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SCCER-SoE Annual Conference 2019

Geophysical Characterization of Fractured Rocks – a Rock Physics Perspective

University of Lausanne, Switzerland
Università della Svizzera Italiana, Switzerland
University of Geneva, Switzerland
University of Bern, Switzerland
ETH Zürich, Switzerland
CONICET, Centro Atómico Bariloche – CNEA, Argentina
Department of Geophysics, Peking University, China

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Reservoir characterization of fractured rocks

What do we want to know?

Geological characteristics

Rock type: lithology, mineralogy

Structural characteristics: fractures/fracture networks, faults, fabric, stress field

Mechanical characteristics

Young's modulus

Poisson's ratio

(Density)

Seismic properties

Hydraulic characteristics

Localized flow zones

Hydraulic conductivity

Storage capacity

Fracture properties

Compliance

Aperture/
hydraulic conductivity

What can we get from (borehole) geophysics?

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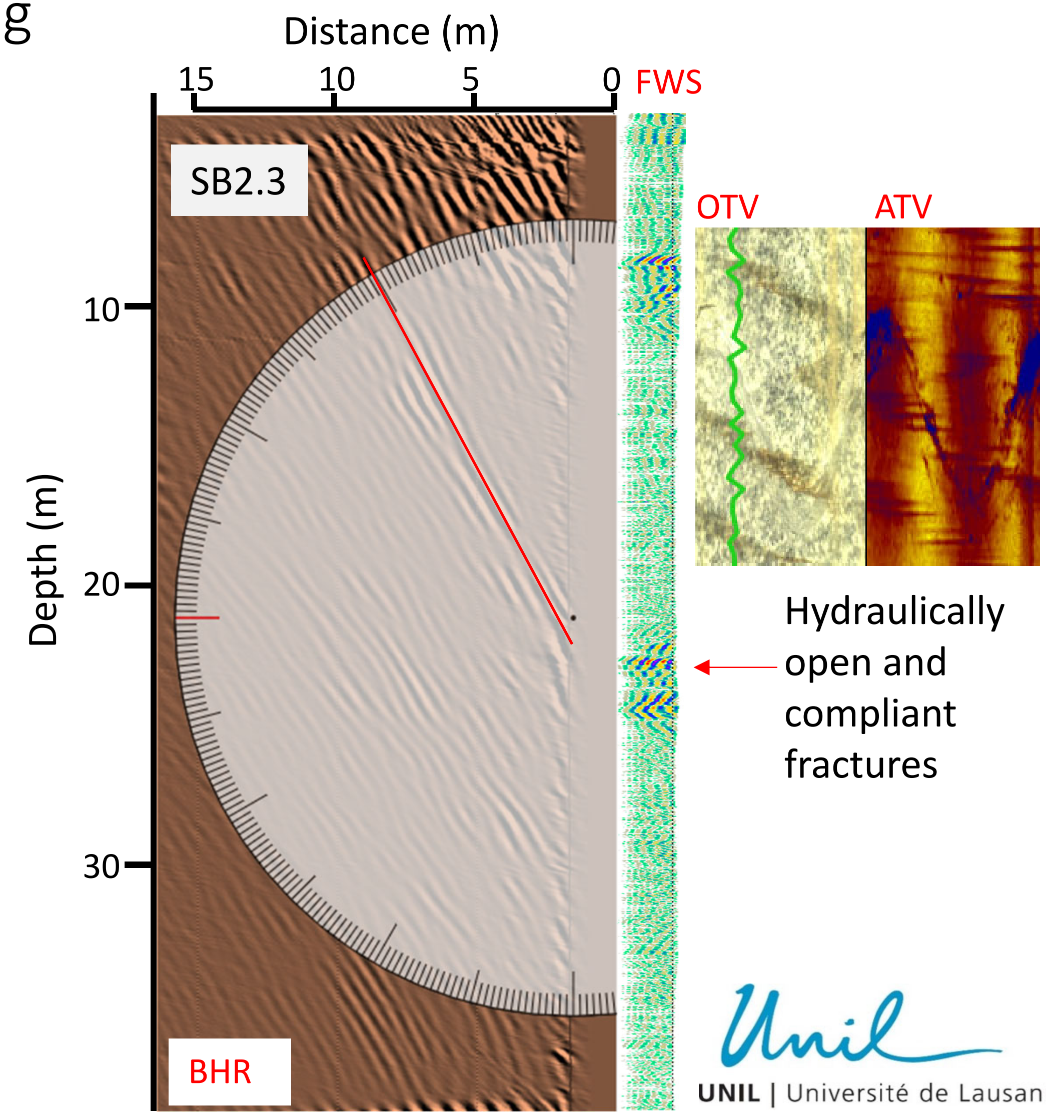
Fracture detection and mapping

Optical and acoustic televiewer (OTV,ATV)

Borehole radar (BHR): fluid filled fractures in crystalline rocks
→ Fracture dip with respect to borehole and extent of the fracture

Full waveform sonic (FWS): hydraulically open fractures

Poster Greenwood et al.: Borehole radar and full waveform sonic measurements of the Bedretto stress-measurement boreholes



