

Field Data Synthesis and Upscaling for Fractured Rocks

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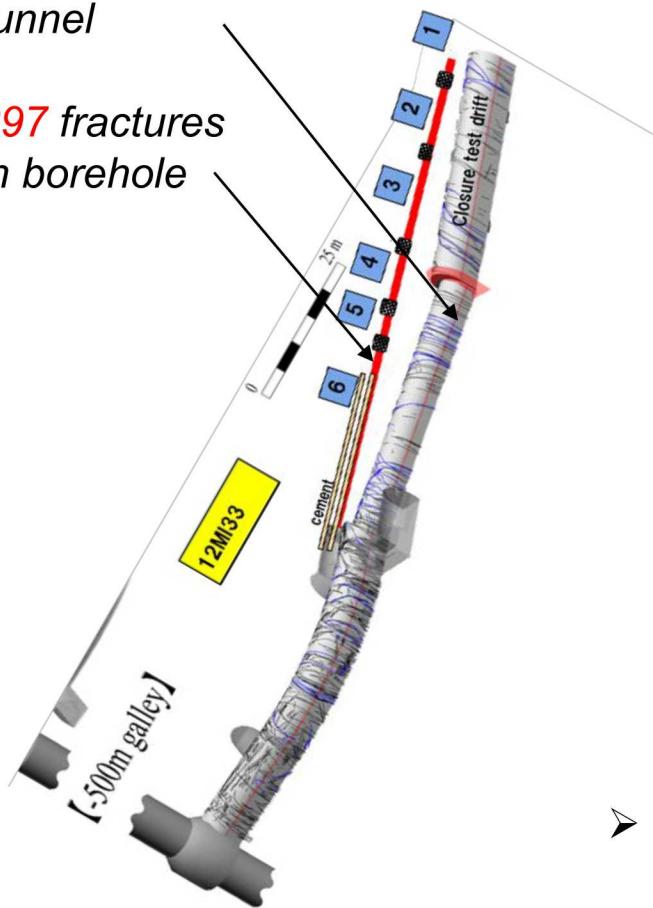
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Field Data

