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Late-stage microstructures in Chang'E-5 basalt and implications for the evolution of lunar ferrobasalt

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Abstract

This study investigates silicate liquid immiscibility (SLI) microstructures in the Chang'E-5 (CE-5) lunar ferrobasalt sample, the youngest recovered mare basalt (ca. ~2.0 Ga). Employing advanced high-resolution imaging techniques and chemical analysis, we examined a subophitic fragment, revealing two distinct types of microstructures indicative of multi-stage SLI events. The first type is observed in the mesostasis pockets and exhibits both "sieve" and "maze" textures, where the Si-K-rich glassy phases are interconnected with Fe-rich minerals, e.g., fayalite. This type of microstructure, similar to previous observations in Apollo and Luna samples, is the product of a stable SLI event. The second type is characterized by K-free but high-Si melt inclusions occurring as emulsions in the rims of plagioclase. The entrapment of these emulsions followed a metastable SLI event, with the Fe-rich liquids serving as precursors to subsequent stable SLI processes. Additionally, the Fe-rich droplets within the emulsions underwent coarsening via Ostwald ripening, a phenomenon in which smaller particles in solution dissolve and deposit on larger particles. Our simulation of this coarsening process suggests a duration of at least 15–32 days for the SLI processes, alongside a slow cooling rate (<0.3 °C/h) of the late-stage CE-5 lava. We propose that metastable SLI may have influenced the effusive signature of the CE-5 lava flow during its late-stage evolution. The metastable SLI process can potentially lead to the formation of various phases during the late-stage evolution of lunar ferrobasaltic magmas, thereby contributing to the diversity of lunar rock types.

Keywords: Chang'E-5 mission, microstructure, silicate liquid immiscibility, lunar ferrobasalt