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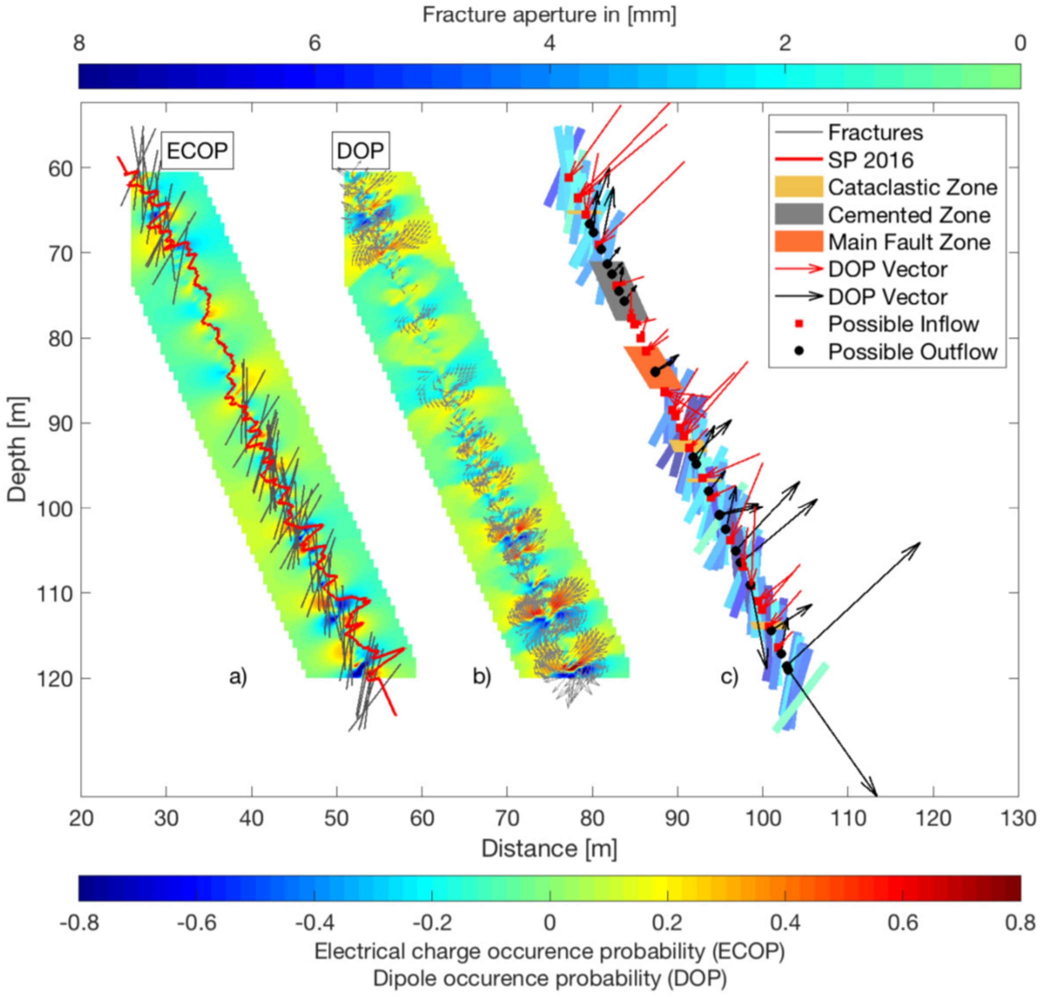
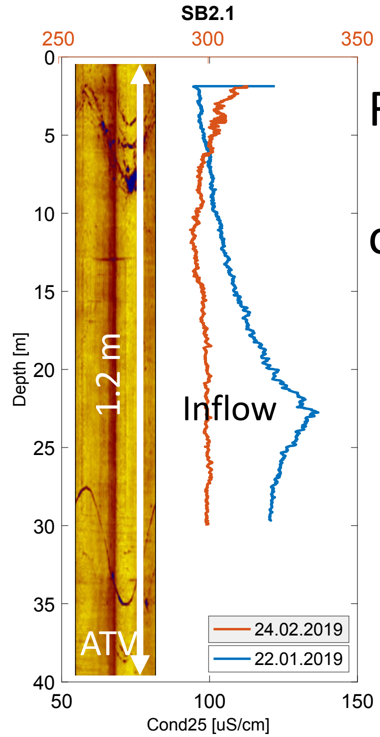
Hydraulic characteristics



Self potential data
→ Localization of in- and outflow zones along fractures



Fluid conductivity
→ Localization of inflow

Poster Caspari et al.:
Wireline logging of Bedretto stress measurement boreholes
- preliminary results

Reservoir characterization of fractured rocks

Can we get quantitative fracture properties ?

Geological characteristics

Rock type: lithology, mineralogy

Structural characteristics: fractures/fracture networks, faults, fabric, stress field

Mechanical characteristics

Young's modulus

Poisson's ratio

(Density)

↑

Seismic properties

Hydraulic characteristics

Localized flow zones

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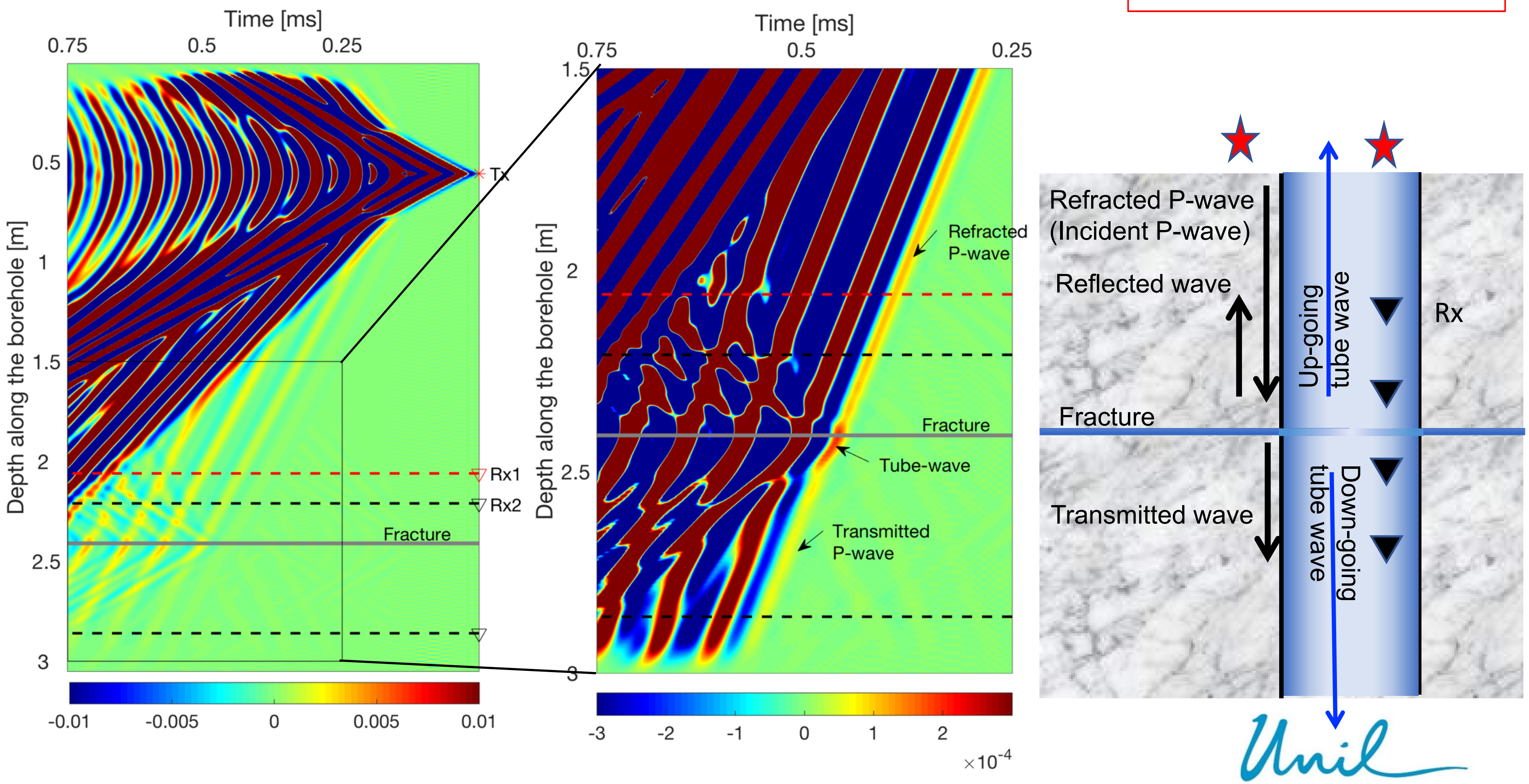
Borehole experiment
– hydrophone VSP and FWS

