THE RELATIONSHIP BETWEEN WATER ABUNDANCE AND THE PHYSICAL AND COMPOSITIONAL PROPERTIES OF LUNAR LOCALIZED PYROCLASTIC DEPOSITS. D. Trang[1], T. Tonkham[1], S. Li[1], L. M. Jozwiak[2], and C. M. Elder[3], [1]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, 1680 East-West Rd., Honolulu, HI 96822 (dtrang@higp.hawaii.edu), [2]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: Lunar pyroclastic deposits are known to contain highly valued resources that are needed to build and maintain a future lunar habitation site, such as water, titanium, iron, oxygen, and helium-3 [1,2]. The resource potential of the much larger, regional pyroclastic deposits (>2500 km^2) are well-known, but far less is known for the smaller (<2500 km^2), localized pyroclastic deposits [1–3]. Further these smaller pyroclastic deposits likely experienced a different geological history and may even have exhibited different dominant eruption styles (i.e., transient versus continuous eruptions) [4], which may influence their resource potential and value relative to the much larger regional pyroclastic deposits.

Localized pyroclastic deposits have been classified into smaller subgroups [5,6]. To determine these subgroups, [6] used a variety of data sets and products to characterize the mineralogical and physical properties of localized pyroclastic deposits. They searched for relationships between various parameters, such as juvenile and pyroclastic deposit volumes, deposit thickness, radar backscatter, surface rock abundance, various mineral and glass abundances, and regolith density. Using a cluster analysis between glass abundance and surface rock abundance, they suggest that there are four different types of pyroclastic deposits: Glassy, Blocky, Crystalline, and Indistinct.

Glassy deposits are known for their high glass and very low surface rock abundance, in which the latter is a characteristic similar to regional pyroclastic deposits [6]. Blocky deposits also exhibit high abundance of glass, but it has high surface rock abundance and is compositionally variable. In contrast, the Crystalline deposits exhibit low glass abundance and much higher pyroxene and plagioclase abundances with low to moderate surface rock abundance. The Indistinct group contain high abundance of crystalline material with high surface rock abundance.

We extend this previous characterization of localized pyroclastic deposits to investigate the water abundance of localized pyroclastic deposits and how they relate to the four groups. In addition, we explore how this water abundance parameter relates to these other physical and compositional parameters, such as surface rock abundance and glass abundance. The map that we use to determine water abundance is the Effective Single Particle Absorption Thickness (ESPAT) parameter [7]. The ESPAT paramter is a measurement of absorption strength of the 3 μm spectral feature in single scattering albedo spectra, which has been calibrated and can be converted into water abundance. This study will help understand the lunar interior, eruption dynamics, and provide new insight to which pyroclastic deposits will be the most fruitful for future lunar exploration and habitation.

Methods: We investigated the water abundance of 34 localized pyroclastic deposits, the same deposits found in [6]. These include deposits in Frigoris, Oppenheimer, Lavoisier, Apollo, Gauss, Alphonsus, Compton, Birt E, Messala, J. Herschel, Mersenius, and Grimaldi. We used the same defined boudaries and extent of the deposits as [6].

Because of our interest in resource potential, we are more interested in the average water abundance in each pyroclastic deposit rather than water abundance variation in each deposit. Thus, we take all ESPAT pixels within each pyroclastic deposit and determine its average ESPAT value. Because water abundance varies with latitude [7], we also calculated the average ESPAT value within the region surrounding each pyroclastic deposit and determined the difference in average ESAPT value. Next, we convert this difference in ESPAT values to water abundance (water=[ESPAT•5000]+20) in ppm [7]. We will call this value the excess water abundance.

After calculating the average excess water abundance of each pyroclatic deposit relative to the surrounding area, we compare this excess water abundance parameter to the other physical and compositional parameters of the localized pyroclastic deposits, which includes glass abundance, mafic mineral abundance, surface rock abundance, Mini-RF 12.6-cm circular polarization ratio (CPR), juvenile and pyroclastic deposit volumes, and mean deposit thickness, which are all values derived from [6]. We also identify how excess water abundance varies with each of the parameter in relation to the type of localized pyroclastic deposit (i.e., Glassy, Blocky, Crystalline, and Indistinct).

Results: In subtracting the water abundance of the background from the water abundance of each pyroclastic deposit, we found five pyroclastic deposits that displayed negative excess water abundances, which indicates the water abundance within these pyroclastic deposits are less than the background. These negative excess water abundances are typically between -10 and 0 ppm, with one as low as -73 ppm. Otherwise, pyroclastic deposits exhibit excess water contents as high as 157 ppm relative to the background.

