CouFrac
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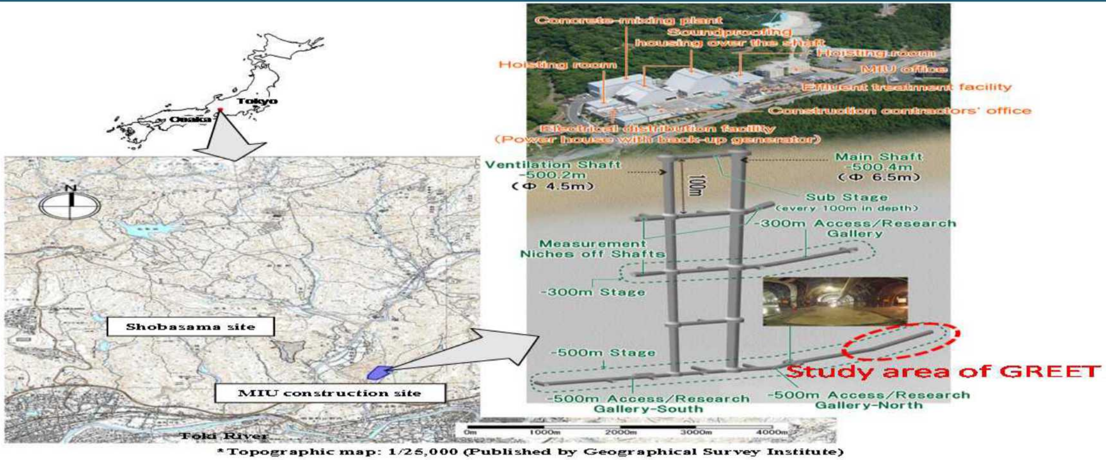
SAND2018-12492C

# Utilization of Fracture Models for Geologic Disposal of Nuclear Waste in Granitic Host Rocks




PRESENTED BY

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SAND2018-XXXX

# Outline of Presentation

- Comparison of DFN and Equivalent Continuum Models
  - dfnWorks from Los Alamos National Laboratory
  - FCM from Sandia National Laboratories
- DECOVALEX 2019 Task C, **GREET**: **G**roundwater **RE**covery **E**xperiment in **T**unnel
  - Hydrology and Geochemical Modeling
- Effect of Grid Block Size

# Fracture Characterization Methods

- A realistic representation of fractures in granite rocks is needed.
- Capabilities of discrete fracture network and equivalent continuum methods compared:

1. **dfnWorks**, a computational tool for discrete fracture network modeling
   - Flow and transport through fractures
2. **F**ractured **C**ontinuum **M**odel (**FCM**)
   - Flow and transport through fractures and rock matrix

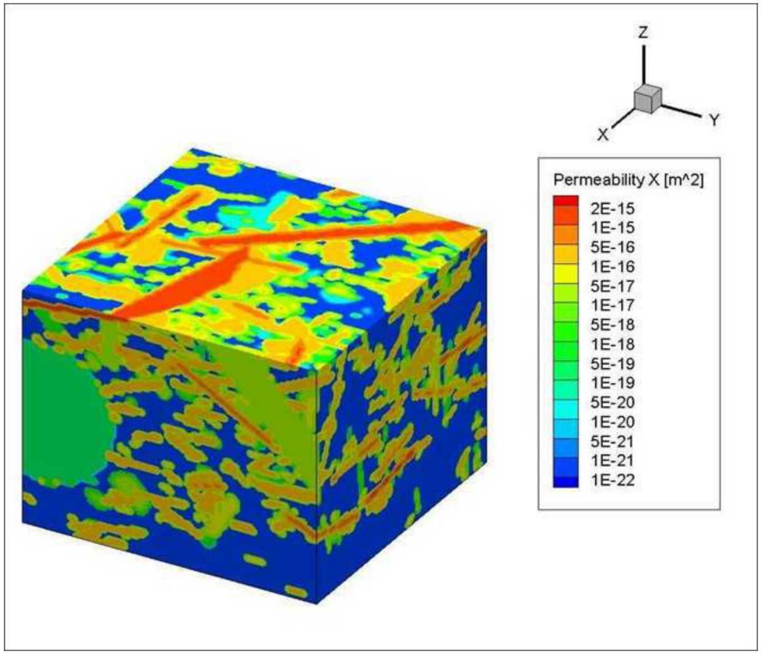
# DFN-FCM Comparison

- Benchmark Simulations used for the comparison
- Realistic distributions of fracture parameters used
- dfnWorks output converted to FCM input to allow direct comparison
  - Eliminates uncertainty in generating fracture network.
  - Compares explicit (DFN) and effective (FCM) representation of fracture network.
  - Effective permeability of the modeling domain and breakthrough curves can be compared for each realization.

