SAND2015-10214PE

Used Fuel Disposition R&D Campaign

Modeling Crystalline Systems: Generic Disposal System Analysis (GDSA) and Deep Borehole (DBH)

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Modeling Crystalline Systems: GDSA

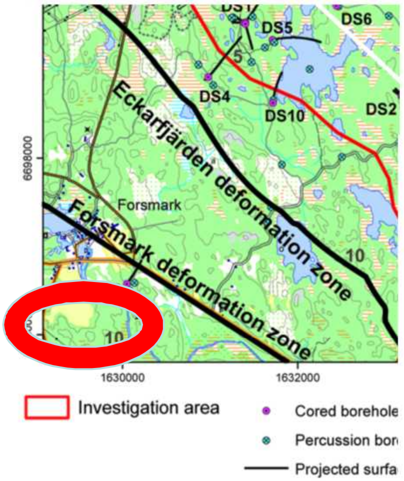
Objective

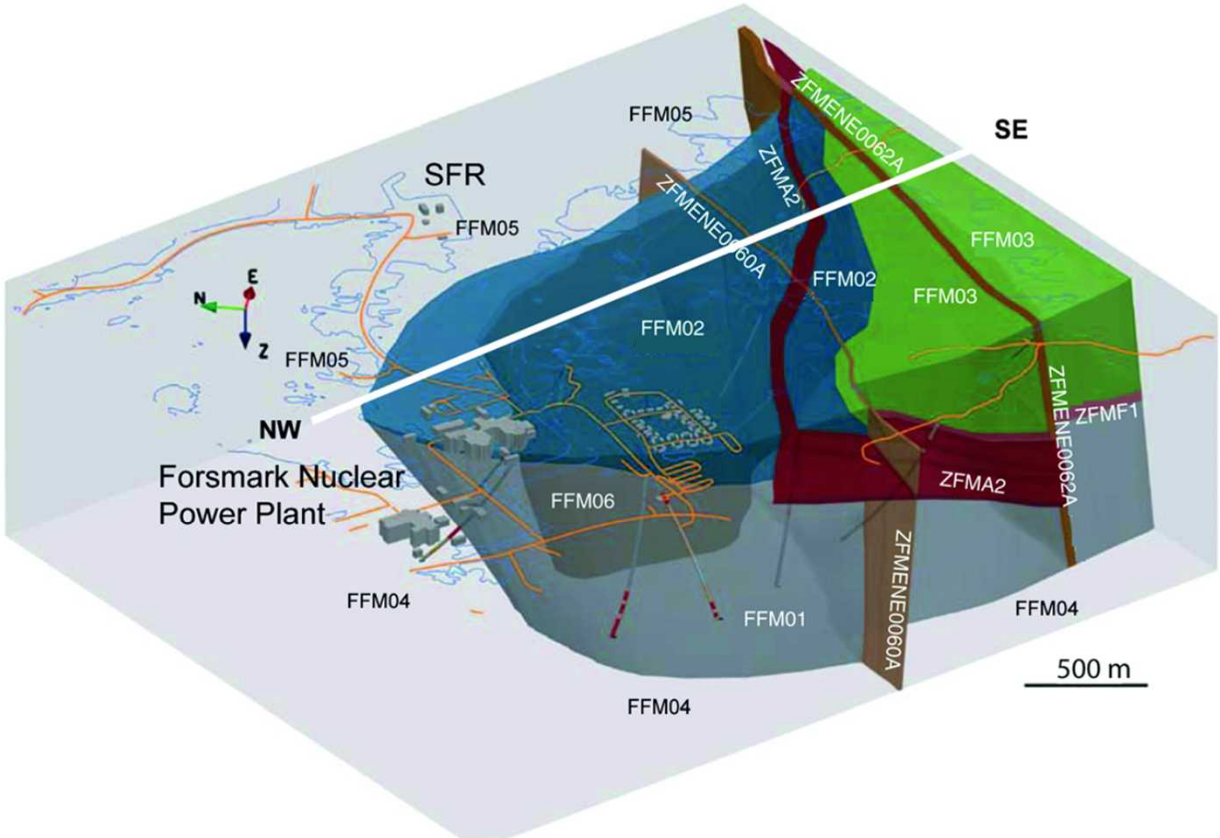
- Develop conceptual and numerical model(s) of sparse fracture networks in crystalline basement

