SAND2017-5266PE

Spent Fuel and Waste Science and Technology

Update of DWR Safety Analysis R&D

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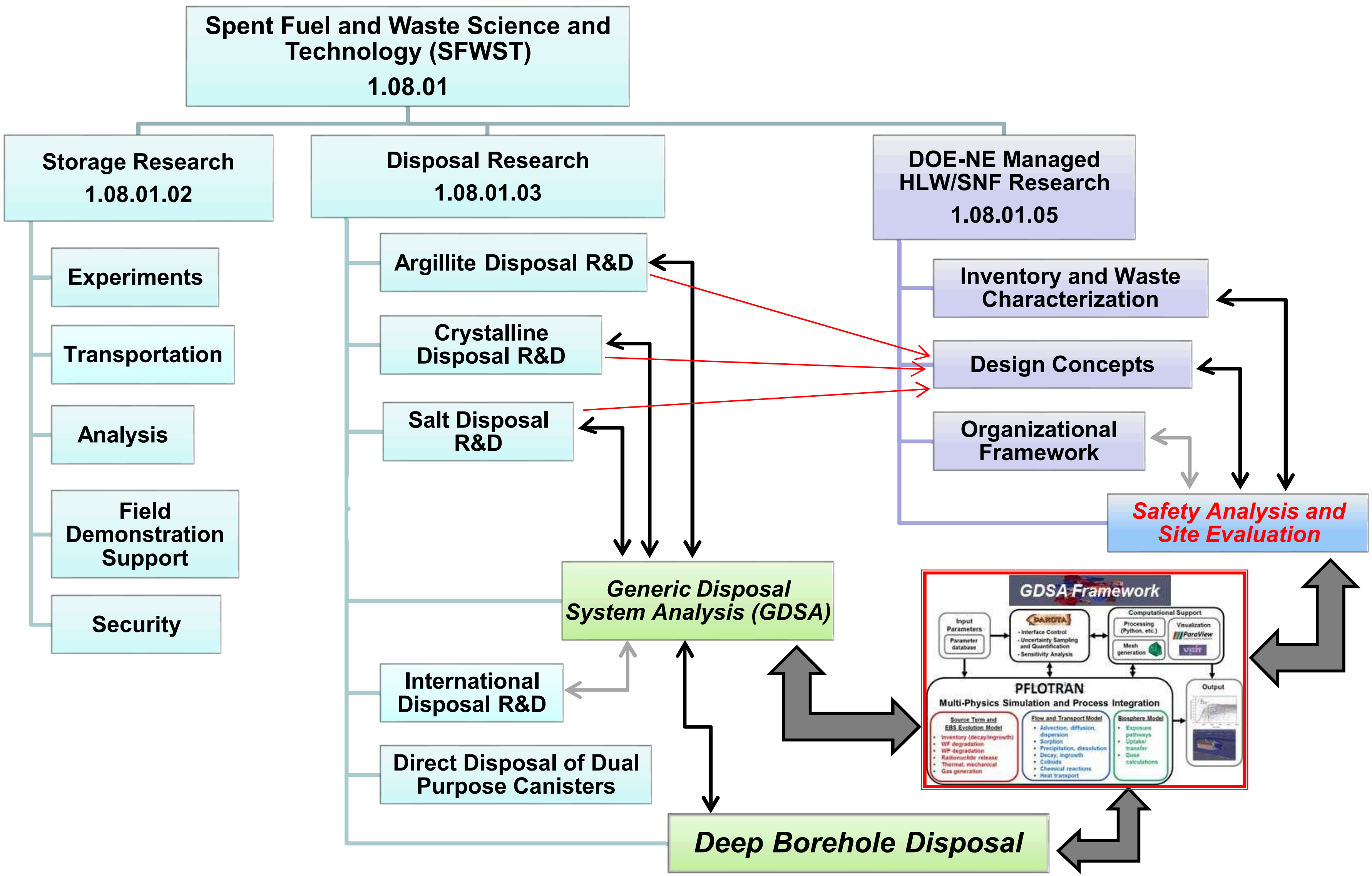
Defense Waste Repository R&D (*Safety Analysis & Technical Site Evaluation*)

- **<u>Objective</u>: address the technical elements necessary to establish the safety case associated with select DWR repository sites**
  - Develop generic reference cases for select geologic media: salt, crystalline, argillite
  - Develop a total system performance assessment (TSPA) for generic repository reference cases, including FEPs analyses and alternative EBS design concepts analyses
  - Define safety/performance objectives for a DWR and a technical site-evaluation plan
  - Regional geologic evaluations for the three host-rock media
- **<u>Accomplishments</u> in past year:**
  - Generic references cases completed (stratigraphy, EBS design, properties)
  - Deterministic and probabilistic simulations completed for generic crystalline and generic salt host-rock repositories; reference case and simulations for argillite later this year
  - Reference-case inventory: all existing and projected Savannah River HLW glass (7824 canisters); all projected Hanford HLW glass (11800 canisters); all DSNF canisters except three canisters with a heat output > 1500 W (in 2038)—94% of DSNF canisters are < 200 W; calcined waste; vitrified Cs/Sr; Naval pkgs < 1000 W; and FRG
  - Effect of decay heat considered in EBS design and in TSPA
  - Transport of I-129 and the Np-237 decay chain have been simulated

