SAND2011-0232P

Used Fuel Disposition Campaign

Features, Events, and Processes (FEPs)

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UFD Working Group Meeting

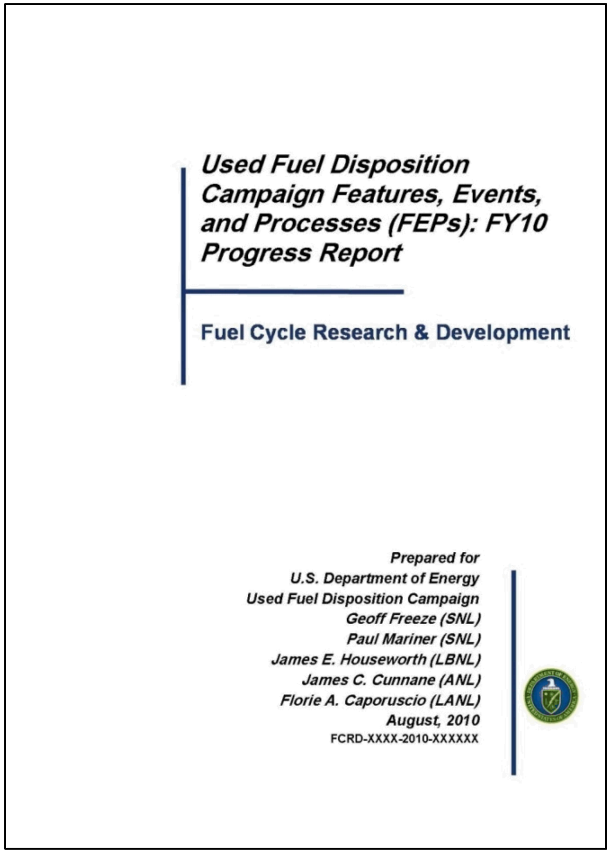
January 19, 2011

UFD FEPs – FY10 Accomplishments

- **Identified 208 generic FEPs**
  - EBS, Geosphere, Biosphere, and System-Level
- **Identified 35 storage and disposal alternatives**
  - 5 Waste Form Groups
    - *1 UNF*
    - *3 HLW (Glass, Ceramic, and Metal)*
    - *1 Less Than HLW*
  - 7 Concept/Setting Groups
    - *1 Surface Storage*
    - *1 Shallow Disposal,*
    - *4 Mined Geologic Disposal (Saturated Hard Rock, Unsaturated Hard Rock, Saturated Clay/Shale, Salt)*
    - *1 Deep Borehole*
- **Currently focused on 20 disposal alternatives**

UFD FEPs – FY10 Accomplishments

- **Initiated FEP evaluations**
  - Compiled relevant existing information from U.S. and foreign programs to support future FEP screening
    - *84 FEPs: information collected to support all 20 (in some cases 35) disposal alternatives*
    - *20 FEPs: information collected to support 4 clay/shale host rock disposal alternatives*
    - *104 FEPs: yet to be addressed*
  - Developed an evaluation template and Sharepoint website to catalog information for FEP scope, applicability, and importance
- **Developed a Summary Tracking Tool**
  - Excel spreadsheet
- **Completed a Level 2 Milestone Report**
- **Provided structure for Disposal R&D Roadmap**


Used Fuel Disposition Campaign Features, Events, and Processes (FEPs): FY10 Progress Report

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition Campaign
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FCRD-XXXX-2010-XXXXXX

UFD FEPs – Plans for FY11 and Beyond

- **Continuation of FEP evaluations**
  - 20 “clay/shale” FEPs: collect information to support the other 16 non-clay/shale host rock alternatives
  - 104 “yet to be addressed” FEPs: collect information for all 20 disposal alternatives
  - All FEPs: continue to identify/evaluate new information
  - Evaluations are collaborative with:
    - *EBS, Natural Systems, and Generic Modeling*
    - *Repository Science*
    - *Storage FEPs and LLW FEPs*
- **“Tool” maintenance and improvement**
  - Sharepoint website
  - Summary Tracking Tool
- **Milestones**
  - Level 3: Progress Report (Aug 19, 2011)
  - Level 4: Progress Feeds (July 15, 2011)

UFD FEP Activities - SNL

UFD FEPs SharePoint Website

- Document control
  - *FEPs list*
  - *FEP evaluations*
  - *FEPs status tool (spreadsheet)*
  - *Group reports*
- Database aspects
  - *Each evaluation has the same sections (i.e., same fields)*
    - Currently ~12 sections (FEP number, description, applicable domain, …)
    - Reason: anticipate future migration to database software (web-based?)
  - *Hyperlinks within FEP evaluations allow quick cross-reference to other FEP evaluations*
    - Important for reducing redundancies and discrepancies across evaluations
- References
  - *NEA FEP database*
  - *Working definitions (e.g., waste form categories)*

UFD FEP Activities - SNL

FEP Evaluations (cont.)