Options

- Homogeneous Continuous Porous Medium (CPM)
  - Largest domains and longest time scales or in absence of site-specific data
- Heterogeneous CPM
  - Middle-size domains (beyond limit of transport) or for modeling flow only
- Discrete Fracture Network (DFN)
  - Local/site-scale domains and for modeling transport
- Coupled DFN and CPM
  - CPM repository in DFN; sedimentary overburden or farfield of domain as CPM

Modeling Crystalline Systems: GDSA

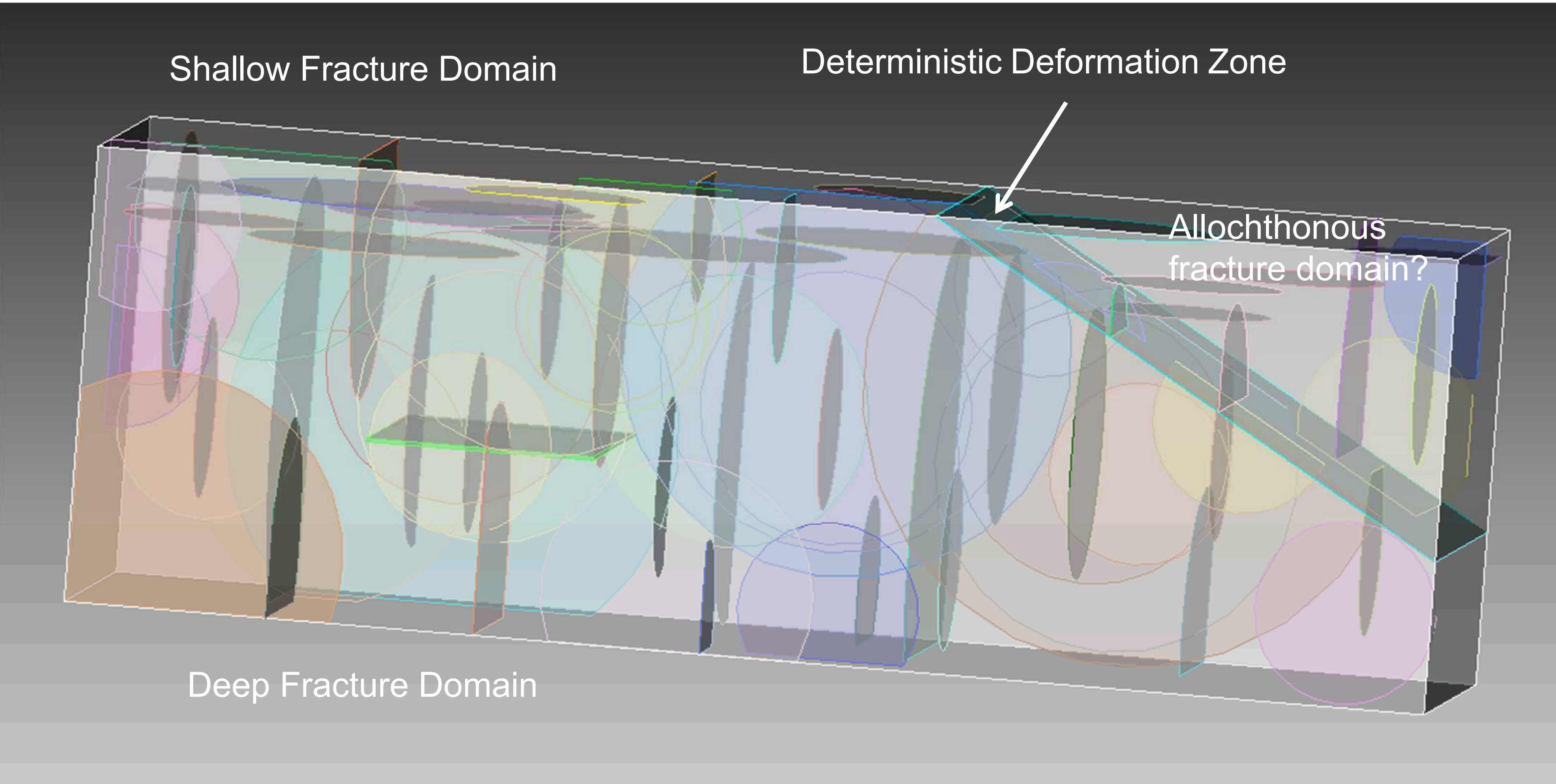




Joyce et al., Hydrogeology Journal (2014) 22:1233-1249

Modeling Crystalline Systems: GDSA

Coupled CPM (repository) and DFN



Modeling Crystalline Systems: GDSA

- **CPM processes**
  - Coupled heat and fluid flow
  - Waste package degradation
  - Waste form dissolution
  - Reactive transport (advection, hydrodynamic dispersion)
- **DFN processes**
  - Coupled heat and fluid flow
  - Reactive transport (advection, hydrodynamic dispersion)
  - Matrix diffusion (1D)

Modeling Crystalline Systems: GDSA

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) (m, −)	Intensity, (P_{32}), valid size interval: r_0 to 564 m (m^2/m^3)	Parameter values for the transmissivity models: Semi-correlated (a,b,σ)	Correlated (a,b)	Uncorrelated (μ,σ)
FFM01 and FFM06>−200	NS	(292, 1) 17.8	(0.038, 2.50)	0.073	$6.3 \cdot 10^{-9}$, 1.3, 1.0	$6.7 \cdot 10^{-9}$, 1.4	−6.7, 1.2
