*Nye County Department*
*of Natural Resources and Federal Facilities*

# Alternate Conceptual Models for EBS Water Chemistry and Performance

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**Nuclear Waste Technical Review Board**
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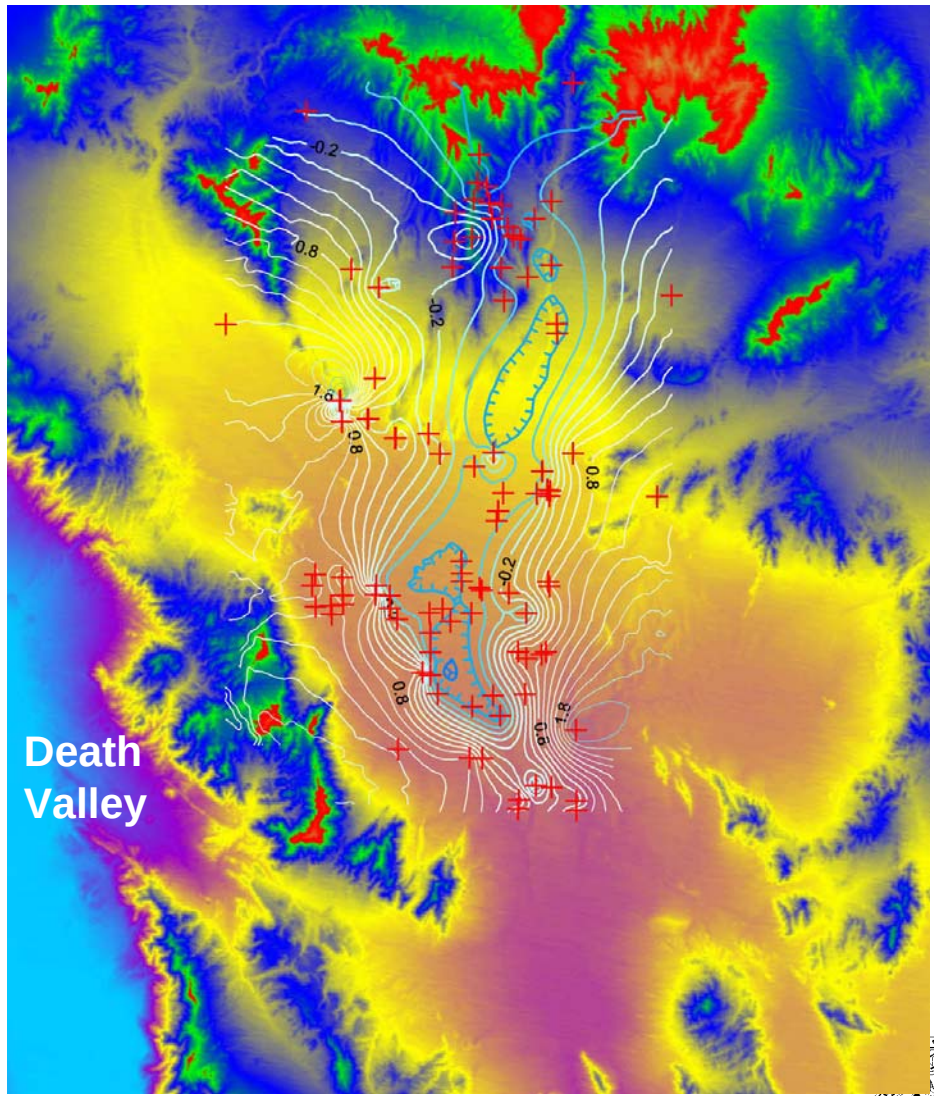
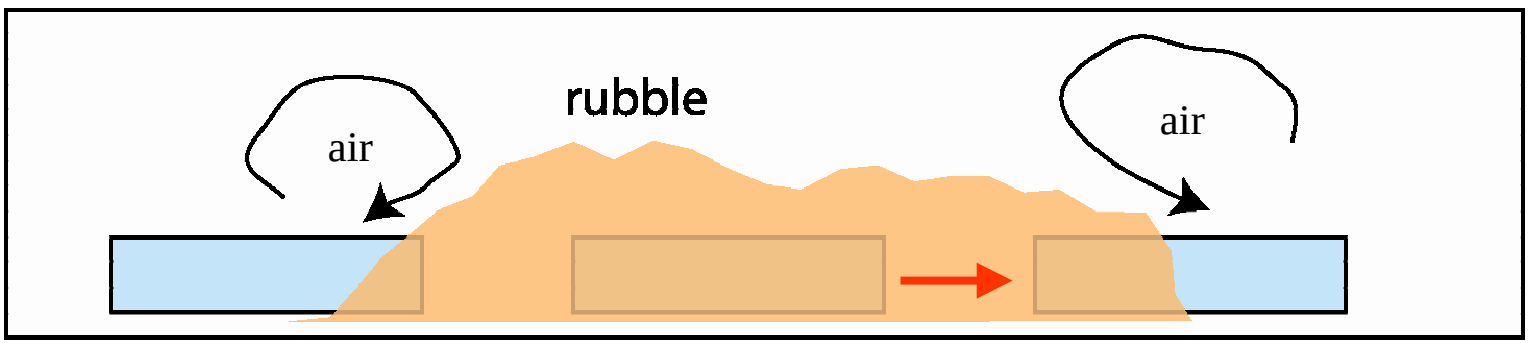
# Outline

- Review of physical processes affecting wetting and water chemistry. How does it change in the near field?
- Alternate conceptual model for EBS water chemistry based upon physical separation of soluble salts.
- Performance credit for partially failed waste packages.



