Friedrich-Alexander-Universität
Naturwissenschaftliche Fakultät

EGU22-11868

Using fractured outcrops to calculate permeability tensors. Implications for geothermal fluid flow and the influence of seismic scale faults

This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

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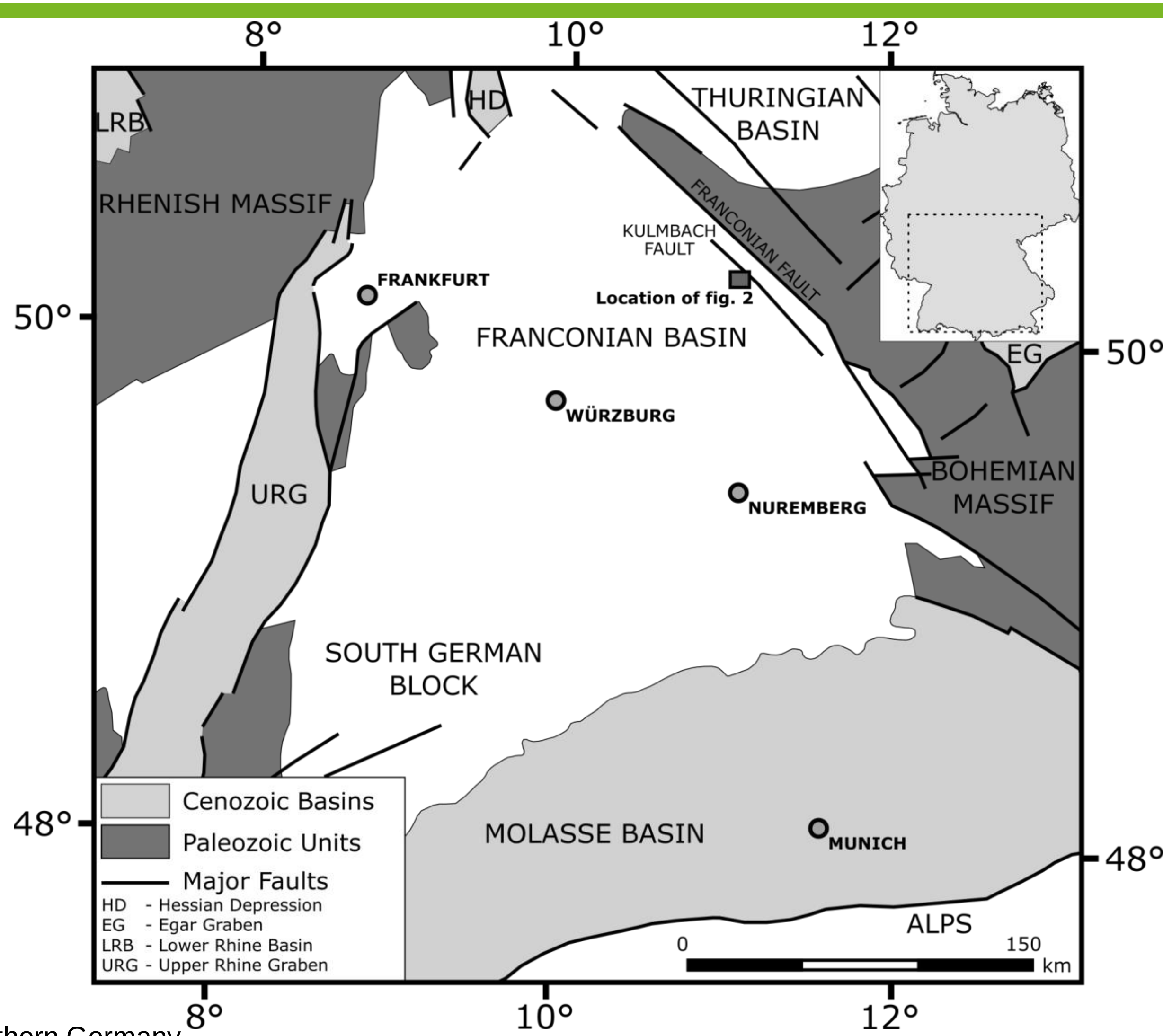
Geothermie-Allianz Bayern

Geological Setting of the Franconian Basin

Structural Overview and Geothermal Potential

- Focus on the Franconian Basin
- Late Palaeozoic to Mesozoic basin (up to 3500m)
- Bounded to east by the Franconian Fault System
- Elevated geothermal gradient within the Malm (~38°C/km)
- Limited work on potential geothermal reservoir in the Franconian Basin and the contribution of fracture networks

