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Supplement of

The role of international collaboration in the United States geologic disposal research program

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The Role of International Collaboration in the United States Geologic Disposal Research Program

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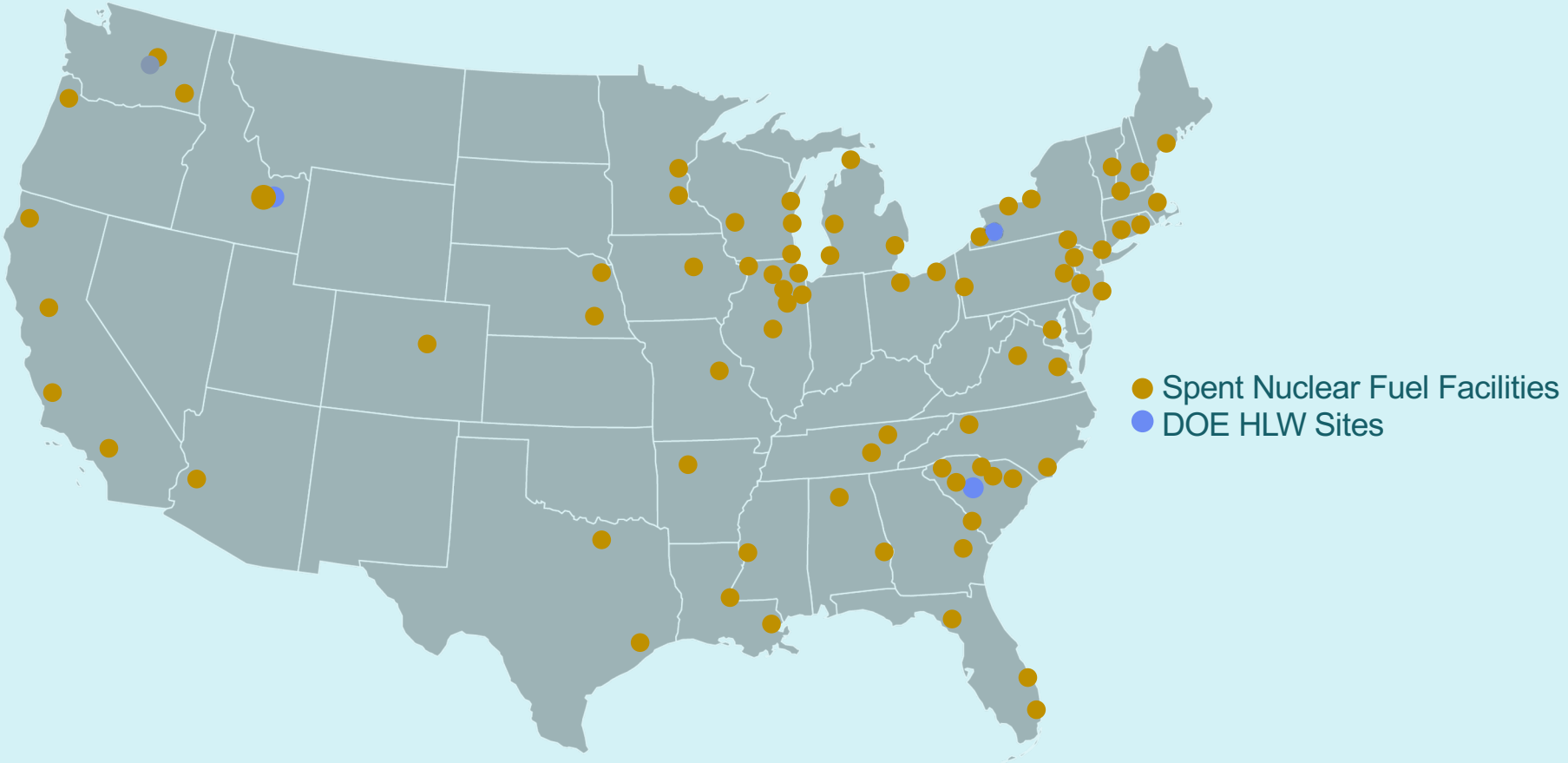
Spent Nuclear Fuel and High-Level Waste (HLW) Storage Sites



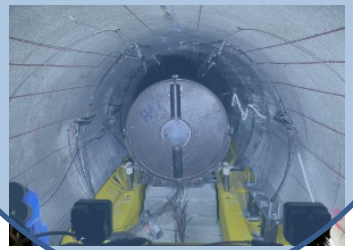
US Geologic Disposal Research Program at a Crossroads in 2010

- In 2010, the United States discontinued all activities focused on unsaturated fractured tuff formation as the geologic disposal option for spent fuel and high-level radioactive waste.
- A new DOE disposal research program was initiated to provide a sound technical basis for alternative disposal options across clay, crystalline, and salt rocks.
- To date, no regulatory framework exists for alternative disposal sites, and only generic (site-independent) disposal research can be conducted.