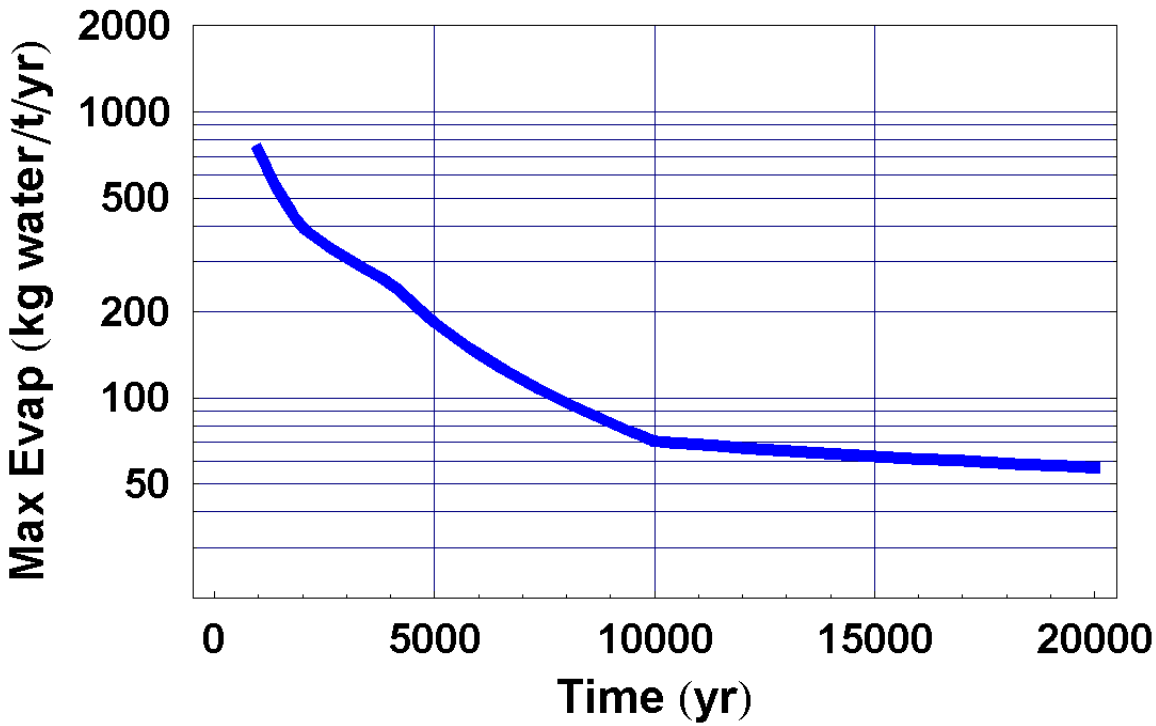
# Evaporation and Condensation

- Evaporation and condensation work at many scales.
  - Repository, drift, waste package, inside failed waste package.
- Rubble may cause sustained temperature gradients and/or elevated temperatures.
  - $k_{rock}$ ~ 2 W/m/C
  - $k_{soil}$ ~ 0.15 W/m/C
  - $k_{rubble}$ = ?
  - $k_{corrosion\ products}$ = ?
- Temperature drops proportional to thermal conductivity and heat generation rate.
- When convection is considered the repository becomes more heterogeneous and condensation is anticipated to occur more frequently.

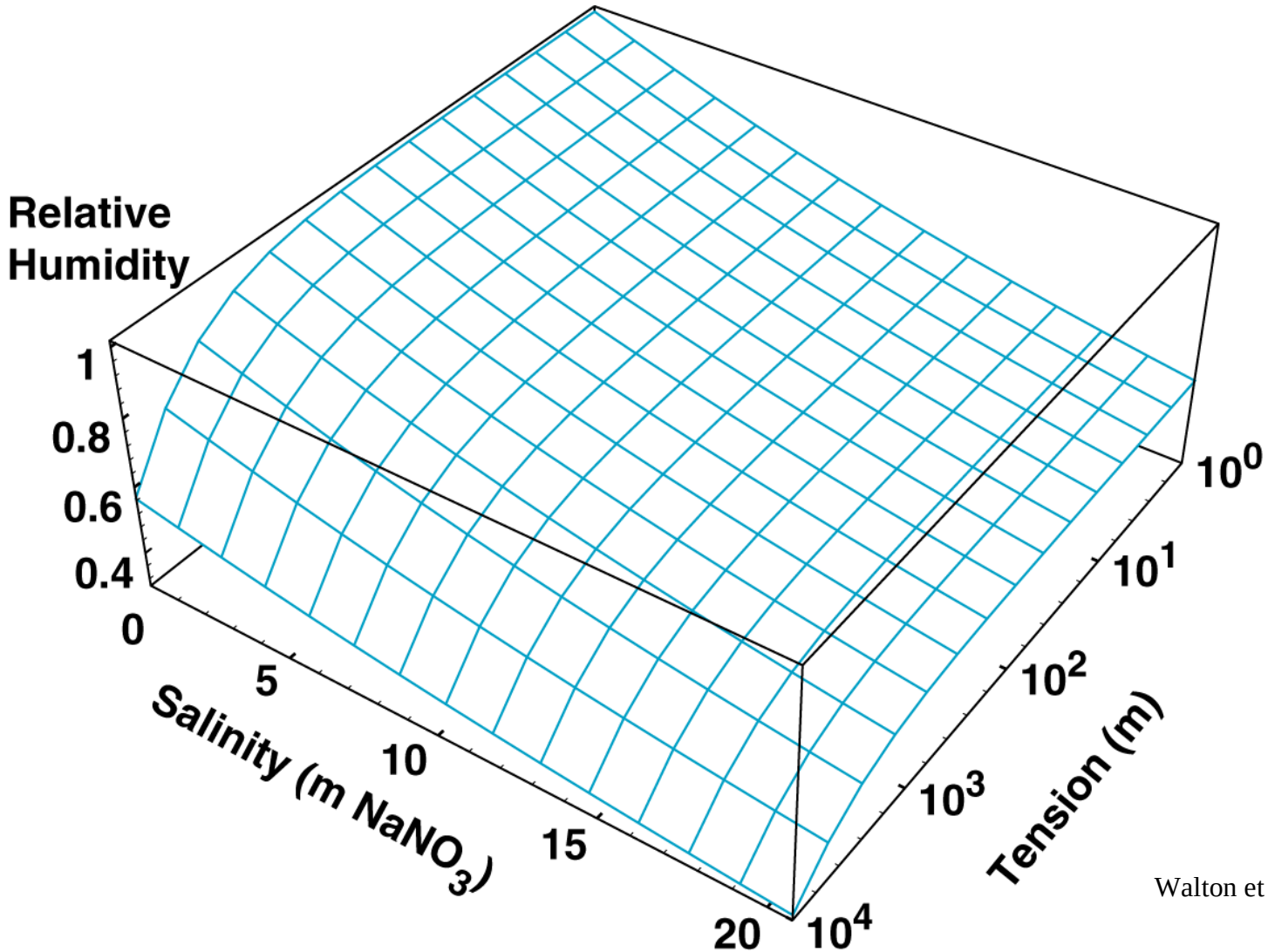


# Heat Generation Rate Divided by Latent Heat of Vaporization

- Heat generation extends indefinitely.
- Evaporation and condensation decrease with time but remain significant.
- Heat stored in rock remains important when ventilation is considered.



# Vapor Pressure: Solutes and Small Pores




Walton et al., 1994

# Alternative Conceptual Model for EBS Water Chemistry

- Many processes (physical, chemical, biological) may be important.
- Most not in codes and not in experiments.
- We have chosen to illustrate one physical process.
- Physical separation of soluble salts based upon differential solubility.

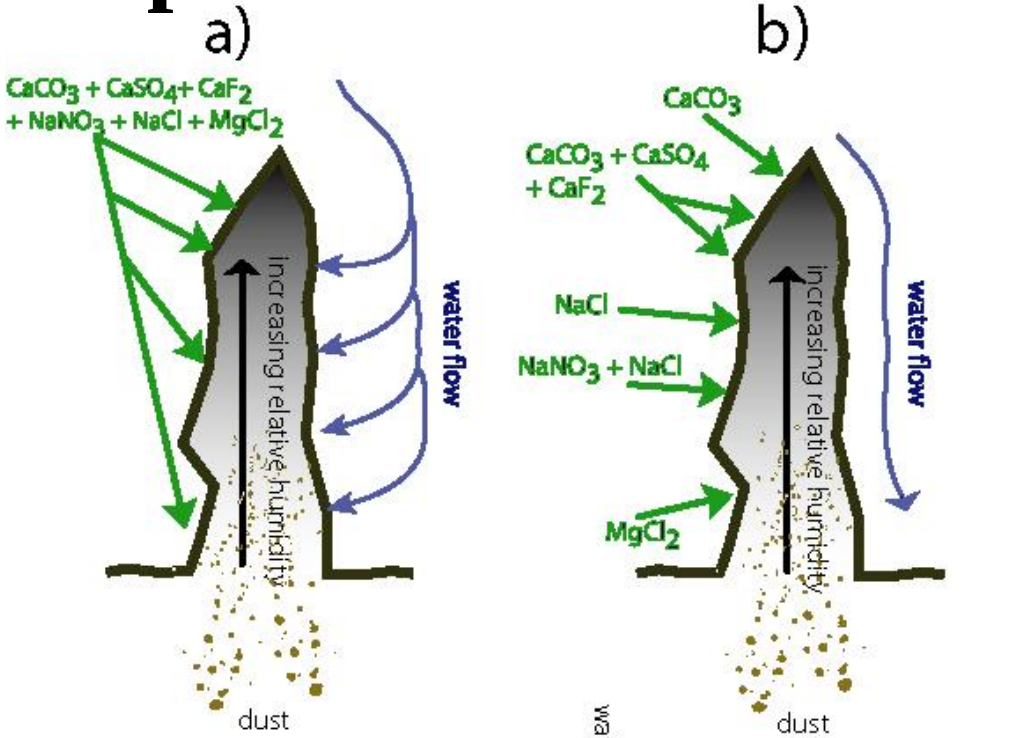
# Alternative Conceptual Model for EBS Water Chemistry (continued)

