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Elasticity of high-pressure clinoenstatite under mantle conditions: implications for the origin of the X-discontinuity

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The X-discontinuities, with 2~8% impedance contrasts between 250 km and 350 km depth, have been detected beneath various tectonic settings such as stable continents, hotspots, and near subduction zones. However, the genesis of the X-discontinuity remains under debate. The coesite-stishovite transition in eclogite is a popular mechanism due to its considerable wave impedance contrasts. But the sole coesite-stishovite transition is insufficient to explain the indistinguishable seismological Clapeyron slope of the X-discontinuity [1] since the transition has a large positive Clapeyron slope. On the contrary, the transition from orthopyroxene (OPX) to high-pressure clinopyroxene (HPCPX) is another candidate mechanism but is often ignored based on its relatively small impedance contrasts reported by Woodland and Angel (1997) [2], which was assumed from Birch's law without direct wave speed measurements.

In the study, we performed first-principle calculations to obtain the elasticity of high-pressure clinoenstatite (HPCEN, $MgSiO_3$), the Mg endmember of HPCPX, at high pressure and temperature. we find that the wave impedance contrasts of the OPX-HPCPX transition are ~6%, almost the double of the previous estimations. The OPX-HPCPX transition can explain the X-discontinuity as long as OPX content exceeds 30%. Since eclogite-derived silica-rich melts not only promote the enrichment of OPX, but also decrease the content of solid-state coesite, the degree of partial melting of oceanic crust is crucial for the X-discontinuity mechanisms. Although partial melting of eclogite is merely considered before, we find eclogite is indeed subject to melting in hot or wet regions. Consequently, we propose that the coesite-stishovite transition dominates where eclogite undergoes no melting while the OPX-HPCPX transition dominates where partial melting of eclogite occurs. The model can interpret seismological observations in an unprecedented way, such as the indistinguishable seismological Clapeyron slope of the X-discontinuity, the double X-discontinuities, and the anomalous shallow X-discontinuities beneath hotspots, indicating the wide distribution and partial melting of eclogite. The origin of the X-discontinuity provides a key way to illuminate the melting situation of eclogite in the deep earth.

References

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