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Experimental study of seismic attenuation by using a rock analogue

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The purpose of this study is to investigate the high-temperature anelasticity of rocks in the seismic frequency range. In order to estimate temperature anomaly and melt distribution in the upper mantle quantitatively by inversion analyses of three dimensional seismic velocity structures, it is absolutely necessary to understand the anelasticity of mantle rocks in detail. Anelasticity is the transitional property between elasticity and viscosity. Change of seismic velocity is caused both by the anharmonic effect and the anelastic effect. The former can be evaluated quantitatively but the latter can not. To better understand the anelastic effect, it is important to measure anelasticity as functions of frequency, temperature, grain size and melt fraction. By using custom fabricated forced oscillation apparatus[Takei et al., 2011], we have measured the viscoelastic properties of polycrystalline organic borneol as an analogue to mantle rock.

In previous studies[McCarthy et al., 2011; McCarthy and Takei, 2011], dispersion of Young's Modulus E and spectrum of attenuation Q^{-1} were measured as functions of temperature, grain size and melt fraction over abroad frequency range ($10^{-4} < f$ (Hz) < 2.15). Using viscosity n measured at each temperature, grain size and melt fraction, the Maxwell frequency $f_M = E_U/n$ was calculated, where E_U represents the unrelaxed Young's modulus measured at ultrasonic frequency. When Q^{-1} spectrum was plotted as a function of normalized frequency f/f_M, all Q^{-1} spectra collapsed onto a single master curve. The Q^{-1} spectra obtained from olivine aggregates[Gribb and Cooper, 1998; Jackson et al, 2002] also collapsed onto the same master curve, when plotted as a function of f/f_M. This efficiency of the Maxwell frequency scaling strongly suggests that the dominant mechanism of anelasticity in the experimental frequency range is "diffusionally accommodated grain boundary sliding". However, the seismic frequencies normalized by the Maxwell frequency in the mantle are considerably higher than the experimentally measured frequencies. Therefore, experiments at higher frequencies, lower temperatures and larger grain size would be needed.

In this study, in order to measure anelasticity at higher normalized frequency, we have modified the apparatus by using high-speed displacement maters that handle higher sampling rate, and low temperature incubator. At higher frequency, lower temperature and/or larger grain size, Q^{-1} of the sample is low. In order to measure low Q^{-1} accurately, we found it important to improve the rigidity of the apparatus. Also, small time delay of load and displacement maters comes to the issue. So we have to measure the delay accurately. The effect of the delay on attenuation is nonnegligible at high frequency. Based on the result of this calibration, we will check the validity of the high frequency part of the Q^{-1} spectrum in our previous study.

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