Tectonic fracture analysis and exploration of metallic deposits

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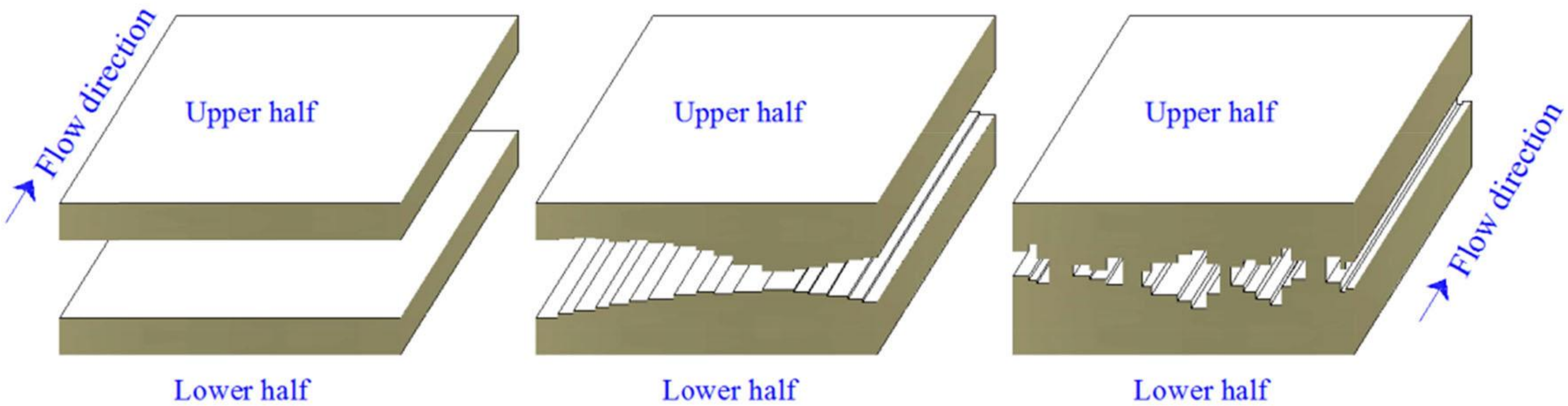
Fractures are common in all kinds of geological environments

Fractures
-accommodate large strains in the upper crust
-weaken the rocks
-**assist fluid, mass and heat transfer**
-**exert strong control on mineralization**

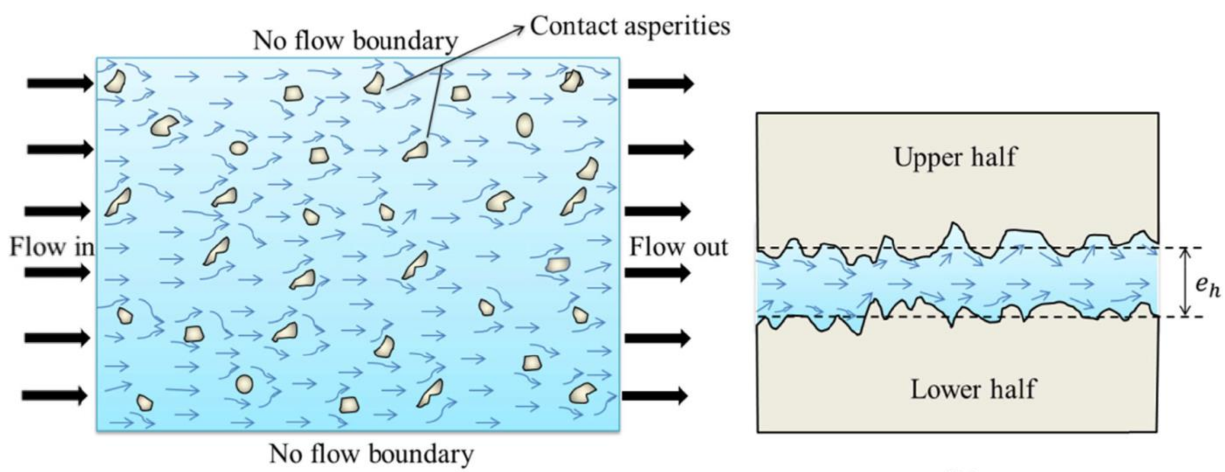
Fractures exert strong control on mineralization

Cashin Mine, SW Colorado, USA.
Photo from Ali Jaffri (Applied Stratigraphix)

Fluid flow modelling in joints/fractures



Parallel plates model **"Local" parallel plates model** **"Local" parallel plates + contact zones**



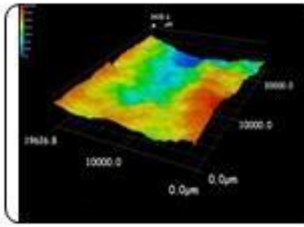
Top view **Side view**

After Zhang et al. (2015)

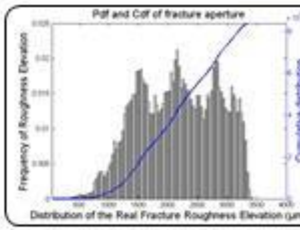
Road map

- Acquisition of joint roughness data
- Characterization of joints with plumose patterns
- 3D fracture flow modeling and characterization in joints
- 3D heat transport modeling and characterization in joints