2,023 fractures in the tunnel

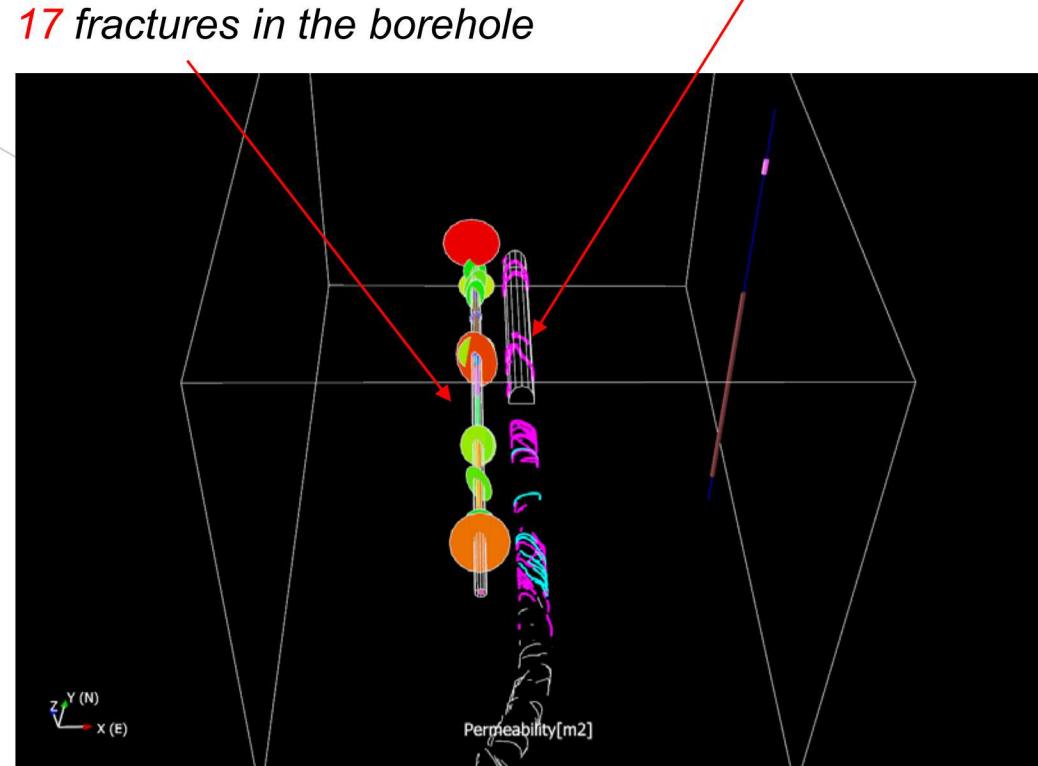
297 fractures in borehole



Model

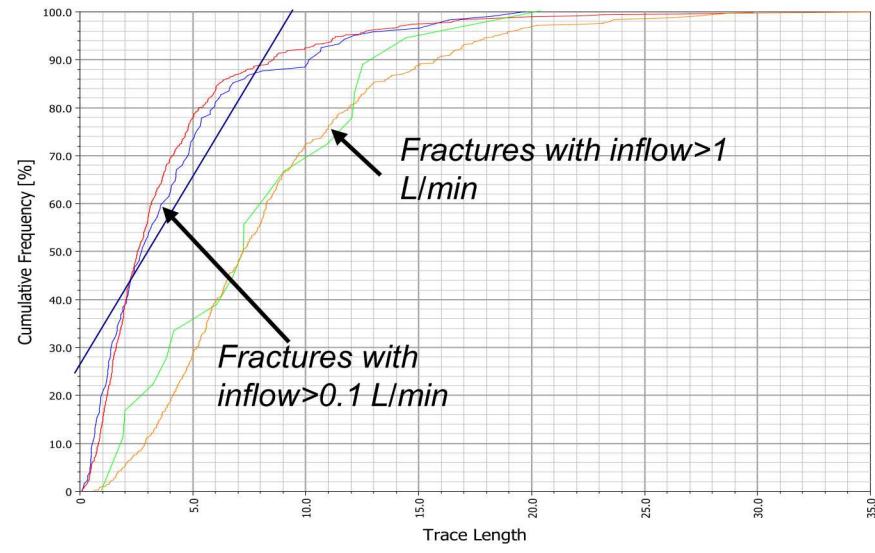
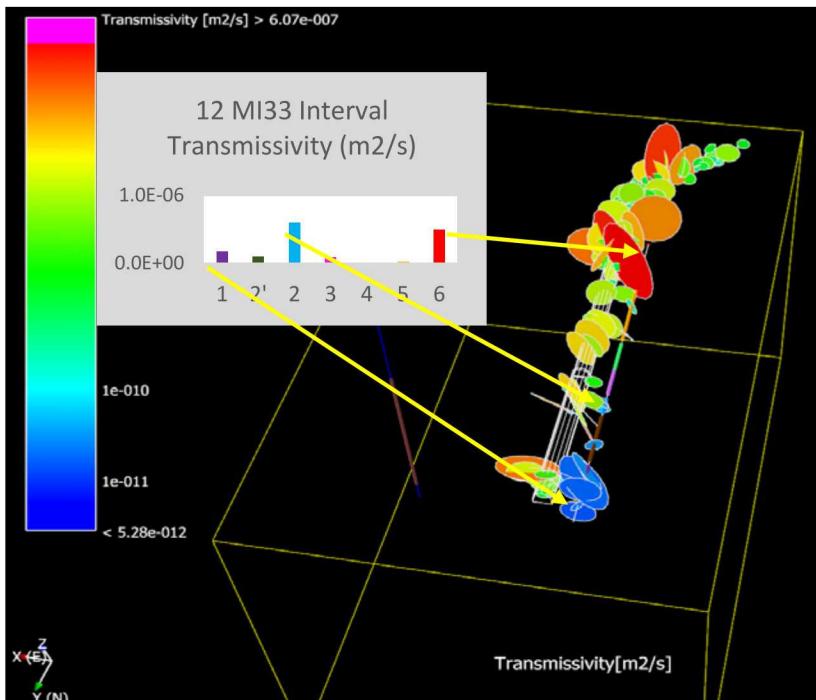
146 fractures in the tunnel

