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Spent Fuel and Waste Science and Technology (SFWST)

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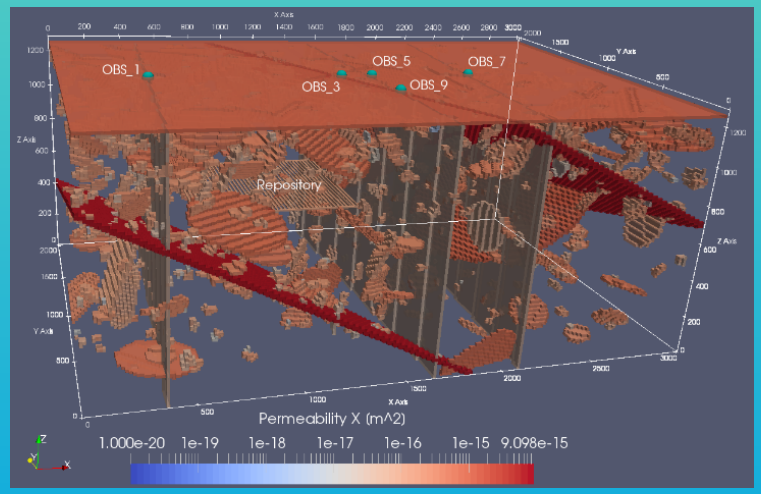

Overview of Engineered Barrier Systems (EBS) Research

US NWTRB Fall 2020 Fact-Finding Meeting
November 4-5, 2020

Ed Matteo
Sandia National Laboratories
Dept. of Nuclear Waste Disposal Research and Analysis

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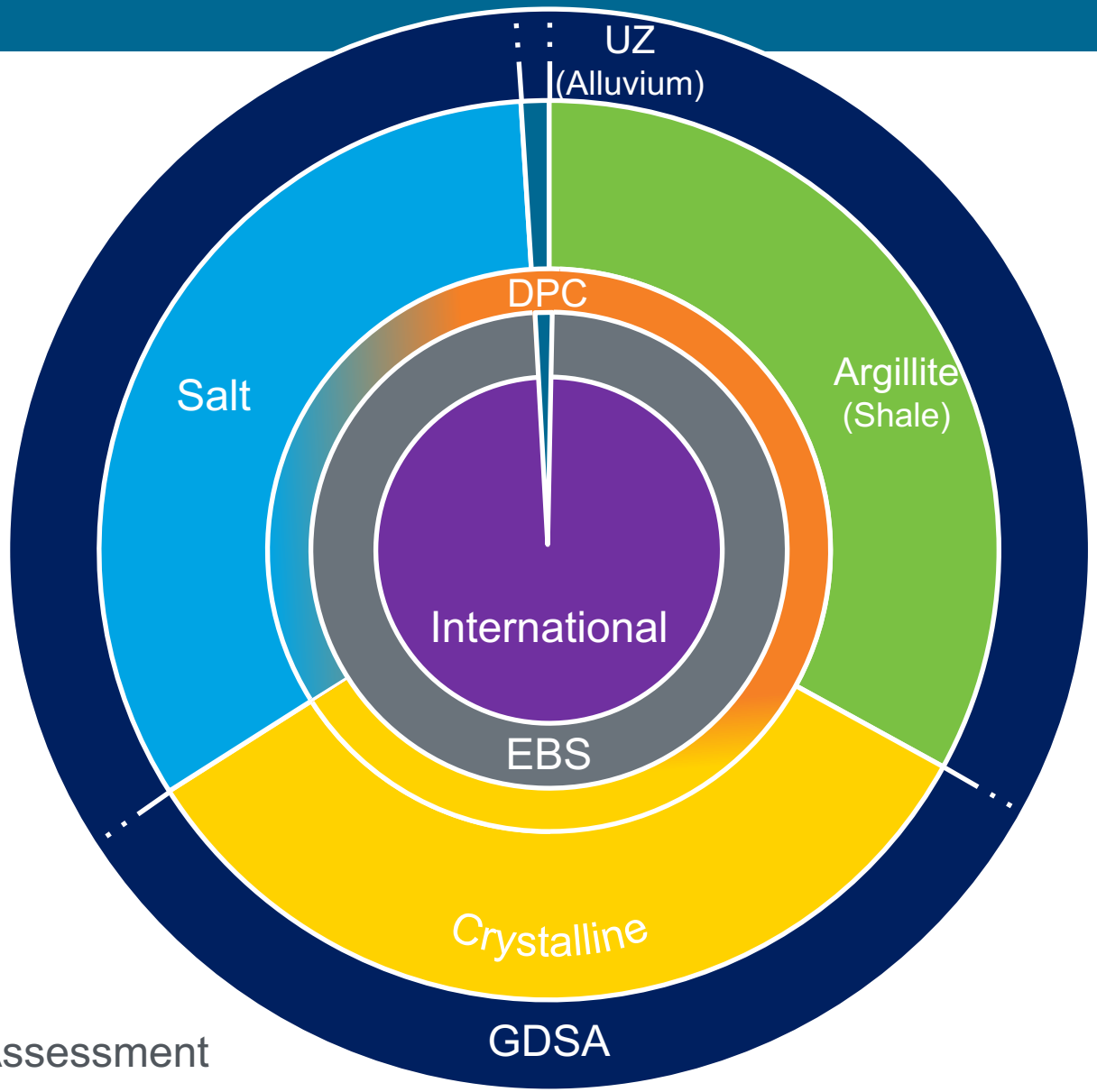
Overview