Fracture compliance
Hydraulic aperture



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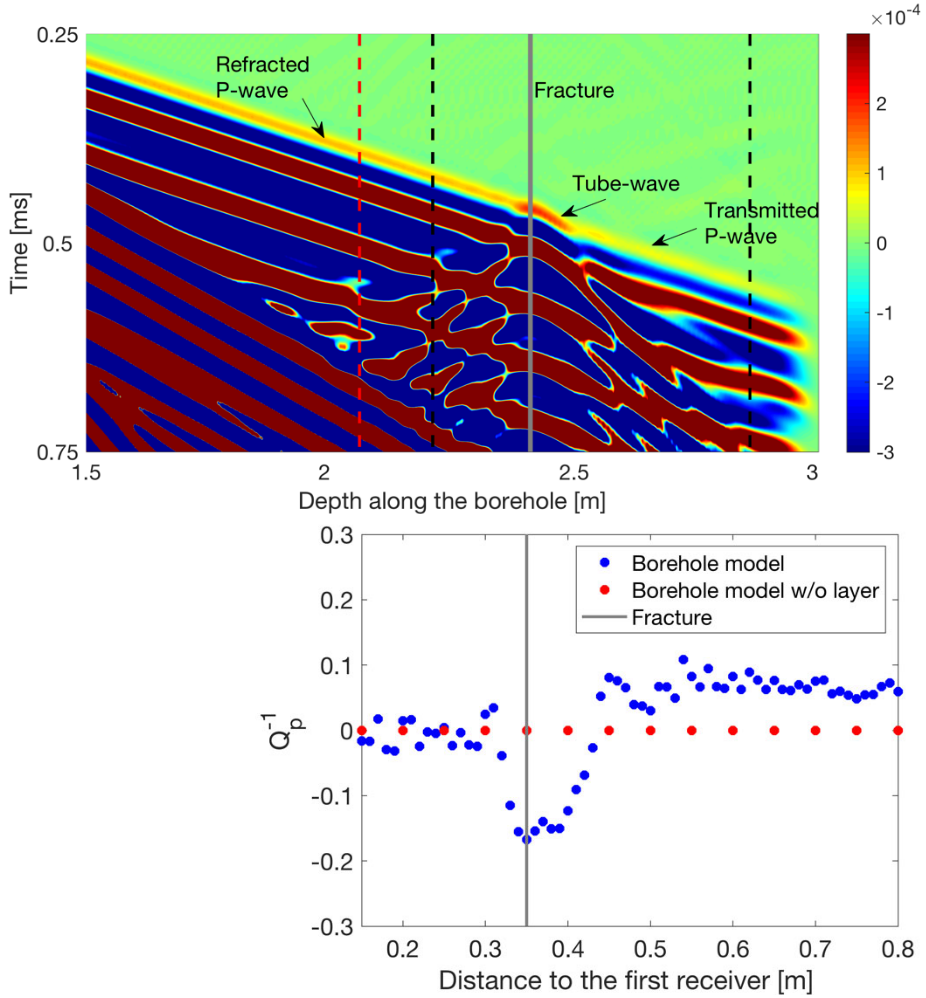
Barbosa et al. 2019, JGR Solid Earth

Full waveform sonic data



$$Q_p^{-1}(\omega) = Q_{spreading}^{-1}(\omega) + Q_{intrinsic}^{-1}(\omega) + \boxed{Q_{transmission}^{-1}(\omega)}$$

$$T(\omega) = \frac{1}{1 + \frac{i\omega I_b \boxed{Z_N}}{2}}$$

Fracture compliance

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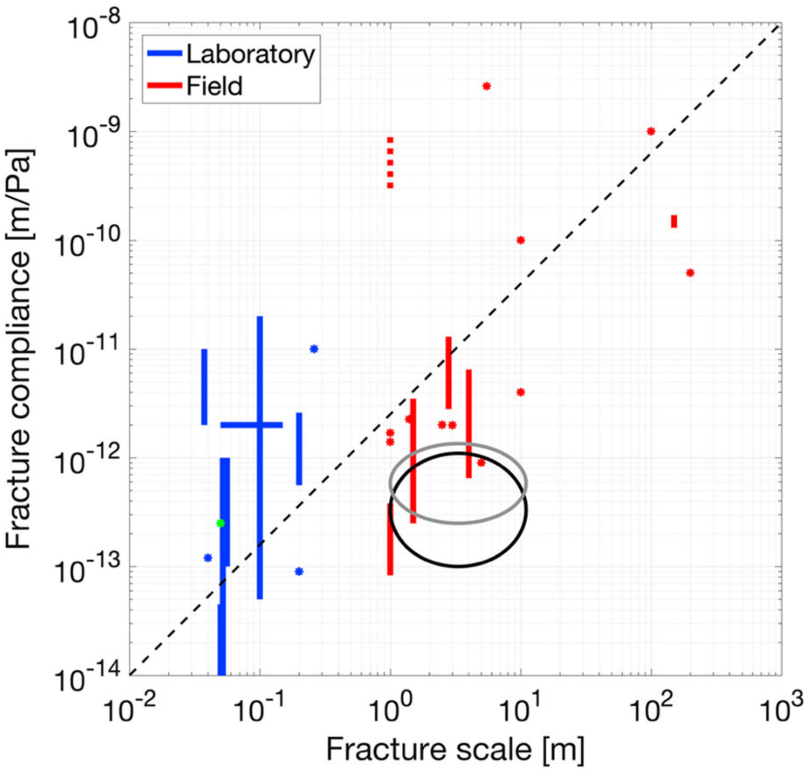
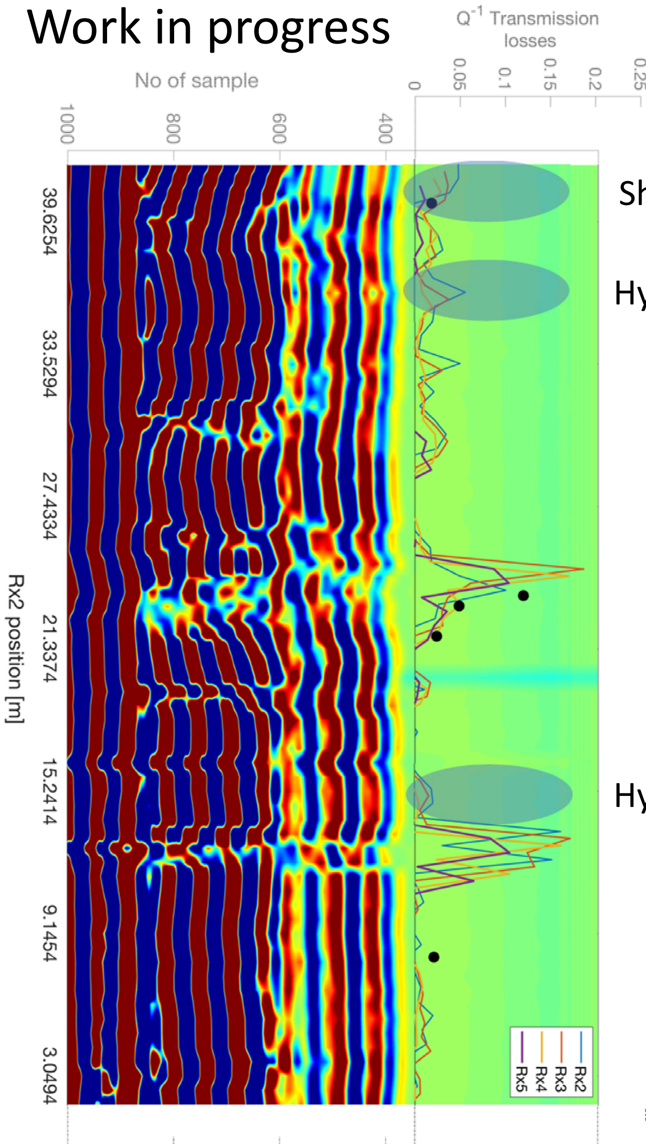
Fracture compliance



