Crystalline Reference Case & R&D Interfaces

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Sandia National Laboratories

SFWD

Spent Fuel & Waste Disposition

Annual Working Group Meeting
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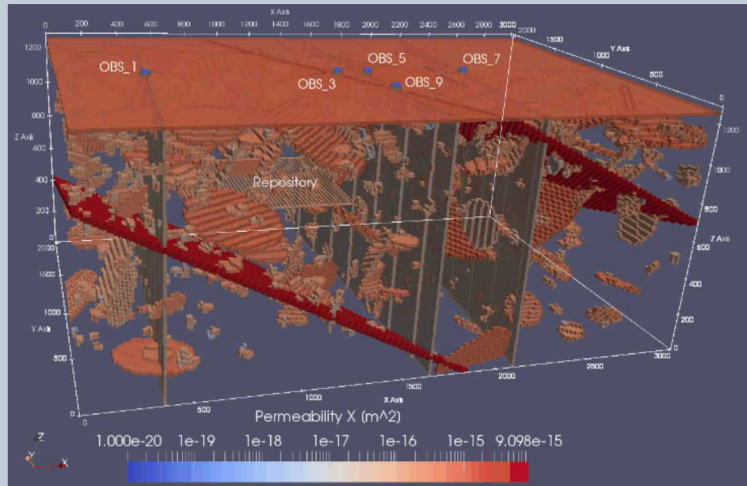

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Argonne NATIONAL LABORATORY

Pacific Northwest NATIONAL LABORATORY

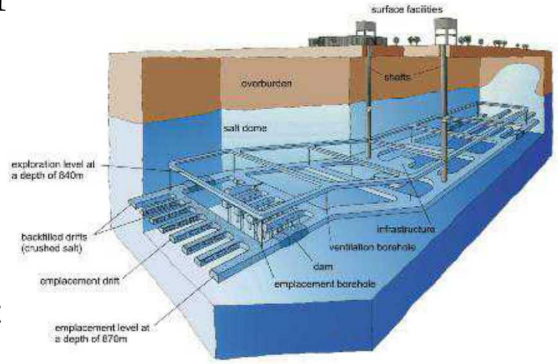
Lawrence Livermore

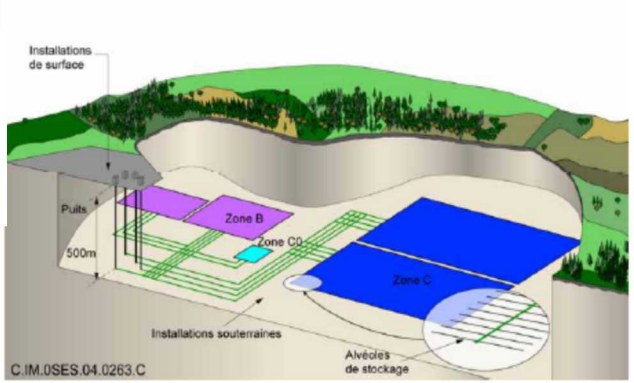
Crystalline Reference Case

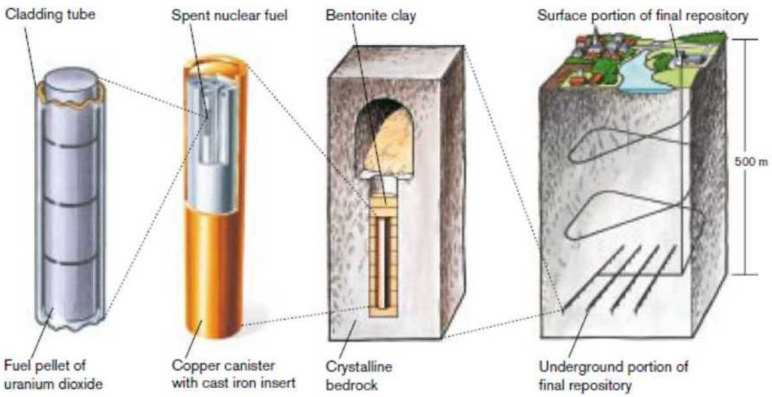
- Importance
  - To prepare for a potential site in crystalline host rock
  - To identify highly important FEPs of the crystalline reference case that need to be well understood
  - To assess the relative importance of FEPs and uncertain input parameters of the crystalline reference case

