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Millennial-scale Residence Time of Permian Dali Picrite, SW China: Constraints from the mineralogical assemblage and Diffusion Chronology

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The evolution and eruption dynamics of magmatic systems are fundamental to understanding volcanic activity and its global environmental and climatic impacts. Diffusion chronology, a pivotal method for estimating volcanic eruption rates, has been extensively utilized based on mineralogical assemblages and diffusive profiles in phenocrysts. This study focuses on the Permian Dali picrite from the Emeishan large igneous province (LIP), employing the mineralogical assemblage and diffusion chronology analyses on both clinopyroxene and spinel to reveal millennial-scale records of magma chamber residence time.

The studied picrite samples from the Dali area, Yunnan Province in SW China, primarily consist of olivine and clinopyroxene phenocrysts, with accessory spinel and plagioclase. Electron microprobe mapping and back-scattered electron imaging reveal diffusion-driven zonation in clinopyroxene and spinel for elements like Fe, Mg, Cr, Al, and Mg# [Mg# = Mg/(Mg+Fe) in atomic ratio] and Cr# [Cr# = Cr/(Cr+Al) in atomic ratio]. Based on experimental diffusion parameters, numerical simulation of Mg# diffusion profiles in clinopyroxene yields a diffusion time of thousand years (kyr), suggesting that the magmas experienced high-temperature residence for millennia before eruption. Similarly, the Cr# diffusion profiles in spinel inclusions record a diffusion time of 0.5-2.0 kyr, supporting the millennial-scale magma chamber residence for the picrites.

The formation of diffusion zone is closely related to magma chamber thermodynamic conditions, revealing pre-eruption magma evolution. Combining clinopyroxene and spinel diffusion chronology, the eruption duration of Dali picrites is inferred to range between 1000 and 4000 years. In the Emeishan LIP, the picrites are considered as primary melts associated with the plume head, contrasting with differentiated high-Ti, low-Ti, and transitional-Ti flood basalts. These picritic magmas with more phenocrysts and greater density suggest longer residence time and higher eruption rates than widespread high-Ti and low-Ti basalts.

Given the Emeishan LIP's eruption volume of approximately 500,000 km^3 over a maximum of 4000 years, the annual flood basalt eruptions exceeded 1200 km^3, releasing vast volatiles into the atmosphere and causing significant environmental impacts, classifying them as supervolcanoes. The rapid extrusion of Emeishan flood basalts may have contributed to massive biological extinction during the Guadalupian stage of middle Permian.