Barbosa et al. 2019, JGR Solid Earth

Work in progress

Grimsel test site



Shearing

Hydraulic fracture

Hydraulic fracture

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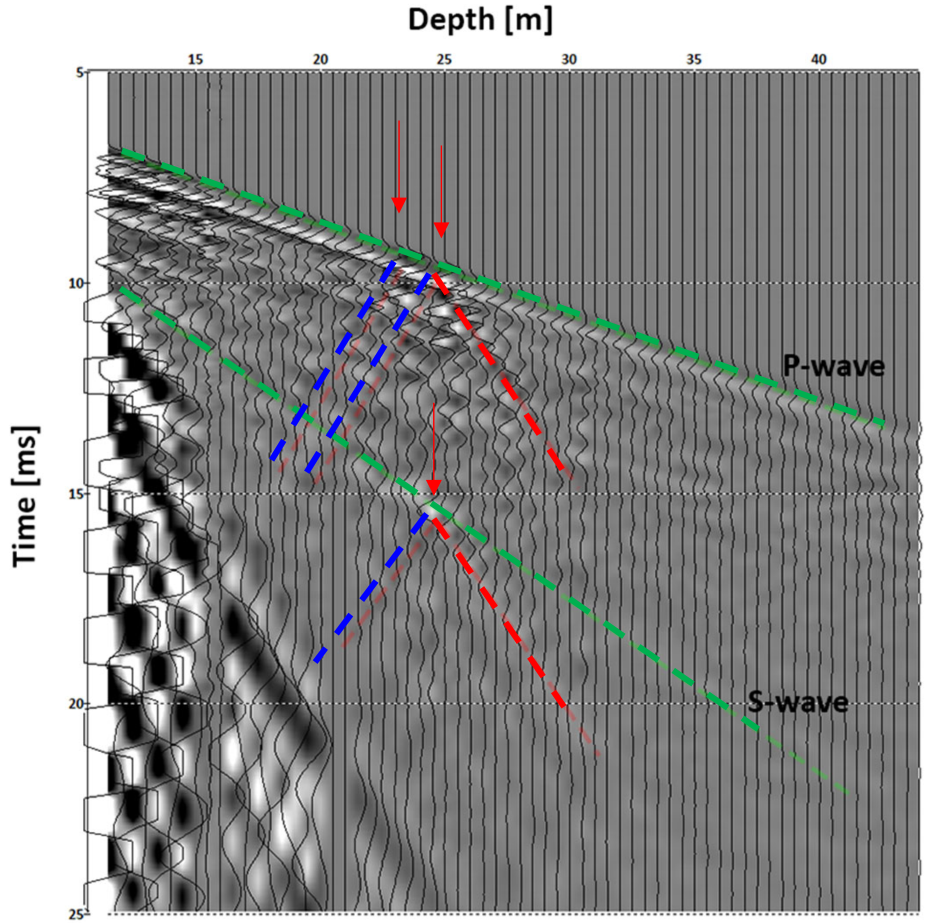
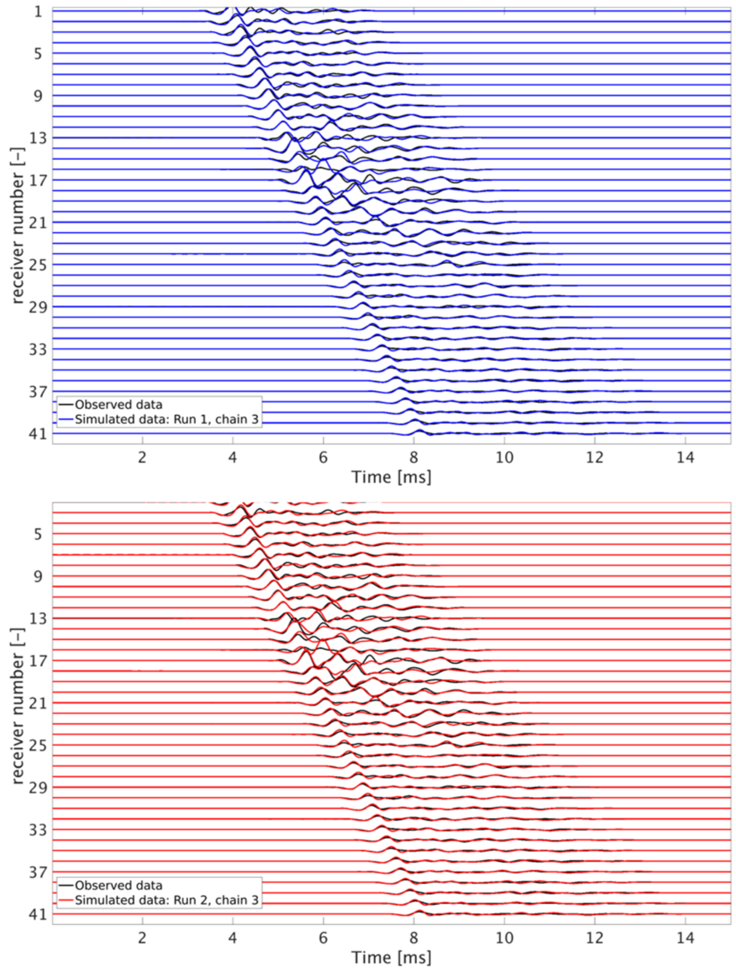