	NE	(326, 2) 14.3	(0.038, 2.70)	0.319			
	NW	(60, 6) 12.9	(0.038, 3.10)	0.107			
	EW	(15, 2) 14.0	(0.038, 3.10)	0.088			
	HZ	(5, 86) 15.2	(0.038, 2.38)	0.543			
FFM01 and FFM06 −200 to −400	NS	(292, 1) 17.8	(0.038, 2.50)	0.142	$1.3 \cdot 10^{-9}$, 0.5, 1.0	$1.6 \cdot 10^{-9}$, 0.8	−7.5, 0.8
	NE	(326, 2) 14.3	(0.038, 2.70)	0.345			
	NW	(60, 6) 12.9	(0.038, 3.10)	0.133			
	EW	(15, 2) 14.0	(0.038, 3.10)	0.081			
	HZ	(5, 86) 15.2	(0.038, 2.38)	0.316			
FFM01 and FFM06<−400	NS	(292, 1) 17.8	(0.038, 2.50)	0.094	$5.3 \cdot 10^{-11}$, 0.5, 1.0	$1.8 \cdot 10^{-10}$, 1.0	−8.8, 1.0
	NE	(326, 2) 14.3	(0.038, 2.70)	0.163			
	NW	(60, 6) 12.9	(0.038, 3.10)	0.098			
	EW	(15, 2) 14.0	(0.038, 3.10)	0.039			
	HZ	(5, 86) 15.2	(0.038, 2.38)	0.141			
FFM02>−200	NS	(83, 10) 16.9	(0.038, 2.75)	0.342	$9.0 \cdot 10^{-9}$, 0.7, 1.0	$5.0 \cdot 10^{-9}$, 1.2	−7.1, 1.1
	NE	(143, 9) 11.7	(0.038, 2.62)	0.752			
	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	$1.3 \cdot 10^{-8}$, 0.4, 0.8	$1.4 \cdot 10^{-8}$, 0.6	−7.2, 0.8
	NE	(326, 2) 14.3	(0.038, 2.50)	0.253			
	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	$1.8 \cdot 10^{-8}$, 0.3, 0.5	$7.1 \cdot 10^{-9}$, 0.6	−7.2, 0.8
	NE	(326, 2) 14.3	(0.038, 2.50)	0.247			
	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			

