

**DEC 2023**

# **UPSCALING OF POROELASTIC PARAMETERS FRACTURED MEDIA USING FINITE ELEMENTS**

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**RENATO POLI (REP2656)**

Literature Brief

Methodology

Validation

Bulk modulus ( $K$ )

Biot coefficient ( $\alpha$ )

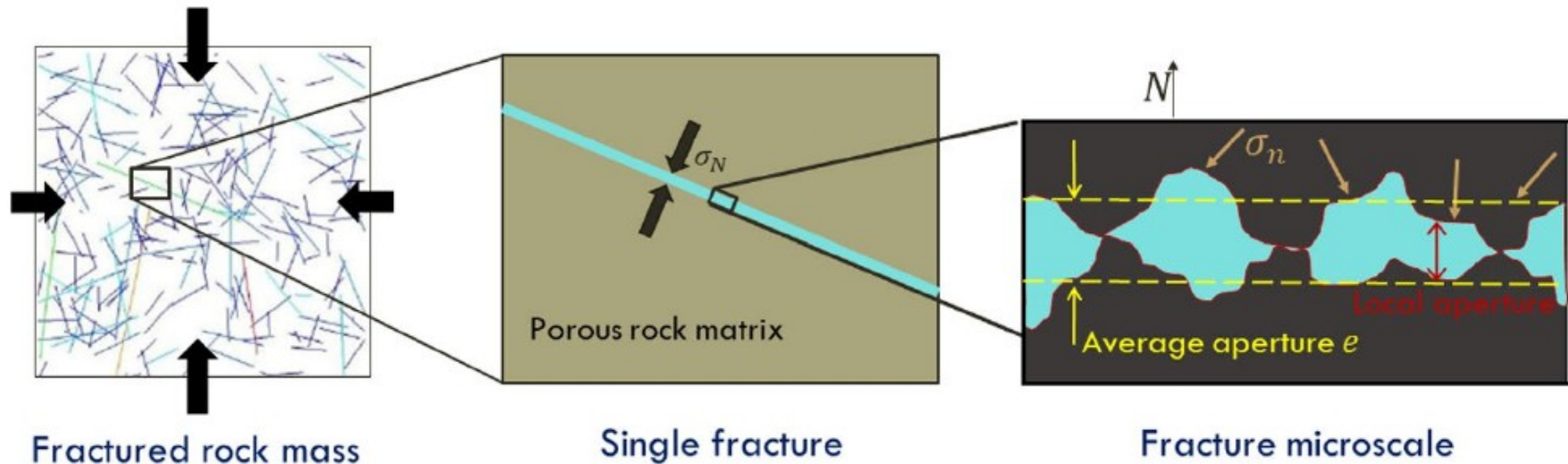
Conclusions

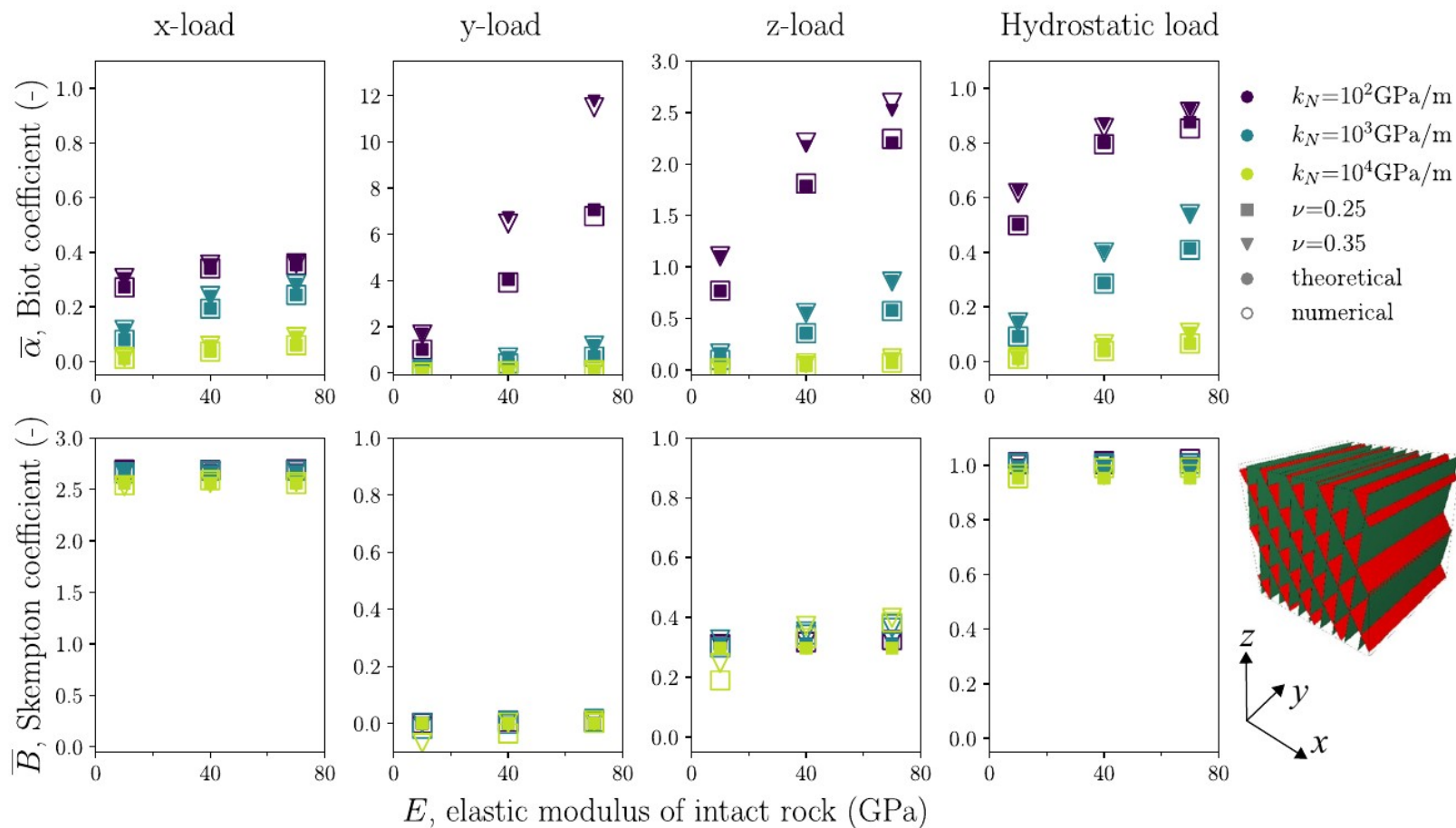
# Equivalent Biot and Skempton Poroelastic Coefficients for a Fractured Rock Mass from a DFN Approach

Silvia De Simone<sup>1,2</sup>  · Caroline Darcel<sup>3</sup> · Hossein A. Kasani<sup>4</sup> · Diego Mas Ivars<sup>5,6</sup> · Philippe Davy<sup>1</sup>

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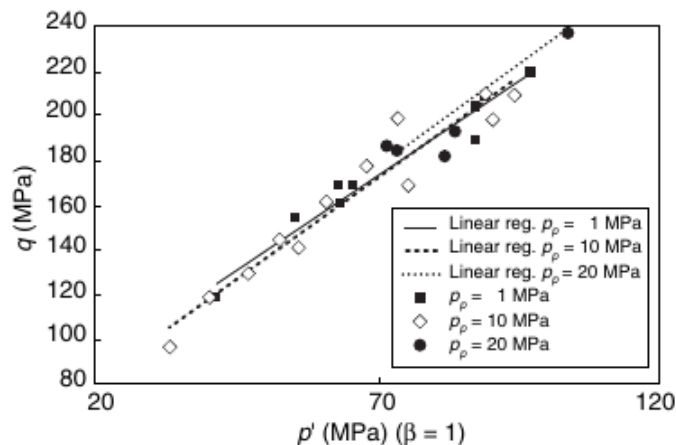
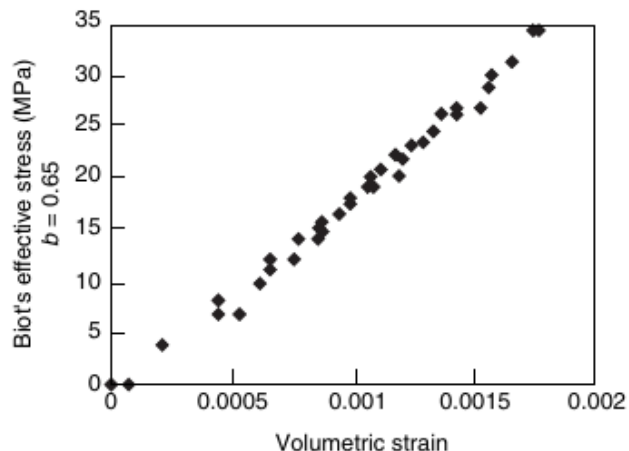
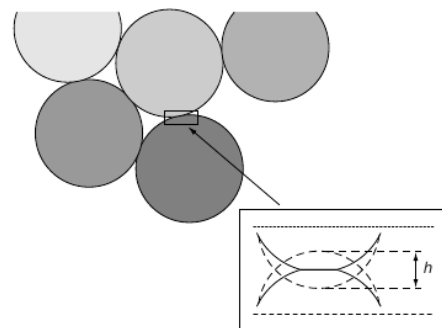
# Mechanical Properties of Rocks: Pore Pressure and Scale Effects

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Effective stress translates MICROscale phenomena to the MACROscale, in different problems:

- 1) **Constitutive equations:**  $\sigma_{ij}^{eff} = C_{ijkl} \epsilon_{kl}$
- 2) **Failure:** shear failure, plasticity criteria
- 3) **Rock properties:**  $K_{eq} = f(\sigma_{eff})$

$$\sigma_{ij}^{eff} = \sigma_{ij} - \alpha p \delta_{ij}$$

Each problem uses different  $\alpha$  for the same rock

One “effective stress” has nothing to do with the other ones...

