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.**

Science paper by *Wood* (1995): The Effect of H_2O on the 410-km Seismic Discontinuity

- **Based on the thermochemical potentials calculation, this paper showed that**

  (1) the strong preference of H_2O for β phase

  (2) very low concentration of H_2O in the transition zone will greatly affect the thickness of the transition interval

Phase relations for partially hydrated (500 ppm H_2O) olivine and β phase

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Smyth, J. R., and D. J. Frost. "The effect of water on the 410-km discontinuity - An experimental study." *Geophysical Research Letters* 29, no. 10 (2002).

Effects of H_2O 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.**
- **<u>However</u>, 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!**
- **<u>This paper</u> 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 (12km) 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: ~ 10^{-8} - 10^{-9} m^2/s (1400°C) → 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.**