Temperature dependence on nitrogen solubility in bridgmanite under lower mantle conditions: its role in formation of deep nitrogen reservoir through solidification of magma ocean.

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Nitrogen occupies about 80% of the Earth's atmosphere and is one of essential elements of life. Despite its importance, nitrogen behavior in the Earth's interior remains poorly understood. Nitrogen is depleted in the Earth compared to other volatiles, especially carbon: this is so-called “missing” nitrogen and has persisted as a mystery. Experimental researches suggested that "missing" nitrogen is caused by nitrogen stored in the deep mantle through magma ocean (e.g., Li et al., 2013; Yoshioka et al., 2018). Yoshioka et al. (2018) is the only study reporting the nitrogen solubility of bridgmanite which occupies about 80 vol% of the lower mantle in the pyrolite model, but their experimental conditions were limited at 24 GPa and 1600 °C.

In this research, we investigated temperature dependence on nitrogen solubility in bridgmanite. High-pressure and high-temperature experiments were conducted using multi-anvil apparatus installed at Geodynamics Research Center, Ehime University. The pressure condition was 28 GPa and temperature conditions ranged from 1400 ℃ to 1700 ℃. Fe-FeO buffer was used to control the redox state equal to the lower mantle. Nitrogen in recovered samples were analyzed using a secondary ionization mass spectrometer (HR-1280, Cameca) installed at CNRS-CRPG, France.

A series of experimental results revealed that nitrogen solubility in bridgmanite increased from 1.8 to 5.6 ppm with increasing temperature. The results implies that the lower mantle can store 3-4 PAN (PAN: mass of Present Atmospheric Nitrogen) only by bridgmanite at maximum. This trend between nitrogen solubility and temperature in bridgmanite is opposite of those in metallic iron reported by Yoshioka et al. (2018). In addition, this concentration is much higher than that of carbon in bridgmanite; i.e. below 30–200 ppb (Shcheka et al., 2006). Bridgmanite firstly crystallized in cooling magma ocean (Stixrude et al. 2009; Ozawa et al., 2018) and would capture nitrogen there. Our study suggests that bridgmanite played an important role in reserving nitrogen through the solidification of magma ocean. Metallic iron in the present lower mantle could reserve nitrogen, which can be supported by the discovery of iron nitride in super deep diamond originating from the lower mantle (Kaminsky and Wirth, 2017). This formation process of "hidden" nitrogen reservoir in the lower mantle may relatively deplete nitrogen in the Earth: only one planet where life has been confirmed in the solar system.

Keywords: Magma ocean, Bridgmanite, "Missing" nitrogen, Secondary ion mass spectrometry, High-pressure and high-temperature experiment, Atmosphere-Mantle coevolution