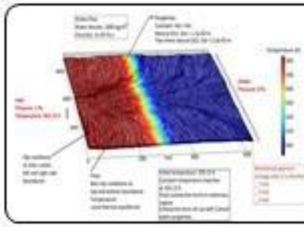
Fractures



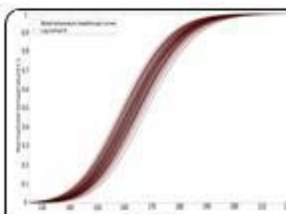
Fracture surface measurements



Fracture surface characterization

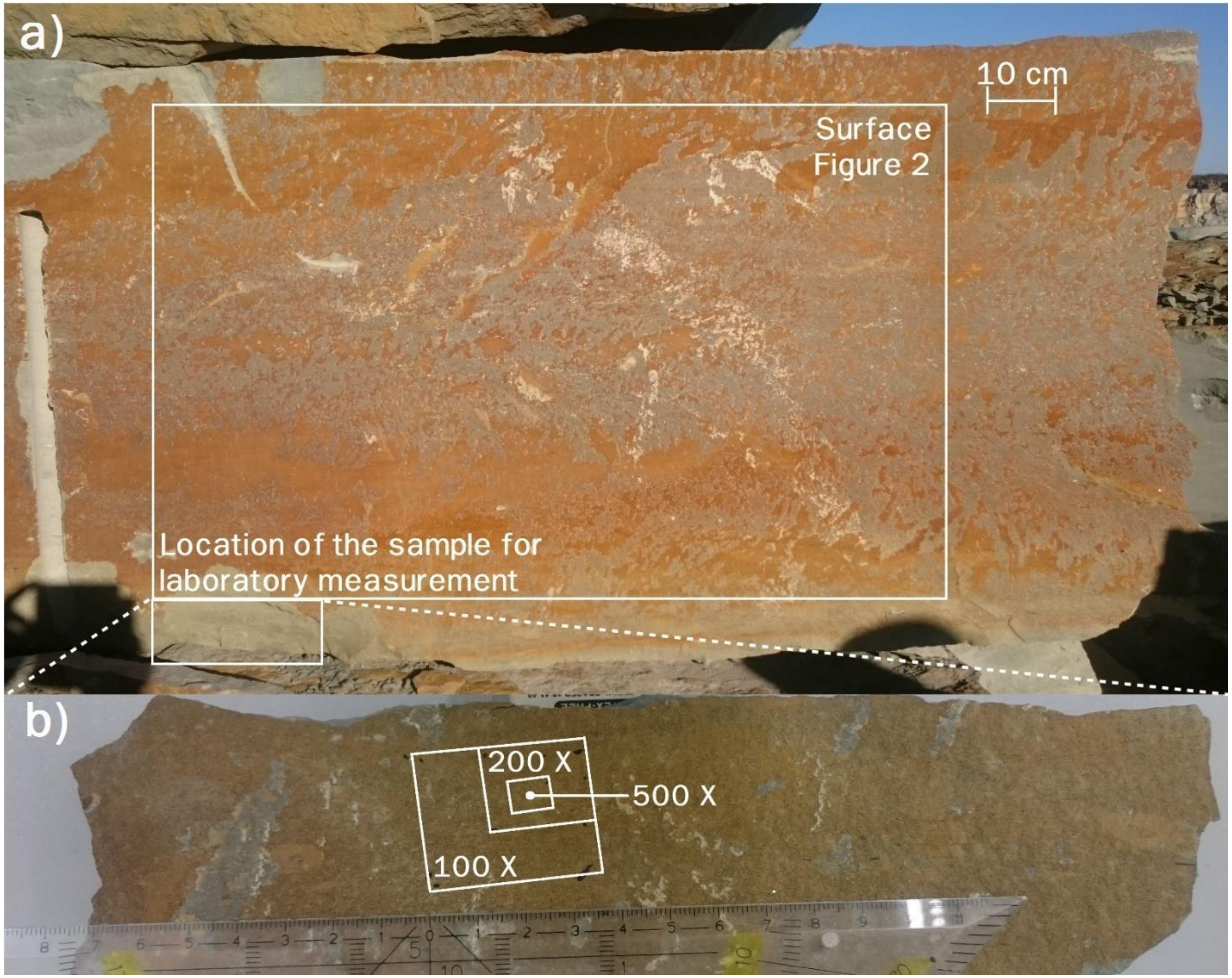


Fracture flow and heat transport modeling



Fracture flow and heat transport characterization

Acquisition of joint roughness data



- Joint in Turonian glauconitic sandstones (mean grain size 0.1 mm)
- S-type plumose
- Klieve quary, southern Münsterland

Acquisition of joint roughness data

- Terrestrial LiDAR *FARO® Laser Scanner Focus*^{3D} *X 330.*

- Four LiDAR scans at 2 to 3 m distance of the joint surface.

- Two scans at the same LiDAR position, very low resolution and quality scan (preview) to define the scan area of the high resolution and quality scans (full space scans would result in too large files, i.e. 710 Mpts, tens GB).

