Introduction to Presentations Addressing the Nuclear Waste Technical Review Board's Comments in their November 25, 2003 Letter

Presented to:
Nuclear Waste Technical Review Board

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Outline

- Background
- Goals/Objectives of Presentations
- Summary of Other Features and Processes in System Performance
- Introduction to Subsequent Presentations that Address the Board's Comments
  - Thermal Hydrology and Thermal Seepage (Bo Bodvarsson)
  - Presence and Characteristics of Deliquescent Brines (Carl Steefel)
  - Aqueous Chemistry Evolution and Evaporation (Carl Steefel)
  - Localized Corrosion Processes (Joe Payer)

Background

- In the January 2003 Board meeting, DOE summarized available test results related to general and localized corrosion of Alloy 22
- In the May 2003 Board Meeting, DOE summarized the status of the technical basis for the unsaturated zone seepage, the in-drift thermo-hydro-chemical environment, and waste package material performance
- On June 30, 2003, the Board provided DOE a letter identifying some initial reactions to DOE's presentations and identified some initial concerns on DOE's technical basis related to:
  - The initiation of localized corrosion
  - Capillary and vaporization barriers

Background
(continued)

- On October 10, 2003, DOE responded to the Board's written comments on the May 2003 meeting, noting:
  - There was insignificant corrosion above the boiling point of water due to the lack of seepage and primarily benign deliquescent brines
  - There was insignificant corrosion below the boiling point of water because of primarily benign seepage brines
- On October 21, 2003, the Board provided DOE a letter summarizing their conclusions related to corrosion
- On October 27, 2003, DOE responded to the Board's letter noting that the referenced corrosion testing results provided an incomplete representation of what is expected to occur in the likely environments in the drifts

Background
(continued)

- On November 25, 2003 the Board provided to DOE a technical report on a variety of corrosion issues with a particular focus on the potential for deliquescence-induced localized corrosion
- Today, we will present additional evidence, including recent data and analyses, that addresses the issues raised by the Board and continues to support DOE's conclusions