# Model Setup for Simulations

- A domain 1km x 1km x 1km cube selected.
- FCM used constant grid block size of 10 m x 10 m x 10m
- Porosity: Anisotropic
- Permeability: Anisotropic
- Initial condition: Hydrostatic pressure
- Boundary pressure: Pressure gradient from west to east

Upscaled continuum permeability field of a realization



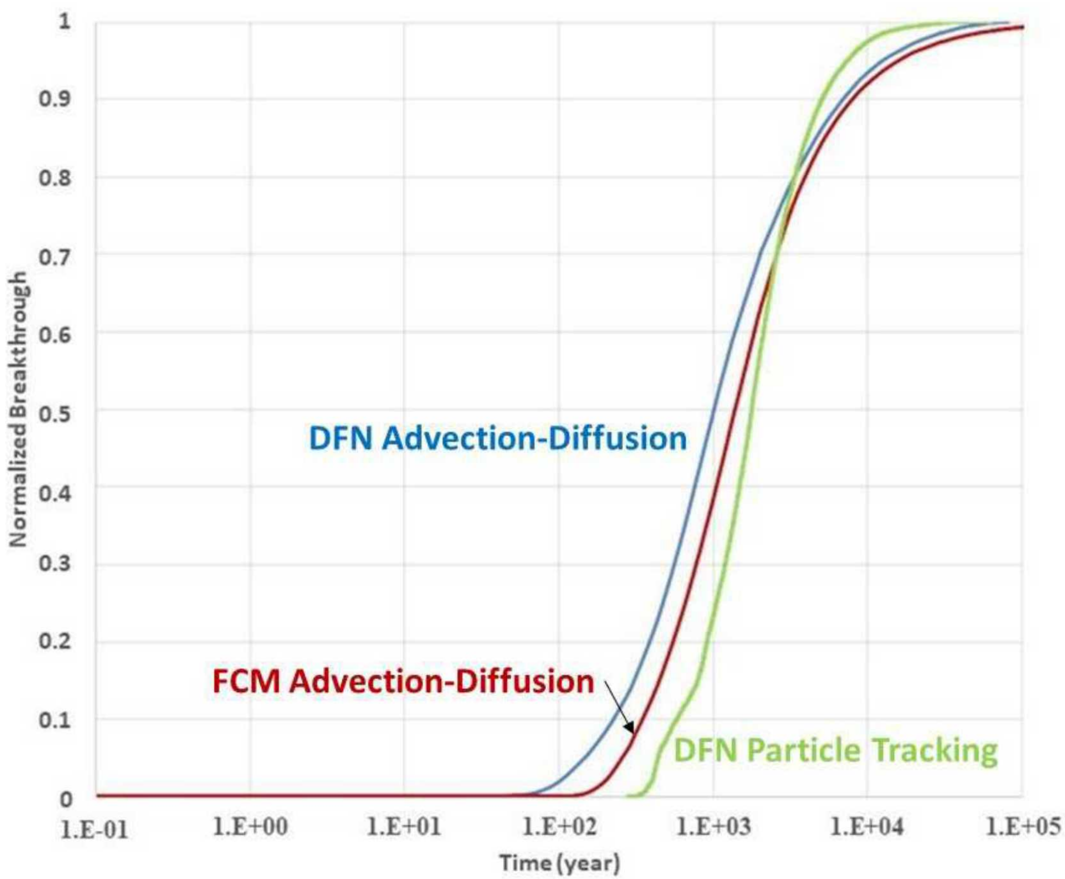
# Effective Permeability Evaluation: dfnWorks Fracture Output Data

- PFLOTRAN numerical simulator used (for both DFN and FCM) advection-diffusion simulations. Particle tracking was also used for DFN.
- Steady state flow utilized to estimate effective permeability for each realization
- Darcy's law and flux used to calculate effective permeability

| Realization | DFN Effective Permeability ($m^2$) | FCM Effective Permeability ($m^2$) |
|---|---|---|
| 1 | $3.77x10^{-17}$ | $4.60x10^{-17}$ |
| 2 | $4.24x10^{-17}$ | $3.91x10^{-17}$ |
| 3 | $4.28x10^{-17}$ | $4.18x10^{-17}$ |
| 4 | $3.81x10^{-17}$ | $3.62x10^{-17}$ |
| 5 | $3.35x10^{-17}$ | $3.81x10^{-17}$ |

# Comparison of Tracer Breakthrough Curves

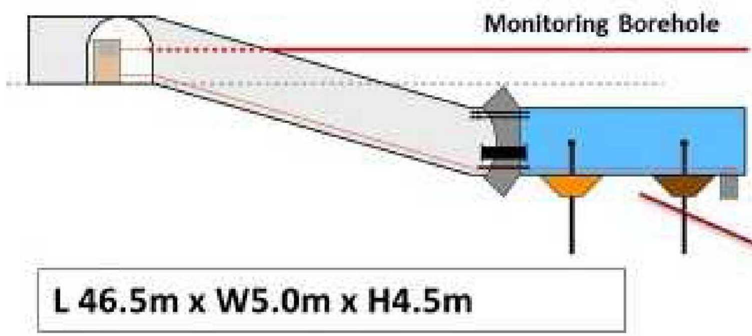
- Tracer breakthrough curves using DFN (Particle Tracking), DFN (Advection-Diffusion) and FCM (Advection-Diffusion) for a realization



