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Experimental evidence of frequency and fluid effects in an icelandic basalt

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An important area of geophysical research is based on the elastic properties variations in rocks. In the laboratory, the responses of the rock elastic velocities to stress changes in saturated or dry specimens have been studied extensively in the past using ultrasonic signals in the megahertz frequency range. However when seismic wave velocities are involved, a direct extrapolation from laboratory to field scale is not straightforward. Laboratory data are indeed obtained in the ultrasonic range, whereas field data from seismological methods are obtained at much lower frequencies (Hz). The interpretation of the seismic wave velocities, measured at the field scale, in terms of fluids and/or in terms of physical properties of the rock formation is complex.

From a theoretical point of view, when cracks or pores are connected, stress can induce fluid flow from one inclusion to another; this is the squirt-flow effect. In saturated samples, several authors have shown that the measured velocities at high frequencies are generally faster than those predicted by the equations of Gassmann, which correspond to the low frequency limit of Biot's theory.

In this study, we investigated the frequency and fluid effects through an experimental point of view. We conducted hydrostatic experiments on an icelandic basalt, characterized by a bimodal porosity ($\sim$1% of cracks and $\sim$7 % of equant pores; the total porosity is $\sim$8%). The bulk moduli were measured through two experimental methods: a classical one using ultrasonic P- and S-waves velocities (frequency 10^6 Hz), and a new one based on oscillation tests (frequency 10^{-2} Hz). Measurements have been performed in the pressure range of 0- 200 MPa, both for low frequency and high frequency.

In dry conditions, no significant differences are observed between high and low frequency bulk moduli. However, in saturated conditions, two effects are highlighted: a physico-chemical effect emphasized by a difference between drained and dry moduli, and a squirt-flow effect evidenced by a difference between high and low frequency undrained moduli. This second effect disappears at high pressure, as cracks are closed. This observation is consistent with a squirt flow from cracks to pores.

Reference :

M. Adelinet, J. Fortin, Y. Guéguen, A. Schubnel and L. Geoffroy. *Frequency and fluid effects on elastic properties of basalt: Experimental investigations*. In press in Geophysical Research Letters