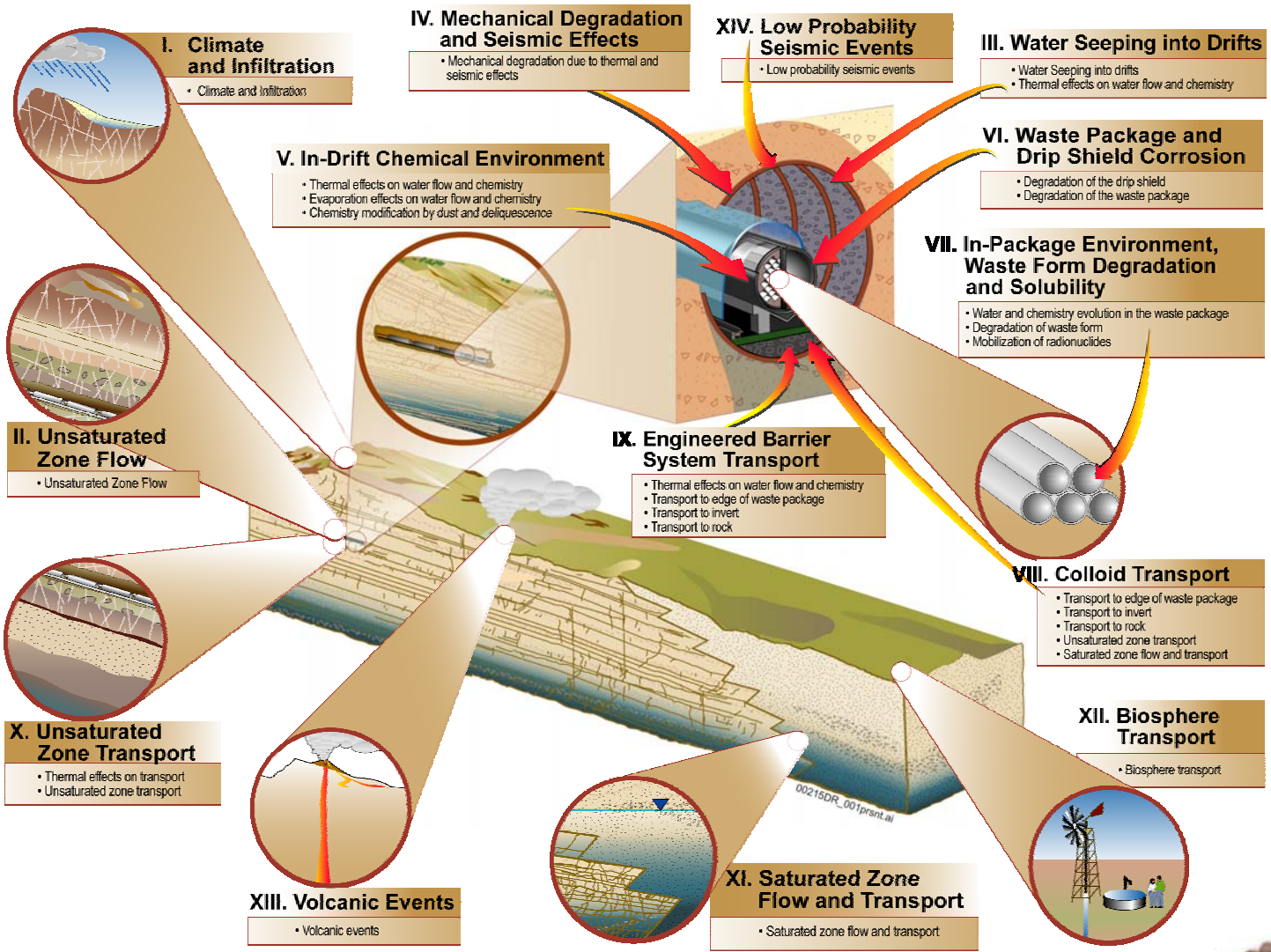
Goals/Objectives of DOE Presentations

- **Answer questions and concerns raised in the Board's November 25, 2003 letter and provide additional clarification on particular topics related to repository performance during the "thermal pulse"**
- **Provide conceptual basis and key data and analyses of issues in the Board's report related to**
  - **The seepage, thermal seepage and thermal hydrologic evolution (Bo Bodvarsson)**
  - **The composition and deliquescence of salts within the dust likely to be present on the waste packages (Carl Steefel)**
  - **The thermal chemical evolution of pore fluids in the rock and, following seepage, the drift (Carl Steefel)**
  - **The general and localized corrosion behavior of Alloy 22 for realistic environments that can form on the waste package (Joe Payer)**

Information that Will not be Presented Today

- **We will not discuss all of the Board's questions**
  - **We will focus on those issues that relate to the likely performance of the waste package during the "thermal pulse"**
- **We will not present other elements that affect repository performance**
  - **Including unlikely features, events and processes that will be included in the performance assessment**
- **We will not present the complete body of technical information that supports the conclusions reached**
  - **Additional information is cited in the applicable Analysis/Model Reports**

Engineered and Natural Components of the Repository System



Placing the In-Drift Environment and Corrosion into a Systems Context

- The repository system includes a range of engineered and natural features that act as barriers to a) keep water away from radioactive waste, b) limit radionuclide release from that waste and c) delay radionuclide transport
- The waste package is one such feature
- The environment in which the waste package sits has a significant effect on the degradation characteristics of that feature
- Other features (such as the unsaturated rocks above and below the repository, the saturated rocks and alluvium, the drip shield and the waste form itself) are included in the performance assessment

Placing the In-Drift Environment and Corrosion into a Systems Context
(continued)

- Thermal, mechanical, hydrological and chemical processes occur within these features
- These processes are described by models and parameters, the basis of which are derived from laboratory and *in-situ* tests, analogs and information from the literature
- Uncertainty in the process models and parameters is included within the performance assessment
- Unlikely events are included in the performance assessment
- The risk of the events and uncertainty are included in the assessment of system performance

Board Comments
Dust Deliquescence

- ***"The Board believes that all the conditions necessary to initiate localized corrosion of the waste packages will likely be present during the thermal pulse because of the deliquescence of salts on waste package surfaces, and thus it is likely that deliquescence-induced localized corrosion will be initiated during the thermal pulse."***
  (November 25, 2003 cover letter)
- ***"Limited data examined to date indicate that dust, which would be present in the proposed tunnels and which would be deposited on waste packages, contains calcium chloride and magnesium chloride salts in amounts sufficient for the development of concentrated brines through deliquescence."***
  (November 25, 2003 cover letter)
- ***"Corrosion experiments indicate that localized corrosion is likely to be initiated if waste package surface temperatures are above 140 C and if concentrated brines, such as would be formed by the deliquescence of calcium and magnesium chloride, are present."***
  (November 25, 2003 cover letter)

Introduction to DOE Responses
Dust Deliquescence

- Bo will present analyses that define the relevant thermal hydrologic conditions at Yucca Mountain
- Carl will present information that neither Ca nor Mg chloride salts are present in the Yucca Mountain dusts
- Carl will present information that even if Ca or Mg chloride salts did exist at Yucca Mountain they are not stable at the temperatures likely to be present following repository closure
- Carl will present information that the salts that are present deliquesce at lower temperatures and contain nitrates
- Joe will present information that significant localized corrosion will not occur due to deliquescence because of a) absence or scarcity of severe environments, b) lack of severe crevices and c) inhibition by nitrates