SFWST Campaign Strategic Focus: Disposal R&D

- Provide a sound technical basis for multiple viable disposal options in the US
- Increase confidence in the robustness of generic disposal concepts
- Develop the science and engineering tools needed to support disposal concept implementation
- Conduct R&D on the direct disposal of existing dual purpose (storage and transportation) canisters

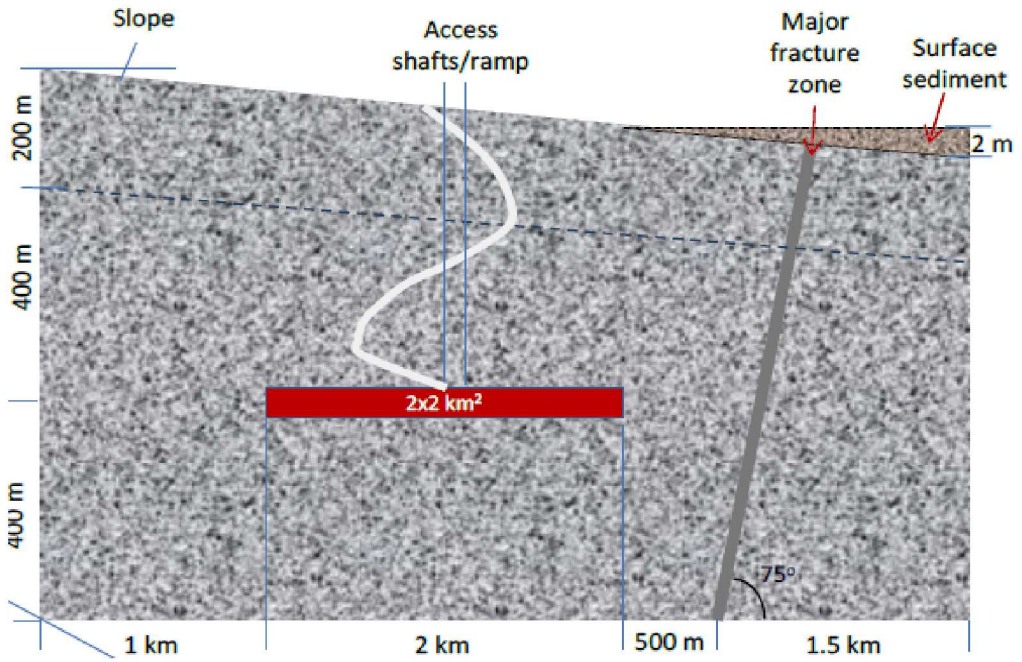




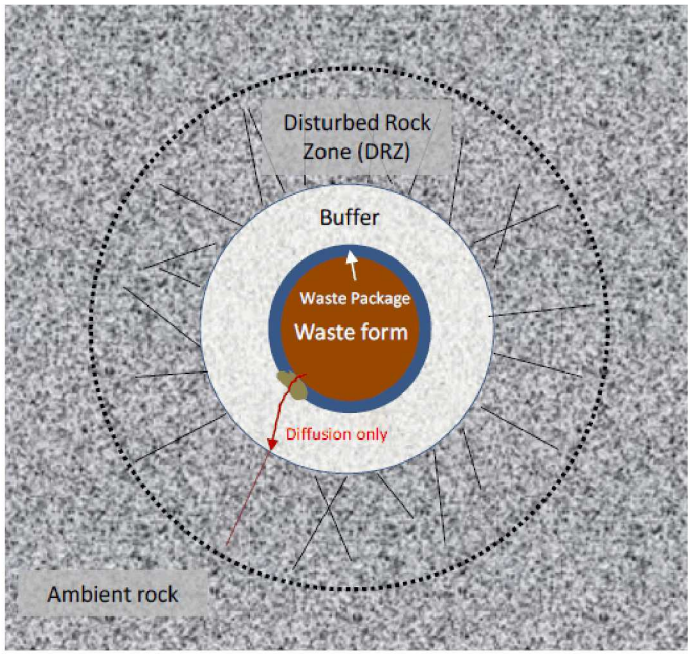


Crystalline Reference Case

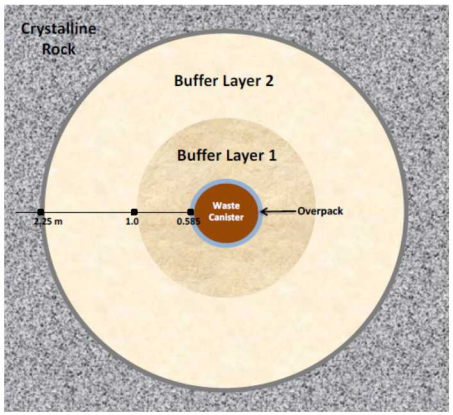
- Conceptual model (Wang et al. 2014)
  - Copper or stainless steel WP