- Common in real world environments:
  - Playa deposits,
  - Near springs in arid regions.
- Water generally moves while evaporating.
- Lower solubility salts precipitate prior to more soluble salts, often at different locations.
- Deliquescence in cooling repository creates new aqueous solutions from the spatially separated precipitates.

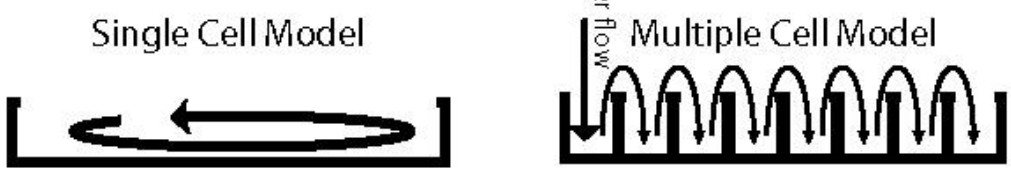
# Sidewalk Example

# Physical Separation in a Fracture

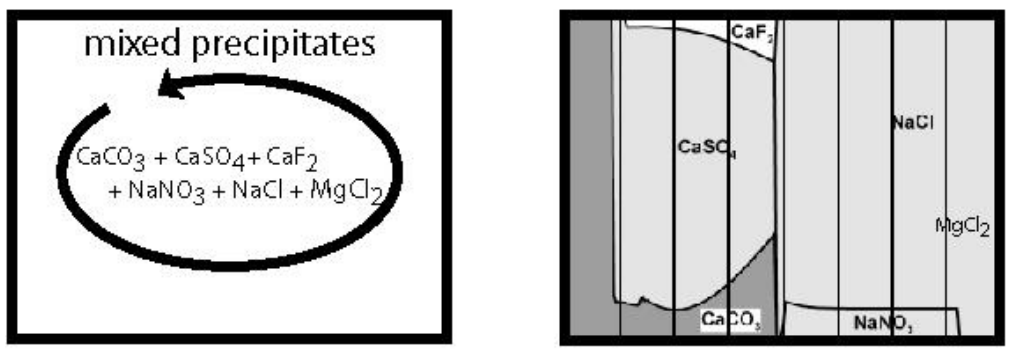
conceptual model



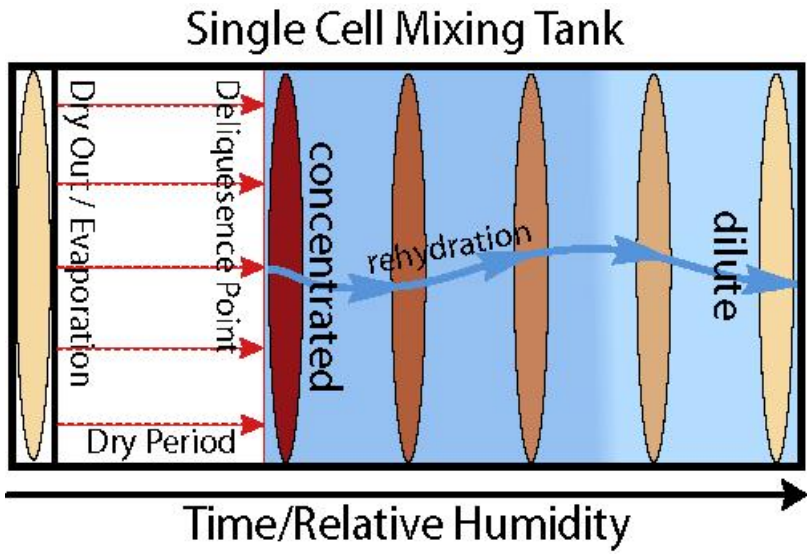

mathematical model

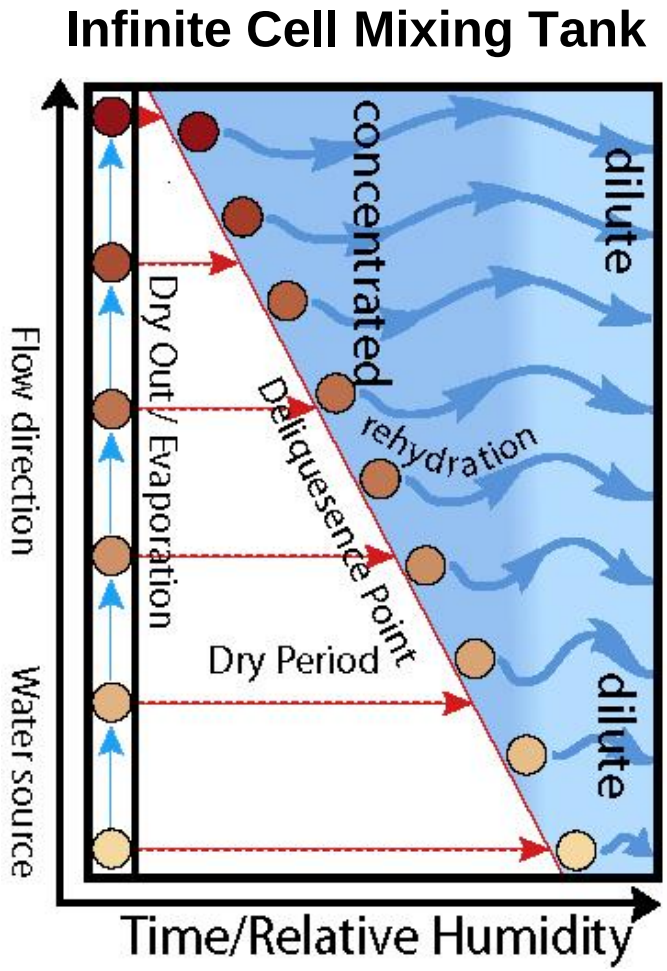



prediction



# Precipitation and Deliquescence



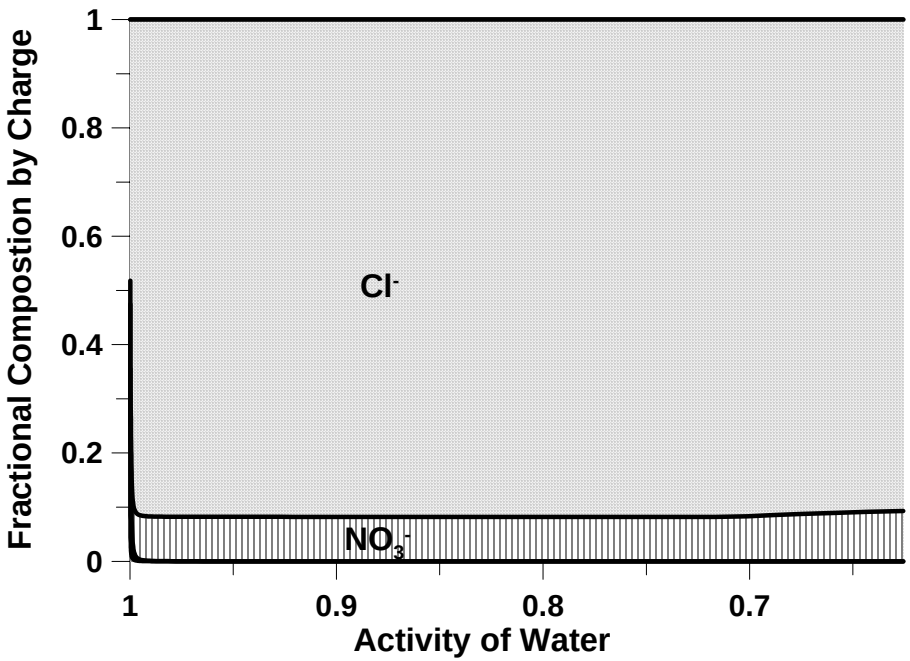



# Numerical Model Description

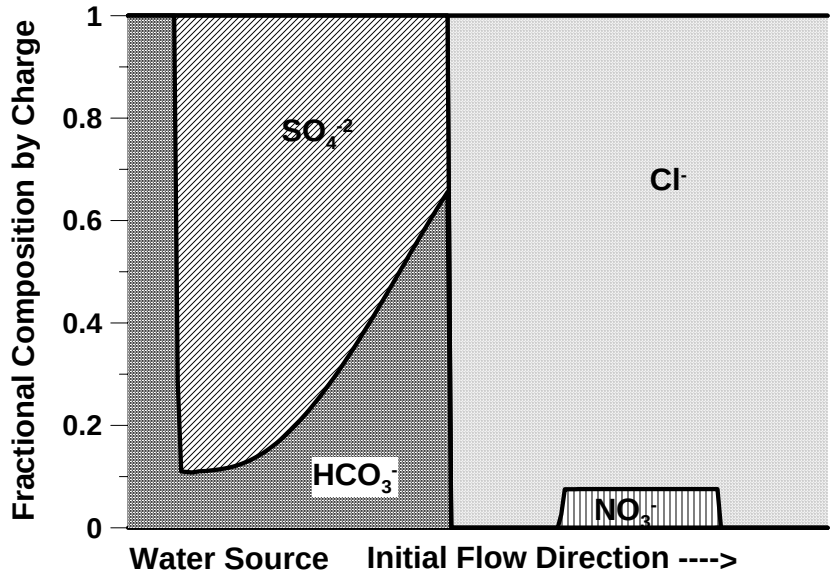
- Simple equilibrium model.
- Suitable for first look semi-quantitative analysis.
- Two endpoints:
  - Single mixing cell (no separation),
  - Infinite series of mixing cells (maximum possible degree of separation by this process).
- Reality likely to be intermediate and highly variable.