DOE's Office of Spent Fuel and Waste Disposition: Mission

R&D on Viable Geologic Disposal Options in the US

- Increase confidence in the robustness of multiple generic disposal concepts in the US
- Develop the science and engineering tools needed to support disposal concept implementation
- Evaluate potential for direct disposal of dual-purpose canisters

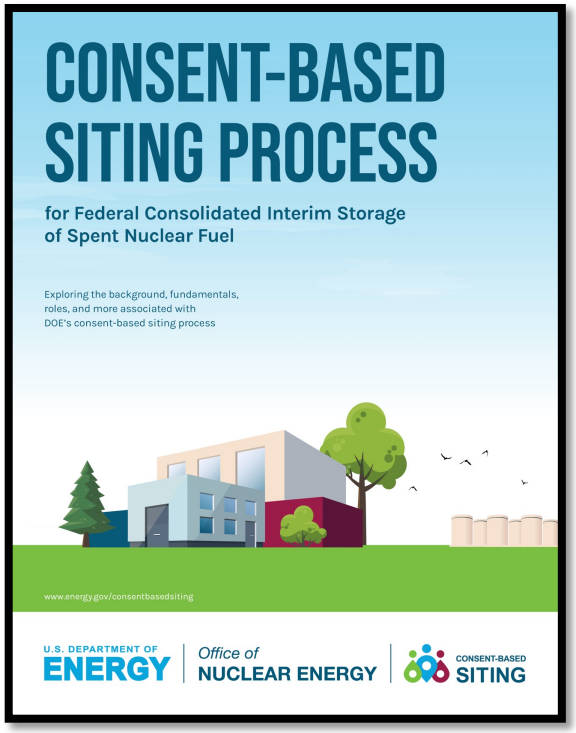


R&D on Extended Storage and Large-Scale Transport

Support the technical basis for evaluating:

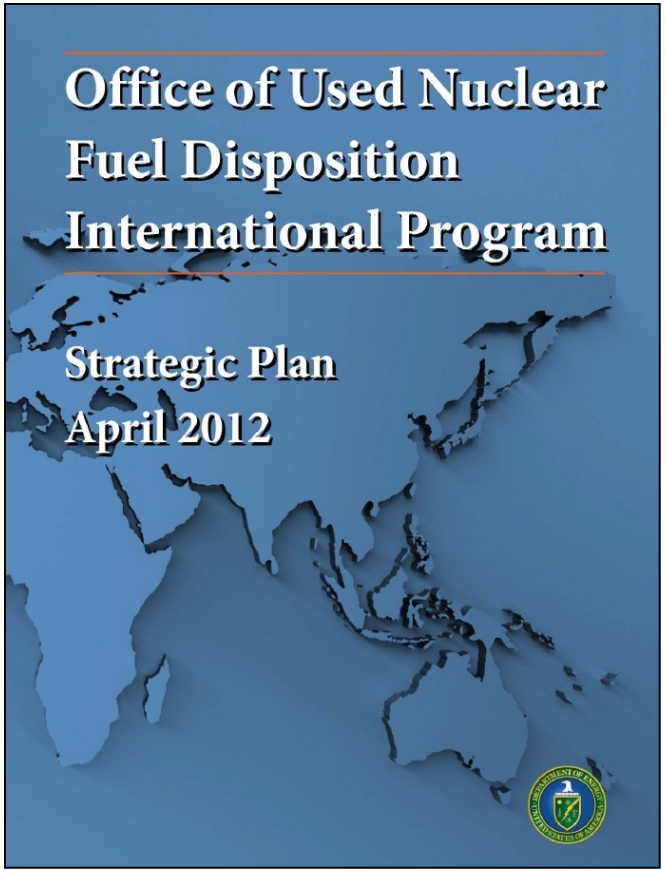
- Extended storage of used nuclear fuel
- Fuel retrievability and transportation after extended storage
- Transportation of high-burnup used nuclear fuel

Implementation of Federal Consolidated Interim Storage



Strategic Plan for International Collaboration in Disposal Research

- Prior to 2010, repository development in unsaturated fractured tuff was so unique with respect to design and geologic environment that overlap with international R&D was quite limited.
- Since the U.S. programs focus shifted to a wide range of other repository designs and host rock environments, there has been a lot more alignment with the international disposal world.
- A strategic decision was made in 2012 to significantly advance international collaboration in geologic disposal research.



