Seismic Evidence for Partial Melt at the Base of Earth's Mantle

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Ultra-Low Velocity Zone (ULVZ)

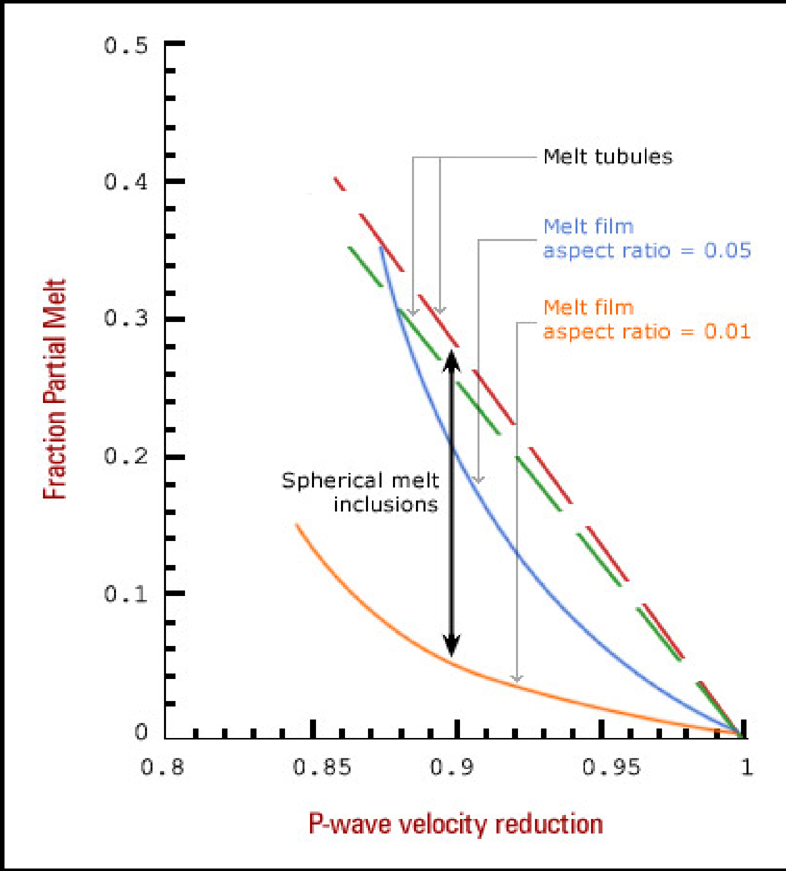
- Anomalously slow V_P at the base of the mantle
  - discrete layer
    - SKS, PcP precursors
    - sharp transition
  - thickness
    - 5 to 40km
    - correlated with mantle upwellings

Possible Explanations

- Partial melting
- Chemical discontinuity
- Phase transition at 135GPa
  - “unlikely” because not observed
  - $CaCl_2$ structure stable up to 130GPa
- Anisotropy
  - no $SP_{diff}KS$ or PcP splitting

Partial Melting: Melt Model

- Aggregate-induced density change assumed small (Δρ ~ 1%)
- Solid-liquid aggregate geometry
  - spherical melt inclusions
  - melt film
- K of melt ≈ 650 GPa
  - good for Fe-rich melt
  - Likely for u-mafic silicate melt



