A COMPARISON OF VOLATILE RELEASE RATES DURING A SIMULATED EXTRACTION FROM LUNAR ICE MIXED WITH HIGHLAND OR MARE REGOLITH. Vincent G. Roux[1], Melissa C. Roth[2], Steven A. Miller[3], [1,2,3]Off Planet Research, LLC 5000 Abbey Way SE, Lacey, WA 98503 [1]Vince@offplanetresearch.com [2]Melissa@offplanetresearch.com [3]contact@offplanetresearch.com

Introduction: One of the early benchmarks in a sustainable return to the Moon is the in-situ extraction of volatiles from lunar ices for the production of rocket fuel and other critical materials. With missions progressing toward launch to find and sample lunar ices and conduct assessments of in-situ volatile extraction methods, it is imperative that some exploratory experiments are conducted to characterize any potential interactions of lunar ices with differing host regoliths during the extraction process.

This experiment was intended to identify potential differences in the physical progress of volatile extractions from lunar ice caused by the presence of Highland or Mare regoliths in the samples. Possible chemical reactions during volatile extraction were avoided and are not addressed in this paper.

Background: After lunar rovers and landers mechanically collect an ice/regolith sample, current volatile extraction processes rely on heating the collected sample to melt and vaporize the ices so the liberated gasses can be drawn off and further processed into their end products.

Information from the LCROSS impact experiment [1] was used to create a simulated lunar ice and set its relative abundance and nature of incorporation [2] into the simulated regolith for this experiment. It is important to remember that this is information from a single location on the Moon and that the ices in other locations may have differing chemical compositions and physical characteristics.

Simulants Used: The lunar regolith simulants used in this work were OPRH2N (Off Planet Research Highland Type 2 Non-Agglutinate) and OPRL2N (Off Planet Research Mare Type 2 Non-Agglutinate). The simulated lunar ice that was created was designated as OPRFLCROSS1, which is based on the data gathered from the LCROSS impact [1] experiment shown in Figure 1; the SO_2 and OH components were not included in the simulated lunar ice for safety reasons. The specifications for these simulants can be found at Offplanetresearch.com/simulants.

Sample preparation: The simulated lunar ice was mixed with the regolith simulants using the percentage for relative ice abundance in the ejecta plume from the LCROSS impact (Figure 2). In an article in Space.com [2], Principal Investigator Anthony Colaprete said that "based on initial observations, it is likely water ice is interspersed between dirt particles on the lunar surface."

It is possible that other locations on the Moon have ice deposits in differing physical states within the regolith, however many proposed processing methods crush the ice/regolith samples as they are transported to the extraction chambers resulting in the same starting condition of the samples for our experiments.

Samples of Highland and Mare simulants of equal dry mass were placed into appropriate stainless steel containers. Liquid nitrogen was used to cool the regolith simulants and equipment and to freeze the simulated lunar ice. The frozen ice was then shaved or crushed into a fine powder and mixed evenly into the simulants in the correct proportions. The ice/regolith sample containers were then sealed and kept cold with liquid nitrogen until the experiment was conducted.

Compound	Molecules cm^{-2}	% Relative to $H_2O(g)$
H_2O	5.1(1.4)E19	100.00%
H_2S	8.5(0.9)E18	16.75%
NH_3	3.1(1.5)E18	6.03%
SO_2	1.6(0.4)E18	3.19%
C_2H_4	1.6(1.7)E18	3.12%
CO_2	1.1(1.0)E18	2.17%
CH_3OH	7.8(42)E17	1.55%
CH_4	3.3(3.0)E17	0.65%
OH	1.7(0.4)E16	0.03%

Figure 1: Table 2 from Colaprete, A. et al [1]. Relative abundances of ice constituents. The uncertainty in each derived abundance in shown in parenthesis.

	Water mass (kg)			
Time (s)	Gas	Ice	Dust mass (kg)	Total water %
0–23	82.4 ± 25	58.5 ± 8.2	3148 ± 787	4.5 ± 1.4
23–30	24.5 ± 8.1	131 ± 8.3	2434 ± 609	6.4 ± 1.7
123–180	52.5 ± 2.6	15.8 ± 2.2	942.5 ± 236	7.2 ± 1.9
Average	53 ± 15	68 ± 10	2175 ± 544	5.6 ± 2.9

Figure 2: Table 1 from Colaprete, A. et al [1]. Summary of the total water vapor and ice and ejecta dust in the NIR instrument FOV.

References: [1] Colaprete, A. et al. (2010) *Detection of Water in the LCROSS Ejecta Plume. Science* 330, 463, DOI:10.1126/science.1186986. [2] Thompson, A. (2009) *Significant Amount of Water Found on Moon. Space.com* Accessed Jan 6, 2027 from https://www.space.com/7530-significant-amount-water-moon.html