C3.4 Mantle structure

- Mantle behaves as a **solid** on short time scales (seismic waves travel through it and this requires elastic behaviour).

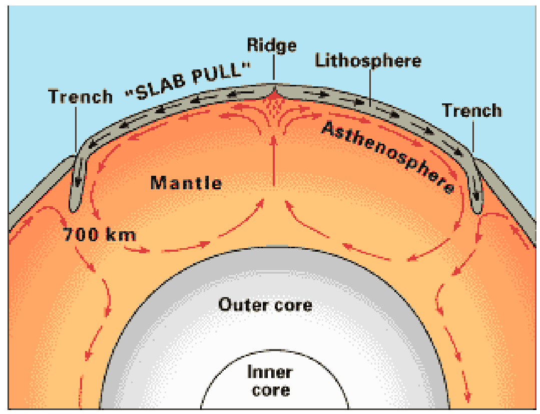
- Over geological time scales the mantle behaves as a very **viscous liquid**. See estimate of viscosity from isostatic rebound in B7.

- With heating from below, and/or cooling from above, convection can occur.

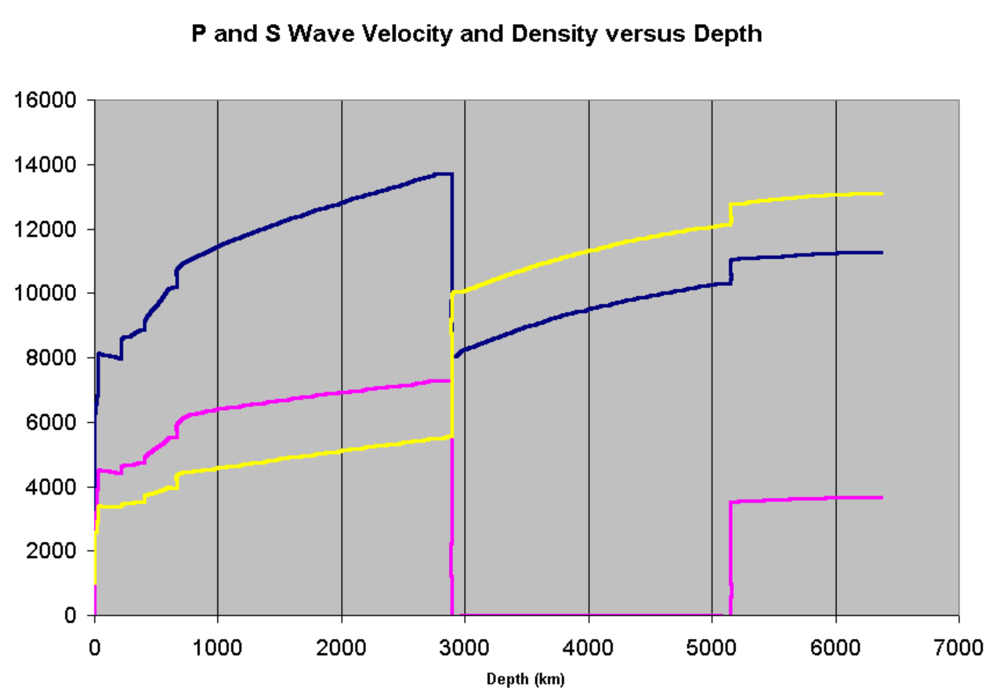
- Material heated at the base of the mantle will rise through buoyancy effects.

- After cooling at the surface, it sinks back. Carries heat from interior to surface.

