Geophysical Research Abstracts
Vol. 14, EGU2012-6727-1, 2012
EGU General Assembly 2012

Laboratory Measurements of Frequency-Dependent Seismic Properties of Cracked and Fluid-Saturated Media

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An understanding of the frequency-dependent seismic properties expected of cracked and fluid-saturated rocks of the Earth's upper crust underpins applications as diverse as earthquake forecasting, geothermal power extraction, enhanced oil recovery, and CO_2 sequestration. The capability to perform laboratory measurements with both low-frequency forced-oscillation and high-frequency wave-propagation methods, under conditions of independently controlled confining and pore-fluid pressure, is therefore critical. An important step in the development of such broad-band capability has been the modification of existing laboratory equipment to newly allow flexural, as well as torsional, forced-oscillation testing of cylindrical rock specimens. Flexural oscillation tests on an experimental assembly containing a fused silica control specimen yield results indistinguishable from those of numerical modelling with both finite-difference and finite-element methods – demonstrating the viability of the method [Jackson et al., Rev. Sci. Instrum., 2011]. Both torsional and flexural oscillation methods along with complementary high-frequency wave propagation methods have been applied to specimens of dense polycrystalline alumina and quartzite, each thermally cracked to generate an interconnected network of cracks of low aspect ratio, and tested dry, and saturated with either argon or water. The shear and flexural moduli vary systematically with effective pressure – providing clear evidence of pressure-induced crack closure. Similar pressure-dependent effective moduli measured in low-frequency forced oscillation dry and either argon- or water-saturated are suggestive of saturated isobaric conditions, whereas higher moduli measured at MHz frequency for a water-saturated quartzite specimen probably belong to the saturated isolated regime.