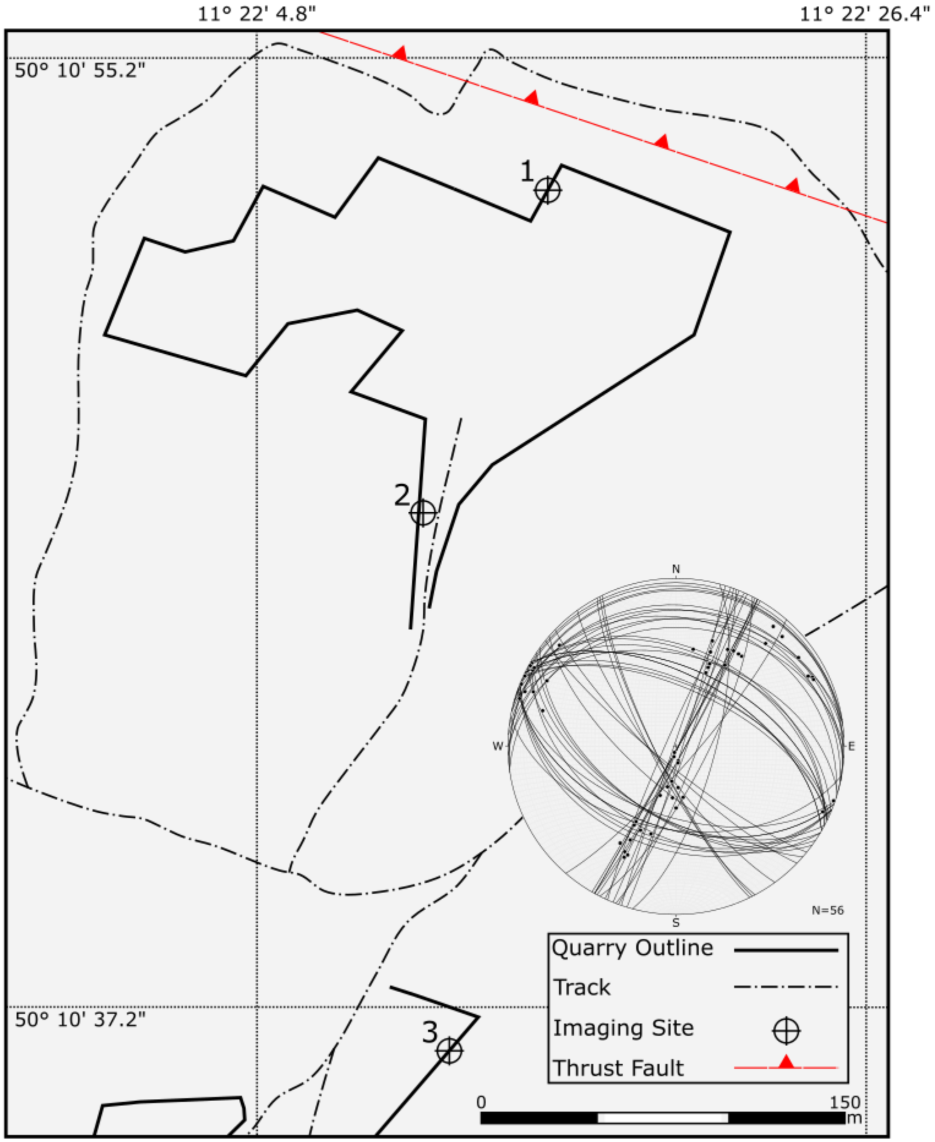


Structural map of Southern Germany

Structural Analysis

Kirchleus Quarry

- Field data acquired from Kirchleus Quarry (NE Franconian Basin)
- ~30m from Kulmbach Fault (Franconian Fault System)
- Reverse fault (800m throw)
- 3 cliff sections at increasing distance from fault imaged and analysed.
- Linked to two main regional phases (Late Cretaceous Inversion & Alpine Orogeny)