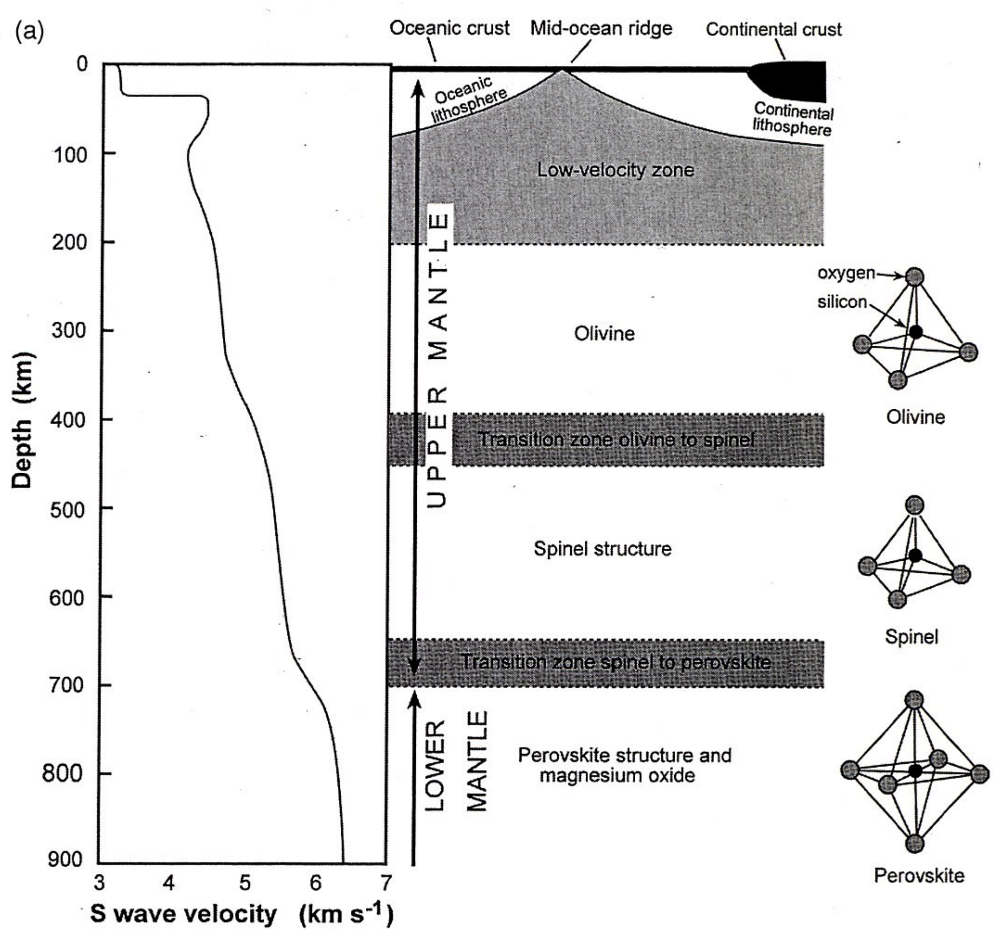
- Drives plate tectonics



C3.4.1 Vertical (radial) variations in mantle structure



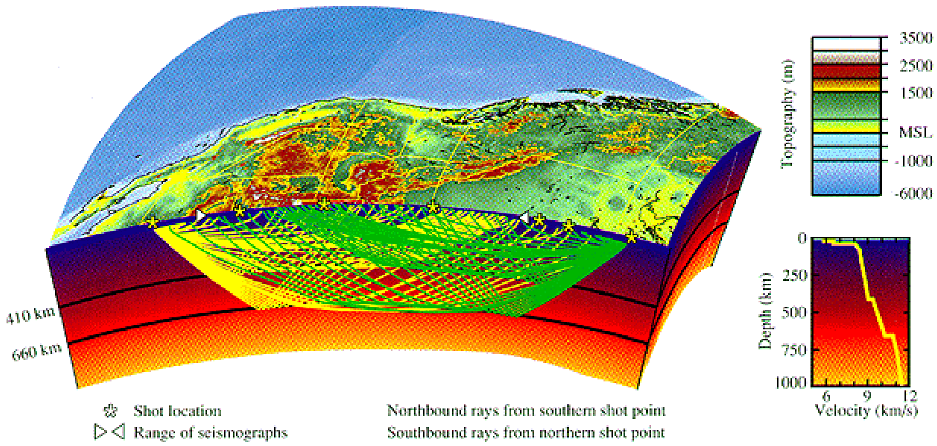
- 100-200 km, slow increase in velocity
- LVZ. Asthenosphere. Partial melt?
- 220 km discontinuity? Not observed everywhere.
- 410 km olivine transforms to spinel
- 660-670 km spinel to perovskite
- Above 600 km is upper mantle
- 410 to 670 km is term the mantle transition zone



