Evidence for a Ubiquitous Seismic Discontinuity at the Base of the Mantle

Sidorin, Gurnis, & Helmberger
Science, 1999
Discontinuity @ CMB

• Sharp 2-3% velocity discontinuity ~250 km above the CMB

• Scd phase between S and ScS (core reflection) in the 65 – 83° distance range

• Variation in relative timing and amplitude
  – Intermittent

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Lowermost 240 km of Mantle

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Add a layer anomaly to match PREM to Tomography
2 Layers = 1 Discontinuity

- What is the depth of this discontinuity?
- How do we use the shear wave anomaly to make inferences about the depth of the discontinuity?
What if the Discontinuity is a Phase Transition

• “Dynamic and seismic models suggest a phase change is more likely than thermal gradients or chemical heterogeneity”
Calculate Synthetic Seismograms

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Statistical Analysis of Phase Boundary Parameter Space Using Synthetic Seismograms

\[
\left\langle \delta T_{\text{Scd}} - s \right\rangle = \left[ \frac{1}{N} \sum_{1}^{N} (T_{\text{synth}} - T_{\text{data}})^2 \right]^{1/2}
\]

Preferred Model

- \( \gamma_{ph} = 6 \text{ MPa/K} \)
- \( h_{ph} = 200 \text{ km} \)
Least Squares fit to the predicted travel time curve

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Compare the fitted curves to observed travel times
Preferred Model

- $\gamma_{ph} = 6 \text{ MPa/K}$
- $h_{ph} = 200 \text{ km}$

$\gamma_{ph} = 0 \text{ MPa/K}$
$h_{ph} = 250 \text{ km}$

$\gamma_{ph} = -4 \text{ MPa/K}$
$h_{ph} = 275 \text{ km}$
Preferred Model

- $\gamma_{ph} = 6 \text{ MPa/K}$
- $h_{ph} = 200 \text{ km}$

Southern Caribbean: 2.75% velocity jump @ 250 km above CMB
Northern Caribbean: 2.45% velocity jump @ 290 km above CMB
Depth Dependent Discontinuity

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Global Model of Phase Transition
Elevation

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Inverse Problem

- If local structure can modulate the strength of triplication (assuming ubiquity).

- Is it possible to predict the observed geographic pattern using the structure inferred by tomographic inversions?

- Central Pacific = Weak triplication

- Caribbean = Strong triplication
According to the data, these synthetics are consistent with actual data. Predicted strength of triplication.
Conclusions

• “The agreement of these trends with observations indicate that the D” discontinuity may a ubiquitous feature with the strength of the resulting seismic triplication modulated by larger scale structure”

• “The discontinuity must be correlated with large scale structures such that it’s elevated in fast regions (hot) and depressed in slow regions (cold) – implying a positive clapeyron slope.”
These guys look pretty smart now!

- “No relevant phase transition has yet been observed in the major elements of the lower mantle”

Ab-initio calculations for Post Perovskite

- 9.56-9.85 MPa/K (Oganov and Ono 2004)
- 7.5±0.3 MPa/K (Tsuchiya et al., 2004)