- Engineered Barrier Systems(EBS) Research relative to other SFWST research areas
- Knowledge and Capability Gaps
- Research Priorities
- HotBENT Deep Dive (presented by Liange Zheng)

R&D Priorities

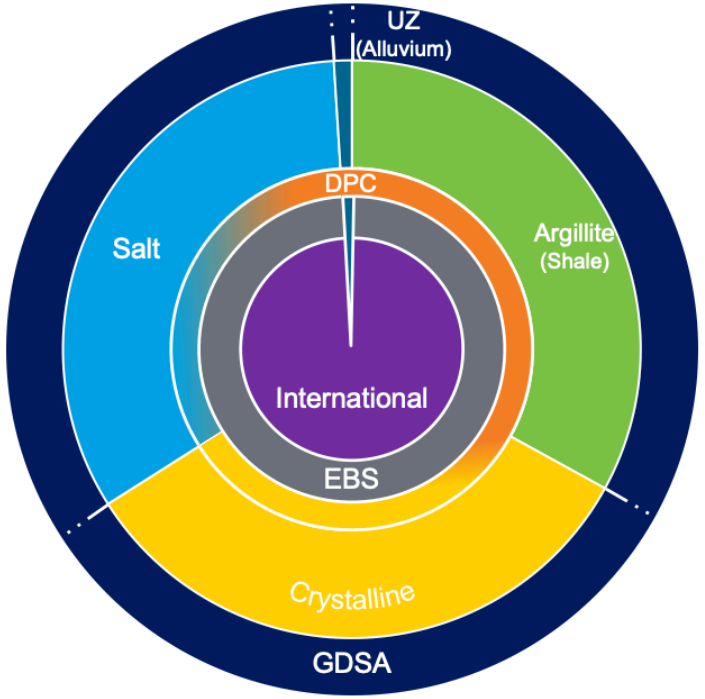
- Gaps in understanding of fundamental processes
  - Integrity of Repository Seals
    - Drift and shaft seals
    - Degradation evolution, esp. permeability evolution
  - Processes at material interfaces
    - Engineered materials and Disturbed Rock Zone (DRZ)
    - Waste Package materials, buffer, and host rock



UZ = Unsaturated Zone
DPC = Dual Purpose Canisters
EBS = Engineered Barrier System
GDSA = Geologic Disposal Safety Assessment

Knowledge and Capability Gaps

- Gaps in understanding of fundamental processes (cont.)
  - Coupled processes
    - Chemo-mechanics
    - Thermal-Hydrologic-Mechanical-Chemical
    - Multi-phase flow
    - Multi-scale phenomenon
    - Linking microstructural scale to continuum scale
  - Particular attention on cementitious materials and bentonite



How are EBS Knowledge Gaps Prioritized?