# The poromec simulator

Started in 2016

2D version published in 2020

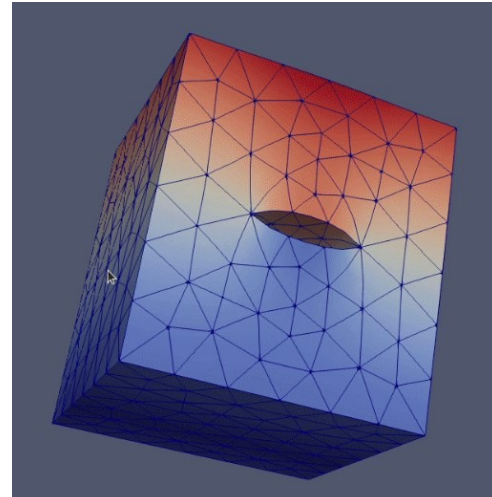
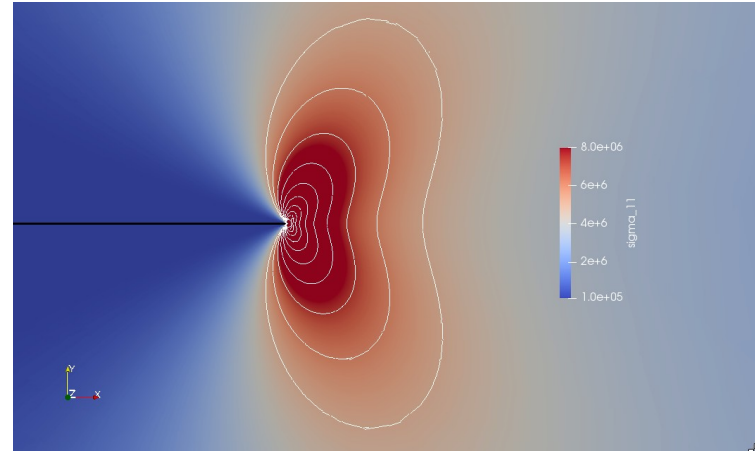
3D version unfinished

Tech:

*C++*, *Python*, *gmsh*, *libmesh*, *petsc*, *MPI*

For this project:

- 3D validation and bug fixing
- mesh generation with many fractures
- integration to a computer cluster
- monte carlo simulation
- post processing
- data fitting and plotting

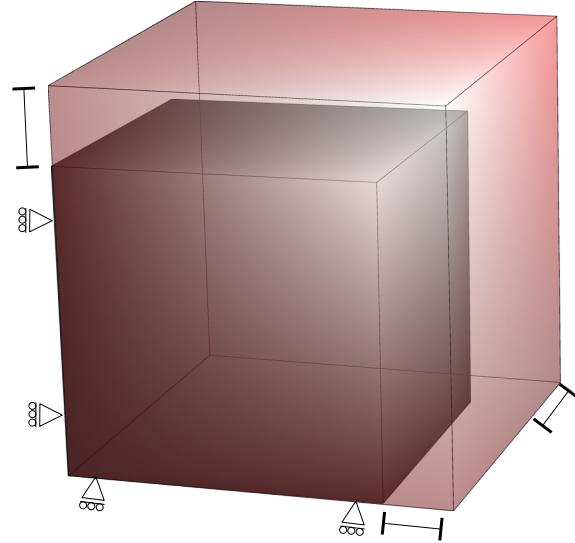


Poroelasticity (Wang, 2000)

$$\zeta = \frac{\delta V_p - \delta V_f}{V} = \alpha \epsilon + \frac{1}{M} p$$

$$\epsilon = \frac{1}{K} \sigma + \frac{1}{H} p = \frac{\delta V}{V}$$

$$\alpha = \left. \frac{\delta \zeta}{\delta \epsilon} \right|_{p=0} \quad K = \left. \frac{\delta \sigma}{\delta \epsilon} \right|_{p=0}$$



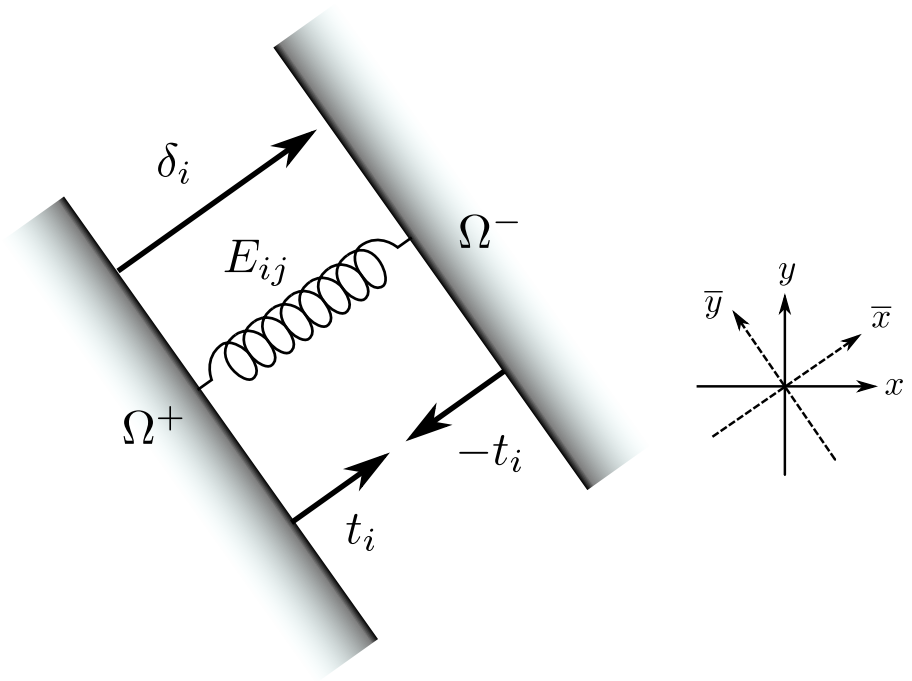


## Tensor rotation

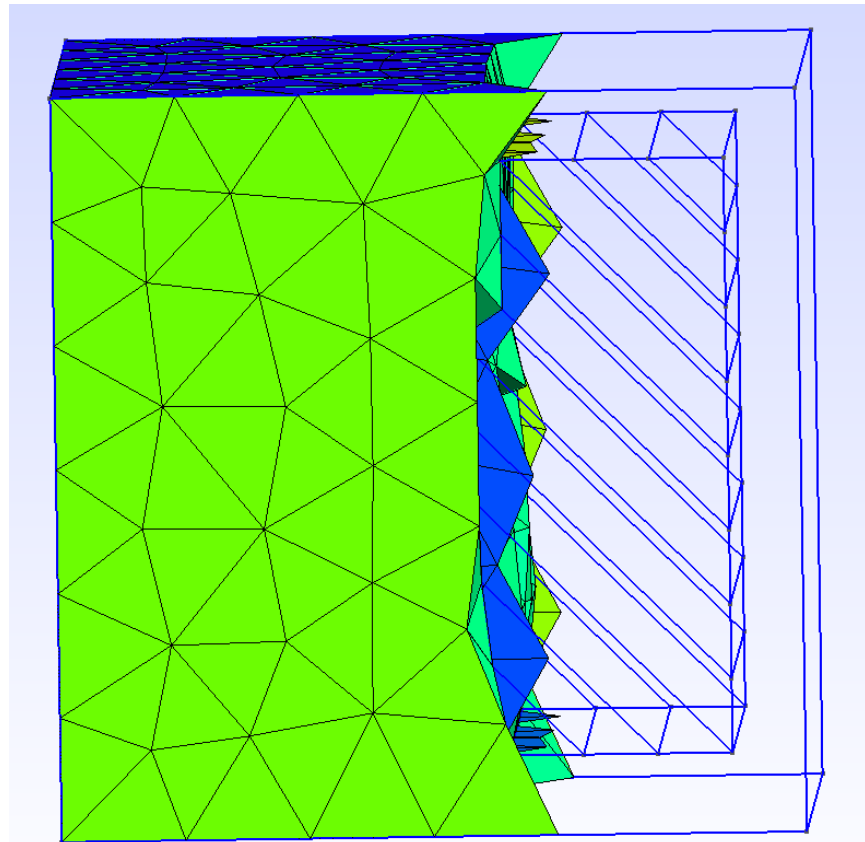
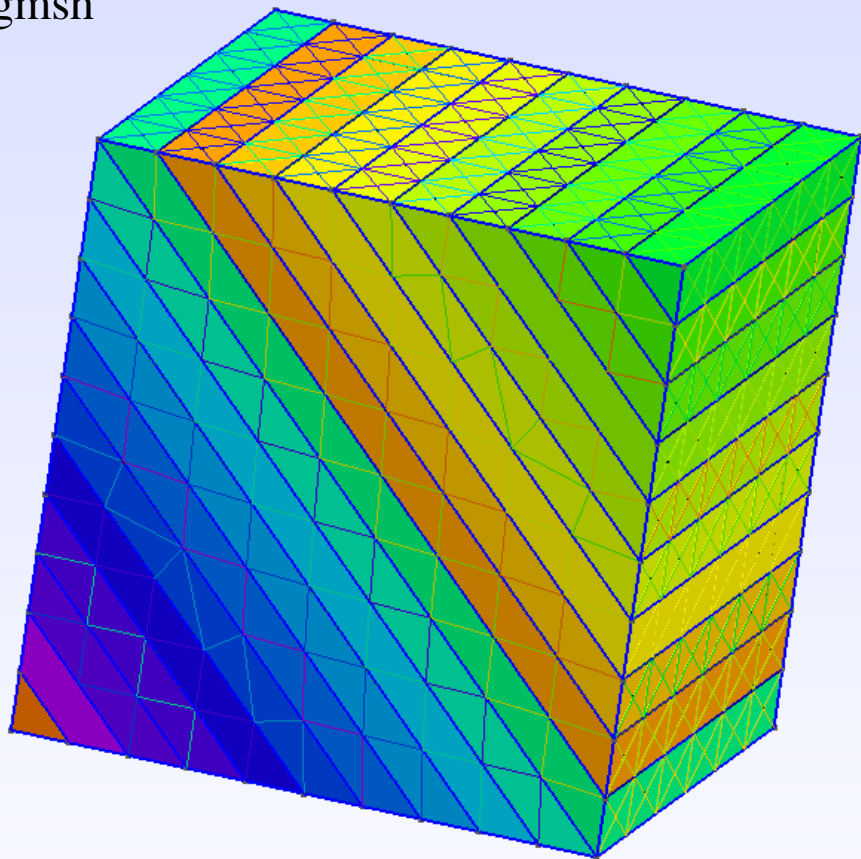
$$T_{ij} = R_{ki} R_{lj} \bar{T}_{kl}$$

