The measurement of dispersion and attenuation of elastic waves propagating solid-liquid composite systems

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In order to detect melt and aqueous fluid in crust and mantle through seismological observation, it is important to study the effects the solid-fluid composite systems have on the propagation of the seismic waves. For the low velocity anomalies caused by the existence of liquid phase, a general theoretical framework has been proposed as a function of liquid volume fraction, pore aspect ratio, and compressibility ratio between solid and liquid [Takei(2002)]. For the attenuation, on the other hand, there has not been established a general theory with which Q of the seismic waves can be estimated quantitatively. In the seismic frequency range, the importance of 'squirt flow' mechanism has been pointed out; the squirt flow between neighboring pores relaxes the microscopic heterogeneity of pore pressure caused by the seismic wave field. It is still difficult to quantitatively estimate the characteristic time scale of the squirt flow for the complicated pore shapes of the real systems. An experimental approach to this problem was undertaken.

The characteristic frequency of the squirt flow is expected to depend on the detailed pore geometry. Hence, it is important to use the samples having a well-known pore geometry. In this experiment, we used borneol-diphenylamine eutectic system (BD).The equilibrium pore geometry of this organic system (eutectic point:43C) is analogous to that of the rock + melt or rock + aqueous fluid systems. Dihedral angle of this system can be varied from 35 to 17 degree by changing the temperature from 47C to 60C.

Velocity dispersion and attenuation were measured independently. The validity of the results can be confirmed by using the theoretical relationship between these quantities [Liu et al.(1976)]. Using the broad-band ultrasonic transducers, elastic waves (from 10^5 to 10^6Hz) were excited by broad-band ultrasonic transducers, whose wavelength is much longer than the grain size. Using the sinusoidal waves, phase velocity was measured as a function of frequency. Burst waves were also used to investigate the effect of the reflected waves. The obtained data were corrected for the frequency-dependent characteristics of (1) the ultrasonic transducers, and (2) the elastic wave excitation from a finite-size source. The validity of this correction was confirmed from the preliminary measurements by using acryl samples.

Q of the partially molten sample was obtained as 3 to 5, which indicates very large attenuation. Q-1 was almost constant through the experimented frequency range. Q-1 was increased with decreasing dihedral angle. The measured velocity dispersion and Q satisfied the theoretically expected relationship. Maximum value of Q-1 can be theoretically calculated by from the relaxed and unrelaxed elastic moduli. If the effective aspect ratio of the present partially molten sample is assumed to be 0.1, which explains well the velocity anomaly, predicted Q-1 is one order smaller than measured Q-1. The obtained dependence of Q-1 on dihedral angle can be explained by the increase of Q-1 by the decreased aspect ratio. The characteristic frequency of the squirt flow, mechanism can be roughly estimated from solid compressibility, fluid viscosity and pore aspect ratio [O'Connell et al.(1977)]. By assuming the aspect ratio to be 0.1, the experimental frequency range is lower than the characteristic frequency. Hence, the observed dependence of Q-1 on the dihedral angle can be also explained by decrease of the characteristic frequency with decreasing aspect ratio. We have not yet obtained an adequate explanation for the experimentally obtained large value of Q-1. Possible contributions from the other mechanism than the squirt flow, such as scattering, should be evaluated.