High Impact R&D Topics	High-Priority R&D Activities	Medium-High-Priority R&D Activities
High Temperature Impacts	D-1, D-4, I-4, I-6, I-16*, E-11, S-5	I-2, I-3, I-7, E-10
Buffer and Seal Studies	I-4, E-9, E-17*, A-8, C-15*	I-2, I-3, I-7, A-4, C-6, C-8, C-11
Coupled Processes (Salt)	S-1, S-3, S-4, I-12, I-13	I-14, S-2, S-7, S-8, S-11*
Gas Flow in the EBS	I-6, I-8, I-18*	I-9, P-17*
Criticality	D-1, D-3, D-4, D-5	
Waste Package Degradation	C-16*, P-12	E-4*, E-6
In-Package Chemistry	E-14*	E-2, E-20, P-15*, P-16*
Generic PA Models		P-1, P-2, P-4, P-11*, P-13*, P-14
Radionuclide Transport		C-11*, C-13*, C-14*, P-15*, P-16*
DFN Issues		I-21*, C-1, C-17*
GDSA Geologic Modeling		O-2, O-3
THC Processes in EBS		E-3

Activity Designator Legend:

A – Argillite
C – Crystalline
S – Salt
D – Dual Purpose Canisters
E – Engineered Barrier System
I – International
O – Other
P – Performance Assessment
* – indicates Gap Activity

High Priority EBS Activities

#	Description	SFWST EBS Activity	Int'l Tie-in
E-09 A-08	Cement plug/liner degradation Evaluation of Ordinary Portland Cement (OPC)	Experimentally verified cement-geomaterial 3D model development in PFLOTRAN (crosscut with Argillite DR) Seals in Salt (crosscut with Salt DR)	EBS Task Force Task Cement Task BATS Heater Test in Salt RANGERS Project
E-11	EBS High Temperature Geochemistry/ Mineralogy	Hydrothermal Experiments examining host, buffer, and canister materials interaction/evolution at elevated temperature (crosscuts with Crystalline and Argillite)	HotBENT

