National Aeronautics and Space Administration

Assessment of pre-eruptive concentrations of volatiles and post-eruptive loss in lunar basalts

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Program: FY22 SURP

Strategic Focus Area: Lunar science

Objectives:

The objective of this research partnership proposal is to answer some of the most important questions about lunar volatiles, how volatiles are lost from the Moon and what are the mantle abundances of volatiles, by systematically assessing pre-eruptive and post-eruptive volatile element concentrations in lunar basalts.

Background

For the objective, understanding post-eruptive loss of volatiles in lunar basalts is critical in assessing pre-eruptive volatile element concentrations and hence mantle abundances (e.g., [1-7]), but also provides essential data for evaluating isotope fractionation related to degassing in the Moon. However, abundant data are only available for H_2O, F, S, and Cl. For many other volatile elements, data are either limited or nonexistent. This research partnership proposal seeks to expand such knowledge to other volatile elements.

Benefits to NASA/JPL

The partnership between the analytical capability at JPL/Caltech and experimental and theoretical expertise at UM will enhance the visibility of lunar science at JPL.

The initiative will lead to long-lasting collaboration at the forefront of lunar science. In the long run, this collaborative effort will lead to lunar mission concepts such as *in situ* missions of volcanic processes or sample returns of new terranes (beads from other dark mantling deposits) or mantle rocks from the wall of large impact craters.

Analytical methods developed in this partnership by pushing the limit of SIMS can be applied to other returned planetary samples, be Mars or asteroids.

Results

- Confirmed the U-shaped Na concentration profiles, and the discovery of U-shaped K and Cu concentration profiles (Figs. 2-4) [A]. Results are submitted and revised a manuscript to EPSL [B].
- Preliminary data showing similar in-gassing features of Na, K and Cu in lunar green beads (Fig. 5) [C].
- Performed analyses of a wide range of volatile elements.

Approach

We constrain the volatile loss by comparing samples produced by fire-fountain eruption (Fig. 1), volatiles in volcanic glass beads (degassed, post-eruption products) and olivine-hosted melt inclusions (least degassed, pre-eruption melt) in Apollo 17 orange beads 74220. For Year 1 and Year 2, in addition to this approach, we also focused our effort on a new finding, in-gassing of volatiles into glass beads.

In Year 1, we performed high resolution analyses of Apollo 74220 orange beads using two instruments, complementing each other in sensitivity and spatial resolution.

In Year 2, we conducted additional elemental mapping of orange beads using Laser-Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) at the University of Michigan.

Significance

- Unanticipated finding of in-gassing of volatiles into orange beads, modeling of which provides insights on lunar volcanic gas and a new means to constrain the cooling of volcanic gas.
- The presence of similar in-gassing profiles in different pyroclastic beads from different eruptions indicates a common behavior of lunar volcanic gas, such as a transient volcanic atmosphere.
- Difference between beads of different eruptions provides key information in the fire-fountain eruptions, e.g., higher initial temperature or an early dissipation of the surrounding transient volcanic gas plume.