Board Comments
Thermal Effects

- ***"The Board believes that the (temperature) calculations may be inaccurate because (1) the DOE's rock mass thermal conductivity estimates for the lower lithophysal rock may be too high, (2) the insulating effect of rockfall and drift degradation on the waste package surface are not included in the DOE's models and (3) the effects of in-drift and in-rock natural ventilation and air circulation after repository closure have not been accounted for."***
  (Exec Summary, p. i)

Introduction to DOE Responses
Thermal Effects

- **Bo will present new evidence on the thermal conductivity in the lower lithophysal rocks that is used in DOE's coupled thermal calculations**
- **Bo will discuss the inclusion of drift degradation effects on coupled thermal calculations. He will present the rockfall and drift degradation calculations used as a basis for coupled effects on thermal calculations**
- **Bo will discuss that the potential effects of in-drift and in-rock natural ventilation on thermal response have been conservatively ignored, but their effects on condensation have been considered**

Board Comments
Seepage Chemistry

- ***"The Board believes that the possibility of seepage where the rocks are above boiling cannot be excluded but that seepage would most likely be limited. The DOE's analyses of water chemistries and their corrosive potential are extremely complex and suffer from empirical and theoretical weaknesses. Thus, the Board does not have a high degree of confidence in the DOE's conclusion that any seepage water would be dilute or noncorrosive, because the methods used in the DOE's analyses have significant technical uncertainties."***
  (Exec. Summary, p. ii)

Introduction to DOE Responses
Seepage Chemistry

- **Bo will present additional evidence and comparison to alternative models that support the seepage and thermal seepage analyses**
- **Carl will present the theoretical and empirical bases for the analyses of water chemistry evolution during and after the thermal pulse**
- **Joe will present additional evidence on the corrosion resistance of Alloy 22 for the aqueous chemistry environment likely in the range of thermal conditions**

Board Comments
Significance of Localized Corrosion

- ***"The Board believes that the experimental evidence is not adequate to demonstrate that corrosive conditions will be present only briefly. The DOE has not established whether nitrate will inhibit localized corrosion over the entire range of temperatures in which brines could exist. Furthermore, based on the DOE's estimates, the Board believes that there is ample chloride to cause a significant amount of localized corrosion."***
  (Exec. Summary, p. ii)
- ***"Crevices are widespread on the waste packages, arising from their design as well as from contacts between the metal and dust particles."***
  (November 25, 2003 cover letter)

Introduction to DOE Responses
Significance of Localized Corrosion

- **Bo and Carl will present evidence that defines the range of possible thermal-hydrologic-chemical conditions on the waste package during the thermal pulse**
- **Carl will present information on the amount of chloride likely to be present**
- **Joe will present information on corrosion resistance of Alloy 22 in a broad range of temperatures for calcium chloride brines and inhibition by nitrates**
- **Joe will present information that describes the potential significance of the chemical environment on localized corrosion**
- **Joe will present information that dust accumulation does not produce the severe crevices used in laboratory tests**

Board Comments
Summary

- ***"Thus, the Board believes that under the conditions associated with the DOE's current high-temperature repository design, widespread corrosion of the waste packages is likely to be initiated during the thermal pulse."***