# Hydrology and Geochemical Experiments at the Mizunami Underground Research Laboratory

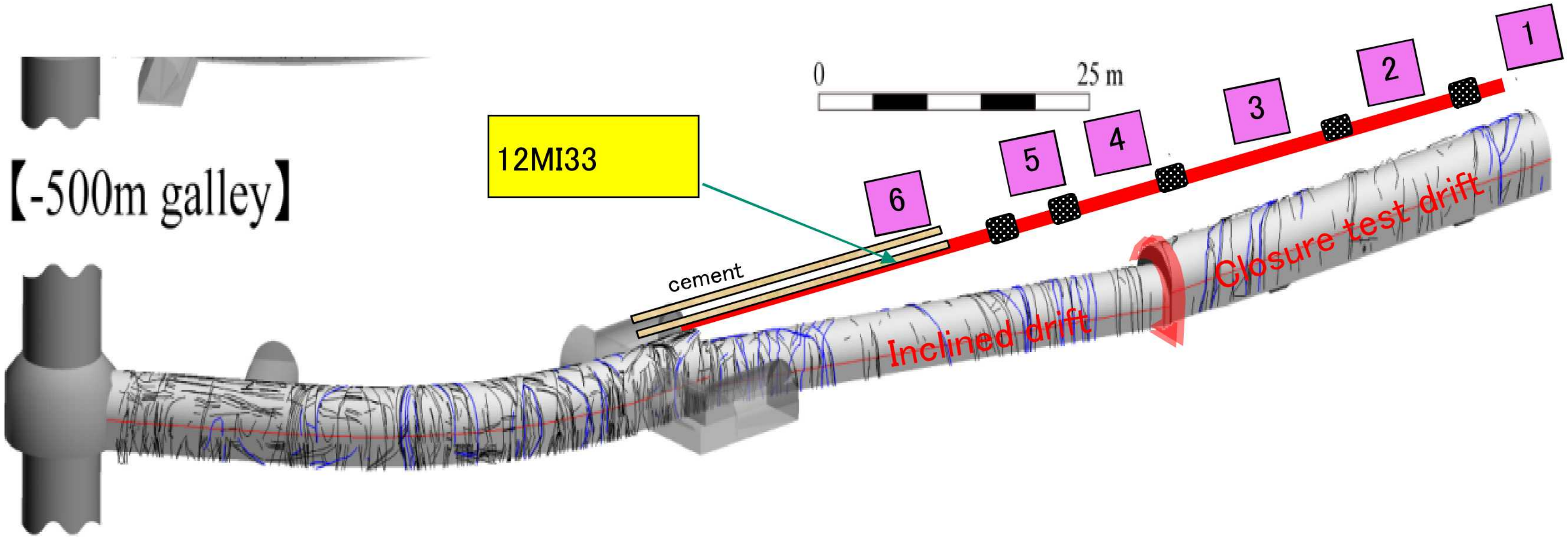
- URL located at Tono area (Central Japan)
- Study is part of DECOVALEX2019 Task C (JAEA experiments)

**GREET(Groundwater REcovery Experiment in Tunnel)** : Preliminary test (drift closure and water-filling) to estimate the recovery process in granitic rock



