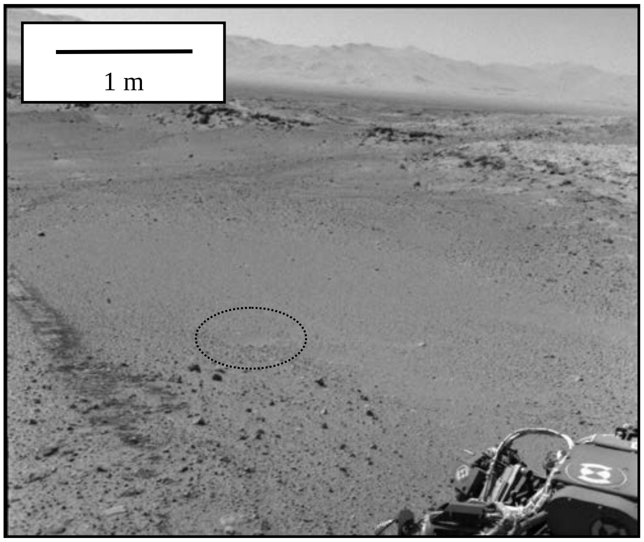
PROPERTIES OF THE SMALLEST IMPACT CRATERS ALONG THE CURIOSITY TRAVERSE USING VIRTUAL REALITY TECHNOLOGY. B.M. Adair[1], H.E. Newsom[1], K. Lewis[2], S. Lemouelic[3], R.C. Wiens[4], A. Winter[5], Z. Gallegos[1], J.M. Williams[1], F.J. Calef, Jr.[5], T.S.J. Gabriel[6] [1]Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131, adairb@unm.edu, [2]Johns Hopkins APL, MD, [3]Nantes, [4]Los Alamos National Laboratory, New Mexico, USA, [5]Jet Propulsion Laboratory, Pasadena CA., [6]Arizona State Univ., Tempe, AZ.



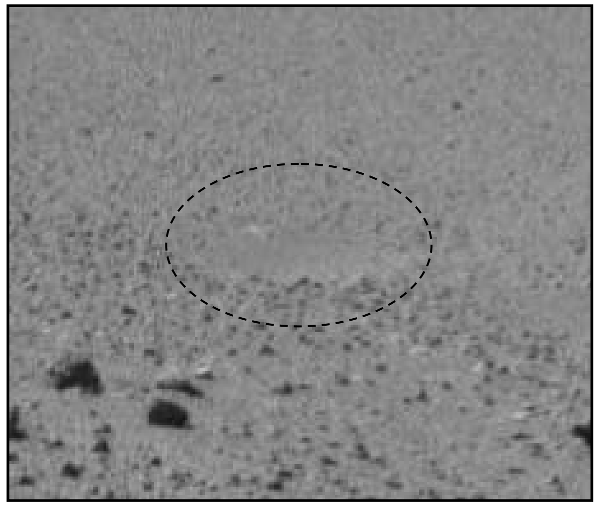


Fig. 1 (left) Shown is a crater imaged on sol 565, which measures less than a meter in length (.56 m). It is one of the smallest in the data set.
Fig. 2 (above) A close up of the crater in Fig. 1.

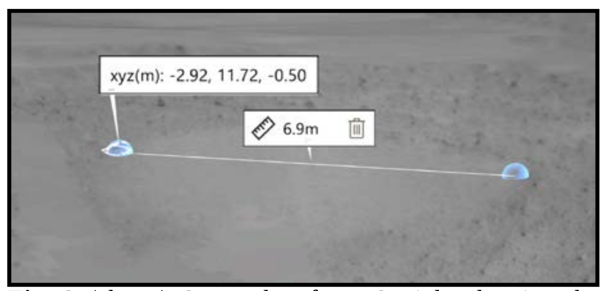


Fig. 3 (above) Screenshot from Onsight showing the ruler tool over a crater.

Introduction: The Curiosity rover has been traversing part of Gale Crater for over five years (1905 sols) across 17 km. During this time, images and data from NavCam, Mastcam, MAHLI, and ChemCam remote micro imager (RMI) has shown a variety of impact craters [1]. This study extends the survey done initially by Newsom et al. [1] to cover more of the rover traverse. MastCam and NavCam images are most useful in finding craters less than a few meters in diameter. However, identification of m-sized craters are limited to locations near the rover, and they are difficult to analyze quantitatively beyond 15 m. Now analysis of the small craters is straightforward with the JPL OnSight program that uses virtual reality (VR) technology, with the Microsoft Hololens headset as well as web versions. The Onsight ruler tool allows us to measure the craters' distance from the rover, as well as their shape. The OnSight ruler has recently been upgraded to allow measurement of the height of crater rims and other features (**Fig. 3**).

