An experimental study on the serpentinization reaction in the olivine + aluminum-free orthopyroxene system under the antigorite-stable P-T conditions

*中谷 貴之[1]、中村 美千彦[1]
*Takayuki Nakatani[1], Michihiko Nakamura[1]

1. 東北大学大学院 理学研究科 地学専攻 地球惑星物質科学科
1. Division of Earth and Planetary Materials Science Department of Earth Science Graduate School of Science Tohoku university

Antigorite serpentinite is a record of water-rock interaction at the convergent plate boundaries and plays an important role in lubricating the plate interface and generating seismic anomalies in the mantle wedge. Despite its importance, few experiments have been conducted to constrain the serpentine stability at high pressure (P) and temperature (T) conditions where antigorite is assumed to be stable. Nakatani and Nakamura (2016) performed hydration experiments in the olivine + aluminum (Al)-bearing orthopyroxene (opx) system in the P-T conditions where antigorite was assumed to be stable, and found that aluminous lizardite formed at 400–580˚C and 1.3 GPa, while antigorite formed at 580˚C and 1.8 GPa. They considered that the aluminum extends the stability of lizardite. To test this interpretation, we have conducted hydration experiments of olivine + Al-free opx system at 400–580˚C and 1.3 and 1.8 GPa for 240–360 hours by using a piston-cylinder apparatus. The SEM-EDS and XRD characterization of the run products demonstrated that serpentine ±talc ±magnetite formed at 400˚C and 1.3 GPa, and at 400–580˚C and 1.8 GPa, while secondary iron-rich olivine + talc ±magnetite was produced without serpentine at 500–580˚C and 1.3 GPa. The results of micro-Raman analyses revealed that serpentines synthesized at 500–580˚C at 1.8 GPa were antigorite, while other serpentine species than antigorite was produced at 400˚C and 1.3 and 1.8 GPa. These experimental results indicate a possibility that antigorite is not stable at 400˚C also in the Al-free system. By the reaction forsterite + H_2O = antigorite + brucite, the experimental P-T conditions cab be divided into two fields: (1) olivine present (500–580˚C and 1.3 GPa, and 540–580˚C and 1.8 GPa) and (2) olivine absent (400˚C and 1.3 GPa, and 400–500˚C and 1.8 GPa) fields. In the olivine-present field, the absence of serpentine (antigorite) at 1.3 GPa may be related to the pressure-sensitive reaction forsterite + talc (at lower pressure) = antigorite + enstatite (at higher pressure), as suggested by Pawley (1998), namely, olivine and talc nucleated metastably prior to antigorite at the lower pressures (1.3 GPa). It is not clear why the serpentine formed at 400℃ and 1.3–1.8 GPa was not antigorite. Our experiments demonstrate that aluminum stabilizes serpentine (lizardite) at relatively lower pressure (1.3 GPa) and higher temperature (500–580˚C).

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