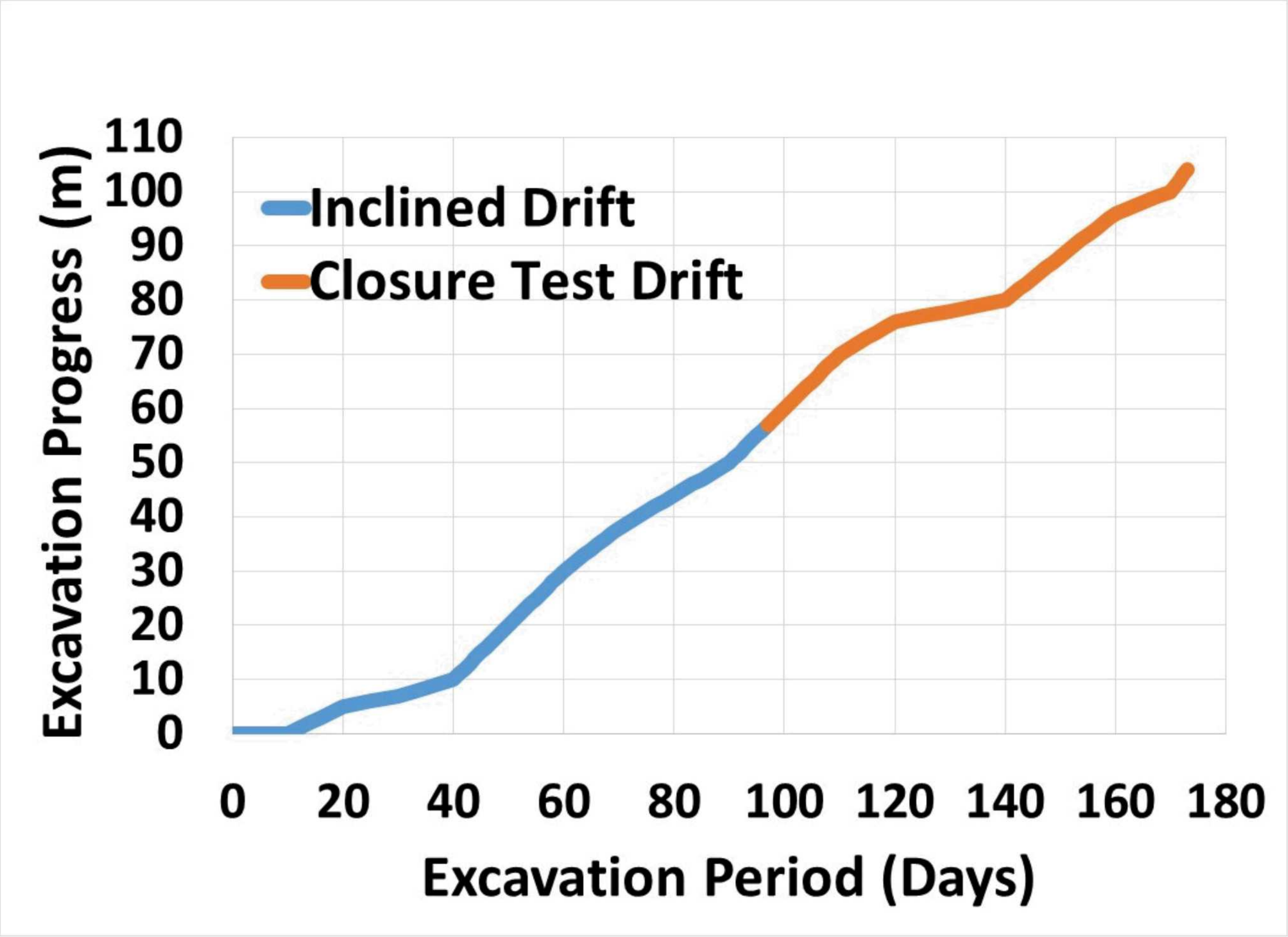

# Study Area: Tunnel and an Observation Borehole

- Tunnel sections: Inclined Drift and Closure Test Drift
- Monitoring Sections in Observation Borehole 12MI33



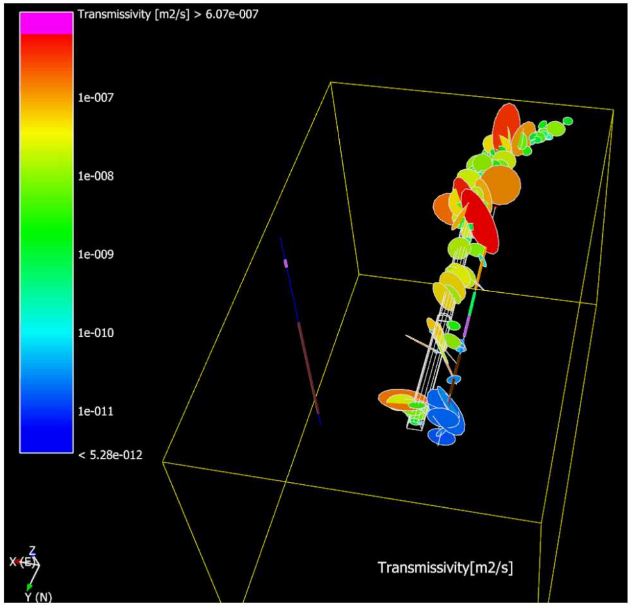
# Tunnel Excavation Progress Data

- Progress of excavation of inclined Drift and Closure Test Drift tunnel sections

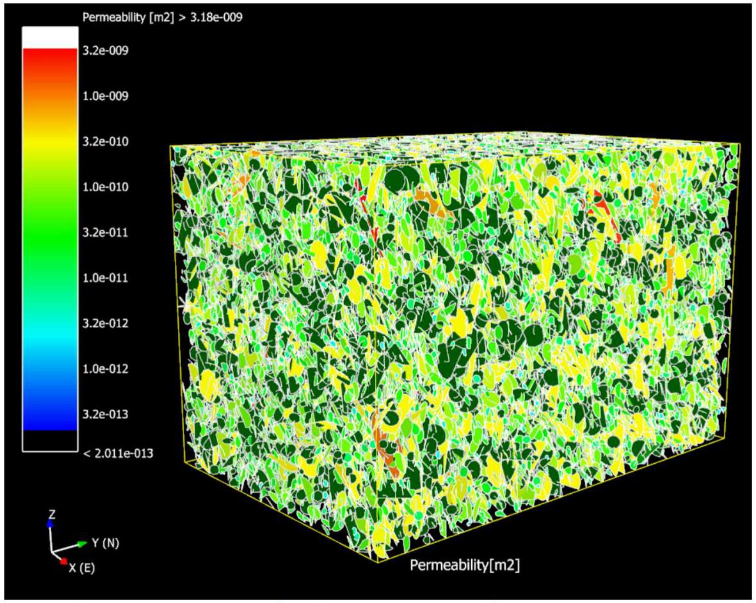


# Fracture Model Development

- Measured fractured data from tunnel walls and Borehole 12MI33
- FracMan used in model development (Kalinina et al., DFNE 2018)