[a] Meters above sea level

For flowing fractures only, P_{32} is on the order of 0 – 10^{-2} m^2/m^3

Joyce et al., Hydrogeology Journal (2014) 22:1233-1249

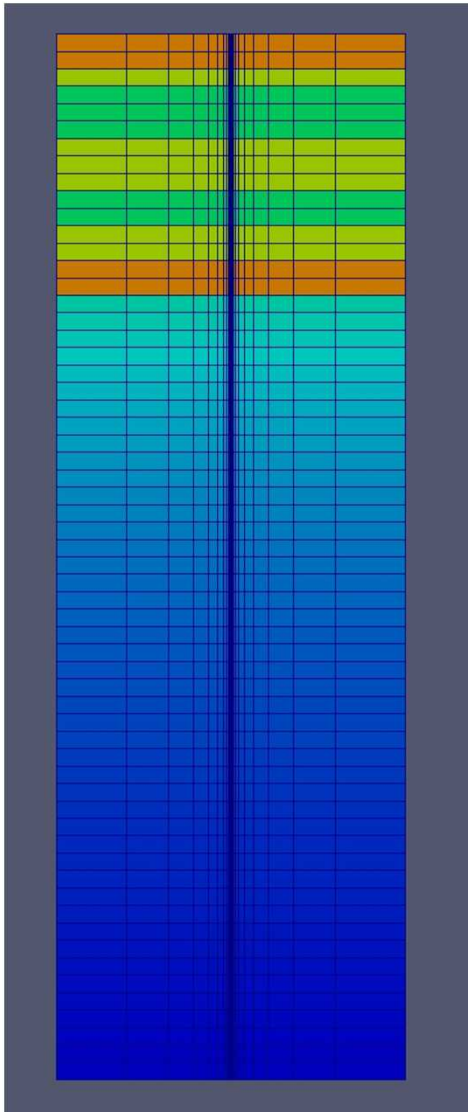
Modeling Crystalline Systems: DBH

Similarities to granite repository modeling

- Crystalline basement
- Sparsely fractured
- Choice of CPM versus DFN will depend on goal and scale of modeling
- Same/similar processes
- Migration to unstructured grid