- Develop the following new FEP evaluations
  - *External factors*
    - Climate processes (1.3.xx.xx)
    - Future human actions (1.4.xx.xx)
    - Other (1.5.xx.xx)
  - *Microbial activity*
    - in EBS (2.1.10.01)
    - in host rock (2.2.10.01)
    - in other geologic units (2.2.10.02)
  - *Gas in the geosphere*
    - Sources and effects (2.2.12.xx)
  - *Surface environment*
    - Hydrologic (2.3.08.xx)
    - Chemical (2.3.09.xx)

UFD FEP Activities - SNL

FEP Evaluations (cont.)

- Improve FY10 SNL FEP evaluations
  - *Incorporate importance of FEPs to subsystems*
    - Currently FEP importance evaluations focus on dose
    - FEPs may be important to subsystems when
      - *demonstrating multiple barriers*
      - *defining boundary conditions for PA models*
      - *developing and validating PA models*
  - *Add natural analogue evaluations where useful*
  - *Further develop existing evaluations as needed*
- Improve integration and consistency across UFD FEPs
- Continue to consult the international NEA FEP database to assess/ensure completeness

UFD FEP Activities - LANL

- **FEP Evaluations**
  - All FEPs: continue to identify/evaluate new information
    - *identify data gaps and strengthen FEP descriptions*
  - Evaluations are collaborative with:
    - *EBS, Natural Systems, and Generic Modeling*
    - *Repository Science*

- **Large-scale Tectonics, Seismic, Igneous**

- **Metamorphism – due to heat and pressure effects (and should cover introduction of new chemical species via water transport)**

- **Mineral Dehydration- heavily dependent on thermal profile of the repository.**

UFD FEP Activities - LANL

- **<u>Large-scale Tectonics, Seismic, Igneous FEPs</u>**

  – Work on this will be done in collaboration with the Repository Science program – Regional Geology (P.I. Frank Perry)

  – Regional Geology work will be able to relatively quickly screen out areas of high seismic, tectonic uplift, or igneous consequences.

  – Will provide data for refining FEPs descriptions and evaluation.

  – RS work will begin shortly, should be very efficient since P.I. will be working on both Regional Geology and FEPs.

UFD FEP Activities - LANL

- Metamorphism FEP (1.2.05.01) – due to heat and pressure effects.
- Although NEA FEP ignores this FEP, we should include "introduction of new chemical species via water transport." into definition.
- This phenomena is covered in part by :
  - Chemical Effects of Waste-Rock Contact [2.1.09.10]
  - Thermally-Driven Flow (Convection) in EBS [2.1.11.11]
  - Chemical Interactions and Evolution of Groundwater in Host Rock / other geologic units [2.2.09.03 / 2.2.09.04]
- However, metamorphism will more thoroughly capture hydrothermal mineralization, sericitization, metal transport, convection cells and how long are temperatures sustained, and flow pathways

UFD FEP Activities - LANL

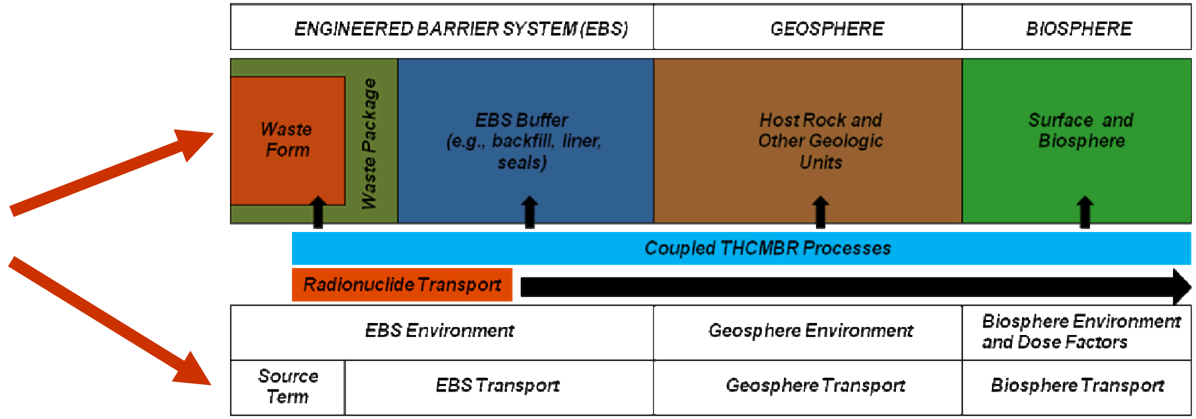
- **Mineral Dehydration (2.2.08.07) – will impact high heat load repositories most.**
  - depend on the type of hydrous mineral,
  - dehydration/dehydroxylation temperature,
  - its content in the host rock/packing material,
  - rock's location
  - thermal profile of the repository.