Fracture transmissivity in tunnel and observation borehole 12MI33




A realization of discrete fracture network

## Developed fracture data

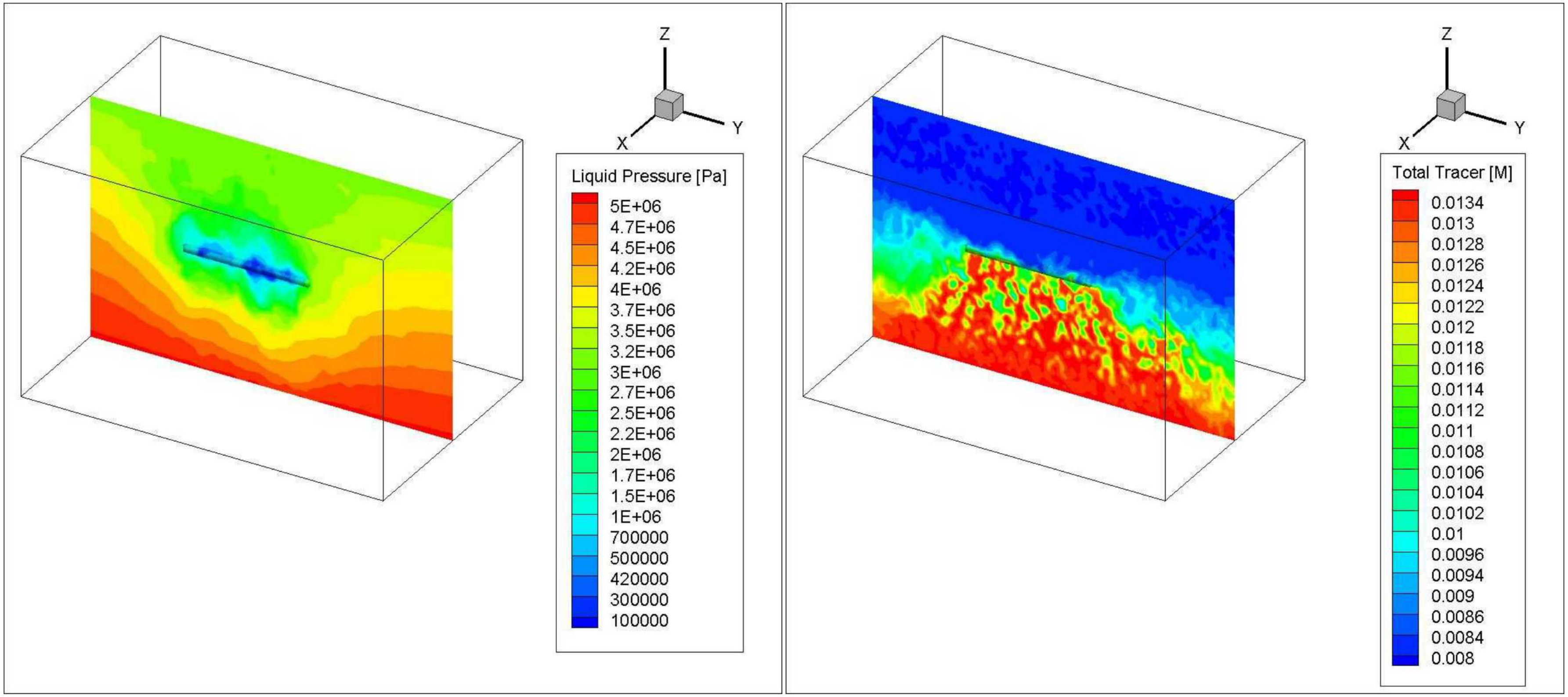
| Fracture Set | Trend ($^0$) | Plunge ($^0$) | Fisher Dispersion $\kappa$ | Volumetric Intensity $P_{32}$ (1/m) |
|---|---|---|---|---|
| Set 1 | 208 | 8 | 7 | 0.22 |
| Set 2 | 303 | 1.3 | 3.6 | 0.086 |

# Simulation Model Development

- Simulation of tunnel excavation, pressure drawdown and chloride concentration
- Domain: 200 m x 300 m x 200 m
  - Grid block size: 2 m x 2 m x 2m
  - Mesh Size: 1,500,000 grid blocks
- Fracture model with two fracture sets; 10 DFN realizations
- Permeability and porosity upscaled to continuum grid
- Initial Condition: hydrostatic pressure and chloride conc. gradient
- Boundary Conditions: specified pressure and chloride concentration
- Pressure and chloride prediction at observation points
- Inflow rate prediction
- DAKOTA, optimization code and PFLOTRAN massively parallel numerical code used