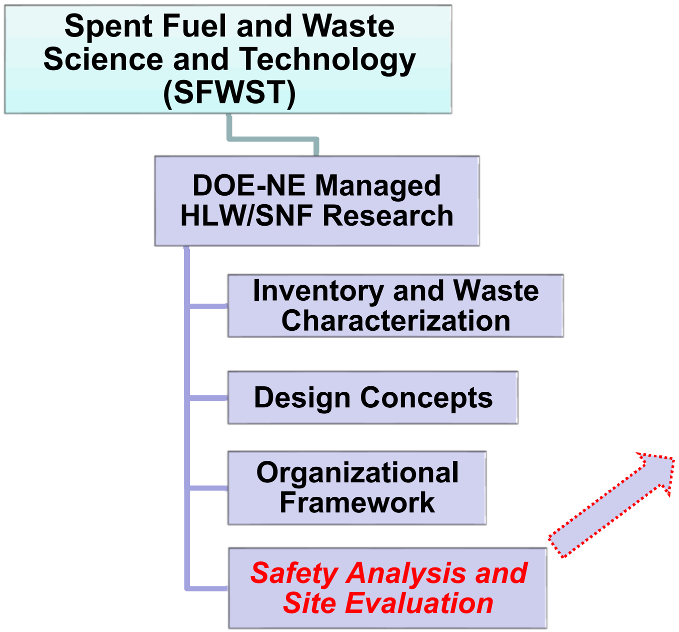
Work Structure for the R&D Program

- **Spent Fuel and Waste Science and Technology (SFWST) 1.08.01**
  - **Storage Research 1.08.01.02**
    - Experiments
    - Transportation
    - Analysis
    - Field Demonstration Support
    - Security
  - **Disposal Research 1.08.01.03**
    - Argillite Disposal R&D
    - Crystalline Disposal R&D
    - Salt Disposal R&D
    - *Generic Disposal System Analysis (GDSA)*
    - International Disposal R&D
    - Direct Disposal of Dual Purpose Canisters
    - *Deep Borehole Disposal*
  - **DOE-NE Managed HLW/SNF Research 1.08.01.05**
    - Inventory and Waste Characterization
    - Design Concepts
    - Organizational Framework
    - *Safety Analysis and Site Evaluation*

Model Integration Linkages—via GDSA



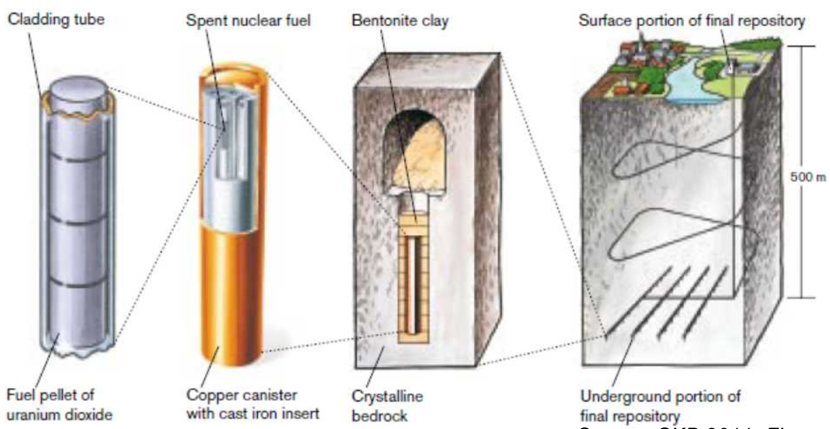
FY17 Safety Analysis Work Packages



- **WP 1 (SNL): Complete Reference Cases for each Geologic Medium ($270K)**
- **WP 2 (SNL): FEPs Analysis ($217K)**
- **WP 3 (*LANL*): FEPs Analysis, aka. pseudo-colloids ($100K)**
- **WP 4 (SNL): Evaluate Alternative EBS Concepts ($210K)**
- **WP 5 (SNL): Define Generic Performance/Safety Objectives ($100K)**
- **WP 6 (*LANL*): Preliminary Regional Geology Evaluation ($333K)**
- **WP 7 (SNL): Document Preliminary Technical Site Evaluation Plan ($142K)**
- **WP 8 (SNL): Total System Performance Assessment ($380K)**

WP 1 (SNL): Complete Reference Cases for each Geologic Medium

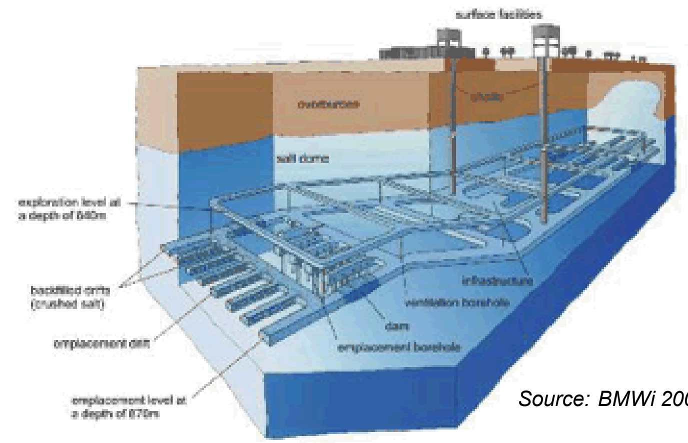
Mined repository in granite or other hard rock



Source: SKB 2011, Figure S-1.