- The two high resolution and quality scans limited to the joint and close surroundings:

    Resolution 1/1 (40960 pt/360°)

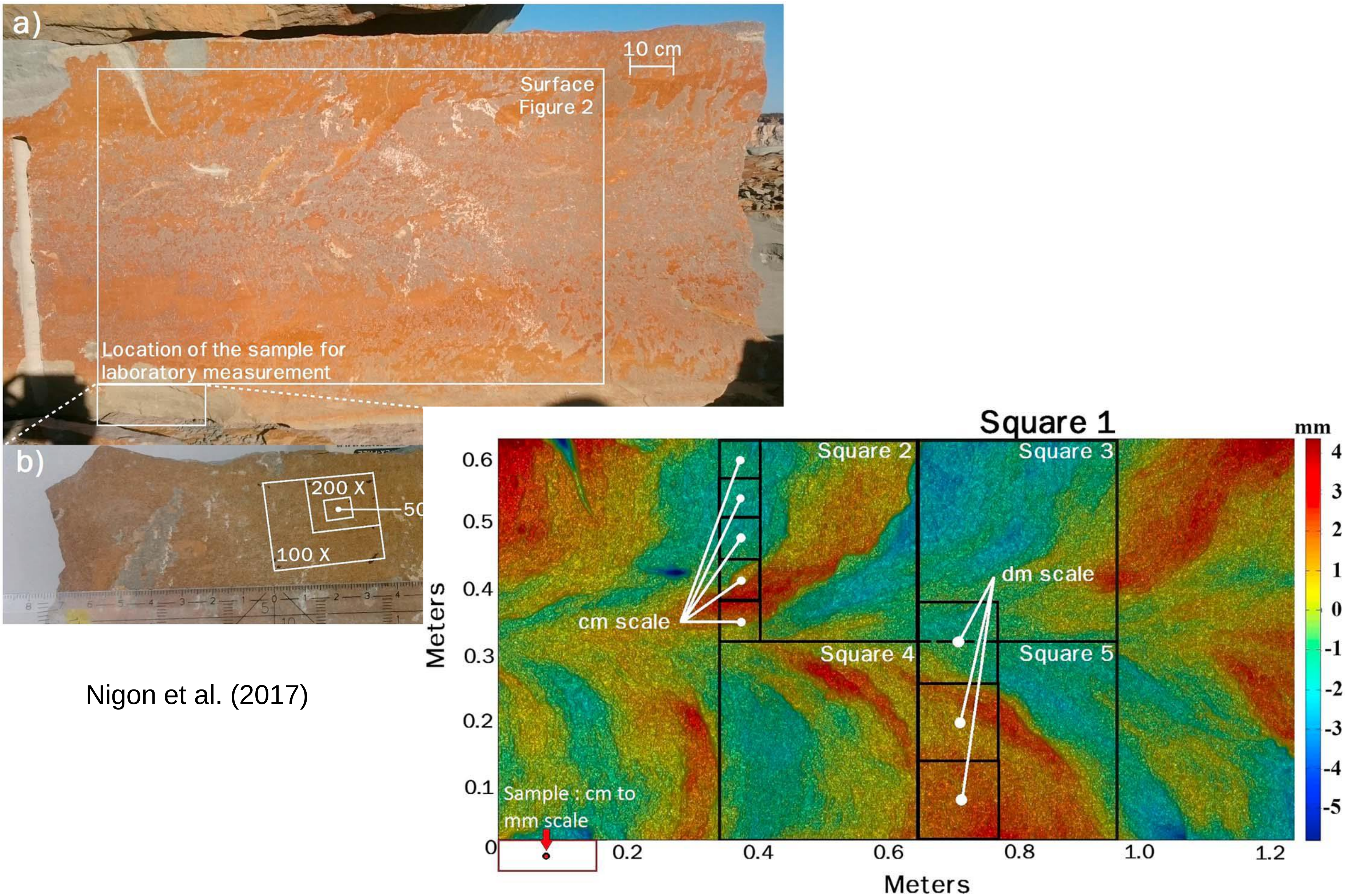
    Quality 3x (244 kpt/s)

    File sizes 800 MB (42.5 Mpts) and 1 GB (65 Mpts)

