

Chlorine isotope composition of “rusty rock” 66095 and Apollo 16 soil. Implications for volatile element behavior on the Moon. C.K. Shearer^{1,2}, and Z.D. Sharp². ¹ Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico. Albuquerque, New Mexico 87131 (cshearer@unm.edu), ² Department of Earth and Planetary Sciences, University of New Mexico. Albuquerque, New Mexico 87131.

Introduction: “Rusty Rock” 66095 has yielded significant confusion concerning its origin, yet it has and will continue to reveal significant insights into the behavior of volatiles on the Moon. Most of 66095 is composed of a fine-grained, subophitic to ophitic impact melt-rock, which also contains a wide variety of lithic clasts [1,2]. Alteration is found in the interior as well as on the surface of 66095. A brownish alteration extends from margins of metallic iron grains into the adjacent silicates and consists of a variety of relatively low-temperature minerals [1-6]. The origin of this alteration and hydrogen and oxygen isotopic signatures have been attributed to alteration on the Moon [7,8] to “terrestrial” alteration during or following transport to Earth [4,9]. Recent observation by Moon Mineralogy Mapper (M³) on the Chandrayaan-1 spacecraft indicating the existence of H species on the lunar surface [10] could be interpreted as indicating the alteration is lunar in origin. Another interesting aspect of 66095 is its enrichment in ²⁰⁴Pb, Cd, Bi, Br, I, Ge, Sb, Tl, Zn, and Cl indicating that portions of this sample contain substantial sublimates [e.g.11-15]. The origins of these enrichments have been attributed to fumarolic-hydrothermal [15], magmatic, or impact processes [12,13]. Here, we examine the Cl isotope composition of 66095 and selected regolith at the Apollo 16 site to gain additional insights into the transport of volatiles in the lunar crust and on the lunar surface.

Cl isotopes and the Moon: Sharp et al [16] observed that unlike the Earth and most other materials in the solar system, samples from the Moon exhibited an extremely wide range of $\delta^{37}\text{S}$ (Where $\delta^{37}\text{Cl} = (\text{R}_{\text{sample}}/\text{R}_{\text{standard}} - 1)1000$ and $\text{R} = {}^{37}\text{Cl}/{}^{35}\text{Cl}$). All data are reported relative to SMOC (Standard Mean Ocean Chloride) with a $\delta^{37}\text{Cl}$ value of 0‰). They concluded that the bulk Moon had a $\delta^{37}\text{S}$ that was similar to Earth (~ 0 ‰) and that the wide variation of $\delta^{37}\text{Cl}$ (-0.7 to 24.5‰) was produced by volatilization of metal halides during the eruption of low H basalts.

Cl isotope composition of 66095 and A16 soils: In addition to mare and KREEP basalts, Sharp et al [16] also analyzed sample 66095 and select A16 soils. The A16 soils that were analyzed included mature soil 64501,232 (maturity index $I_s/\text{FeO}=61$) and immature soil 61220,39 (maturity index $I_s/\text{FeO}=9.2$). In these samples, there is a substantial correlation between Cl and Zn, Cd. In 66095, the leachate had a Cl isotope composition of +14.0‰, whereas the non-leachable Cl

has a composition of +15.6%. The leachate from mature soil (64501) had a Cl isotope composition of +5.6‰ and a non-leachable Cl composition of +15.7‰. The immature soil has a similar Cl isotope composition with the leachate with a Cl isotope composition of +6.1‰ and the non-leachable Cl composition of +14.3‰. Like all the other lunar lithologies analyzed by Sharp et al. [16], the leachates have a lower $\delta^{37}\text{Cl}$ than the non-leachable Cl. There is no apparent correlation between $\delta^{37}\text{Cl}$ and other stable isotopic measurements (e.g. $\delta^{34}\text{S}$, $\delta^{13}\text{C}$).

Discussion: Although coming from different lunar environments, samples that exhibit mobility of elements in the shallow lunar crust (sulfide replacement of magmatic silicates) or at the lunar surface (pyroclastic deposits, rusty rock) have common attributes in that they exhibit similar enrichments of Cl and calcophile elements (e.g. Zn, Cu, Se, Sb) and fractionation of both Cl and S isotopes from bulk Moon. All of these processes have a common link: the vapor phases that are responsible for elemental mobility and isotopic fractionation are relatively low in water. In the case of rusty rock 66095, these enrichments and fractionations may be a product of fumarolic activity. The few Apollo 16 soil samples analyzed by Sharp et al [16] may have a Cl component derived from “rusty rock” lithologies. The Cl isotopic fractionation observed in these soils is not a product of different degrees of soil maturity.

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