(primary focus of FY16, in conjunction with GDSA work)

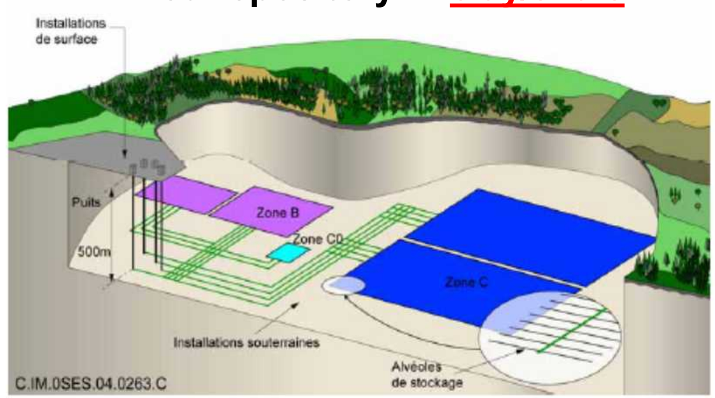
Mined repository in bedded salt



Source: BMWi 2008, Figure 15.

(completed an update in FY16)

Mined repository in clay/shale

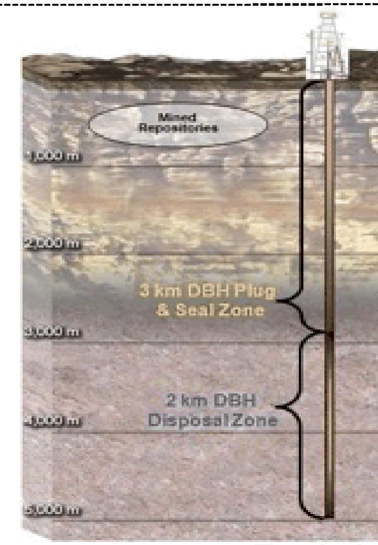


(Main focus of FY17)

Source: ANDRA 2005b.

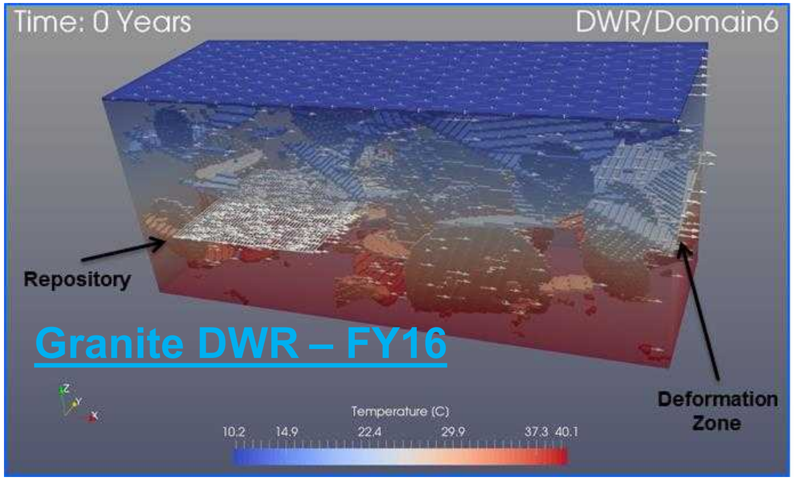
Deep borehole in crystalline basement rock

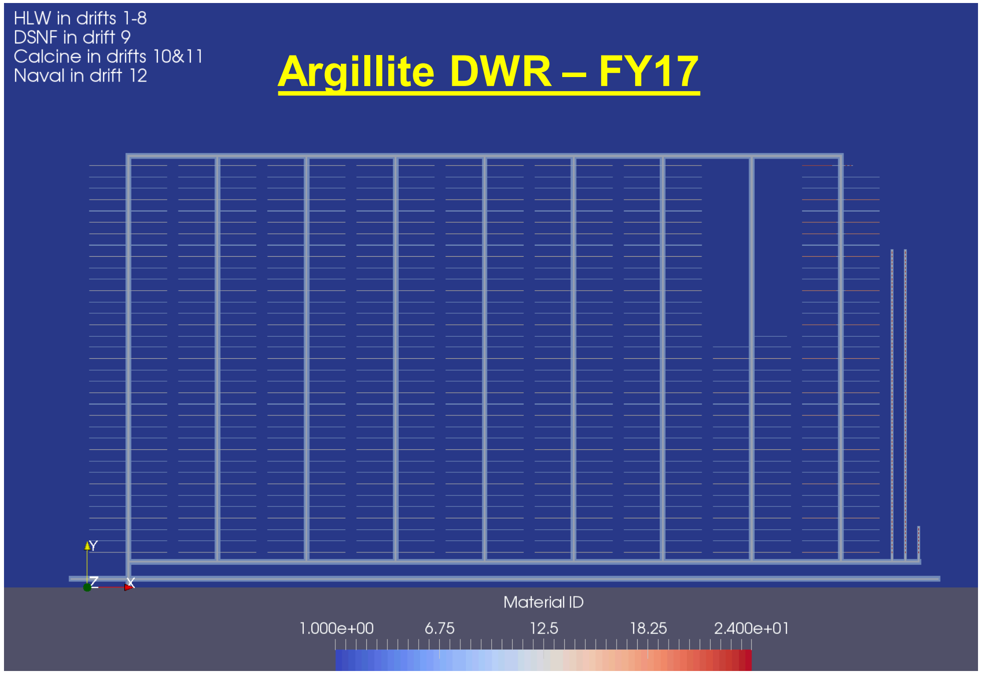
(R&D conducted under DBFT WPs)

