**INITIAL SMALL CRATER SURVEY OF THE MER SPIRIT ROVER TRAVERSE.** S. J. Shafer¹, M. E. Hoffman¹, H. E. Newsom¹, ¹The University of New Mexico, Albuquerque NM 87131, USA (ss6432@unm.edu).

**Introduction:** The Spirit rover traversed across over 7 kilometers of Martian terrain in Gusev Crater [1]. Over the course of its mission, the rover encountered several small circular depressions thought to be formed by impact cratering [2, 3]. Small craters below diameter, D < 5.0 meters are difficult to distinguish with even the best HiRISE imagery, which has a resolution of ~25cm/pixel. Rover imagery provides a unique opportunity to survey the smallest craters that form on the Martian surface. These small impactors are important because they serve as indirect geological evidence of the recent conditions of the Martian atmosphere [4 - 6].

The obliquity, or tilt, of Mars is theorized to be unstable and to fluctuate semi-periodically [7]. Similar to Earth, these changes in planetary tilt can produce dramatic changes in the atmosphere [8]. When Mars is at a lower obliquity (0-30 degrees), the poles are exposed to less sunlight in the summers and are able to “freeze” out more carbon dioxide from the atmosphere and store it in polar ice. During periods of higher obliquity angle (30-60 degrees), the poles are exposed to sunlight longer and more CO₂ sublimates, contributing to the density of the atmosphere. These fluctuations in obliquity cause corresponding changes in atmospheric density which in turn, changes the number of craters being formed at the surface [4, 8].

**Cratering Mechanics:** When the density of the Martian atmosphere is thicker, it is able to filter out more incoming projectiles from space that could form a small crater at the surface if it is travelling at hypervelocity when it impacts [4, 5, 8]. When the Martian atmosphere is less dense, more incoming projectiles survive ablation and declaration to reach the surface with enough velocity to form a crater [5]. Fragmentation is also a key factor in determining impactor survivability through an atmosphere [9]. However, fragmentation occurs less in smaller, D < 5 m crater forming impactors while being more common in larger, D > 5 m crater forming impactors [8].

Another consideration is the influence of secondary craters in the crater catalog. Secondary craters are craters formed from ejecta emitted from a larger, primary impact on the planet’s surface. Secondary craters are not an accurate reflection of cratering rates as one primary impact can create hundreds or thousands of secondary impacts. There is ongoing debate in the literature of how to account for secondary cratering [10, 11]. For this study, which focuses on D < 6 m craters, the craters are approximately 100 Ma or less with most smaller craters under 1.0 meters in diameter being < 20 Ma, given current erosion rate estimates [12]. Additional evidence of secondary cratering such as rays or clustering would be more apparent given their young ages. It is not obvious if the majority of these small craters are primary craters or distant secondaries, which are secondary craters that travel further from their original location and have a stronger resemblance to primaries. The contamination of distant secondaries in this catalog cannot be ruled out due to substantial evidence of secondary cratering in Gusev Crater.

**Methods:** Crater candidates include craters near the rover with a long axis of less than six meters in length. Documented crater candidates are identified using compilations of the rover’s panoramic and navigation camera’s landscape photos. Midnight Planets, a program that combines images, data, and text from the Mars Rover missions, including Spirit, is used for this identification. After identifying a crater, the crater’s azimuth, distance from rover, short axis lengths, and long axis lengths are measured with the location and ruler tools in Analyst’s Notebook. For crater candidates that are questionable, Analyst’s Notebooks profile tool is used to draw a topographical profile of the crater. If the profile showed the crater to have a circular depression, it is added to the crater data.

*Figure 1. An image of a small crater 5.5m from the rover from sol 74 with an average diameter of 1.99m.*

**Crater Survey Overview:** For the first 500 Sols of the Spirit mission, 267 small craters were found and documented. The smallest of the documented craters found had a long axis length of 0.24 meters and a short
axis length of 0.22 meters. This follows predictions for the smallest diameter impact crater that can form under current Martian atmospheric conditions [5, 13, 14]. Of these craters, 38 had a measured long axis length of less than or equal to 1.5 meters. Of the 267 small craters found, 213 were documented between sols 1 and 155. Between sols 155 and 500, only 54 craters were found and documented. Accounting for this change in crater density is the arrival of the Spirit rover at Columbia Hills which occurred on sol 155. From sol 1 to sol 155 the landscape is flat allowing the rover to cover larger distances between each sol, and for craters to be easier to identify. Additionally, the flat surface allows impact craters to form unobstructed. Incoming projectiles can make clean contact with the target material. However, in rougher terrains, incoming projectiles have a higher chance of impacting boulders or other protruding geological features, interfering with the formation of a simple impact crater. An increase in surface roughness or rock abundance generally leads in a decrease to identifiable small craters. The arrival of the rover at Columbia Hills accounts for the change in crater density observed and documented.

![Traverse map of the Spirit rover made using Analyst Notebook highlighting the transition of the terrain. The locations where the rover stopped to conduct science are represented with corresponding sol numbers.](image)

**Atmospheric Implications:** If the density of the Martian atmosphere is fluctuating with obliquity, then the effects of these changes should be seen in the crater catalog [8]. Theoretical models can be used to predict the small crater size frequency distribution which can then be used to compare to observations. A previous study in Gale Crater with the Curiosity rover found fewer than expected small craters than predicted which is tied to Mars having a denser atmosphere is the last 20 Ma [15]. This study provides an additional sample of small craters in another location on Mars. There are more small craters at Gusev but this may be the result of terrain texture. Further work is needed to confirm if the density of the Martian atmosphere is fluctuating and filtering out a greater number of small projectiles.

**Erosion Rates:** Current estimates for the rate of erosion at Gusev Crater are some of the slowest across Mars at ~0.03nm/year [12]. These rates reflect a slow deflation by aeolian processes that have persisted at the Gusev plains for billions of years. Small craters are slowly buried by deposition of sediments in the crater and the simultaneous erosion of the rim [2, 3, 12]. If the atmospheric pressure is fluctuating, then eolian-driven erosion rates may also be changing throughout Martian history. Periods of higher obliquity and higher atmospheric density could be associated with higher erosion rates which could bury small craters faster, removing from the record. The opposite would occur and more small craters would be visible if the atmosphere was less dense in recent history.

**Conclusions:** Small crater populations can be surveyed by rover missions across Mars to create multiple data points for understanding how a potential fluctuating atmosphere can be influencing geologic features at the surface. We are extending the study of the smallest craters along the Curiosity traverse [15] to the extensive record from the MER rover missions. This initial survey of the smallest craters across the first 500 sols of the Spirit traverse supplements past observational studies of these smallest craters and will help reconcile the actual data with theoretical predictions.