Wave velocities of enstatite at high-pressures: Implications for chemical variations in the upper mantle

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1. Introduction

Seismic "X" discontinuity:

- Depth range: 240-340 km
- Shear impedance increase: 3-7.5%
- Widespread, but not global
- Large depth variation
- Potential relationship to orthoenstatite (Oen) transitions

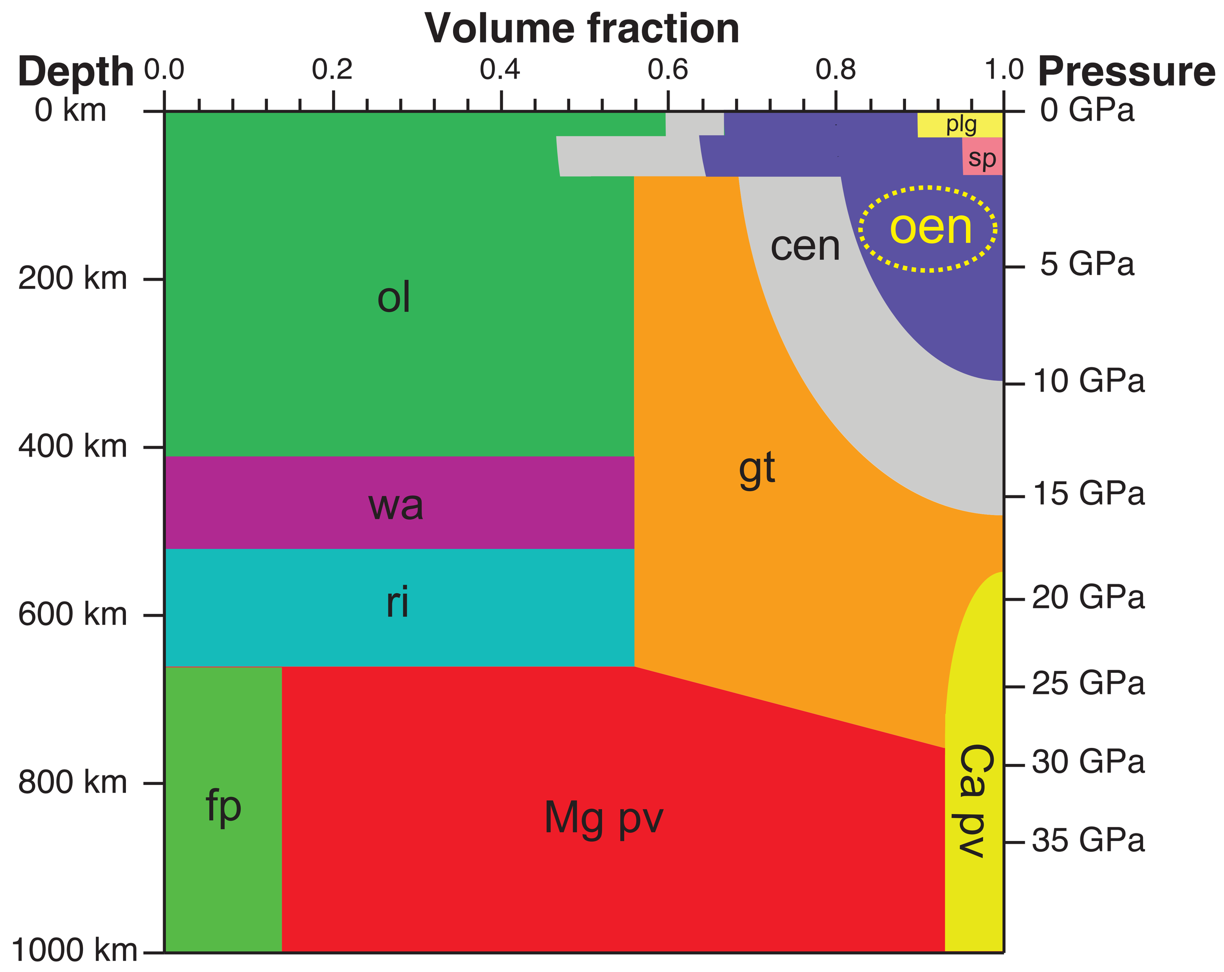
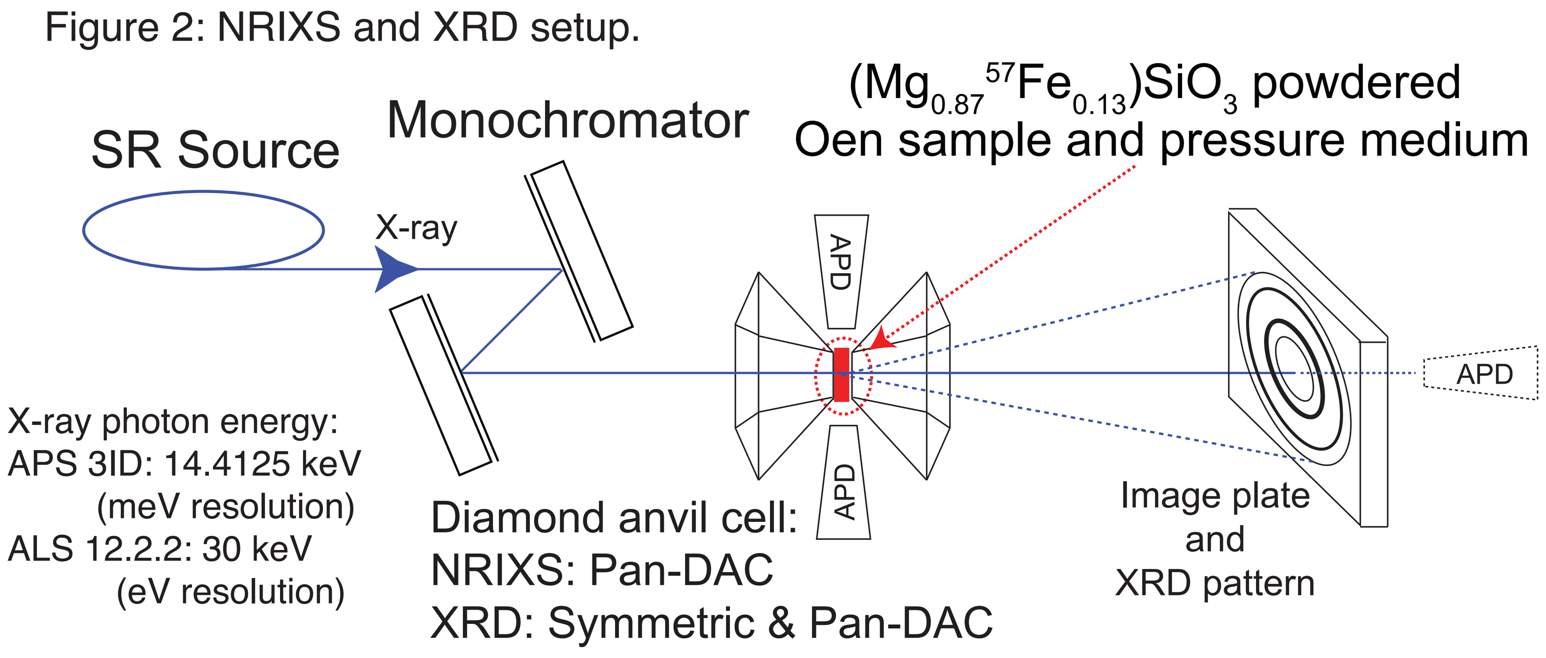


