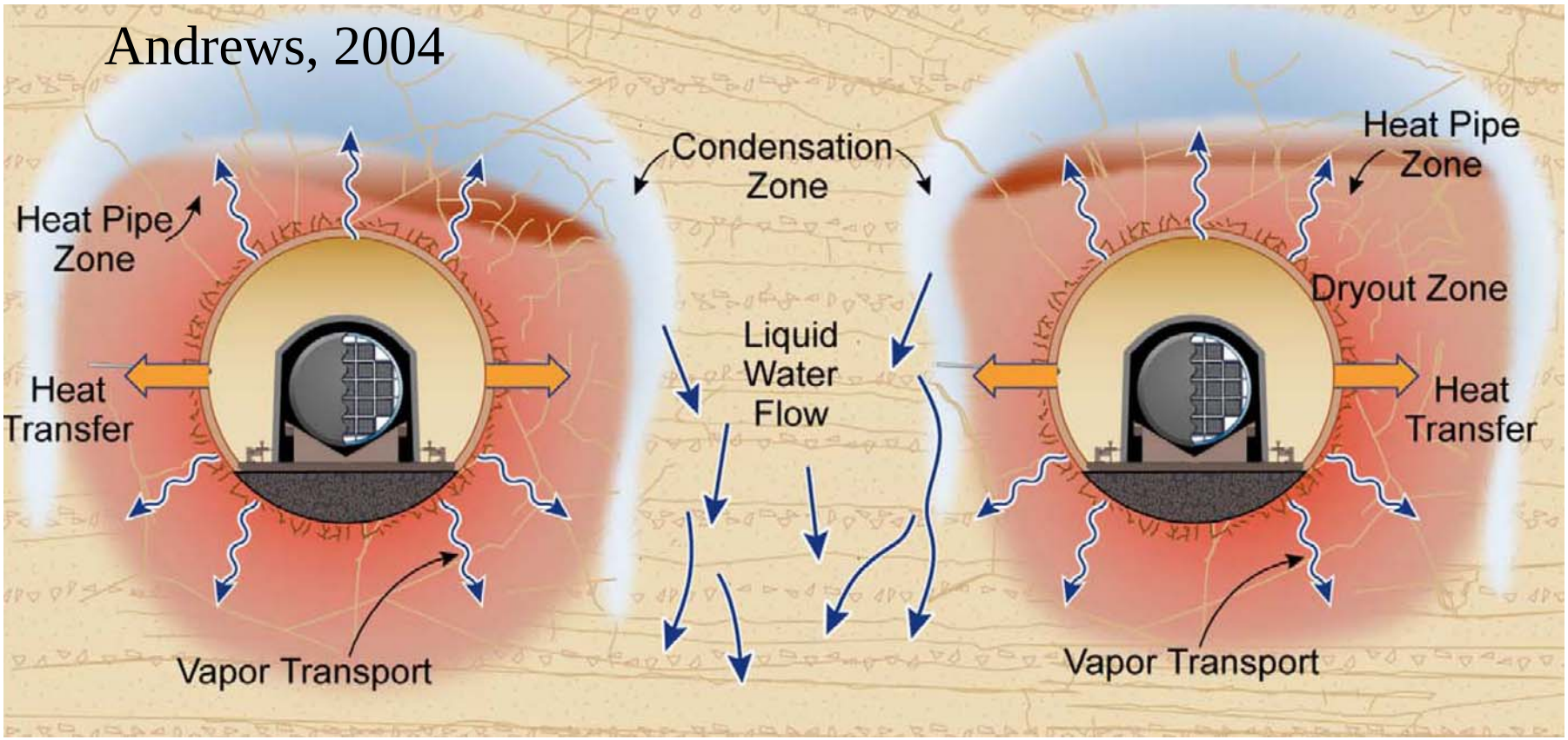
water attraction ratio

(vapor flux into drift / percolation over drift footprint)