The U.S. International Collaboration Program: Benefits and Principles

Principles

- Prioritize international R&D activities based on key issues, technical merit, relevance to safety, and cost/benefit
- Emphasize active R&D participation and access to experiments in underground research laboratories (URLs)
- Balance portfolio across host rocks, repository designs, and key R&D areas

Scientific and Technical Benefits

- Tap into global knowledge, stay abreast of science advances, gain access to international datasets and experiments
- Test and validate advanced process-modeling and experimental tools
- Understand research needs arising from critical (and sometimes surprising) issues related to “real” rocks and sites
- Leverage resources and share cost of science campaigns, in particular large experimental projects

Other Benefits

- Build valuable relationships and re-establish the U.S. disposal program as a committed international partner
- Work towards a common set of disposal best practices and lessons learned
- Attract, develop and retain a new generation of “waste disposal” scientists

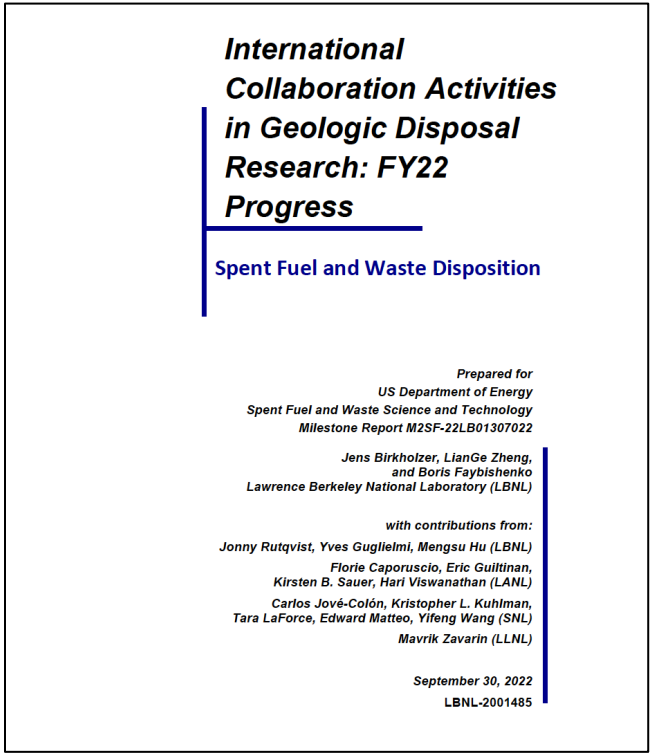
Tapping into Multinational Initiatives and Individual Collaborations

Multinational Initiatives

- Cooperative research partnerships, often requiring formal participation agreements
- Examples with active research focus: DECOVALEX Initiative, Mont Terri Project, Grimsel Test Site Projects, SKB Task Forces, etc.
- Other examples with focus on information exchange and data base development are provided, for example, by Nuclear Energy Agency (NEA) (e.g., Clay, Salt Club, and Crystalline Clubs)

Bilateral Collaborations

- Informal or formal research collaboration with individual organizations
- A prominent example is the comprehensive collaboration on salt disposal between U.S. and German organizations



International Collaboration Activities in Geologic Disposal Research: FY22 Progress

Spent Fuel and Waste Disposition

Prepared for
US Department of Energy
Spent Fuel and Waste Science and Technology
Milestone Report M2SF-22LB01307022

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Mavrik Zavarin (LLNL)

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LBNL-2001485

International Collaboration Report FY22, 393 pp

Multinational Initiatives with Focus on Underground Research Labs

Initiative	Host Rock	URL	Attributes
DECOVALEX DEvelopment of COupled models and their VALidation against Experiments Project	Multiple	Multiple	• Long-term international model comparison initiative • **Multiple modeling tasks** with validation against experiments
Mont Terri Project	Argillite	Mont Terri, Switzerland	• **Multiple experiments** are conducted and evaluated collaboratively • Access to data and results from past and ongoing experiments
SKB Task Forces SKB = Swedish Nuclear Fuel and Waste Management	Crystalline	Äspö Hard Rock Lab, Sweden	• Collaborative modeling of **multiple tasks** • Focus on flow and transport in fractured rock and engineered barrier system
Colloid Formation and Migration Project (CFM)	Crystalline	Grimsel Test Site (GTS), Switzerland	• Long-term project with several test phases • Investigation of colloid formation, colloid migration, and radionuclide transport
FEBEX-DP Full-Scale Engineered Barrier Experiment - Dismantling Proj.	Crystalline EBS Focus	GTS, Switzerland	• Dismantling and characterization of full-scale heater test after 18 years of heating • Collaborative analysis of data and samples
HotBENT	Crystalline EBS Focus	GTS, Switzerland	• Conduct a full-scale high-temperature heater test at 200°C maximum temperature