# Paintbrush Non-welded Tuff Pore Water

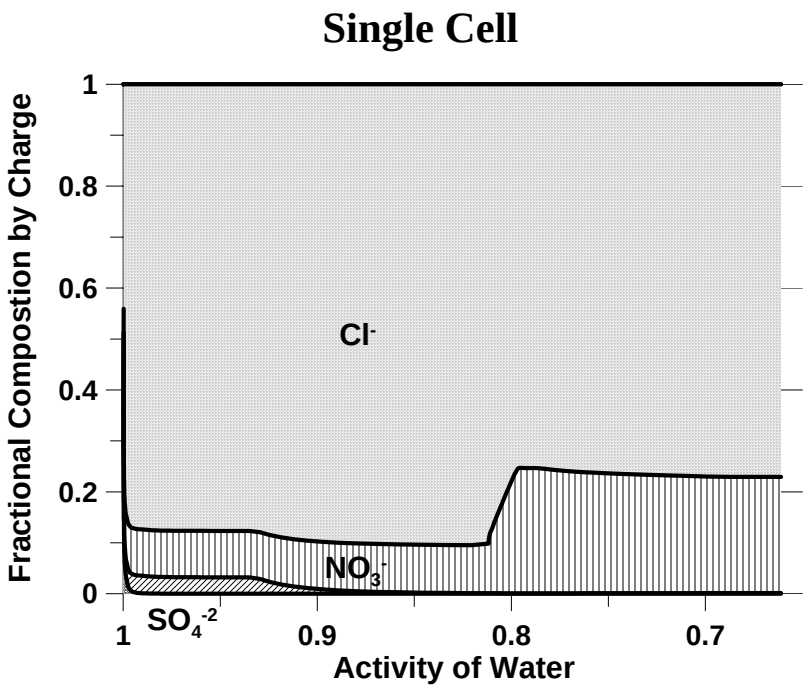
**Single Cell**

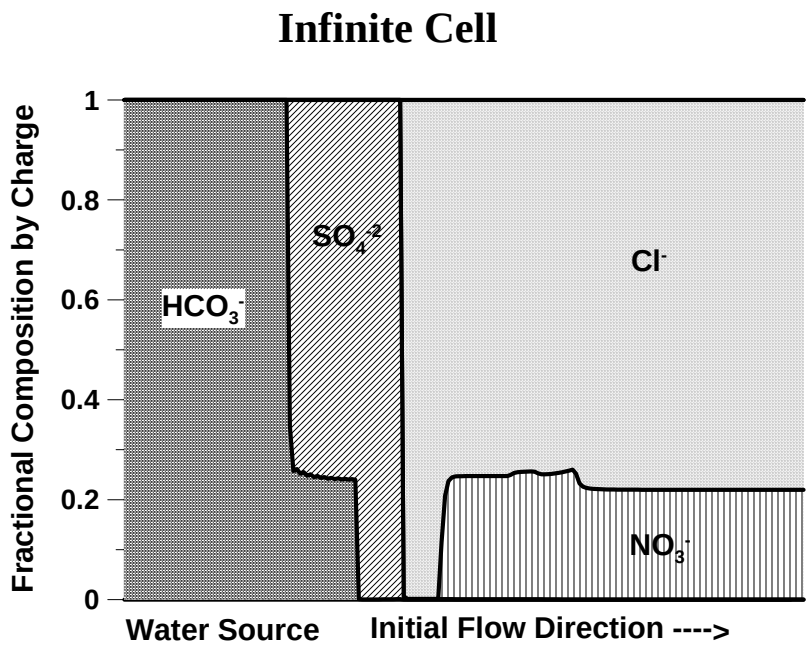



**Infinite Cell**



# Topopah Spring



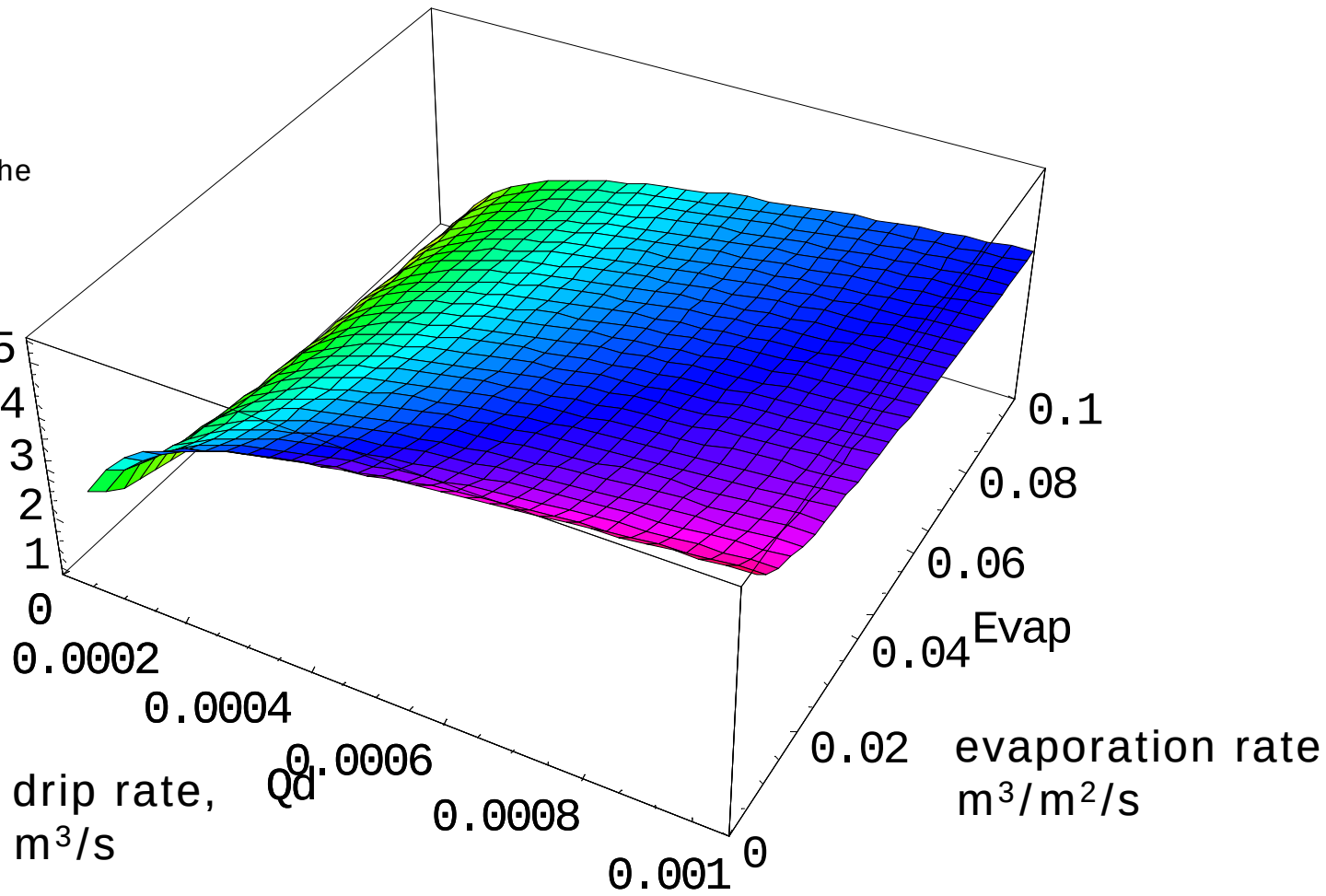
# Physical Separation: When will it occur?

- Diffusion equalizes concentrations as water moves.
- If diffusion > advection, no physical separation.
- Advection > diffusion conducive to physical separation.
- Derive and examine ratio of advective to diffusive transport (form of Peclet number) called separation factor.
