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The effect of oxygen fugacity on the olivine to wadsleyite transformation: Implications for remote sensing of mantle redox state at the 410 km seismic discontinuity

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Abstract

High-pressure and -temperature multianvil experiments were performed to test the effect of varying oxygen fugacity on the olivine to wadsleyite transformation. Two capsules, containing samples of $(Fe,Mg)_2SiO_4$, were placed in each experiment; the first buffered the oxygen fugacity with an assemblage of Re and ReO_2, whereas the second ensured the lowest possible ferric iron concentration through the presence of excess Fe metal. Measurements of coexisting olivine, wadsleyite, and ringwoodite compositions from the Fe metal saturated experiments were used to accurately determine the pressure in each experiment using established phase relations. Under the more oxidizing conditions of the Re-ReO_2 buffer, the stability field of wadsleyite was found to expand with respect to both the olivine and ringwoodite stability fields. Mössbauer spectroscopy measurements reveal $Fe^{3+}/\Sigma Fe$ ratios for wadsleyite buffered by Re-ReO_2 of 0.1–0.25, while olivine appears to be Fe^{3+}-free. A thermodynamic model that employs the wadsleyite end-members $(Fe^{3+}_{5/3}\square_{1/3})Fe^{3+}O_4$-$Fe_2SiO_4$-$Mg_2SiO_4$ is used to examine the effect of varying bulk mantle $Fe^{3+}/\Sigma Fe$ ratio on the depth and depth interval of the 410 km seismic discontinuity. $Fe^{3+}/\Sigma Fe$ ratios in the range 0.02–0.12 would cause the depth interval or thickness of the 410 km discontinuity to increase from ~8 to 15 km but would have very little effect on the seismically observable absolute depth. Very large bulk mantle $Fe^{3+}/\Sigma Fe$ ratios (>0.2), unrepresented in recovered mantle samples, would be required to explain recent seismic observations that the depth interval of the 410 km may be >20 km beneath certain regions. Such observations are more likely to be explained by moderate local enrichments in both ferric iron and H_2O in the mantle, most likely as a result of slab interaction.

Keywords: Ferric iron, multianvil, transition zone, seismic discontinuity