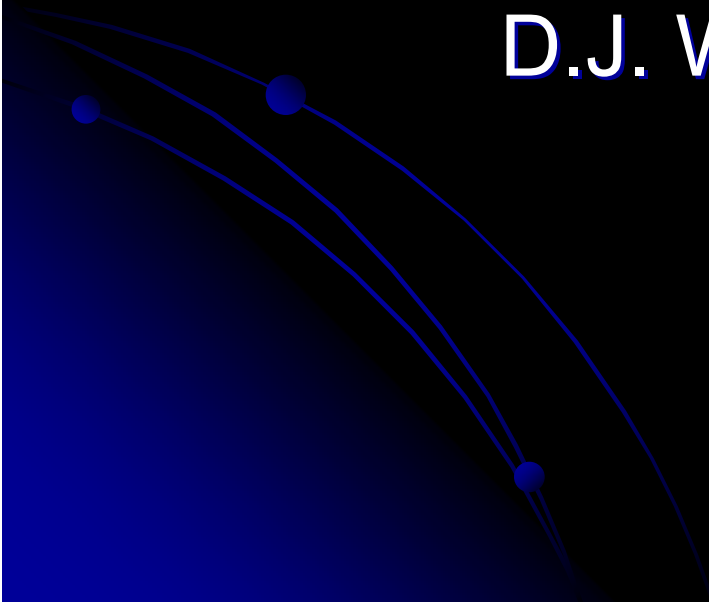


# Chemical and Clapeyron- induced buoyancy at the 660 km discontinuity

D.J. Weidner & Y. Wang  
1998



# 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

Image removed due to copyright considerations. please see:

Shim, S. H., T. S. Duffy, and G. Shen. "The post-spinel phase boundary in  $\text{Mg}_2\text{SiO}_4$  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 $\text{Al}^{3+}$

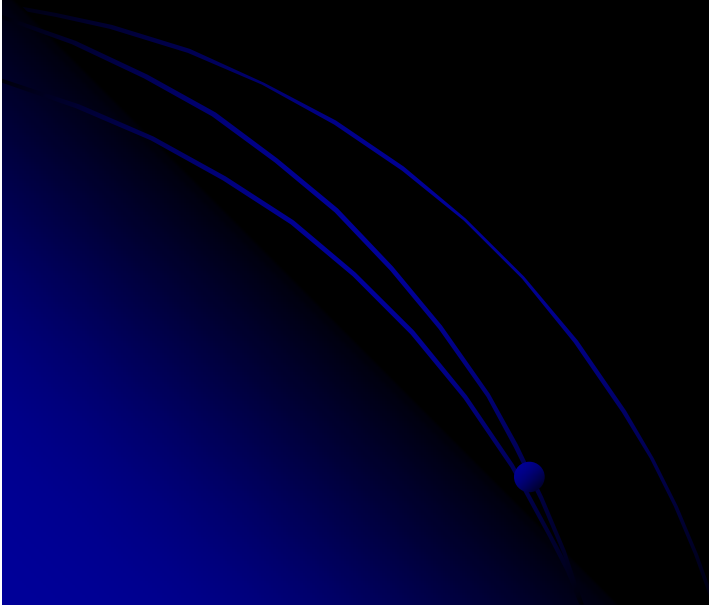
- Broadens Garnet Stability Field
- Links Perovskite producing reactions
  - Pv is in equilibrium with garnet and contains  $\text{Al}^{3+}$  (*Pv can contain  $\leq 12$  mol% Irifune, 1994*)
  - As  $\gamma \rightarrow \text{Pv}$  the  $\text{Al}^{3+}$  content of Pv gets depleted unless gt transforms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

# Pyrolite + $\text{Al}_2\text{O}_3$ (CMAS System)

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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. □□



# 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<sup>3+</sup> case)

Image removed due to copyright considerations.

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. □□

- 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

Image removed due to copyright considerations. 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. □□

- $\rho(T-100^\circ) - \rho(T) =$  buoyancy contrast
  - Pos. : hinders convection
  - Neg. : assisted convection
- $\alpha$  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  $\gamma$ +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

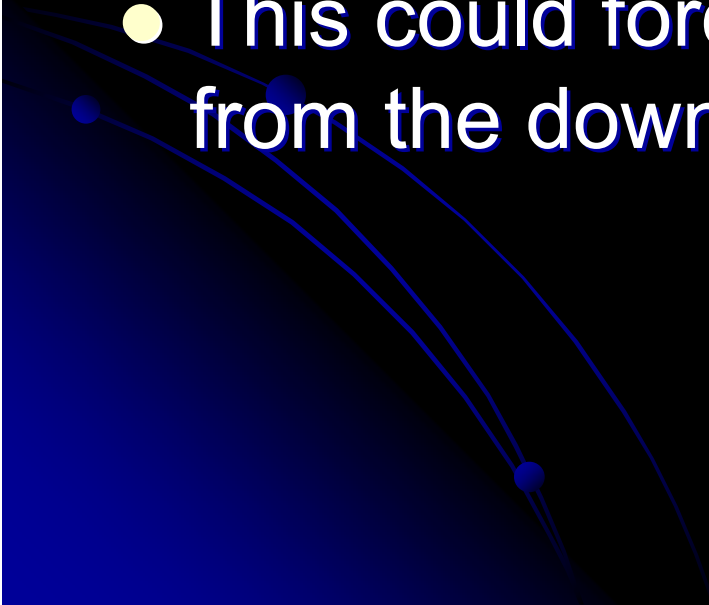
Image removed due to copyright considerations.

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

- $\text{Al}^{3+}$  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  $\text{Al}^{3+}$  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  $\text{Al}^{3+}$  in Pv effect the bulk sound velocity?
- Is it reasonable to assume starting saturation of  $\text{Al}^{3+}$  in perovskite will force a garnet – spinel reaction in the transition zone?
- Could there be free corundum ( $\text{Al}_2\text{O}_3$ ) in the lower mantle?