Apollo 16 “rusty rock” alteration by metal transport and deposition from an experimental fumarolic gas

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The Apollo 16 impact melt breccia 66095, named “Rusty Rock”, is distinguished by an unusual enrichment of the volatile elements S and Cl, as well as some metals including Zn, Cd, Pb and Tl [1]. In particular, the rock contains Fe metal, FeS (troilite), Fe-hydroxides, $FeCl_2$ (lawrencite) and ZnS (sphalerite) [2]. Isotopic evidence from Zn, Fe, and Cl suggests that the enrichment of the rock in volatile elements occurred via the deposition from a fumarolic gas phase [2,3,4]. Such a lunar volcanic gas was reducing (1-2 log$f$$O_2$ units below the iron-wüstite buffer, IW) and likely dominated by the gas species CO, S_2 and H_2 [5].

We present results of an experimental investigation testing the conditions at which sulfides and chlorides of Fe and Zn are deposited from a lunar fumarolic gas. We conducted experiments in 30 cm long evacuated silica tubes [6] suspended in a vertical tube furnace with a temperature gradient of 1260-320 °C. The reagent contains ZnO, FeS and $MgCl_2$ in relative molar abundaces of 1:1:2 and is pressed into a pellet which is placed at the hot end of the silica tube (1260 °C). A Gibbs free energy minimization calculation suggests that the $f$$O_2$ of the experimental gas mixture at 1250 °C is at IW-1. The silica tube was suspended in the furnace for 24 hours. After the experiment the tube was cut in 1 cm long sections and the deposits on the inner tube wall were analyzed using SEM/EDS.

In the hot source of the experiment (1260 °C) the materials $MgCl_2$, ZnO and FeS decompose and react to form a Fe-Zn-Cl-S gas mixture and refractory MgO. The metals deposit as sulfides and chlorides in the temperature range of 420-700 °C. We observe the four primary phases $FeCl_2$, FeS, $ZnCl_2$ and ZnS. Upon exposure to air $ZnCl_2$ hydrates rapidely. ZnS and $FeCl_2$ occur together in the temperature window of 500-580 °C suggestive of the temperature conditions of fumarolic activity that altered the Apollo 16 “rusty rock”. In the future we will investigate the isotope fractionation of S, Cl, Zn and Fe, which occurs in these experiments along the thermal gradient of 1000 °C.

[1] Krahenbuhl et al. (1973) *LPSC* **4**, 1325-1348. [2] Shearer et al. (2014) *GCA* **139**, 411-433. [3] Day et al. (2017) *PNAS* **114**, 9457-9551. [4] Day et al. (2019) *GCA*, in press. [5] Renggli et al. (2017) *GCA* **206**, 296-311. [6] King et al. (2018) *RiMG* **84**,