Evolution of Near-Field Environments
(Alternative Models)

Presenter: Don L. Shettel

GMII Geosciences Management Institute, Inc.

1000 Nevada Way, Suite 106, Boulder City, NV 89005
702-294-3064; fax -3006
www.geomii.com

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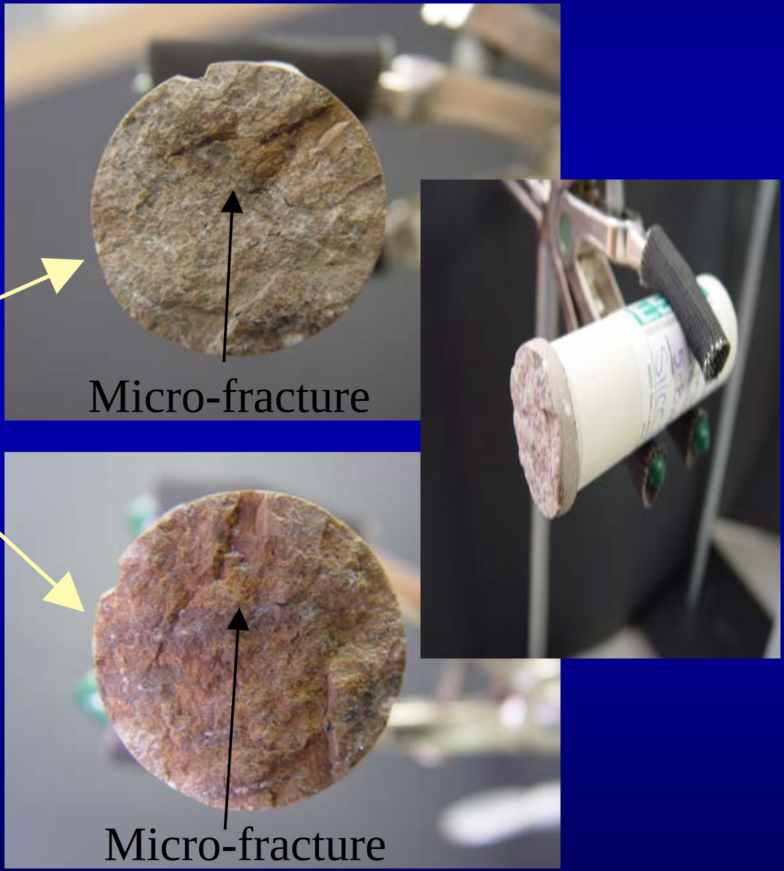
Wet Fractures in Cored Sample

1.2 inch core extracted from sample ECRB-1 (CS 20+81m) in about an hour with water. Wet fractures are visible, matrix is dry.

1.2 inch diameter core from Tptpll (lower lithophysal) sample. Fractures are wet, matrix is dry.