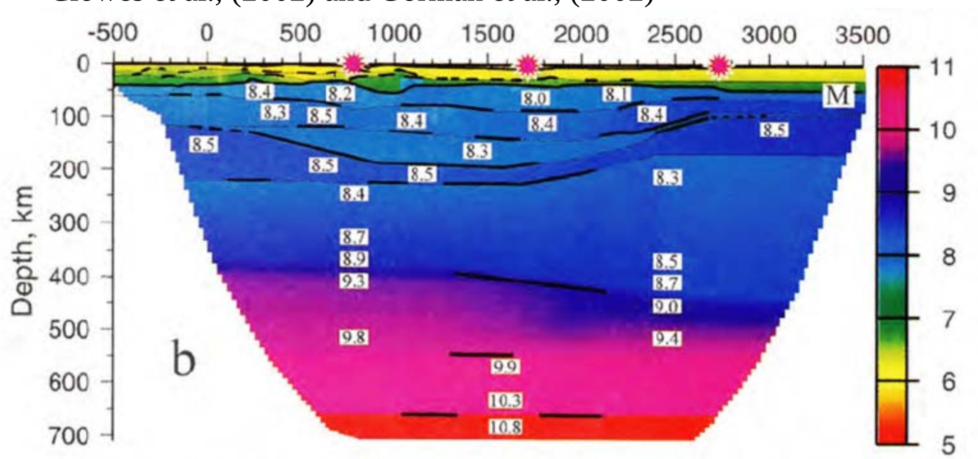
Fowler 8-11

- Does mantle convection extend all the way from the surface to the CMB?
- Or is it divided into two convecting systems divided by the mantle transition zone (440-660 km).

C3.4.2 Refraction surveys that sample the upper mantle



- DeepProbe experiment in Canada and U.S.
- Clowes et al., (2002) and Gorman et al., (2002)



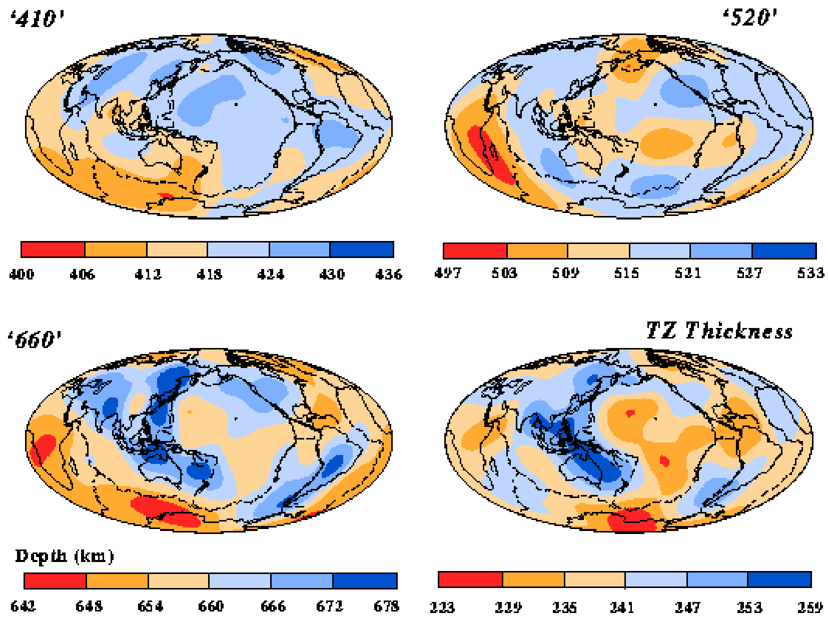
- Deep seismic sounding in Soviet Union using peaceful nuclear explosions (PNEs)
- Details in Morozova *et al*., J. Geophys. Research, (1999)

C3.4.3 Departure from radial symmetry – seismic tomography

- significant variations in velocity with horizontal position occur.
- Smaller than variation in velocity in vertical direction. Horizontal changes expressed as a percentage of the expected value (e.g PREM).
- Map variations in seismic velocity with seismic tomography.

- Need many seismic rays from many earthquakes that cross each other.

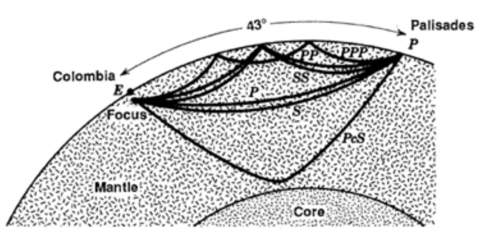
(a) Global Depth variations in 410 and 660 km

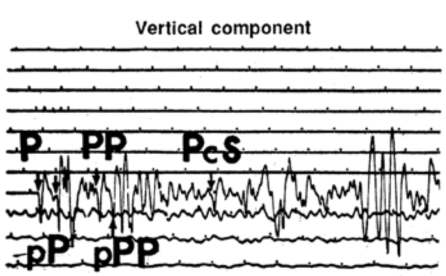


Shearer and Masters (1992)