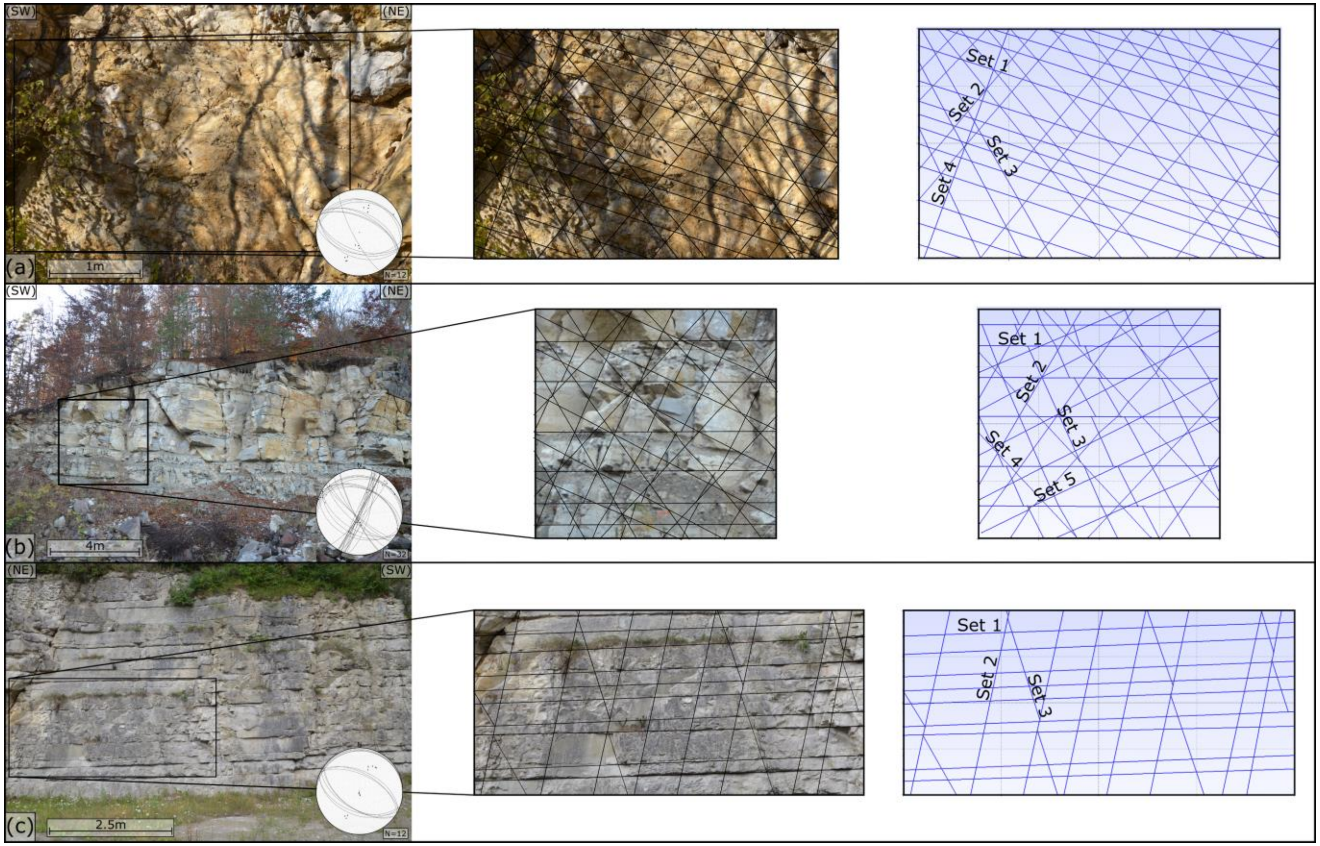
Location map of Kirchleus Quarry and three cliff faces analysed

Structural Analysis

2D Fractured Cliff Faces

- Three cliff sections imaged and fracture networks traced
- Sections approximately 5mx5m
- Connectivity and fracture density of the 2D networks calculated
- Five fracture sets defined by orientation