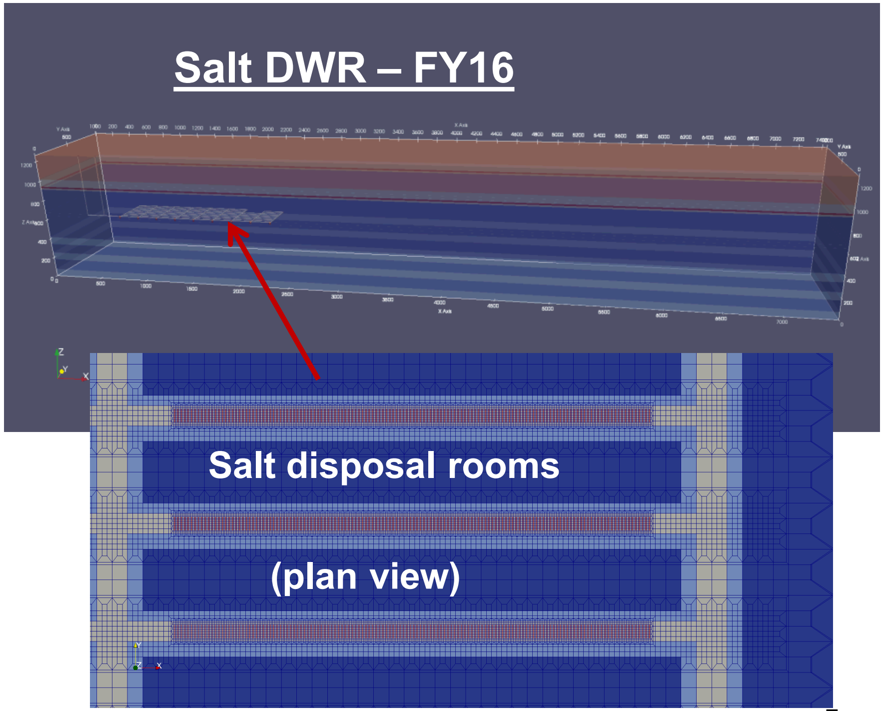


WP 1: Reference Cases (continued)

- **Augment generic reference cases being developed under the GDSA work package for various host-rock media (salt, argillite, crystalline, and deep borehole). In FY17,**
  - Adapt and augment the initial clay/shale/argillite GDSA reference case developed in FY15 to a repository for defense waste
  - Continue the development of the crystalline reference case







WP 2 (SNL): FEPs Analysis

- **In previous FYs, a new FEPs approach was developed in collaboration with GRS personnel (Germany) for a generic salt site**
  - Developed a revised FEP matrix and revised FEP numbering scheme
  - Developed a revised FEP list for a generic salt site
- **Preliminary FEP screening for a generic granite site completed in FY16**

FEP Matrix

Characteristics, Processes, and Events / Features / Components		Processes											Events					
	Characteristics	Mechanical and Thermal-M	Hydrological and Thermal-H	Chemical and Thermal-C	Biological and Thermal-B	Transport and Thermal-T	Thermal	Radiological	Long-Term Geologic	Climatic	Human Activities	Other	Nuclear Criticality	Early Failure	Seismic	Igneous	Human Activities	Other
Glossary / Definitions	CP	TM	TH	TC	TB	TT	TR	RA	LG	CL	HP	OP	NC	EF	SM	IG	HE	OE
Waste and Engineered Features																		
(WF) Waste Form and Cladding	1	1	3															
(01) SNF and Cladding				1														
(02) Vitrified HLW				1														
(03) Other HLW				1														
(04) Metal Parts from Reprocessing																		
(WP) Waste Package and Internals	1																	
(01) SNF																		
(02) Vitrified HLW																		
(03) Other HLW																		
(04) Metal Parts																		
(BB) Buffer/Backfill	1	1																
(01) Waste Package Buffer		1																
(02) Drift/Tunnel Backfill																		
(MW) Mine Workings																		
(01) Drift/Tunnel/Room Supports																		
(02) Liners																		
(03) Open Excavations/Gaps																		
(SP) Seals/Plugs																		
(01) Drift/Tunnel Seals																		
(02) Shaft Seals																		
(03) Borehole Plugs																		
Geosphere Features																		
(HR) Host Rock		1																
(01) Disturbed Rock Zone (DRZ)																		
(02) Emplacement Unit(s)																		
(03) Other Host Rock Units																		
(OU) Other Geologic Units																		
(01) Overlying / Adjacent Units (including Caprock, Aquifers)																		
(02) Underlying Units																		
Surface Features																		
(BP) Biosphere																		
(01) Surface and Near-Surface Media and Materials																		
(02) Flora and Fauna																		
(03) Humans																		
(04) Food and Drinking Water																		
System Features																		
(RS) Repository System																		
(01) Assessment Basis																		
(02) Preclosure/Operational																		
(03) Other Global																		