Figure1: Mineral volume fractions in the mantle's top 1000 km based on the pyrolite model (Frost, 2008)

2. Methodology

Nuclear **R**esonant **I**nelastic **X**-ray **S**cattering: APS Sector 3-ID
X-Ray **D**iffraction: APS Sector 3-ID & ALS Sector 12.2.2
First-principle **D**ensity **F**unctional **T**heory calculation

Figure 2: NRIXS and XRD setup.



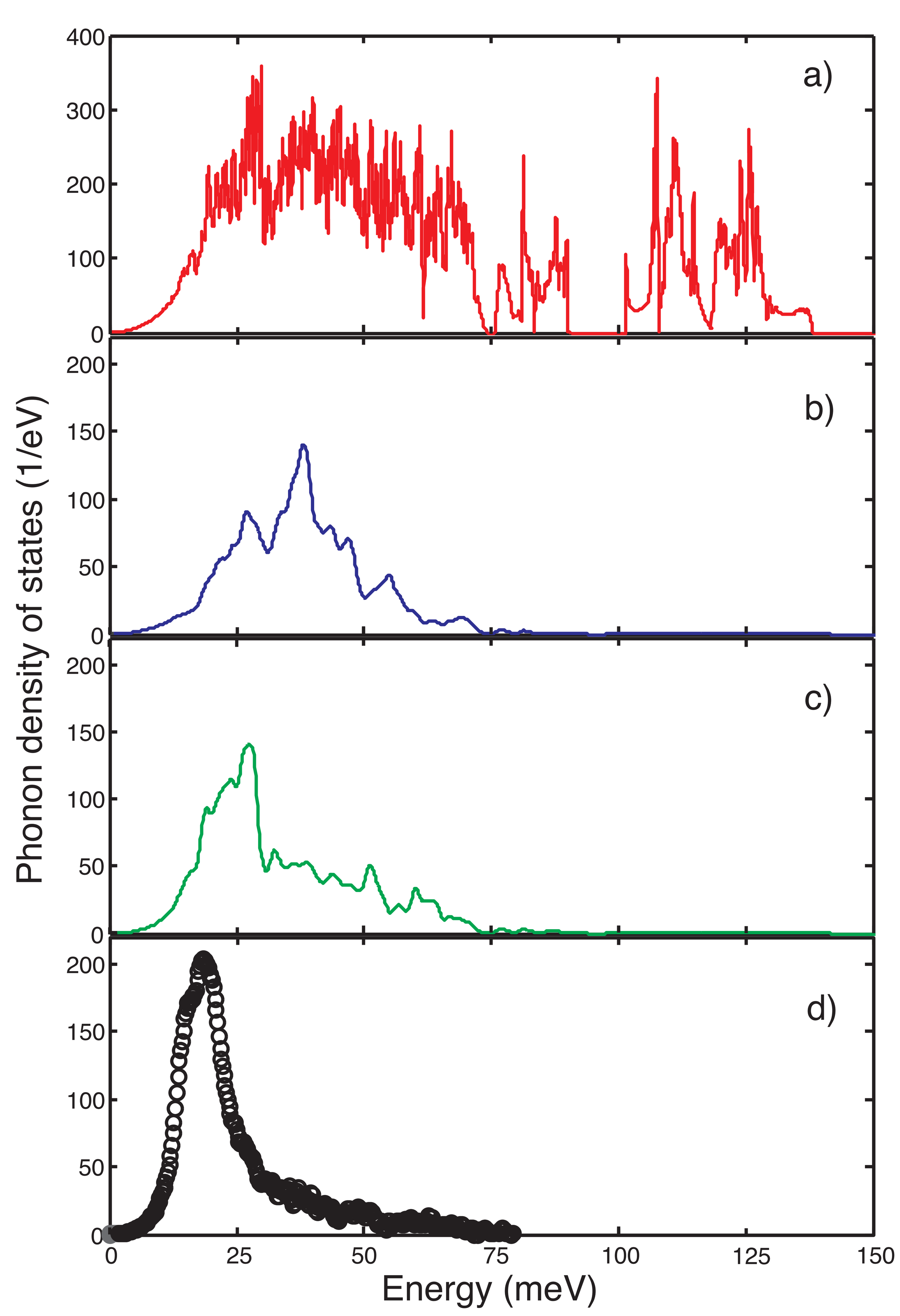


Figure 3: The DFT-calculated phonon DOS (at 0 K) and measured Fe partial projected phonon DOS for Oen at ambient pressure (at 300 K): (a) total phonon DOS of $Mg_2Si_2O_6$ Oen, (b) partial phonon DOS for 25% Mg replaced by Fe on the M1 site, (c) partial phonon DOS for 25% Mg replaced by Fe on the M2 site, and (d) measured Fe partial projected phonon DOS for En87 at 300 K.

