Relationship between elastic wave velocity and attenuation ; An example of water-saturated granite

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Seismic wave attenuation and velocity depend on microcracks and pore fluid in rocks, and these are important physical properties in seismic survey to understand the state of crustal rocks. Especially, excess pore pressure can be the trigger for earthquakes, since effective confining pressure decreases due to the elevated pore pressure. Observing the change of pore pressure is expected to lead to the prediction of earthquakes. Therefore, it is essential to investigate how much seismic wave attenuation and velocity change by the increase of pore pressure quantitatively. Previous experimental studies have measured elastic wave attenuation in sedimentary rocks mainly and the data in igneous rock is poor. Moreover, there are few studies which are focused on the number of microcracks and the change of pore pressure. In this study, we measured elastic wave attenuation and velocity during hydrostatic tests under dry and wet (water-saturated) condition and investigated effects of microcracks and pore fluid on them.
Fine-grained granite, which is collected in Aji region of Kagawa Prefecture, was used in all experiments and its porosity is about 0.8 % under atmospheric pressure. Samples were cored from the same block and formed into cylindrical shape (25 mm in a diameter, 20 mm in a length). Hydrostatic tests were carried out under dry condition at room temperature, using Intra-vessel deformation and fluid-flow apparatus at Hiroshima University. Under dry condition, confining pressure was increased from 5 MPa to 200 MPa. Elastic wave attenuation and velocity were measured by the pulse transmission method, in which the specimen was put in two aluminum spacers with piezoelectric transducers (P- and S-wave) attached. Elastic wave attenuation (Q^{-1}) was estimated from the spectral ratio method using aluminum as a reference spectrum. Elastic wave velocity (V) was calculated by dividing the length of a sample by the travel time passing through it. Axial and radial strains were simultaneously measured by directly attaching a strain gauge to the side of the specimen. Volumetric strain was obtained from them, and the change of porosity was estimated during hydrostatic test quantitatively.
As a result, P-wave attenuation (Qp^{-1}) decreases with increasing confining pressure, while P- and S-wave velocities (Vp, Vs) increases. The change in both attenuation and velocity is large at low confining pressure and it levels off at high pressure. This suggests that the closure and locking of cracks by pressure have an effect on attenuation and velocity. As confining pressure is increased from 5 MPa to 200 MPa, Vp and Vs increase by 18-20 %, whereas Qp^{-1} decreases by 80 %. Therefore, elastic wave attenuation is more sensitive to microcracks in a rock than velocity. In term of porosity, it decreased by 35 % from initial porosity with increasing pressure up to 200 MPa. This result indicates that the closure of microcracks causes the decrease of attenuation and the increase of velocity.
Future tasks are (1)measuring S-wave attenuation (Qs^{-1}), (2)measuring under wet condition, (3)quantitative evaluation of the number of microcracks. By combining these data, we will discuss about the relationship between elastic wave velocity and attenuation under water-saturated condition.

Keywords: Elastic wave attenuation, Elastic wave velocity, Pore pressure, Granite, microcrack