Matrix FEP Number	Description	Associated Processes	UFD FEPs [VSG FEPs]	Matrix Row	Matrix Col
WF.00.TM. 01	Dynamic Response of Fuel Rods and Cladding	- (A) Swelling of fuel pellets and corrosion products - (B) Unzipping of cladding - (C) Bending, buckling, or rupture of fuel rods from rock block impacts - (D) Bending or buckling of fuel rods from contact with internal support structures or end caps	2.1.07.06 2.1.07.07 2.1.11.06 2.1.02.06 2.1.11.06 2.1.02.06 2.1.11.06 2.1.02.06 2.1.11.06	1WF.0 0	P1-TM
WF.00.TM. 02	Dynamic Loading on Waste Form From Closure of Entries or From Buffer-Backfill Compaction/ Expansion	- (A) Creep closure of the excavation causes deformation, buckling, or cracking of the waste form - (B) Buffer-backfill compaction / expansion causes deformation, buckling or cracking of the waste form - (C) Mechanical stresses generated by interaction of co-located waste forms	2.1.11.06 2.1.07.06 2.1.07.09 2.1.11.06 2.1.01.04 2.1.07.09	1WF.0 0	P1-TM

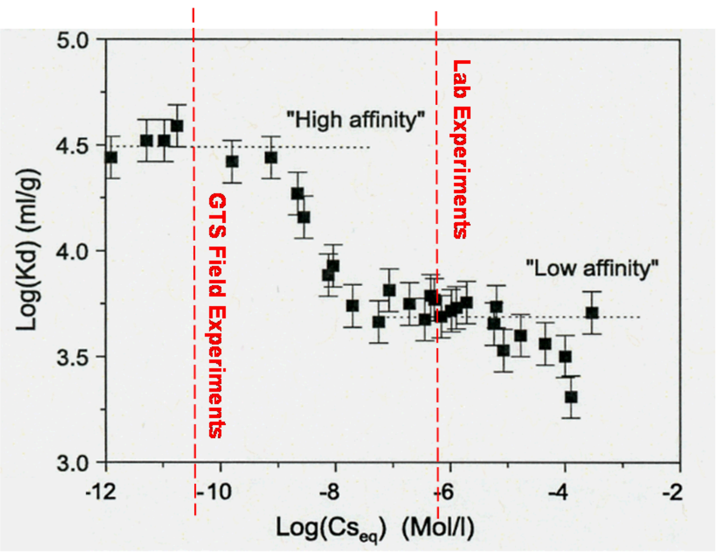
WP 2 (SNL): FEP Activities in FY17

- **Have nearly completed the FEP "Master List" to encompass responses of salt, crystalline rock, and clay-shale sites**
- **Prepared crosswalk between UFD FEP list and the new FEP list**
  - Crosswalk confirmed completeness of the new FEP "Master List"
- **Performing preliminary FEP screening for a generic clay/shale/argillite site with DHLW and DSNF, based on the following assumptions:**
  - Reference case stratigraphy, properties, and EBS design, as defined in Reference Case work package
  - Peak buffer temperature less than 100°C is a design constraint, to be achieved by: (i) decay storage, if necessary, (ii) waste package and drift spacing, and/or (iii) designing a buffer with lower thermal conductivity
  - A continuous facture network does not exist in clay-rich strata—diffusive transport is expect to be the main transport process in a clay-rich host rock

WP 3 (LANL): FEPs Analysis – Colloids

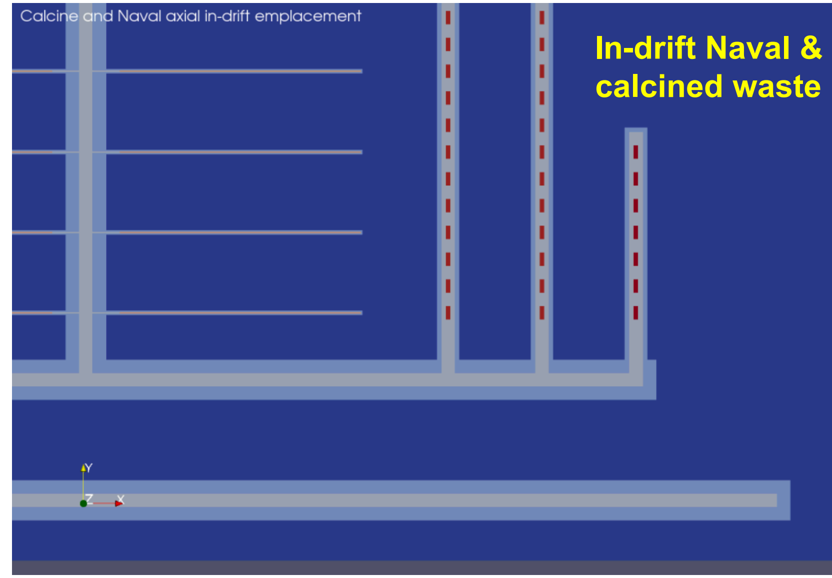
- **Incorporate pseudo-colloid model into PFLOTRAN (deferred to FY18)**
  - M4 milestone in Aug 2017: *Mathematical Basis and Test Cases for Colloid-Facilitated Radionuclide Transport Modeling in GDSA-PFLOTRAN*
  - Model described in FY16 LANL M3: *Colloid-Facilitated Radionuclide Transport: Current State of Knowledge from a Nuclear Waste Repository Risk Assessment Perspective:*
- **Model is high on GDSA Priority List:**