Acquisition/processing of joint roughness data: 3D point cloud

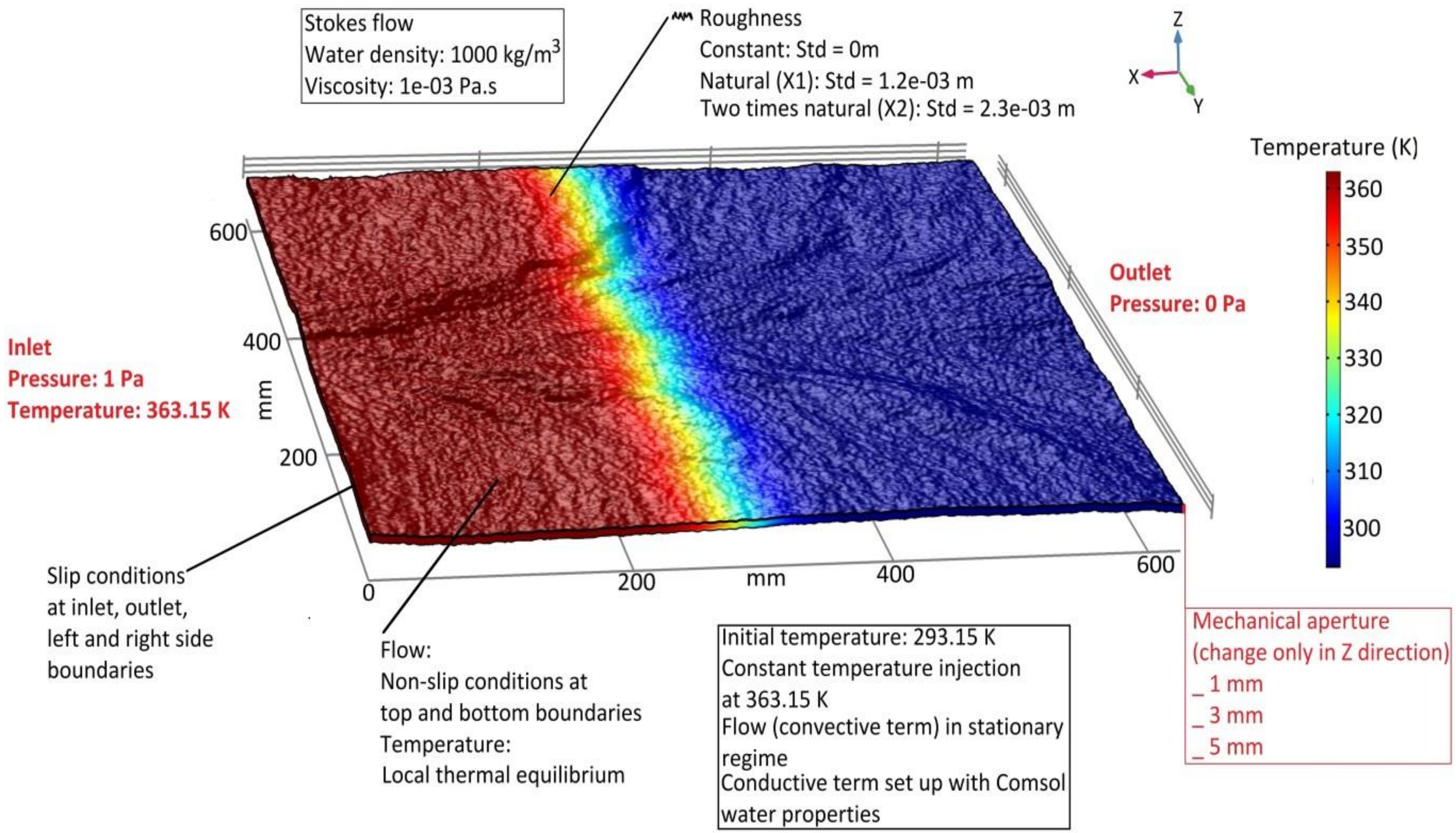
Volumetric density resulted in 1251 points/cm³ with minimum and maximum volumetric densities of 426 and 4267 points/cm³ respectively

Numerical modelling of fluid and heat transfer through a fracture with realistic geometry



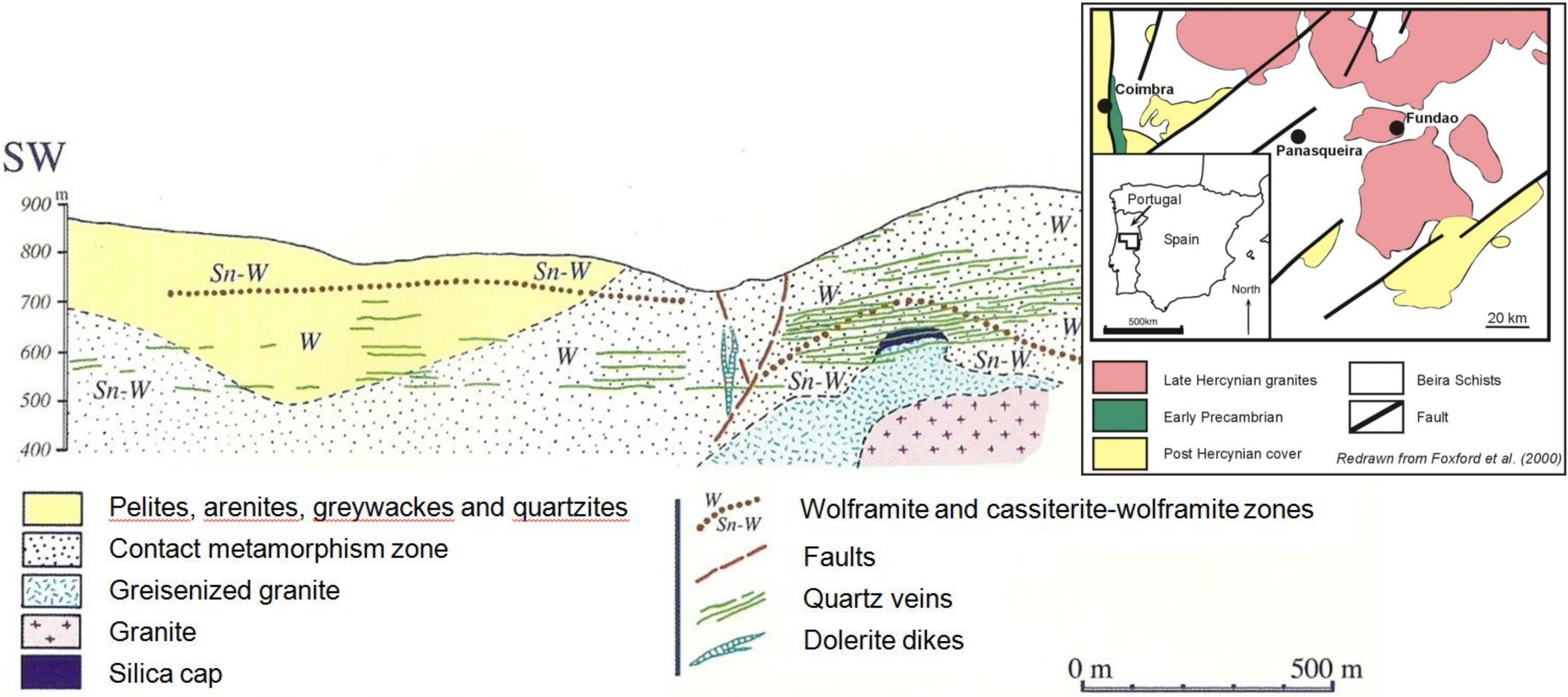
Nigon et al. (2017)