3. Results

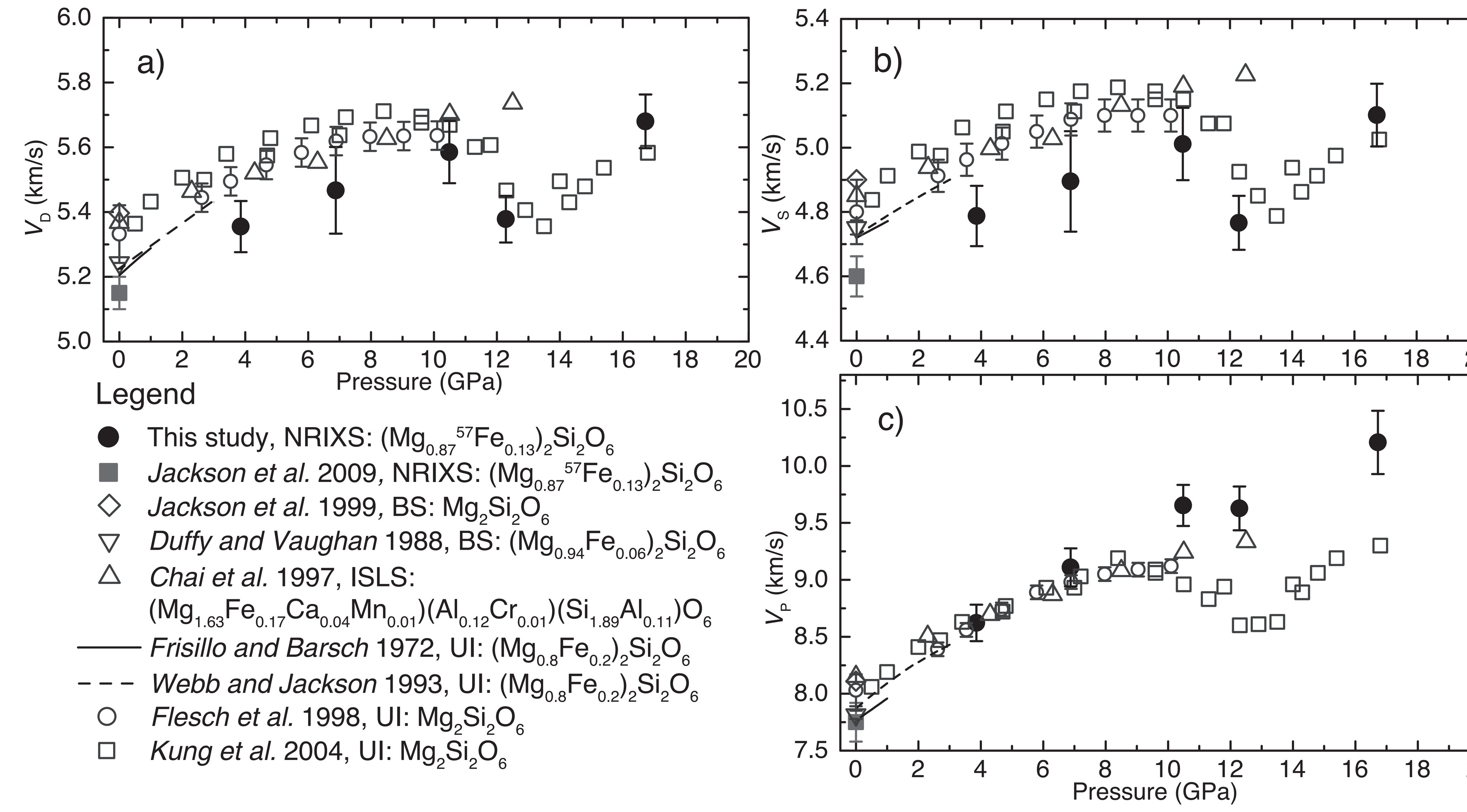


Figure 4. Sound velocities determined from this experiment and from previous measurements (see Legend). (a) Debye velocity (V_D), (b) shear velocity (V_S), and (c) compressional velocity (V_P). UI: ultrasonic interferometry; BS: Brillouin spectroscopy; ISLS: impulsive stimulated light spectroscopy.

