Chemical and Clapeyron-induced buoyancy at the 660 km discontinuity

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Introduction

- The degree to which 660 helps or hinders whole mantle convection is a function of density contrasts derived from chemical and/or structural changes in the mineral assemblage
- In order to understand the dynamics of this discontinuity it must be considered for a bulk mantle composition like pyrolite

Simplistic view of 660

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Shim, S. H., T. S. Duffy, and G. Shen. "The post-spinel phase boundary in Mg2SiO4 and its relation to the 660-km seismic discontinuity." *Nature* 411 (2001): 571-574.

Pyrolite Model

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Please see

Weidner, D. J., and Y. Wang. "Chemical- and Clapeyron-induced buoyancy at the 660 km discontinuity." *Journal of Geophysical Research* 103 (1998): 7431-7441.

These phase diagrams ignore Fe, Al, & Ca which are considered important components

Effect of adding Al^{3+}

- Broadens Garnet Stability Field
- Links Perovskite producing reactions
  - Pv is in equilibrium with garnet and contains Al^{3+} *(Pv can contain ≤ 12 mol% Irifune ,1994)*
  - As $\gamma \rightarrow$ Pv the Al^{3+} content of Pv gets depleted unless gt transforms
  - Too much Al^{3+} in gt will produce free corundum in lower mantle *(this paper assumes that this not realistic)*

Pyrolite + Al_2O_3 (CMAS System)

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Implication of Phase Stability

- Olivine dominated 660 discontinuity correlates to a negative clapeyron slope
  - Hi Temp = Shallower Discontinuity
- Garnet dominated 660 discontinuity correlates to a positive clapeyron slope
  - Hi Temp = Deeper Discontinuity
- If temp is known then composition of Al^{3+} may be constrainable

Density and Sound Velocity vs. Depth (3% Al^{3+} case)

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- Parameters are calculated based on previous experimental results
- Shear modulus is poorly constrained
  - Absolute values should be ignored
  - Shape of curves are robust

Phase Transition Induced Buoyancy

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- $\rho(T-100°) - \rho(T)$ = buoyancy contrast
  - Pos. : hinders convection
  - Neg. : assisted convection
- α is integrated from 500-800 km

Heterogeneous Slab

- pyrolite = 0.2 basalt + 0.8 harzburgite
- Pyrolite Equivalent Package (PEP)
  - Oversaturation of silica in MORB
  - Undersaturation of silica in harzburgite
- PEP is 0.6 - 1.0% denser relative to pyrolite in T.Z. *(due to the presence of γ+st+il instead of majorite – from silica enriched MORB and Al depleted hz)*
- At lower mantle conditions PEP will be buoyant *(due to ~ 5.8% vol of $MgSiO_3$ existing as SiO_2 + MgO from MORB component)*

Density Contrast Between Harzburgite and Pyrolite

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Please see:

Weidner, D. J., and Y. Wang. "Chemical- and Clapeyron-induced buoyancy at the 660 km discontinuity." *Journal of Geophysical Research* 103 (1998): 7431-7441.

Consideration of MORB

- Complete transition to perovskite in MORB will occur much deeper than pyrolite
- There will be a zone over which MORB is positively buoyant
- This could force a detachment of MORB from the downgoing slab

Conclusions

- Al^{3+} couples the ol-norm and px-norm components of the pyrolite system
- Pyrolite appears at the crossroads between spinel & garnet dominance in terms of buoyancy
  - If temp is known then composition of Al^{3+} may be constrainable
- The relative density of MORB in the lower mantle is less than pyrolite
- The relative density of Harzburgite is greater than pyrolite in the lower mantle

Further Considerations

- How does Fe effect the pyrolite system phase equilibria?
- How does Al^{3+} in Pv effect the bulk sound velocity?
- Is it reasonable to assume starting saturation of Al3+ in perovskite will force a garnet – spinel reaction in the transition zone?
- Could there be free corundum (Al_2O_3) in the lower mantle?