Geophysical Research Abstracts
Vol. 17, EGU2015-3590, 2015
EGU General Assembly 2015

Experimental Rock Deformation under micro-CT: ERDμ

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Typically, the static elastic moduli of a rock differ from the corresponding dynamic rock-moduli. Such frequency-dependent characteristic, called modulus dispersion, implies also velocity dispersion (i.e. Vp- and Vs-dispersion). Velocity dispersion can be seen, in fact, as the result of a viscoelastic response of the geo-material to the externally imposed stress (e.g. seismic wave). Viscoelasticity can be conveniently expressed as attenuation ($1/Q$), which describes the loss of elastic energy for each stress cycle and comprises the measurement of the complex elastic modulus. As $1/Q$ at frequencies < 100 Hz is strongly influenced by the presence of saturating fluids, $1/Q$ represents an important seismic attribute as it can aid the subsurface imaging accuracy. For instance, the study of $1/Q$ is fundamental for the oil and gas industry as valuable natural resources, such as oil-sands or gas-shales, exhibit significant attenuation (e.g. $1/Q \sim 0.3$ at 1 Hz), or for volcanic and earthquake related studies as fluids are often involved in those natural processes.
In the last five years, employing the Broad Band Attenuation Vessel (BBAV), the attenuation of partially saturated rocks has been investigated along with the fluid pressure transient caused by a sudden increase of stress. In particular, those studies shed light on the relationships between $1/Q$ and i) saturation, ii) confining pressure, and iii) strain. The combination of laboratory and numerical results helped demonstrating that wave induced fluid flow (WIFF) on the mesoscopic scale is responsible for the large and frequency-dependent attenuation observed in the laboratory measurements of a partially saturated sandstone.
However, these studies lay bare limitations: the behavior of attenuation as a function of i) the distribution of fluids in the pore space and ii) the role of dissolution-precipitation of new mineral phases are still unclear. For instance, when CO_2 is injected in the Earth's crust to pursuit carbon sequestration it would be extremely useful understanding the impact of the gas-water-rock reactions on the rock elastic properties. Potentially, the imaging of the internal structure and fluid distribution in the sample, combined with the measurement of $1/Q$, could serve to this goal helping subsurface monitoring and surveying. This is the primary purpose of our research: uncovering the relationships between i) saturation and dissolution-precipitation, and ii) the elastic properties of a rock.
The present contribution reports the design of a new high-pressure X-Ray transparent vessel which can fit and perform measurements inside the X-Ray computed tomography apparatus (μCT) installed at the University of Toronto. Hence, the scientist can measure changes in $1/Q$ in the sample and, simultaneously, link them to saturation variations, or precipitation-dissolution of minerals. We discuss how the use of the μCT will allow shedding light on the physics of $1/Q$, and present the preliminary results obtained with the new vessel in the μCT. This technological development, together with the results already obtained, will enrich the knowledge of seismic wave attenuation mechanisms for partially saturated rocks to aid geophysical methods.