

Reducing the uncertainty of discrete fracture network models by ground penetrating radar imagery: case study at the Äspö Hard Rock Laboratory, Sweden

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1. Introduction

Discrete Fracture Network (DFN) modeling is a methodology that allows us to derive flow and mechanical properties of fractured rock mass. It relies on the statistical distributions of fracture network properties: sizes, orientations, transmissivities, stiffnesses, etc.

Fracture networks are characterized by a very large range of fracture sizes that cover different orders of magnitude: microfractures to tectonic fault. Therefore, assessing scaling laws is a key issue of any DFN model.

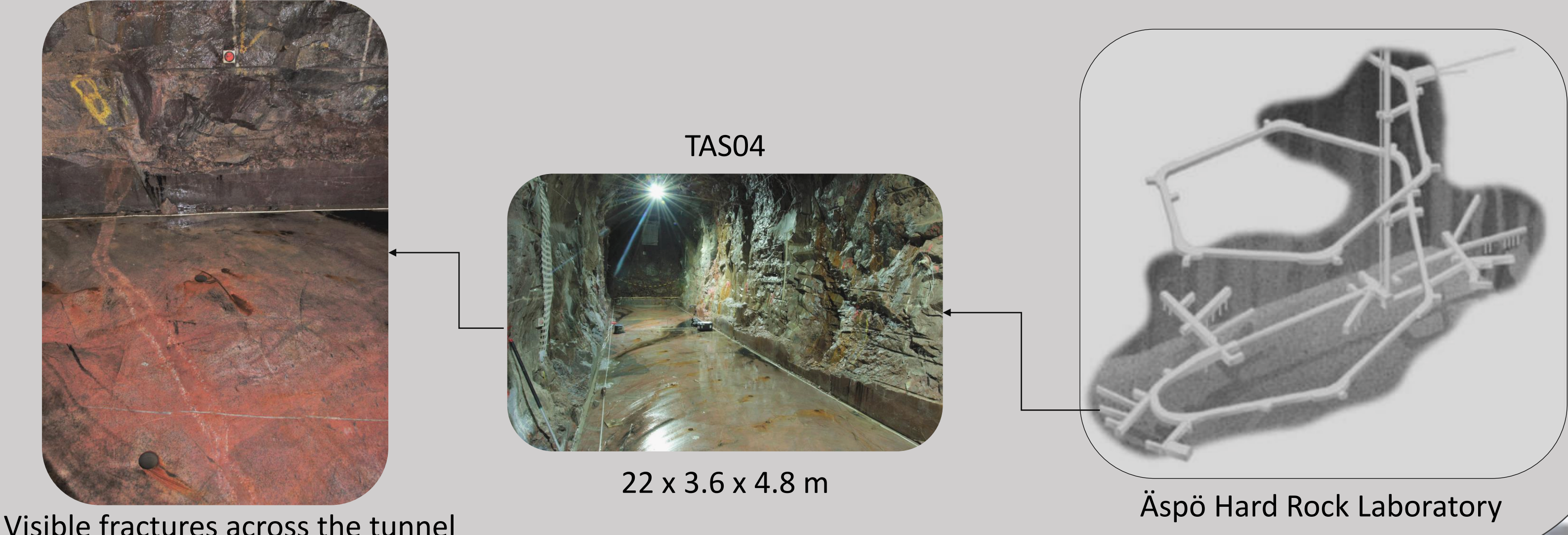
Currently, most of the constraints used for DFN modeling arises from outcrop and core mapping, and very few from 3D mapping [Darcel et al. 2009]. The present research project is focused on the conditioning of DFN models to geophysical imaging data associated with borehole and tunnel data.

We firstly investigate the possibility of using Ground Penetrating Radar (GPR) to identify fractures close to tunnel walls at depth. Secondly, the geophysical data shall be introduced into a broader DFN modelling framework associated with borehole and tunnel data. At last, hydraulic data will be introduced to build a hydrogeological DFN model. The objective is to develop a new approach for better assessing the safety of the bedrock barrier around canisters for nuclear waste disposal.