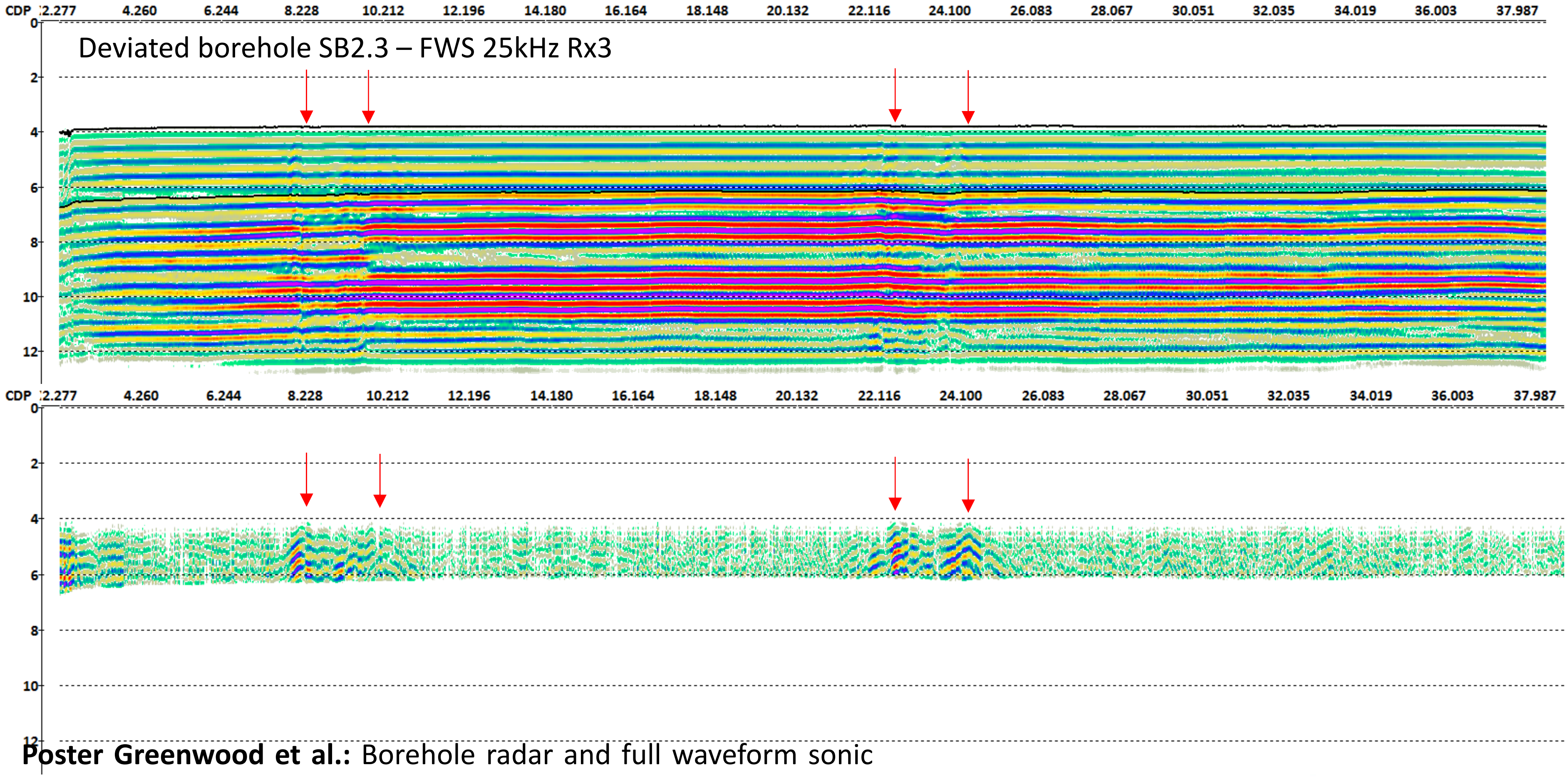
Tube wave inversion – hydrophone VSP data Grimsel test site





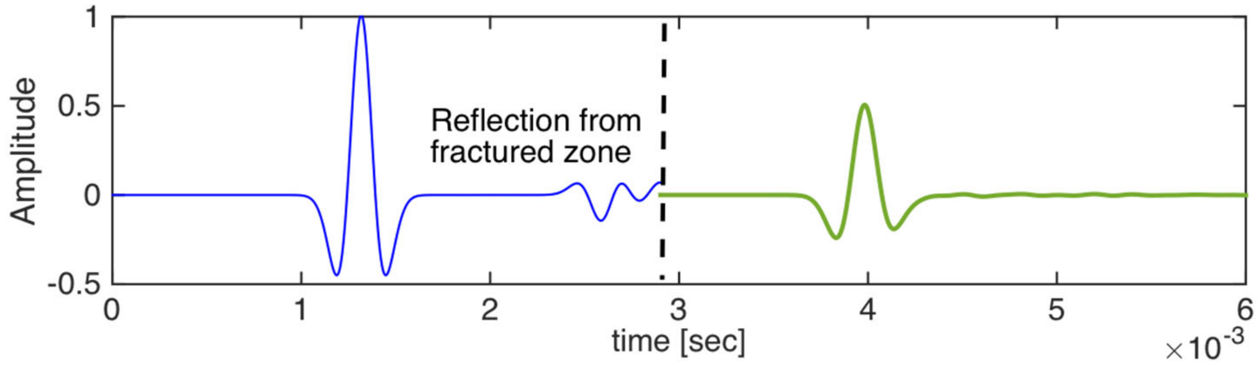
Poster Hunziker et al.: Bayesian inversion of tube waves to estimate fracture aperture and compliance: Application to a real dataset

