Fuzzy Patches on the Earth's Core-Mantle Boundary?

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Introduction

- Seismological investigations revealed the presence of ULVZ in many locations at the base of the mantle
- Siginifcant reductions in V_P and V_s were invoked to match the observed waveforms: **$-\delta V_p \leq 5\text{-}20\%$, $-\delta V_s \leq 10\text{-}50\%$** and thickness **~5-50 km**
- Such low-velocities were interpreted in terms of partial molten just above the CMB
- Significant heterogeneity in properties within ULVZ were suggested

Modeling trade-offs

1. Significant tradeoffs are recognized in ULVZ modeling, but only a relatively narrow range of models satisfying the seismological observations have been explored
2. Modeling of the SPdKS waveform allows other models to be evaluated
3. Considering the effects of perturbations in ρ and wave velocities (**V_s, V_p**) in modeling data

Modeling trade-offs

Fig. 1 summarizes results for several models that match data obtained from the 3/31/94 Fiji event

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Clearly, a range of ULVZ thicknesses (2-10km), density perturbations (0-60%), and velocity perturbations can be found that match data.

A more comprehensive analysis of tradeoffs among ULVZ characteristics for the Fiji data set

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ULVZ Density Considerations

The modeling results indicate the possibility of surprisingly large density increases of up to 60%

- require a major variation in bulk composition but no phase transition having density change >10-15%
- Can be ascribed to chemical reaction/contamination at the lowermost mantle by the core

ULVZ (reductions in V_s and V_P)

$V=[M/\rho]^{1/2}$

M decrease

Density increase

Partial melting

?

?

Partial melting (δV_S:δV_P=3:1)

Chemical contamination (and reaction) by the core

Mutually reinforcing

Partial melting is in some cases incompatible with a ULVZ containing large ρ anomalies

Partial melt vs no melt condition

$V=[M/\rho]^{1/2}$

$\delta\ln V=(1/2)\delta\ln M-(1/2)\delta\ln\rho$

and $-\delta\ln V=(1/2)\delta\ln\rho-(1/2)\delta\ln M$

If $\delta\ln M<0$ (caused by partial melting)

then $-\delta\ln V>(1/2)\,\delta\ln\rho$ for melting

else if $-\delta\ln V\leq(1/2)\,\delta\ln\rho$ $(\delta\ln M>=0)$

then partial melting is not possible

For a sufficiently large density increase, the entire drop in velocity is due to density; the modulus does not decrease, and an increase in modulus may even be required in order to match the velocity change

No melt condition

$-\delta \ln V \leq (1/2)\delta \ln \rho$

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Model solutions w/o melt correspond to conditions involving the most extreme perturbations in velocities and density, along with the small values of thickness (< 3-7km)

Not all anomalies require lowermost mantle partial melting, the authors suggested that

(1) A thin (~1km) “core rigidity zone” at the top of the outer core (CRZ)

(2) A core-mantle transition zone (CMTZ) at the top of the outer core

Can also explain the observations

Comparing synthetic seismograms for CRZ with those of ULVZ that fits the Fiji data shows the strong similarity in SPdKs behavior

But CRZ must have a non-zero V_S, the perferred thickness is ≤ 1km.

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ULVZ 5km	δV_P -10%	δV_S -30%	$\delta\rho=0$
CRZ 1.5km	V_P 8km/s	V_s 3km/s	ρ 9.6Mg/m^3

ULVZ 5km	δV_P -10%	δV_S -30%	$\delta\rho=0$
CRZ 1km	V_P 8km/s	V_s 3km/s	ρ 9.6Mg/m^3
CMTZ 2km	Properties change from pure mantle to pure core		
PREM	Preliminary Reference Earth Model		

ULVZ, CRZ and CMTZ waveforms match data well, and are clearly distinguishable from the PREM waveforms

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CMTZ or CRZ models of thickness ~1km can produce observable waveform **disortions**

Changing the thickness yields different separations between the arrivals of SKS and SPdKS waves, or PcP (or ScP) and precusors (or post-cursors)

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Discussion & Conclusion

- The physical interpretation of seismologically anomalous zones at the CMB are necessarily speculative and waveform modeling sucks
- Both partial melting and chemical contamination may be necessary to explain the anomalous data
- Fuzzy patches at the CMB may be zones of intense chemical and physical interactions between the mantle and core