Fractured faces and digitised fracture networks

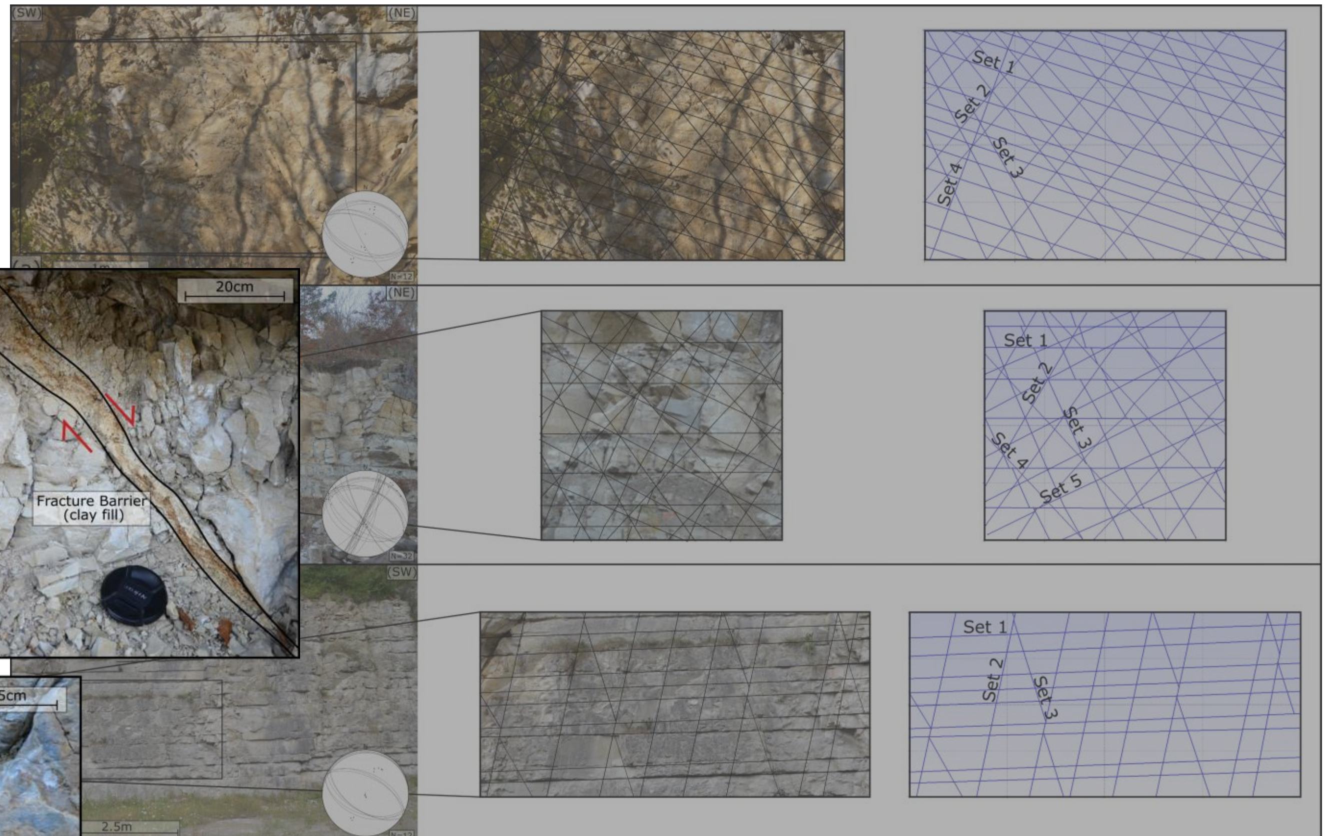


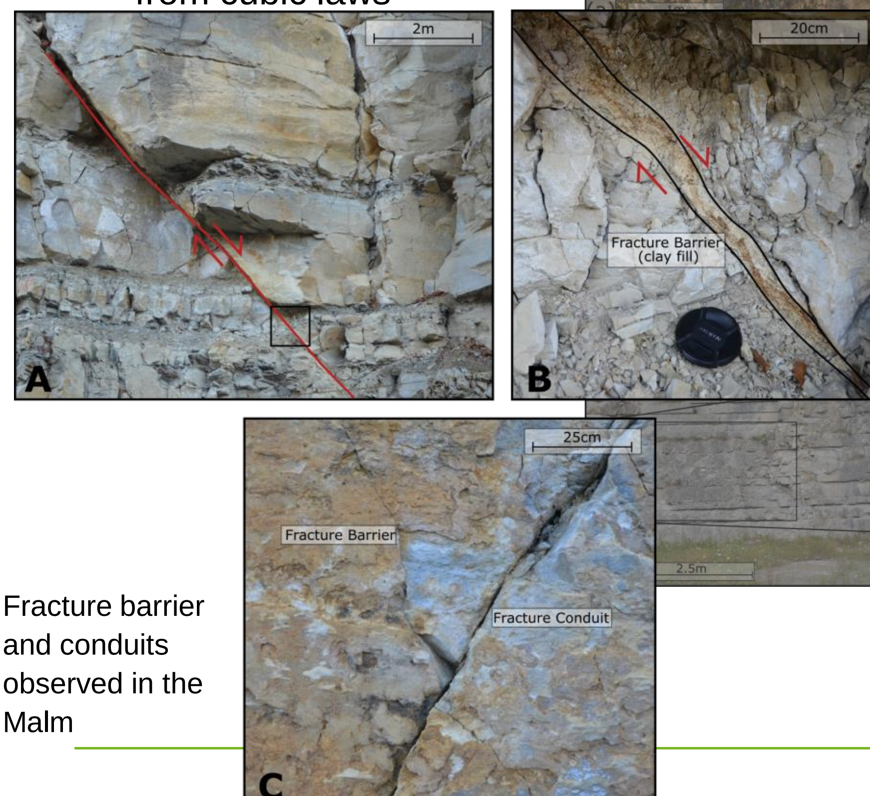
Structural Analysis

2D Fractured Cliff Faces

- Fractures defined as conduits or barriers
- Aperture for each set estimated within the field
- Permeability approximated from cubic laws