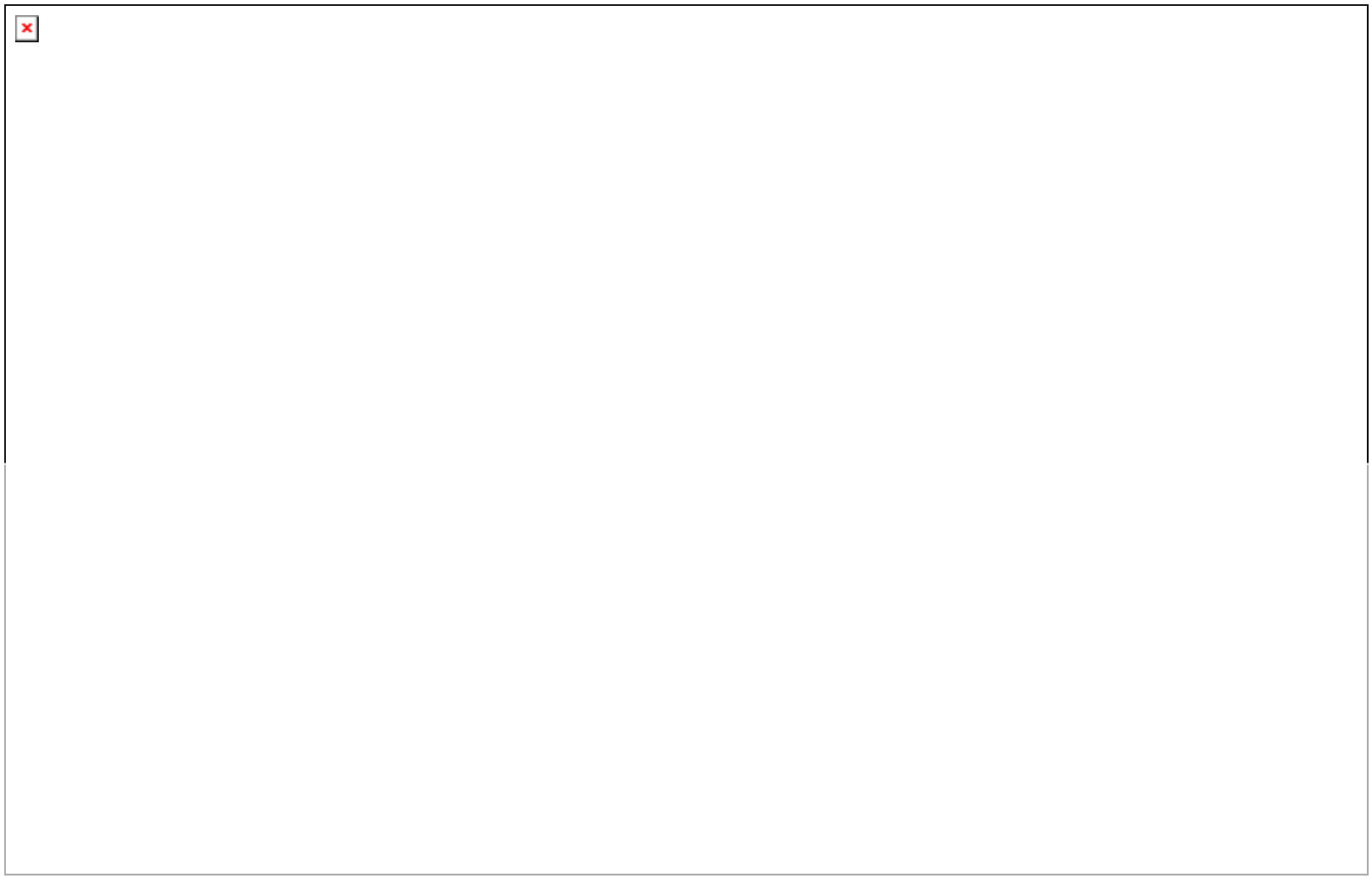
potential chloride accumulation in drift wall

preliminary figures, for informational purposes only

Historical Vapor Predictions – Now Reversed In Dryout Zone



Paradigm Shift



Early Time Flow System

- Water will flow through columns between drifts
- Net flux of water towards drift, mostly as vapor
- Thermal shedding does not occur since vapor flux through drift exceeds infiltration during thermal period
- Accumulation of salts in near field rock
- Length of drift attractor period depends upon design and water percolation assumptions