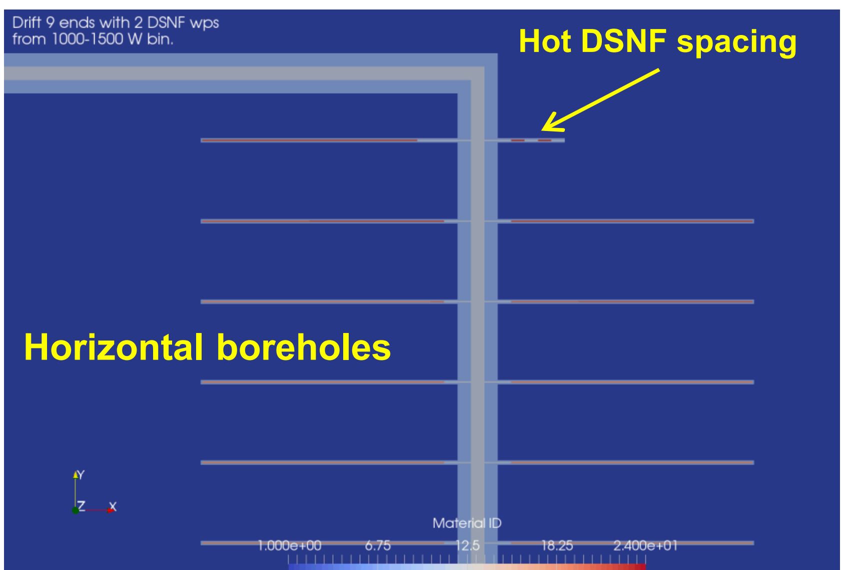
			C = complete; LF = lower fidelity (or what can be done by 2020); HF =				
			By 2020 (e.g., *candidate sites* selected for evaluation)				
Priority	Task #	Process Model	Argillite	Crystalline	Salt	DBH (Cs/Sr)	2020 GDSA LOE
N/A	A	Hydrology (H)	HF	HF	HF	HF	
N/A	B	Thermal (T)	HF	HF	HF	HF	
1	C	Radionuclide Transport & Chemistry	LF -> HF?	LF -> HF?	LF -> HF?	LF -> HF?	
2	83	Waste Form-Canister-Buffer Discretization (1D -> 3D)	LF	LF	LF	LF	M
3	63	Basic biosphere model	LF	LF	LF	LF	L
4	4	SNF Degradation	LF -> HF?	LF -> HF?	LF -> HF?		M
N/A	84	HLW WF degradation (simplified)	LF	LF	LF		C
5	8	HLW WF degradation (process model)					
6	68	Simplified Representation of Mechanical processes in PA			LF (IC)	?	M
7	5	(Pseudo) Colloid-Facilitated Transport Model	HF	HF		HF	M
8	6	Intrinsic Colloids	HF	HF	?	HF	M
9	13	Simplified Representation of THMC processes in EBS (clay illitization)	LF	LF	LF	?	M
9	14	Simplified Representation of THM (BBM) model of buffer materials (unsaturated)	LF	LF	LF	?	M
9	15	Simplified Representation of Rigid-Body-Spring-Network (RBSN)	LF	LF	LF	?	M
10	7	Discrete Fracture Network (DFN) Model		LF		LF	M - H

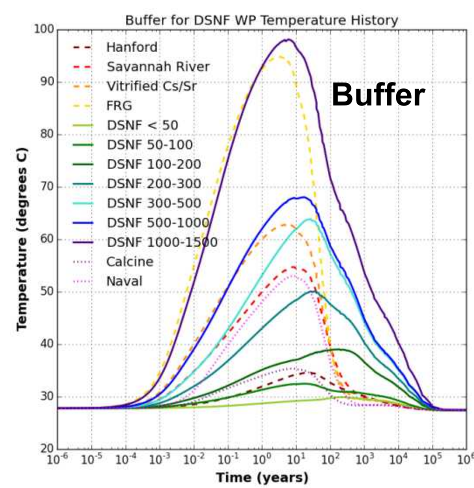


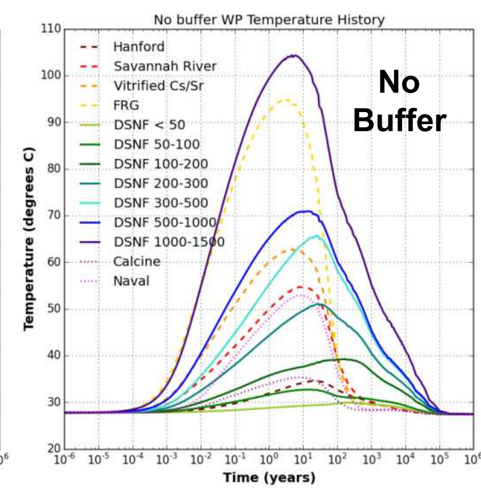
WP4 (SNL): Evaluate Alternative EBS Concepts

- **Developed in collaboration with WBS 1.08.01.05.02 “Preliminary Design Concepts” (Matteo)**
- **For FY17 in *argillite*, start with Concept #2 in Hardin and Kalinina (2012):**
  - Based on the Andra (2005) concept in France
  - Horizontal boreholes on either side of an access drift
  - Possible clay buffer for DSNF but not for DHLW