Fractured faces and digitised fracture networks





Fracture barrier and conduits observed in the Malm

Fractured Numerical Modelling

Outcrop to 2D Mesh

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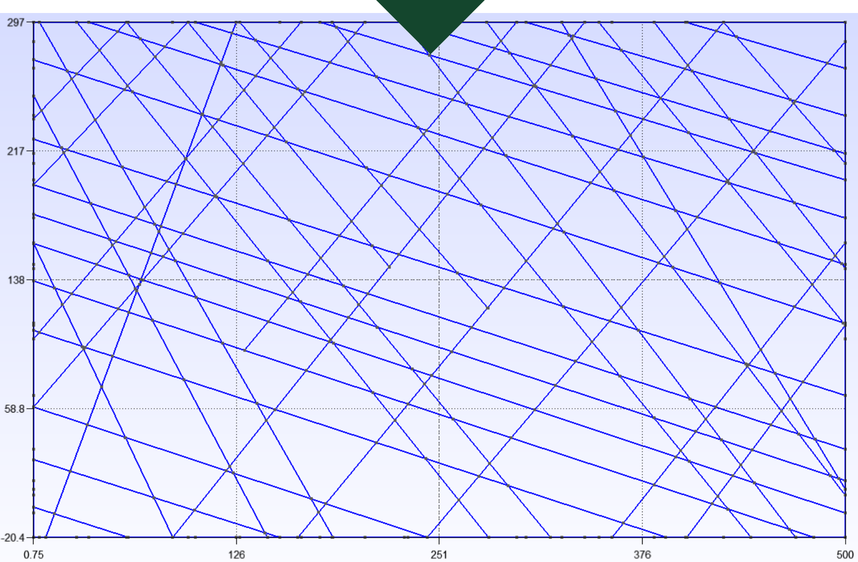
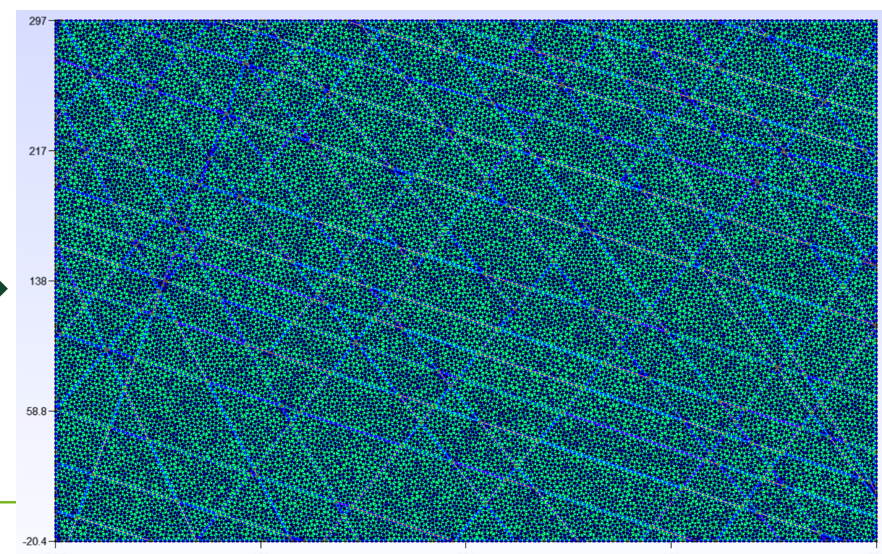
- Fractures are treated as infinitely thin geometric features (lower dimensional elements)
  - More efficient for simulation than continuum based simulation
  - Thickness properties implemented numerically during simulations.

