Effects of temperature, melt, and volatile on polycrystal anelasticity: Toward the application to subduction zone

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Recent progress in the experimental approach to the polycrystal anelasticity shows that the reduction of seismic velocity and Q by partial melting occurs in two stages: reduction just before partial melting and that at the onset of partial melting [Yamauchi and Takei 2016]. This new experimental result significantly affects the interpretation of the upper mantle seismic structures. We present a new anelasticity model derived from these new data, together with some applications to the oceanic mantle. The new model is sensitive to the volatiles, which play important roles in subduction zones.
We measured elasticity, anelasticity, and viscosity of polycrystalline aggregates at near-solidus temperatures ($0.89 =< T/T_m =< 1.01$; T_m = solidus temperature), by using organic polycrystals (borneol + diphenylamine binary eutectic system, eutectic temperature T_m = 316 K) as partially molten rock analogue [Yamauchi and Takei 2016]. The results showed that the high-frequency part of the attenuation spectrum was significantly enhanced just below the solidus temperature ($0.94 < T/T_m < 1$) in the absence of melt. In this temperature range, viscous deformation was also enhanced. These changes are called subsolidus effects. The onset of melting at $T = T_m$ caused further enhancement of the elastic, anelastic, and viscous deformation. These changes are called direct effects of melt. When the samples can produce very small amounts of melt (Φ= 0.4 –0.5%) at $T = T_m$, the direct effects of melt were negligibly small, but the subsolidus effects were large. Therefore, due to the subsolidus effects, a region without melt or with a very small amount of melt can be detected as low V and low Q region. We performed a detailed parameterization of the subsolidus effects and presented a new anelasticity model.
The new model successfully explained the steep reduction of shear wave velocity just below the solidus temperature observed near the Pacific ridge [Priestley and McKenzie 2013]. Because the model includes the nondimensional parameter T/T_m, the solidus depression by volatiles affects the prediction of seismic velocity and attenuation under a given T. So far, the application of this model to the upper mantle is limited to the oceanic mantle, where melt fraction is expected to be very small (Φ<< 1%) even beneath the ridge axis. In the subduction zone, melt fraction in the mantle wedge can be larger, and the direct effects of melt may not be negligible. Although the direct effects of melt on elasticity and viscosity are understood well, the direct effect on anelasticity has a large uncertainty. Hence, further experimental study is needed before the application to the subduction zone. Although Yamauchi and Takei [2016] showed that the direct effect of melt on anelasticity is non-negligible for Φ> 1%, quantitative assessment is difficult, because the samples with Φ> 1% used in this previous study had a connected network of solidified melt at $T < T_m$. We are planning an improved experiment to clarify the direct effect of melt on anelasticity, particularly, the effect of melt connection on anelasticity.

Keywords: anelasticity, partial melting, seismic attenuation, seismic low velocity, melt network