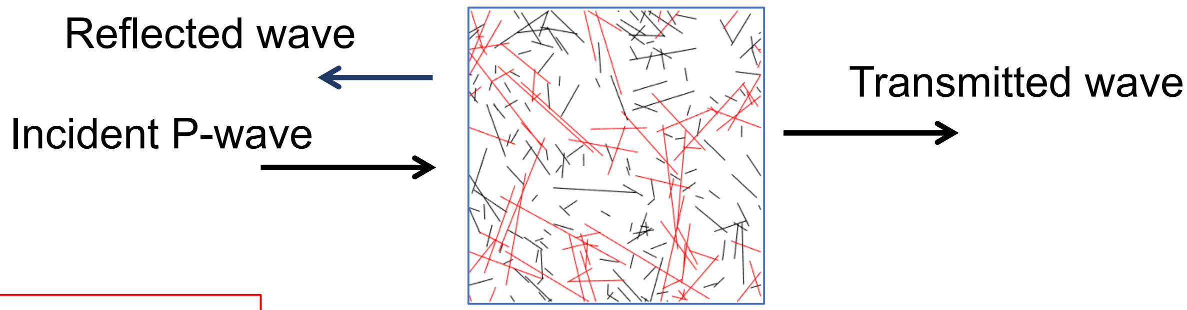
Outlook: Tube wave inversion of full waveform sonic data ?



Poster Greenwood et al.: Borehole radar and full waveform sonic measurements of the Bedretto stress-measurement boreholes

From discrete fractures to fracture networks and their seismic signatures





Talk Marco Favino:
Hydromechanical Coupling in Heterogeneous and Fractured Media

Hunziker et al. 2018, JGR Solid Earth

Numerical upscaling procedure

Effective seismic properties

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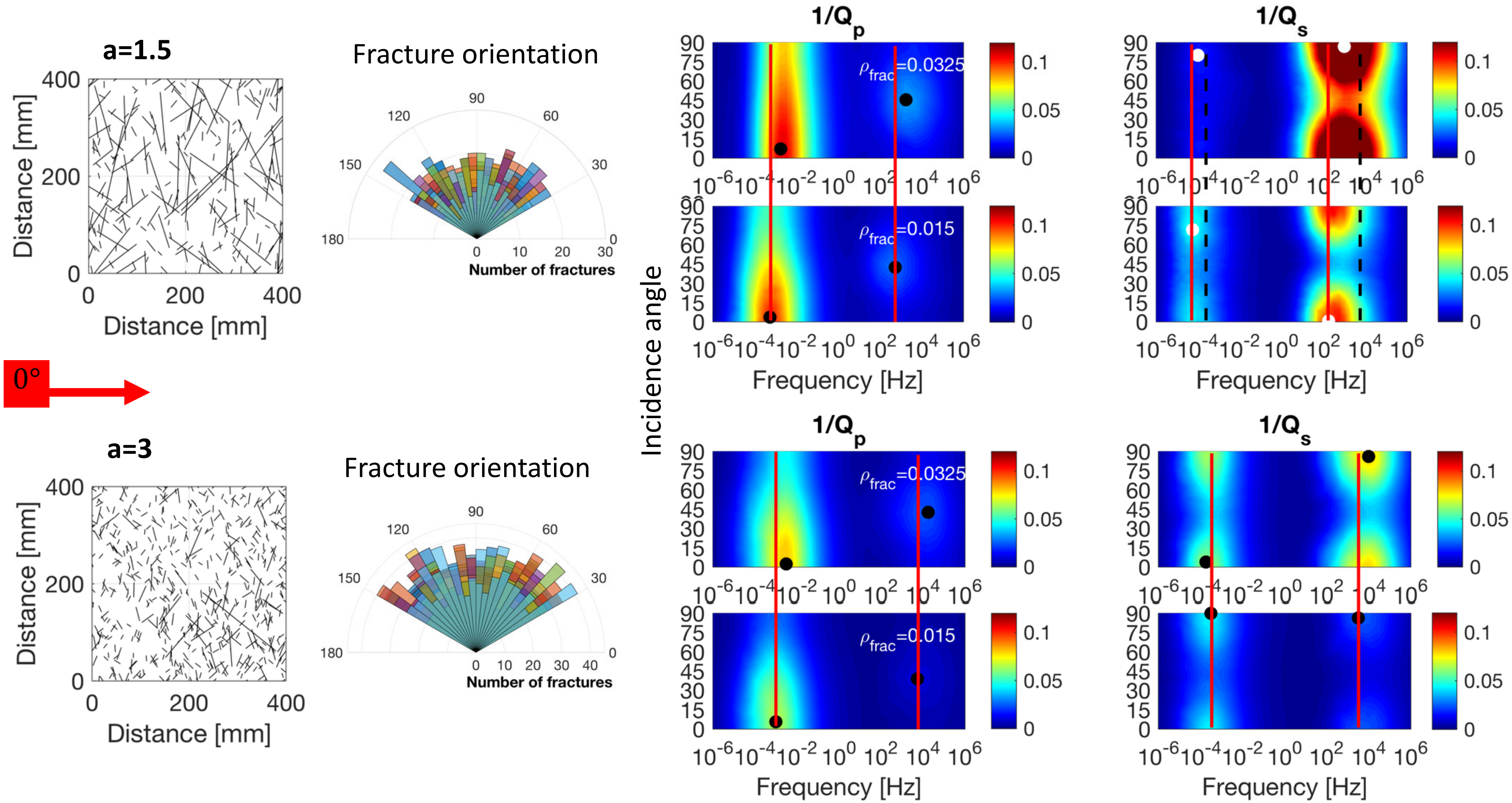
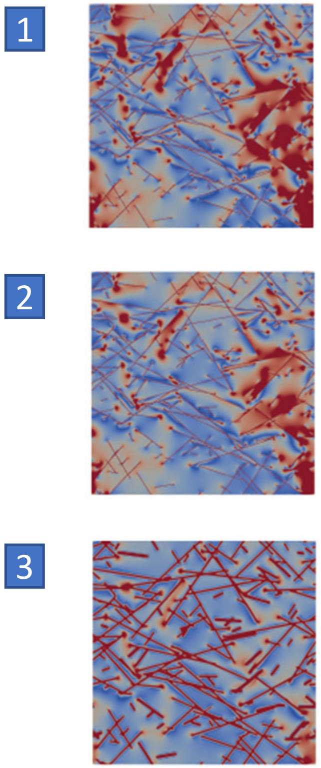
Seismic signatures of fracture networks - Numerical simulations

