4.2 THE MANTLE

What about the mantle? The approach petrologists took was to find rocks that

a) occur on the surface so their properties are known

b) have the physical properties know, from seismology, to exist in the upper mantle (α ~8 km/s, ρ ~3.3g/cm^3)

c) could be the source of the basalt that makes up the oceanic crust.

ASIDE - later we'll see that the oceanic crust is formed by volcanic activity at (spreading centers, mid-ocean ridges) - so the mantle must be a source for the oceanic crust.

The most likely possibilities were proposed

I. Peridotite-ultra basic rock

α = 7.8-8.0 km/s ρ = 3.3g/cm^3
60 - 80 % olivine $(Mg, Fe)_2SiO_4$
pyroxene - enstatite $MgSiO_3$; diopside $CaMgSi_2O_6$
garnet/spinel/plagioclase - contain the Al_2O_3

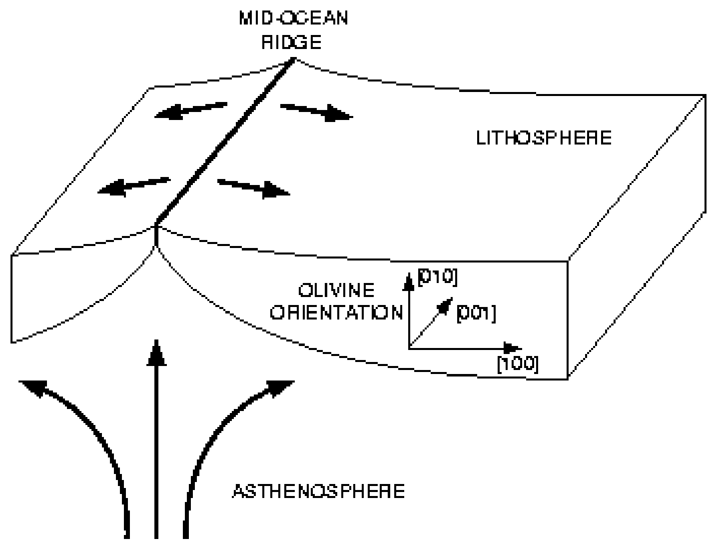
II. Eclogite-basic rock
α = 8.0-8.2 ρ = 3.4-3.5 g/cm^3
garnet
pyroxenes-diopside $CaMgSi_2O_6$
-jadite $NaAlSi_2O_6$
Eclogite is chemically identical to basalt and results from higher pressure.
plag feldspar + pyroxene + olivine $\longrightarrow$ eclogite (garnet + pyroxene + quartz)

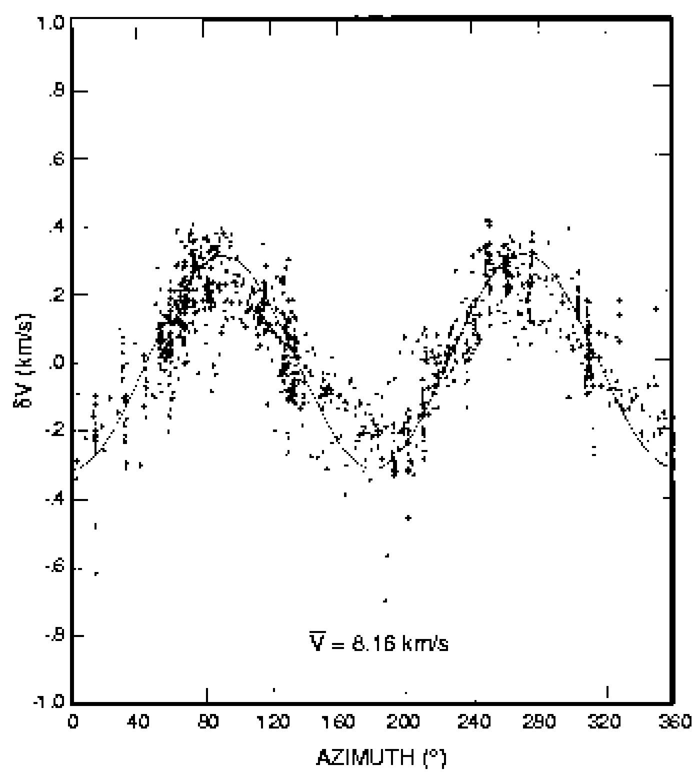
The Moho would be a different type of boundary for each case

The peridotite model is generally accepted now, based on laboratory experiments (experimental petrology) for details take one of Bina's classes. It also fits seismological data better (Bott).

One interesting idea - If the Moho were a phase boundary, its depth would depend on the thermal gradient.

However, this doesn't seem to be the case. The seismological data shows that the uppermost mantle velocity (Pn-headwave velocity) depends on direction:





This *anisotropy* would be expected for olivine rich mantle, since olivine crystal structure is strongly anisotropic, but not for a garnet - pyroxene mantle, so it favors the peridotite model.

