Earthquake Research Institute Visiting Researcher Report

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During my time at ERI, I worked with Dr. Yasuko Takei on an experimental project designed to explore seismic wave attenuation. Specifically, we measured attenuation and modulus dispersion in a novel material that has a melting temperature near room temperature. This organic crystalline material called borneol proved to be a very good analogue to mantle rock. The relatively low melting temperature allowed us to explore a much broader range of frequencies than previous studies on olivine-dominated samples [e.g., *Tan et al*., 1997; *Gribb and Cooper*, 1998; *Jackson et al*., 2002, 2004; *Sundberg and Cooper,* 2010]. When normalized by the Maxwell frequency (f_M=E_U/η, where E_U is the unrelaxed modulus and η is viscosity), all data from our study (and previous studies) collapse onto a single attenuation Q^{-1} master curve, regardless of grain size, temperature or compositional differences. By using the analogue material, Dr. Takei and I widely expanded the range of experimental data, thereby accomplishing several important things: 1) we demonstrated that the frequency dependence of Q^{-1} is not constant, but varies over the experimental range; 2) we provided an explanation for small discrepancies in previous datasets: they merely represent different windows on the same master curve; 3) we proved that the Maxwell frequency scaling is universal and that the master curve shown below represents the intrinsic response of quite possibly all crystalline materials; and 4) we demonstrated that anelasticity is a unique function of normalized frequency $f_n=f/f_M$, where f_n is a function of frequency f, grain size d, and temperature T as:

$$f_n(f,d,T)=\frac{f}{f_M(d,T)}=f\cdot J_U(T)\cdot\eta_0 d^p\exp\left(\frac{U}{RT}\right),$$

from which the individual Q^{-1} dependences of each can be calculated (in the function, $J_U=1/E_U$, p is the grain size exponent, U represents the activation energy, and R and T are the gas constant and temperature, respectively). These new findings, while consistent with previous experimental observations, represent a significant difference in the way that experimental data should be scaled to be applied to seismic observations.

With this opportunity of extending my stay via the International Office Visiting Researcher program, Dr. Takei and I were able to finalize these experiments and submit two complimentary papers for publication [*Takei et al.,; McCarthy et al.*] Additionally we were able to commence experiments on partially molten organic samples. Although that data is still being collected at this time, our initial results suggest that the universality described above can be extended to include melt fraction. The presence of partial melt decreases the viscosity and increases the attenuation such that the effect is accurately captured and scaled by the Maxwell frequency. The full findings from this study will be reported in the near future.

I am very grateful to the International Office for providing me with this extra time to complete my experimental study with Dr. Takei. I have learned so much from her. I look forward to much fruitful collaboration in the future with the many kind people I have met during my stay at ERI.

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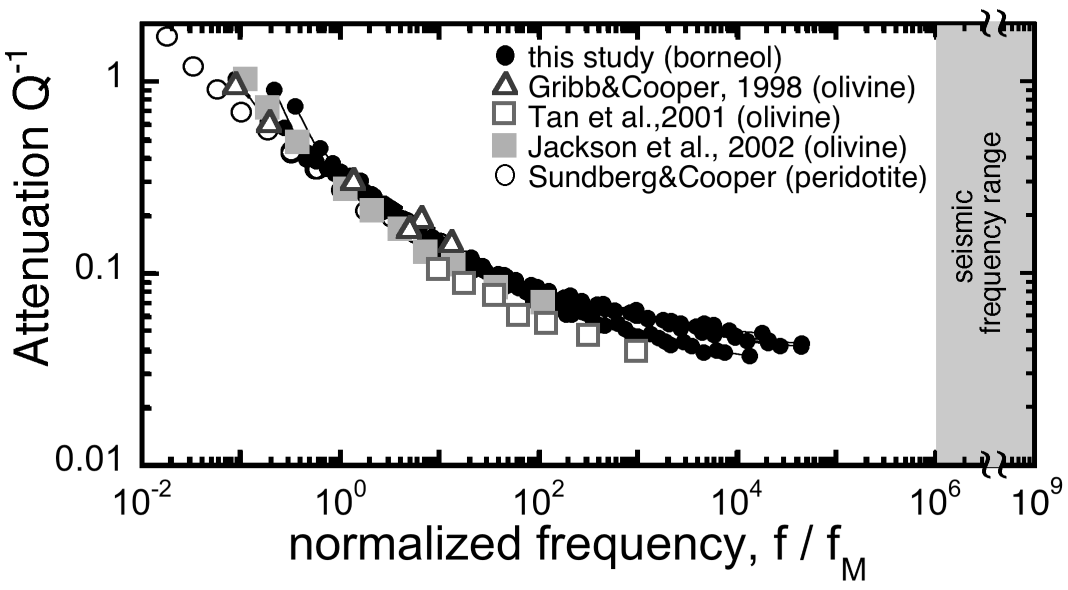

Figure 1: Measured Q^{-1} values from five different studies. All have been normalized by the Maxwell frequency. For McCarthy et al. (black circles), the measured viscosities of polycrystalline borneol and E_U = 2.5 GPa were used (*T*=23-48°C; *d*=3-22μm). For the other studies, the measured viscosities reported in each and the published mildly temperature-dependent shear modulus of olivine (62 GPa; Isaak, 1992) were used. Conditions of those studies were: Gribb and Cooper, T=1200 and 1250°C, *d*=3 μm; Tan et al., T=1200°C, *d*=23.6 μm; Jackson et al., T=1200°C, *d*=2.9 μm; Sundberg and Cooper, T=1200 and 1300°C, *d*=5 μm.