$$\bar{E}_{kl} = \bar{E}_{kl}(d, \bar{\delta}_l) = \begin{bmatrix} \bar{E}_n & - & - \\ - & \bar{E}_s & - \\ - & - & \bar{E}_t \end{bmatrix}$$

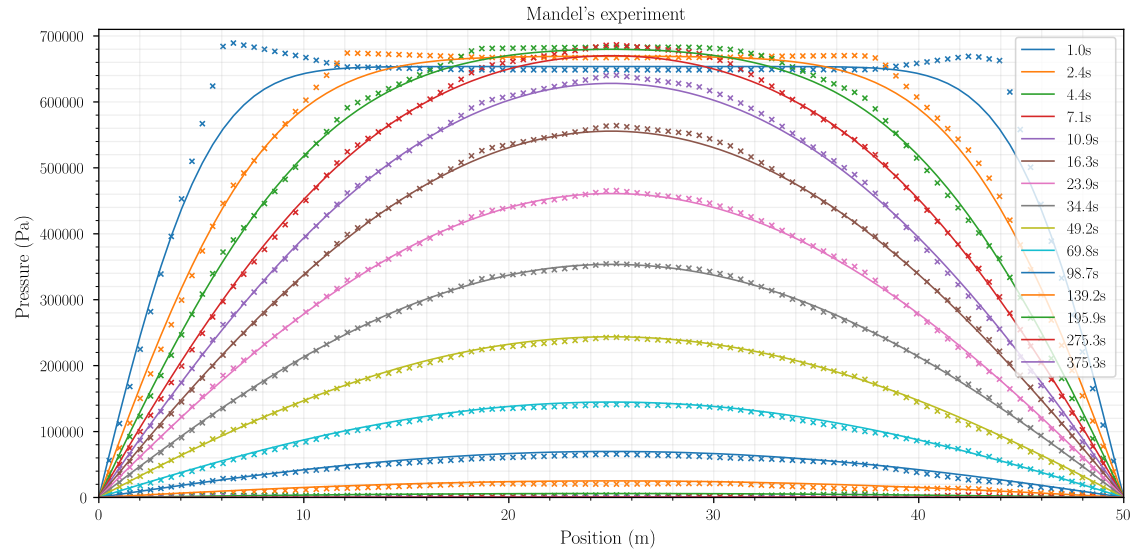
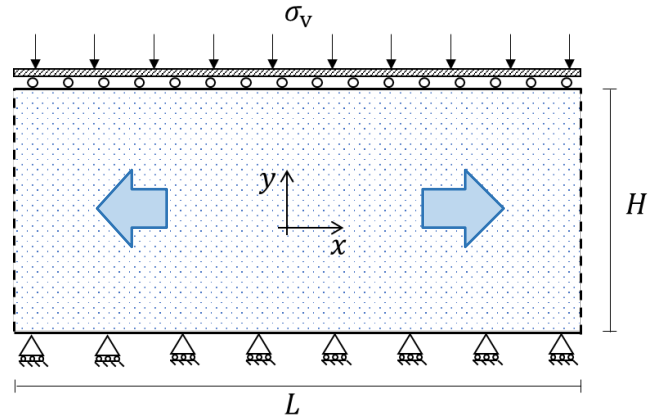
$$t_i = R_{ki} R_{lj} \bar{E}_{kl} (u_j^+ - u_j^-)$$



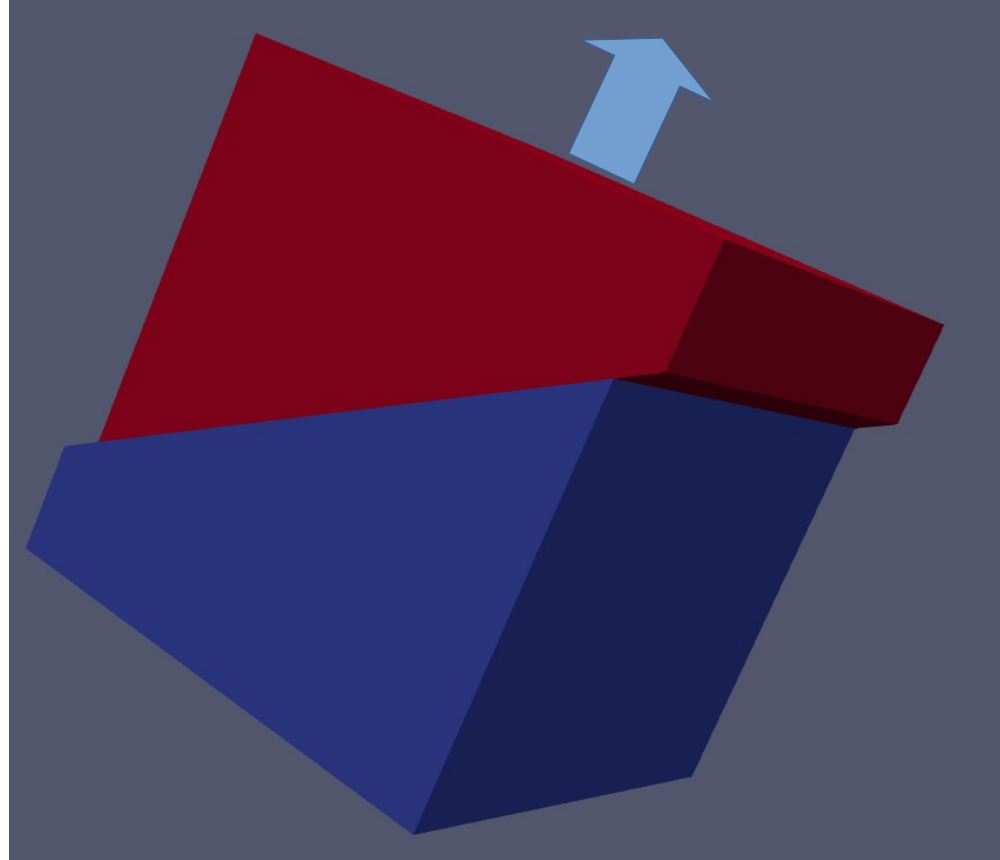
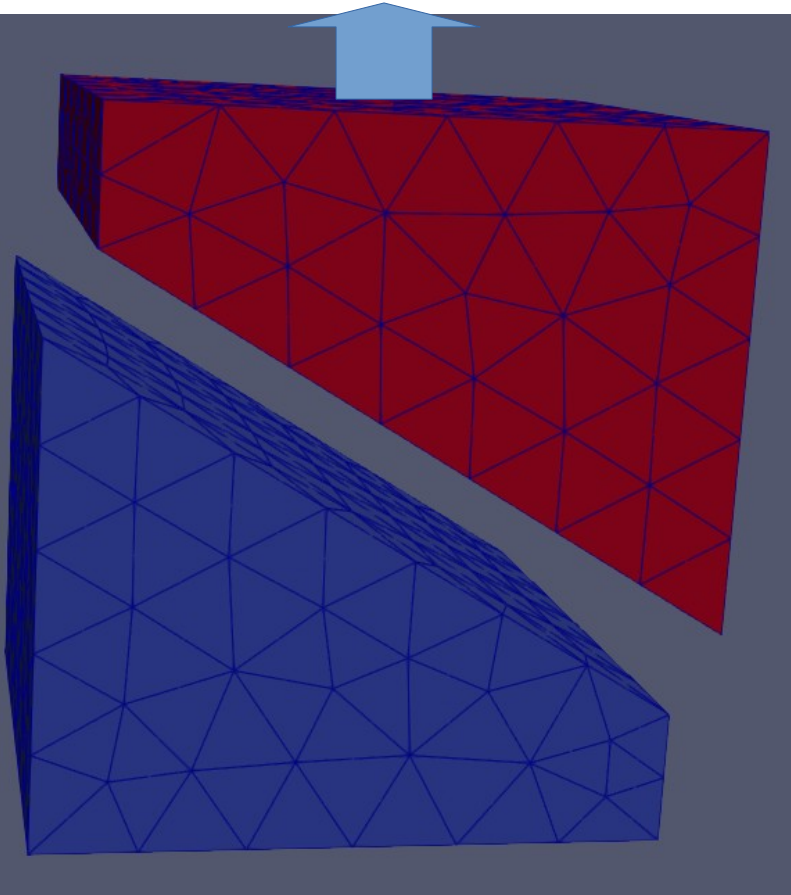
gms