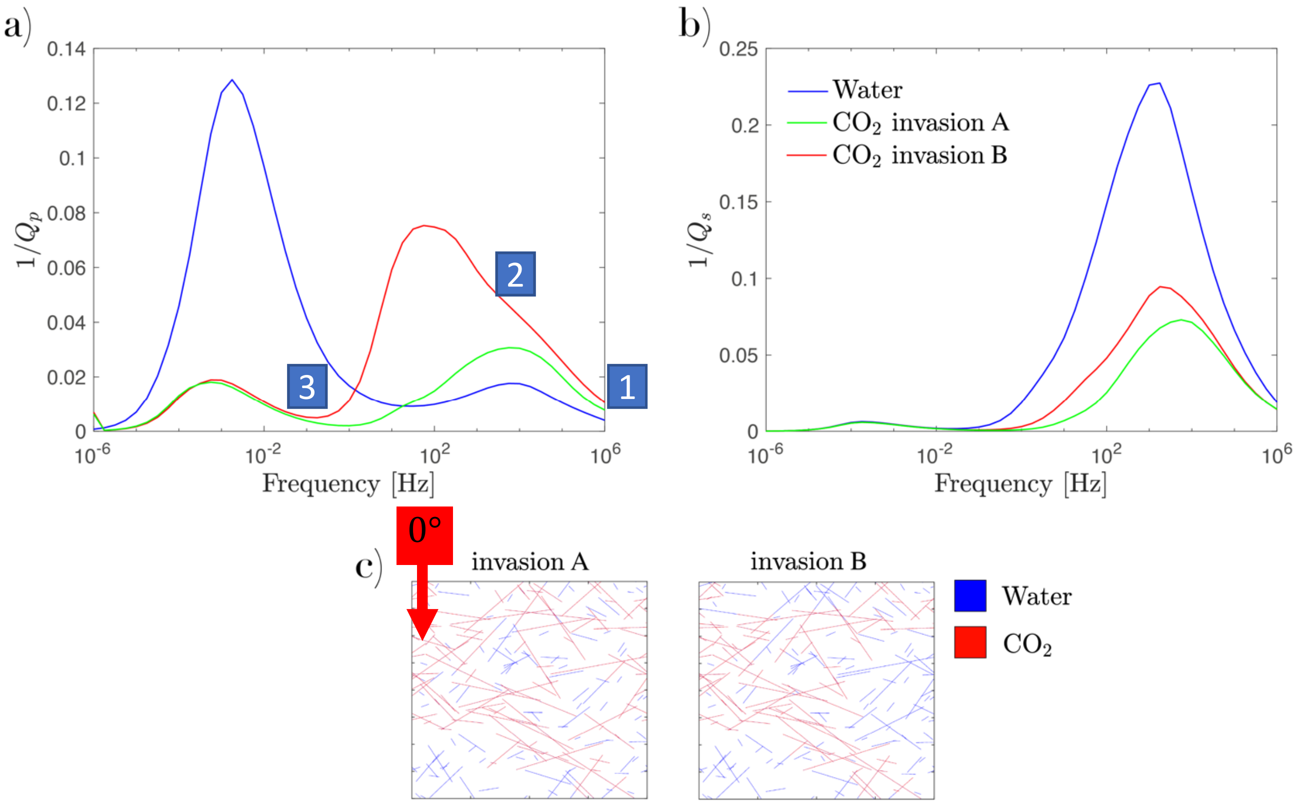


Caspari et al. 2019, EAGE expanded abstract, Hunziker et al. 2018, JGR Solid Earth

Seismic signatures of fracture networks - Numerical simulations

Fluid pressure





Poster Solazzi et al.: Seismic signatures of porous rocks containing partially saturated fracture networks

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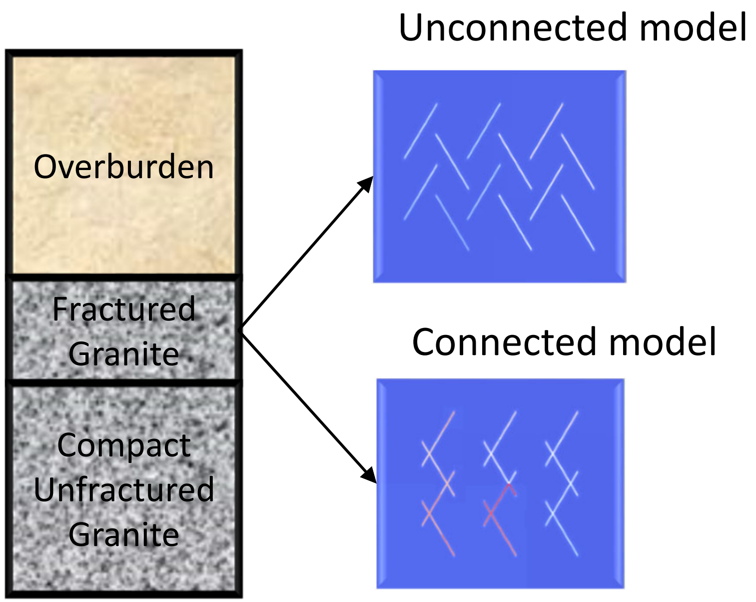
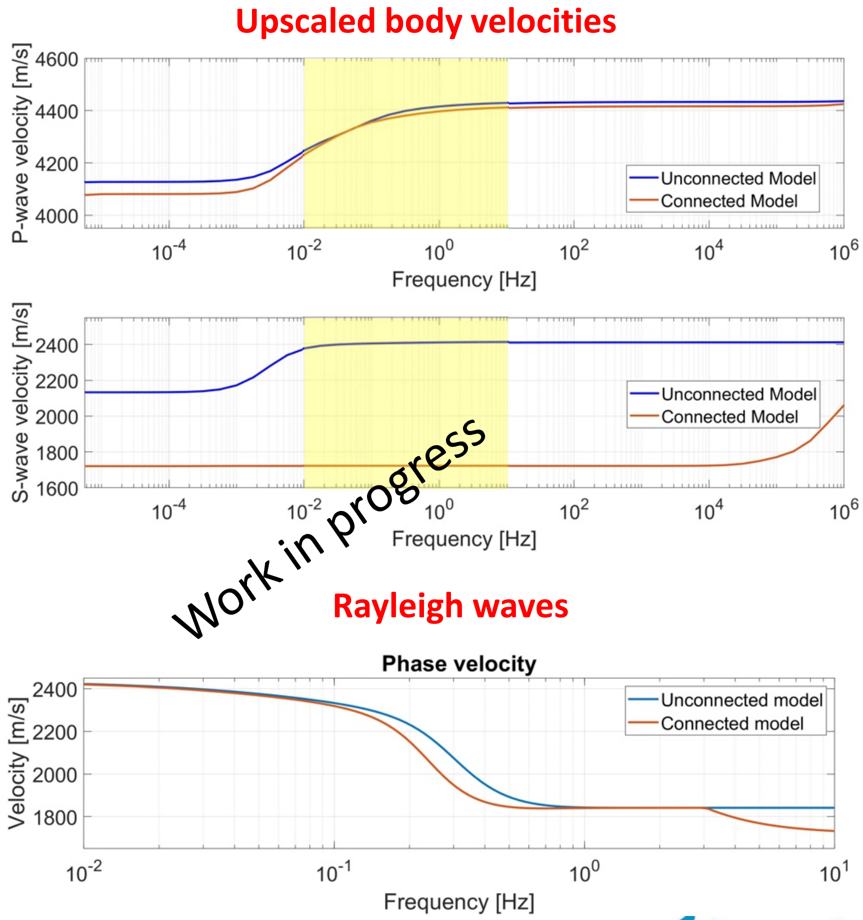
Seismic signatures of fracture networks - Numerical simulations