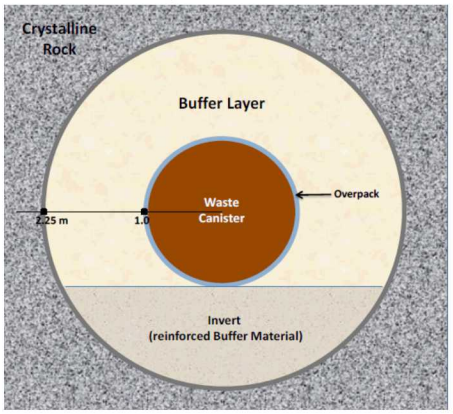
Near Field and EBS



12-PWR Canister



Dual Purpose Canister



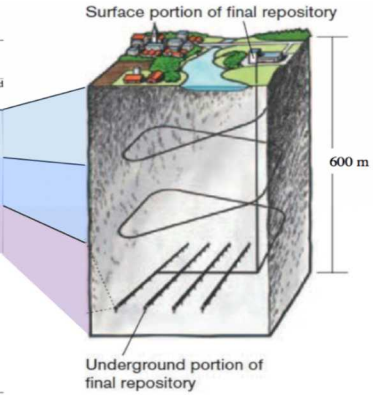
Crystalline Reference Case

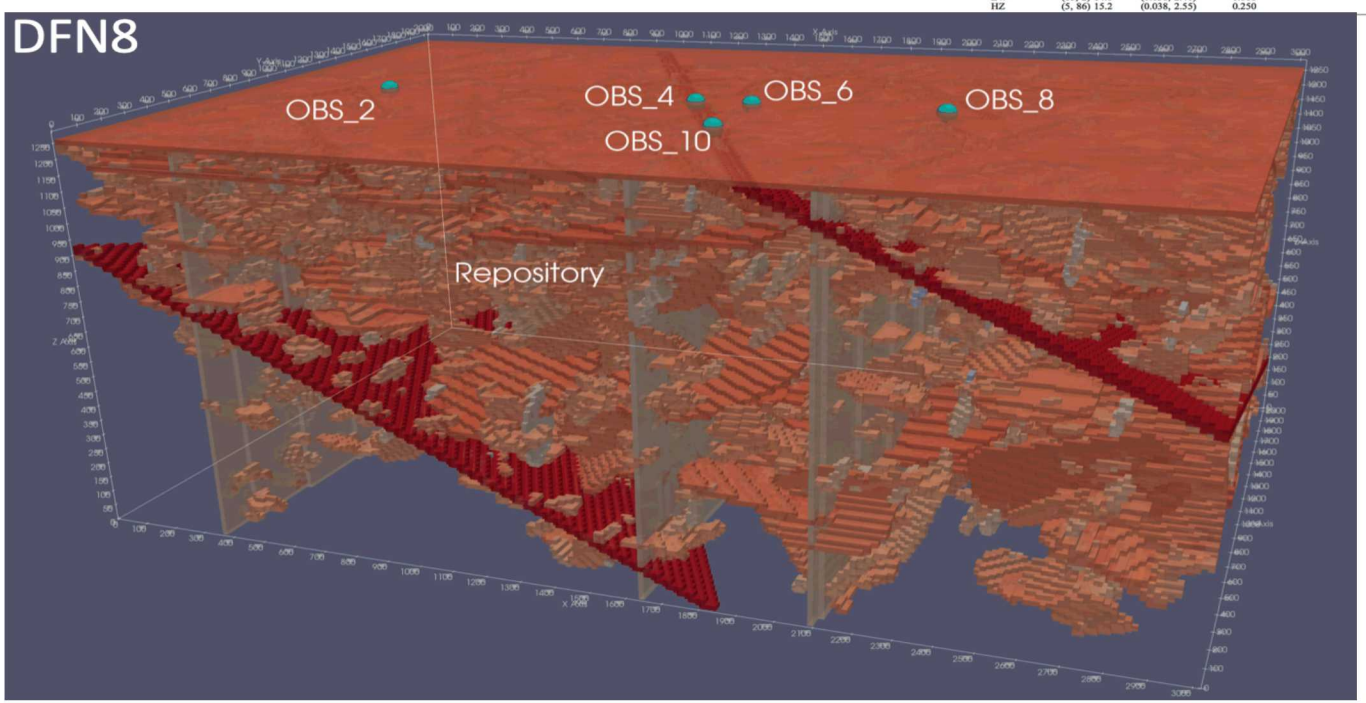
- Computational model
  - Discrete fracture networks (DFNs)
  - Deterministic fracture zones
  - Equivalent continuous porous medium (ECPM)

Table 2 Hydrogeological DFN parameters for each fracture domain, fracture set and depth zone

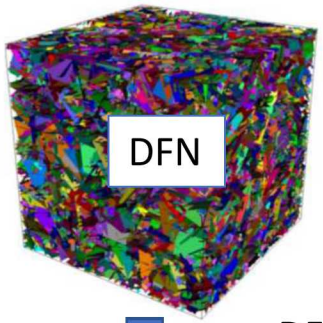
Fracture domain/elevation (m.a.s.l)[a]	Fracture set name	Orientation set pole: (trend, plunge), conc.	Size model, power-law (r_0, k_r)	Intensity, (P_{32}), valid size interval: r_0	Parameter values for the transmissivity models		
FFM01 and FFM06>−200	NS						1.2
	NE						
	NW						
	EW						
	HZ						
FFM01 and FFM06 −200 to −400	NS						0.8
	NE						
	NW						
	EW						
FFM01 and FFM06<−400	NS						1.0