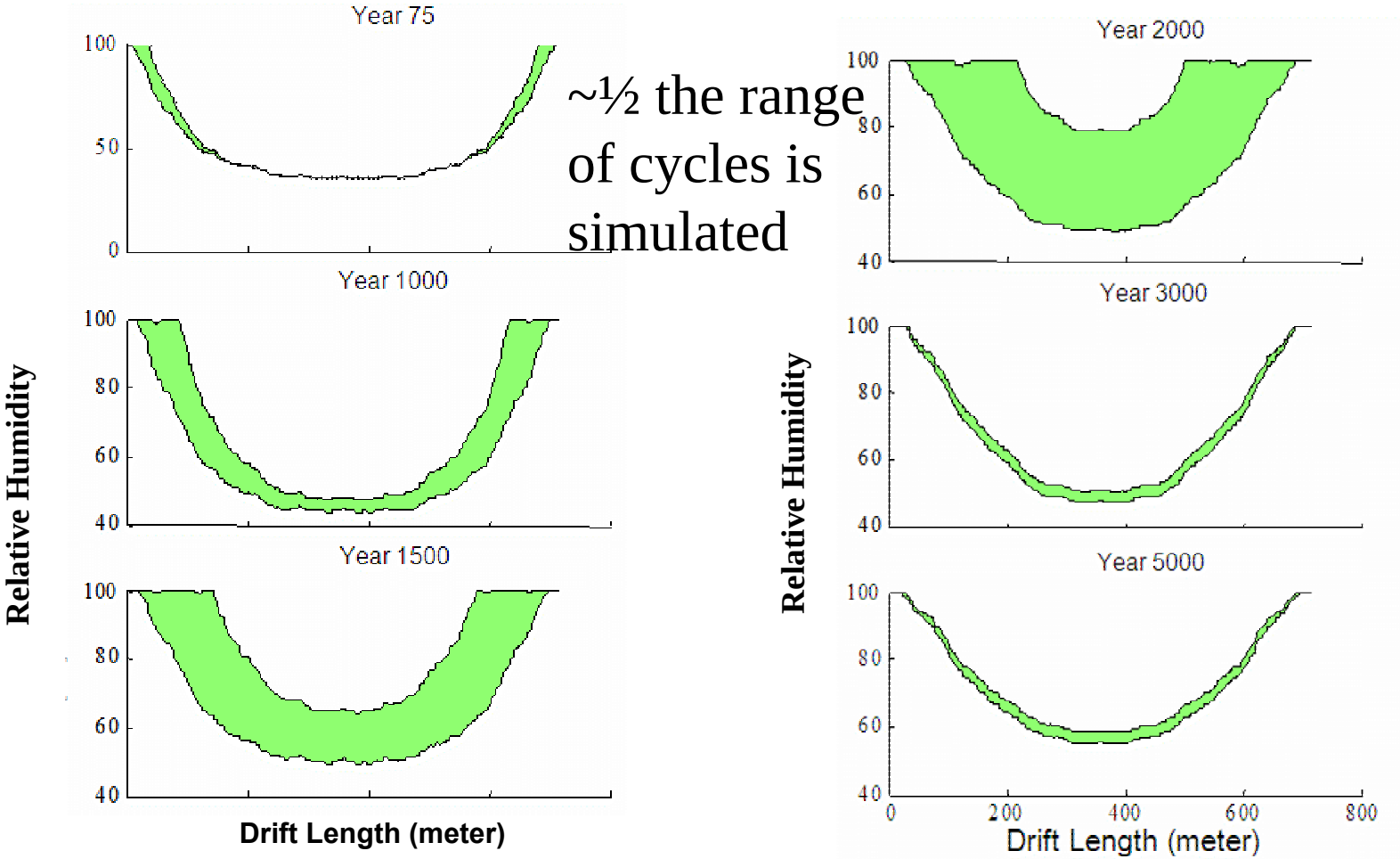
Barometric Pressure

- Extensive USGS well studies indicate pressure wave reaches repository
- Pressure wave propagation does not require large amount of air displacement
- Repository is more permeable than intact rock
  - disturbance of rock
  - access to fast pathways
- Changes in pressure cause changes in vapor flux

Barometric Pressure (cont)

- Flow direction shifts cause cycles in relative humidity
- Cycling of relative humidity leads to cyclical corrosion environment
  - alternating deliquescence and efflorescence (wet/dry)
  - alternating ionic strength
  - changing solution composition
  - changes in adsorbed water