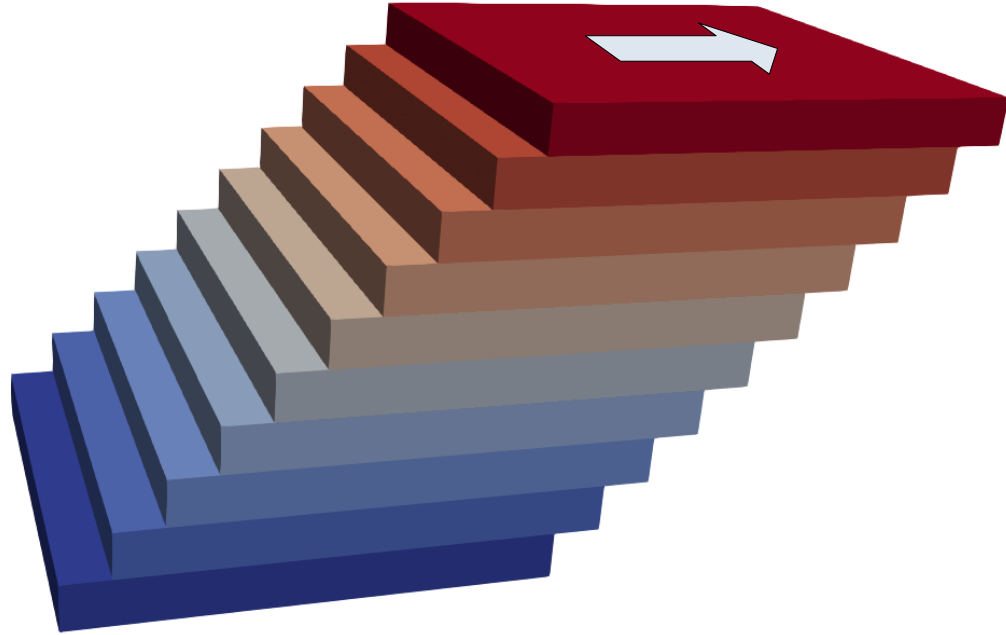
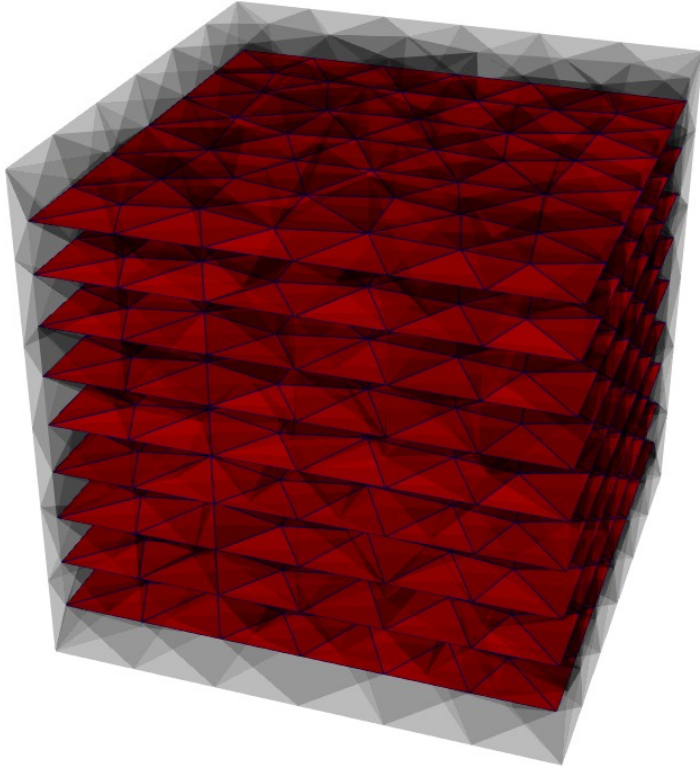
# Mandel's analytical solution

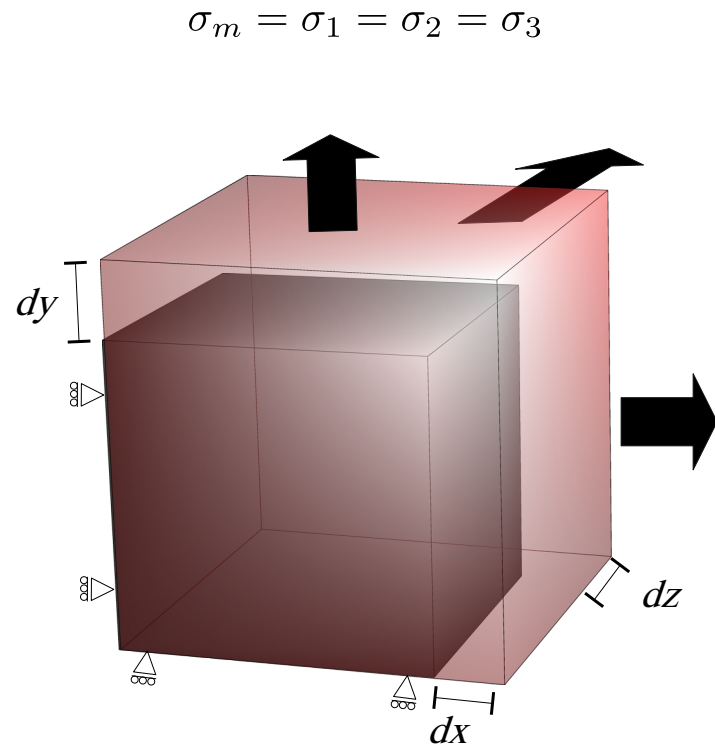
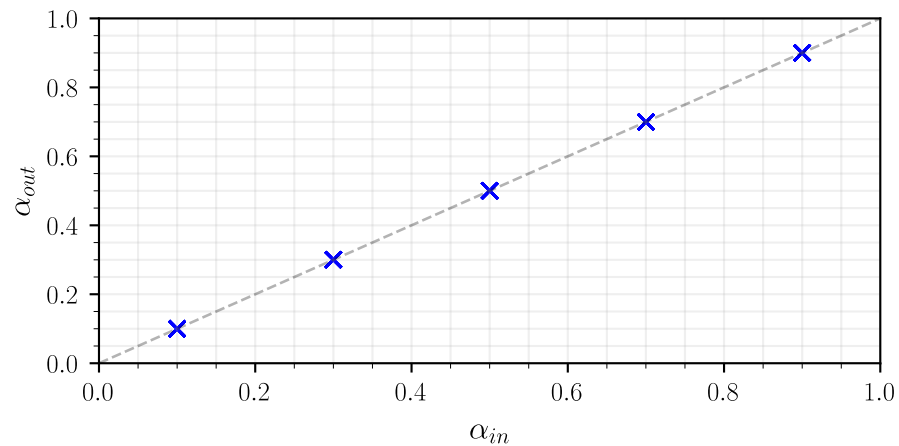
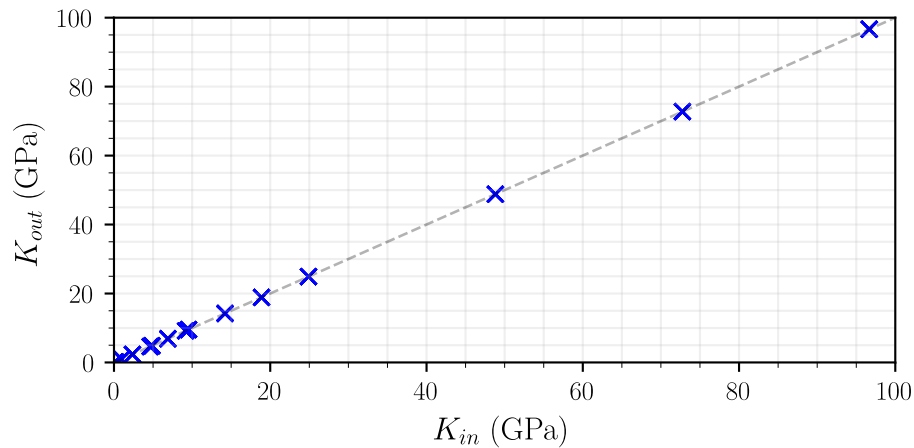