  - Water film, function of drip rate, evaporation rate, film thickness.
  - Porous media, function of tension and constitutive properties.
- Calculations support likelihood of physical separation.

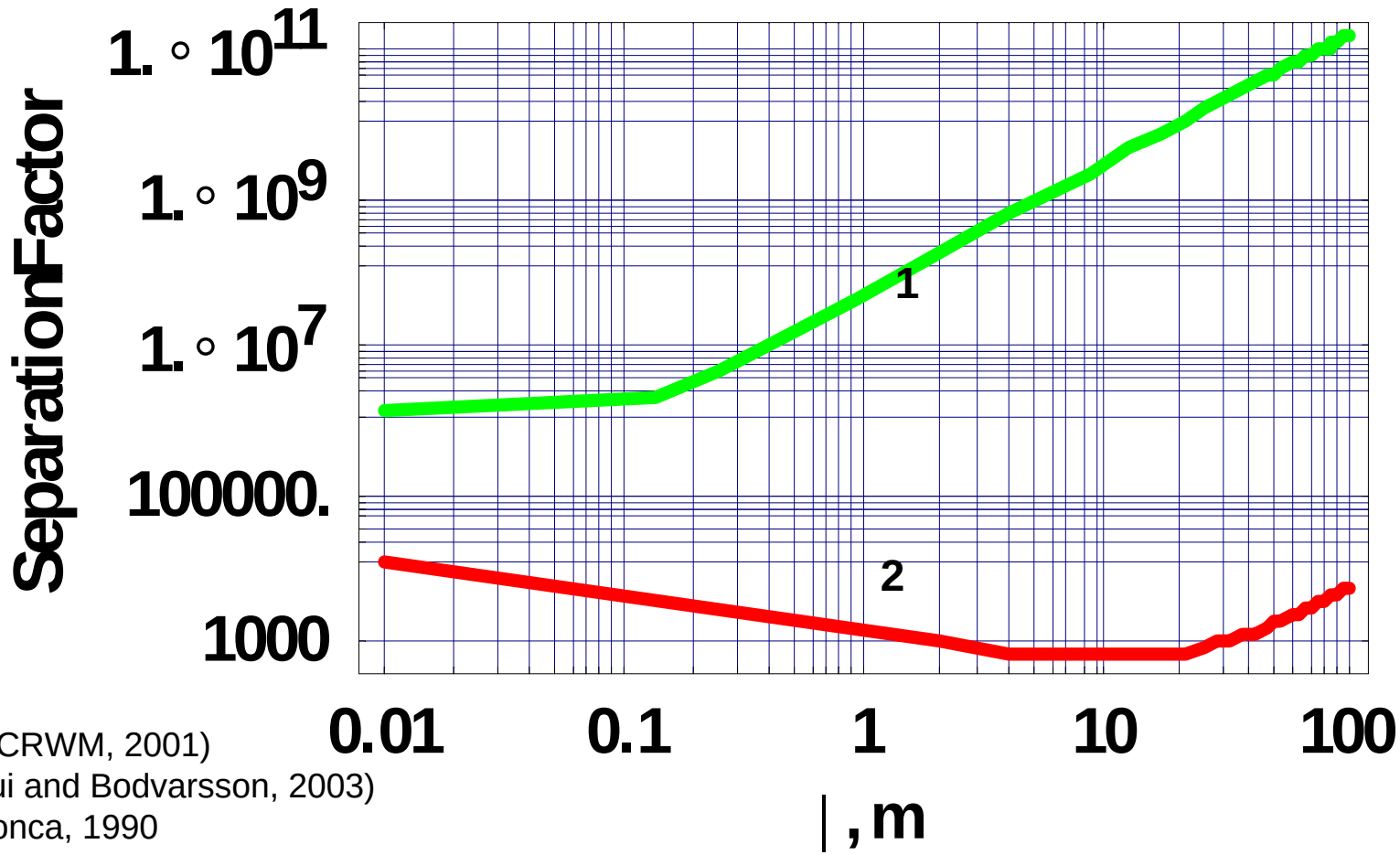
# Physical Separation in a Water Film

when drip rates are low the water “flashes off” a hot surface in one location giving little separation

a slower evaporation process gives more separation as long as the wetted area does not exceed the available surface area



