Review of the high-pressure stability of serpentine

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Recent much progress in understanding of subduction zone systems shed light on the role of the serpentine minerals (the typical composition is $Mg_3Si_2O_5(OH)_4$) in addition to being the water source for arc magmatism. I will review the high-pressure stability of a serpentine mineral, antigorite, and post-antigorite hydrous phases in peridotite systems.

Subducting hydrated peridotite becomes antigorite (Atg)-dominant serpentinite at depths around 30-km (Evans et al., 1976). Bose and Ganguly (1995) first predicted phase relations of antigorite at high pressures in the MgO-SiO_2-H_2O (MSH) system based on thermodynamic calculations. They also found that an invariant point occurs on the antigorite dehydration reaction at 6.8 GPa and 720degC, where Atg, enstatite (En), forsterite (Fo), phase A (phA), and water are stable. From this invariant point, a dehydration reaction originates toward high-P-T side; phA + En = Fo + H_2O which was termed the 'water-line' by Liu (1987). They suggested that slab peridotite carry water beyond the stability of antigorite to deeper levels only when the slab temperature passes lower-T than the invariant point.

From the experimental side, Ulmer and Trommsdorff (1995) reported that the thermal stability of antigorite was 730degC at 2.1 GPa and the invariant point was at 580degC at 6.2 GPa. Their antigorite included some amounts of iron and aluminum. Wunder and Schreyer (1997) used an antigorite with less impurity and showed it had a smaller stability field than in Ulmer and Trommsdorff (1995); the thermal stability is 650degC at 2-3 GPa and the invariant point was at 4.2 GPa and 580degC. They claimed that the starting material in Ulmer and Trommsdorff (1995) was not well characterized and might be contaminated with some other phases which gave rise to unexpected reactions. Bromiley and Pawley (2003) revisited this phase relation with a careful characterization of the sample which was almost pure MSH antigorite. Their antigorite stability field was a little smaller than in Wunder and Schreyer (1997).

On the other hand, Komabayashi et al. (2005) determined the P-T location of the 'water-line' in the pure MSH system by in-situ X-ray diffraction experiments at SPring-8. In addition, they determined the stability of the MSH antigorite based on the precisely pressure-calibrated quench experiments. Considering the pressure effect on the electro motive force of thermocouples, they found that Wunder and Schreyer (1997), Bromiley and Pawley (2003), and Komabayashi et al. (2005) are all consistent in terms of antigorite stability. The invariant point is located at 5.1 GPa and 550degC.

Recently Hilairet et al. (2006) made a new thermodynamic calculation with a refined antigorite volume-compression data. The stability of antigorite is consistent with the previous experimental data except for Ulmer and Trommsdorff (1995) and the P-T location of the invariant point is same as in Komabayashi et al. (2005).

Bromiley and Pawley (2002; 2003) showed that addition of Al_2O_3 to the MSH system expanded antigorite stability and stabilized other hydrous phases, chlorite and Mg-sursassite. They proposed that Mg-sursassite and chlorite transfer the water from antigorite to phase A.

In addition to the phase relations above, I will discuss the water transportation by antigorite in the subduction zones.

References

Bose and Ganguly, Earth Planet. Sci. Lett., 136, 109-121, 1995; Bromiley and Pawley, Am. Mineral., 88, 99-108, 2003; Bromiley and Pawley, Contrib. Mineral. Petrol., 142, 714-723, 2002; Evans et al., Schweiz. Mineral. Petrogr. Mitt., 56, 79-93, 1976; Hilairet et al., Geophys. Res. Lett., 33, L02302, doi:10.1029/2005GL024728, 2006; Komabayashi et al., Phys. Earth Planet. Inter., 151, 276-289, 2005; Liu, Phys. Earth Planet. Inter., 49, 142-167, 1987; Ulmer and Trommsdorff, Science, 268, 858-861, 1995; Wunder and Schreyer, Lithos, 41, 213-227, 1997.