2. Experimental site

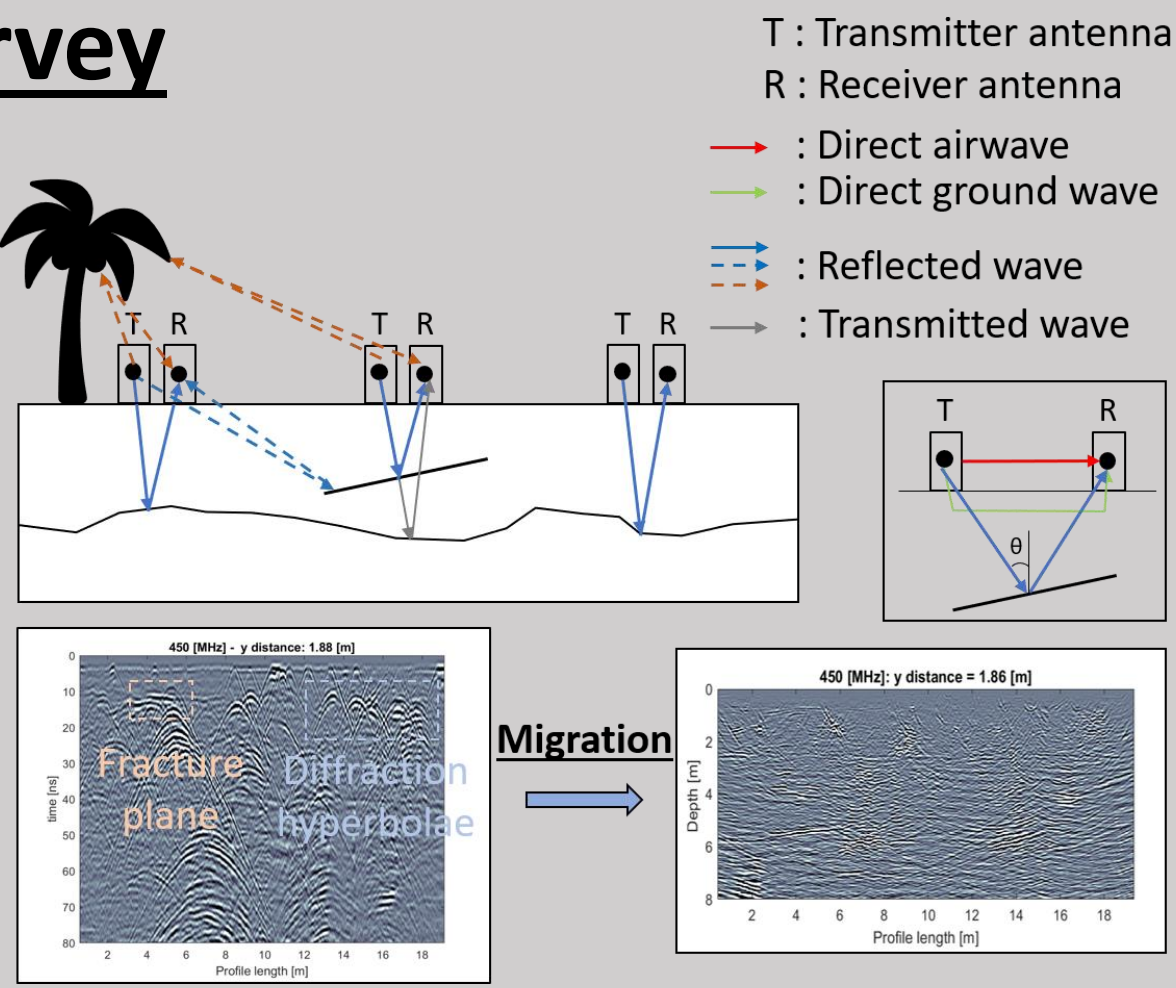
The Äspö Hard Rock Laboratory (AHRL) is an underground laboratory of almost 500 m of depth on the island of Äspö in southeastern Sweden. The main objective is to build the know-how for constructing a the repository of nuclear waste disposal.

Our experimental tunnel (TAS04) is situated at 410 m of depth. The floor was sawed and is equipped with 42 boreholes between 1 and 2 m deep. The tunnel's geology is composed of granite, diorite, and granodiorite [Ericsson et al. 2015].