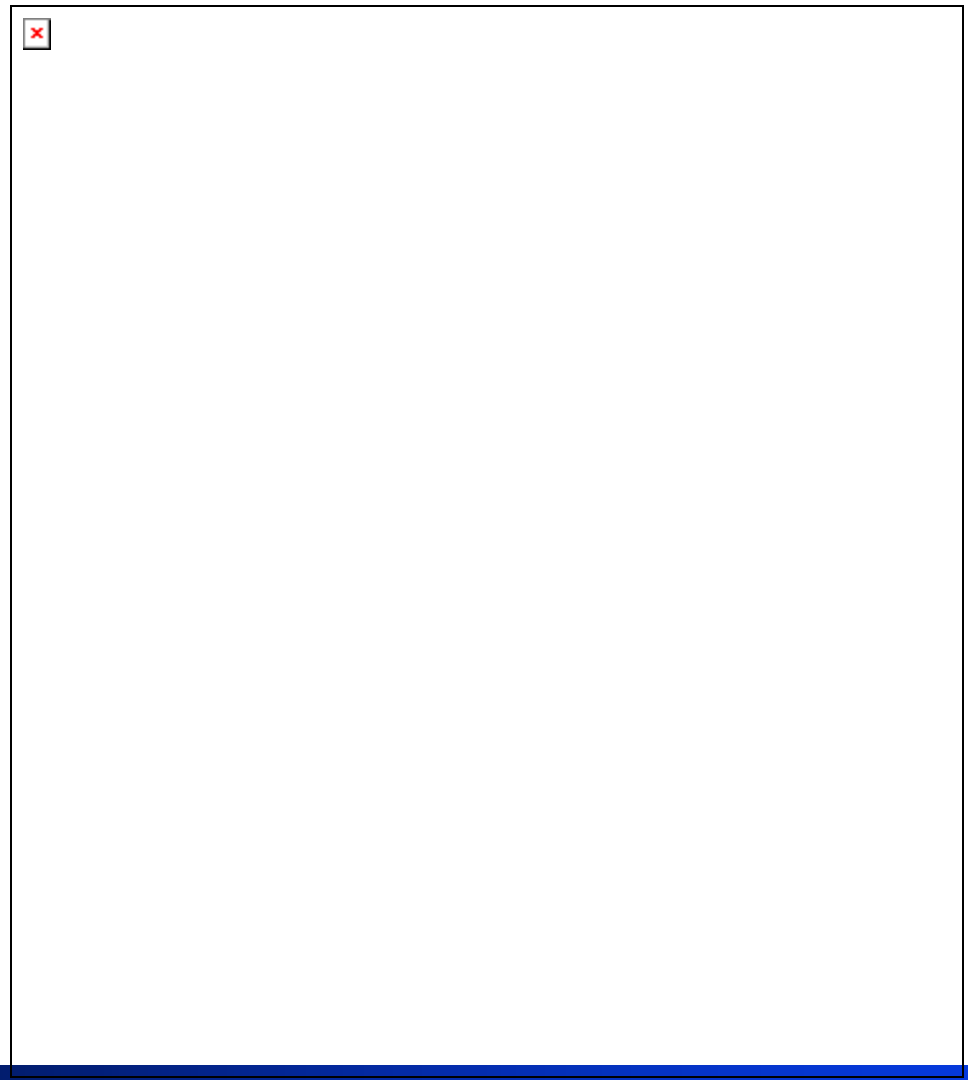
Barometric Pressure Response



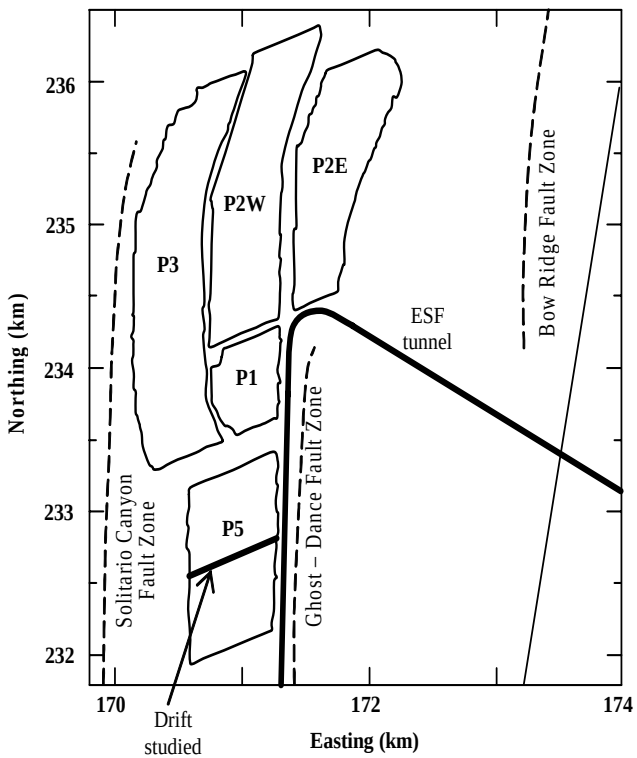
~½ the range of cycles is simulated

Source: Danko, G. and Bahrami, D., 2005. 'Coupled Hydrothermal-Ventilation Studies for Yucca Mountain.' Nye County Annual Report for April 2004-March 2005