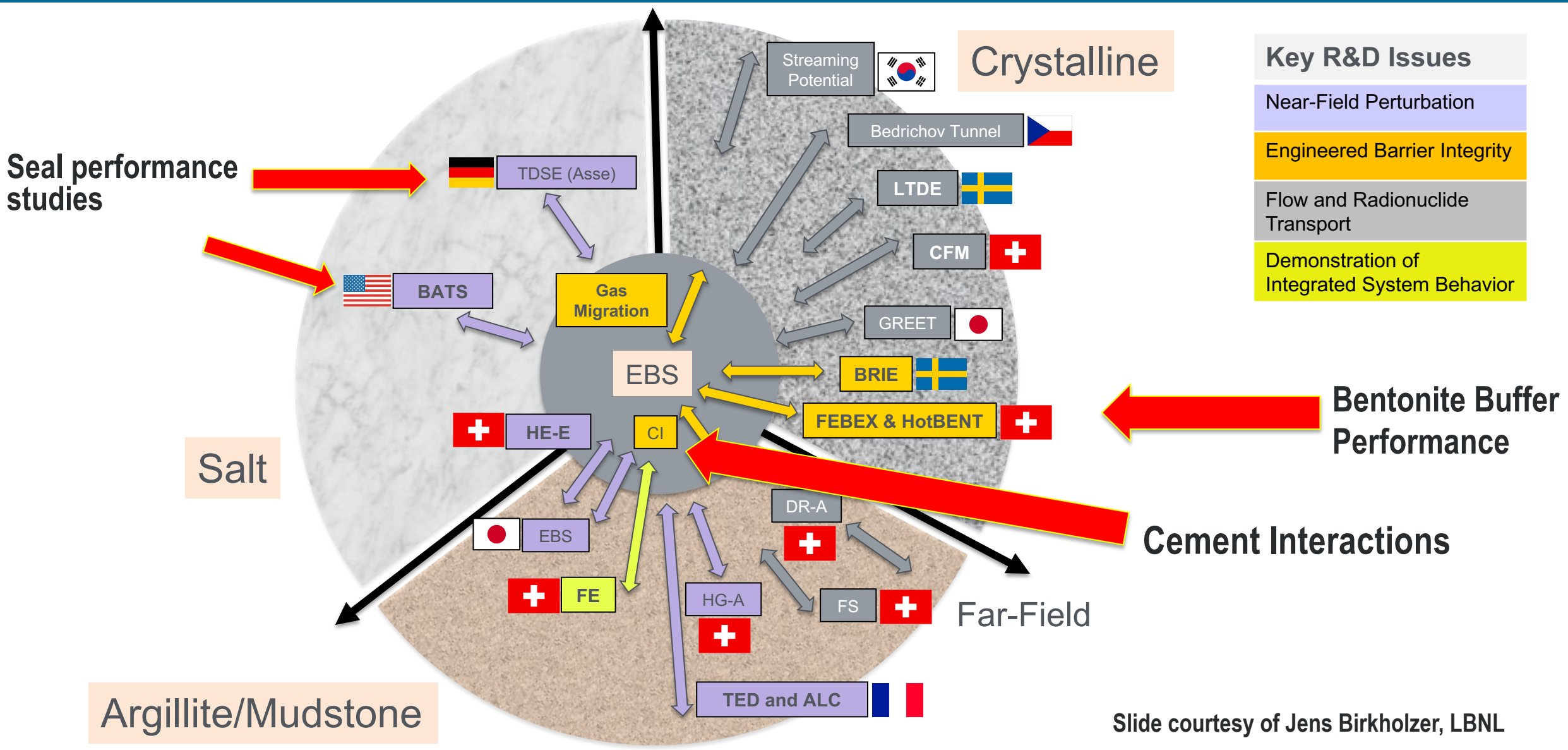
High Priority EBS Activities (cont.)

#	Description	SFWST EBS Activity	Int'l Tie-in
E-03 I-08	TH/THC Processes in EBS Advective gas flow in bentonite	Various Bentonite Studies -chemical controls -molecular scale -bench scale -drift scale	FEBEX activities DECOVALEX 2023 • Task B: Modeling Advection of Gas in Clays (MAGIC) • Task C: THM Modeling of the FE Experiment • Task E: Brine Availability Test in Salt (BATS)
I-04 E-10	Experiments of Bentonite at High Temperature High Temperature Behavior	Benchtop High Temp Bentonite Column Test Modelling Support of HotBENT and Benchtop Tests	HotBENT EBS Task Force Column Test

Knowledge and Capability Gaps

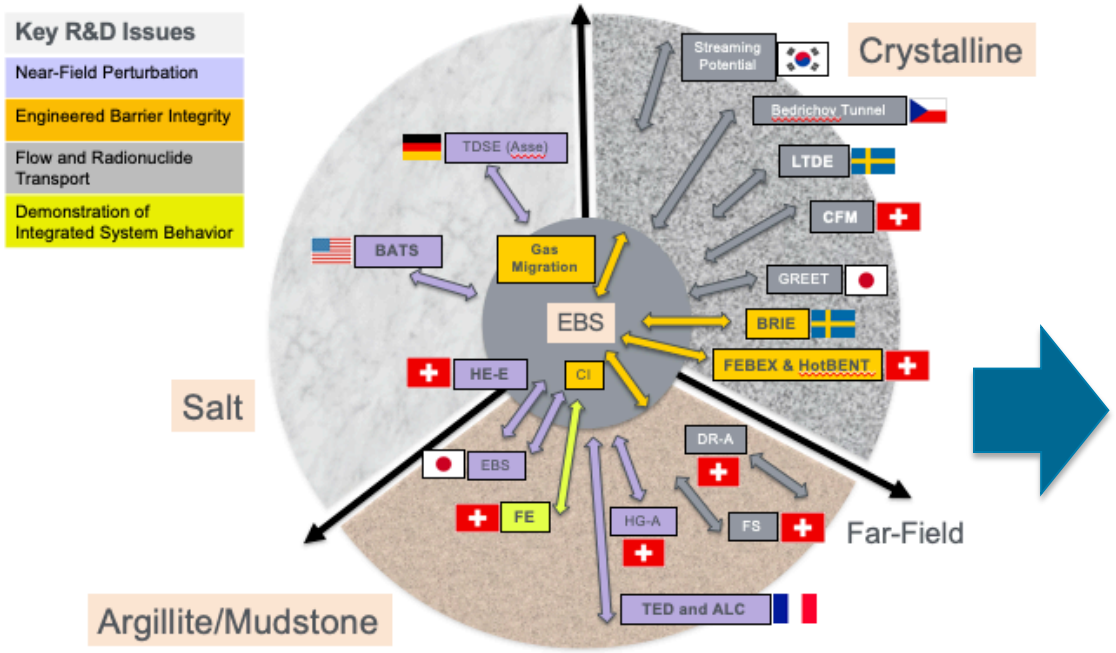
- Gaps in Process Models
  - Cement models for evolution of plugs and liners
    - Chemo-mechanical coupling
    - Fracture models
  - Saturation/Re-saturation of Cementitious Materials and Bentonite
  - Bentonite buffer
    - THMC models refinement
- Benefits of filling these gaps:
  - Impact representation of seal representation in GDSA, or at least improve confidence in permeability values for seals/interfaces
  - Improve understanding of near field geochemistry

