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: -δV_p≤5-20%, -δV_s≤10-50% 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 p 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

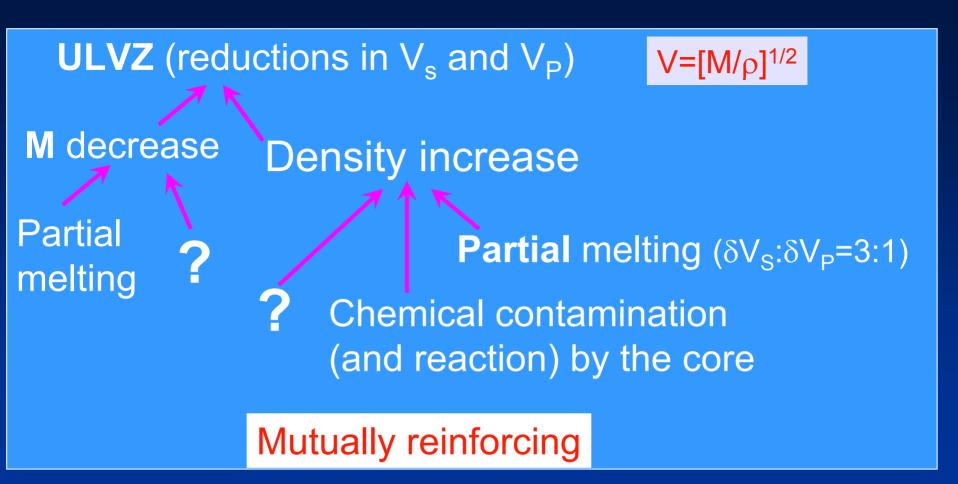
Clearly, a range of ULVZ thicknesses (2-10km), density perturbations (0-60%), and velocity perturbations can be found that match data.

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

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



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

Partial melt vs no melt condition

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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 δlnM<0 (caused by partial melting)
then -\delta \ln V > (1/2) \delta \ln \rho for melting
else if -\delta \ln V \le (1/2) \delta \ln \rho (\delta \ln M > = 0)
then partial melting is not possible
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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 –δlnV≤ (1/2)δlnρ

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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.

ULVZ	δV _P	δV _S	δρ=0
5km	-10%	-30%	
CRZ	V_{P}	V _s	ρ

3km/s

9.6Mg/m³

8km/s

1.5km

ULVZ	δV_P	δV_{S}	02	
5km	-10%	-30%	δρ=0	
CRZ	V_P	V_s	ρ	
1km	8km/s	3km/s	9.6Mg/m ³	
CMTZ	Properties change from			
2km	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

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)

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