	NE						
	NW						
	EW						
	HZ						
FFM02>−200	NS	(83, 10) 16.9	(0.038, 2.75)	0.342	$9.0 \cdot 10^{-9}$,	$5.0 \cdot 10^{-9}$,	−7.1, 1.1
	NE	(143, 9) 11.7	(0.038, 2.62)	0.752	0.7, 1.0	1.2	
	NW	(51, 15) 12.1	(0.038, 3.20)	0.335			
	EW	(12, 0) 13.3	(0.038, 3.40)	0.156			
	HZ	(71, 87) 20.4	(0.038, 2.58)	1.582			
FFM03, FFM04 and FFM05>−400	NS	(292, 1) 17.8	(0.038, 2.60)	0.091	$1.3 \cdot 10^{-8}$,	$1.4 \cdot 10^{-8}$,	−7.2, 0.8
	NE	(326, 2) 14.3	(0.038, 2.50)	0.253	0.4, 0.8	0.6	
	NW	(60, 6) 12.9	(0.038, 2.55)	0.258			
	EW	(15, 2) 14.0	(0.038, 2.40)	0.097			
	HZ	(5, 86) 15.2	(0.038, 2.55)	0.397			
FFM03, FFM04 and FFM05<−400	NS	(292, 1) 17.8	(0.038, 2.60)	0.102	$1.8 \cdot 10^{-8}$,	$7.1 \cdot 10^{-9}$,	−7.2, 0.8
	NE	(326, 2) 14.3	(0.038, 2.50)	0.247	0.3, 0.5	0.6	
	NW	(60, 6) 12.9	(0.038, 2.55)	0.103			
	EW	(15, 2) 14.0	(0.038, 2.40)	0.068			
	HZ	(5, 86) 15.2	(0.038, 2.55)	0.250			