# Porous Media: Two Examples

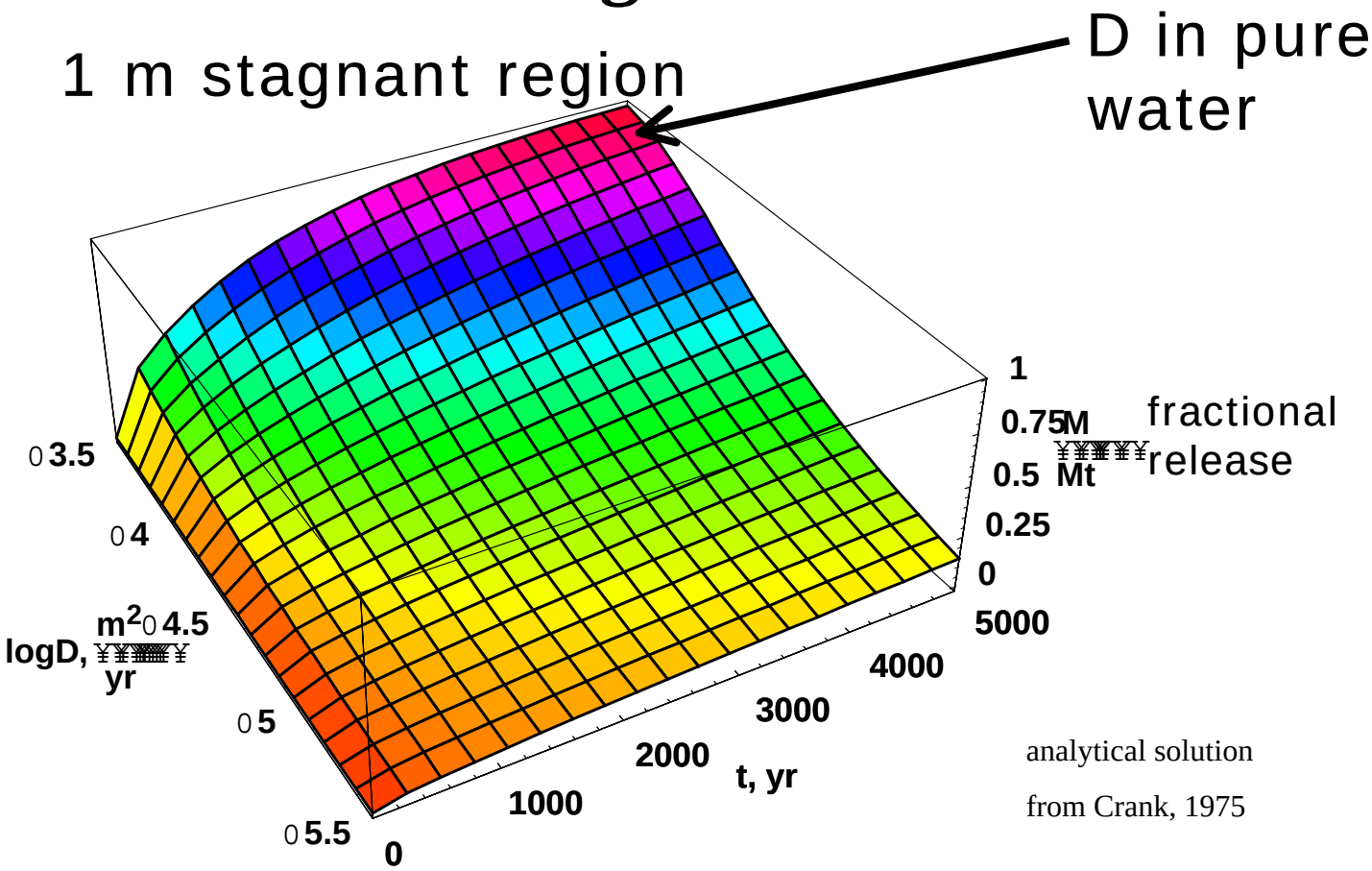



1.(OCRWM, 2001)
2.(Lui and Bodvarsson, 2003)
J. Conca, 1990

# Partial Waste Package Failure Credit – Simple Diffusion

- Localized waste package failures (aggressive solution) generally not aligned with seepage (generally less aggressive).
- Diffusion from stagnant zones out to advective transport areas.
- Example calculation without retardation.
- One meter region, analytical solution (Crank), variable effective diffusion coefficient.

