AVIRE CRATER: GULLIES, DUNES, AND POTENTIAL PALEOLAKE. Tanya N. Harrison, Malin Space Science Systems, P.O. Box 910148, San Diego, CA, 92191-0148, USA (harrison@msss.com).

Introduction: Since the first observation of gullies in the martian mid- to high-latitudes by the Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) in 1997 [1] and the discovery of multiple sites of gully activity occurring within the last decade by MOC and the Mars Reconnaissance Orbiter (MRO) [2,3,4], whether they formed—and are still forming—via processes requiring liquid (i.e. debris flows initiated by groundwater release [i.e. 1] or melting of snow/frost/near-surface ground ice [i.e. 5, 6]) or entirely dry mechanisms (dry granular flow [i.e. 7]) has been a matter of great debate. Determining how the gullies formed is an important question geologically as hundreds of thousands of individual gullies are present on Mars, as well as astrobiologically if their formation did (and still does) indeed involve liquid water.

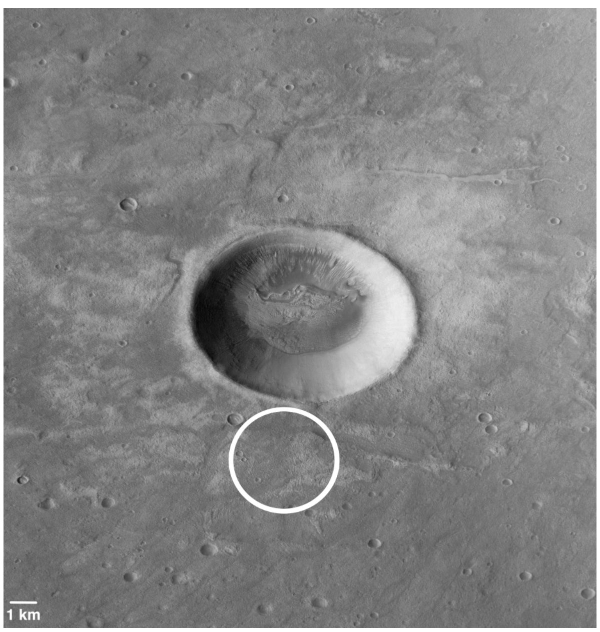

Figure 1: CTX B07_012351_1389_XN_41S159W of Avire Crater with proposed landing ellipse marked. The ellipse is centered at 41.25°S, 159.86°W at an elevation of -0.77 km with respect to the MDIM 2.1 ellipsoid in MOLA planetographic coordinates. The prime science targets are gullies, dunes, and "fill" material within the crater. North is up.

Avire Crater (41.15°S, 159.85°W) (Fig. 1), a small (6.6 km in diameter) gullied crater within Newton Crater, provides many aspects ideal to a future rover mission. It has been previously hypothesized to be the location of a former paleolake with multiple episodes of ponding and deposition [8]. Gullies occur almost continuously on the southwest wall clockwise to the northeastern wall. Dark-toned dunes are present in the northern portion of the crater, in some places obscuring gullies while cut by gullies in others (Fig. 2). No changes in the extent or appearance of the dunes have been observed since they were first imaged by MOC in January of 2000. The dunes lack superimposed craters, indicating that the gullies that cut through them are geologically very youthful. Layered lobate features are present at the base of the gullies on the northern wall (Fig. 3), seen in many other craters on Mars (not always in association with gullies), which have been suggested to have formed as terminal moraines of ice-rich flows [9,10,11]; in Avire, these features have also been suggested to be paleolake deposits [8]. The crater floor is obscured by mid-latitude "fill" material, hypothesized to be partially comprised of ice based on morphologic evidence that the material has been partially removed [12-16]. As gullies, dunes, and "fill" material occur in many places on Mars, a single rover mission to a site containing these features would provide valuable information applicable to thousands of other locations across the planet.

Figure 2: Subset of HiRISE ESP_012206_1390 showing gullies on the northeastern wall of Avire Crater cutting through dunes. Note the lack of craters on the dunes, indicating that they, and subsequently the gullies cutting through them, are geologically young.