We compared the excess water abundance to the two main components used to define the four localized pyroclastic deposits groups, glass abundance and surface rock abundance. In general, we see a slight increase in excess water abundance with increasing glass abundance (Fig. 1a) with some outliers where there are pyroclastic deposits with high glass abundance with very low excess water abundance (~0 ppm). As for the surface rock abundance, we see a decreasing excess water abundance with increasing rock abundance (Fig. 1b) where the relationship become significantly scattered at surface rock abundances >0.40. Because surface rock abundance tends to correlate with ΔH (difference between the thermal inertia of the pyroclastic deposit relative to the surrounding area) and CPR [6], unsurprisingly, excess water abundance decreases with CPR (Fig. 1c) and increases with ΔH (Fig. 1d). Interstingly, we do observe that the relationship is stronger between excess water abundance and CPR and ΔH than with surface rock abundance. Furthermore, the outliers observed in comparing excess water abundance with glass and surface rock abundance, disappear.

When dividing these pyroclastic deposits by group, we observe that Glassy deposits generally have higher excess water abundances relative to the other deposits, with some outliers. Crystalline deposits exhibit lower excess water abundances than Glassy deposits. In contrast to these other groups, Indistinct deposits display some of the lowest excess water abundances. Blocky deposits exhibit varying excess water abundances with values as high as the Crystalline deposits, but as low as the Indistinct deposits.

We also compared excess water abundance with other parameters, such as mafic mineral abundance, plagioclase abundance, mean pyroclastic deposit thickness, pyroclastic deposit volume, and juvenile volume. We did not observe any relationships between these parameters.

Discussion: We observe a general relationship between excess water abundance and glass and surface rock abundance, but with some outliers. On the other hand, we found that excess water abundance appears to have a stronger relationship with CPR and ΔH instead of surface rock abundance (Fig. 1c and d). This difference is due to the fact that surface rock abundance, CPR, and ΔH are sensitive to different physical aspects of the regolith. For example, the surface rock abundance parameter is sensitive to >1 m blocks on the surface [8]. In contrast, CPR is sensitive to 0.01–1 m rocks on the surface as well as the subsurface (to a depth of ~1 m) and ΔH is sensitive to the density of the regolith in the top ~10 cm [9]. This suggests that excess water abundance is related to the fines within the pyroclastic deposits and not the larger boulders. Because the excess water abundance is more related to CPR and ΔH, this indicates that water abundance is greater in pyroclastic deposits with finer grains and where the regolith consists of rounded and equant grains. Unsurprisingly, this would also indicate that water abundance is related to degree of fragmentation of the eruption, where more water in the magma results in greater fragmentation of the erupted material.

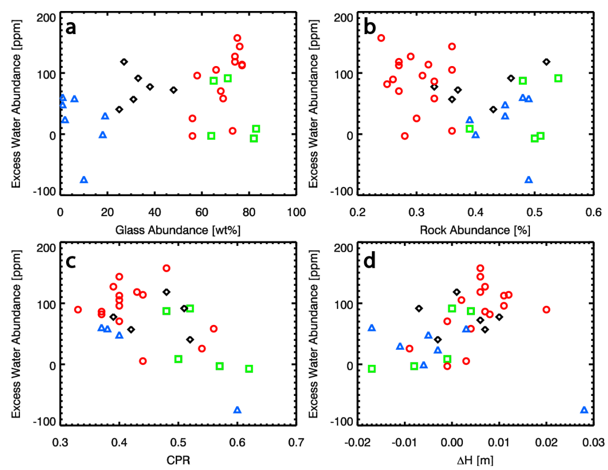

Fig. 1: The relationships between excess water abundance and a) glass abundance, b) rock abundance, c) CPR, and d) ΔH. Each of the four groups, Glassy (red circles), Crystalline (black diamonds), Blocky (green squares), and Indistinct (blue triangle) are represented.

References: [1] Hawke, B. R. et al. (1990) *Proc. Lunar and Planet. Sci. 20th*, 249–258. [2] Hawke, B. R. and Coombs, C. R. (1994) SPACE IV, 1008–1019. [3] Gaddis L. R. (2000) *JGR*, 105(E2), 4245–4262. [4] Head, J. W. And Wilson L. (1979) *Proc. Lunar and Planet. Sci. 10th*, 2861–2897. [5] Hawke B. R. et al. (1989) *Proc. Lunar and Planet. Sci. 19th*, 255–268. [6] Trang, D. et al. (2017), *JGR*, 283, 232–253. [7] Li, S. and Milliken, R. E (2017), *Sci. Adv.*, 3(9), e1701471. [8] Bandfield, J. L. et al. (2011), *JGR*, 116, E00H02. [9] Hayne, P. O. et al. (2017), *JGR*, 112, 2371–2400.