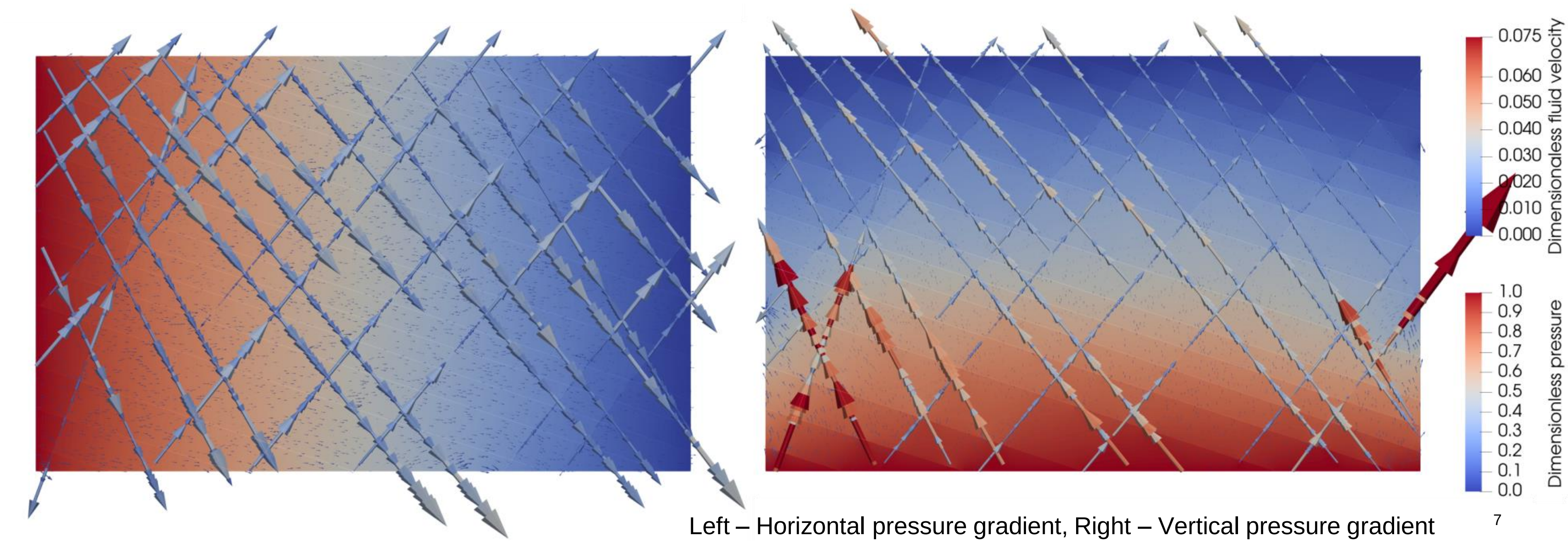




Fractured Numerical Modelling

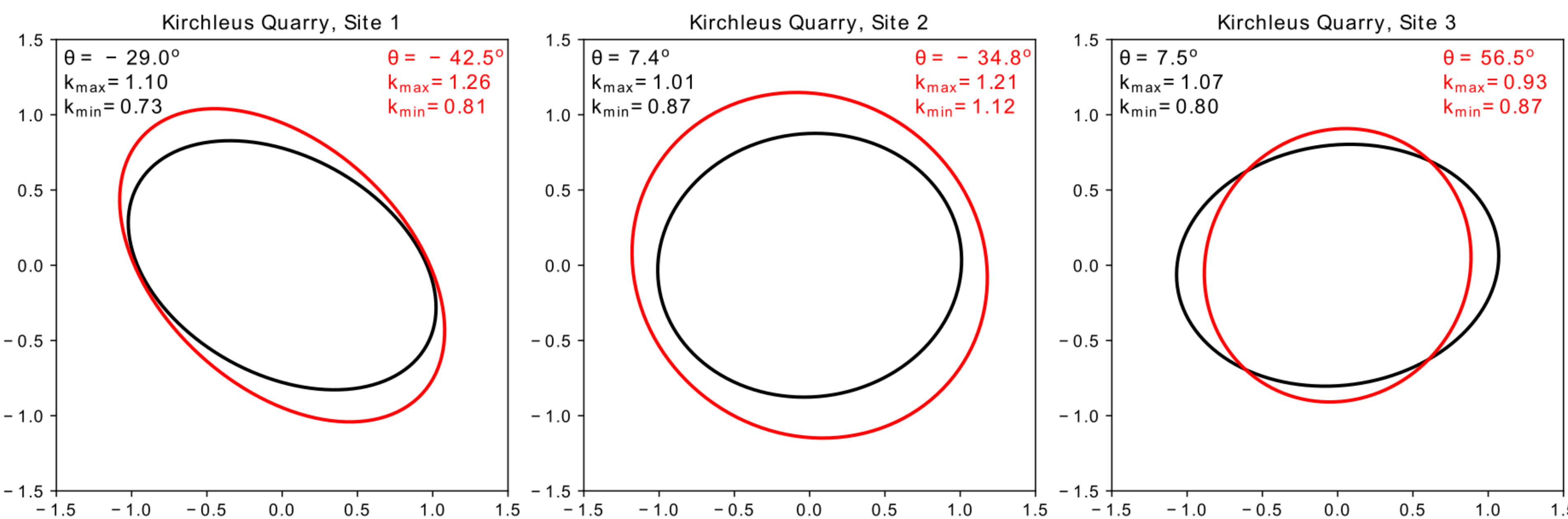
DFN Simulation and Processing

- Finite element simulator REDBACK (based on MOOSE) is used to simulate flow horizontally and vertically
- For each site, two simulations are run
  - Fully homogeneous – all fractures are equal K (transveral = 0,01D; longitudinal = 100D)
  - Non homogeneous – longitundial permeability controlled by orientation
- The fluid velocities obtained from the fluid flow simulations are used to calculate the permeabity tensors for the fracture network