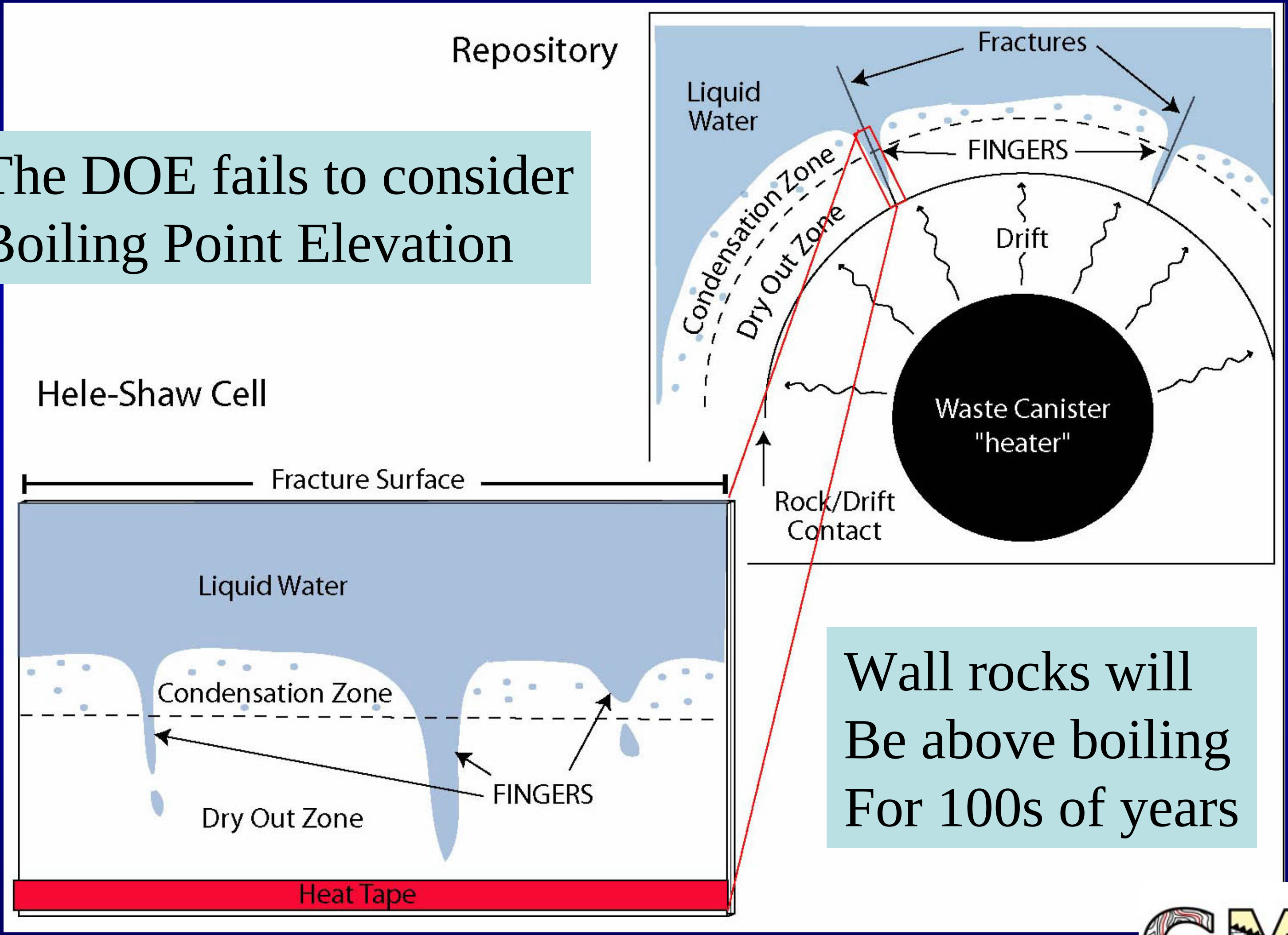
Hydrogeological Modeling

- TSPA-VA = 100 y
- GMII Experiments:
  - Water saturated
    - micro-fracture 1st (hrs. - days)
    - matrix 2nd (days to weeks)
  - Humidity Difference
    - No affect on fracture flow
    - Significant affect on matrix flow
- DOE time step is too long