Fracture networks modeled after Forsmark (3 zones)

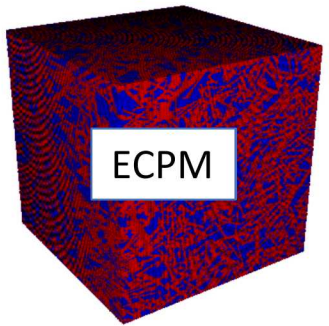




dfnWorks

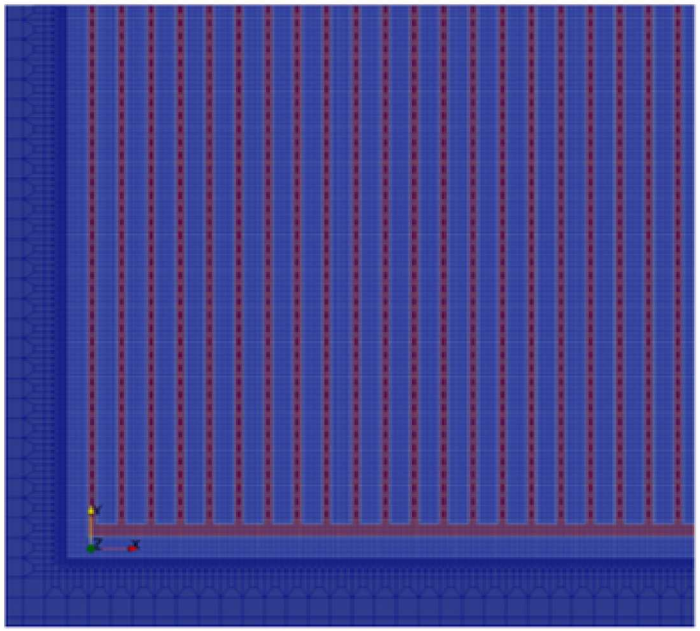


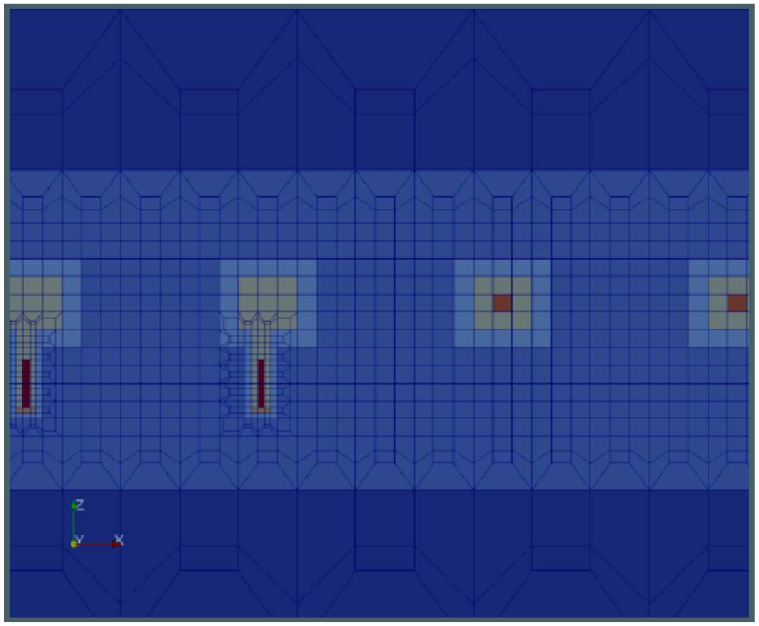
mapDFN



Crystalline Reference Case

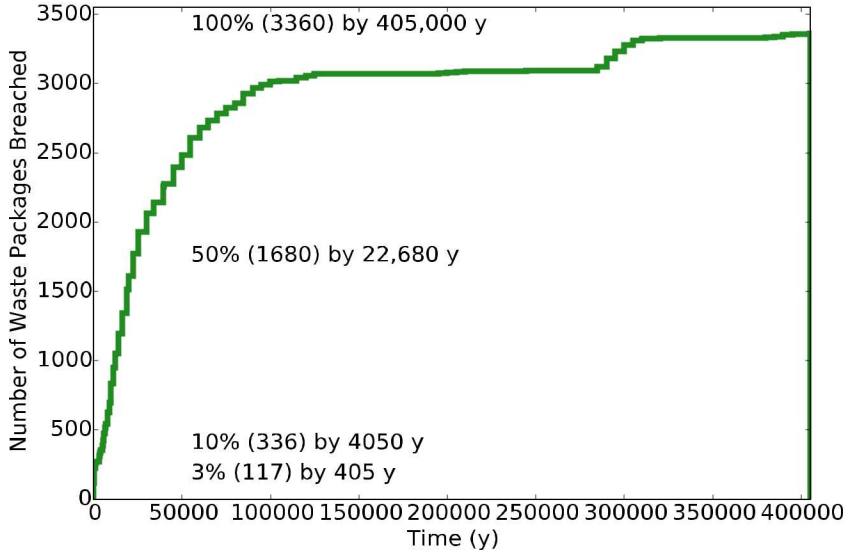
- Two reference cases
  - Commercial waste
  - DOE managed waste





- Simulation
  - PFLOTRAN – TH processes, radionuclide source term and transport
  - Dakota – probabilistic realizations, sensitivity analysis