DOE Responses
Summary

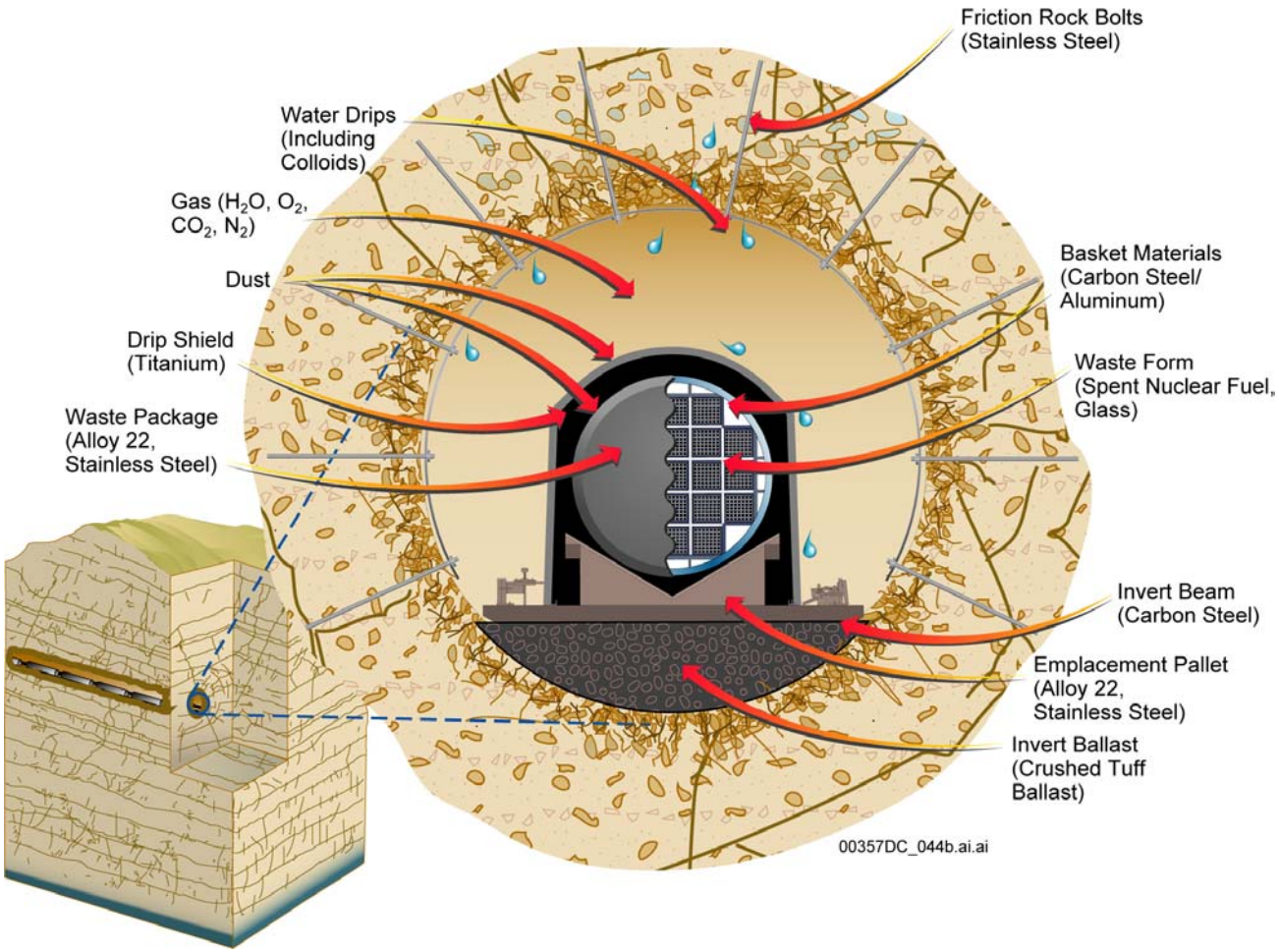
- **DOE concludes that widespread corrosion of the waste package will not occur during the thermal pulse**

Summary

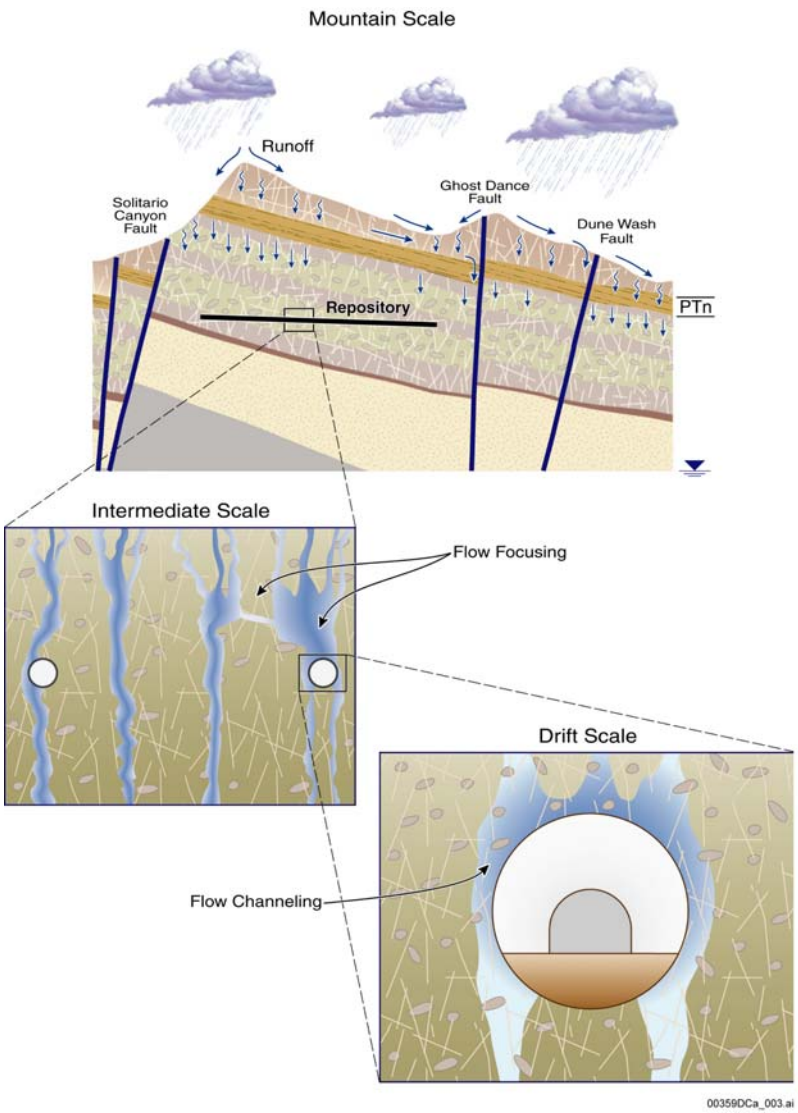
- **The Board's comments in the Nov 25 2003 letter reflect in part inferences derived from information that was not presented in the May 2003 meeting**
  - **Magnitude and effect of drift degradation**
  - **Thermal hydrologic response**
  - **Composition of deliquescent brines**
- **Additional data and analysis (completed subsequent to the meeting last May) have improved the conceptual understanding of these processes**
  - **The most significant of these new data will be presented today**

