The effect of water on the 410-km discontinuity: An experiment study

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1. Introduction

• 410 km discont. : olivine (α) → wadsleyite (β)
• How thick is this transition interval?
  
  *Experiment in the dry peridotite system: ≥ 15 km*
  *Thermochemical measurements: 18 km*
  *Seismic studies: ≤ 4 km*
• Results from electrostatic bond strength calculations suggested that wadsleyite can be very large reservoir of H in the planet.

• Smyth & Kawamoto (1997) reported an additional variation of wadsleyite, which requires significant amounts of H, is another possible explanation for 520-km discontinuity.
The Effect of H$_2$O on the 410-km Seismic Discontinuity

- Based on the thermochemical potentials calculation, this paper showed that
  (1) the strong preference of H$_2$O for $\beta$ phase
  (2) very low concentration of H$_2$O in the transition zone will greatly affect the thickness of the transition interval
Phase relations for partially hydrated (500 ppm H₂O) olivine and β phase

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Effects of H₂O contents (0 → 1000 ppm in olivine) on the olivine - β phase transformation

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• *Hellfrich and Wood* (1996) estimated that the effect of 10-km transition interval might appear seismically a 5-km linear velocity gradient.

• **However**, 15 – 18 km transition interval in the experiments of the dry system is still too broad for the observed interval (≤ 4 km) in seismic studies. In the hydrous system, their discrepancy will be much larger!

• **This paper** tested the hypothesis of *Wood* (1995) from the experimental approach.
2. Experimental

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3. Results and discussion

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• Results are consistent with the prediction of Wood (1995), but still too broad to be consistent with seismic observations (4 km) in both hydrous case (12 km) and anhydrous case (40 km).

• In hydrous system, H content of wad. ~ 10 times that of olivine. And there is a sharp H-diffusion-controlled boundary between olivine and wad. while in anhydrous system wad. Grains appear evenly distributed.
• Hydrous wad. is ~ 5% more dense than anhydrous olivine. In a hydrous system consisting mainly of olivine + wad. over a depth of 20 km, gravitational equilibrium can be approached by diffusion of H without the much slower movement of Fe, which can sharpen the boundary (perhaps to 4 km or less).
Estimation of Some parameters that might constrain the diffusion effect:

1. The velocity of diffusion will constrain H distribution equilibrium.

   H diffusion coefficients in solid-state, single crystal olivine: $\sim 10^{-8} - 10^{-9}$ m$^2$/s (1400°C) $\rightarrow$ large enough to allow H distribution equilibrium over a 20 km interval in a few hundred million years.

   If consider the grain boundaries effect, H distribution equilibrium over 10 km interval will be a few ten million years.

2. the estimation of driving forces for establishment of gravitational equilibrium
Conclusions

• 1. Under near saturated conditions, the pressure of transition is 0.5 – 1.5 GPa lower under anhydrous conditions. And the two-phase interval broadens from 0.4 GPa (12 km) in the anhydrous system to 1.3 GPa (40 km) in the water-saturated system.

• 2. H content is the largest chemical difference between olivine and wad.

• 3. H diffusion controls the spatial distribution of the olivine and wad. phases and may cause sharper boundary at 410 km.