- **Mineral phases most susceptible – clays, sulphates, zeolites.**
  - clay dehydration data should be particularly useful to the LBNL work on bentonite.

- **Potentially allows for volume contraction and water expulsion.**

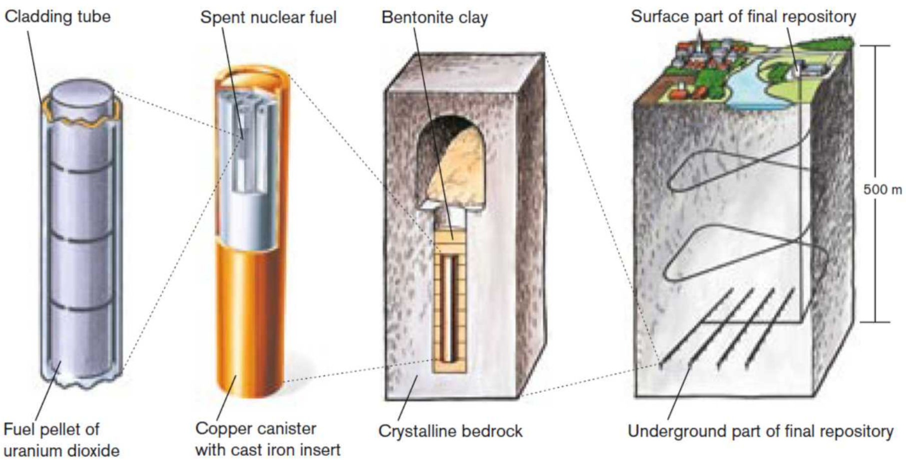
UFD FEP Activities - ANL

Argonne FEPs Focus

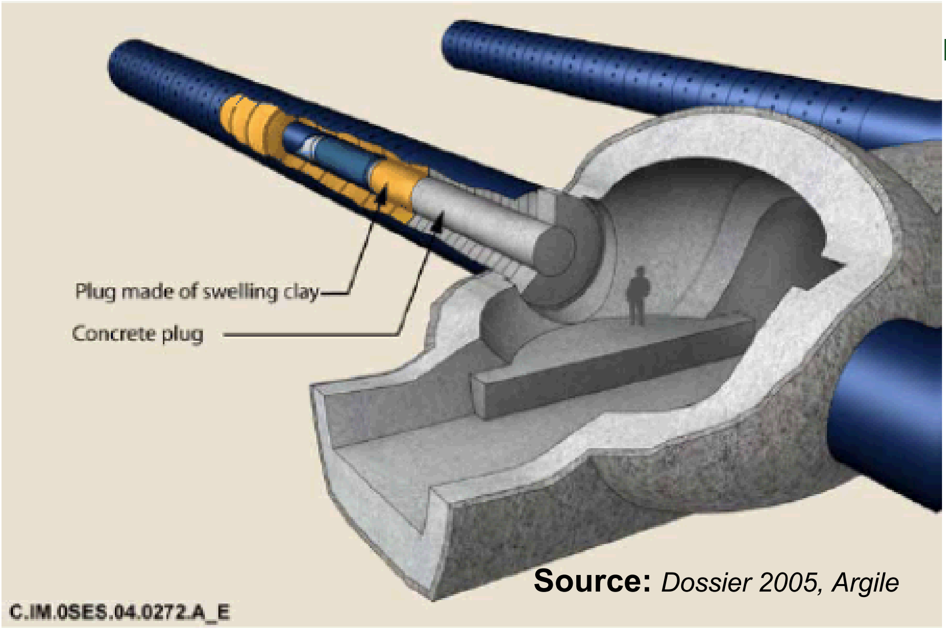


- **Waste Form (UNF, HLWG, HLC/GC, MAWF, LTHLW, Other) - (2.1.2) FEPs**
  - Spent Nuclear Fuel (SNF) Degradation (2.1.02.01)
  - High Level Waste Degradation (2.1.02.02)
  - Degradation of Organic/Cellulosic Materials in Waste (2.1.02.03)
  - High Level Waste (Glass, Ceramic, Metal) Recrystallization (2.1.02.04)
  - Pyrophoricity or Flammable Gas from SNF or HLW (2.1.02.05)
  - SNF Cladding Degradation and Failure (2.1.02.05)
- **FY 10 Evaluation Scope**
  - FY10 Scope addressed comprehensive overview of the waste form categories and host rock types
  - Status summarized in UFD Milestone Report (M3508040101)