Thus, we think of the mantle as having a peridotite chemical composition: a common model is called "pyrolite"

Above the transition zone (depth < 400km) the composition is

Uppermost Mantle Composition

		Wt %
Olivine (Fo_{89})	$(Mg, Fe)_2SiO_4$	57
Orthopyroxene	$(Mg, Fe)SiO_3$	17
Clinopyroxene	$(Ca, Mg, Fe)_2Si_2O_6 - NaAlSi_2O_6$	12
Pyrope-rich garnet	$(Mg, Fe, Ca)_3(Al, Cr)_2Si_3O_{12}$	14

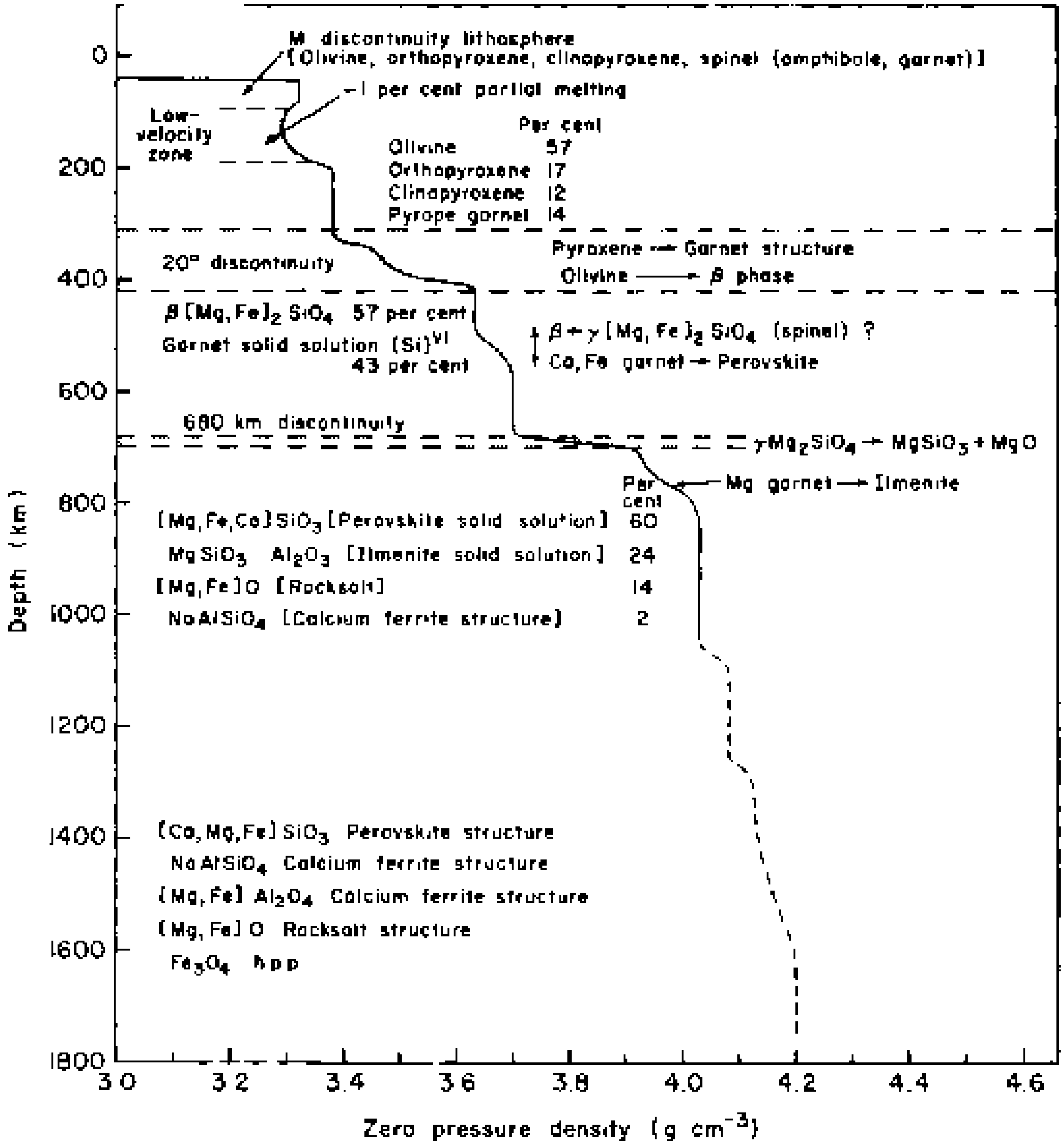
Note: Olivine is 90% Mg, 10% Fe, Pyrope is the Mg-garnet, $Mg_3Al_2Si_3O_{12}$ with increasing pressure, these minerals undergo changes to higher pressure phases.

To illustrate this, consider a common model: For a mantle composition, note that at a pressure corresponding to the depth (400 km discontinuity) the olivine-spinal phase change occurs. The pyroxene components go to a garnet structure.

With depth, further phase changes occur, and by the 660 km discontinuity another set of phase changes occur:

$$Mg_2SiO_4 \rightarrow MgSiO_3 \ + \ MgO$$

spinel structure $\rightarrow$ perovskite structure + rock salt structure



Similarly, other components have phase changes. Hence the rapid velocity changes in the 400-700 km depth range reflects phase changes.

The smooth increase in velocity with depth in the lower mantle below this, presumably, represent density increase with depth due to self-compression.

A yet unresolved question: Does the lower mantle have the same chemical composition as the upper mantle or is it enriched in iron?