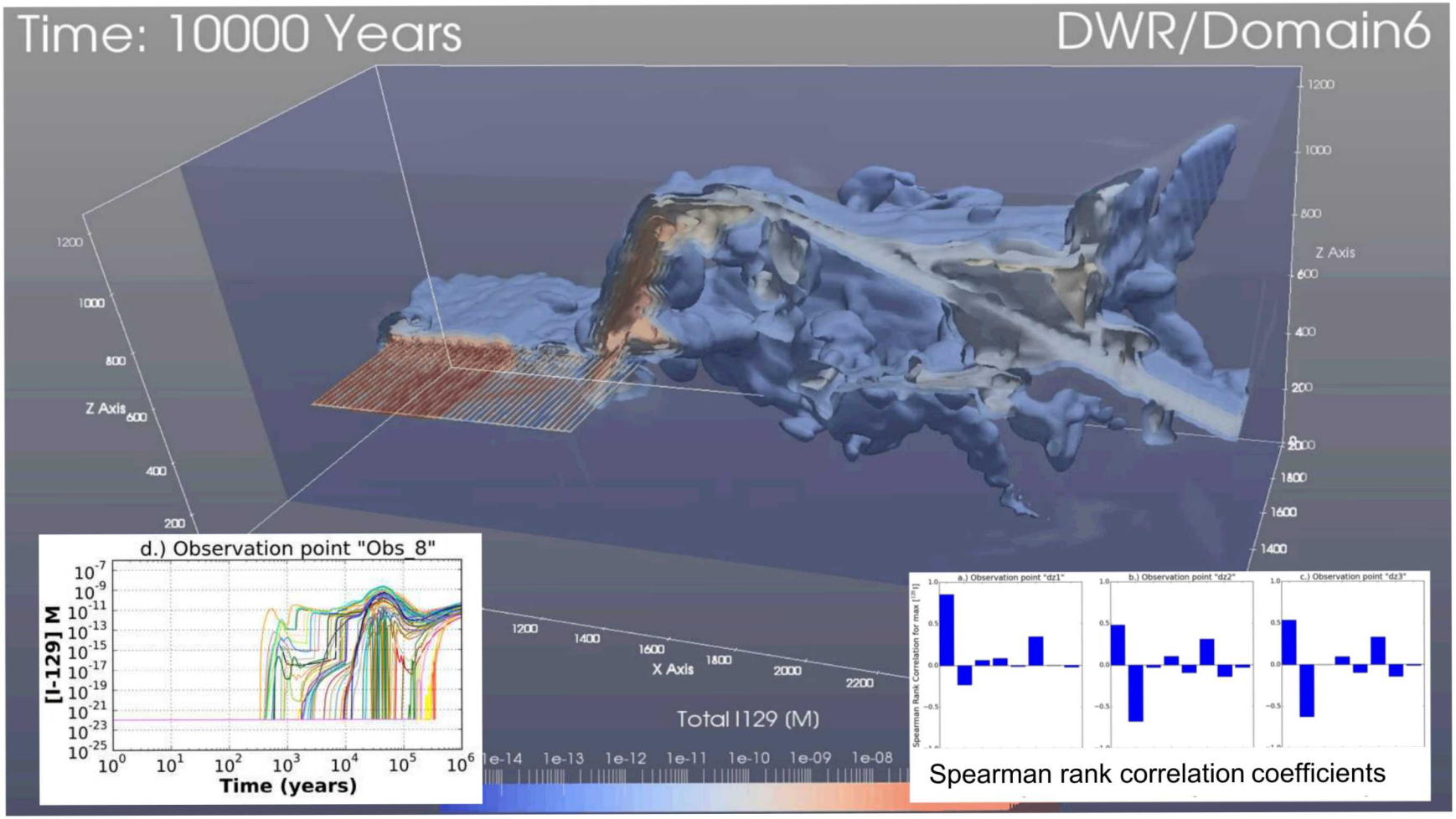
Crystalline Reference Case



- EBS simulation
  - Waste package (WP)
    - Distribution placeholder for general corrosion rate
  - Waste form (WF)
    - Spent fuel
      - Instantaneous release fraction
      - Fractional degradation rate distribution (min 10^{-8}, mean 10^{-7}, max 10^{-6})
      - Coupled fuel matrix degradation (FMD) model – slow
        - Surrogate FMD models under development
    - HLW glass dissolution rate equation
    - Metallic fuels – instantaneous dissolution
  - Buffer and DRZ