- **FY 11**
  - Deeper Dive - Specific engineered barrier systems in host rock types of interest
  - Performance models and evaluation results
  - Research topics and results

The EBS Concepts and Functions for Used UOX and MOX Disposal in Granite and Clay



Source: *SKB TR-07-12R*



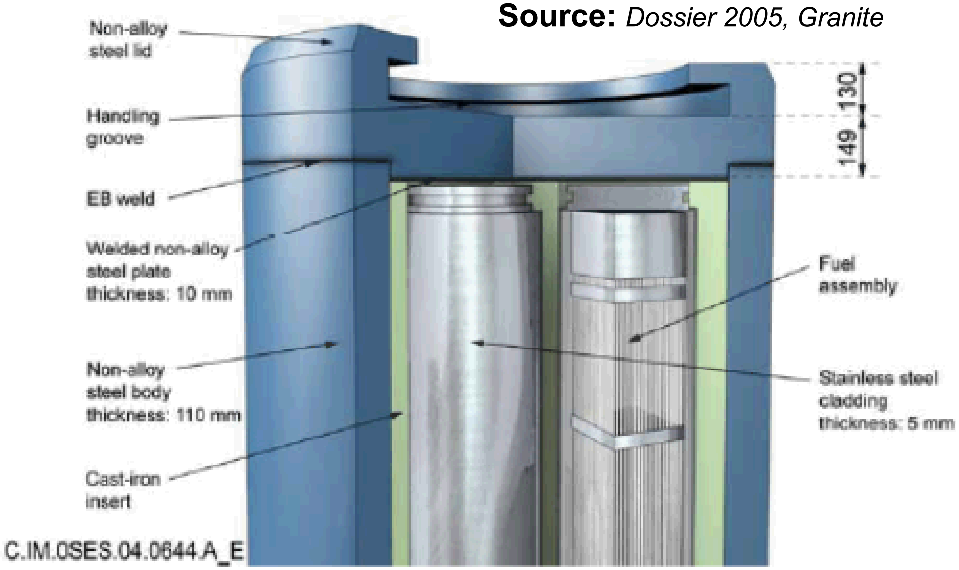
Source: *Dossier 2005, Argile*

- EBS Functions: contain, immobilize, delay and reduce migration
- Contain: Long-lived waste package
- Immobilize: Prevent radionuclides from dissolving, and when dissolution occurs, encourage their precipitation as insoluble solids.
- Delay and reduce migration: Establish a diffusive regime within the disposal cells, by means of a buffer surrounding the spent fuel packages using rings and plugs of compacted bentonite.

Used Fuel Disposition

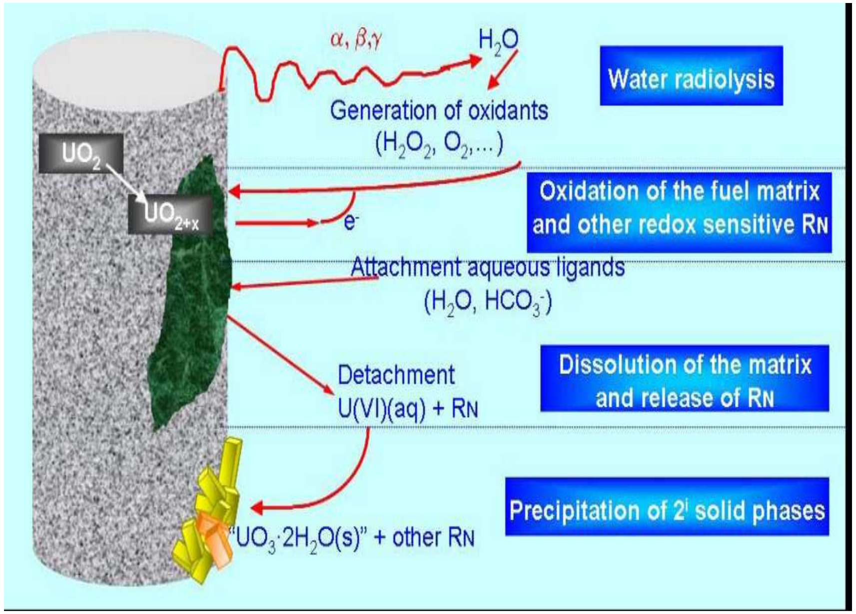
Used Fuel (UOX and MOX) Degradation Conceptual Models – Clay and Granite