(b) Some models from tomography

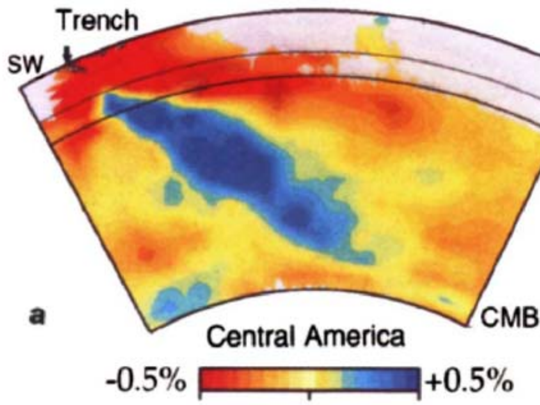
Dziewonski and Woodhouse (1987) (Harvard)





- Early models, showed high velocity in upper mantle under continents, slow under mid-ocean ridges.

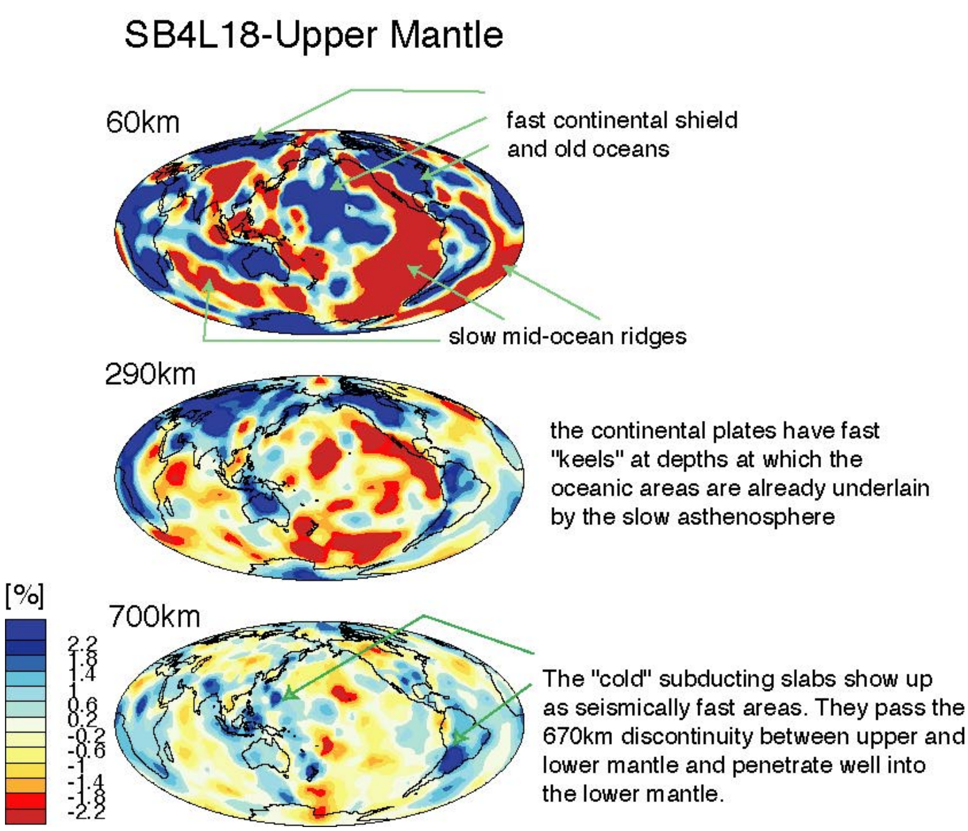
Van der Hilst (MIT)



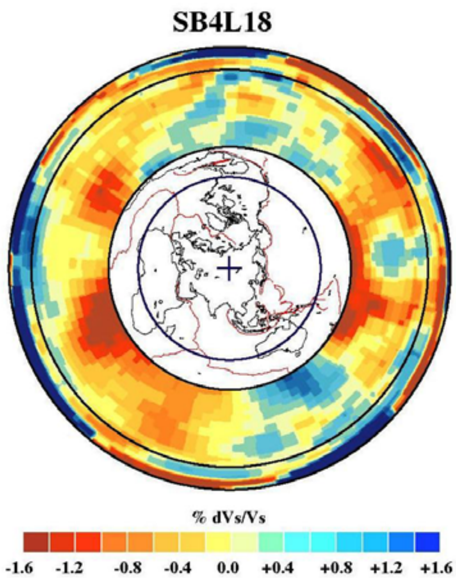
- Showed slabs penetrate the transition zone
- Resolution tests to prove these structures can be resolved.