Multi-Purpose

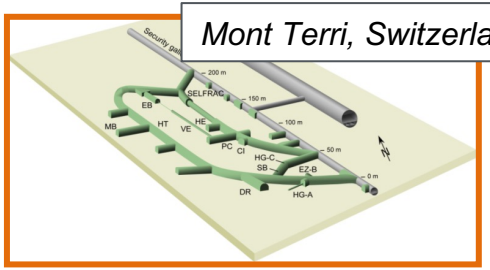
Single Purpose

Currently active

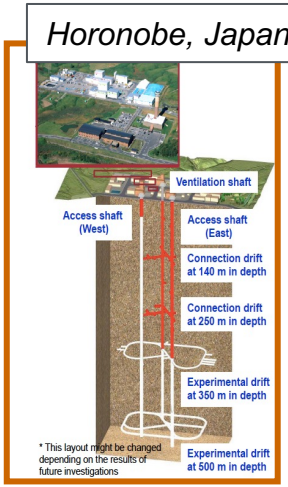
International URLs with U.S. Participation (plus WIPP facility for salt)

Clays and Mudstones

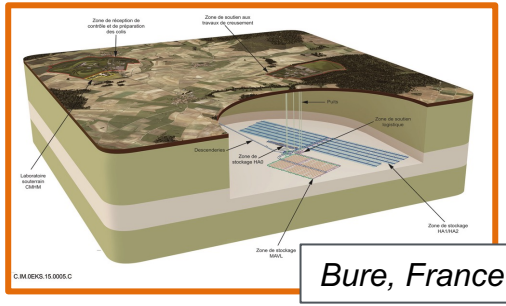
Mont Terri, Switzerland



Horonobe, Japan

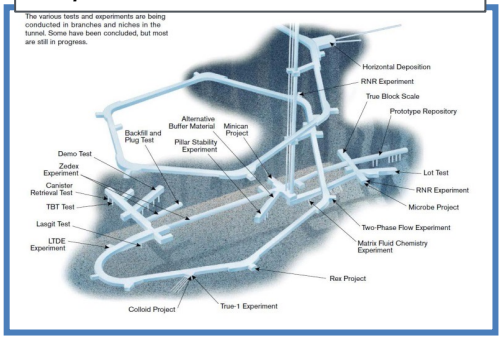


Bure, France

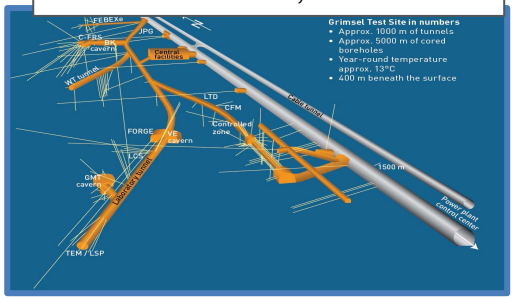


Crystalline

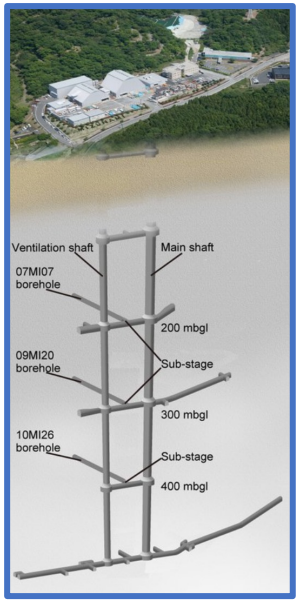
Äspö Hard Rock Lab, Sweden



Grimsel Test Site, Switzerland



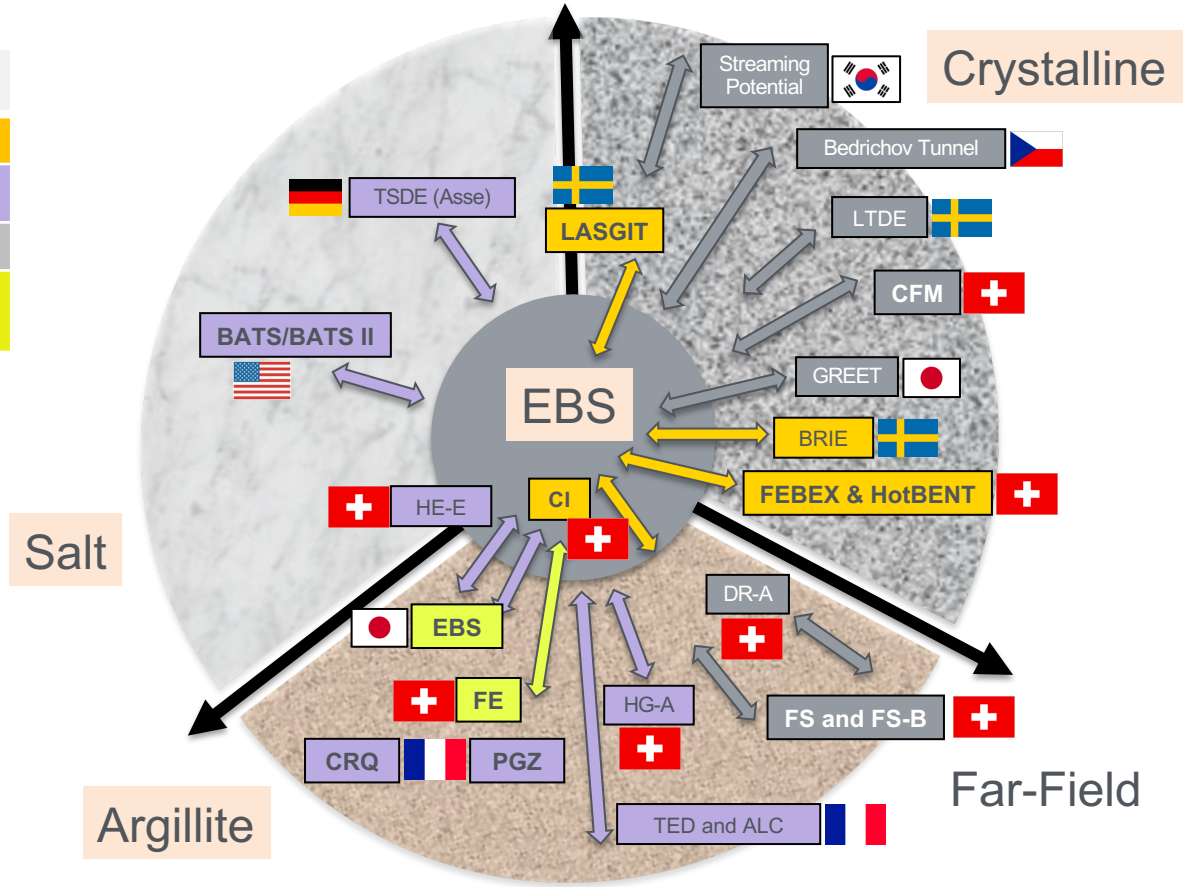
Mizunami, Japan



International Activities Involving Field Experiments (Since 2012)

Key R&D Issues

- Engineered Barrier Integrity
- Near-Field Perturbation
- Flow and Radionuclide Transport
- Integrated System Behavior and Performance Assessment



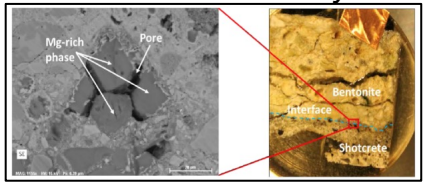
International Efforts Are Integrated Into DOE Priority Research: Understanding High Temperature Effects

Can waste package and bentonite buffer temperature safely be raised to 200°C, without causing performance relevant alteration and damage in barrier behavior?