Source: *Dossier 2005, Granite*



Source: *Dossier 2005, Shale*

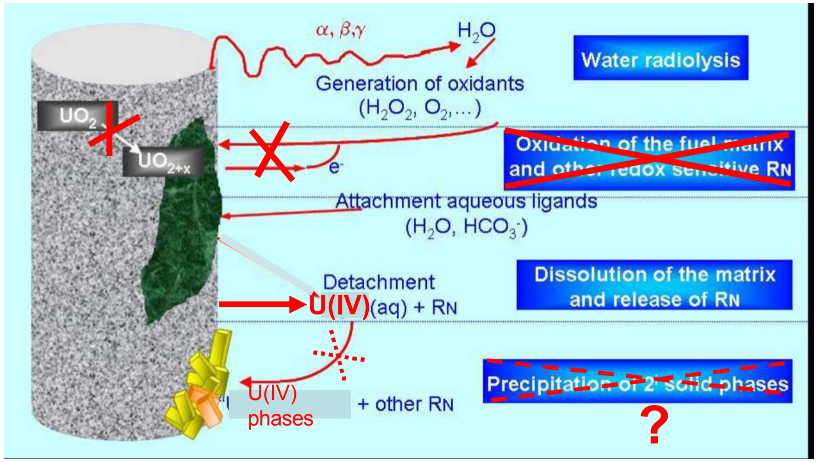
- the labile release fraction linked to accelerated diffusion by alpha
- Alpha radiolytic dissolution model for the matrix – the “radiolytic model”

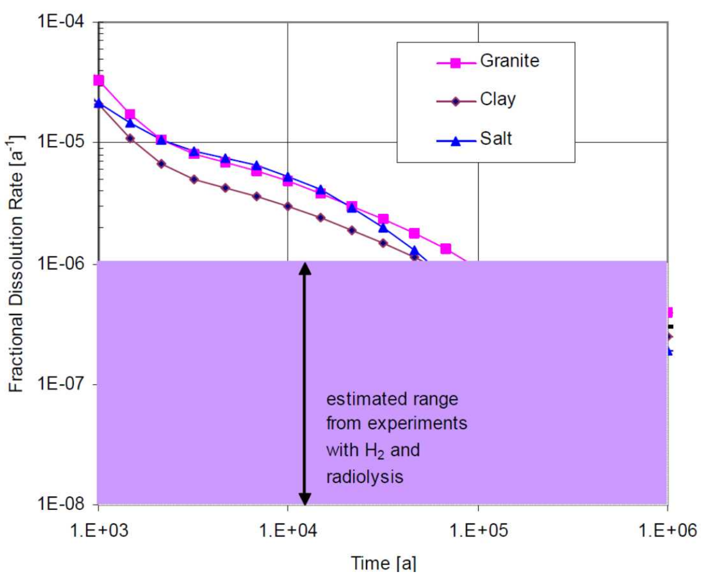


Source: *Poinssot et al. European Commission Report for Contract No. FIKW-CT-2001-00192 SFS*

Used Fuel Disposition

Ongoing Research – Combined Effects of Radiolysis and Reducing Agents (e.g. Hydrogen)





