Effect of water on the spinel-postspinel transformation in Mg_2SiO_4

* Pressures for spinel – postspinel phase boundary has been subject of debate

- XRD measurements indicates that the transition pressure is 2 GPa lower than that expected at 660 km depth….may be a problematic interpretation of seismic discontinuity at these depths

* Inconsistency can be due to :

- Effect of other relatively minor elements
- Accuracy of the available pressure scale
- possible chemical homogeneity in the deep manlte

Effect of minor elements have been studied using a pyrolytic composition → spinel – postspinel transition is similar to or even slightly lower than that in pure Mg2SiO4.
Present study → presence of H_2O can increase the spinel – postspinel transition pressure

Issues

660 km discontinuity: due to transformation of ringwoodite (high pressure polymorph of olivine) → perovskite ($MgSiO_3$) and ferropericlase (Mg,Fe)O

High pressure x-ray studies: postspinel transformation is 2 GPa lower than expected 660 km seismic discontinuity [Irifune et al]

Spinel – Postspinel transformation pressure in pyrolite composition lower than the discontinuity by similar degree

Water→ important volatile in the Earth, transported by subducting slab

Major transition zone high pressure phases (wadselyite and ringwoodite) can accomomdate 2-3 wt % of water in their crystal structure

It can change the densities and thermodynamic parameters of the anhydrous forms, therefore it can affect the nature of phase transformation

Aim

To clarify the effect of water on the phase boundary between ringwoodite and perovskite + periclase

To determine H_2O contents of ringwoodite and perovskite

Nature of 660 km discontinuity

High Pressure apparatus

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Pressure Calibration at RT and at High Temperature

ZnS (15.6 GPa)

GaP (23.0 GPa)

Postspinel transforamtion boundary in Mg_2SiO_4 (21.1 GPa 1600 C EOS gold Anderson ?)

Table 1. Experimental conditions and the results for Mg_2SiO_4 under anhydrous and hydrous conditions

Three hydrous starting materials Mg_2SiO_4 + 1, 2 and 3 wt% H_2O Studied

Anhydrous sample: Single crystal of forsterite pulverized and heated at 150 C was used, expected water content < 0.2 wt %

Both hyd. and anhyd. samples were placed in one cell assembly for a direct comparison

Water content was measured by a secondary ion mass spectroscopy

RESULTS

Anhydrous Samples

→ Complete dissociation of ringwoodite to perovskite + periclase at 21.2 GPa

1 wt % water

→ Ringwoodite coexisted with dissociated perovskite + periclase at 21.2 GPa
→Complete dissociation above 21.5 GPa implying transformation starting at ~21.2 and ends at ~21.3 GPa

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2 wt% water

→Ringwoodwite appeared in system at 21.2 GPa implying that ringwoodite is stable at hydrous conditions at high pressure than in anhydrous conditions

3 wt% water
→ Magnesian liquid (Mg/Si >3) coexisted with ringwoodite + perovskite + periclase at 21.2 GPa while exactly same assembly was observed for 1 wt % water samples.
→ Formation of liquid should reduce the water content of in ringwoodite because of partition behavior
of water between crvstal and fluid

Conclusions

- *Phase boundary between ringwoodite, perovskite + periclase at 1600 C under hydrous conditions with 1-3 wt % H_2O
- *Boundary moved to higher pressure side by ~0.2 GPa for hydrous condition experiments
- *SIMS experiments: Ringwoodite accepts ~1wt % water, perovskite accept ~0.05 wt % in their crystal structure
- *Discrepancy between the pressure of 660 km seismic discontinuity and that of the post-spinel transformation (in situ x-rays studies) is not explained by the effect of water on the transformation

Table 2. Chemical compositions of the recovered samples

* Small Mg deficit noted in ringwoodite under hydrous conditions
•No Mg or Si deficit observed in perovskite
SIMS measurements:
* Products with 1 wt % of water shows presence of water if ~1.1 wt % in ringwoodite
* ~0.05 wt % in perovskite