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Seismic dispersion in fluid-saturated carbonates: experimental investigation using the forced-oscillations method.

Jan Borgomano (1), Lucas Pimienta (2), Hanjun Yin (1), Jérôme Fortin (1), and Yves Guéguen (1)

(1) Ecole Normale Supérieure de Paris, France (borgomano@geologie.ens.fr), (2) Ecole Polytechnique Federale de Lausanne, Switzerland

For fluid-saturated rocks, comparing ultrasonic measurements (1 MHz) in the laboratory and seismic (100 Hz) or logging (10 kHz) measurements in the field is not straightforward due to dispersion of the body-wave velocities. The frequency-dependent mechanisms involved are wave-induced fluid flows that occur at different scales. In fully saturated sandstones, one identified mechanism for dispersion is squirt-flow between microcracks and stiff pores. However, in carbonates, which bear more complex and heterogeneous pore types, little is known on the dispersive behavior. The dispersion and the attenuation of the elastic moduli of four fluid-saturated limestones, of different microstructure, have been studied experimentally. The selected samples are an oolitic (Lavoux), a bioclastic (Indiana), a rudist-dominated (Rustrel) and a coquina limestone. Moreover, the effect of thermal cracking was investigated on the Indiana sample.
Measurements were done over a large-frequency range in laboratory, by the combination of forced oscillations (0.001 to 100 Hz) and ultrasonic measurements (1 MHz) in a triaxial cell, at various effective pressures. The forced oscillations were either hydrostatic to deduce the bulk modulus, or axial to deduce Young's modulus and Poisson's ratio. The measurements were done in dry-, glycerin- and water-saturated conditions to investigate the effect of viscosity. For all our samples, the global drainage and the possible squirt-flow mechanisms were characterized experimentally, in terms of amplitude of dispersion, amount of viscoelastic attenuation, and cut-off frequencies. Biot-Gassmann's theory was found to be valid at seismic frequencies (10-100 Hz) for all the samples except the thermally cracked Indiana. Squirt-flow transitions were observed for all the samples besides the Lavoux. The cut-off frequencies were all in the range of logging frequencies (10-20 kHz), for water-saturated conditions.