动力学模型：橄榄石中高 Sr 熔体包裹体的成因

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Melt inclusions in primitive olivine phenocrysts, which has been thought to represent the primitive melts (Schiano, 2003), have increasingly been applied to studies of igneous processes (Audétat and Lowenstern, 2014; Kent, 2008), including lunar magmatism (Chen et al., 2015; Hauri et al., 2011; Saal et al., 2013). However, some melt inclusions in primitive olivine phenocrysts in various tectonic settings, showing unusual high Sr contents, suggest that plagioclase appears to be present in the inclusions as a ‘ghost’ trace element signature (Danyushevsky et al., 2003; Kent et al., 2002; Maclennan, 2008; Sobolev et al., 2000). A mantle origin (assimilation of an ancient recycled oceanic crust in the mantle) (Kent et al., 2002; Ren et al., 2005; Sobolev et al., 2000) or a crustal origin (shallow-level assimilation of plagioclase-rich cumulates in the present-day lower oceanic crust) (Danyushevsky et al., 2003; Maclennan, 2008; Peterson et al., 2014) has been suggested to explain this signature. However, the absence of this signature in the host lavas is difficult to be explained by these two models.

Alternatively, here we propose a kinetic model to clarify its origin. Geodynamic models show that magma replenishment on a decadal timescale is required to prevent a magma chamber freezing in mid-ocean ridge (Liu and Lowell, 2009; Moore et al., 2014; Morgan and Chen, 1993). This suggests that early injected primitive magma had undergone a rapid cooling and reheating process. During the rapid cooling stage, the boundary layer of rapid-growing olivine (growth by diffusion), will enrich in Al_2O_3 due to its lower diffusivity in silicate melt and its incompatibility in olivine (Newcombe et al., 2014; Zhang et al., 2010), thus plagioclases can be oversaturated within the boundary layer. At the reheating stage, the crystallized plagioclase will redissolve due to the relaxation of Al_2O_3, while the olivine grows continually at relatively slow rate (growth by interface attachment). Since Sr is compatible in plagioclase (Blundy and Wood, 1991), dissolving of plagioclase cause the melt inclusion formed at this stage has the positive Sr anomaly. Because Sr has higher diffusivity than many other trace elements (Behrens and Hahn, 2009), thus longer boundary layer thickness of Sr is expected, therefore melt inclusion can be formed with only ‘ghost plagioclase’ signature without other trace element anomalies. Our modeling results verify this. Clinopyroxene can be also saturated within the boundary layer of a rapid growing olivine. Our modeling successfully show that the diffusive dissolution of the clinopyroxene leads to the ‘depleted’ melt inclusions, found in oceanic island basalts (Sobolev et al., 2000).

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