Numerical modelling of fluid and heat transfer through a fracture with realistic geometry



Nigon et al. (2019, 2024)

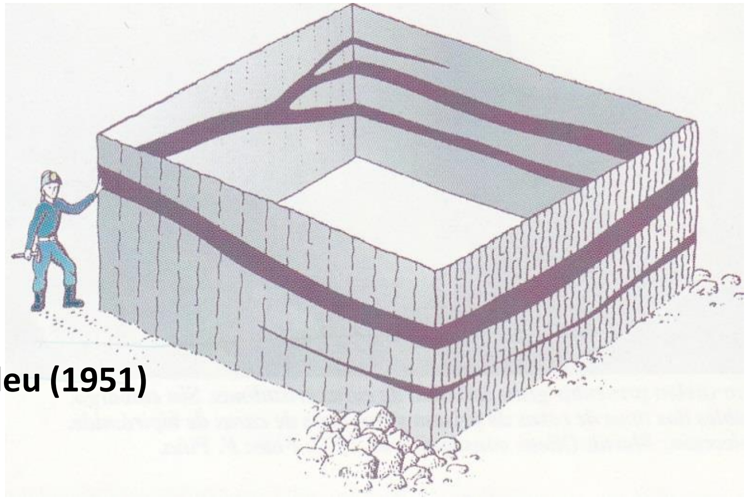
The quartz veins of Panasqueira Mine, Portugal



After Kelly and Rye (1979)

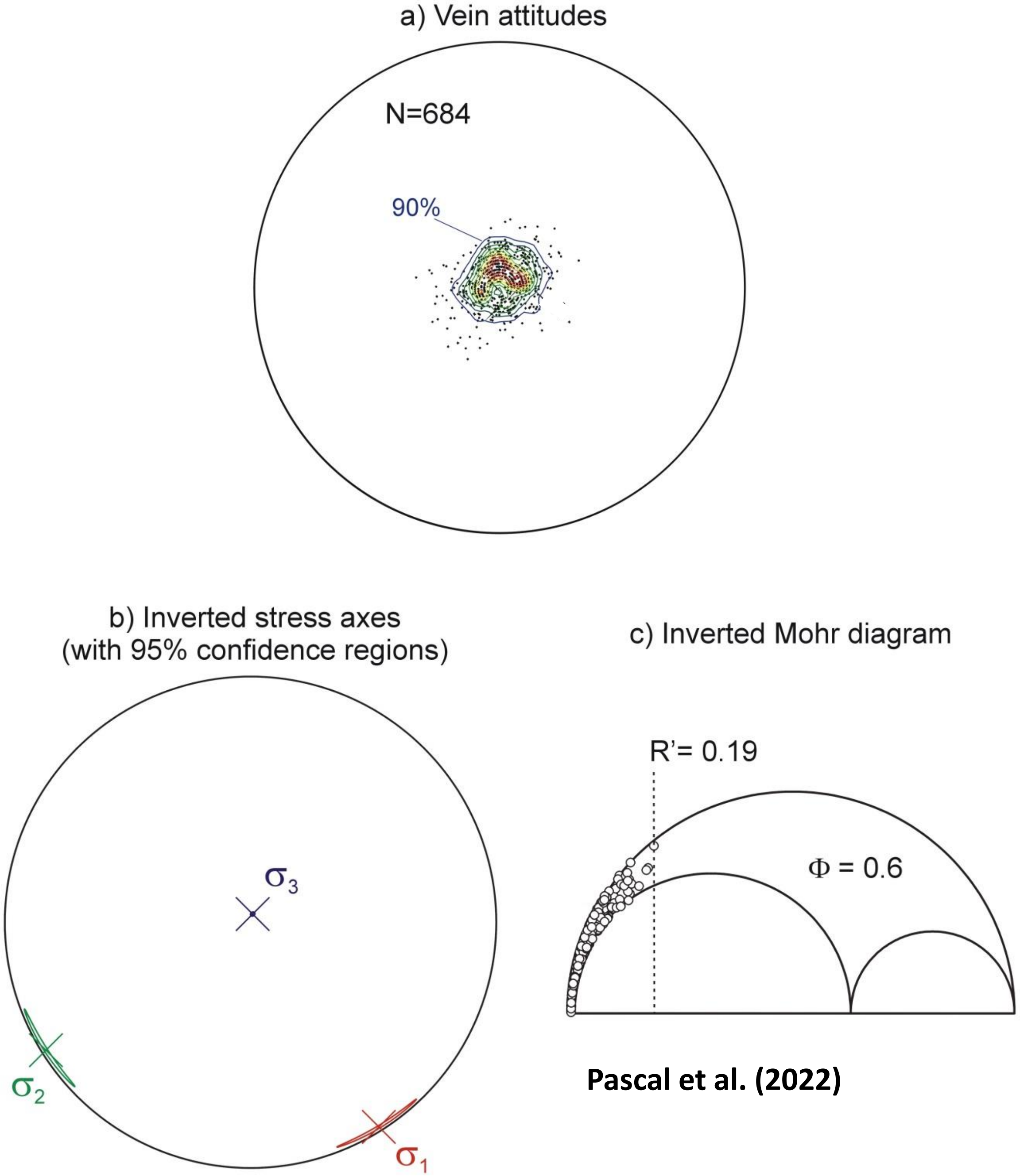
Studied geological objects

The quartz veins of Panasqueira Mine, Portugal



After Tadeu (1951)