## Shear/normal fracture control

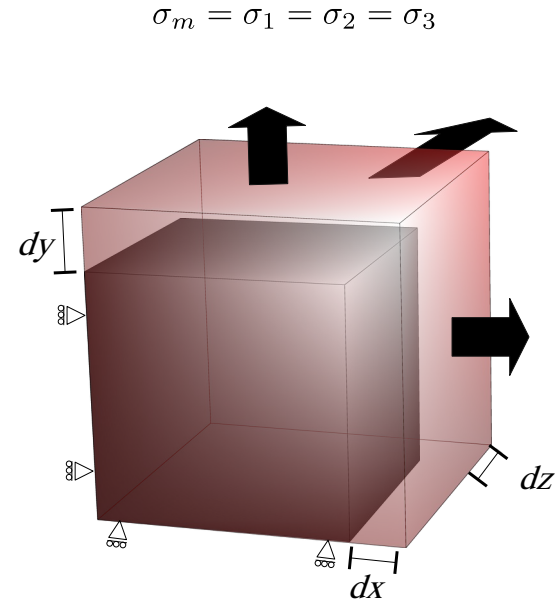
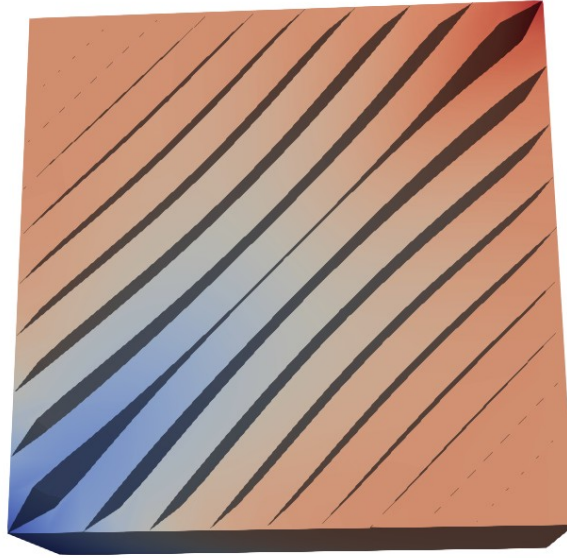
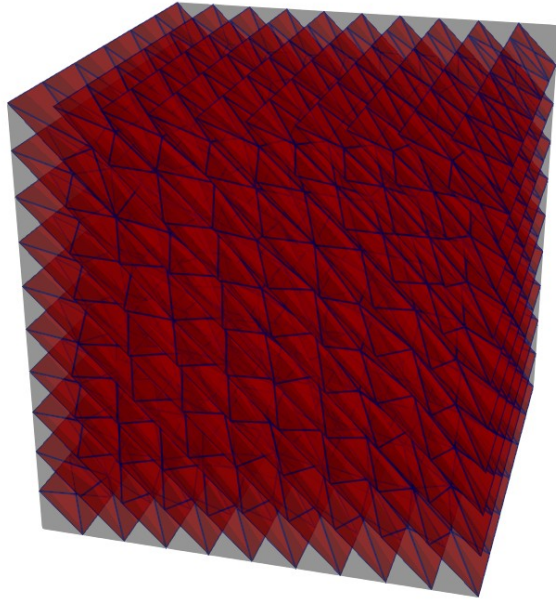


## Shear – multiple fractures



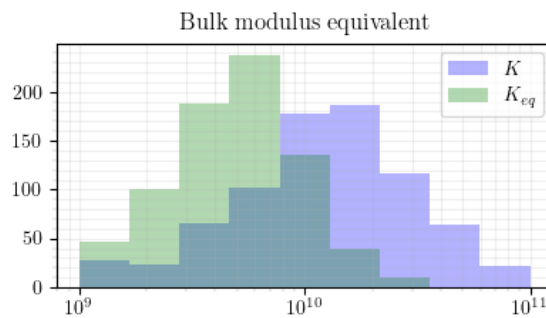
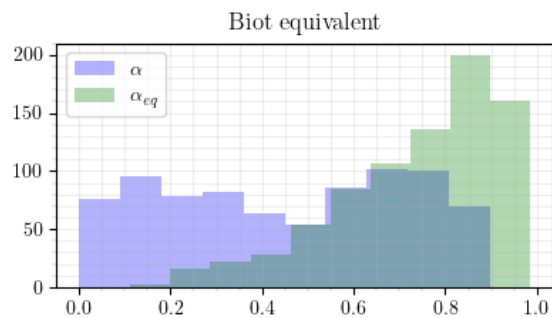
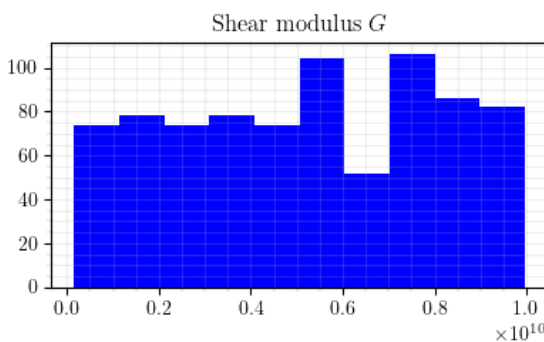
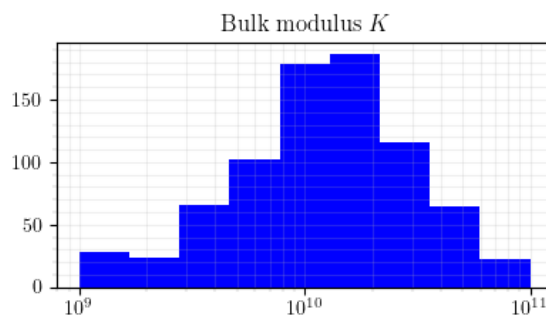
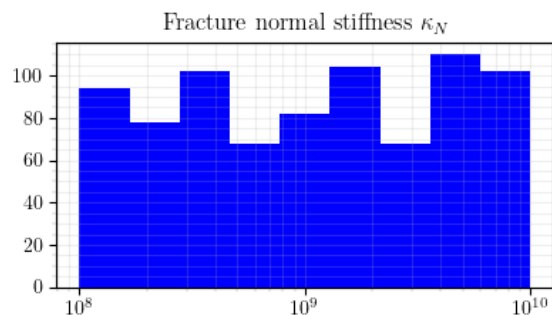
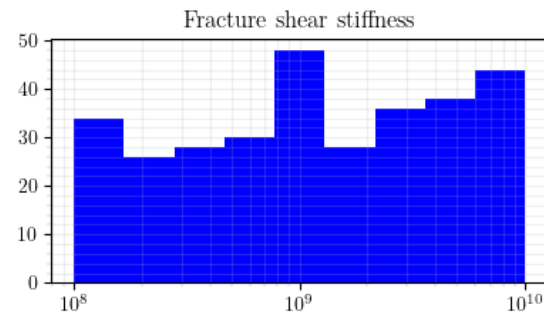
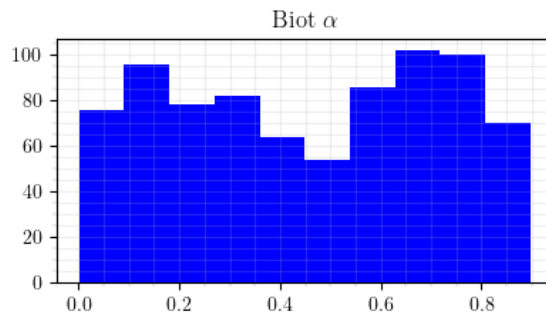
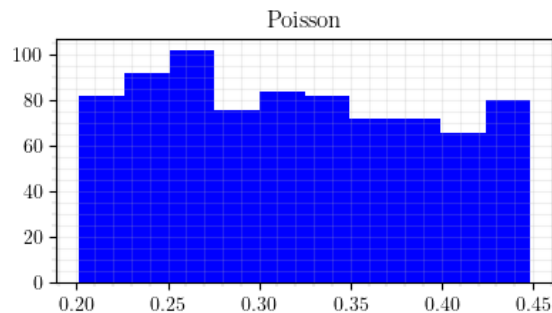


