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SECTION DE GÉNIE CIVIL

Laboratory for Experimental Rock Mechanics

Micromechanical Modelling of Elastic Wave Velocity Variations for Intact Brittle Rocks

Author: Antoine Guggisberg

Supervisors: François Passelègue[1] / Prof. Marie Violay[1]

[1] Laboratory of Experimental Rock Mechanics (LEMR) EPFL

Introduction

In the upper crust where brittle deformations are predominant, the growth and coalescence of cracks lead to the formation of faults that play a critical role in lithosphere deformations and earthquakes.

Cracks affect elastic parameters, anisotropy and reduce elastic wave velocities. Sayers & M. Kachanov [1] presented how elastic wave velocities are directly linked with an estimation of damage (crack density tensors).

The wing crack model of Ashby & Sammis [2] is a micromechanical model that provides an estimation of the strength according to linear elastic fracture mechanics (LEFM). As the model predicts the crack geometry, we coupled it with the Kachanov's theory to estimate elastic wave velocities.

Laboratory experiments were conducted to test the effectiveness of this new coupling.

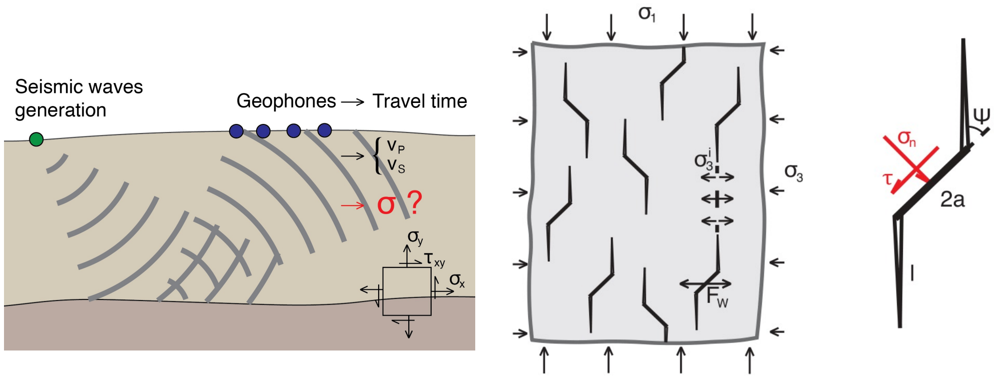

Figure 1: estimating in-situ stresses thanks to elastic wave velocity measurements is proposed by extending the wing crack model (on the right) with Kachanov's theory.

Laboratory experiments

Triaxial experiments were realized on Westerly Granite at various confining pressures while measuring stress, strains, acoustic emissions and the evolution of seismic velocities (P and S-waves) with various orientations.

The crack density tensors are directly inverted from the stiffness variations measured by the seismic velocities.

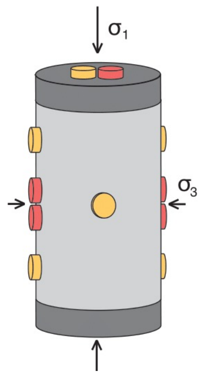

Figure 2: Triaxial loading set-up with piezoelectric transducers emitting P and S-waves.