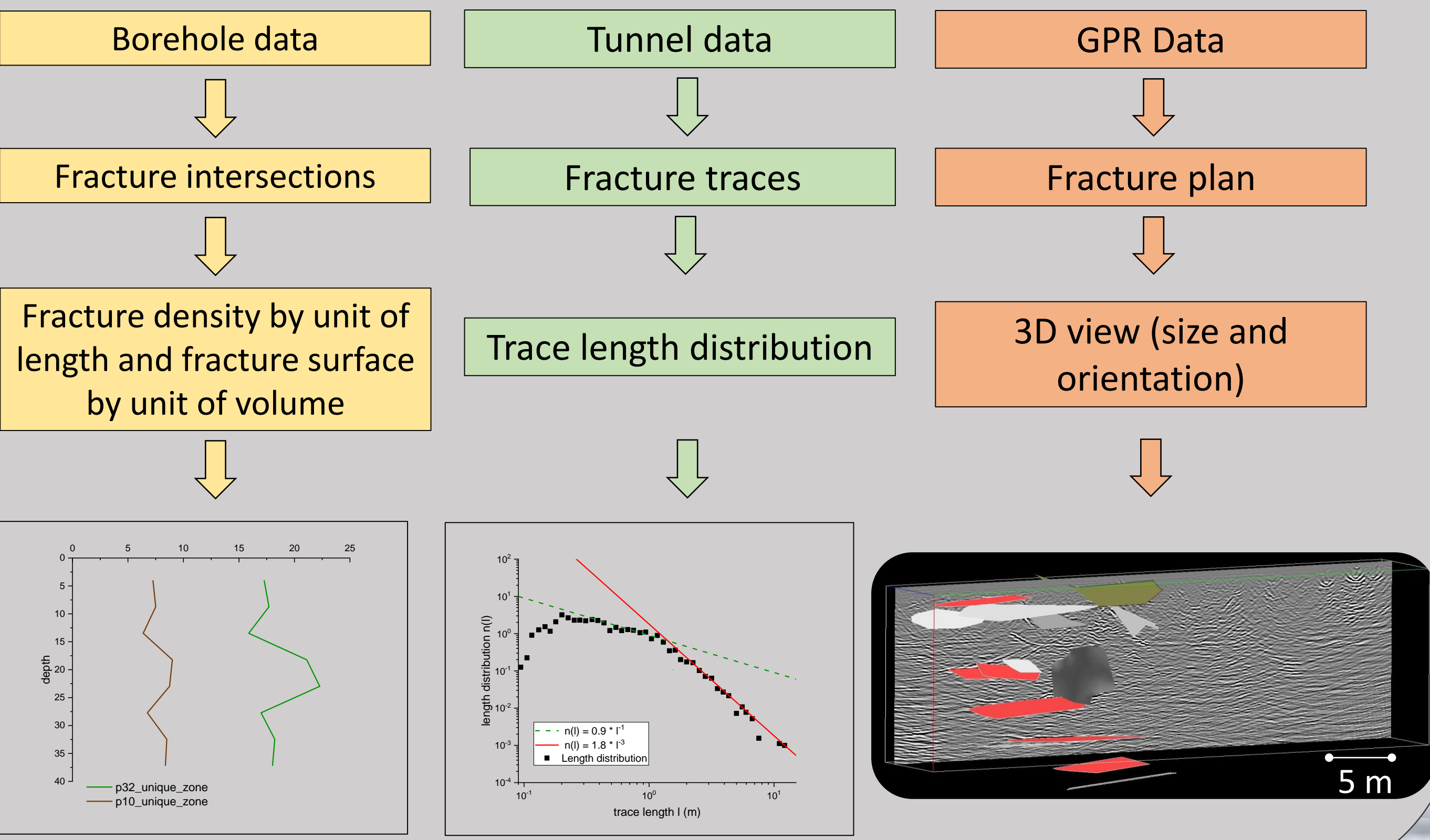


3. GPR survey

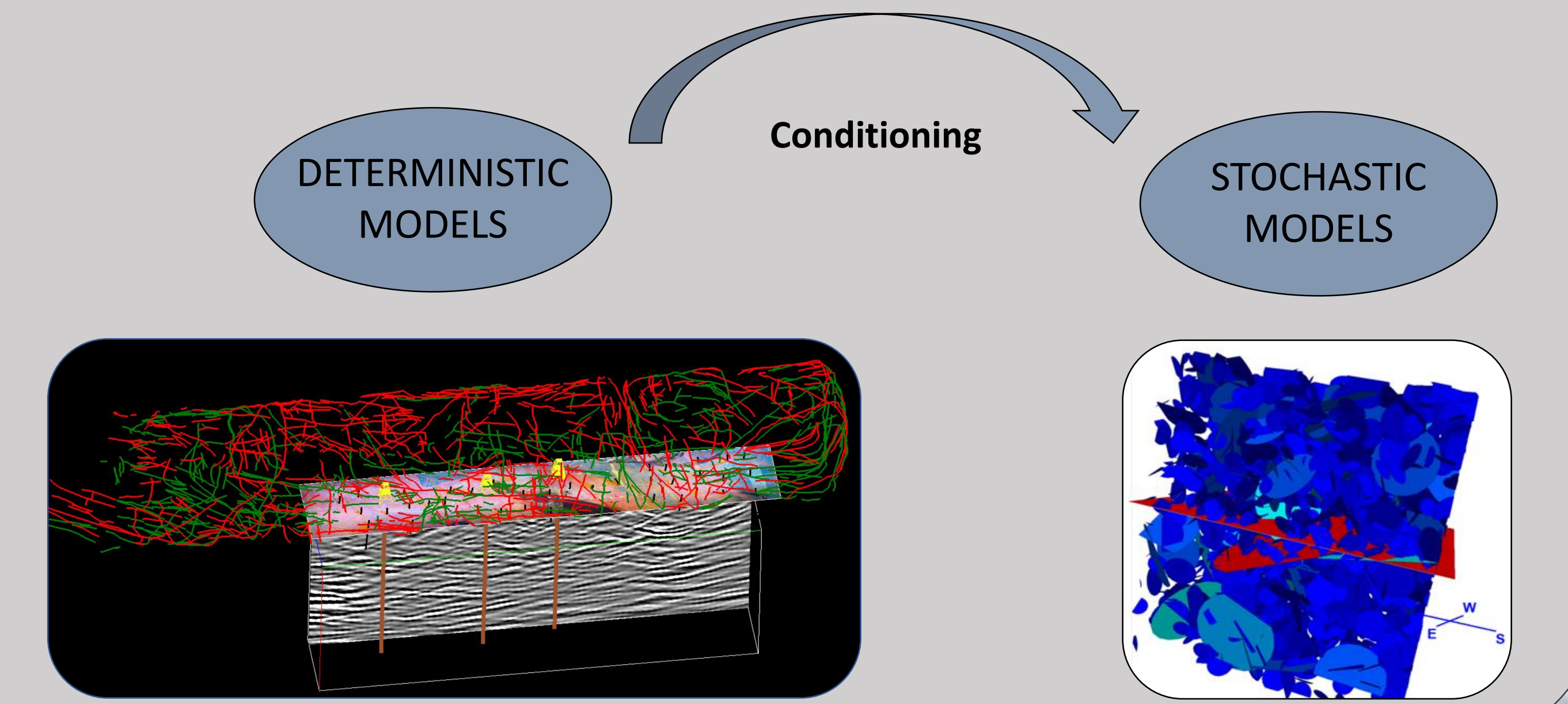
Fractures with filled material are considered as electrical dipole in a dielectric rock matrix. The electromagnetic incident wave from the transmitting antenna is scattered to give a reflection and transmission between two interfaces, as a function of the incident angle θ of the incoming signal [Shakas and Linde 2015].



6. Data integration



8. Stochastic model construction



10. Next GPR experiment

GPR monitoring of fractures: geometry of fracture connectivity and tracer pathways study in the upper 8 m below TAS04.