## Testcase 40



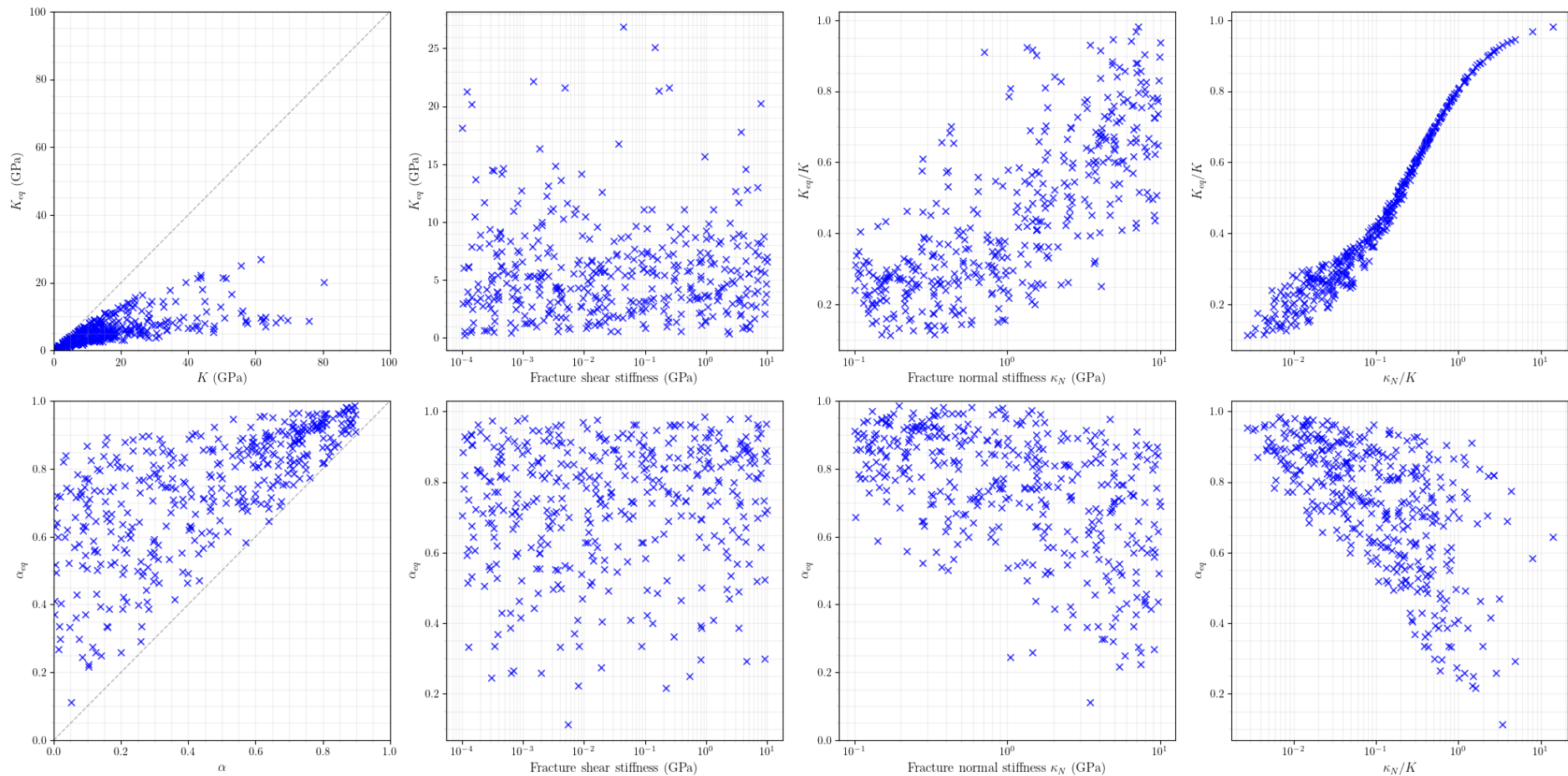


# Fractured rock rock - Bulk modulus ( $K$ ) and Biot coefficient ( $\alpha$ )

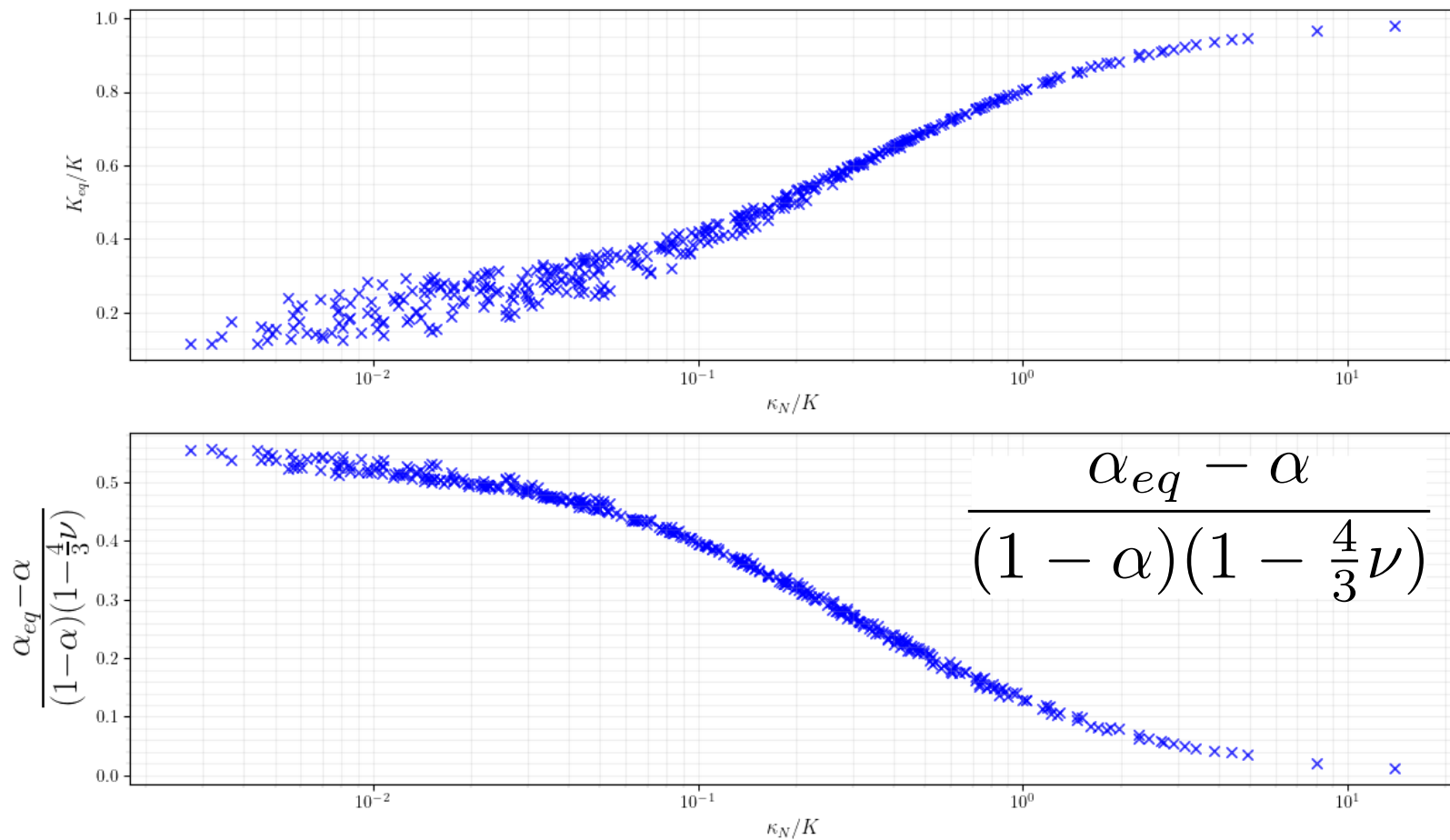




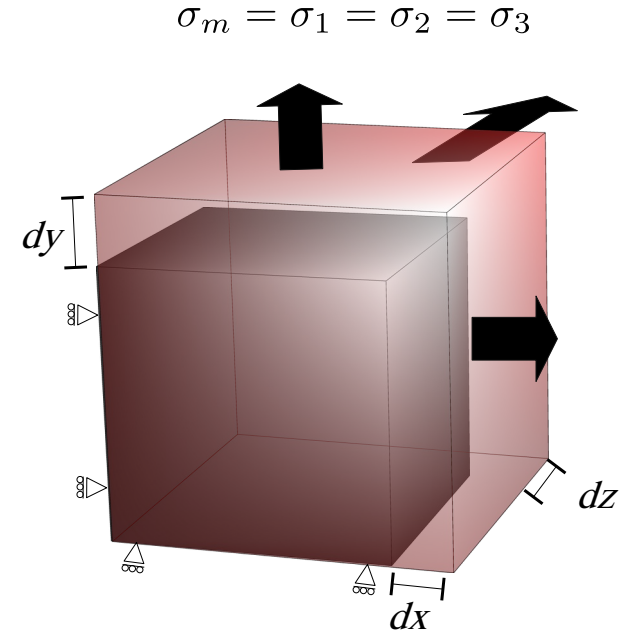
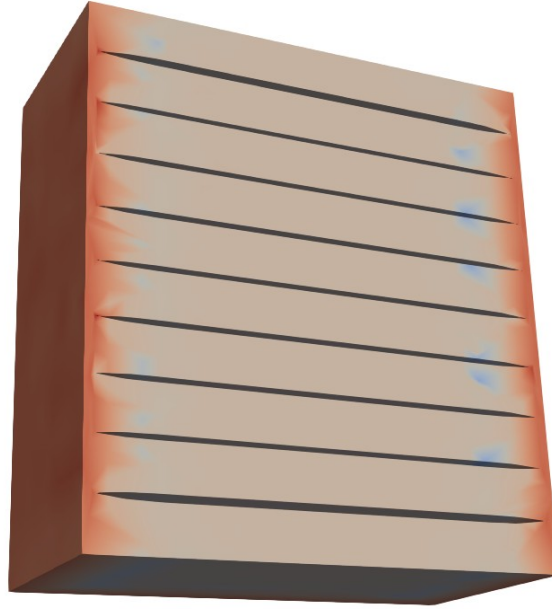
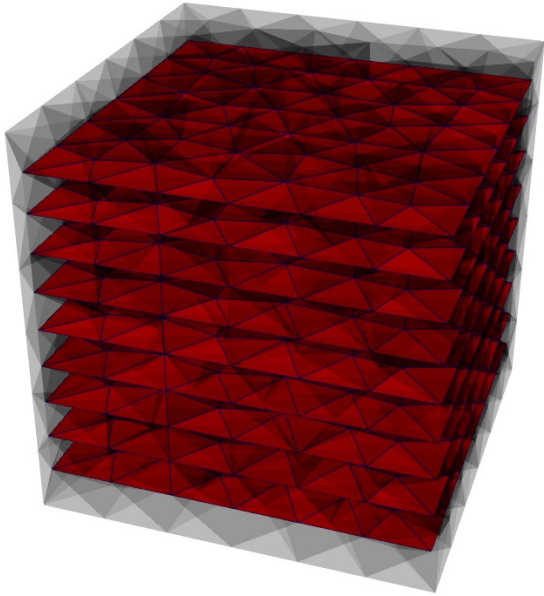
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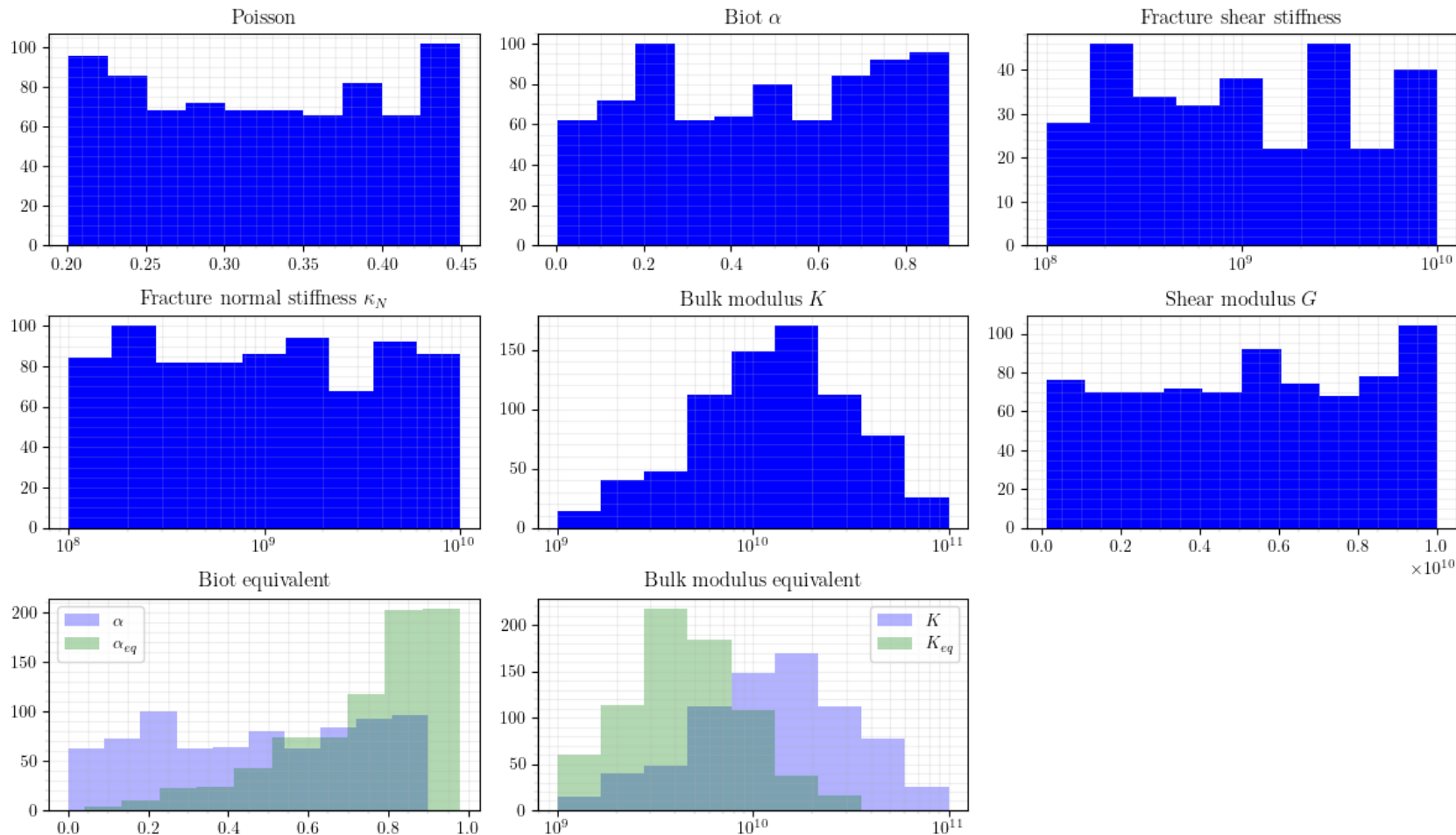
