

Chlorine isotope composition and carbon mineralogy of “rusty rock” 66095. Implications for the petrogenesis of rusty rock, origin of “rusty” alteration, and volatile element behavior on the Moon. C.K. Shearer^{1,2}, Z.D. Sharp², F. McCubbin^{1,2}, and A. Steele³. 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, ³ Geophysical Laboratory, Carnegie Institute of Washington, Washington DC 20015

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]. 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.10-14]. The chloride mineralogy has not been fully described [8]. The origins of these enrichments have been attributed to fumarolic-hydrothermal [14], magmatic, or impact processes [11,12]. Here, we examine the Cl isotope composition of 66095 and selected regolith at the Apollo 16 site and the carbon mineralogy of 66095 to gain additional insights into the petrogenesis of the rusty rock, the origin of the “rusty” alteration, and transport of volatiles in the lunar crust and on the lunar surface.

Analytical Approach: The $\delta^{37}\text{Cl}$ (Where $\delta^{37}\text{Cl} = (\text{R}_{\text{sample}}/\text{R}_{\text{standard}} - 1)1000$ and $\text{R} = {}^{37}\text{Cl}/{}^{35}\text{Cl}$) was determined for 66095 and A16 soils using the method of Sharp et al [15]. All data are reported relative to SMOC (Standard Mean Ocean Chloride with a $\delta^{37}\text{Cl}$ value of 0‰). The carbon mineralogy of 66095 was explored using Raman Spectroscopy following the approaches outlined in Steele et al. [16].

Cl isotope composition of 66095 and A16 soils: In 66095, the leachate had a Cl isotope composition of +14.0‰, whereas the non-leachable Cl has a composition of +15.6‰. The A16 soils that were analyzed included mature soil 64501,232 ($I_s/\text{FeO}=61$) and immature soil 61220,39 ($I_s/\text{FeO}=9.2$). 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 composi-

tion of +14.3‰. Like all the other lunar lithologies analyzed [15], 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 isotopes ($\delta^{34}\text{S}$, $\delta^{13}\text{C}$).

Carbon Mineralogy: Previously, carbon compound cohenite (Fe_3C) in metallic iron was described [5]. Raman spectra collected on fresh fracture surfaces of 66095 indicate the possible presence of a carbon compound that are associated with the alteration veins. The suspected C-compound is closely associated with oxides and hydroxides, including goethite. Further analyses are being conducted to characterize the suspected C-compound.

Discussion: Sharp et al [15] observed that unlike the Earth and most other materials in the solar system, samples from the Moon exhibited an extremely wide range of $\delta^{37}\text{Cl}$. They concluded that the bulk Moon had a $\delta^{37}\text{Cl}$ 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 and/or following the loss of H from lunar basalts. In the case of rusty rock 66095, fumarolic activity is more likely to fractionate the Cl more so than either impact or magmatic processes. The few Apollo 16 soil samples must 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. The appearance of C closely associated with the “rusty” alteration does have implications for the origin of this alteration.

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