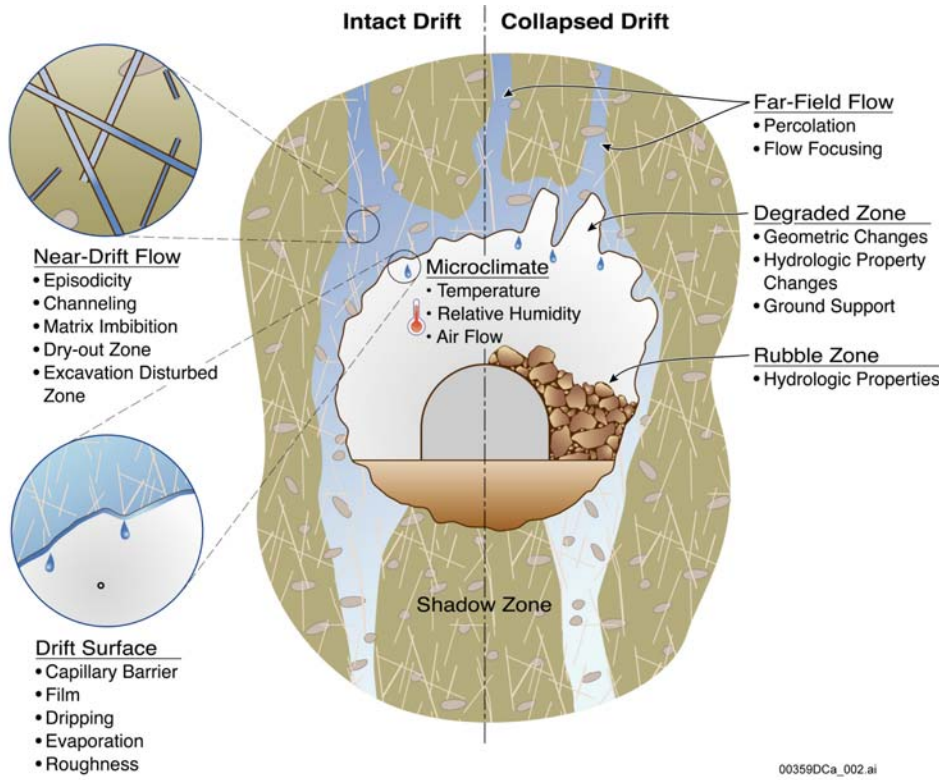
Back Up slides

General Schematic of Emplacement Drift and the Engineered Barrier System - Drip Shield and Waste Package