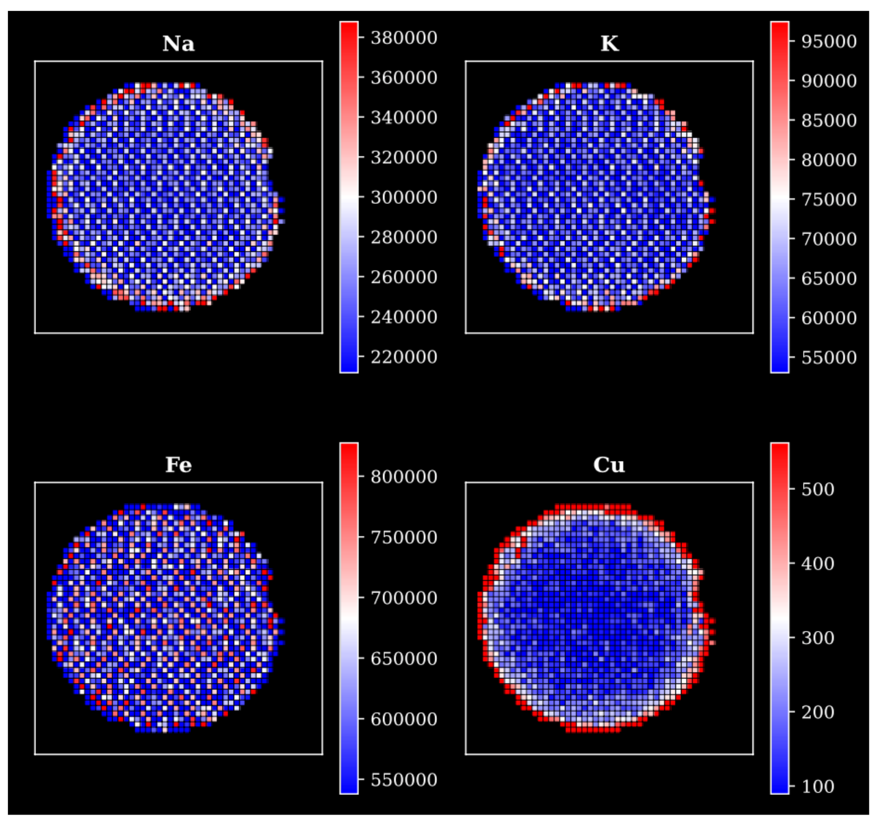


Fig. 2. Na, K, Fe and Cu intensities (counts/seconds) of orange bead GB-G6 from LA-ICP-MS mapping. Each pixel is 7 × 7 μm.

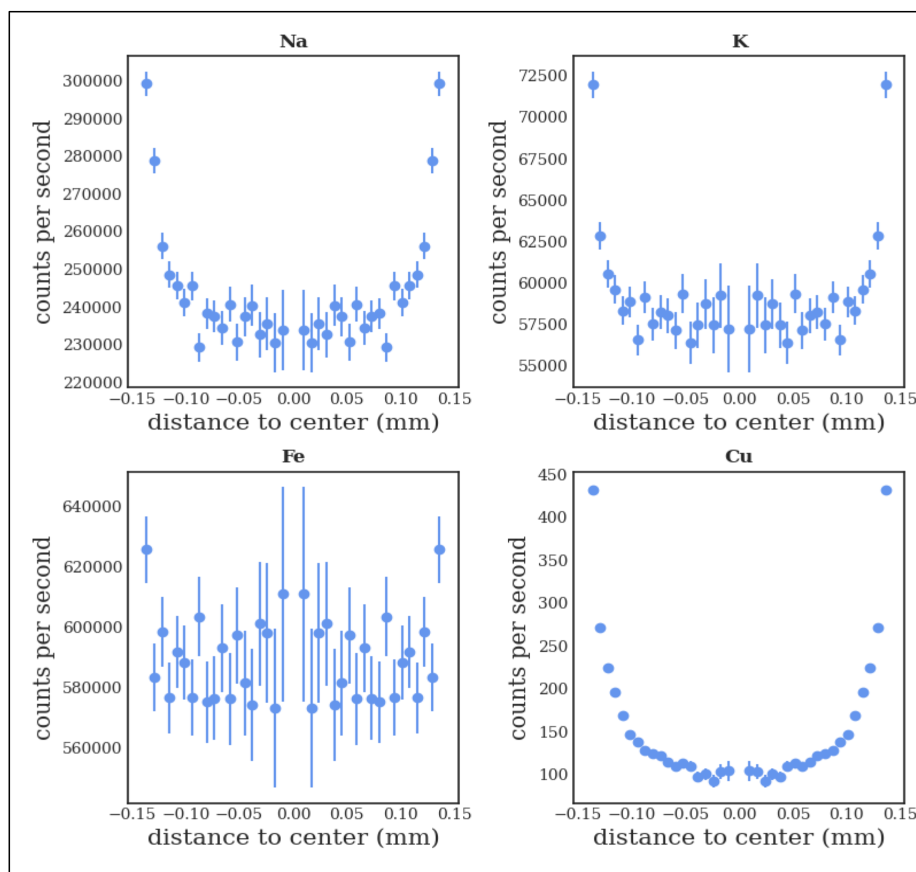
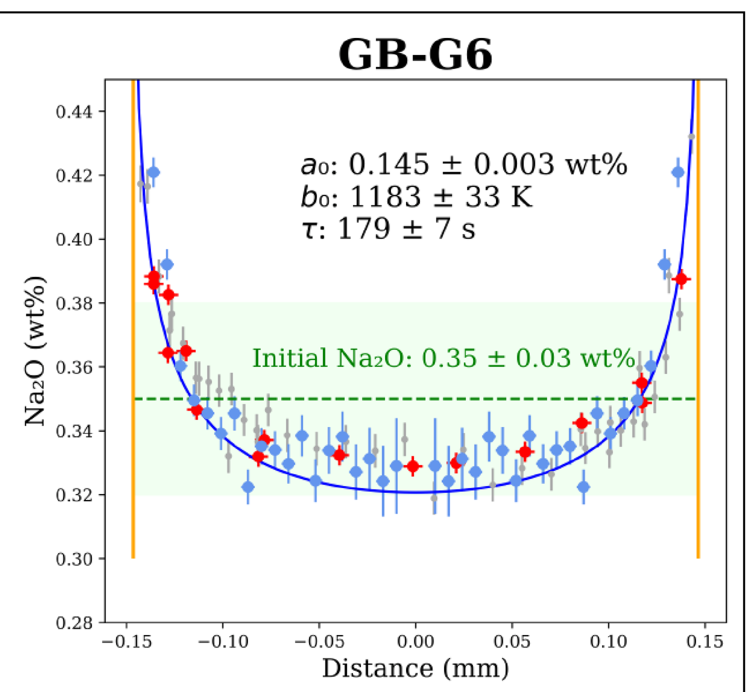