# Diffusion from Stagnant Zones in Waste Packages

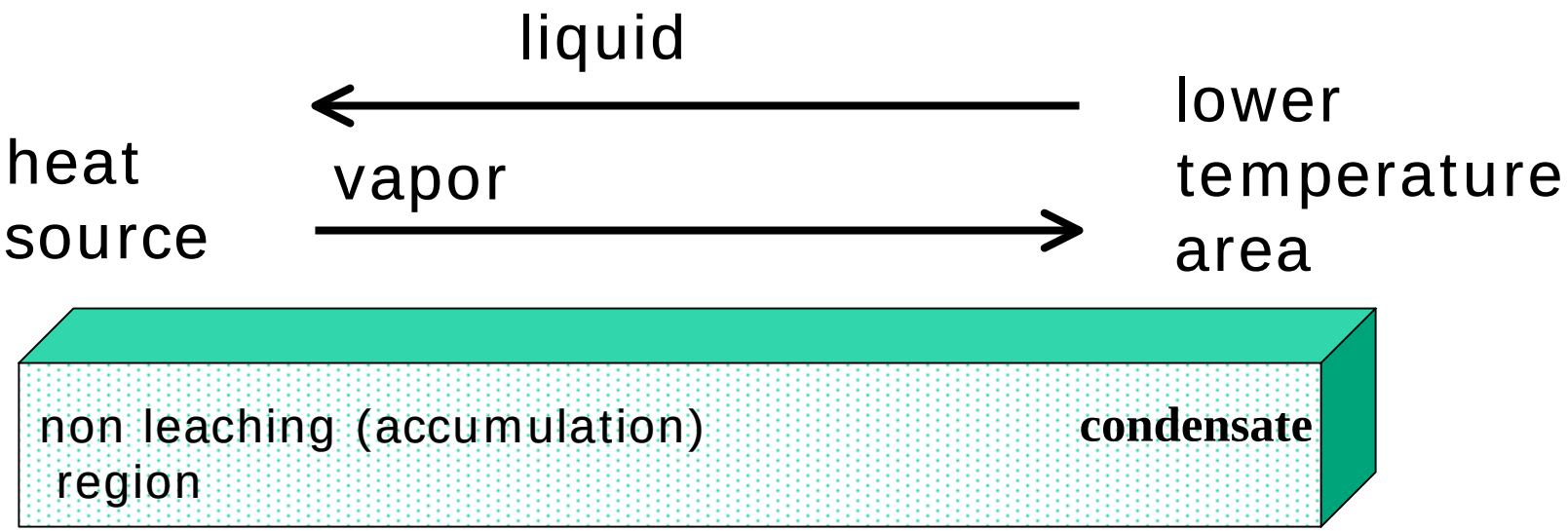



analytical solution

from Crank, 1975

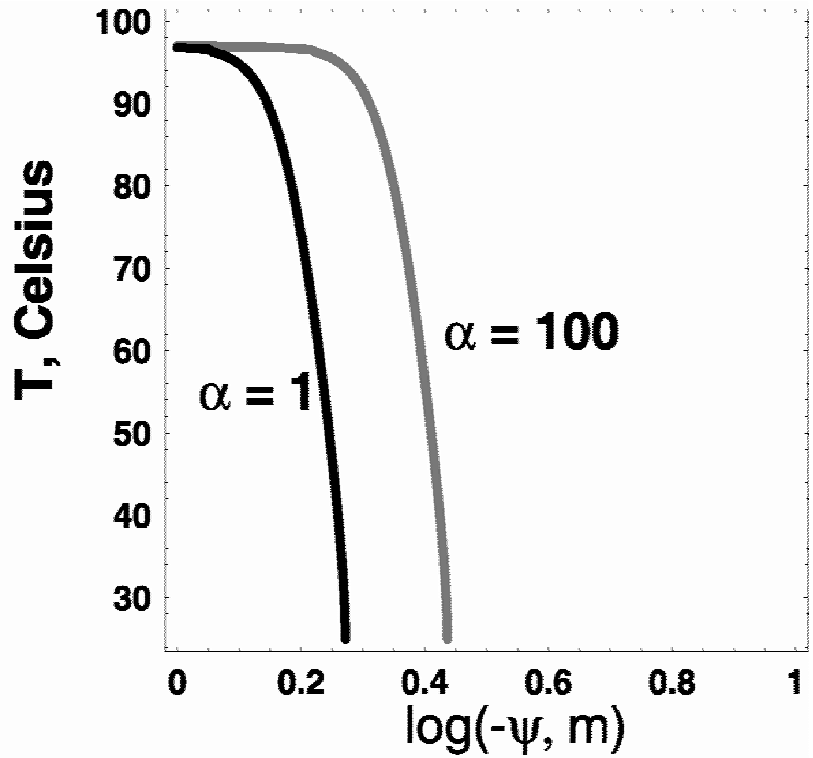
# Evaporation in Intact Areas of Failed Waste Packages

- Long term heat generation protects portions of the WP.



# Evaporation Protects Areas from Release

- $\alpha$ is the ratio of potential vapor diffusion to liquid advection.
- At $\alpha > 1$ liquid flow is towards the heat source.
- Effectively prevents liquid release.
- Assumes rubble and corrosion products have properties of sand.




Lichtner and Walton; CNWRA 94-022, 1994

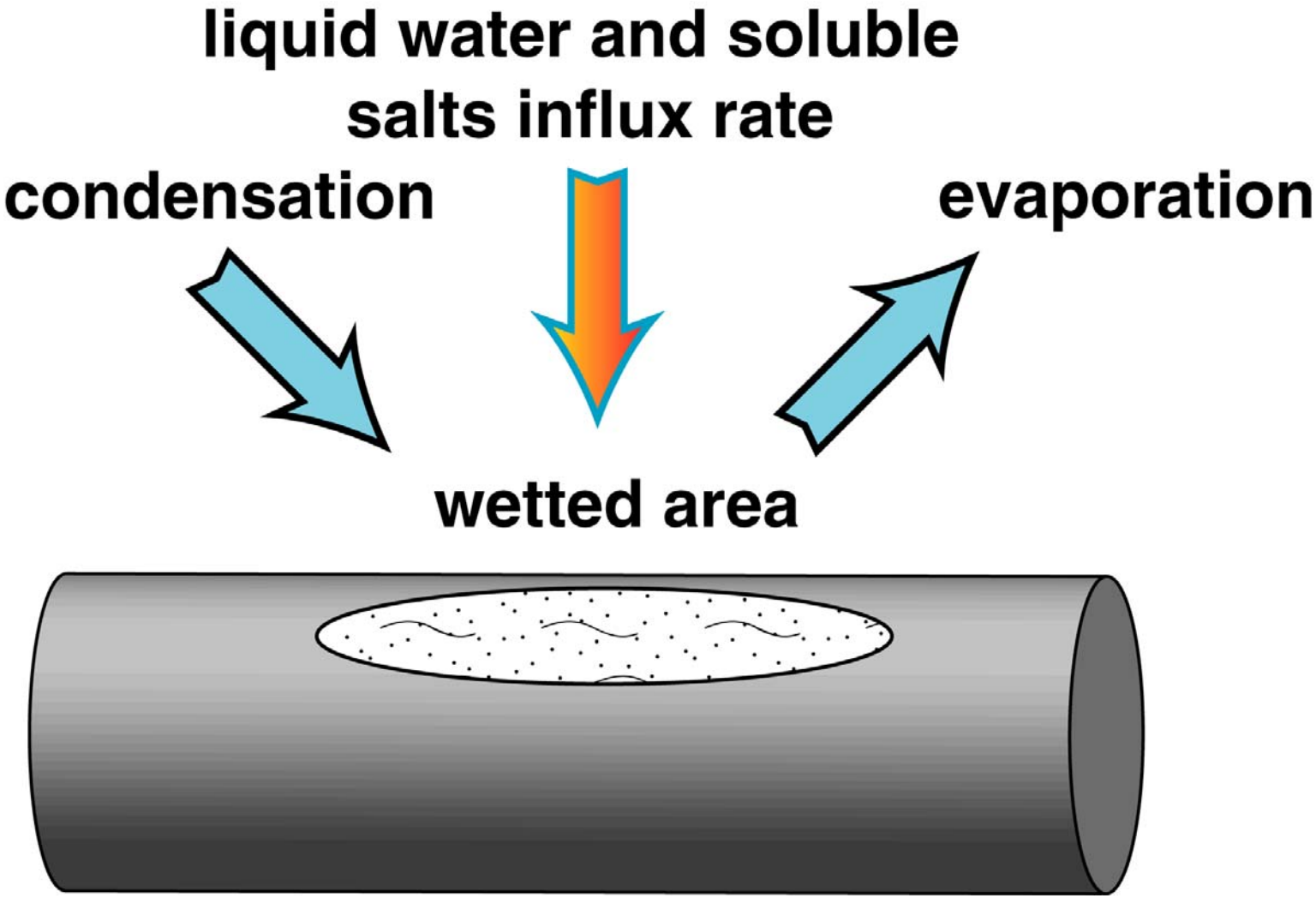
# Conclusions

- EBS chemistry more variable than has been assumed.
- Nitrate will sometimes be separated from chloride.
- Changes in design could make this less important (e.g., lower average temperature).
- Some high temperatures will occur in “cold” repository with partial roof collapse.
- Microenvironments persist for > 10,000 years.
- Other defensible factors could be considered for performance credit:
  - Evaporation driven flow system within failed containers,
  - Diffusion in partially failed containers.