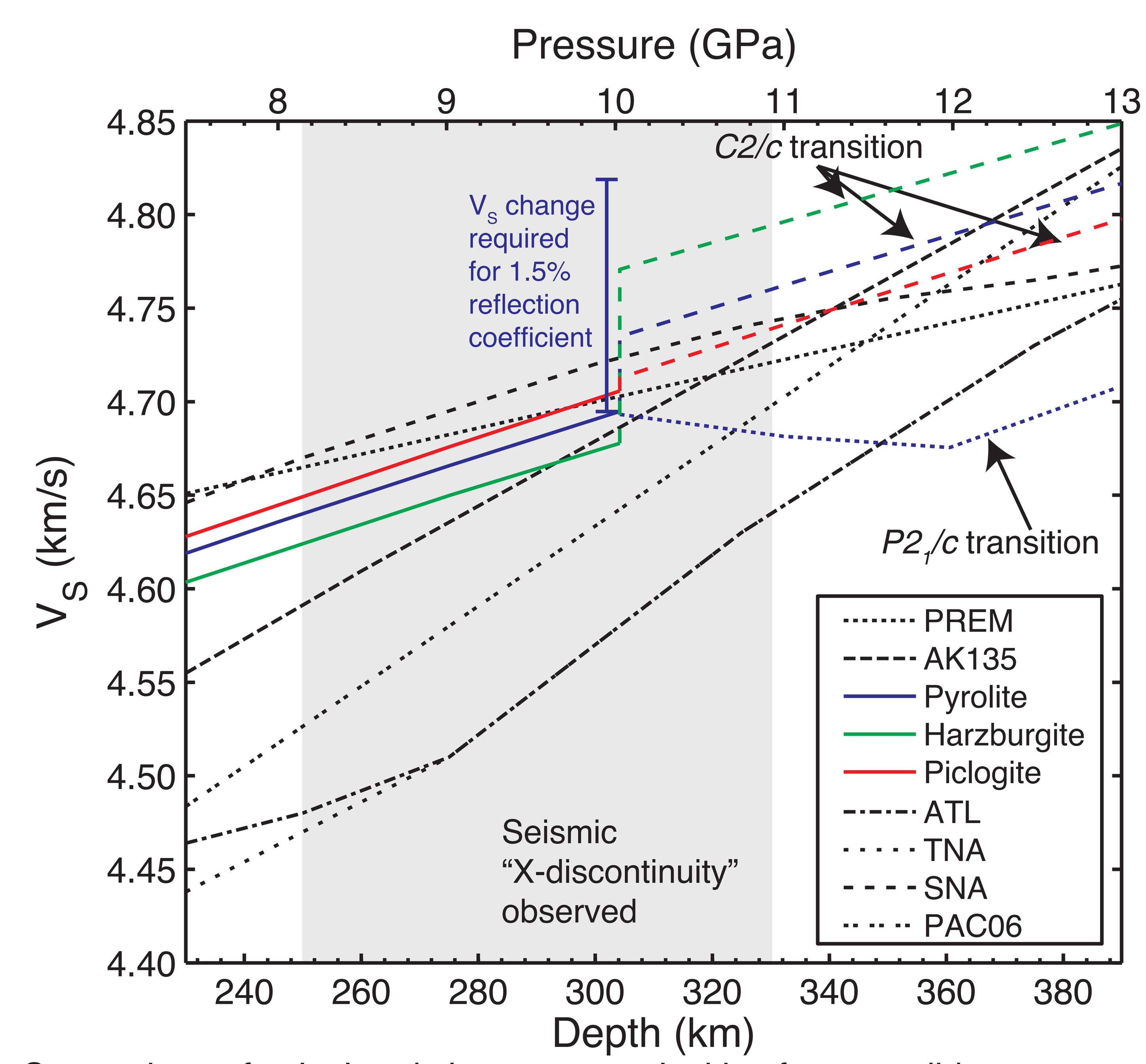


Figure 5. Comparison of calculated shear wave velocities from candidate upper mantle petrological models (1400°C adiabat) with seismic profiles. At P >10 GPa: assuming *C2/c* transition (dashed curve, Kung et al., 2005); speculating that the $P2_1/c$ transition occurs (dotted curve, this study). Seismic "X" discontinuity observed (shaded region, Revenaugh and Jordan, 1991; Bagley and Revenaugh, 2008). Global seismic models: PREM (230–390 km in depth, 7.5–13.0 GPa in pressure, interpolated between reported values, Dziewonski and Anderson, 1981) and AK135 (Kennett et al., 1995). Regional seismic models: SNA (Grand and Helmberger, 1984), TNA (Grand and Helmberger, 1984), ATL (Grand and Helmberger, 1984), and PAC06 (interpolated between reported values, Tan and Helmberger, 2007). Shear velocity jump required for a seismic reflection with 1.5% reflection coefficient in a pyrolytic mantle (blue scale at 300 km, Bagley and Revenaugh, 2008).

4. Conclusions

- Experiments done at high-pressures to determine V_P, V_S, and density of iron-bearing enstatite
- Phase transition occurs around 12 GPa (360 km depth), characterized by low velocities
- Note global models do not agree – regional studies are crucial to understand chemistry
- Enstatite-rich rocks not as low as active tectonic regions, but lower than stable regions

Selected references

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