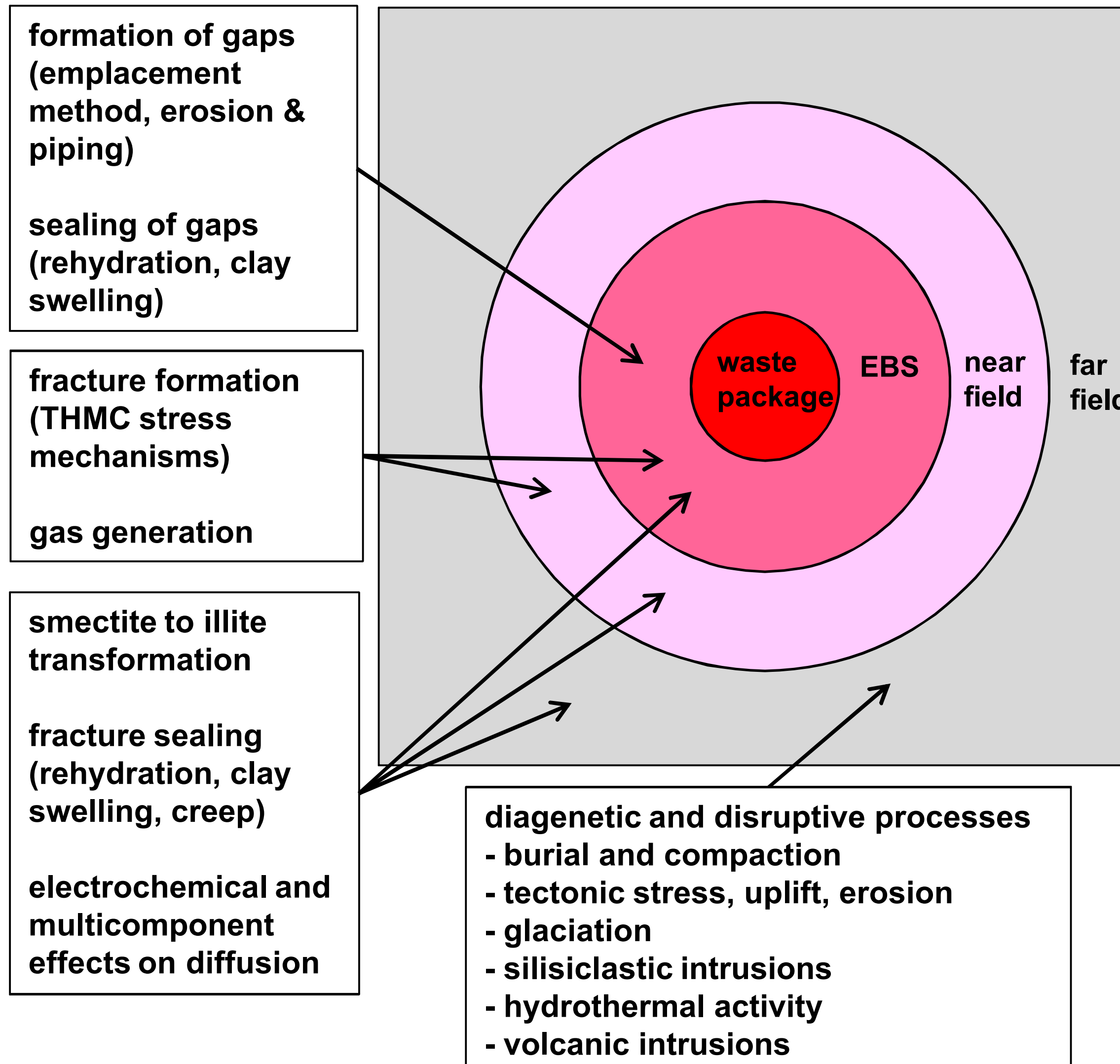
- **Hydrogen scavenges the radiolytic oxidizing agents**
- **The fuel U(IV) matrix is not oxidized nor are the multivalent radionuclides oxidized from their lower valence/less soluble states; <u>oxidative dissolution is shut off</u>**
- **The fuel degrades by saturation-limited dissolution of the UO_2 matrix (i.e. saturation within the waste package and dissolution limited by the slow rate of diffusion into the bentonite buffer with anionic exclusion)**

Result - fuel matrix may last more than a million years in reducing repository settings with appropriate engineered barrier systems

Source: *Poinssot et al. European Commission Report for Contract No. FIKW-CT-2001-00192 SFS*

