Mg/Si ratios of aqueous fluids coexisting with forsterite and enstatite based on the phase relations in the Mg$_2$SiO$_4$-SiO$_2$-H$_2$O system

TATSUHIKO KAWAMOTO,1,* KYOKO N. MATSUKAGE,2 KENJI MIBE,3 MAIKO ISSHIKI,4 KOSHI NISHIMURA,1 NAOKI ISHIMATSU,5 AND SHIGEAKI ONO6

1Institute for Geothermal Sciences, Graduate School of Science, Kyoto University, Beppu 874-0903, Japan.
2Department of Environmental Sciences, Faculty of Science, Ibaraki University, Mito 310-8512, Japan
3Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Road, NW, Washington, D.C. 20015, U.S.A.
4Japan Synchrotron Radiation Research Institute, SPring-8, Mikazuki, Hyogo 679-5198, Japan
5Department of Physical Science, Graduate School of Science, Hiroshima University, Higashi-Hiroshima 739-8526, Japan
6Institute for Frontier Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology, Natsushima, Yokosuka 237-0061, Japan

ABSTRACT

Direct observation of aqueous fluids coexisting with MgSiO$_3$ (enstatite) and/or Mg$_2$SiO$_4$ (forsterite) was performed at 0.5–5.8 GPa and 800–1000 °C with an externally heated diamond-anvil cell and synchrotron X-rays. At 1000 °C in the MgSiO$_3$–H$_2$O system, forsterite crystallizes below 3 GPa but not above that pressure. At 1000 °C in the Mg$_2$SiO$_4$–H$_2$O system, forsterite congruently dissolves into the aqueous fluids up to 5 GPa. These observations suggest that the aqueous fluids coexisting with enstatite and forsterite have Mg/Si < 1 below 3 GPa and 1 < Mg/Si < 2 above that pressure.

Comparison with the previous studies reporting Mg/Si ratios of the aqueous fluid coexisting with enstatite and forsterite indicates that the Mg/Si ratios change rapidly from SiO$_2$-rich to MgO-rich at around 3 GPa and 1000 °C. This change can be related to possible structural changes of liquid water under these conditions. The aqueous fluids coexisting with enstatite and forsterite do have Mg/Si ratios similar to those found in the partial melts of H$_2$O-saturated peridotite. Somewhere within the upper mantle, these two fluids unite to form a single regime and cannot be distinguished from each other.