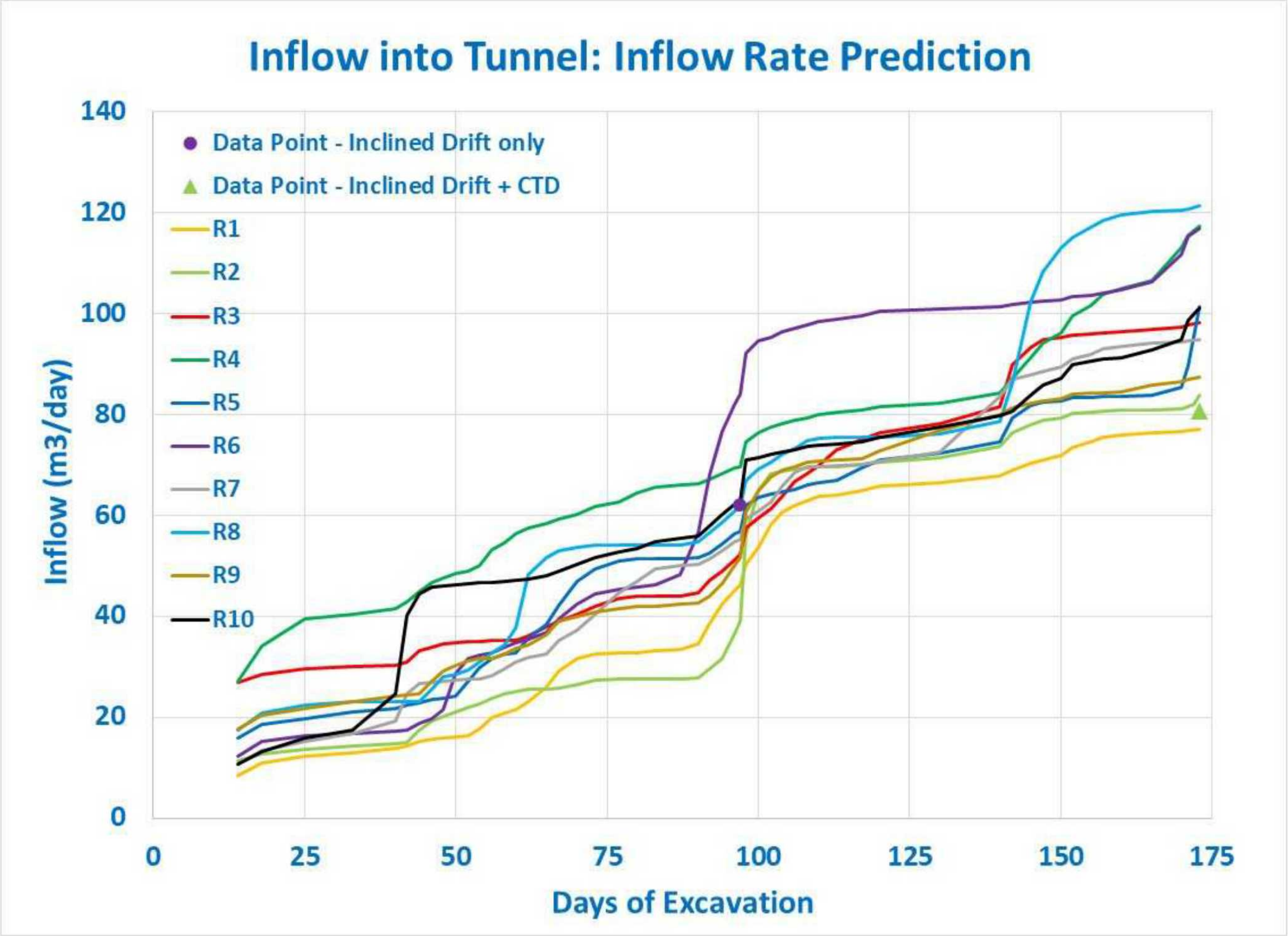
# Predicted Pressure and Chloride Distribution Results for a Fracture Realization

- Pressure and Chloride distribution along tunnel axis, after 173 days simulation time



# Predicted Inflow of Water into Tunnel

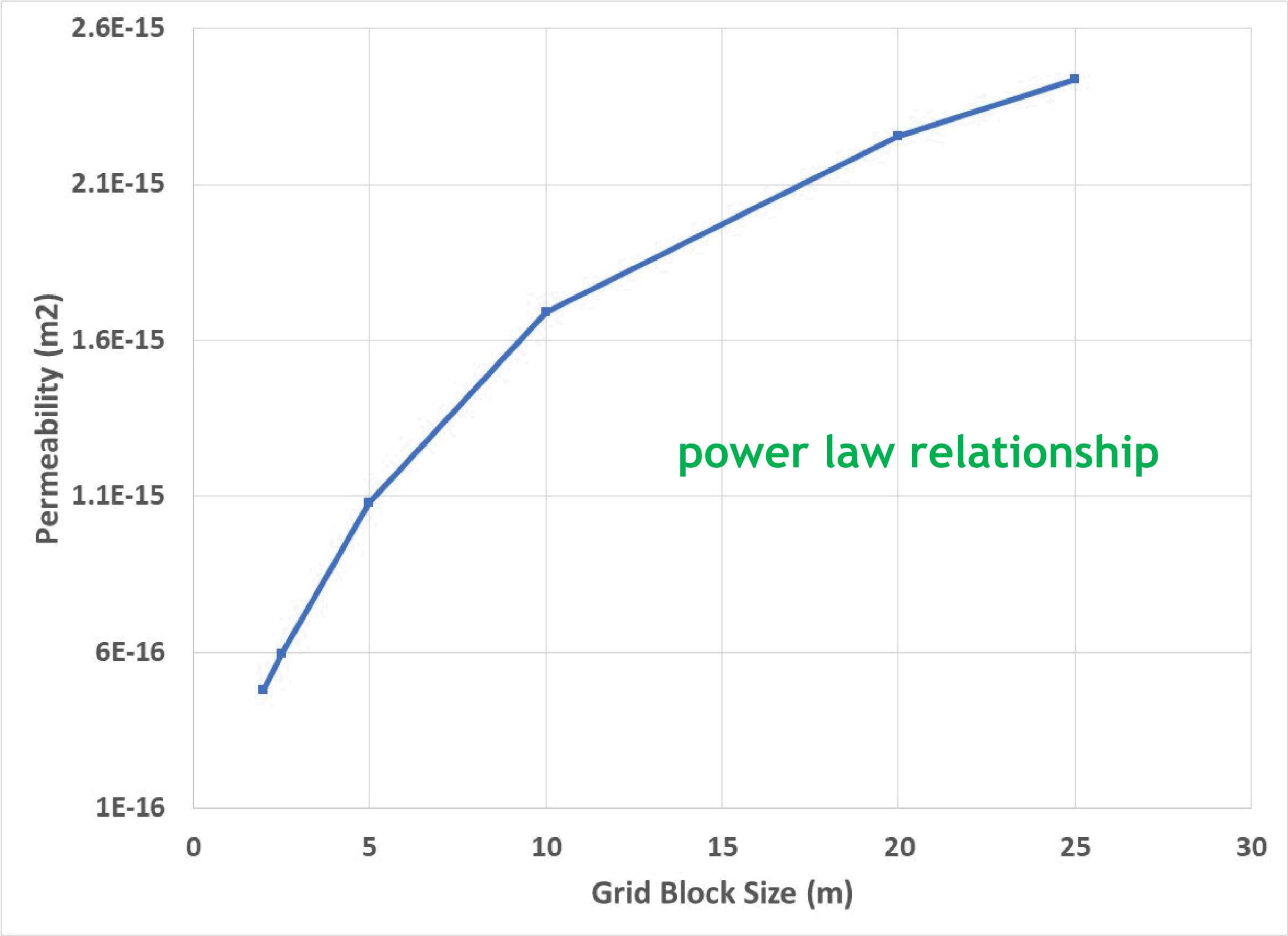
- Inflow of water during excavation of Inclined Drift and Closure Test Drift (CTD) for 10 fracture realizations



