The measurement of velocity dispersion and attenuation of elastic wave in a solid-liquid composite system

Kazuhiro Fujisawa[1]; Yasuko Takei[1]

[1] ERI, Univ. Tokyo

Melt and aqueous fluid phases existing in the Earth interiors have been expected to be a cause of seismic attenuation. However, the quantitative estimation of this effect is still difficult, because of the difficulty to estimate the characteristic time scale. Squirt flow is a mechanism proposed by Mavko and Nur [1975] and is considered to be important in the seismic frequency range. In this mechanism, microscopic heterogeneity of the fluid pressure is induced by the elastic wave field and is reduced by the viscous flow of the fluid between the neighboring pores. The characteristic time scale of the flow of this attenuation mechanism strongly depends on the pore geometry. The purpose of this study is to clarify the effect of pore geometry on the characteristic time scale, so as to answer the question whether the fluid fluid squirt flow actually affects the seismic attenuation.

In this study, we measured the attenuation of the elastic waves (10^5-10^6 Hz), by using two types of solid-liquid composite samples, which have well-known pore geometries. One sample is an analogue partially molten system of a binary eutectic system of organic compounds. This sample has the equilibrium texture, in which the interfacial energy is at a minimum. The dihedral angle was controlled in the range from 35^o to 17^o, close to that of a rock + melt systems [Takei, 2000]. Melt fraction was controlled with the composition. In the other sample, the solid framework was manufactured by sintering the spherical stainless-steel powder, and the interstitial pores were filled with water (fluid viscosity: 1 mPa s) or glycerol (0.3 Pa s). At the experimental frequencies, Biot's mechanism [Biot, 1956] can work as well as the squirt flow mechanism. The latter sample was used to distinguish these two mechanisms, because the dependences of the characteristic frequency on the fluid viscosity are different between these two mechanisms.

Longitudinal and shear waves were excited by the ultrasonic transducers. By using the sinusoidal waves, phase velocity and amplitude decay were measured as functions of frequency. Q^-1 was estimated from velocity dispersion and amplitude reduction independently. The validity of the results was confirmed from the agreement of these values. The data were corrected for the frequency-dependent response of the transducers and the frequency-dependent efficiency of the elastic-wave excitation by the finite-size source. Theoretical model were used for these corrections. In the solid framework sample, burst waves were used, and the travel time was determined by using the direct wave and the reflective wave.

Q^-1 of the partially molten sample was as large as 0.1-0.3. At the same temperature, Q^-1 of the solid phase of this sample was smaller than 0.01. Hence, the large attenuation was due to the coexisting melt phase. Q^-1 was increased with decreasing dihedral angle. Q^-1 was almost constant in the measured frequency range. (QP^-1)/(QS^-1) was nearly 1. The dependence of Q^-1 on the melt fraction was small. For the sintered stainless-steel + liquid sample, QS^-1 was nearly 0.005 for water and smaller than 0.001 for glycerol. This dependence on the fluid viscosity does not agree with the prediction from the squirt flow mechanism. Hence, the squirt flow has a minor effect in the experimental frequency range. Biot's mechanism well explains the results for the sintered stainless-steel + liquid sample, but cannot explain the large Q^-1 in the partially molten sample. These results suggest that the attenuation of the partially molten sample cannot be explained by the viscous flow of the fluid. Viscous deformation of the solid may affect the attenuation. The obtained dependences on the dihedral angle and on the melt fraction, and also the obtained (QP^-1)/(QS^-1) may provide a clue to consider the contribution of the solid anelasticities.