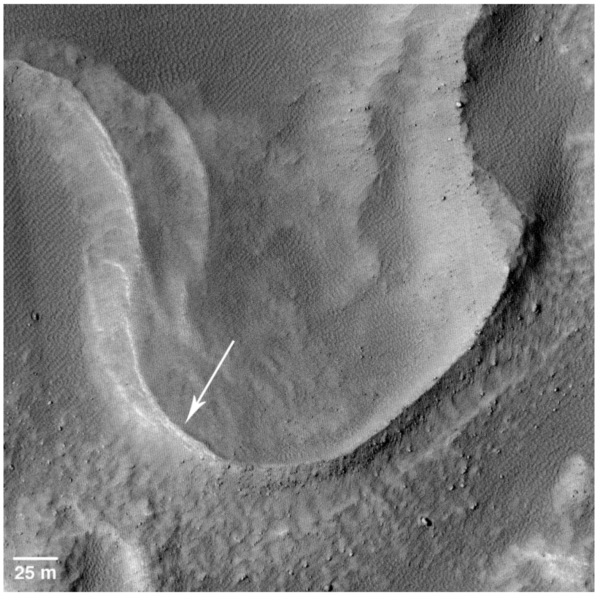

Figure 3: Subset of HiRISE ESP_012272_1390 with light-toned layers exposed within one of the lobate features off the northern wall of Avire Crater indicated by the arrow.

Mission Description: A rover sent to the crater would require instrumentation to determine the composition and grain size of the various units it would encounter within the crater. To avoid driving up the crater walls or through the dunes to examine the gullies, a camera with adequate zoom capability would be well suited in order to image the various portions of the gully channels. Avire also lies close to the Sirenum Fossae region where a large number of light-toned gully flows (including 2 that formed within the last decade) are present relative to the rest of the planet [3]. This region has been subjected to multiple episodes of tectonic activity in the past [17], and if tectonic activity plays a role in the concentration of gullies in this region, an instrument capable of detecting seismic activity would prove useful. If for some reason the rover lands and it is determined that it cannot drive into Avire, a number of adjacent craters also contain gullies, mid-latitude “fill” material, and mantling material on the crater walls that would be of scientific interest (Fig. 4) and could provide viable alternatives.

Science Merit Related to Mission Objectives: Assessing whether the gullies formed via a process requiring liquid (with the most likely candidate being water, including brines) and whether the crater once hosted a lake will aid in evaluating the paleoenvironment of the area and determining whether or not that environment might have been conducive to sustaining life. Examining the layers of the lobate features on the northern wall may help to answer the question of whether these features are terminal moraines or lake sediments, which is important in understanding Mars' climatic history. Determining the composition and grain size of the dunes within the crater would provide insight into the suspension and saltation capability of the past and present martian atmosphere. Establishing the grain size of the debris fans of the gullies will help answer the wet vs. dry debate of gully formation; long-runout entirely dry flows on Earth only occur with larger grain sizes [18] (coarse gravel-sized grains and larger (>16 mm [19]), with mobility increasing with volume [20]) and therefore if the gully fans are predominantly comprised of finer-grained material then it would support formation mechanisms requiring liquid.

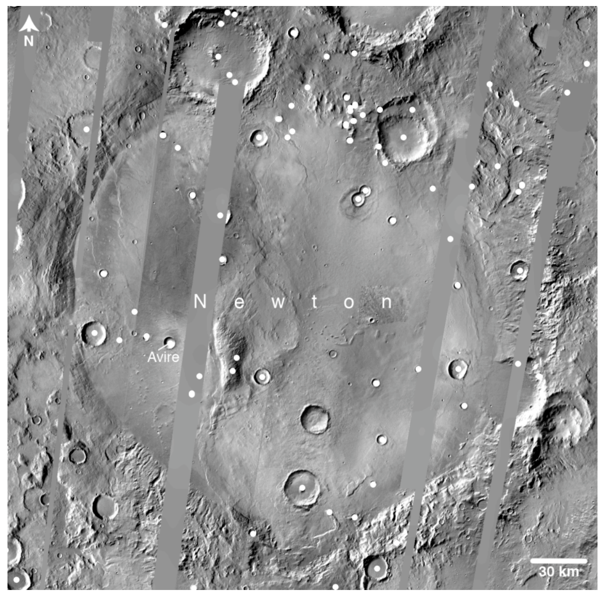

Figure 4: THEMIS daytime IR mosaic of Newton Crater. White dots indicate gullied craters.

Engineering Constraints: The low elevation of the ellipse and crater floor (-0.75-1.5 km) are favorable for existing landing systems; however, the latitude of the site would require an orbital relay with an appropriate orbit for communications and a launch window allowing for direct-to-Earth communications during EDL. The small size and rugged floor of Avire would require landing outside of the crater and then driving into it, making it a go-to site. Despite the shallowest-sloping wall of the crater being the northern wall, the landing ellipse has been chosen south of the crater in order to avoid driving through the dunes. The southern wall of the crater has a slope of ~22°, which may be within the range of accessibility of a MAX-C-type rover as there is no evidence of significant mass movement along the crater's southern wall at HiRISE scale (30 cm/pixel). Due to the presence of gullies and their possible water-involved origin, Avire is a “special region” and would be subject to planetary protection issues, which would need to be addressed during rover construction and mission planning.