Left – Horizontal pressure gradient, Right – Vertical pressure gradient

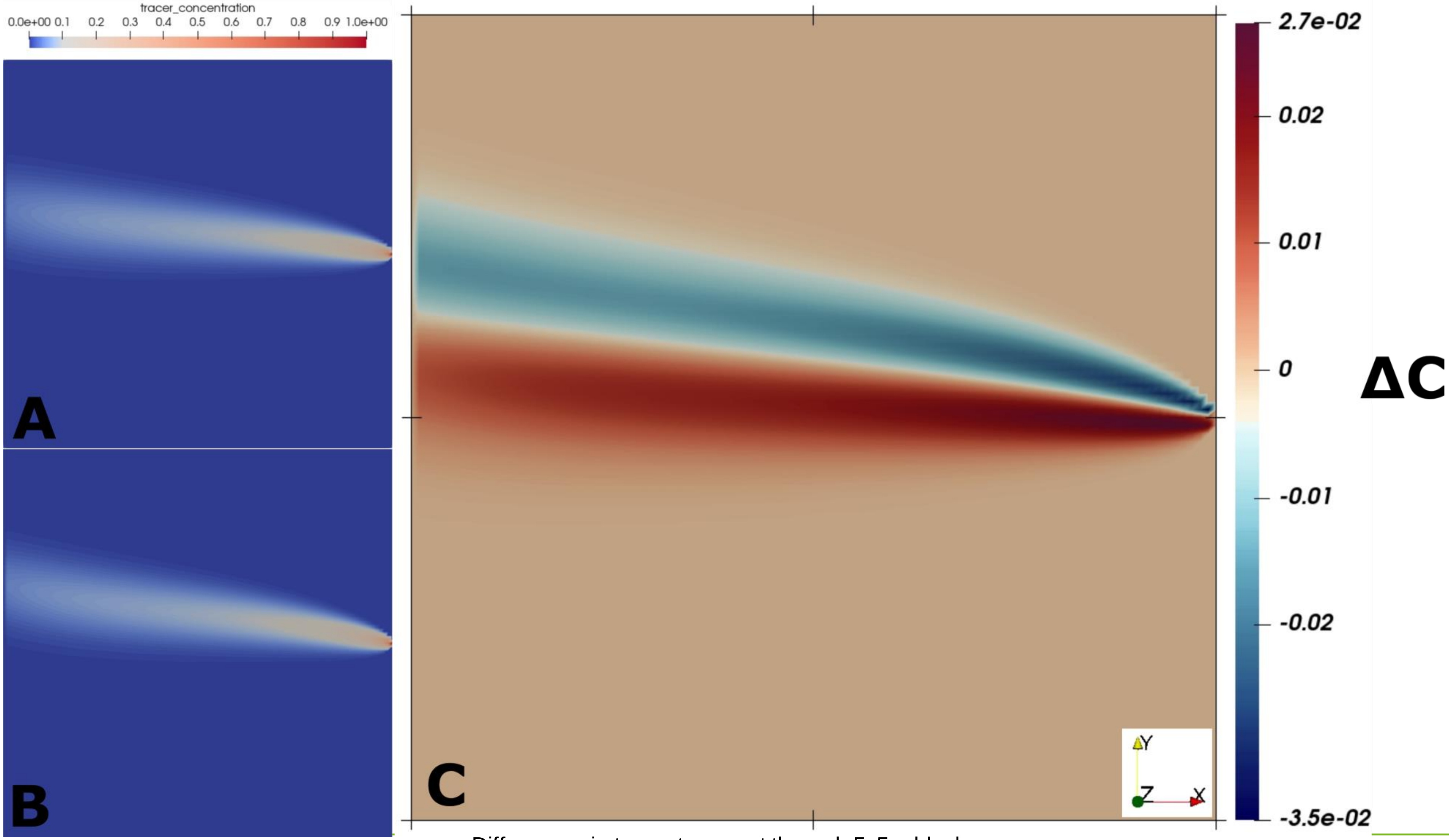
- Permeability ellipses are used to visualise the calculated tensors
  - Plotted using the eigenvalues of the tensor for the radii and eigenvector orientations for rotation
  - Kmax highest in site 1
  - Kmax higher for non homogeneous case (red)
  - Site 1 orientation parallel to Kulmbach fault dip.



