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Discovery of a zinc-rich mineral on the surface of lunar orange pyroclastic beads

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Abstract

We present the first discovery of a Zn-rich mineral on the pristine surface of orange pyroclastic beads from Apollo sample 74220. This Zn-rich mineral is wide occurring, trigonal or hexagonal in shape, with a normalized composition of ~59 wt% Zn, ~26 wt% O (calculated), ~6 wt% S, ~5 wt% Na, and ~4 wt% Cl. The crystal morphology, homogeneity, and chemistry of individual grains are most consistent with gordaite, a zinc chlorohydroxosulfate mineral, showing an empirical formula of $Na_{1.02}Zn_{3.98}[(SO_4)_{0.84}(OH)_{0.30}](OH)_6[Cl_{0.50}(OH)_{0.50}]\cdot nH_2O$, albeit the exact amounts of OH and H_2O are uncertain. The pristine 74220 sample used in this study was only directly exposed to air for a cumulative period of 18 days before our study. The same Zn-rich crystals, examined 12 to 15 months apart, show no visible physical and chemical changes. Thus, this zinc-rich mineral likely formed through rapid alteration (oxidation and hydration) by terrestrial air of the original vapor-deposited Zn, Cl, S, and Na-bearing solids. The composition of the zinc-rich mineral indicates that the vapor condensates consist of metallic Zn and metallic Na with either ZnS or native S, and either $ZnCl_2$ or NaCl. This is the first direct evidence that metallic Zn and Na are key components in the vapor condensates of lunar volcanic gas, which implies lunar volcanic gas may be under higher pressure than previously thought, and the gas composition may be different than previously inferred. Our study is also relevant to the collection, handling, curation, and sample preparation of returned samples from other planetary bodies.

Keywords: Lunar orange beads, volcanic gas, vapor condensates, the Moon, zinc-rich mineral, gordaite