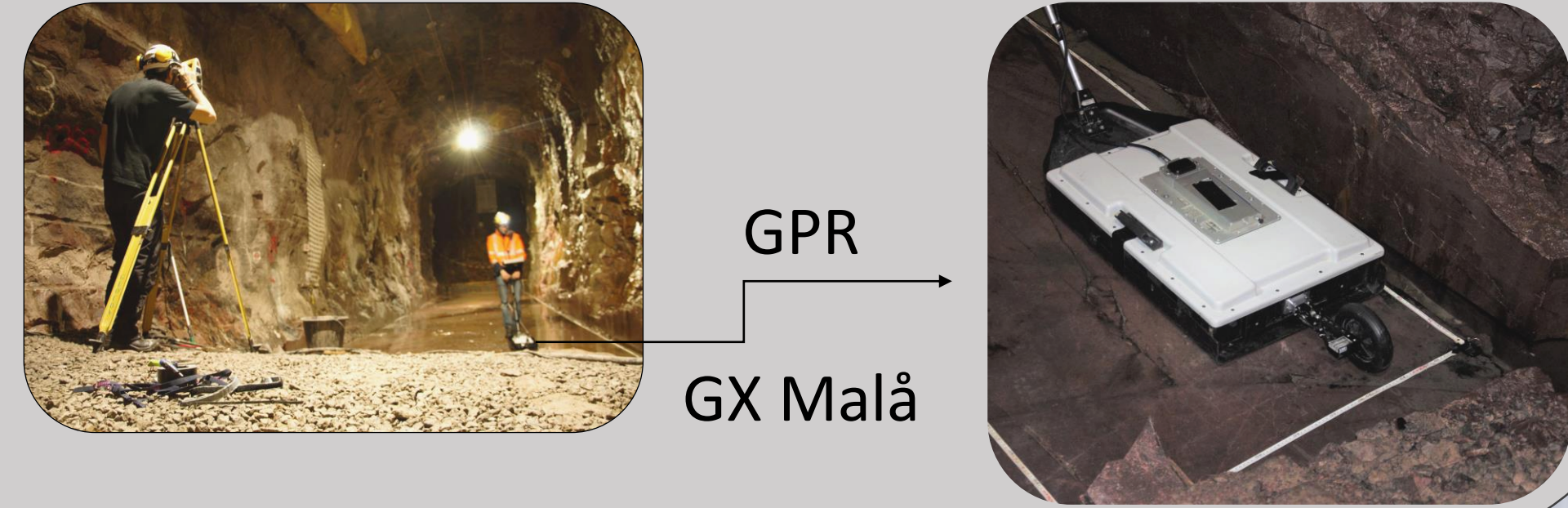
- Surface GPR monitoring
- Push-pull/ Single Well Injection Withdrawal (SWIW) tests
- Convergent dipole test