Fig. 3. Na, K, Fe and Cu profiles of GB-G6 converted from the maps in Fig. 1

Fig. 4. Na_2O concentration profiles of GB-G6 from SIMS (red dots), EMP (grey dots) data and LA-ICP-MS (blue dots) data, verifying the in-gassing profile. Orange lines are the edge of the glass bead. Green dashed line is initial Na_2O content with uncertainty (field) from [2]. Blue curve is the fitting profile from the diffusion model with τ is the cooling time scale



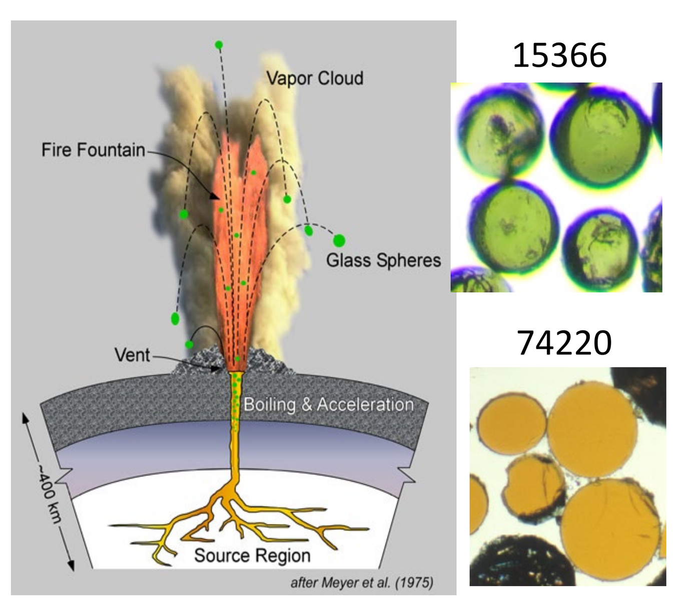


Fig. 1. Glass beads from fire fountain eruptions on the Moon.

