



Frequency, pressure, and pore fluid dependence of elastic wavespeeds: new laboratory measurements on Fontainebleau sandstone

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Measuring and modelling the frequency dependence of elastic moduli in the laboratory has been proven to be a very difficult task. Elastic properties are generally only accessible either in the very low-frequency regime (static), or the high frequency, ultrasonic range (~ 1 MHz), but there are currently very few sets of data available between the two limiting regimes. This is of crucial interest for correctly interpreting measurements of wavespeeds in the field that are in the seismic (~ 1 Hz) or sonic (~ 1 kHz) band.

We have carried out a series of experiments on two hydrostatically stressed samples of Fontainebleau sandstone, having porosities of 4% and 17%, and permeabilities of around 1 milliDarcy and 1 Darcy, respectively, using a new apparatus recently commissioned at the Ecole Normale Supérieure of Paris. The samples were saturated with three different fluids (argon, glycerine, water), with the pore pressure in each case held constant at 5 MPa.

Strain, pore volume change, permeability, and ultrasonic (1 MHz) velocities have been recorded, as well as low-frequency values for the bulk modulus (K) in the range 10^{-3} to 1 Hz, as a function of hydrostatic confining pressure, up to 95 MPa. The low-frequency measurements of K were obtained using the stress-strain method (Adelinet et al., GRL, 2010), by oscillating the confining pressure. Very sensitive semiconducting strain gauges, glued on the sample, allowed us to measure very low strain amplitudes (of the order 10^{-6} , and even down to 10^{-7}), thereby avoiding issues such as inelasticity or amplitude effects.

At a confining pressure of 10 MPa, on both Fontainebleau sandstone samples (4% and 17%), a piezoactuator was placed between the axial load piston and the end cap in order to produce small axial stress oscillations of a few tens of kPa. The stress oscillations amplitude was measured by an aluminium force gauge placed next to the sample in the jacket, equipped with semiconducting strain gauges as well. Again, the axial strain was measured directly on the rock (down to 10^{-7}) using the semiconducting strain gauges. This new design worked successfully. In such a way, we have obtained measurements of Young's modulus E , in the complete frequency range going from 10^{-3} to 200 Hz, and with three different saturation fluids.

This combination of techniques allows us to measure a set of two elastic constants over a large frequency range (low and high frequencies), and under pressure, which had never been performed before in the laboratory.

Here we present these new experimental results, and discuss some possible interpretations in terms of poroelasticity theory and pore pressure relaxation mechanisms.