    - Buffer evolution surrogate models under development

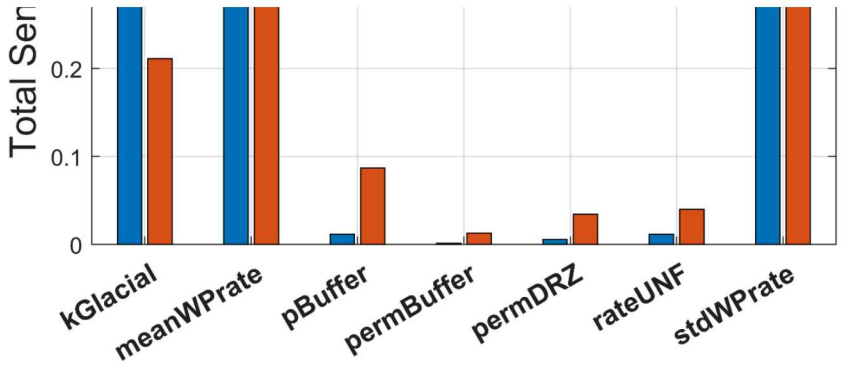
Crystalline Reference Case

- Output



Crystalline Reference Case

- Sensitivity analysis – initial findings
  - Uncertainty in magnitude and timing of predicted concentrations at any given location in the model domain is larger due to fracture distribution than to other sampled parameters
  - Peak concentrations and breakthrough times are also particularly sensitive to
    - WP package degradation rate mean and variance
    - Permeability along the flow path
    - Sorption coefficients