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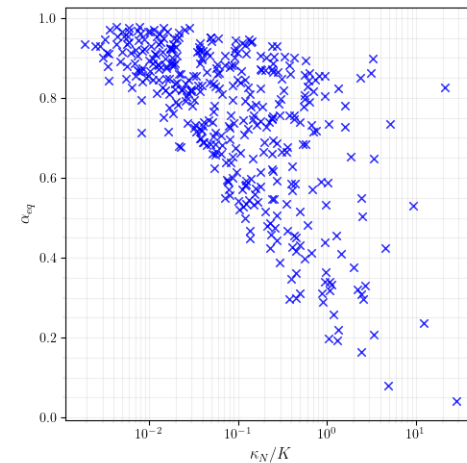
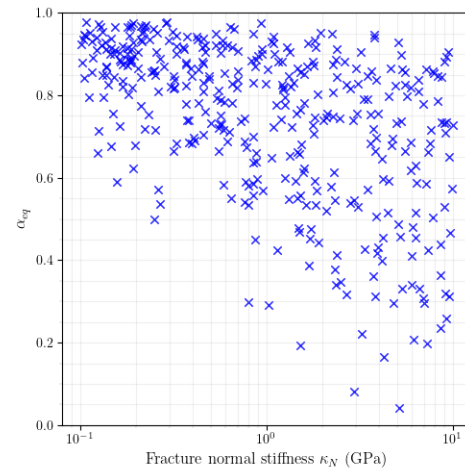
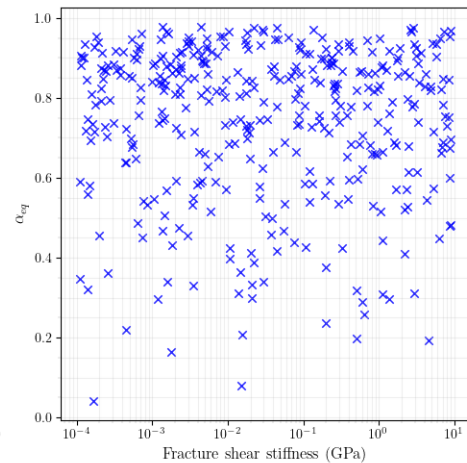
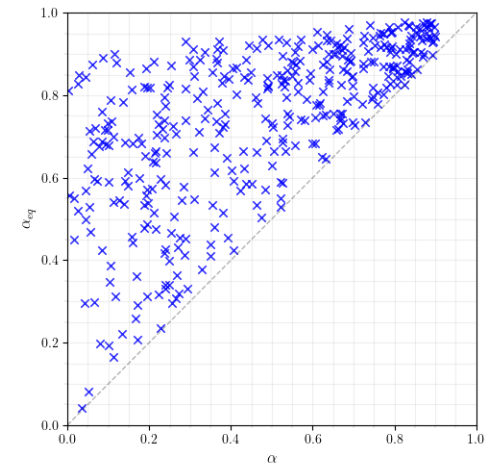
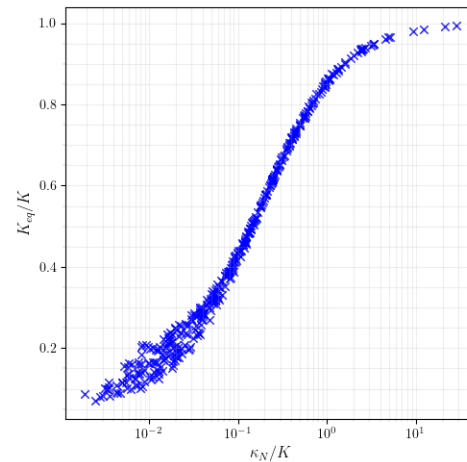
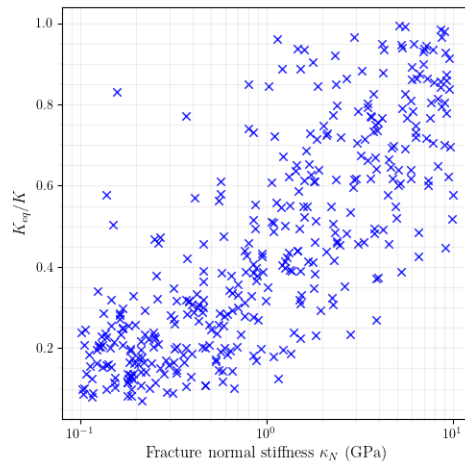
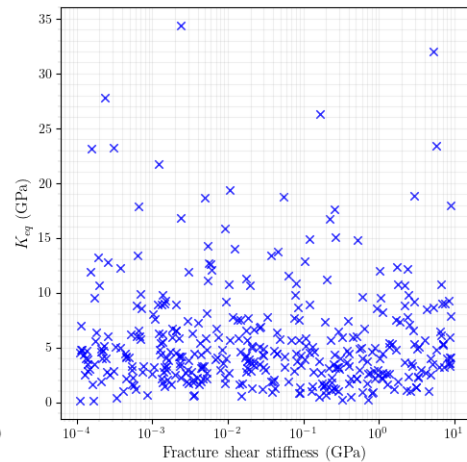
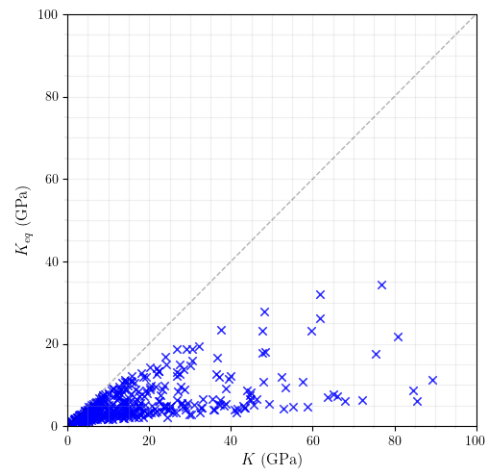
## Testcase 42 – Horizontal fractures



