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A Novel Diffusion Chronometer for Complex Diffusion Profiles in Glass Beads: Using Lunar Pyroclastic Beads as an Example

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Concentration profiles caused by diffusion carry valuable information and can serve as a good tool in diffusion chronometry to constrain magma ascent rate (e.g., [1]) and cooling rates (e.g., [2]). However, diffusion profiles of multiple elements in lunar volcanic beads with complicated boundary conditions present a challenge for diffusion models. Here, we present a diffusion model that can simultaneously simulate the concentration evolution of elements in the beads through time, reproduce the observed diffusion profiles, and constrain the cooling rates of the beads. The model only treats spherical glass beads so far but is adaptable for other shapes in the future if the need arises.

The model has been applied to lunar volcanic glass beads [3–4]. Lunar volcanic glass beads are solidified spherical lava droplets produced in ancient lunar fire-fountain (or pyroclastic) eruptions [5]. Lunar orange glass beads are observed to exhibit interesting “U-shaped” diffusion profiles of Na, K and Cu [3], and both “U-shaped” and “W-shaped” diffusion profiles of sulfur [4], reflecting both early degassing and late in-gassing. By modeling the profiles, it is found that the shapes of the diffusion profiles of different elements are closely tied to the boundary condition, the diffusivity of the elements, and the cooling rates of the beads. Cooling time scale in individual glass beads ranges from 40 s to 263 s from the model. This diffusion chronometer has more applications to interpret diffusion profiles observed in glass beads, either of volcanic origin or impact origin. For example, this work can be extended to other types of lunar volcanic glass beads such as yellow and green beads. Furthermore, the methodology is adaptable for assessing diffusion of volatile elements and thermal history of Hawaiian volcanic glass beads, commonly referred to as Pele's Tears, as well as impact glass beads [6].

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