Vein inversion



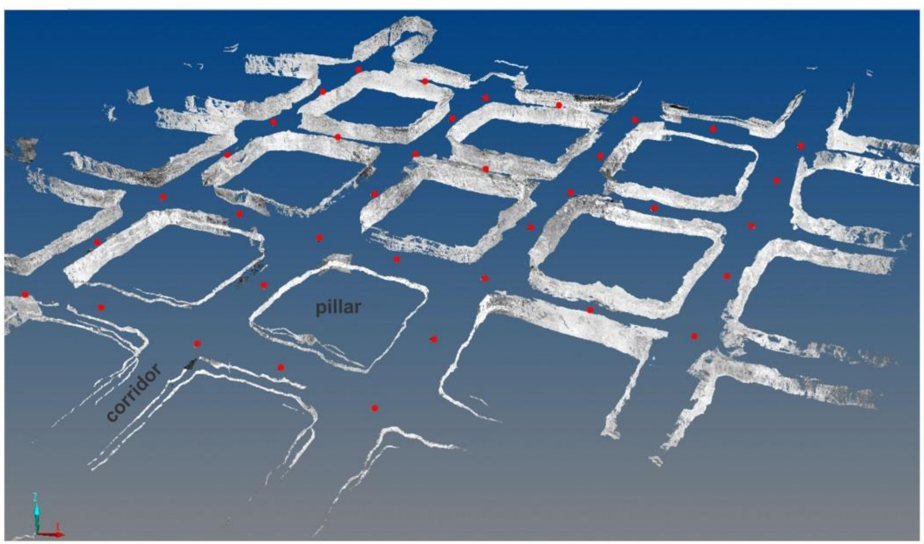
Pascal et al. (2022)

Results

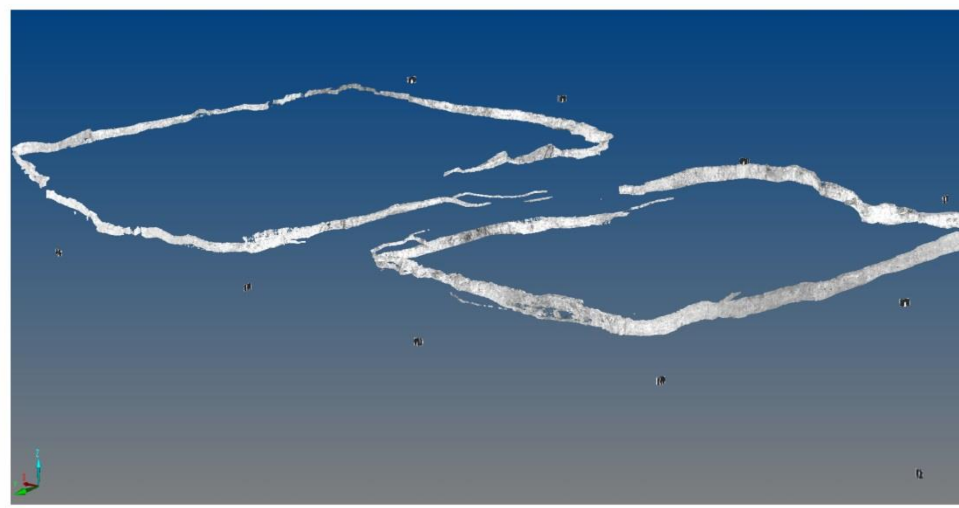
DETERMINING 3D GEOMETRIES OF NATURAL HYDROFRACTURES, PANASQUEIRA MINE, CENTRAL PORTUGAL

Example of mineralised vein (~50 cm thick)