Masters et al., (2000) UCSD

SB4L18 From group at Scripps Institution of Oceanography (Masters et al., 2000)



- large amplitude velocity anomalies in the upper mantle that correlate with surface tectonics
- moderately large amplitude anomalies in the lowermost mantle
- small-amplitude but significant anomalies in the mid-mantle (slabs?)

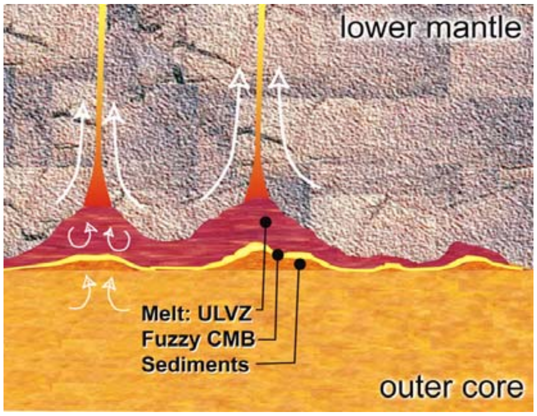


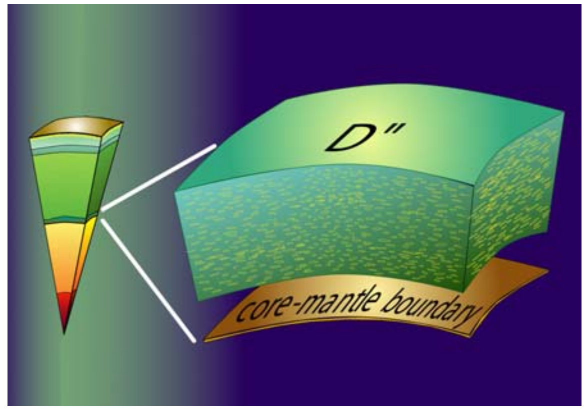
"*This figure shows a slice through SB4L18 that goes through the center of the Earth. The cut of the slice is along the great circle that is marked by the blue circle in the center of the plot. One of the most prominent features is a seismically fast slab-like anomaly that extends from the surface beneath the Continental US well throughout the whole mantle. This is thought to be the image of the subducted Farallon plate.*

Other marked features include two large slow anomalies under Africa and the central Pacific Ocean that originate at the CMB (core-mantle boundary) and extend well up into the lower mantle. Also prominent are the seismically fast continental shields in the upper mantle: the South and West African Cratons, the southern extension of the Canadian Shield and the Australian Shield. Mid-ocean ridges are associated with slow anomalies in the upper mantle. The black circle marks the 670km discontinuity between upper and lower mantle."

http://mahi.ucsd.edu/Gabi/3dmodels.html

C3.4.4 D"





From http://garnero.asu.edu/research_images/index.html

- 150-200 km thick
- Boundary layer between core and mantle
- High degree of lateral variability.

References

Clowes, R. *et al*, Crustal velocity structure from SAREX, the Southern Alberta seismic experiment, *Canadian Journal of Earth Sciences*, **39**, 351-373, 2002.

Dziewonski, A.M., and J.H. Woodhouse, Global images of the Earth's Interior, Science, 236, 37-48, 1987.

Gorman, A.R. *et al*, Deep probe: imaging the roots of western North America, *Canadian Journal of Earth Sciences*, **39**, 375-398, 2002.

Masters G., Laske, G., Bolton, H. and Dziewonski, A., 2000. "The Relative Behavior of Shear Velocity, Bulk Sound Speed, and Compressional Velocity in the Mantle: Implications for Chemical and Thermal Structure" in: S. Karato, A.M. Forte, R.C. Liebermann, G. Masters and L. Stixrude (eds.) "Earth's Deep Interior", AGU Monograph 117, AGU, Washington D.C.

Shearer, P., and G. Masters, Global mapping of tomography on the 660 km discontinuity, Nature, 355, 791-796, 1992.

Van der Hilst, S. Widiyantoro, E.R. Engdahl, Evidence for deep mantle circulation from global tomography, Nature, 386, 578-584, 1997.