Effect of pore pressure on attenuation of seismic waves in thermally cracked granite

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Elastic wave attenuation is one of important physical properties to estimate the subsurface structure by geophysical explorations, and it is very sensitive to the existence of cracks and pore fluid. Especially, pore pressure is essential parameter that is closely related to geothermal fluid productions and earthquakes. To quantify pore pressure or observe its change over years may lead to the precise evaluation of the geothermal fluid reservoir and prediction of earthquakes. Therefore, it is needed to understand the quantitative relationship between elastic wave attenuation and pore pressure. Previous experimental studies have measured elastic wave attenuation, in those experiments pore pressure is constant and confining pressure is increased. However, there are few studies that measured elastic wave attenuation focusing on the change of pore pressure. In this study, We carried out hydrostatic tests using thermally cracked granite and investing the effect of pore pressure on elastic wave attenuation.
The material we used throughout this study is Aji granite. Specimens were cored from the same block and shape into cylindrical (20 mm in a diameter, 40 mm in a length). Thermal cracking was introduced by slowly heating and cooling specimens up to 200, 400, 600℃ and thereby porosity (initial 0.6%) increases to 0.8, 0.9, 2.8% respectively. Hydrostatic tests were performed under dry and wet (water fully saturated) condition, at room temperature, using intra-vessel deformation and fluid-flow apparatus at Hiroshima University. Under dry condition, confining pressure was increased to 60 MPa. Under wet condition, confining pressure remained a constant value of 60 MPa and pore pressure was decreased from 50 MPa to the atmosphere. Elastic wave was measured by the pulse transmission method and transducers were glued to both sides of specimens. We calculated elastic wave velocity (Vp, Vs) from waveforms recorded in the oscilloscope, and estimated elastic wave attenuation (Qp^{-1}, Qs^{-1}) using Fourier spectral ratio method. As a result, Vp and Vs increase with confining pressure under dry condition whereas they decrease with increasing pore pressure under wet condition. In terms of the attenuation, $Qp^{-1}$and Qs^{-1}decrease as confining pressure increases under dry condition while they increase with pore pressure under wet condition. As confining pressure is increased, attenuation by friction decreased due to the closing and locking of crack contacts. In the experiment of specimen which was heated to 600℃, $Qp^{-1}$is much smaller than Qs^{-1}under wet condition, and the trend is differ from that under dry condition. Under wet condition, attenuation by fluid flow must have a greater effect on Qs^{-1}than Qp^{-1}. Our results indicate that the response to pore pressure is different between velocity and attenuation: as pore pressure increases, Vp/Vs increases but Qp^{-1}/Qs^{-1}decreased. Because attenuation changes more greatly than velocity and is more sensitive to the change of pore pressure, elastic wave attenuation could be useful to observe the change of pore pressure under the ground.

Keywords: Elastic wave attenuation, Pore pressure, Elastic wave velocity, Aji granite, Thermal cracking