WP 5 (SNL): Generic Performance/Safety Objectives

- **Began about halfway through FY17**
  - M4 milestone in Aug 2017: *Generic Safety/Performance Objectives for a Defense Waste Repository*
  - Define generic post-closure-safety performance objectives and metrics, tailored toward the DWR site-selection and site-evaluation phases
- **Problem:**
  - Siting guidelines established by the Nuclear Waste Policy Act do not apply to the DWR
  - Siting guidelines are based on preclosure and postclosure performance, which are currently unknown
- **Solution:**
  - Select guidelines from those applicable to a commercial repository, consistent with a risk-informed, performance-based regulatory framework
    - Select guidelines from those applicable to Yucca Mountain that are not specific to Yucca Mountain
  - Review other literature (DOE, international, other countries)
  - Describe use of PA modeling for supporting a risk-informed, performance-based selection basis

WP6 (LANL): Regional Geology Evaluations

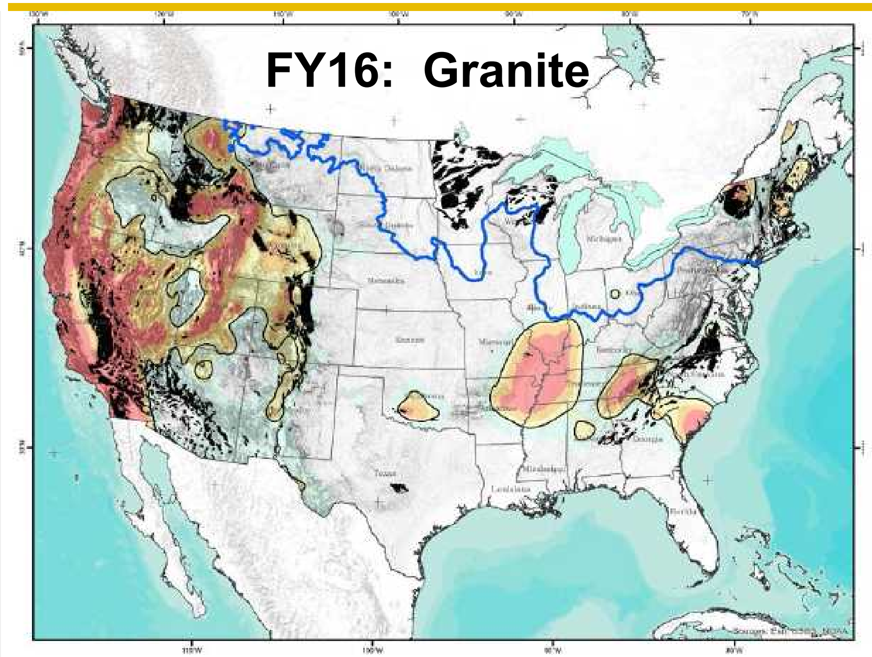


Figure 2-2. Distribution of exposed or near-surface crystalline rocks (black) in the conterminous US. Features shown at this scale that could influence siting of a repository include topography, maximum extent of the last glaciation (blue line) and seismic ground motion hazard. Red color shading indicates areas of the US with the highest seismic hazard. The black lines enclose areas with a 2% probability in 50 years of exceeding a peak ground acceleration of 0.16 g, an indicator of tectonically active regions of the US.

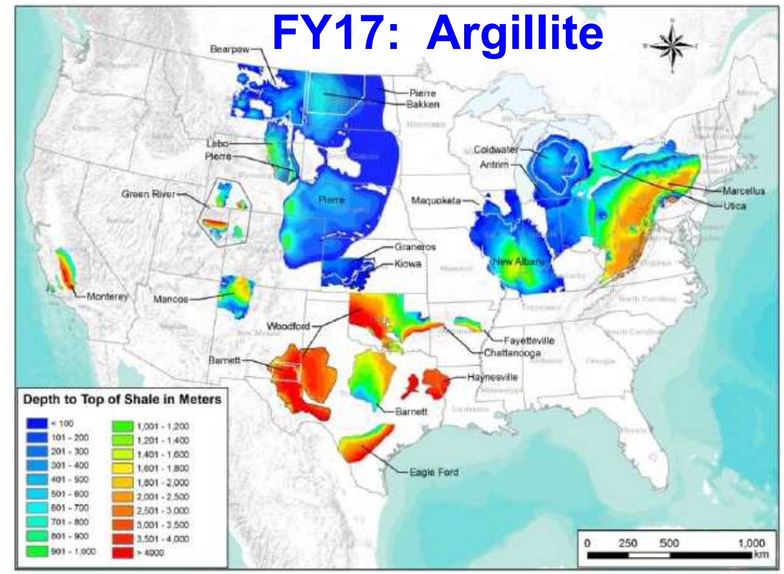


Figure 8. Distribution of the clay-rich formations in the USA along with depth to top mapping (updated from Perry (2014a))

- Comparisons of granitic terrane and fracture features at Forsmark, Sweden—used as a basis for the crystalline reference case—to granitic provinces in North America
- Thickness of sedimentary overburden; hydrology and hydrogeochemistry
- External factors/events: glaciation, seismicity, human intrusion (natural resources)