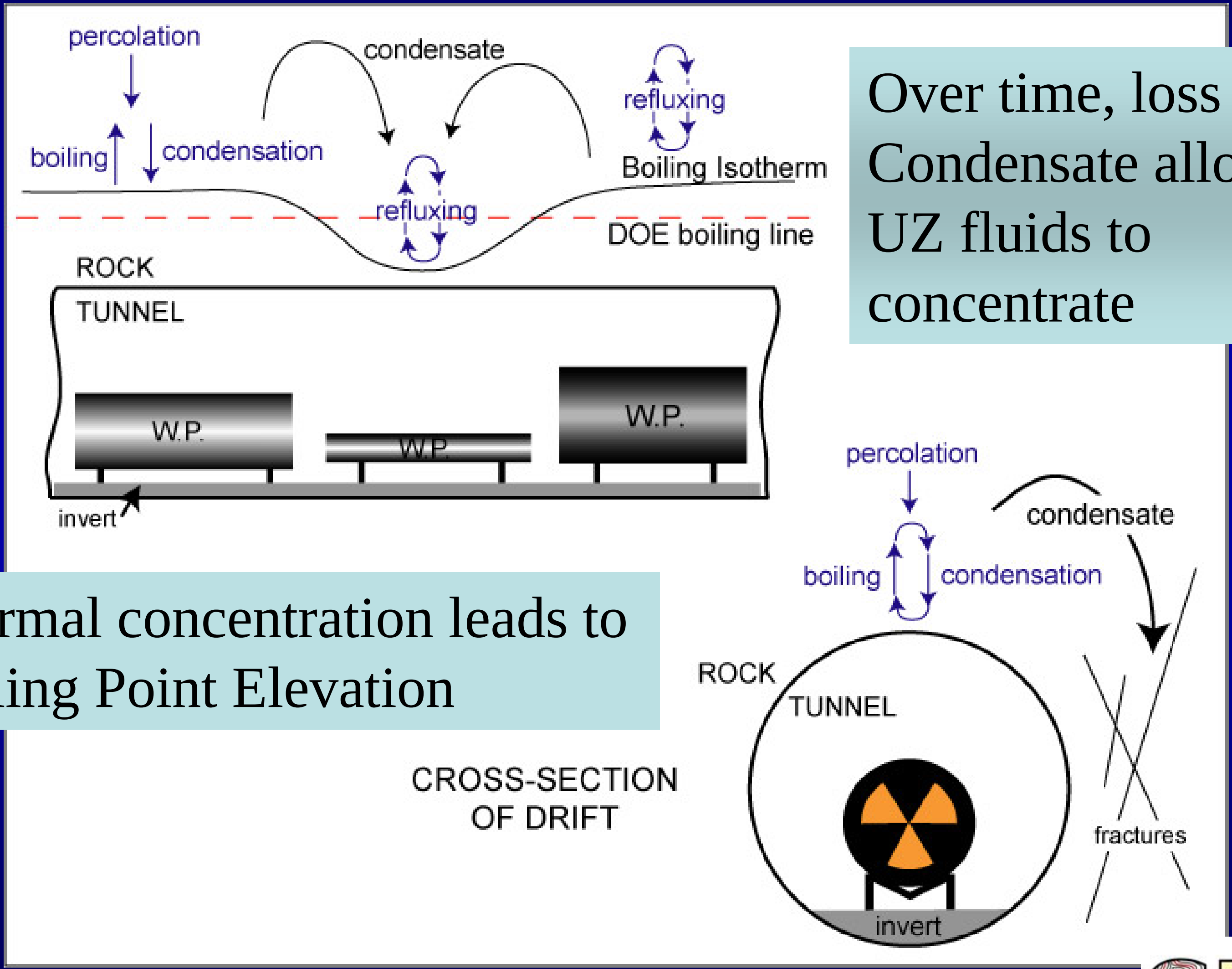
Liquid Fingering in Heated Fractures

The DOE fails to consider Boiling Point Elevation



Wall rocks will
Be above boiling
For 100s of years

Concentration of UZ Waters



Over time, loss of Condensate allows UZ fluids to concentrate

Thermal concentration leads to Boiling Point Elevation

Magnesium Removal?

• DOE claim that Mg is removed from evaporating solutions early as *Sepiolite*, $Mg_4(Si_2O_5)_3(OH)_2 \cdot 6H_2O$

• NOT found in evaporation experiments relevant to Yucca Mt. (UZ pore water, at/above repository level):

- CUA has not found any Mg-silicates experimentally (sepiolite, karpinskite, carlosuranite, stevensite-15A/saponite)
- Rosenberg et al. (2001) found only Mg-smectite (amount not specified in experiment with tuff)