Point cloud of one corridor, note bright mineralised veins



Point cloud of one stope, distance between each corridor is ~10 m



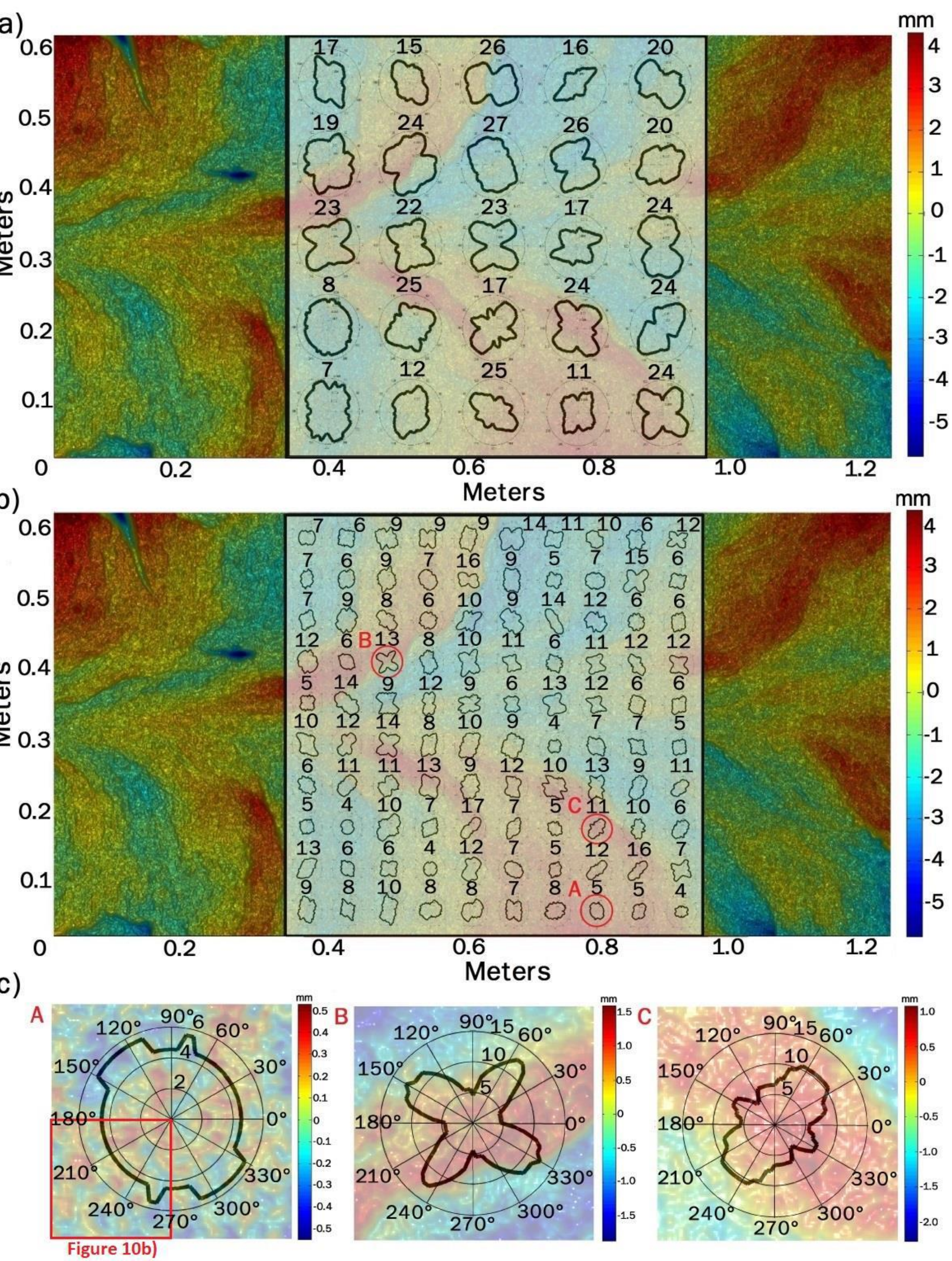
Mineralised veins on two consecutive pillars, note branching points and complex propagation path of the initial hydrofracture

Summary

Structural geology has entered a digital revolution involving technologies, which allow for fast acquisition and processing of data with unprecedented detail.

However, the outcomes of these powerful methods will always need to be controlled by traditional mapping and the human eye/brain.

Old stope of Panasqueira Mine.