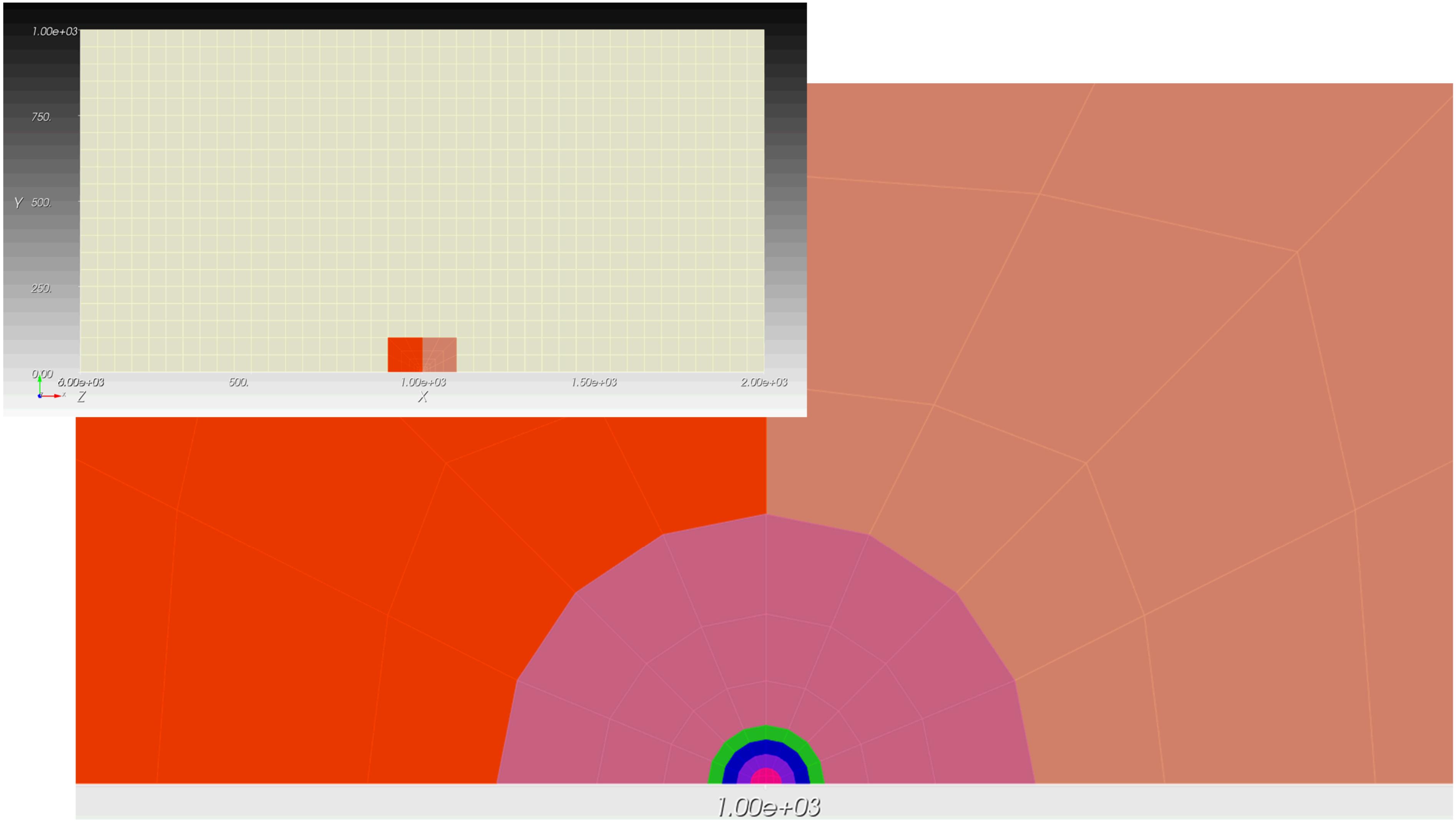
DBH Model Materials

- Crystalline rock
- Crystalline DRZ
- Sedimentary rock (various)
- Sedimentary DRZ (various)
- Seal (various?)
- Drilling mud (grout, fill?)
- Waste packages