Fundamentals of Physico-Chemical Alterations

- Laboratory imaging/characterization of heated samples
- Detailed coupled processes modeling of individual components

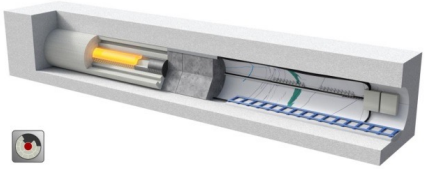
Micro-structural analysis



Barrier System Behavior

- Laboratory or *in situ* testing of barrier systems
- Validation of predictive process models for system behavior
- Predictions of engineered and natural barrier perturbations
- Optimization studies (e.g., alternative backfill materials)

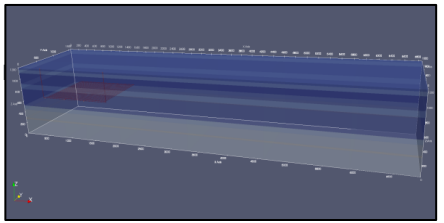
Lab and field experiments



Performance Assessment

- Include high temperature effects in performance assessment models
- Determine scenarios and parameters with significant impact on high-temperature repository performance
- Conduct performance assessment for different thermal designs

Performance assessment modeling

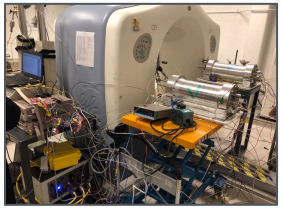


International Efforts Are Integrated Into DOE Priority Research: Understanding High Temperature Effects

Can waste package and bentonite buffer temperature safely be raised to 200°C, without causing performance relevant alteration and damage in barrier behavior?