# Effect of Grid Block Size in Upscaling DFN to Continuum Grid

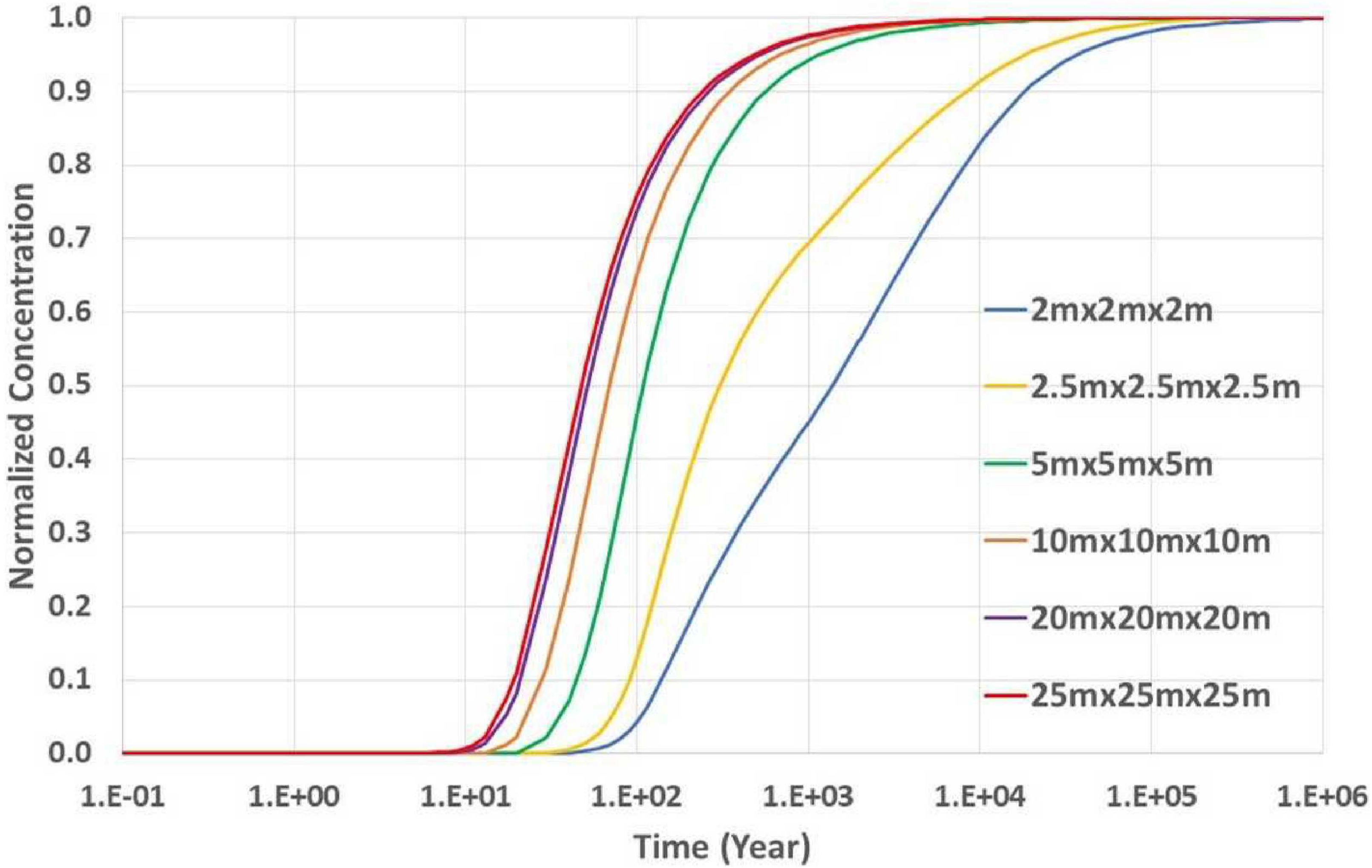
- For the DECOVALEX Task C modeling DFN was upscaled to continuum in FracMan using the Oda method.
- The Oda method is a geometric based upscaling method
- Modeling analysis conducted to study effect of grid block size
- Different domain sizes and grid block sizes considered
- A fracture realization was used for the exercise
- Pressure and tracer concentration gradient applied
- Effective permeability and tracer breakthrough estimated
- PFLOTRAN numerical code used for flow and transport simulation