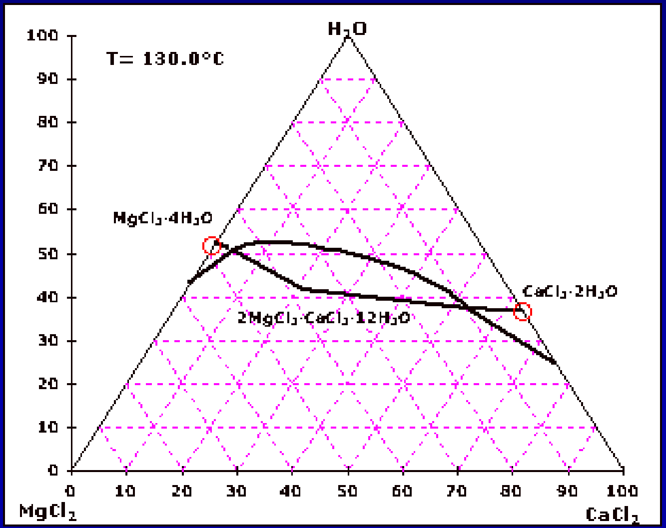
• Mg removal by *Sepiolite* ppt is an artifact of geochemical modeling and does not occur during thermal concentration

- Ca removal actually occurs by ppt of Calcite, Gypsum, Anhydrite

Deliquescence

• DOE relies on simple binary salt pairs (such as KCl, NaCl, $CaCl_2$, $NaNO_3$) for RH

• Mg and Ca salts have lower mutual deliquescence relative humidity (MDRH) than Na/K salts [Pabalan et al., 2002]