Processes Affecting Seepage

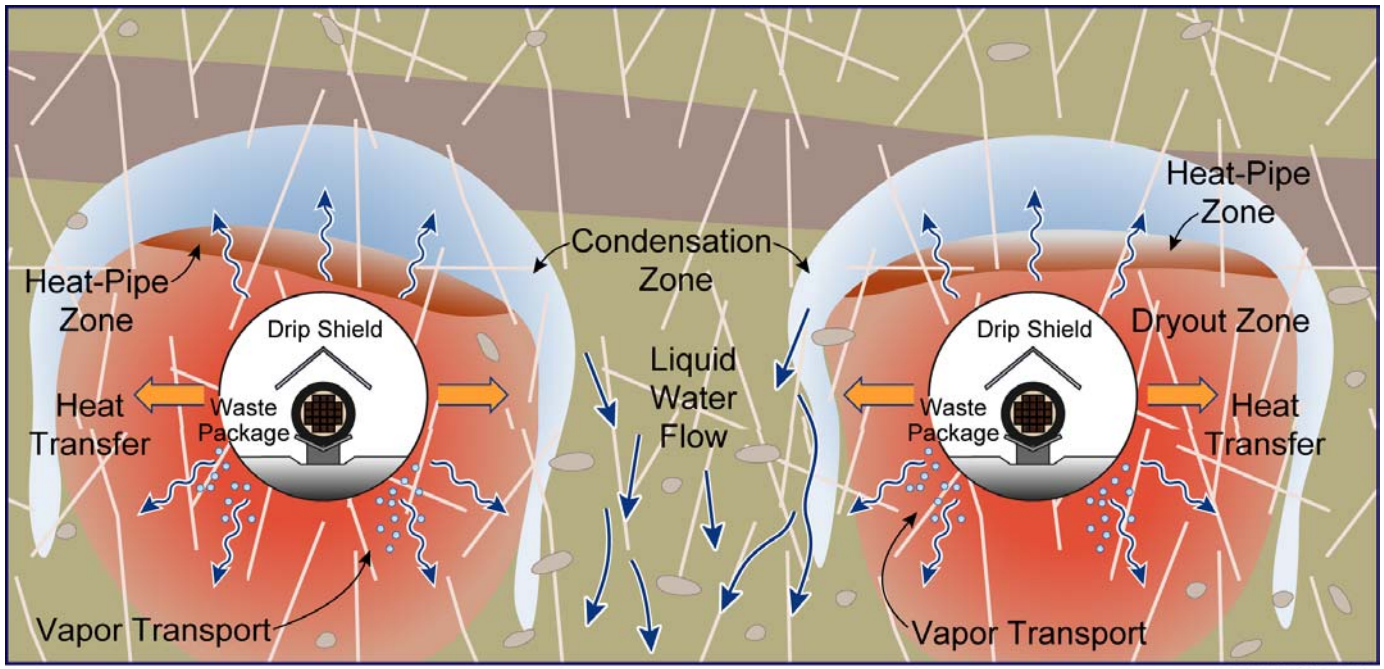




Factors affecting seepage

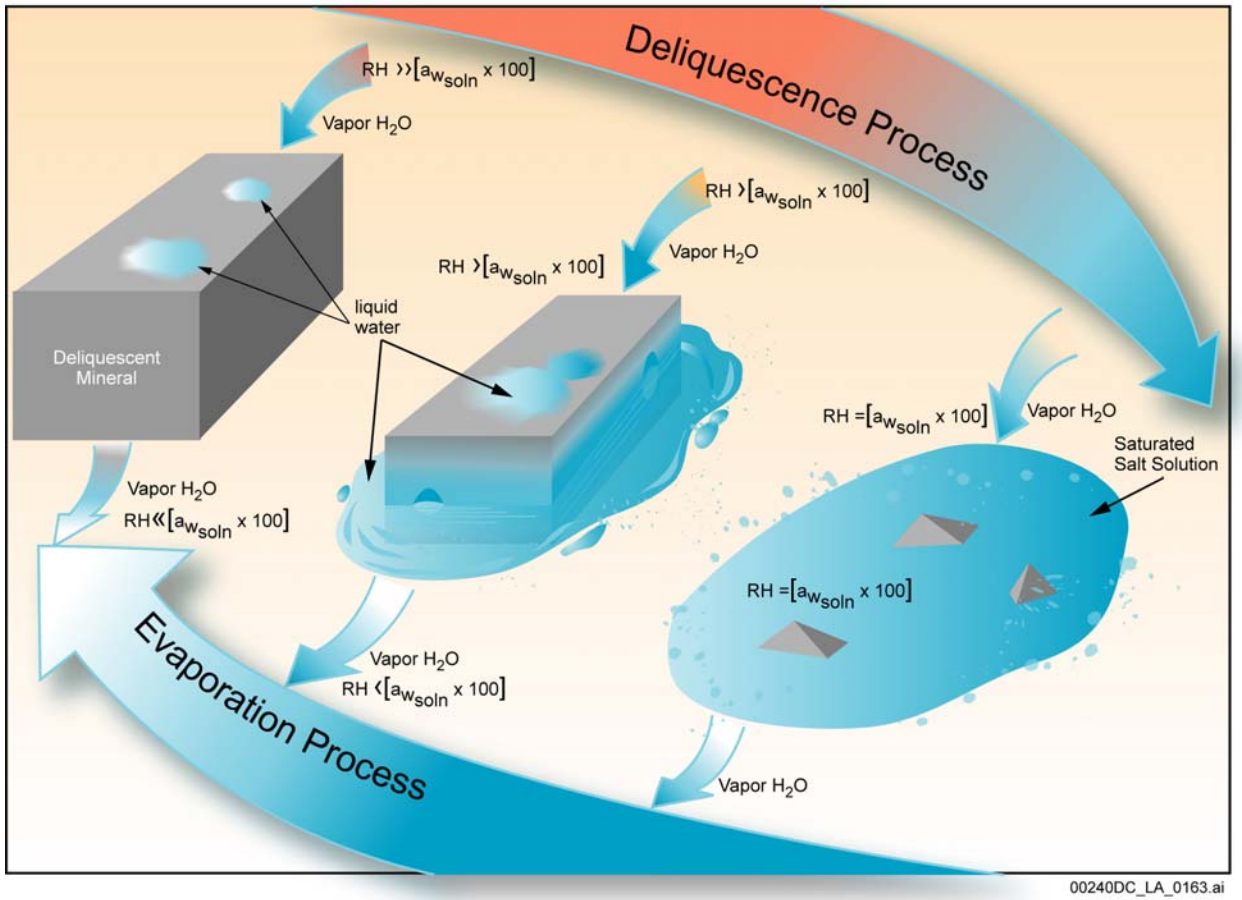
- **Percolation flux**
- **Rock/fracture characteristics**
- **Drift degradation**
- **Thermal hydrology**