# Effective Permeability vs Grid Block Size



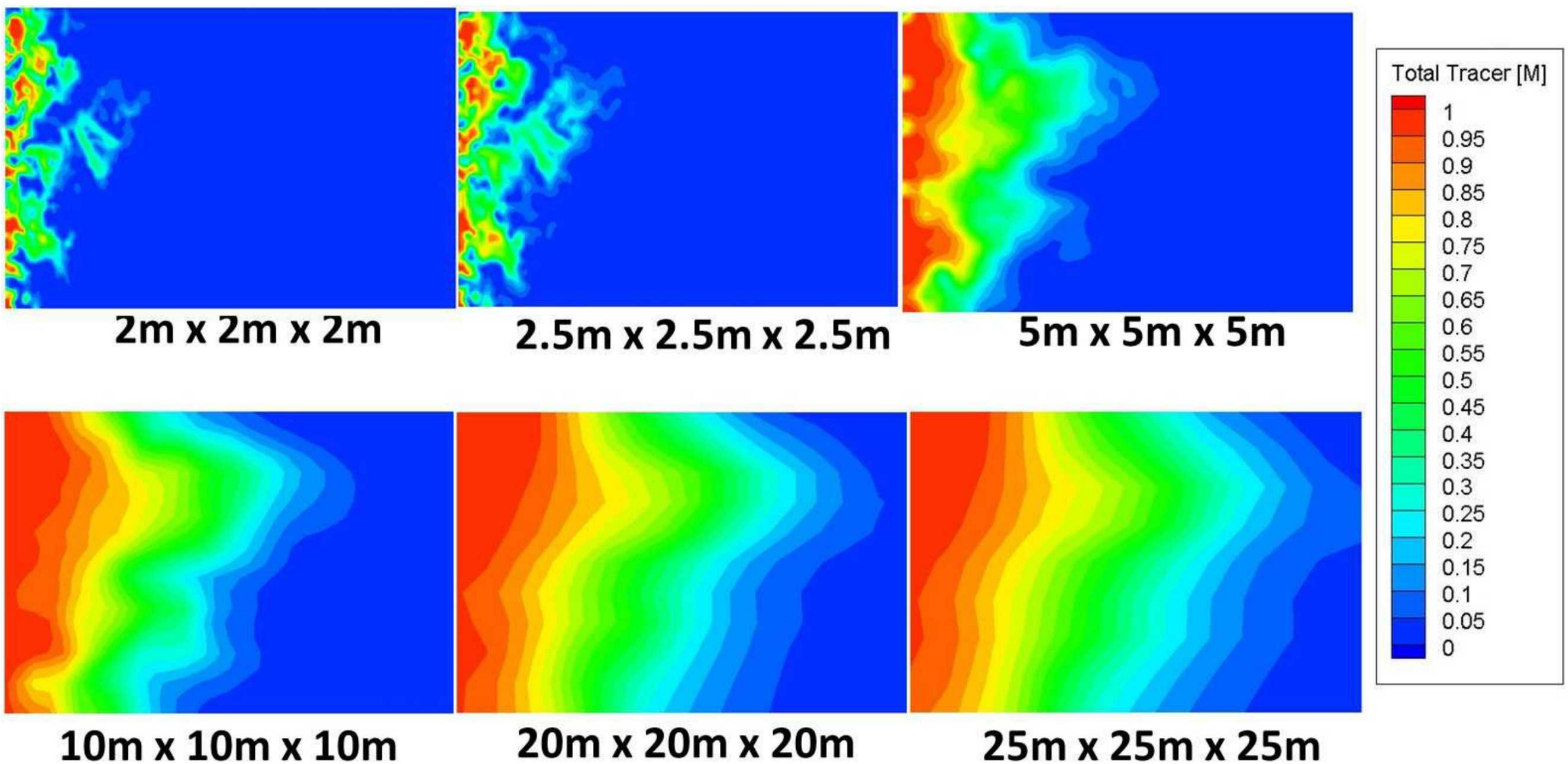
# Tracer Transport Breakthrough Curves for Different Grid Block Sizes

- Simulations show grid block size limits of 0.5 m to 25 m
- Direct DFN simulations may help optimize grid block size



# Distribution of Tracer for Different Grid Block Sizes

- Grid block side sizes: 2m, 2.5m, 5m, 10m, 20m, 25m
- Simulation Time: 10 years



# Conclusions

- Three fracture models tested: dfnWorks, FCM and FracMan
- Results show upscaled fracture model provides better representation of fractured crystalline rocks compared to homogenous porous medium assumption
- Oda upscaling method is grid block size dependent
  - Output shows a power law relationship between permeability and grid block size
  - There is a need to compare upscaled results to DFN simulation results to optimize grid size

# Acknowledgements

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