Permeability tensors for the cliff faces - black (homogeneous); red (non-homogeneous)

Discussion

Effect of Variable Fracture Permeability on Fluid Transport

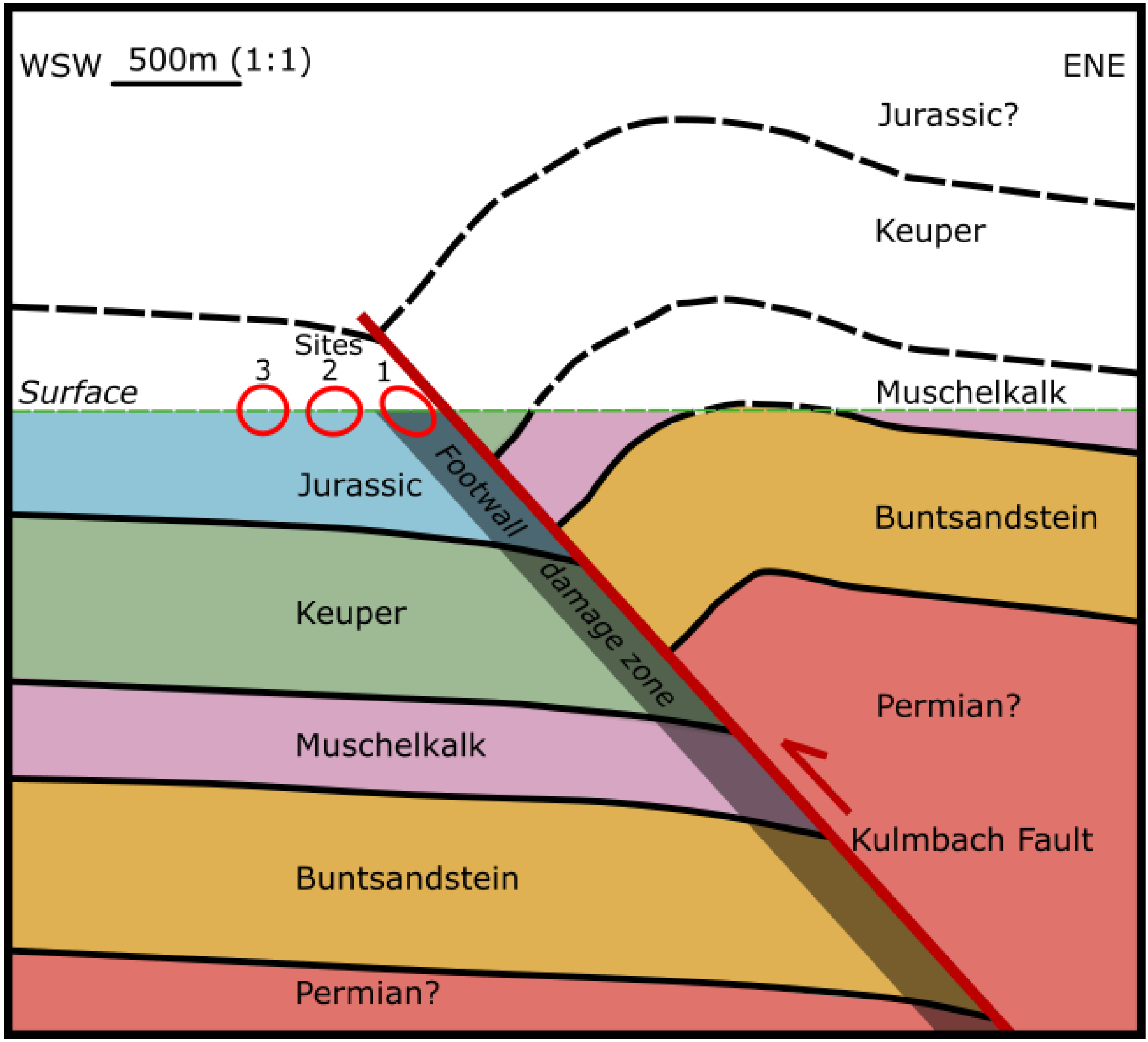


Differences in tracer transport through 5x5m block.

Discussion

Influence of the Kulmbach Fault

- Kulmbach fault nearby influences the magnitude and orientation of the permeability tensor
- Tensor magnitude reduces further away from the fault
- Likely a defined damage zone



Schematic cross section through the Kulmbach Fault at Kirchleus Quarry showing the changes in fracture network permeabilities

Conclusions

- Process presents an efficient way of upscaling fluid transport through fractured media from outcrop data
- Accurately defining the fracture permeabilities vital to reducing uncertainties in the simulation especially when upscaling to larger areas/volumes
- 2D permeability tensors and ellipses show the influence of the seismic scale Kulmbach fault on the fracture flow
- These faults are likely to impact the transport through the networks within defined damage zones

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