

Elastic Moduli of single crystal Forsterite at 295 K as a function of pressure

- ▶ **Linear variation** of all elastic moduli with pressure.
- ▶ Difference between ISS (Impulsive stimulated Scattering) on $(\text{Mg}_{0.9}\text{Fe}_{0.1})_2\text{SiO}_4$ and Brillouin scattering: Difference in **iron contents** in sample
- ▶ **c_{55} is linear** in present study up to 16.5 GPa and it is reported **non-linear in ISS** study : NOT CLEAR
- ▶ Upper mantle mineralogy models have used low pressure ultrasonic data ($\leq 1\text{GPa}$) extrapolated to higher pressures for comparison to seismic data.
- ▶ Pressure derivative and elastic moduli from present study are $30 \pm 10\%$ and $20 \pm 10\%$ lower than low pressure data

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Pyrolite Model of mantle composition: ~60% of olivine by volume

- ▶ **Uncertainty** → (1) derived from samples that originate from shallow depths (≤ 200 km) (2) Chemical homogeneity of mantle as whole is assumed
- ▶ **Problem** → Seismic velocity profiles provide the most direct constraints on the deep mantle. Seismic and lab data on acoustic wave velocities in $(\text{Mg,Fe})_2\text{SiO}_4$ are conflicting (mainly because of uncertainties in the relevant pressure and temperature dependence of the elastic moduli.
- ▶ **Aim** → To do elasticity measurements on forsterite to transition pressures and to combine with other data on elasticity data on α - β system to constrain the amount of $(\text{Mg,Fe})_2\text{SiO}_4$ consistent with lab and seismic data for 410 km discontinuity.
- ▶ **Experiment** → Elastic Moduli of single crystal forsterite (α - Mg_2SiO_4) at pressure between 3 and 16 GPa using Brillouin scattering in Diamond Anvil Cell. Using Brillouin scattering. The acoustic velocities can be determined from the frequency shifts of light scattered from thermally generated acoustic waves.
- ▶ **Assumptions** → (1) α - β phase change in a homogenous mantle composition is sole cause of discontinuity.....(2) ignoring any phase transition, (3) changes in element partitioning and (4) the proportions of other phases across the transition. **Last two** effects can be neglected to first order: Phase equilibria...**First effect** would further reduce amount of olivine
(5) No texturing of mineral aggregates dK_s/dK_p and dG/dP of b-phase assumed to be equivalent to a-phase: If the value is lower, the allowed olivine content will be much higher (52%)

TABLE 1 Elastic properties of $(\text{Mg}_{0.9}\text{Fe}_{0.1})_2\text{SiO}_4$

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Bulk and Shear modulus and density defines the compressional and shear wave Velocities of a random polycrystalline aggregates.

- ▶ At ambient pressures and temperature, P and S wave velocity contrasts between α and β -phases of Mg_2SiO_4 are 13%
- ▶ Velocity contrasts near 410 km: 4-5 % for compressional waves, 4-4.6 % for shear waves (from 1D seismic velocity profiles of upper mantle constructed from body waves analysis)
- ▶ Amount of forsterite constituent :30-40% by volume (α - β velocity contrast is independent of pressure and temperature.
- ▶ **Comparison on pressure effect on the velocity contrast** (from present study, ultrasonic measurements of acoustic velocities in polycrystalline Mg_2SiO_4 to 3 GPa, and 1 GPa ultrasonic data for α -phase) :
 - ▶ From previous reports: α - β velocity contrast decreases significantly with pressure (at RT) Present Study: velocity contrast is nearly unchanged from ambient values (12 % of P and 14% for S waves) at 13.8 GPa → the velocity contrast between α and β phases of Mg_2SiO_4 is largely independent of pressure at ambient temperature
- ▶ **Effect of both pressure and temperature on α - β velocity contrast:** Densities and moduli are corrected for the effect of temperature and extrapolated adiabatically using 3rd order finite strain theory. Elastic moduli: linear functions of temperature and corrected for 10 mol% of Fe.

Aggregate Bulk and Shear moduli of forsterite as a function of pressure

- ▶ Solid symbols: present study
Solid lines: third order fit to finite strain equation
Error bars: Voigt and Reuss limits
dashed line: ISS study on $(\text{Mg}_{0.9}\text{Fe}_{0.1})_2\text{SiO}_4$.
- ▶ At 13.8 GPa, aggregate velocities measured in the present study is 2.7 GPa $\pm 0.7\%$ higher than extrapolated data.
- ▶ Bulk modulus agrees to data on Fe bearing samples to 3 GPa and 12.5 GPa
- ▶ Pressure derivative of the bulk modulus determined by Brillouin data is consistent with that from X-rays

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Sound velocities in $(\text{Mg}_{0.9}, \text{Fe}_{0.1})_2\text{SiO}_4$ along 1250 C adiabat compared to seismic velocity profiles for upper mantle

- ▶ Solid Curve calculated using $dG/dT = -0.014 \text{ GPa/K}$ for β -phase, consistent with α -phase
- ▶ Acoustic velocities of Spinel phase is also included which is stable below 540 km depth
- ▶ Fraction of Olivine corresponding to the magnitude of seismic jumps
27% for Shear waves
32% for compressional waves
assuming 4.3% and 4.5% seismic velocity discontinuities, resp.
- ▶ Olivine Abundance necessary to satisfy this data: 38%
- ▶ Considering large dG/dT (high sensitivity of β -phase to temp.,) current data is not consistent with an olivine composition at 410 km

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- ▶ This study suggest that olivine content in the upper mantle should be in the range of 30-50% to match the observed velocity jump at 410 km depth
- ▶ Other experiments concluded that pyrolite or peridotite compositions within 60 vol% olivine are also acceptable
- ▶ Irifune showed that olivine becomes Mg rich with increasing pressures

Density of olivine is higher with increasing iron content and variations in iron content can overcome or at least reduce the above said difficulties encountered with pyrolite model.

Velocity jumps are dependent on pressure and temperatures: decreases with increases pressure...