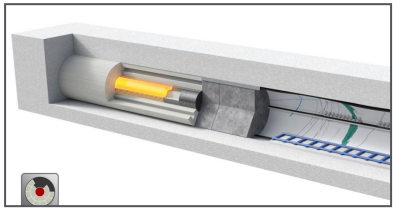
- **Long-term demonstration experiment at 100 °C**
- **Exploratory simulations for 200 °C: THMC modeling**
- **High-temperature laboratory testing at 200 °C**
- **Long-term demonstration experiment at 200 °C**
- **Performance assessment of 200 °C repository**

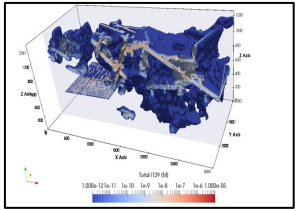
FEBEX Dismantling Project



SKB EBS Task Force

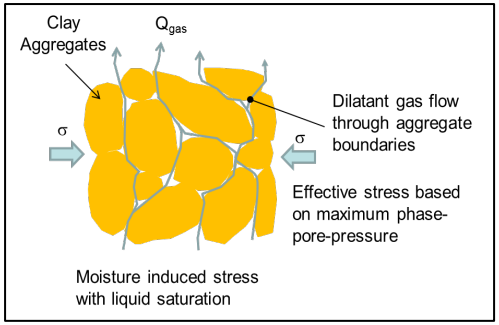
HotBENT Project



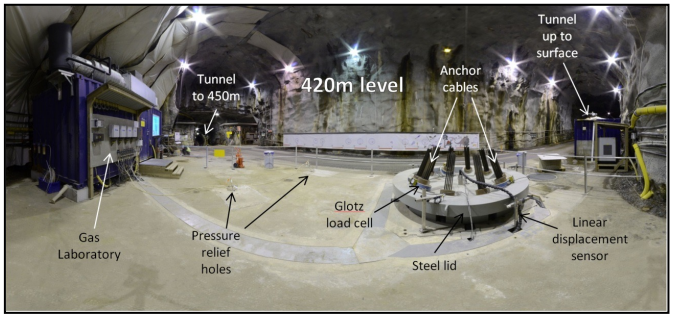


DECOVALEX 2023 and 2027

International Efforts Are Integrated Into DOE Priority Research: Understanding Gas Migration in Clay-Based Materials

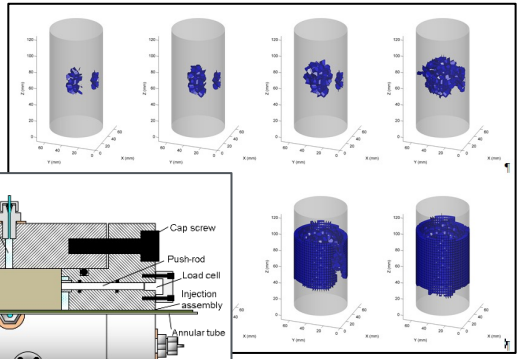


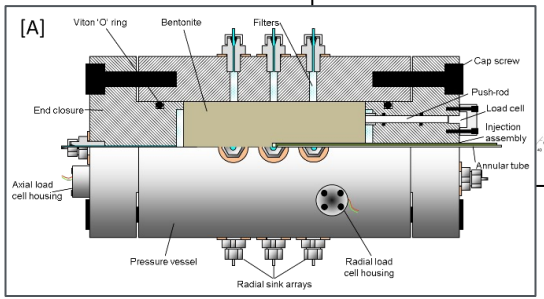
Step 2: ***Full-scale behavior and predictive modeling***