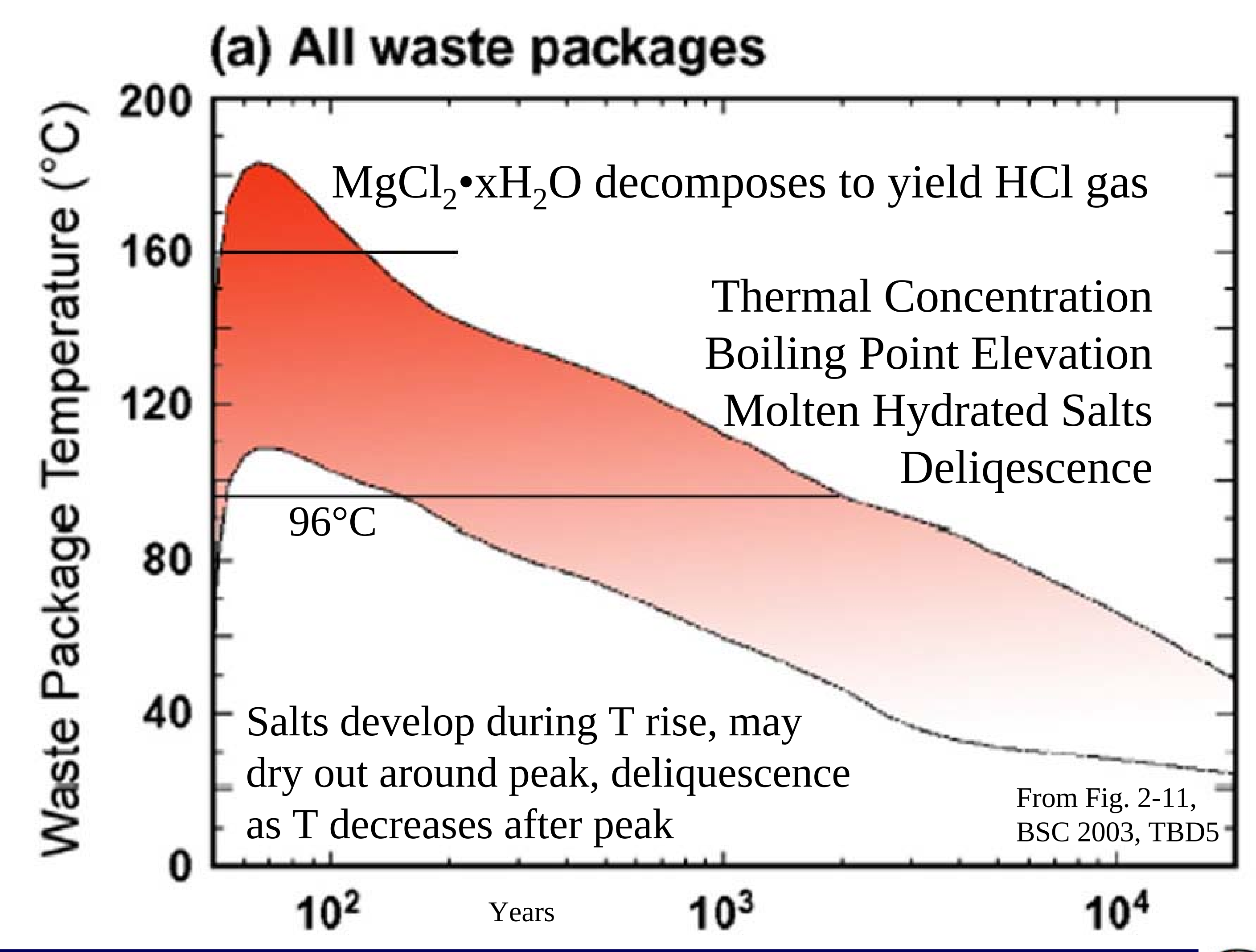


K. Thomsen, 2003, Pers. Comm.

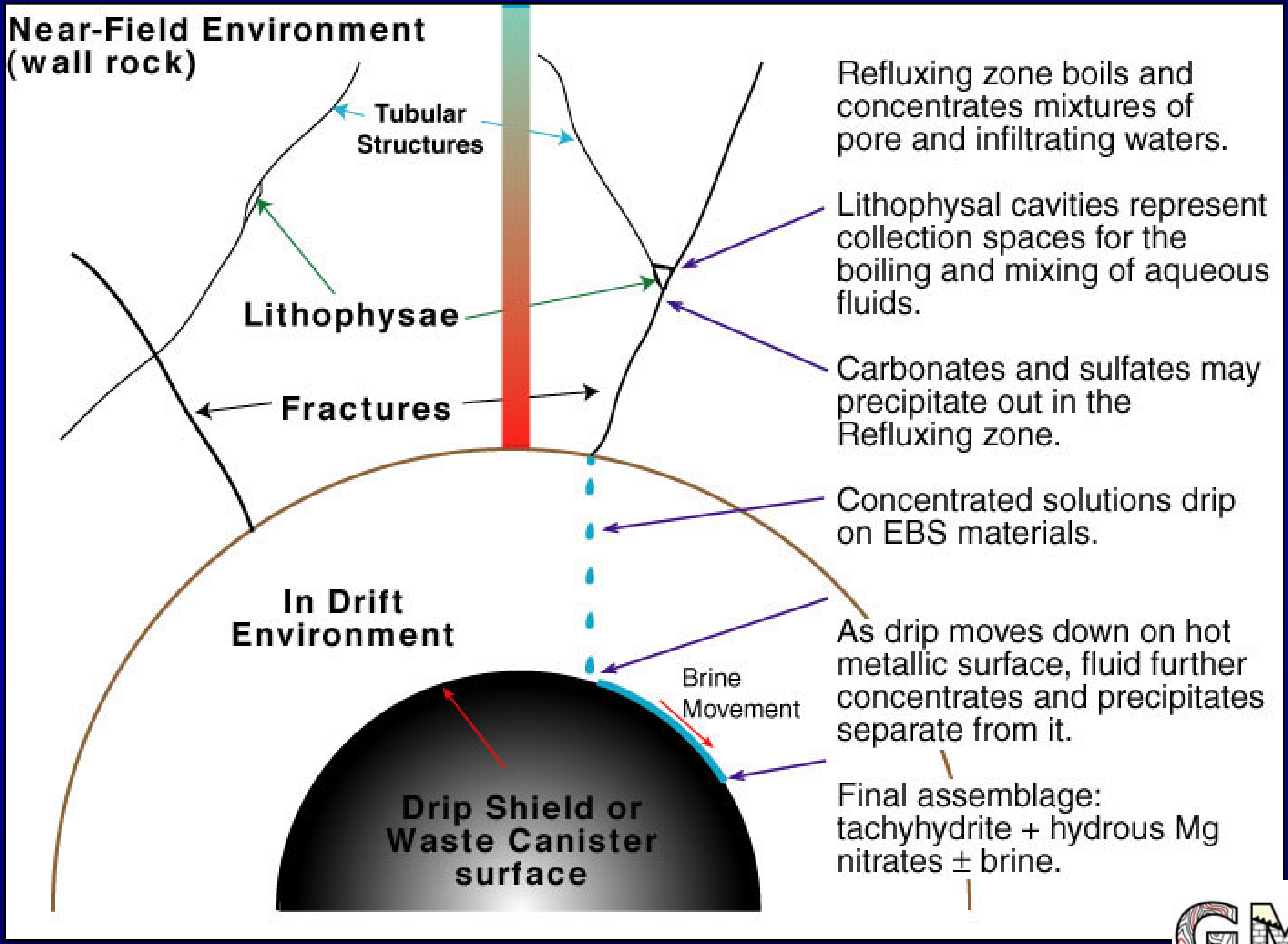
• DOE fails to consider aqueous ternary and quaternary systems (such as Ca-Mg-Cl, Ca-Mg-NO_3, Ca-Mg-Cl-NO_3)