FY17 scope:

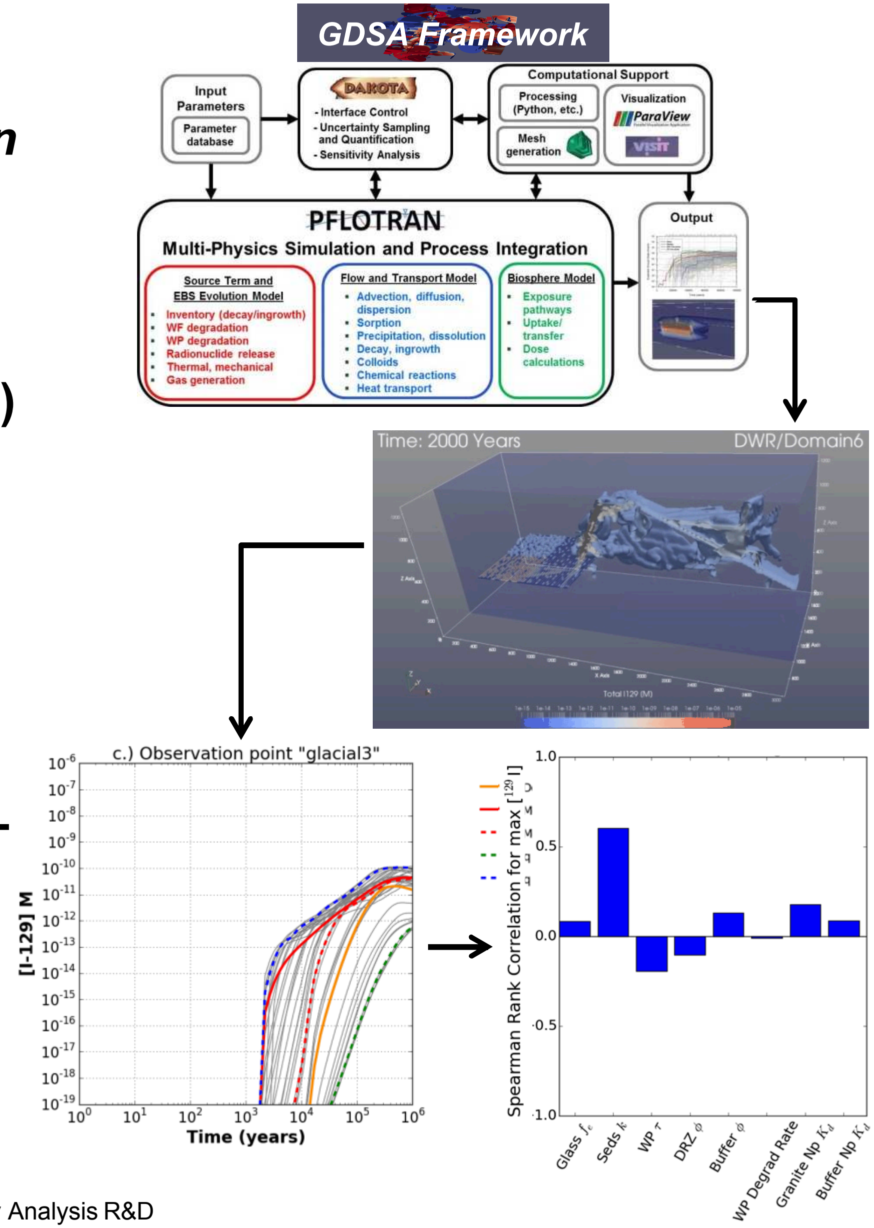
- M4 milestone in Sep 2017: *Generic Safety/ Performance Objectives for a Defense Waste Repository*
- Evaluate existing geologic, geophysical and hydrologic data to constrain included FEPs.
- Identify types of data needed for future regional site evaluations and site characterization
- Integrate with development of a technical site evaluation plan (WP7)

WP 7 (SNL): Preliminary Technical Site Evaluation Plan

- **Began about halfway through FY17**
  - M4 milestone in Sep 2017: "*Preliminary Technical Site Evaluation Plan for a Defense Waste Repository*"
  - Define technical suite of activities necessary to support the DWR technical bases and safety assessment in various host-rock media and disposal concepts
  - Suggest characterization activities needed for sites with little previous geologic information as well as those already well characterized
  - Integrate with Preliminary Regional Geology Evaluation work package, e.g., how geologic constraints should be considered during technical site selection and evaluation activities
  - Integrate with Generic Safety/Performance Objectives on how such objectives may influence technical site evaluation
    - Apply existing environmental and regulatory framework, as appropriate, for siting a DWR
    - Select guidelines from those applicable to a commercial repository that are consistent with a risk-informed, performance-based regulatory framework

WP8 (SNL): Total System Performance Assessment

- M2 milestone in Nov 2017: "*Safety Analysis and Technical Site Evaluation Status Report*"
- PA simulations mainly for the argillite reference case, conducted with the *GDSA Framework* (Dakota/PFLOTRAN)
- UA/SA for the argillite DWR reference case
- Integrate with other DWR work packages: Inventory; EBS Concepts
- Integrate subsystem and process models developed under other SFWST work packages
- Run additional simulations/analyses for other reference cases:
  - fractured granite host rock



Back-Up Slides