In-Situ **LASGIT Experiment at Äspö Hard Rock Lab in DECOVALEX 2023**

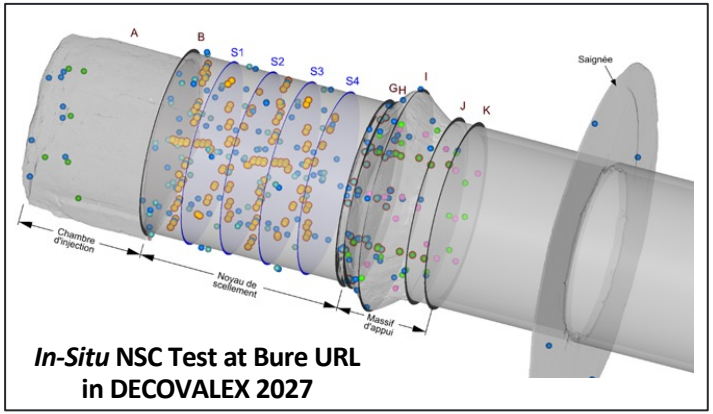
Step 1: Basic process understanding





Laboratory Experiments in DECOVALEX 2019

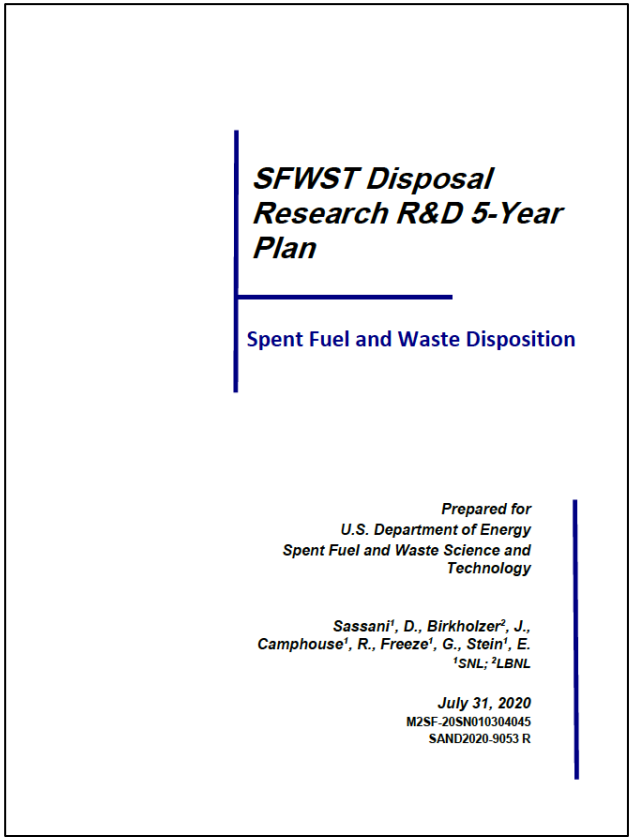
Step 3: ***Testing of a gas permeable seal***



In-Situ **NSC Test at Bure URL in DECOVALEX 2027**

International Collaboration in Disposal Research Five-Year Plan (2020)

- Ongoing Activities
  - ✓ Continue **participation within international R&D** in URLs for a range of geologic systems
  - ✓ Pursue a **more active role in conducting experimental work** in international URLs (e.g., HotBENT)
  - ✓ Contribute to **integration and confidence building** for safety assessment models (e.g., DECOVALEX task)
  - ✓ Continued assessment and integration of **new international opportunities:** e.g., Sealing Elements
- New Directions
  - ✓ Utilize international activities for **workforce development in disposal science**
  - Develop best practices and technologies for **site selection and characterization**



SFWST Disposal Research R&D 5-Year Plan

Spent Fuel and Waste Disposition

Prepared for
U.S. Department of Energy
Spent Fuel and Waste Science and Technology

Sassani[1], D., Birkholzer[2], J., Camphouse[1], R., Freeze[1], G., Stein[1], E.
[1]SNL; [2]LBNL

July 31, 2020
M2SF-20SN010304045
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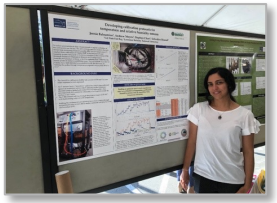
Next Gen Workforce Development Pilot Program at LBNL, SNL, LANL

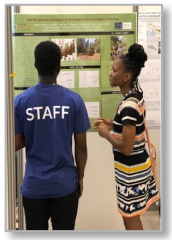
Stimulating Student Interest:

- Seminars Series
- Summer Courses



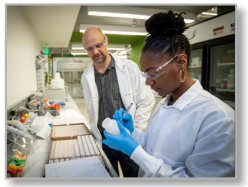
Creating the Pipeline:

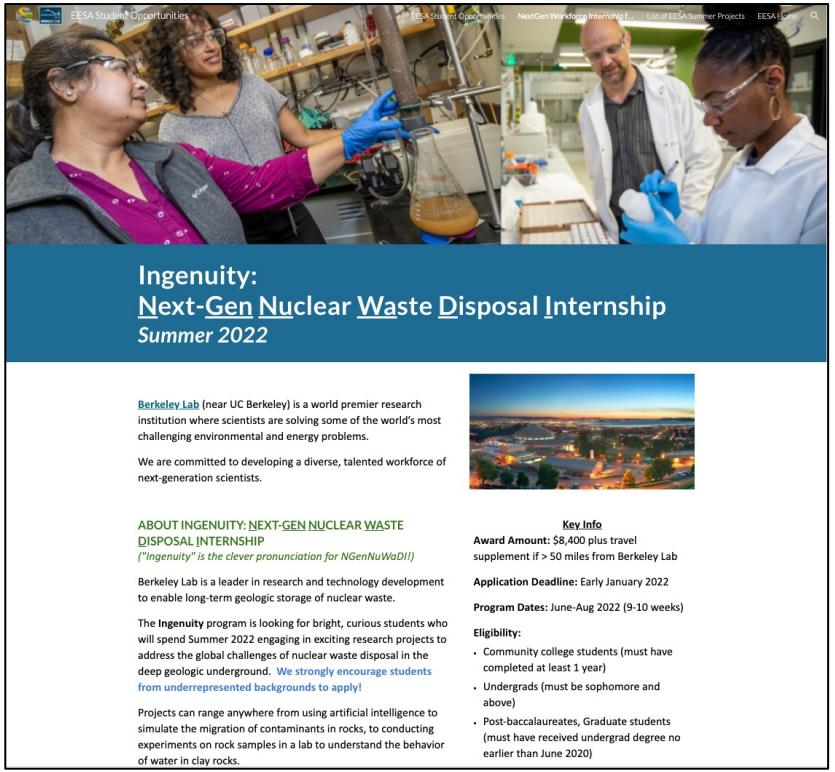
- Undergraduate/Graduate Intern Program at National Labs
- Opportunities of Time Abroad with International Collaborators