UFD FEP Activities - LBNL

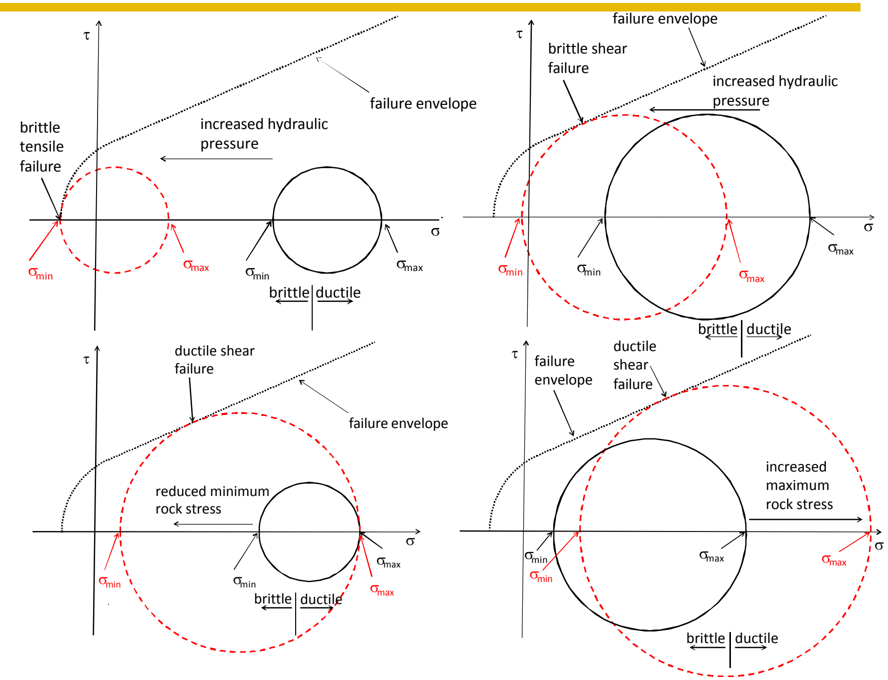
- **LBNL is investigating FEPs for clay/shale host rock and bentonite backfill**
  - EBS, near-field host rock, and far field host rock
- **LBNL FEP investigations for 2011 will include the following areas**
  - repository thermal limits
  - resaturation of near field and EBS
  - natural disturbances of a clay/shale host rock



Used
Fuel
Disposition

UFD FEP Activities - LBNL

- **Natural Disturbances of a Clay/Shale Host Rock**
  - clay/shale formations subject to mechanical damage, particularly from pore-water overpressure
    - *overpressure generally associated with low-permeability formations*
    - *burial/compaction, tectonic stress, glaciation, smectite/illite, …*
    - *pore water overpressure more likely to increase overconsolidation ratio*
    - *ductile/brittle transition*



Houseworth 2011

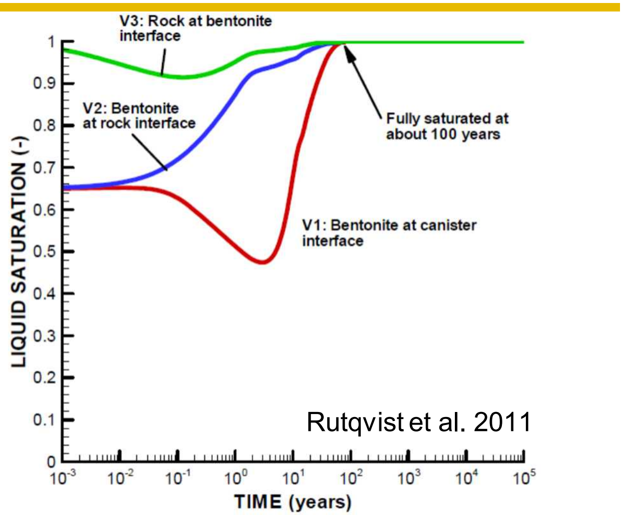
  - diagenesis can also lead to effectively high overconsolidation ratios
  - one potential outcome of overpressure: episodic hydraulic fracturing
    - *may be difficult to recognize because of fracture self-sealing*