Injected water = deionized water + tracer

4. GPR Methodology

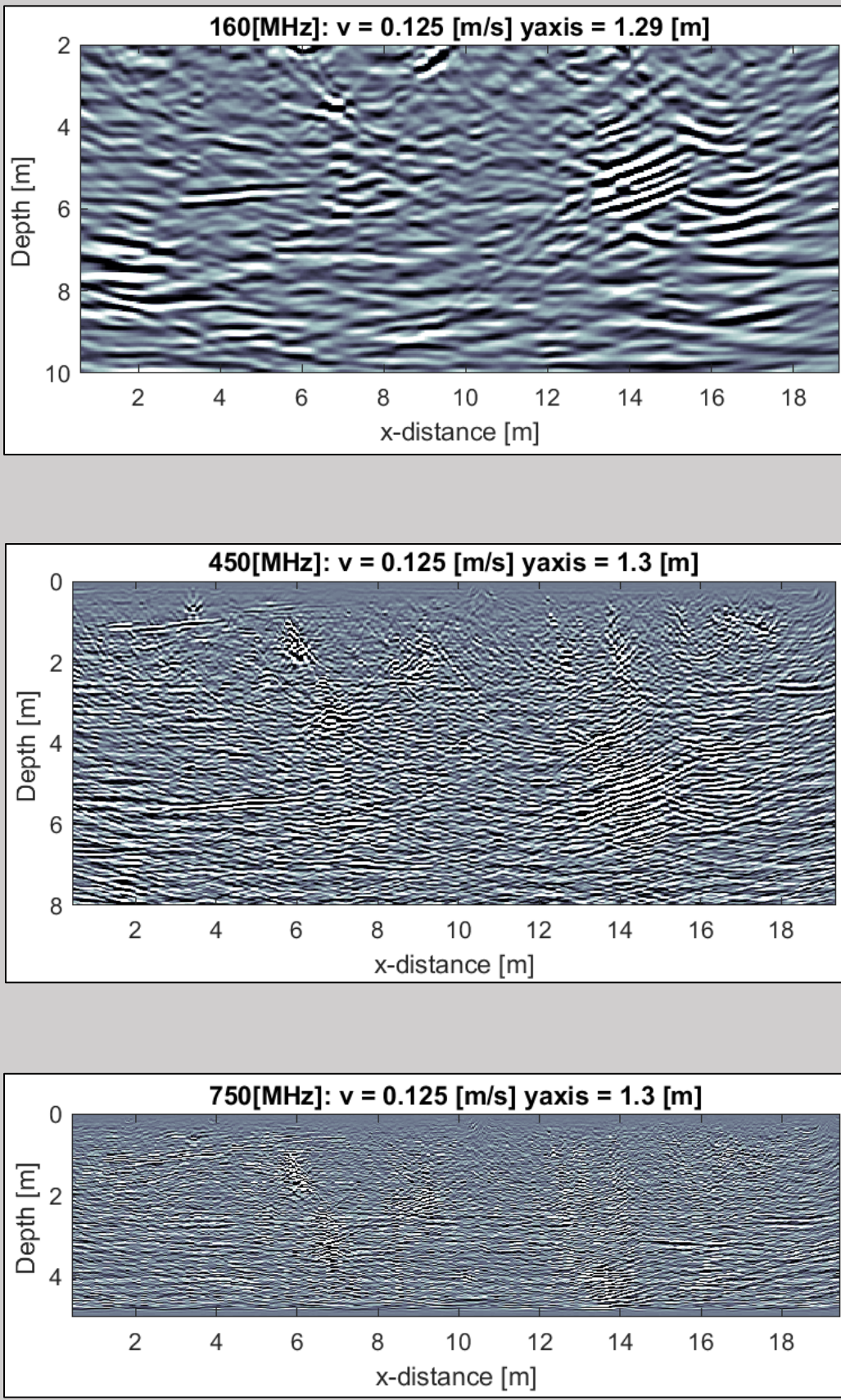
Three frequencies were used to investigate different depths and resolutions. The GPR was pulled along the tunnel floor. Each profile was separated by 0.05 or 0.10 m.

Frequency	160 [MHz]	450 [MHz]	750 [MHz]
Investigation depth	2 – 10 m	0 – 8 m	0 – 5 m
Wavelength	0.8 m	0.28 m	0.18 m
Horizontal resolution	0.8 m	0.25 m	0.18 m
Vertical resolution	0.2 m	0.06 m	0.04 m