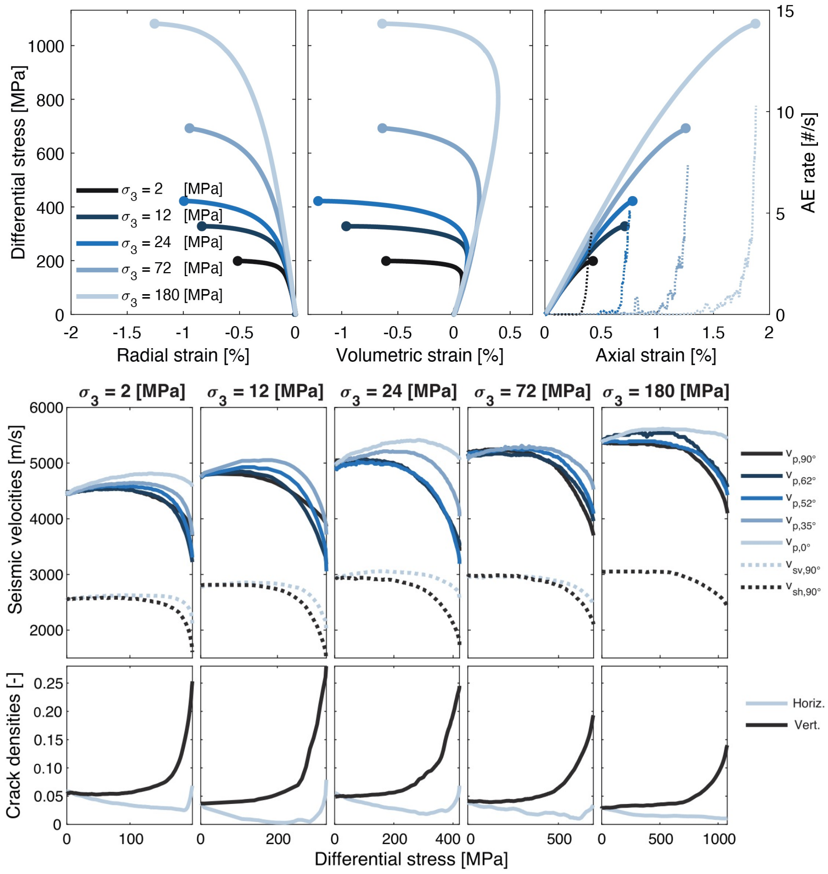

Figure 3: mechanical results of the triaxial tests (strain - stress, seismic velocities, crack densities). After an initial horizontal cracks closure, a long elastic phase is succeeded by a weakening caused by vertical cracks propagation.

Wing crack model

The failure envelope of these experiments fitted the parameters of the wing crack model with acceptable accuracy. Then, the coupling with Kachanov's theory is realized from the definition of the crack density.

We obtained a decent correlation between predicted and observed results. Until now, the model has only been used for failure predictions but with this new coupling, it can predict the velocity losses for any given loading.

The validity of the model is discussed through an energy budget and comparisons with in-situ measurements of velocity changes. It results that the model might be used for brittle intact rocks or at depth where cracks are healing, which could bring a new geophysical tool.

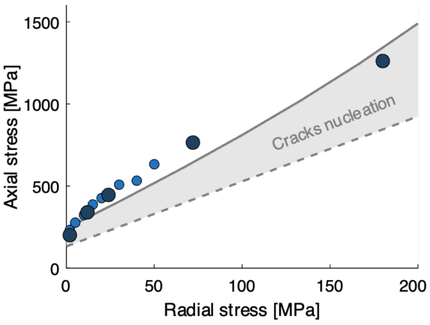

Figure 4: failure envelope of the wing crack model.

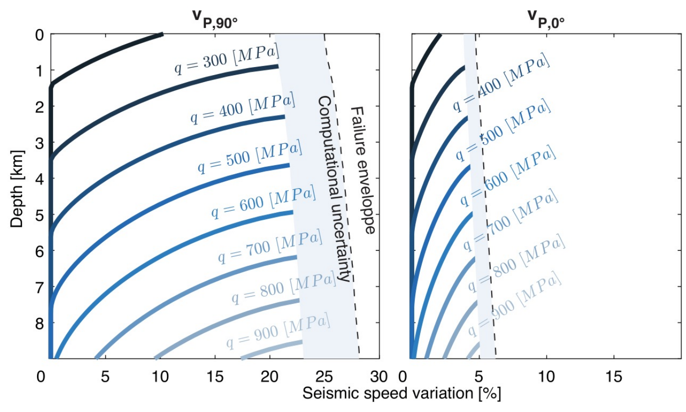

Figure 5: predicted velocity losses as a function of differential stress and depth. The angle to the principal stress is critical; the velocity variations are only significant in a perpendicular direction.

References

1. Sayers, C. M. & Kachanov, M. Microcrack-induced elastic wave anisotropy of brittle rocks. Journal of Geophysical Research: *Solid Earth* 100, 4149–4156 (1995).
2. Ashby, M. & Sammis, C. The Damage Mechanics of Brittle Solids in Compression. *Pure and Applied Geophysics* 133, 489–521 (1990).