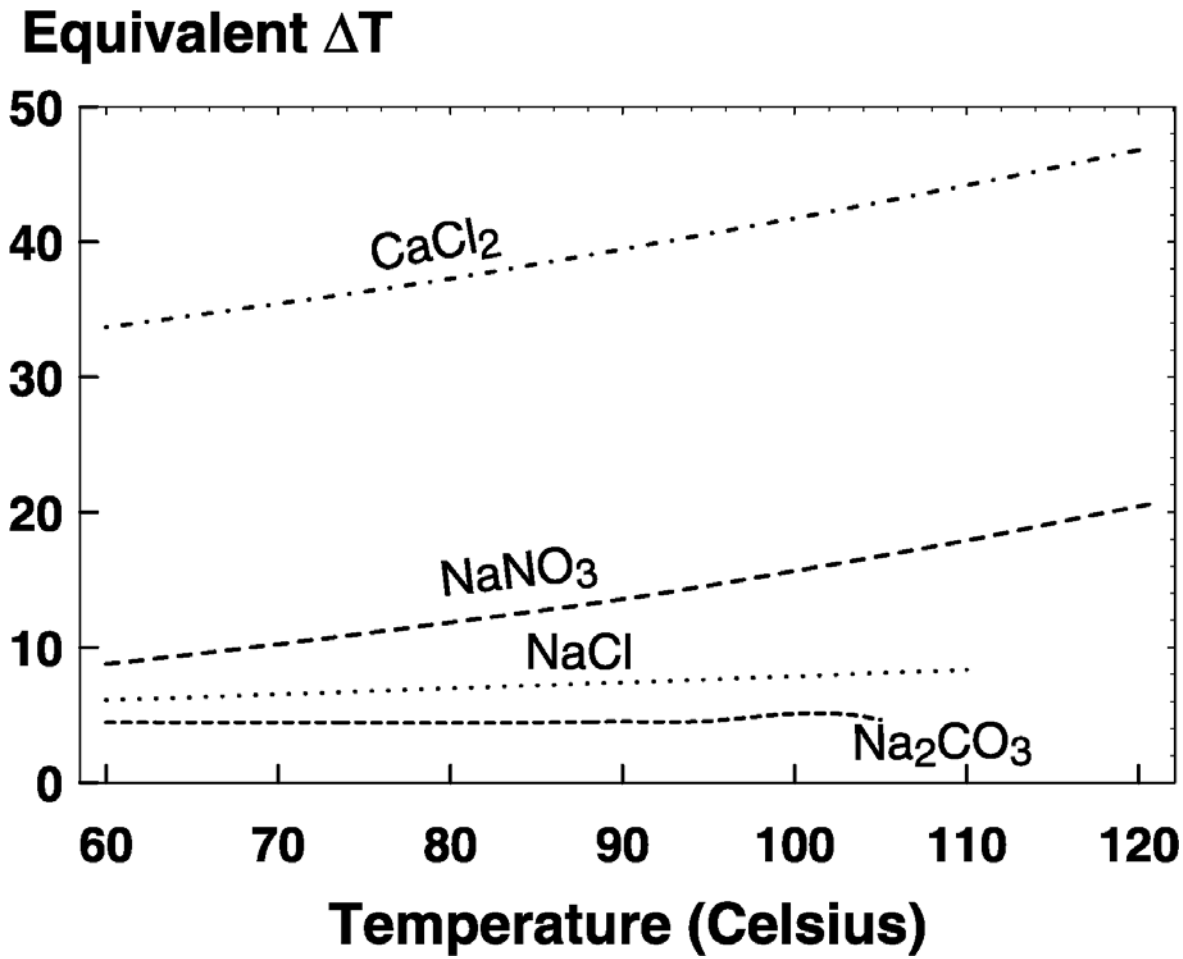

desert spring

# Backup Slides

# Liquid Film


liquid water and soluble
salts influx rate
condensation
evaporation
wetted area

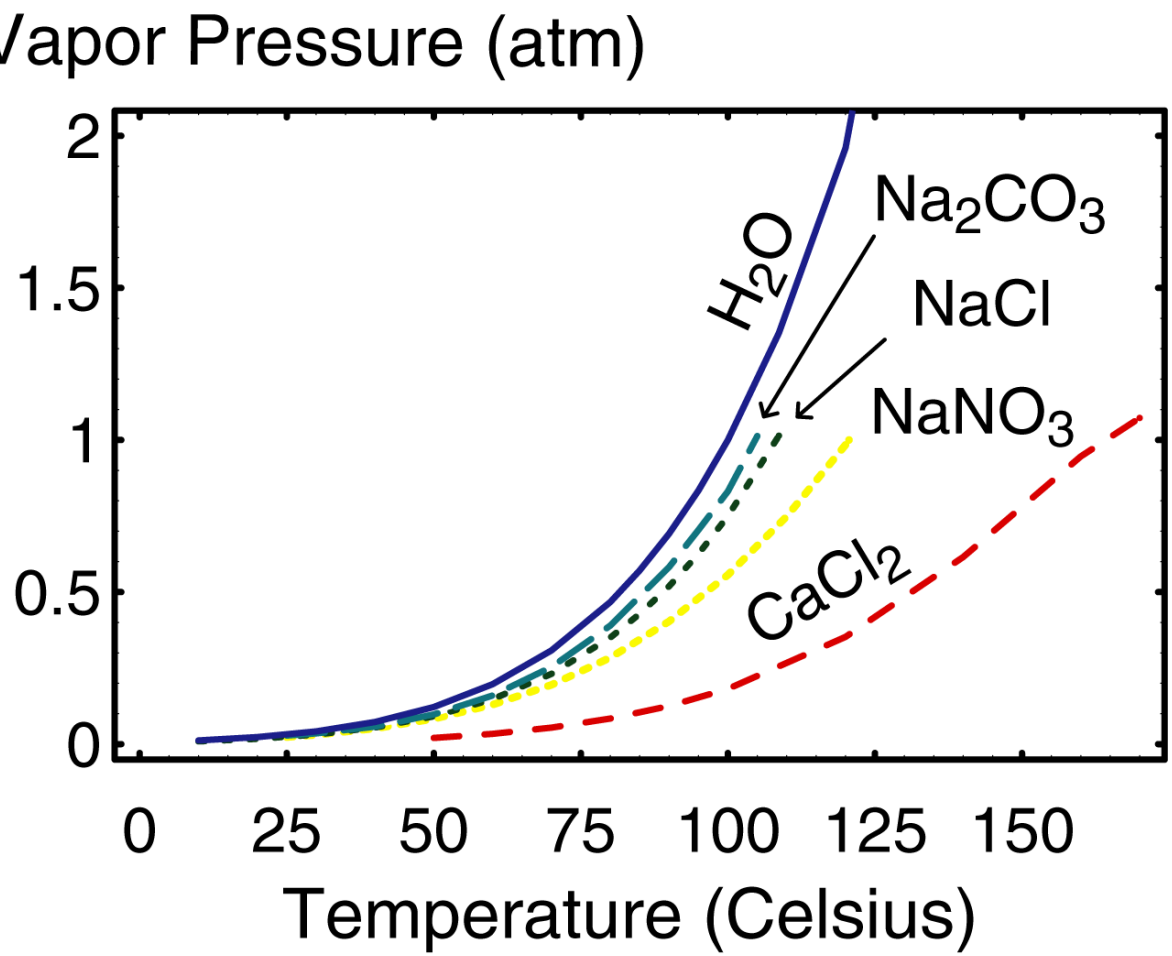
# Temperature Gradients




temperature difference between saturated solutions and pure water at same vapor pressure

Walton, 1993

# Vapor Pressure of Saturated Solutions




Walton, 1993