Strategies for finding craters: Finding these craters begins with looking at the Navcam and Mastcam images to identify circular features. Characteristics of these craters vary depending on the sol and location. Some were completely dust filled and only identifiable because of the discoloration of material within the crater. We then use the OnSight tools to measure the craters for their length, width, rim heights, and depth. We can also observe how irregular a craters shape is by walking the craters' perimeter virtually with the Hololens.

The preliminary distribution of craters near the traverse is shown on **Fig. 4**, and the variability may partly be due to the effect of the substrate on formation and preservation. However, the variation in abundance of craters is partly controlled by the amount of imagery taken at each stop and the distance between rover stops. Some small craters were undoubtedly missed due to data gaps because of the long daily drives across the Bradbury Group.

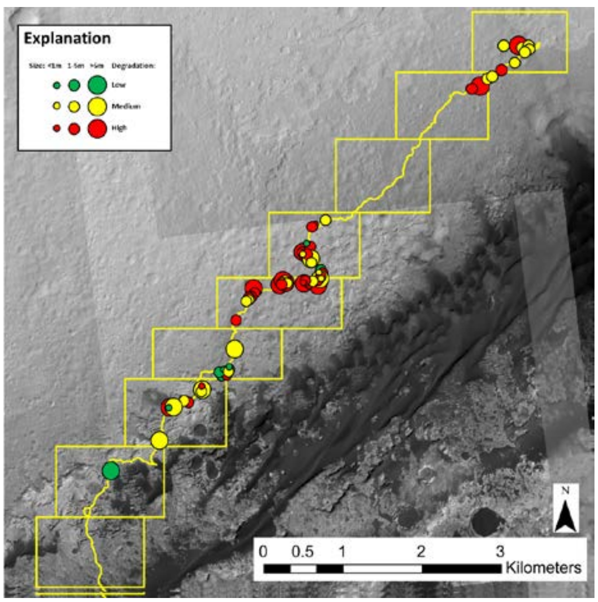


Fig. 4 Distribution and degradation state of small craters along the MSL traverse.

Examining the smallest craters: Within this study, covering the area between the Kimberly and Ogunquit Beach, the OnSight program has allowed for the measurement of over 80 craters, 16 of which were less than a meter in size. The smallest known crater in the data set was 0.52 m in diameter. Of the ten smallest craters, all shared similar features. All ten were very shallow and filled with fine grain regolith, which made measureing depth and rim height difficult. All seemed to have very eroded rims, and the changes in elevation around the rim were minimal. Only a few appeared to have ejecta blocks on their rims that could be due to impact. All of the small craters were close to circular and varied in diameter by < 12 centimeters. These craters were all less than 12 m from the rover. At greater distances, they become obscured and harder to characterize. No evidence of impactites, including shatter cones were observed. Irregular small depressions and swales are present along the traverse, but none has the characteristics, like ejecta, of being impact related, and they are likely due to aeolian erosion.

Discussion and conclusions: The circularity of the craters is consistent with primarily vertical impacts. Implying that small meteorites hitting the Martian atmosphere at 45 degrees at 5 km/s (Mars escape velocity) would lose most of their horizontal velocity component but still hit at hypervelocity speeds [2]; however more detailed modeling of small bolides in the Martian atmosphere is required. This suggests that closer investigation of these impact craters should uncover evidence of hypervelocity impact, e.g. shock melt, spallation fractures, high-pressure polymorphs, nearby impactites, and upturned crater rims.

There is a distinct cut off in minimum size near 0.5 m in diameter for the craters investigated so far. The minimum size of these craters is consistent with data from the MER rovers, that the atmospheric density has not been lower than present for many millions of years [3].

Future work will include evaluation of crater degradation processes, based on quantitative measurements of the rims, rim blocks, crater fill, and evidence for aeolian effects correlated with prevailing wind directions.

References: [1] Newsom H.E. et al., 2015, Icarus, 249, 108-128. [2] Williams J.-P. et al., 2014 Icarus 235, 23-36. [3] Paige, D.A. et al., 2007. 7th Intl. Conf. on Mars, Abstract 3392.