Advancing the Pipeline:

- Dedicated Post-Doc at National Labs (e.g., the HotBENT post-doc)
- Opportunities of Time Abroad with International Collaborators





Special focus on underrepresented communities and minority-serving universities

International Collaboration in Site Selection and Characterization

Best Practices and Lessons Learned

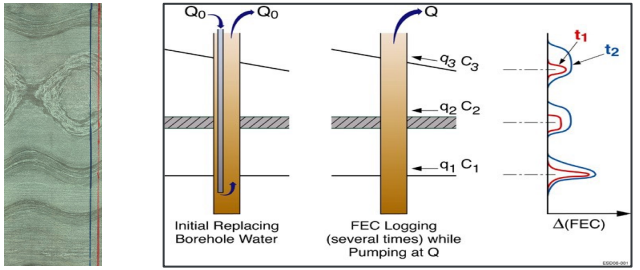
Germany: is currently in early stages of site selection with broad range of host rocks.

Switzerland: has just down selected from three siting regions to one.

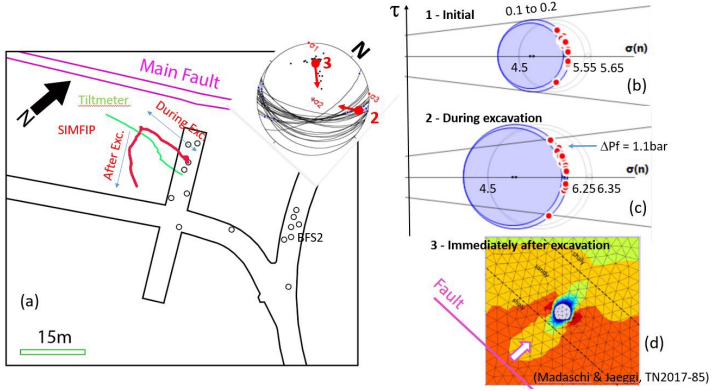
Canada: has narrowed its search from initially 22 areas to two sites.

Sweden: has has finalized its site selection and site characterization process.

Site Characterization Methods



Characterization of flowing fractures in deep borehole at COSC Project, Sweden



Fault characterization studies at Mont Terri, Switzerland

Summary

- **Active collaboration with international programs is a central and fully integrated element of United States Disposal Research Program**
- **International research activities have been extremely beneficial:**
  - Improving science base, reducing uncertainty, and building confidence in alternative geologic disposal options
  - Testing new advanced process-modeling and monitoring tools
  - Shared cost for large expensive experiments
  - Information and knowledge exchange in terms of best practices, state of the art simulation and monitoring methods, R&D priorities elsewhere
- **We are always interested in additional opportunities for expansion of our international disposal research activities (e.g., best practices in site selection, EURAD-2 collaboration)**

Thank You!

Funding for this work was provided by the Spent Fuel and Waste Science and Technology Campaign, Office of Nuclear Energy, of the U.S. Department of Energy, under Contract Number DE-AC02-05CH11231 with Lawrence Berkeley National Laboratory.

Second International DECOVALEX Coupled Processes Symposium: November 14-16, 2023 in Troyes France

DECOVALEX 2023 DECOVALEX 2023 Symposium

Home Committees Attend Abstract Submission Program

Second International DECOVALEX Coupled Processes Symposium

November 14-16, 2023; Troyes, France

Coupled thermo-hydro-mechanical-chemical (THMC) processes in geological systems are critically important to the performance and safety assessment of geologic disposal systems for radioactive waste and spent nuclear fuel. Understanding of such processes is also essential for a number of other subsurface engineering processes, including mining, geothermal exploration, geological carbon sequestration, energy storage, and oil and gas production.

The Second International DECOVALEX Symposium on Coupled Processes in Radioactive Waste Disposal and Subsurface Engineering Applications invites you to the beautiful city of Troyes, France on November 14-16, 2023. This in-person symposium is jointly hosted by ANDRA, Lawrence Berkeley National Laboratory, and the DECOVALEX project - an international collaboration for advancing the understanding and numerical simulation of coupled THMC processes in a geological system.

This open symposium will feature internationally recognized keynote speakers and researchers focusing on coupled processes, including computational methods, lab experiments, and in situ tests. The symposium will also provide exciting insights from the current phase of the DECOVALEX project, referred to as DECOVALEX-2023.

https://2023-decovalex-coupled-processes-symposium.lbl.gov/home