Cyclical Corrosion Environment



Repository Scale Air and Vapor Circulation

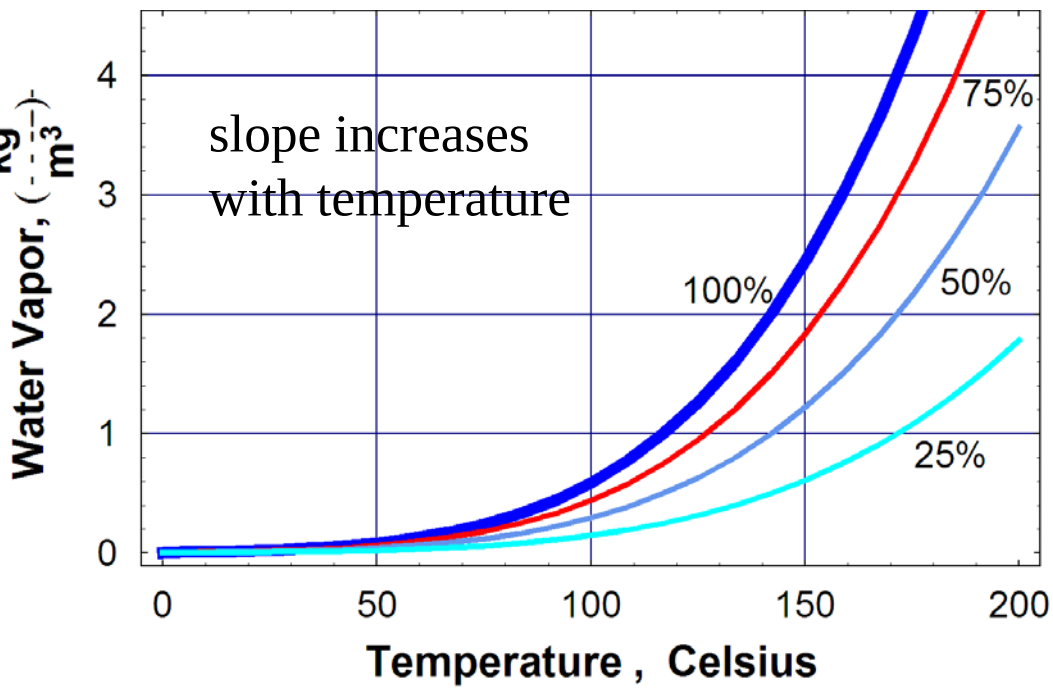


- Heterogeneous fractured system
- Permeability changes from excavation, drying, temperature changes, moisture redistribution, changes in seals
- Forcing functions: barometric pressure, temperature gradients, u-tube circulation
- Large “lung” with a very complex breathing pattern

Above Boiling Repository System Dynamics

- **Convection systems**
  - **Mountain Scale: down and up fault systems**
  - **Repository Scale: through fracture systems or connecting drifts**
  - **Drift Scale: center to ends of drifts**
  - **Waste Package Scale: hot to cold waste packages**
- **Barometric pressure**