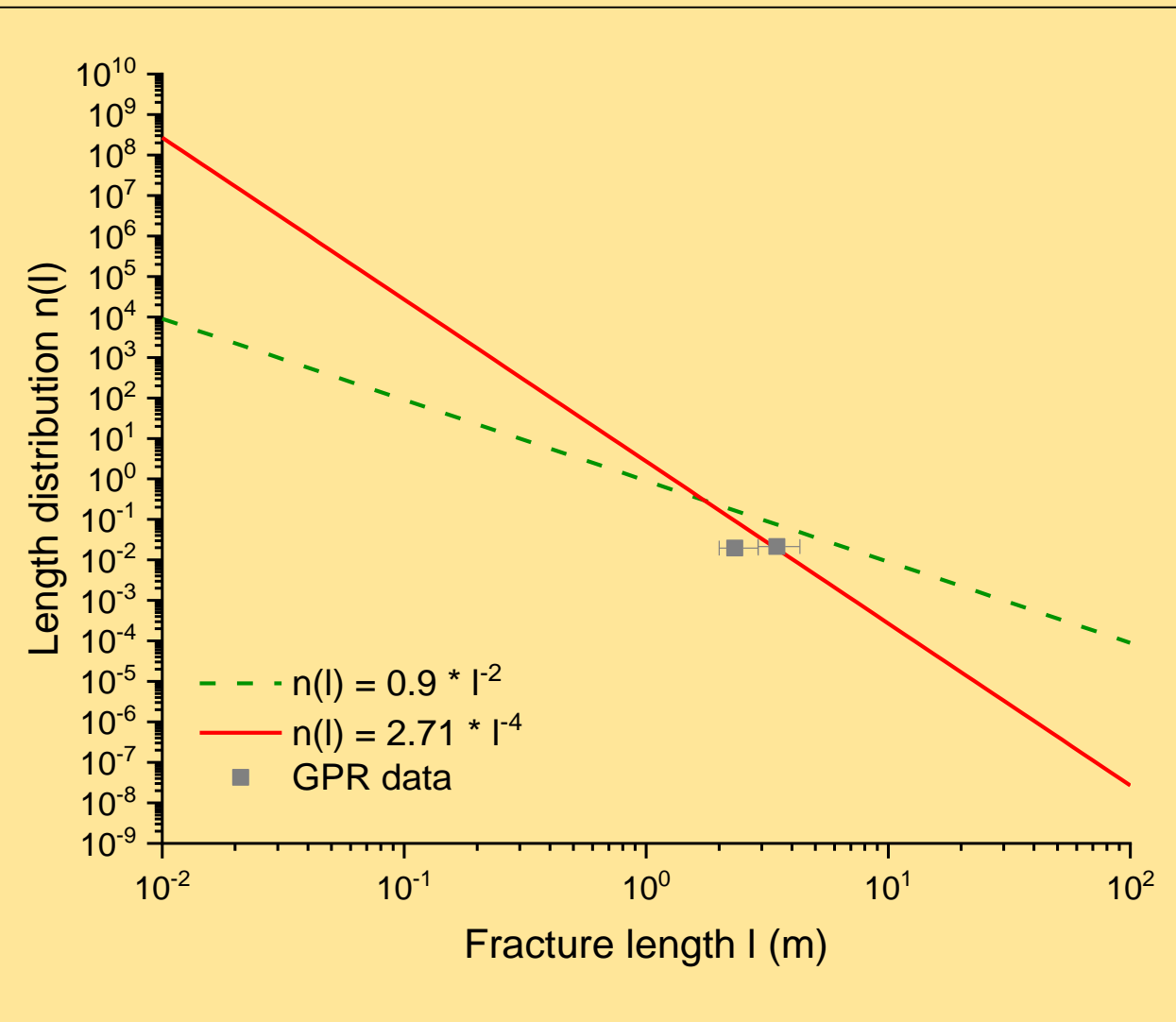


5. GPR results

2D slices after data processing and migration.

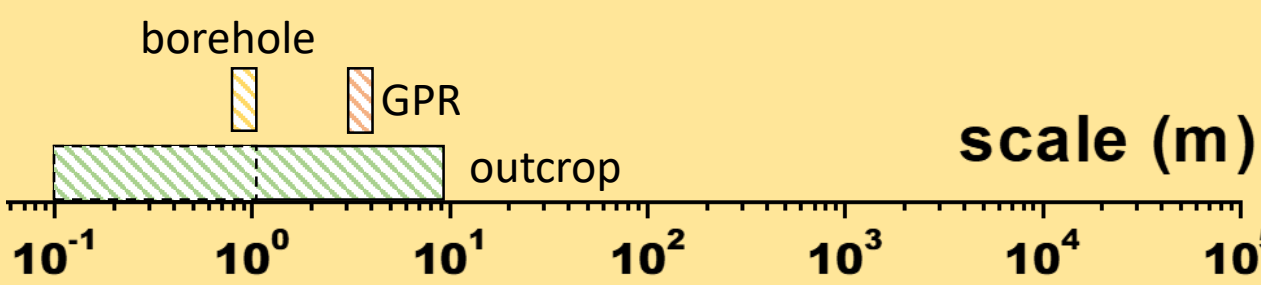


7. Statistical 3D Model and scaling observation



The density of fracture length in 3D was calculated with outcrop data, based on stereological rules [Darcel et al. 2009]. The fractures from GPR surveys were integrated and are consistent with the distribution model. However, fractures below 3 m are underestimated.

- The cause is not clear yet but the possible causes can be :
- Incomplete fracture picking
 - GPR resolution
 - Fracture aperture



9. Conclusions and perspectives

Currently, stochastic DFN models are conditioned on deterministic elements such as boreholes and outcrops data. The geophysical component adds additional information about the 3D spatial fracture extent. However, fracture GPR imagery is uncertain. To reduce this uncertainty, three boreholes will be drilled to verify if GPR structures represent fractures. In addition, a hydraulic component will be added to improve conditioning to hydraulic models.

References

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