Processes Affecting Thermal Hydrology and Thermal Seepage



- **Factors affecting thermal hydrology and thermal seepage:**
  - **design**
  - **location**
  - **rock type**
  - **thermal characteristics**
  - **- hydrologic characteristics (flux)**
  - **- drift degradation**

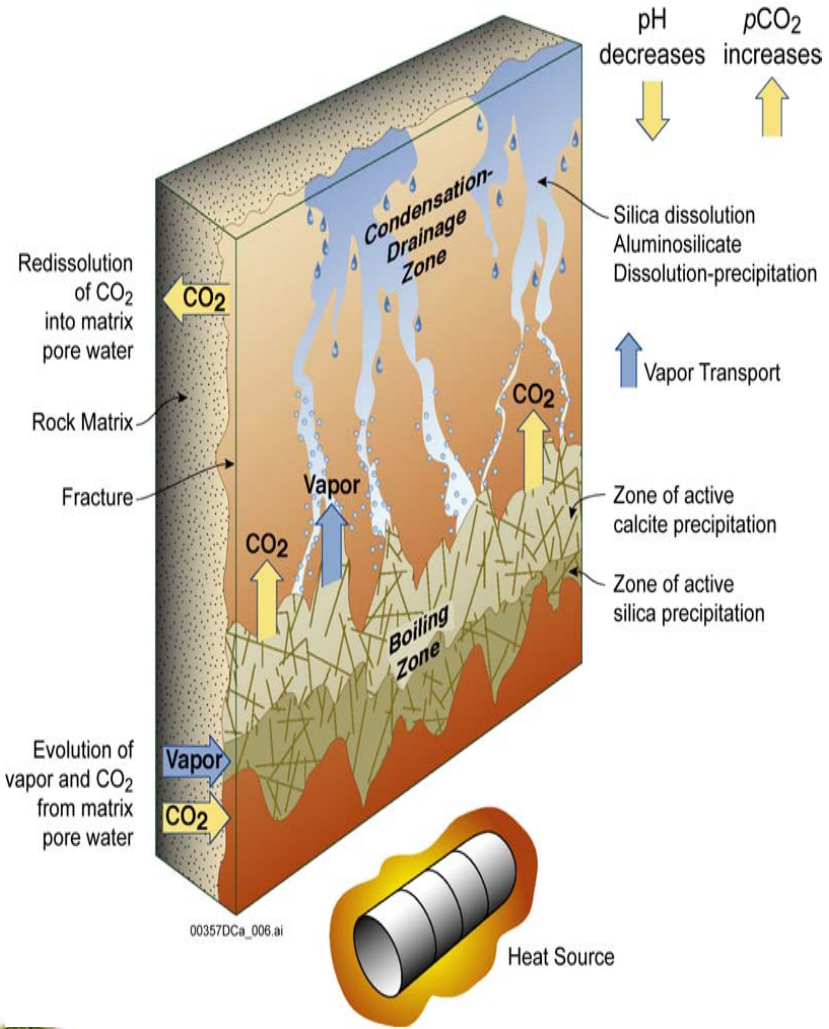
Processes Affecting Deliquescence and Evaporation