  - **cyclic flows into and out of rock**
  - **along drift and cross drift barometric pressure driven flow (air permeability is heterogeneous)**
- **Different time constants means overall system behavior is transient rather than stationary state**
- **Time constant ~hours or days rather than ~decades**

System Dynamics Depend Upon Temperature



- Vapor transport driving force is ∇ vapor pressure
- Axial vapor transport opposite to relative humidity gradient
- Non-linearity of vapor pressure curve accentuates temporal variability in an above boiling repository
- Lower temperature repository = less dynamic, more predictable

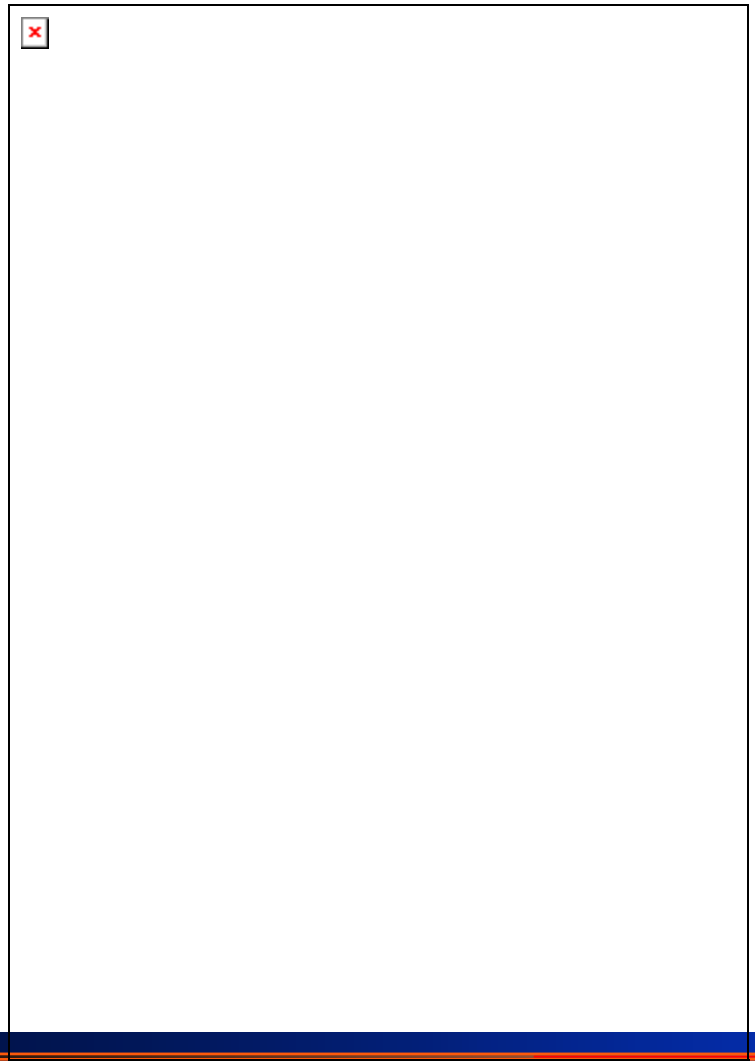
Coupling of C↔H stronger than previously anticipated