melt film aspect ratio = 0.01 ⇒ 5% melt

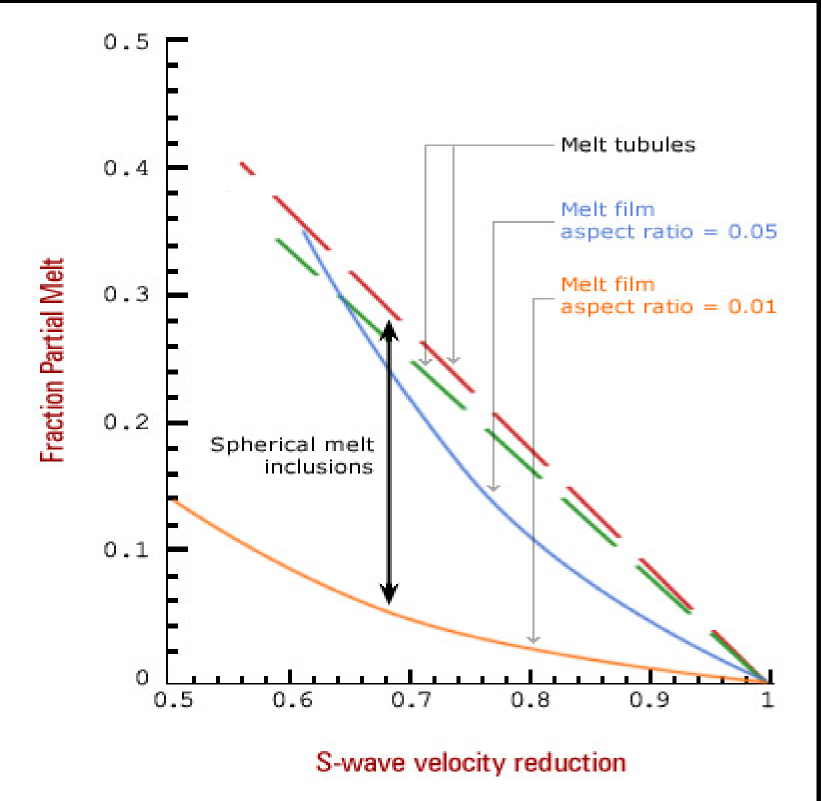
worst case ⇒ 30% melt

Partial Melting: Fe-rich fluid ?

- intercalated melt
  - higher $\rho \Rightarrow$ 20% melt
- wetting of grain boundaries
  - same as silica melt
- stability ??
  - High ρ , low $\eta \Rightarrow$ descent to outer core

Partial Melting: Testing

- the partial melting model predicts S-wave velocities anomaly of 30%
  - no measure available at the time of the paper
  - now an observation !

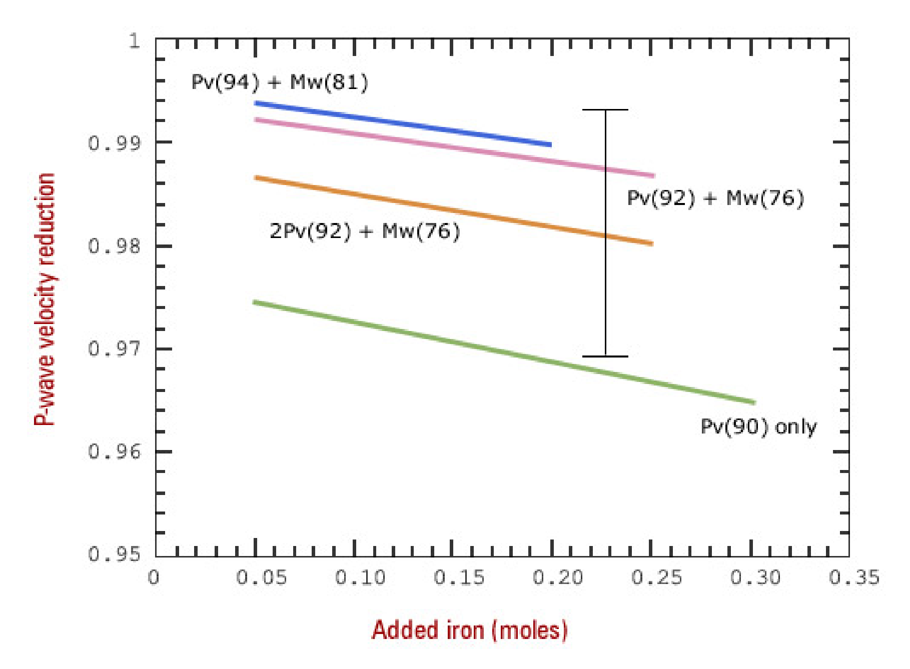


Chemical Discontinuity: solid reaction

- Possible reaction:

$$(Mg_x Fe_{1-x})SiO_3 + 3(1-x-s)Fe = xMgSiO_3 + (1-x-s)FeSi + sSiO_2 + [3(1-x)-2s]FeO$$

- very small P-wave velocity variations (<4%)



Chemical Discontinuity: solid alloy

- Solidified core or Fe-rich alloy in ULVZ
  - 20 to 75 % (depending on shear modulus and outer core material liquidus)
- Implies complex velocity structure
- Needs the top of the outer core to be close to liquidus

More about the Melting

- Abrupt transition if geotherm intersects eutectic temperature
  - global character
  - thickness varies with T anomalies (upwellings)
- Constraint on mantle mineralogy
  - magnetowüstite ≈ 5-30%
- Phase diagram at CMB conditions uncertain

Consequences of a melt layer

- viscosity of mantle drops
- modification of heat transport
- stability of thermal boundary layer
- higher electrical conductivity
  - Influence on geomagnetic field

Summary

- Partial melting explains P- and S-waves velocities anomalies
- Melt fraction depends largely on melt layer structure
- Important geodynamical consequences