Poster Quiroga et al.: Effects of fracture connectivity on Rayleigh wave dispersion

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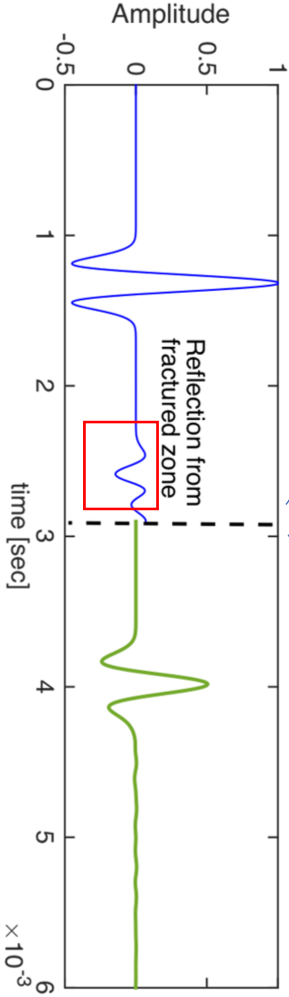
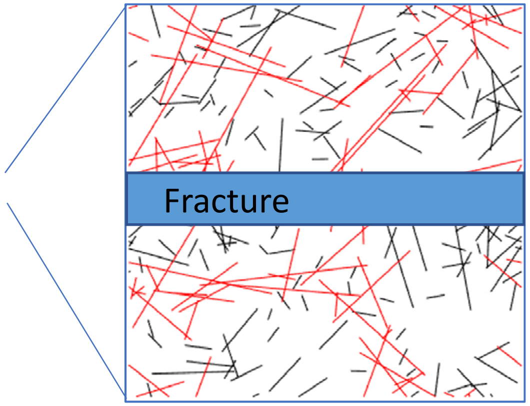
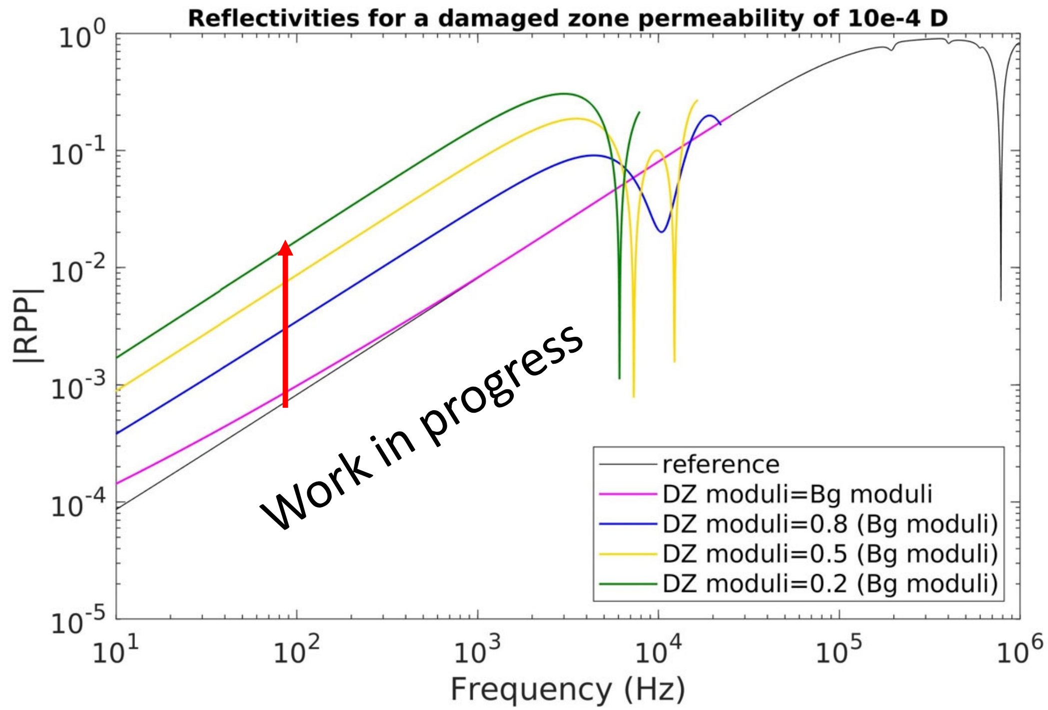
Seismic signatures of fracture networks (plane wave solution)







Poster Sotelo et al.: Poroelastic effects of the damaged zone on fracture reflectivity

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Summary

Discrete fractures

Localization of discrete fractures, geometrical characteristics, hydraulic characteristics

Quantitative estimation of physical fracture properties: mechanical compliance and hydraulic aperture

Fracture networks

Numerical simulations: Seismic response is sensitive to various fracture network characteristics and their saturating fluids

Can we link this response to attributes which can be obtained from field data?

References

Barbosa, N.D, Caspari, E., Rubino, J.G, Greenwood A., Baron, L., and Holliger, K. [2019] Estimation of fracture compliance from attenuation and velocity analysis of full-waveform sonic log data Journal of Geophysical Research: Solid Earth, 124, 2738-2761.

Caspari, E., Barbosa, N. D., Novikov, M., Lisitsa, V., Hunziker, J., Quintal, B., Rubino, J.G. and Holliger, K. (2019, June). Seismic Attenuation Mechanisms in Fractured Fluid Saturated Media–Numerical and Field Examples. 81st EAGE Conference and Exhibition, London, 2019 Workshop Programme.

Hunziker J., Favino M., Caspari E., Quintal B., Rubino J.G., Krause R. and Holliger, K. [2018] Seismic attenuation and stiffness modulus dispersion in porous rocks containing stochastic fracture networks. Journal of Geophysical Research: Solid Earth, 123, 125–143.

Sidler, R., Carcione, J. M. and Holliger, K. [2014] A pseudospectral method for the simulation of 3-D ultrasonic and seismic waves in heterogeneous poroelastic borehole environments, Geophysical Journal International, 192, 1134-1151.

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