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Cooling Time Scales of Lunar 74220 Orange Glass Beads from Na and Cu Profiles

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Formed in fire-fountain eruptions [1], the lunar 74220 orange glass beads are known to have undergone extensive outgassing. The outgassing effect leads to lower concentrations of volatiles in the orange glass beads than in olivine-hosted melt inclusions (OH-MIs) in the same sample [2, 3], and resulting in decreasing volatile contents in the glass beads towards the surface. We previously reported U-shaped Na concentration profiles across 74220 orange beads measured by EMPA and SIMS with Na enrichment near the bead surface, and proposed that they were formed by first out-gassing and then in-gassing of Na [4]. Here, we show that Cu concentration profiles in the same orange beads are also U-shaped as mapped by LA-ICP-MS. Similar U-profiles in both moderately volatile Na and Cu confirm these beads have experienced both first out-gassing and later in-gassing when they were flying through the volcanic gas plume and falling back to the lunar surface. The in-gassing might be attributed to a transient and localized atmosphere [5].

To understand the whole process that forms the U-shaped profiles of Na and Cu, a quantitative diffusion model is developed. The model assumes an asymptotic cooling history for spherical glass beads with a homogeneous initial composition and surface equilibrium with the ambient atmosphere. The model leads to out-gassing at high temperature and subsequent in-gassing as beads cool down. By fitting the measured Na and Cu profiles, cooling time scales of individual orange glass beads are estimated. It is found that cooling time scales () of the orange glass beads have a positive relationship to bead diameter (Fig. 1), consistent with size-dependent heat transfer coefficient. Cooling time scales modeled from Cu profiles are about ½ of those from modeling Na profiles. The difference might reflect errors in the input data (such as diffusivity as a function of temperature) and potential uncertainties in the model.

References: [1] Heiken et al. (1974) *GCA,* 38, 1703-1704. [2] Hauri et al. (2011) *Science,* 333, 213-215. [3] Chen et al. (2015) *EPSL,* 427, 37-46. [4] Su et al. (2021) *AGU Fall Meeting*, P41C-06. [5] Needham & Kring (2017) *EPSL,* 478, 175-178.

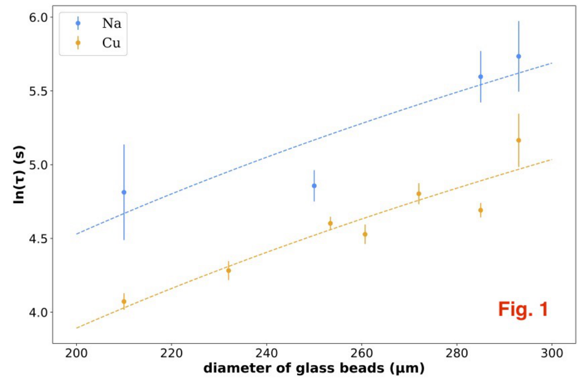

Fig. 1