- Vapor transport into drifts means greater salt accumulation in rock
- Cool down leads to deliquescence and mobilization of salts
- Dripping will depend upon strongly coupled C↔H↔T processes
- Heavy reliance on drip shields to protect Alloy-22 from excess salt
- Heavy reliance on models rather than data

Flow Separation

- Nitrate and chloride not always mixed
- Present dust samples not necessarily representative of the future

Conceptual Evolution



- High solubility at end of flow path
- High solubility hydrates first
- Superimpose relative humidity fluctuations

Nitrate Reduction & Uptake

- **Nitrate reduction is likely to occur in some microenvironments**
- **Along rock bolts, Adjacent to steel mesh**
- **Oxygen solubility in water decreases with temperature, reaction rates increase**
- **“Even if some anaerobic microenvironments may exist in rock matrix, their impact on nitrate concentration has already been captured by the current water analysis.”**
- **Reference:** Evaluation of Potential Impacts of Microbial Activity on Drift Chemistry **ANL-EBS-MD-000038 REV 01**
- **Potential loss of inhibitory ions**
- **Do current conditions fully capture much more complex and different future conditions?**

Drip Shields

- Important to protect Alloy-22 from excess salt during thermal period
- Require that a future congress come up with large sums of hard cash to purchase the required titanium
- Will Congress be bound by a financial commitment from the distant past?
- Dichotomy: risk versus licensing
- Independent analysts must consider the probability that each barrier will actually be present when performing risk analyses
- P(risk reduction | drip shield) * P(drip shield) = ?

Assumed Percolation

Assumptions for baseline YM calculations:

- **0 – 600 years 12 mm/yr percolation**
- **600 – 2000 years 20 mm/yr percolation**
- **2000 – 5000 years 37 mm/yr percolation**
- **These numbers are:**
  - **plausible**
  - **arbitrary**
  - **important to predictions of the corrosion environment**
- **Assumption that infiltration increases over time leads to higher predicted relative humidity**
- **Past calculations have also underestimated drying processes (e.g., axial vapor transport in drift underestimated)**

Water Flux and Risk

- Alloy-22 corrosion issues related to concentrated solutions
- Concentrated solutions thermodynamically unstable at high relative humidity
  - concentrated solutions have lowered vapor pressure
  - moisture transport responds to the vapor pressure gradient thereby lowering the concentration
- High relative humidity thus protects against corrosion of Alloy-22
- Models and assumptions that over estimate moisture availability and relative humidity under estimate the size of the vulnerability window for Alloy-22 localized corrosion

Conclusions

- After 20^{+} years of study by outstanding scientists the predicted primary direction of near field vapor movement has reversed
- Corrosion environment is dynamic, periodic, and poorly understood
- Coupling of C↔H stronger than previously anticipated
- High reliance on drip shields
- Limited testing data on environment under repository relevant conditions
- Limited corrosion testing under repository relevant (periodic/dynamic) conditions
- ***Perhaps we should be more humble concerning our ability to predict conditions in an above boiling repository?***