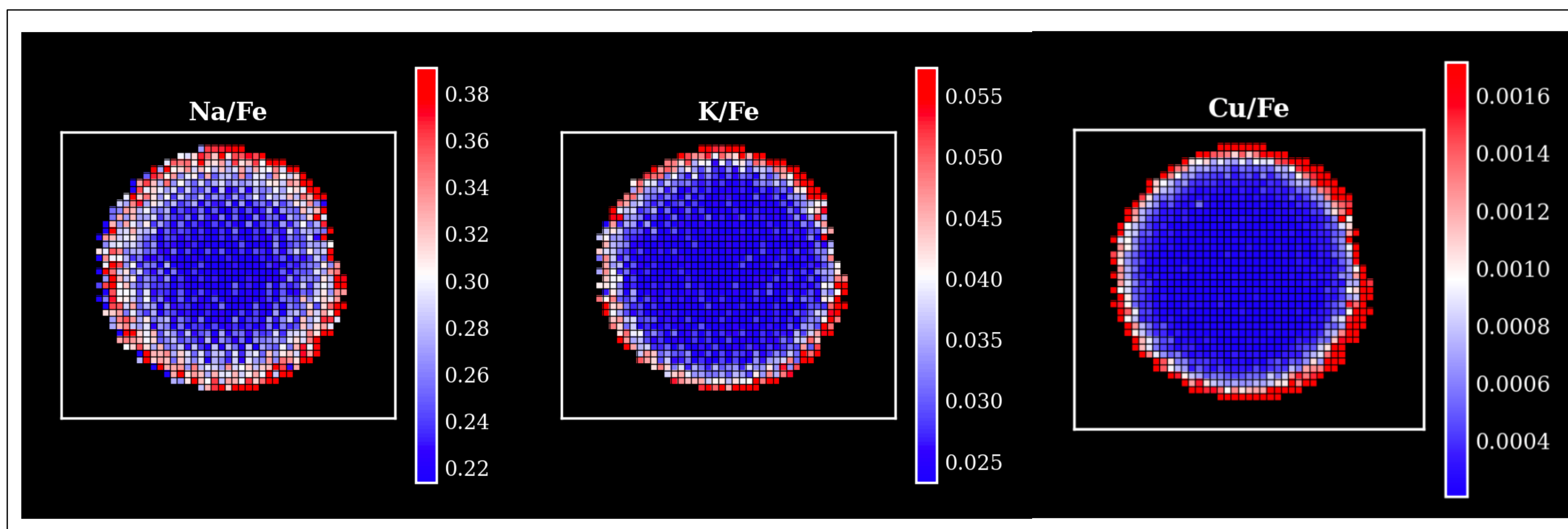


Fig. 5. Na, K and Cu distribution in a green bead from Apollo 15366. Data are normalized to Fe. Each pixel is 8 × 8 μm.

References

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National Aeronautics and Space Administration

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Clearance Number: CL# 22-4625
Poster Number: RPC-180

Publications:

[A] X. Su, Y. Zhang, Y. Liu, and R. Holder, “Cooling Time Scales of Lunar 74220 Orange Glass Beads from Na and Cu Profiles”, Abstract [#11573], presented in *Goldschmidt,* Honolulu, Hawai‘i, 10-15 July, 2022.
[B] X. Su, Y. Zhang, Y. Liu, and R. Holder, “Outgassing and In-gassing of Na and Cu in Lunar 74220 Orange Glass Beads”, *Earth and Planetary Science Letters* (2022, under review)
[C] X. Su, Y. Zhang, Y. Liu, and R. Holder, “In-gassing of Na, K and Cu in Lunar 15366 Green Glass Beads”, Abstract AGU Fall meeting, 2022.

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