

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

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# 1. Introduction

- **410 km discontinuity : olivine ( $\alpha$ )  $\rightarrow$  wadsleyite ( $\beta$ )**
- **How thick is this transition interval?**

*Experiment in the dry peridotite system:  $\geq$  15 km*

*Thermochemical measurements: 18 km*

*Seismic studies:  $\leq$  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<sub>2</sub>O on the  
410-km Seismic Discontinuity**

- **Based on the thermochemical potentials calculation, this paper showed that**
  - (1) the strong preference of H<sub>2</sub>O for  $\beta$  phase**
  - (2) very low concentration of H<sub>2</sub>O in the transition zone will greatly affect the thickness of the transition interval**

# Phase relations for partially hydrated (500 ppm H<sub>2</sub>O ) olivine and β phase

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Please see:

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).

**Fig. 2.** The calculated effect of 500 ppm H<sub>2</sub>O (by weight) on the α+β region of Fig. 1; β-(Mg,Fe)<sub>2</sub>SiO<sub>4</sub> appears at a pressure 0.6 GPa lower (16 km higher in the mantle) than in the anhydrous case, and the α+β loop is expanded from 7 to 22 km.

# Effects of H<sub>2</sub>O contents (0 → 1000 ppm in olivine) on the olivine - β phase transformation

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**Fig. 3.** The olivine-β-phase transition interval for initial H<sub>2</sub>O contents of olivine of 0, 200, 500, and 1000 ppm. Addition of H<sub>2</sub>O elevates the point at which β-(Mg,Fe)<sub>2</sub>SiO<sub>4</sub> appears (shifts it to lower pressure) and broadens the transformation interval. Given a seismically determined transformation interval of <10 km, the maximum H<sub>2</sub>O content of upper mantle olivine at a depth of 400 km is constrained to about 200 ppm.

- *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 ( $\leq 4$  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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**Figure 1.** Plot of experimental results at 1400°C. Solid symbols represent olivine and open symbols wadsleyite. Gray symbols and boundaries represent the hydrous experiments and black the anhydrous.

- **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:  $\sim 10^{-8} - 10^{-9} \text{ m}^2/\text{s}$  (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.**