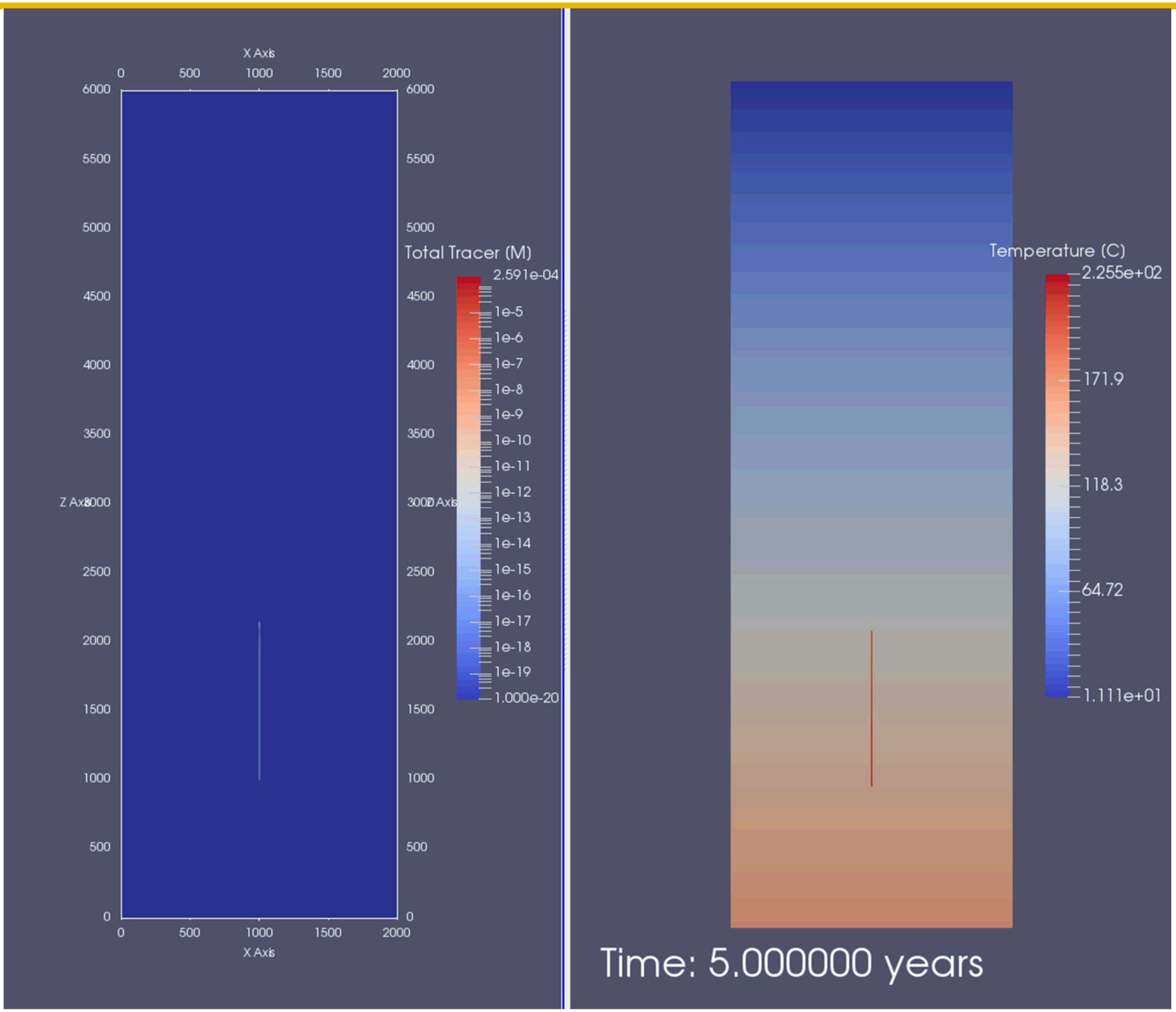


Structured grid in the past…

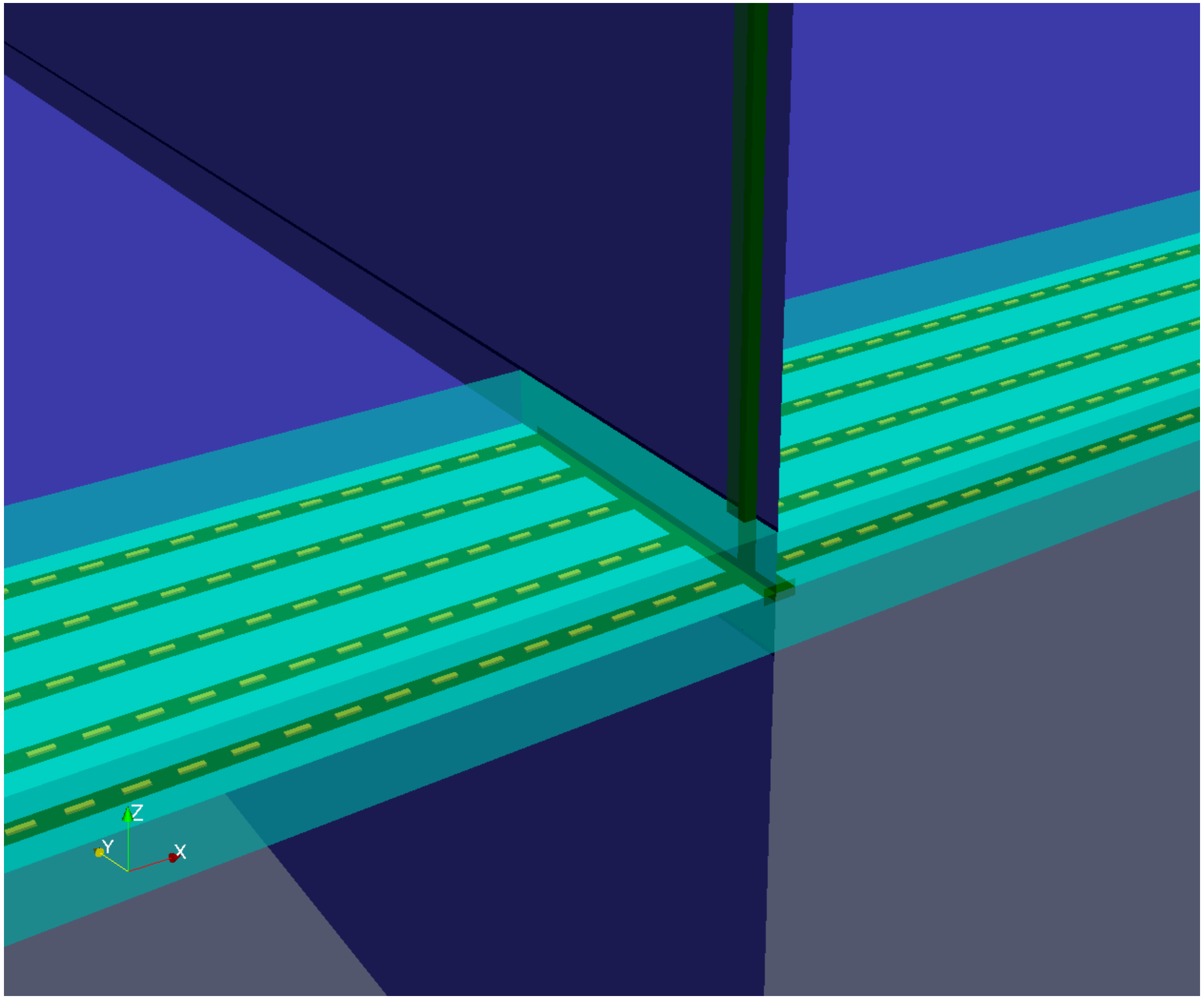
Modeling Crystalline Systems: DBH



Modeling Crystalline Systems: DBH

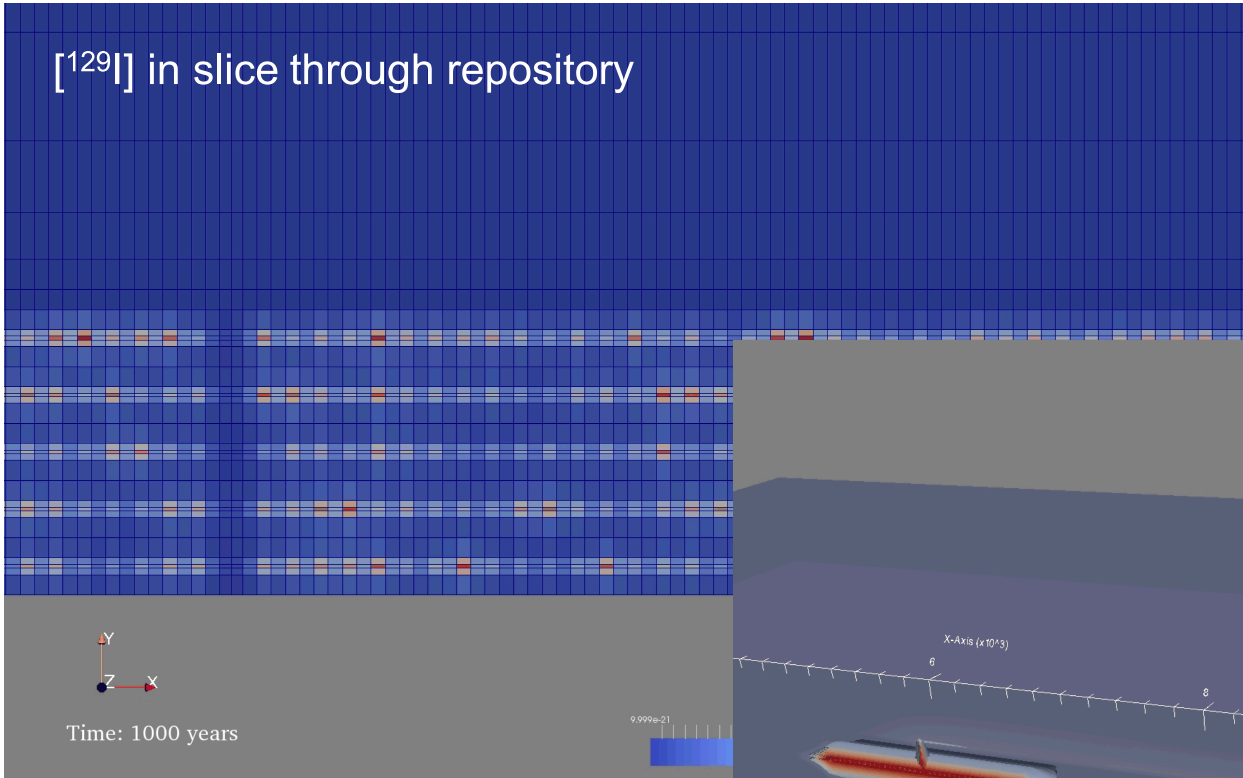


Modeling (not) Crystalline Systems: Salt HLW

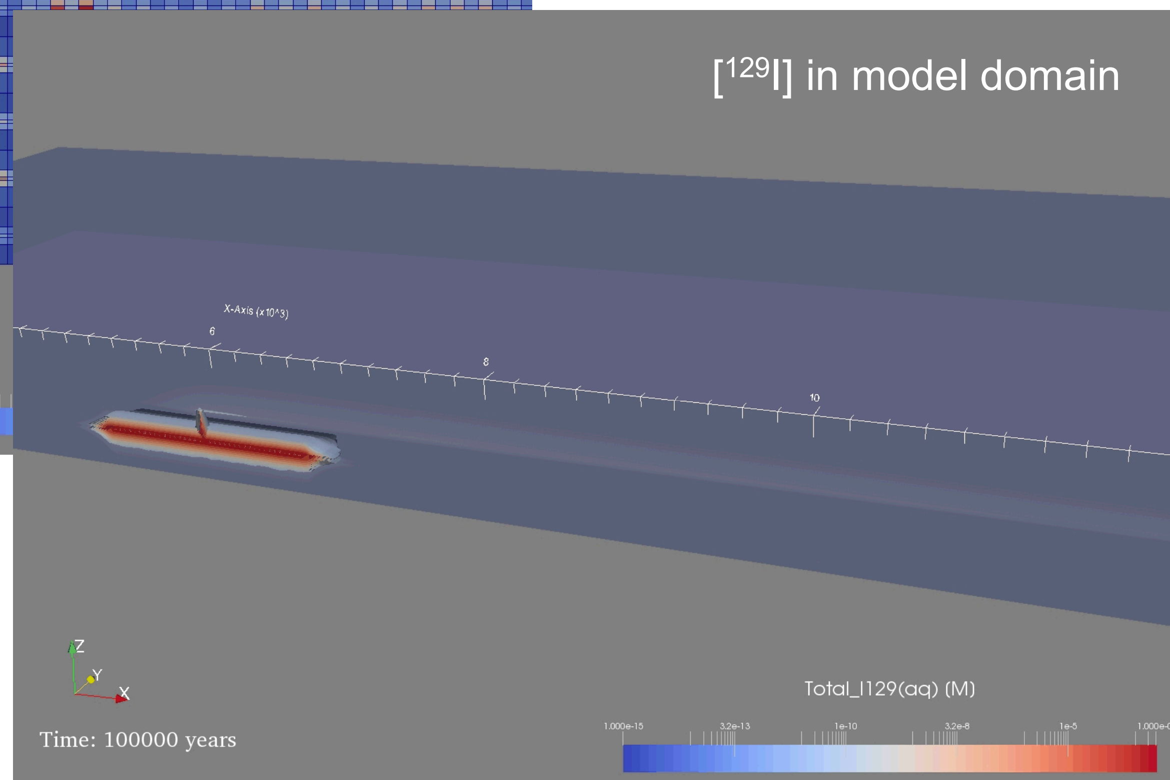


- **Similarities to crystalline**
  - Repository is CPM
  - Processes
    - *Heat & fluid flow*
    - *Waste form degradation*
    - *Reactive transport*
- **Differences**
  - CPM works for the entire domain
  - Salt case assumes immediate waste package failure
  - Structured grid

Modeling (not) Crystalline Systems: Salt HLW



Waste form degradation
- Temperature-dependent rate constant
- Random surface exposure factor (4-17)



- Radionuclide inventory in 2047 for projected vitrified waste from the Hanford Site (*Carter et al. 2013*)
- Estimated 11,079 canisters (1600 modeled)

Mariner et al. (2015)