17 fractures in the borehole



- Fractures in the tunnel and borehole have deterministic locations and stochastic sizes and properties.

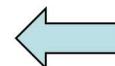
- Fracture Size distributions from trace length analysis.



- Fracture transmissivity from the observed fracture discharge (analytical solution).



- Correlations between fracture radius (R), fracture aperture (b) and permeability (k):

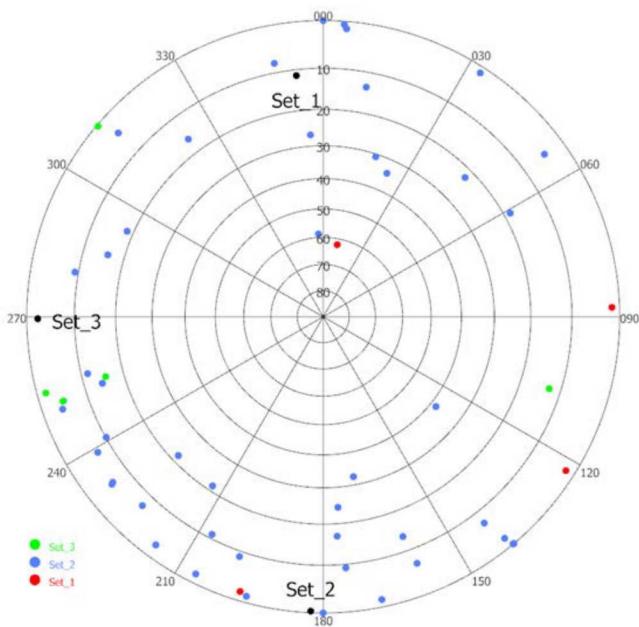


$$k = \gamma_1 \cdot R^\omega \quad b = \gamma_2 \cdot R$$

- Transmissivity from Packer Tests Compared to Transmissivity of Generated Fractures

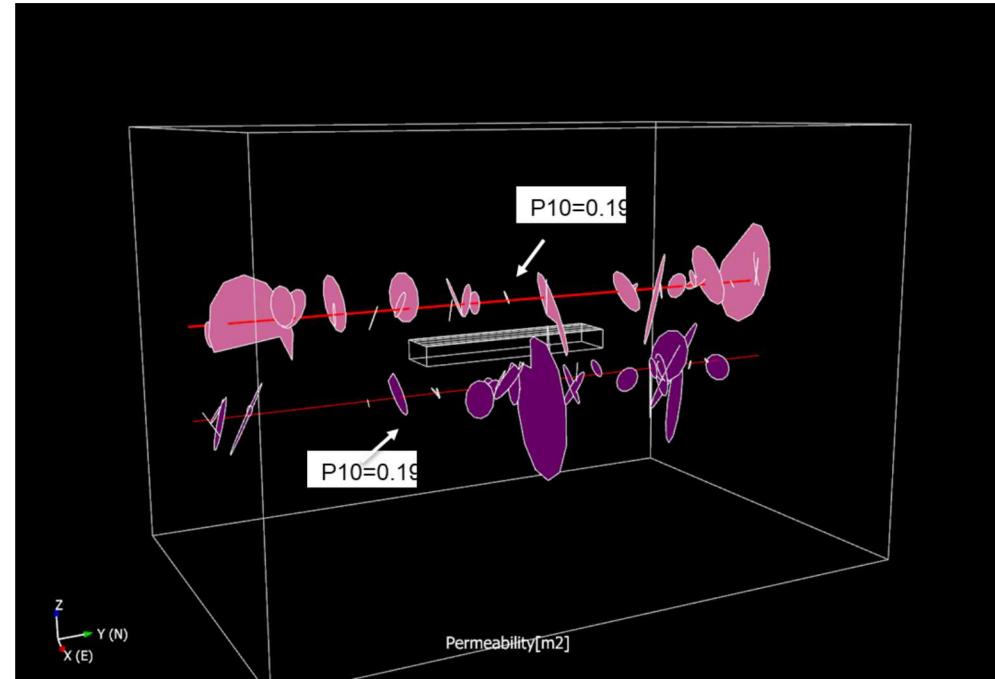
Additional Information Required to Generate Stochastic Fractures