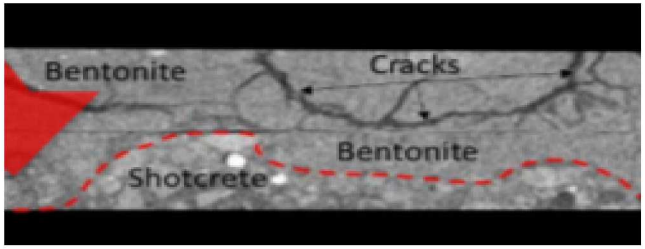


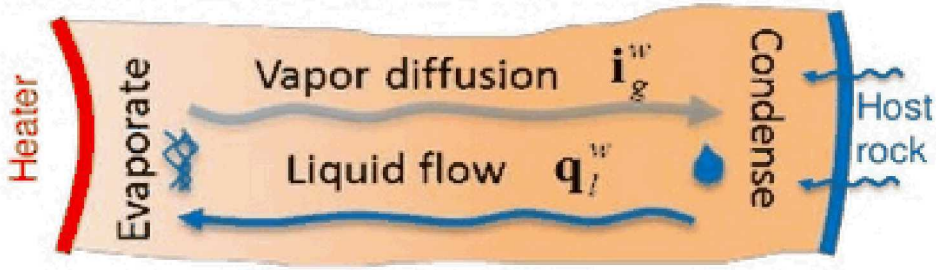
Crystalline Reference Case

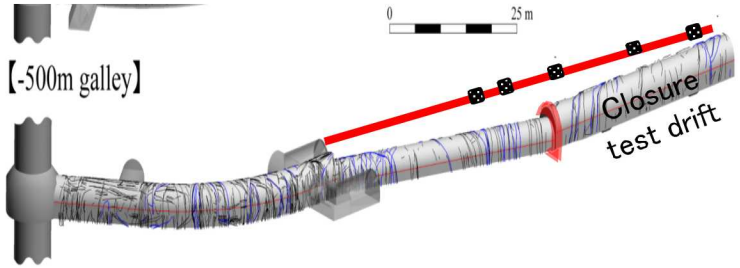
- Reference case design and simulation findings
  - PA simulations indicate that crystalline rock is a poor natural barrier for released radionuclides
    - Crystalline rock, however, may provide a conducive environment for WP longevity
      - Depends on the WP and EBS materials
    - For PA, performance specifications for WPs and EBS barriers may be needed
      - PA modeling could help inform such specifications
  - Reference case simulations should not place WPs near connected fractures that would likely be detected and avoided during repository operations
    - Specifications needed here as well

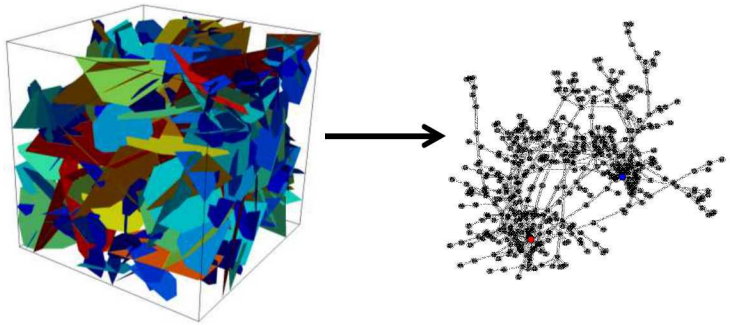
Crystalline Reference Case R&D Interfaces

- Work package R&D interfaces
  - Crystalline
  - Argillite
  - International
  - EBS
  - DPC









QUESTIONS?

SFWD

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Thanks to the DOE SFWST team and the many process modelers and performance assessment modelers at SNL, LBNL, LANL, ANL, and ORNL whose ideas and figures found their way into this talk.