Knowledge and Capability Gaps also Crosscut with the International Field Test Portfolio and Host Media



Slide courtesy of Jens Birkholzer, LBNL

EBS Involvement with International Activities



- FEBEX
  - Two-stage heater test with bentonite block buffer in the Grimsel granodiorite
  - Engineered Barrier System Task Force Task 9 (completed March 2020)
- DECOVALEX 2023 Task B, Task C, Task E
- Engineered Barrier System Task Force New Tasks
  - Cement-Bentonite Interactions
  - HotBENT Column Test at LBNL
- RANGERS
  - shaft and drift performance study in collaboration with Germany
- HotBENT Field Test
  - High temperature bentonite field test

FEBEX = Full-scale Engineered Barriers EXperiment

DECOVALEX = Development of Coupled models and their Validation against Experiments

RANGERS = Entwicklung eines Leitfadens zur Auslegung und zum Nachweis von geo-technischen Barrieren für ein HAW Endlager in Salzformationen

HotBENT = High Temperature Effects on Bentonite Buffers

Priority R&D – A Forward Look

- Continued participation in International EBS Studies
  - Continued participation in EBS Task Force, DECOVALEX, HotBENT, etc.
  - Collaboration with German partners in salt investigations of seal performance
  - Other emerging collaborative URL-based activities
- Improved understanding of fracture development in EBS materials, esp. cementitious materials and bentonite
  - Leverage tools for fracture representation from Crystalline or GDSA
  - Meshless methods for fracture representation
- Next generation materials, including cementitious materials
  - 21st century materials for are evolving towards a decarbonized energy infrastructure
  - Availability of supplemental cementitious materials (e.g. fly ash)
  - New materials, e.g. cements /binders with lower carbon intensity

References

J. Birkholzer, et al. *International Collaboration Activities in Different Geologic Disposal Environments.* US Department of Energy Spent Fuel and Waste Science and Technology Milestone Report M2SF-20LB010307012. LBNL-2001353, September 30, 2020.

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SFWST EBS Research Teams

Lawrence Berkeley National Laboratory

L. Zheng, L. Lammers, P. Fox, C. Chang, H. Xu, S. Borglin, M. Whittaker, C. Chou, C. Tournassat, N. Subramanian, Y. Wu, P. Nico, B. Gilbert, T. Kneafsey

Los Alamos National Laboratory

F. Caporuscio, K.B. Sauer, M.J. Rock

Sandia National Laboratories

E.N. Matteo, T. Dewers, S. Gomez, T. Hadgu

Vanderbilt University

C. Gruber, M. Steen, K.G. Brown, R. Delapp, A. Taylor, J. Ayers, D.S. Kosson