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Reconstruction of paleo-magmatic processes in Jeju Island, South Korea by observing depth-dependent zoning patterns in olivine phenocrysts

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The chemical zoning observed in olivine within basalt reflects compositional variations resulting from crystallization, magma mixing, and diffusion during magma storage and eruption. The diffusion trends of major elements (Mg-Fe and Ni) in olivine phenocrysts provide insights into pre- and post-eruptive processes and fine-scale temporal magmatic events. This study focuses on understanding the eruptive behavior and timescales of basaltic magmatism in Jeju Island in South Korea by exploring the chemical zoning of olivine phenocrysts.

Samples were obtained from drill cores at Eoseungsangak, Jeju Island, at depths of 109 m, 125 m, and 154 m. These samples represent basaltic lava flows from the eruption that formed the main volcanic complex of Mt. Halla, which occurred ca. 138 ka ago, before the eruption that formed Eoseungsangak. Note that the samples used in this study are collected from different core depths in main basaltic body to observe variations in textural and geochemical characteristics due to the differences in magma residence time and possible magma recharge.

To classify textural characteristics of olivine phenocrysts depending on the core depth, backscattered electron (BSE) imaging was obtained, revealing both normal and reverse zoning. Normal zoning was mainly observed at 109 m, both normal and reverse zoning were observed at 125 m, and reverse zoning was dominantly observed at 154 m. To analyze the diffusion trends within olivine phenocrysts with zoning, rim-to-core linear profiles were obtained using electron probe microanalysis (EPMA) for 90 selected phenocrysts.

EPMA results confirmed depth-dependent variations in the geochemical composition of olivine phenocrysts, suggesting the thermodynamic changes affecting olivine phenocrysts retrieved from deeper depths (i.e., 154 m) during magma differentiation. The forsterite (Fo) mol% values, which change toward the rims, were quantified in terms of timescales using diffusion chronometry, providing a detailed understanding of magma storage and ascent processes on a fine temporal scale.

This study shows that olivine phenocryst textures and elemental diffusion characteristics vary with core depths, reflecting differences in magma differentiation and recharge processes. These findings enhance our understanding of the ascent and eruption history of Jeju basaltic magmas on fine temporal scales and provide valuable insights into pre-eruptive magmatic processes.