Factors Affecting Salt Deliquescence

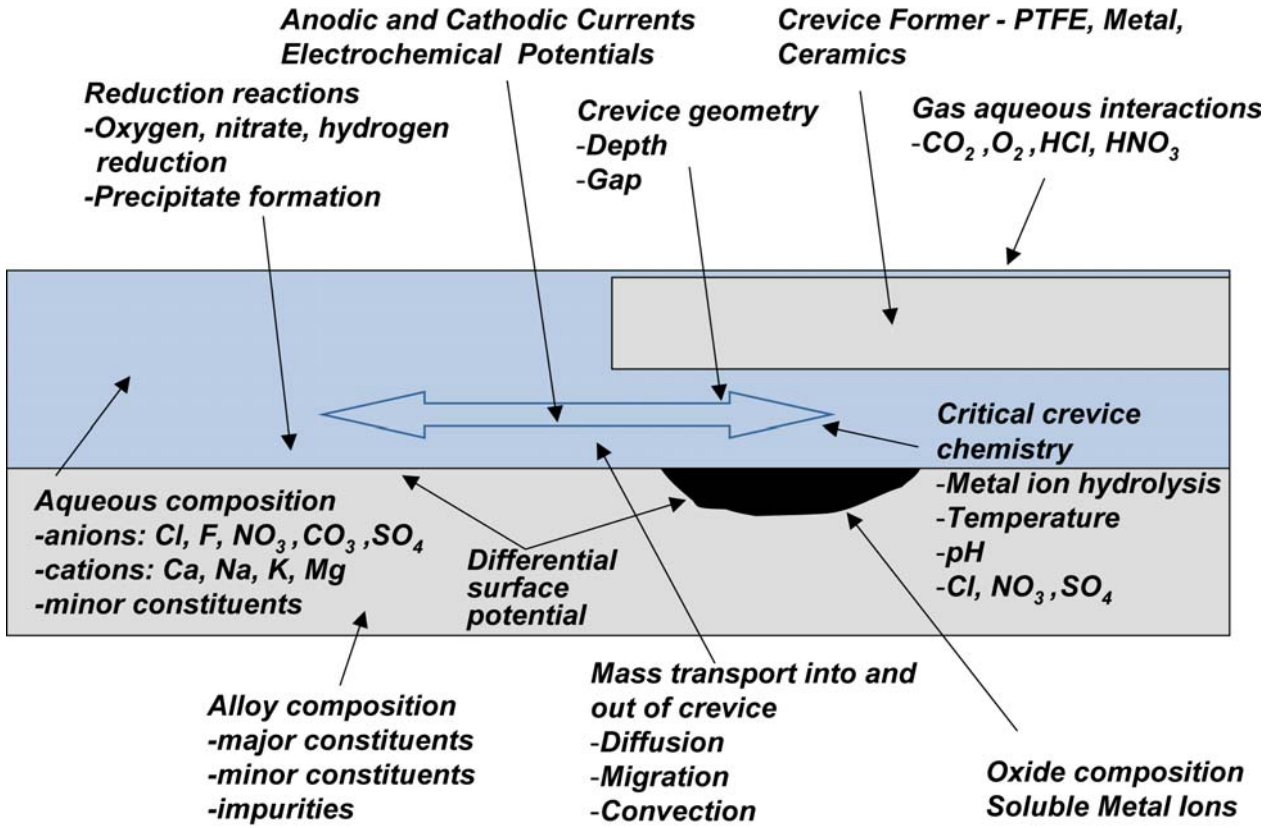
- Initial composition of salts in dust
- Thermal hydrologic evolution (temperature and relative humidity)
- Amount of deliquescent brine and reaction with other constituents of dust

Processes Affecting Thermal Chemical Evolution in the Rock



- **Factors affecting aqueous chemical evolution:**
  - **Thermal hydrologic response**
  - **Initial pore water chemistry**
  - **Rock mineralogy**
  - **Location within repository and location in rock mass above crown**

Processes Affecting the Initiation and Propagation of Localized Corrosion



- **Factors affecting corrosion**
  - **Presence of crevice and stress conditions at crevice**
  - **Temperature**
  - **Chemistry of aqueous phase on the surface of the crevice**
  - **Material characteristics including welding and heat treatment**