- Number of fracture sets.
- Orientation distribution for each fracture set.



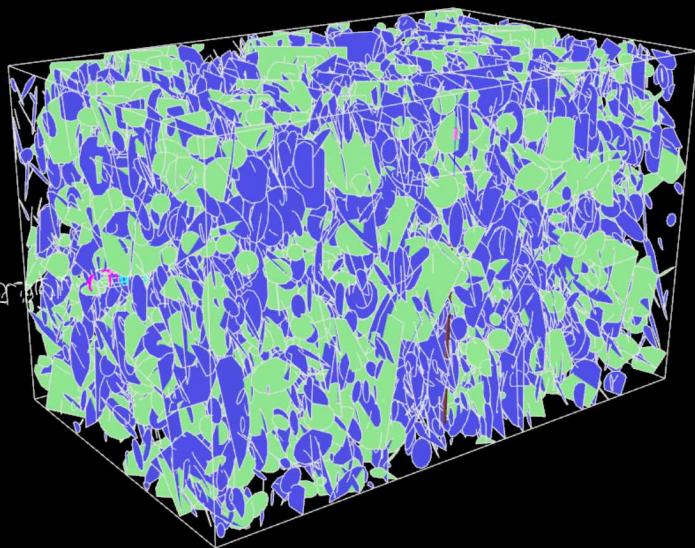
- Fracture intensity for each set.

Stochastic Fractures Intersecting Arbitrary Horizontal Boreholes



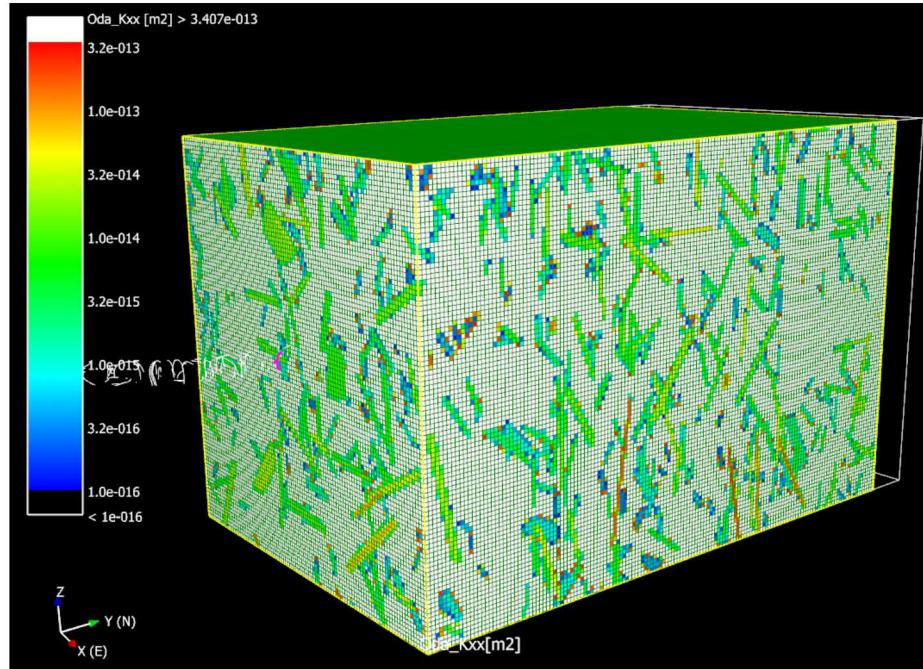
- Identifying fracture sets from tunnel fracture orientation and plunge