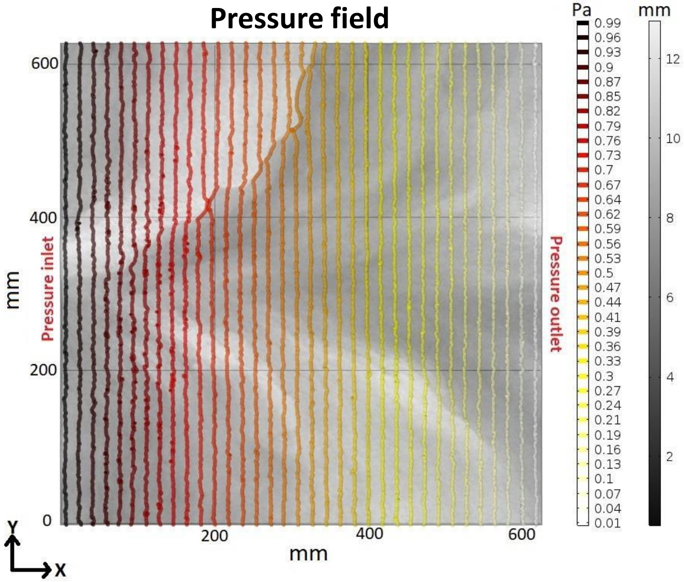


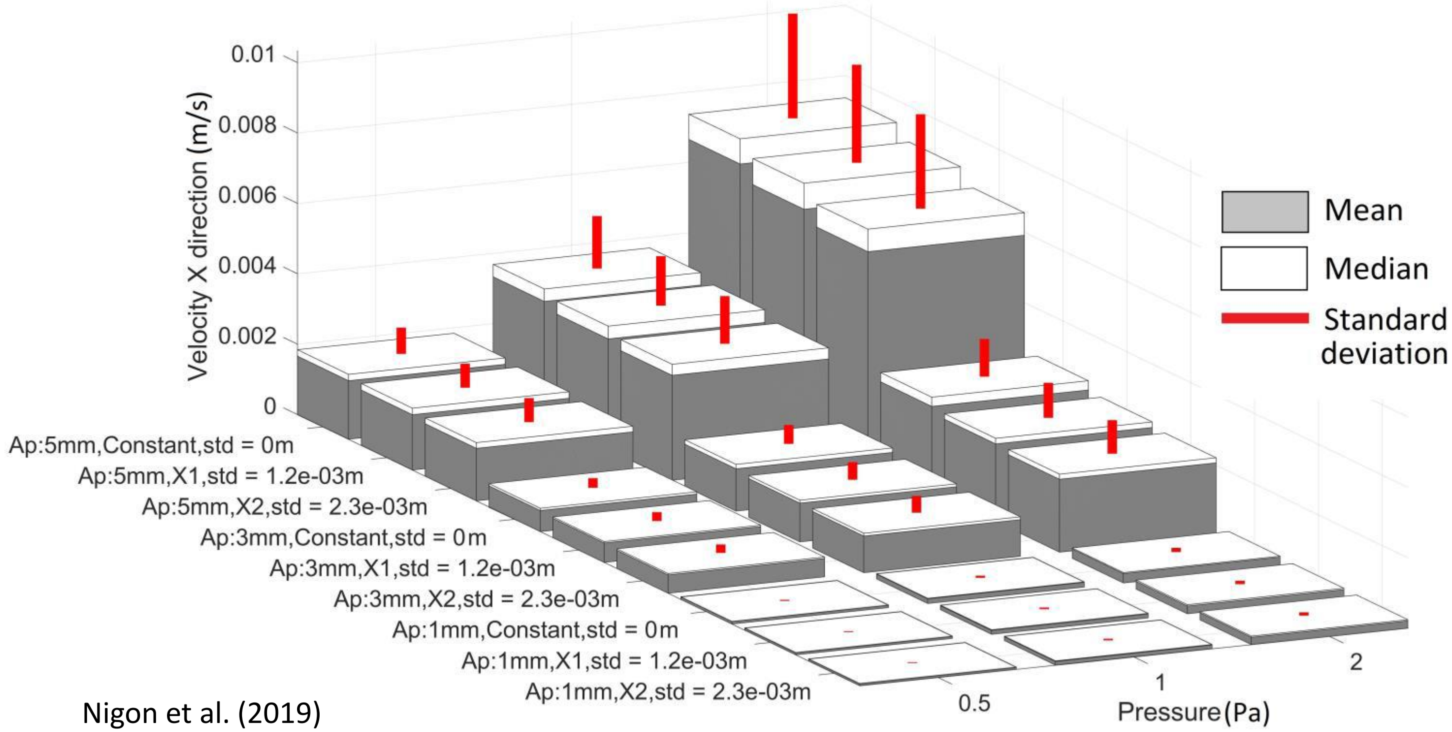
Characterization of joint roughness

Multi-directional joint surface correlation length in mm based on normalized autocovariance analyses after planar detrending: **(a)** at the 1-dm-scale, **(b)** at the 6-cm-scale and **(c)** three magnifications of typical multi-directional correlation length plots (A, B and C) at the 6-cm-scale. The joint surface topography is derived from LiDAR measurements.

Nigon et al. (2017)

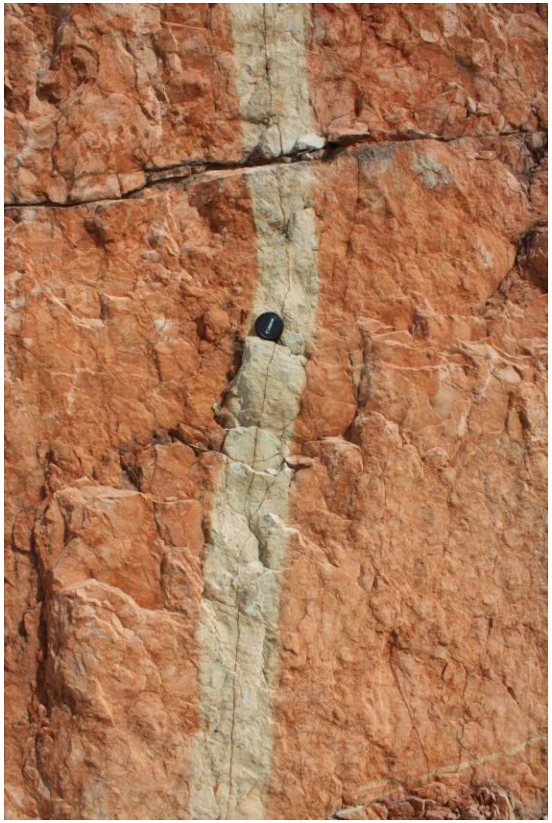
Fluid flow modelling: results



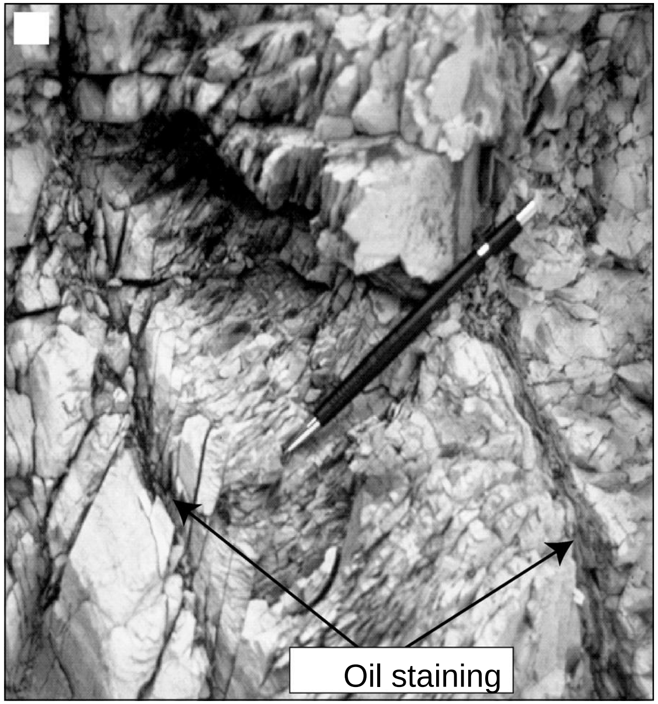


Nigon et al. (2019)

Fractures assist fluid, heat and solute transfer



Fluid-rock interaction, Amadorio, Spain



Dholakia *et al*. (1998).