ATMOSPHERIC IMPLICATIONS FROM THE CRATER RECORD ALONG CURISITY'S TRAVERSE, GALE CRATER, MARS.

M. E. Hoffman[1], H. E. Newsom[1], B. M. Adair[1], J. M. Comellas[1], J. M. Williams[1], J. P. Williams[2], F. J. Calef [3], J. A. Grant[4], R. C. Wiens[5], S. Le Mouélic[6], and K. Escarcega[1], [1]Univ. of New Mexico (mehoffman13@unm.edu), [2]Univ. of Los Angeles, [3]JPL/Caltech, [4]Smithsonian Inst., Washington, DC, [5]Los Alamos National Lab, [6]Univ. of Nantes, FR

Introduction: Mars has undergone semi-periodic obliquity fluctuations that have influenced the characteristics of the atmosphere [1]. When Mars is at a higher obliquity, the poles are exposed to direct sunlight for prolonged periods, resulting in a temporarily warmer climate caused by the solid reservoirs of carbon dioxide evaporating and contributing to the atmospheric density of Mars. When the planet is experiencing a lower degree of obliquity, the opposite occurs, and the poles withhold more of the atmospheric carbon dioxide, resulting in a less dense planetary atmosphere. These fluctuations in obliquity and atmospheric pressure can be seen in geologic features such as threshold craters, or the smallest craters that are expected to be observed given a specific planetary atmospheric pressure [2].

Cratering Mechanics: All objects that impact an atmosphere will encounter some degree of deceleration, ablation, and possibly fragmentation. Deceleration results in a reduction of speed for a projectile, sometimes below hypervelocity. Deceleration is more sensitive to the size of the impactor, so smaller objects experience a greater degree of deceleration [2]. When trying to understand the smallest objects that survive entry through a planetary atmosphere, deceleration greatly effects the speed at which these small, sometimes centimeters in diameter, projectiles impact into the Martian surface. If a projectile does not impact at hypervelocity, it will not impact with sufficient energy to form an impact crater [3]. Ablation is the vaporization of the projectile as it interacts with the atmosphere or the transfer of energy from the projectile into heat [2]. Smaller, faster objects are filtered out by the atmosphere through vaporizing completely before reaching the surface. The density of the atmosphere will affect the threshold for the size of projectile that will survive vaporization and the resulting smallest crater diameter that can be seen at the surface. Fragmentation occurs in approximately half of the primary projectiles that impact Mars [4], but that percentage decreases to about 4 percent for projectiles forming craters of $D < 5$ m [2]. Since, this study is focused on craters of $D < 5$ m, we assume that most craters are formed from primary impactors that did not experience fragmentation and survived deceleration and ablation with the minimum energy required to form an impact crater.

Crater Catalog: Over the first 2300 sols, from the start of the mission through the Vera Rubin ridge, a total of 198 craters were found along the traverse. Of the 198 total craters: 5 were $D < 0.5$ m, 28 were $D < 1.0$ m, and 148 were $D < 5.0$ m. The smallest crater identified was $D = 0.33$ m. All craters were found over 418,100 m^2.

Previous theoretical models have predicted that under the current conditions on Mars, the smallest craters expected to form are $D \approx 0.25$ m [2] [3] [5]. The lack of small, cm-sized craters indicates that the atmosphere would have been more dense in the past 5-20 million years, or the estimated age of the smaller craters [6], [7].

Atmospheric Implications: If the atmosphere was more dense in the last 5-20 million years than present-day Mars, then it would explain why there are fewer than expected small cm-sized craters along Curiosity's traverse. The atmosphere must have been more dense than it is today to prevent new small craters from forming or by eroding small craters at a faster rate.

A denser atmosphere could result in the better facilitation of transport or preservation of life. Having a denser atmosphere and a more habitable surface environment could have allowed temporary locations near the surface, such as pods or a shallow aquifer, where life may have propagated and been deposited. It is possible that these deposits could be preserved at the surface before water could evaporate due to the higher pressure of the atmosphere. If such deposits contained microorganisms or other forms of life, there may be evidence contained within these geologic features. A denser atmosphere allows for a more habitable surface environment and the ability for liquid water to transport materials and possibly signs of life to the surface before evaporating.

Conclusions: One possible explanation for the crater record is that the Martian atmosphere may have been more dense approximately 5 to 20 million years ago or more recently during short-term spikes in obliquity angle, supporting the literature on obliquity fluctuations [1]. A denser Martian atmosphere could provide a warmer, more habitable environment and preserve an event that exposes microorganisms in a fluid deposit or a shallow aquifer where life was able to propagate.

References: [1] Laskar J. et al. (2004). *A&A, 428,* 261-285. [2] Williams J. P. et al. (2014). *Icarus, 235,* 23-36. [3] Popova O. et al. (2003). *Meteoritics & Planet. Sci., 38,* 905-925. [4] Dauber I. J. et al. (2013). *Icarus, 225*, 506-516 [5] Horz F. et al. (1999). *Science, 285*, 2105-2107. [6] Williams et al. (2018). *Icarus, 170,* 343-364. [7] Golombek M. P. et al. (2014) JGR, 119, 2522-2527.