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The effect of elemental diffusion on the application of olivine-composition-based magmatic thermometry, oxybarometry, and hygrometry: A case study of olivine phenocrysts from the Jiagedaqi basalts, northeast China

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Abstract

Olivine compositions are widely used to constrain magmatic thermodynamic conditions such as magmatic temperature, oxygen fugacity, and H_2O content. However, elemental diffusion may change the initial compositions and lead to large uncertainty on the estimation of these thermodynamic conditions. In this study, we conducted LA-ICP-MS elemental mapping and EPMA analysis of olivine phenocrysts and olivine-hosted spinel from the Jiagedaqi (JGD) alkaline basalts in northeast China to evaluate the influence of elemental diffusion on olivine-composition-based geothermometry, oxybarometry, and hygrometry. The JGD olivines show normal Fo [Mg/(Mg + Fe) × 100 in moles] zoning, with cores having Fo of 77–87 and rims having Fo of 67–73. The constant P contents from core to rim indicate that these compositional zonings were caused mainly by diffusion. Because Al is a slow-diffusing element and its content is relatively constant from core to rim, the temperature calculated by the Al-in-olivine thermometer is not influenced by elemental diffusion and preserves the JGD olivine crystallization temperature up to 1150 °C. The temperatures calculated using the Sc/Y-in-olivine thermometer, the oxygen fugacity calculated using the olivine–spinel oxybarometer, and the H_2O content calculated on the basis of Ca partitioning between olivine and melt are strongly influenced by the diffusion of Fo, Sc/Y, and Ca. However, the compositional plateaus in olivine cores, which were not influenced by elemental diffusion, preserve the magmatic temperature (1150 °C), oxygen fugacity (QFM+1.4), and H_2O content (4 wt%) that applied during the formation of the JGD olivines. Together, these findings suggest that the mantle source of the JGD basalts was metasomatized by fluids released from the subducted slab. This study highlights that elemental diffusion in olivine phenocrysts can strongly affect the application of olivine-composition-based geothermometers, oxybarometers, and hygrometers. However, primitive olivine cores that have not been influenced by diffusion preserve the initial magmatic thermodynamic conditions.

Keywords: Olivine, diffusion, magma storage, compositional zoning, NE China, Jiagedaqi basalts