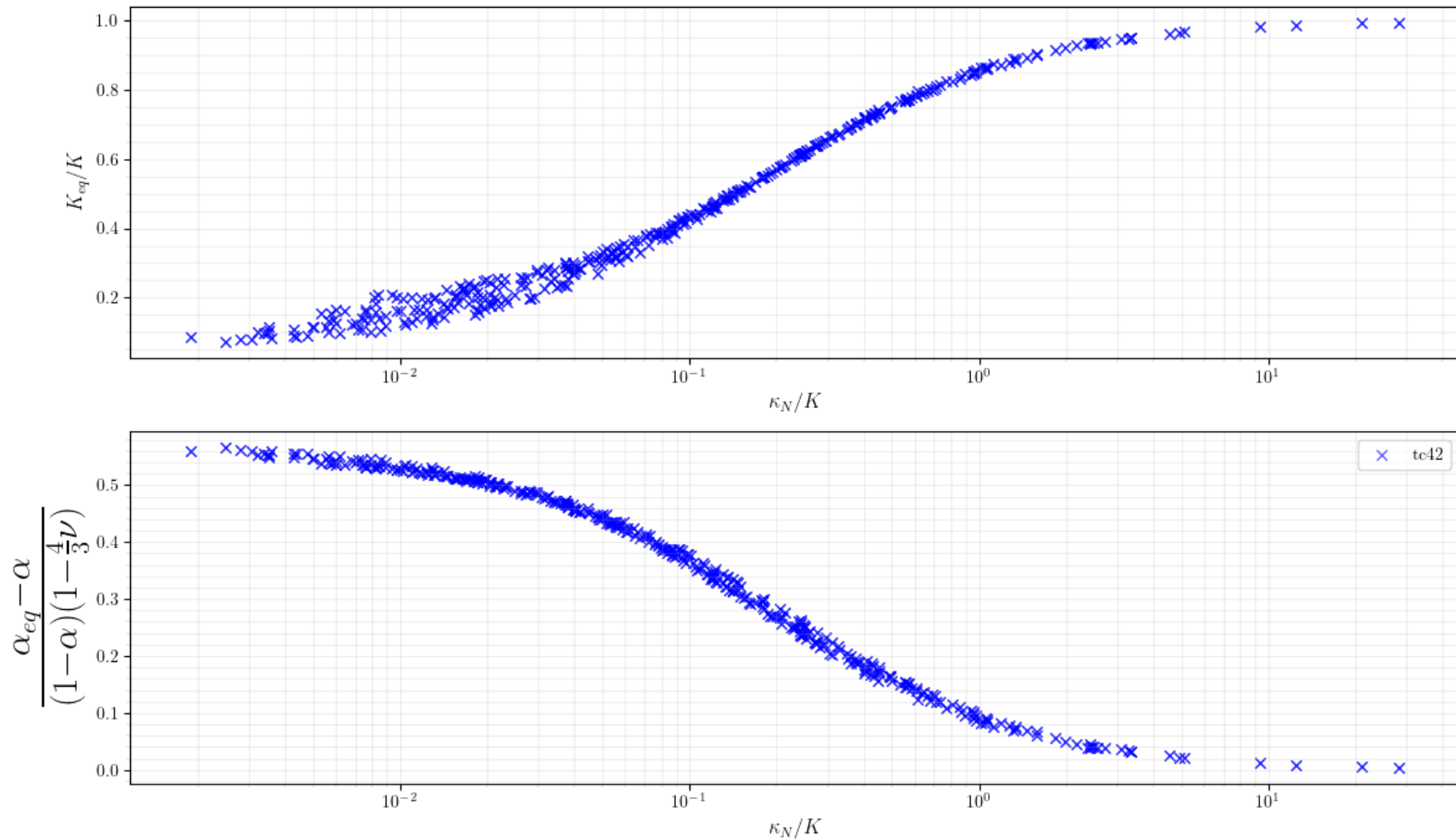
# Fractured rock rock - Bulk modulus ( $K$ ) and Biot coefficient ( $\alpha$ )



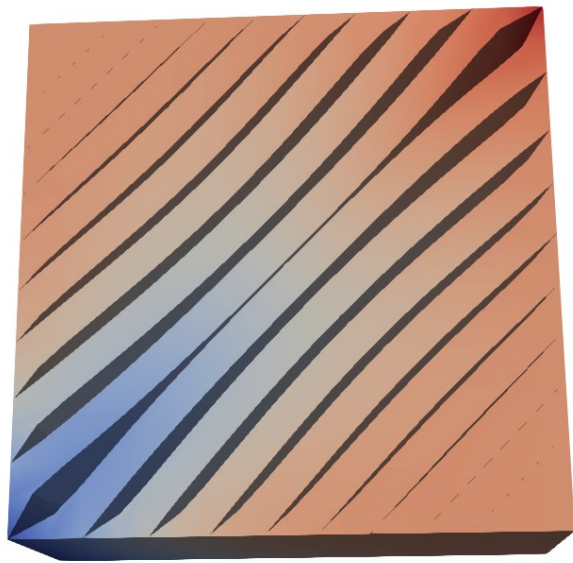
# Fractured rock rock - Bulk modulus ( $K$ ) and Biot coefficient ( $\alpha$ )



# Fractured rock rock - Bulk modulus ( $K$ ) and Biot coefficient ( $\alpha$ )

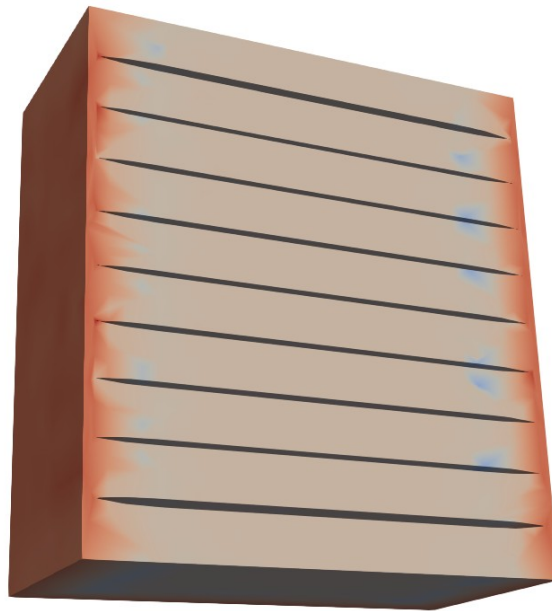


TC40



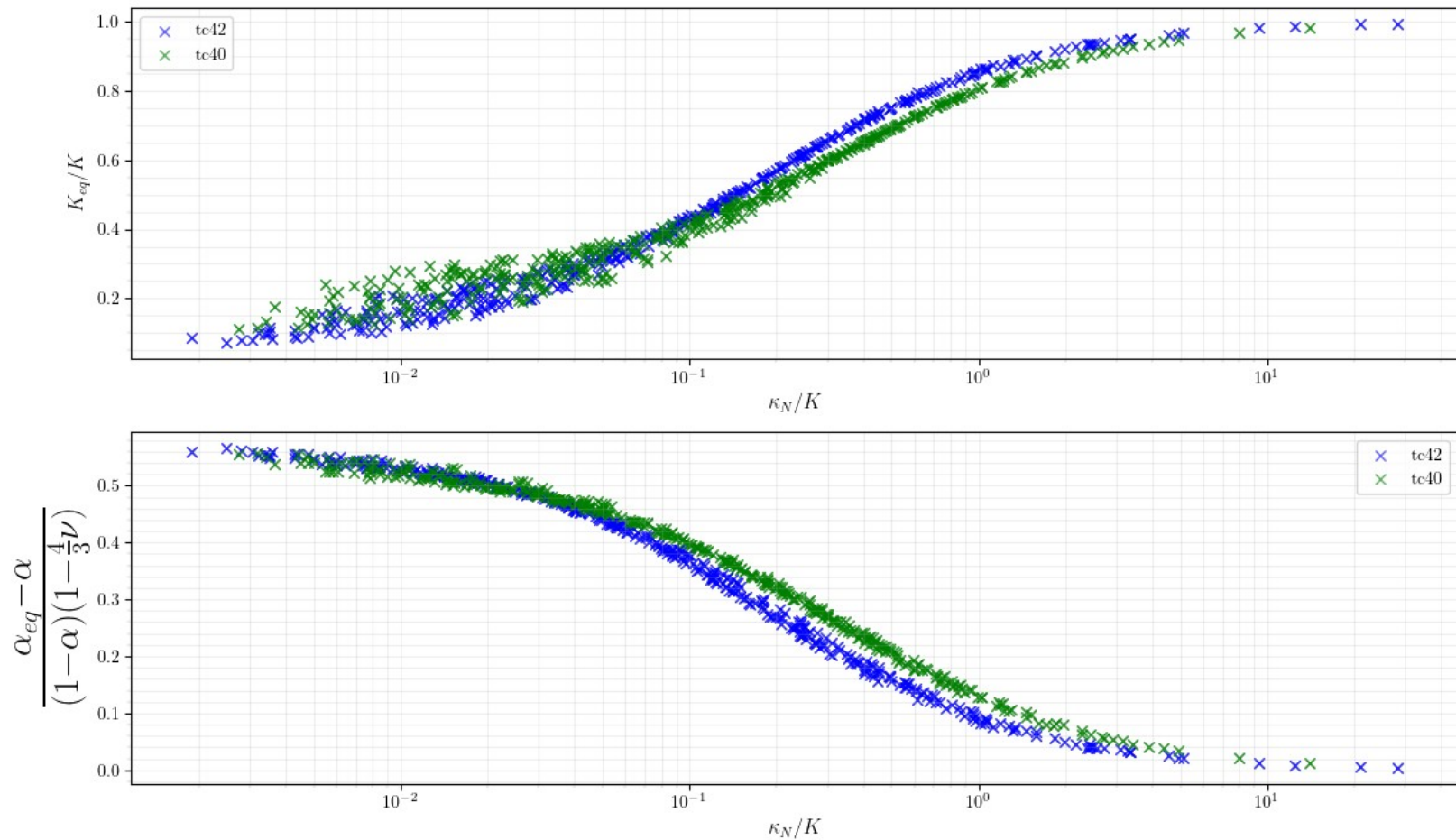
VS.

TC42





# TC40 vs TC42 - Bulk modulus ( $K$ ) and Biot coefficient ( $\alpha$ )





Bulk modulus ( $K$ ) and Biot coefficient ( $\alpha$ ) were investigated

Fractures have high impact on their macroscale equivalents

Upscaling is highly uncertain and depends on many parameters ... BUT ...  
... it is not random! ...

*Code => <https://github.com/rebpoli/chimas4d>*

Extensive validation

Fracture density

Temperature

Broader range of parameters

...