- Calculating volumetric intensity (P_{32}) by matching linear intensity (P_{10}) of generated fractures with the P_{10} of observed fracture.



➤ ***Discrete Fracture Network Model (DFN)***

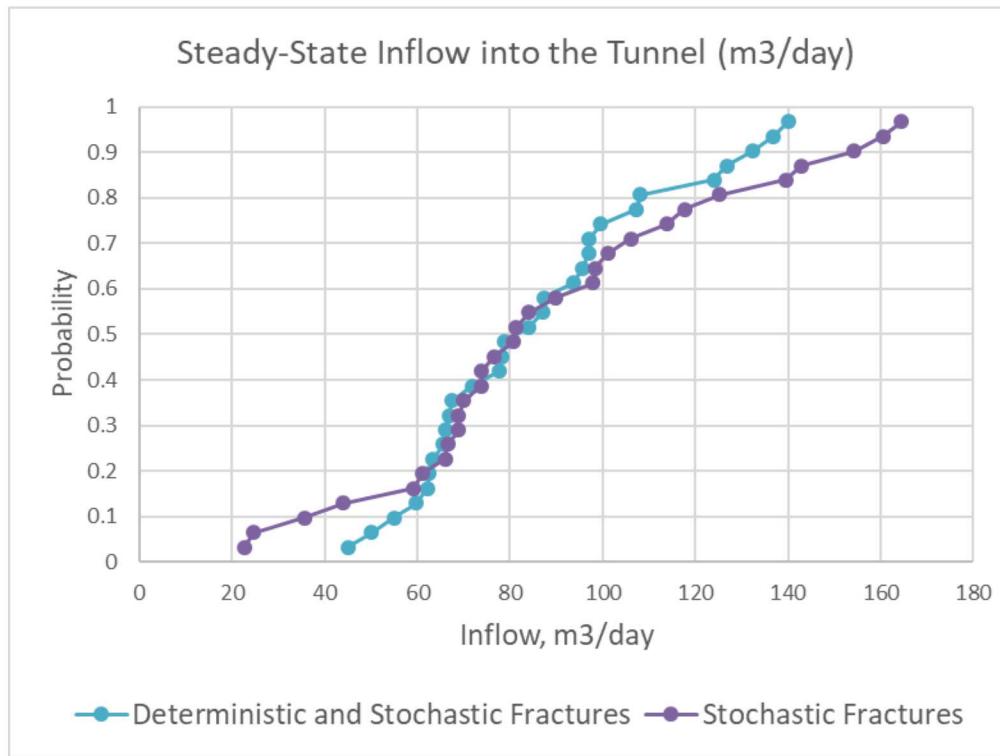
- Total number of fractures: 7,758
- Deterministic fractures in the tunnel and borehole.
- Two sets of stochastic fractures



➤ ***Effective Continuum Model (ECM)***

- DFN was upscaled to 1m x 1m x 1m ECM
- Upscaling with Oda's method.
- Oda calculates permeability tensors in three dimensions for each cell.

Total Inflow into the Tunnel Calculated Using Two Different DFNs



- ***The uncertainty is reduced when DFN includes the observed fractures in the tunnel and borehole.***
 - ***DFN1, Deterministic and stochastic fractures: Q= 45 m³/day – 140 m³/day ($\Delta=95$)***
 - ***DFN2, Stochastic fractures only: Q= 22 m³/day – 165 m³/day ($\Delta=143$)***