• Mixed salts have lower MDRH

Temperatures of Waste Packages



Development of Corrosion Fluids



Examples of Lithophysal Cavities


12” Borehole near ESF 6,500m

Topopah Spring lower lithophysal (approximately 70% of repository will be in this unit)

12” Borehole in ECRB

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Chemistry of Evaporation

- J-13: heating with excess HCO_3^- leads to higher pHs:

  $HCO_3^- + H^+ \Leftrightarrow H_2O + CO_2(g)$

  $Mg^{2+} + HCO_3^- \Leftrightarrow Mg(OH)_2 + 2CO_2(g)$

- UZ Pore Water: heating with excess Ca^{2+}

  $Ca^{2+} + 2HCO_3^- \Leftrightarrow CaCO_3 + 2H^+$

  $Ca^{2+} : HCO_3^- > 1:2$

  other anions become important: Cl^- and NO_3^-

- Mg-Cl hydrates and M-NO_3 hydrates subject to thermal decomposition, $x = H_2O:Mg^{2+}$, $0<x<2$: sensitive to wet-dry cycling

C-22 Exposure to Conc. HCl

Brochure H-2019E “Hastelloy C-22 Alloy” Haynes International, 1997, p.8.
Corrosion Rate in Boiling 10% HCl = 10 mm/year

103°C for 43.2 hours
Thinning, uniform corrosion
Corrosion rate: 2.2 mm/year

98°C for 43.2 hours
Significant thinning, portion exposed to vapor is almost gone
Corrosion rate: 4.4 mm/year

NOTE: Rapid corrosion can take place in absence of *Nitrate*

Important NFE & In-Drift Processes

- Thermal concentration & Boiling Point Elevation
- Fingering of Concentrated Solutions in Heated Fractures
- Mixed salt (Ca-Mg-Cl-NO_3) deliquescence
- Molten hydrated salts and their thermal decomposition (acidic vapors)
- Evolution of Acidic Solutions & Vapors
- Wet - Dry cycling (intermittent seepage)

Conclusions

- High Temperature Operating Mode (HTOM) design is fatally flawed
- Emplacement of Repository in Saturated Zone is less complicated in terms of processes and TSPA

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Boiling Point Elevation

Addition of solutes (dissolved solids) to a solvent, such as water, lowers solution's vapor pressure, which in turn causes Boiling Point Elevation (and freezing point depression).
These concepts were formulated and proven by S.A. Arrhenius in the 1880s.