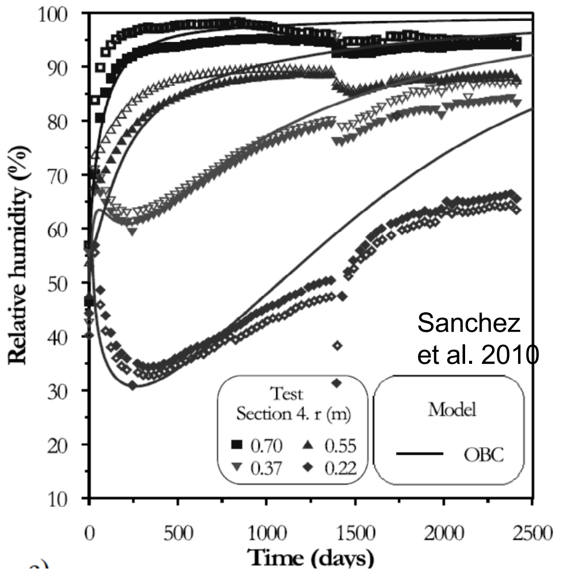
Used Fuel Disposition

UFD FEP Activities - LBNL

Resaturation of Near Field and EBS

- At repository closure, near-field host rock and EBS are unsaturated
  - *excavation leads to partial desaturation of the near field*
  - *bentonite is emplaced under partially-saturated conditions*
- Resaturation affects
  - *bentonite swelling to fill gaps*
  - *sealing of EDZ fractures*
- Comparisons of predicted to measured resaturation of bentonite indicates that the process is not well understood
  - *more smectite/illite reaction prior to buffer/EDZ “healing”*
  - *exposure to heated vapor may lead to increased permeability*





Used
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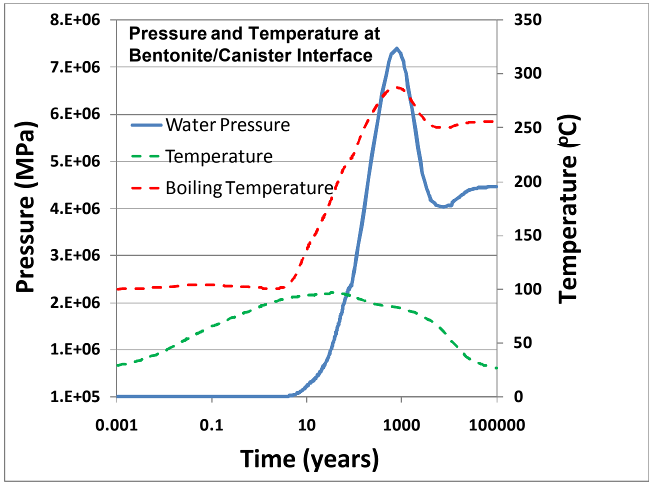
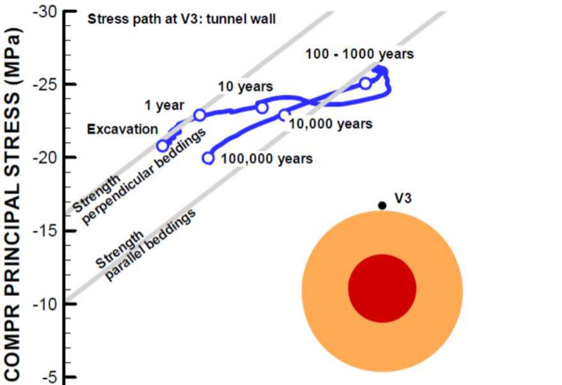
UFD FEP Activities - LBNL

- **Repository Thermal Limits**
  - Limited to <100 °C for initial FEPs analyses based on limits imposed by European programs
  - May be difficult to reach boiling in a low permeability clay/shale environment
  - Even for low thermal limits pressures will be significantly affected by repository heat
  - Limiting Factors?
    - *European limits generally based on formation thermal history and natural analogues*
    - *leads to greater overconsolidation after thermal period*
    - *smectite to illite may occur at temperatures as low as 60° C, but reactions not well understood*
      - activation energy
      - access to potassium

Modified from Rutqvist et al. 2011





Rutqvist et al. 2011

UFD FEP Activities - LLNL

- **Summary Tracking Tool**
  - *Statistics* sheets (regular and binary) were updated to be consistent with the slightly revised FEP list and with the modification of WF types (reduced from 7 to 6)
  - An *organization* summary sheet was added to identify the number of responsible organizations listed for each FEP/ environment/ WF combination (color codes are red for none, green for 1, and yellow for 2 or more)
  - Midway through updates to assimilate the information in the FY10 end-of-year deliverable

UFD FEP Activities – LLNL

- **FEP Evaluations**
  - LLNL has taken initial responsibility for EBS, material, thermal, and near-field FEPs.
    - *Responsibility will be shared with other labs as appropriate for these FEPs*
    - *LLNL will contribute to FEP evaluations led by other labs, where LLNL has particular expertise*
  - The materials survey work done as part of the EBS work package will be the beginning of the materials FEP evaluations, and is currently being converted to the FEP evaluation format