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Softening of P waves in the mantle due to phase transitions

D. Weidner(1) and L. Li(1)

(1) Department of Geosciences, Stony Brook University, Stony Brook, NY, 11794-2100, USA

The bulk modulus, defined as the ratio of pressure change to resulting volume strain, generally reflects the elastic restoring force. In regions that are undergoing phase transitions, additional contribution to the volume strain are possible. At equilibrium, a small pressure increase will increase the amount of the high pressure (small volume) phase while a pressure decrease will increase the amount of the large volume phase. Thus, the bulk modulus of a material at conditions inside a two phase loop will exhibit a very soft bulk modulus if the perturbing pressure is slowly applied relative to the equilibrium time constant. Typically the effective bulk modulus will be an order of magnitude lower than the elastic bulk modulus. If the time scales are similar, then energy will be absorbed, accompanied with a reduction in the bulk quality factor, Q_K, and some softening of the bulk modulus. If the equilibrium time scale is shorter or equal to the P wave period, then we should expect two phase regions (including olivine to wadsleyite, wadsleyite to ringwoodite, ringwoodite to perovskite, pyroxene to garnet, and garnet to perovskite) to have anomalously slow P waves and, possibly, bulk attenuation.

Here we report laboratory data in which bulk modulus is softened by a stress induced variation of the proportion of coexisting phases. We use Fa70Fo30 olivine as our sample. Experiments are performed in a multi-anvil high pressure apparatus (Deformation DIA) using synchrotron (NSLS) X-ray radiation as the probing tool. Pressure is up to 12 GPa and temperature is up to 1400 ^{o}C. Measurements were carried out within the binary loop where alpha-gamma olivine phases coexist. We apply uniaxil oscillation stress onto the sample and Young's modulus and Q^{-1} are measured at frequency of 0.1-0.01Hz. Our results indicate that the sinusoidal force applied to the sample in

$\alpha + \gamma$ region has much lower bulk modulus and higher Q^{-1} than at in the single phase regions.

Our data are consistent with a diffusion controlled model of Jackson, 2007, where the characteristic time decreases with decreasing strain. If we extrapolate the model to Earth conditions with probing P waves, we conclude a relaxation time of the reaction of less than one second. This suggests that the two phase zones in the Earth should have slow P waves.