Information Required for Potential New Landing Sites: Complete MRO Context Camera (CTX) stereo coverage of Avire and the surrounding terrain has already been acquired. HiRISE has acquired stereo coverage of the eastern half of the crater, but only one image of the western half, which was taken under somewhat shadowed conditions. Therefore, HiRISE stereo coverage of the western wall under better illumination conditions would be required in order to generate a DEM of the crater in its entirety. Additional HiRISE coverage of the terrain to the south of the crater within the landing ellipse is also necessary. No CRISM data is currently available of Avire and therefore should be acquired; the crater and landing ellipse can easily be covered by 1-2 CRISM full-resolution targeted observations.

Landing Ellipse: The proposed landing ellipse lies to the south of the crater, centered at 41.25°S, 159.86°W. Fig 5 shows a representative sample of the terrain within the ejecta blanket at HiRISE scale, as no HiRISE data is currently available of the center of the landing ellipse. Table 1 summarizes the characteristics of the landing ellipse and science target sites.

Summary: Avire Crater hosts a diverse collection of geologic features in a relatively small area. The features of interest within the crater are present in many other locations on Mars, and therefore rather than only learning about the specific landing site, a single rover mission to Avire would provide data applicable to thousands of other locations on the planet.

Table 1: Landing site characteristics.

Site Name	Avire
Science Target Center Coordinates Landing Ellipse Center Coordinates	41.15°S, 159.85°W 41.25°S, 159.86°W
Elevation	-0.77 km in landing ellipse; as low as -1.5 km in crater floor
Ellipse Size	4.0 km
Prime Science Targets	Gullies, mid-latitude fill material, layered lobate features, dunes
Distance of Science Targets from Ellipse Center	Gullies – 5.0 km to NW on west wall; 6.9 km to NW on north wall; 7.1 km to NE to gullies cutting through dunes on NE wall Lobate features, “fill” material, and dunes – 6.6 km to N

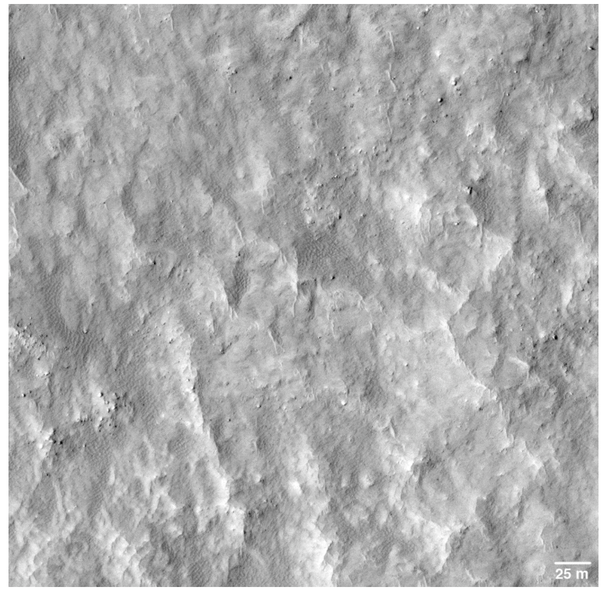

Figure 5: Subset of HiRISE ESP_012206_1390 showing a representative sample of the terrain within the landing ellipse. No HiRISE coverage of the center of the ellipse has been acquired at the time of writing.

References: [1] Malin M. C. and Edgett K. S. (2000) *Science, 288*, 2330-2335. [2] Malin M. C. et al. (2006) *Science, 314,* 1573-1577 [3] Harrison T. N. et al. (2009) *DPS 41*, Abstract #57.03. [4] Dundas C. M. et al. (2009) *Fall AGU 2009,* Abstract #P22A-02. [5] Hartmann W. K. et al. (2002) *LPSC XXXIII,* Abstract #1904. [6] Costard F. et al. (2002) *Science, 295,* 110-113. [7] Pelletier J. D. et al. (2008) *Geology, 36,* 211-214. [8] Cabrol N. A. and Grin E. A. (2003) *Global and Planetary Change, 35*, 199-219. [9] Milliken R. E. et al. (2003) *JGR., 108,* E05057. [10] Berman D. C. et al. (2005) *Icarus, 178*, 465-486. [11] Head J. W. et al. (2008) *PNAS, 105,* 13258-13263. [12] Mangold N. (2003) *JGR, 108,* 8021. [13] Pierce T .L. and Crown D. A. (2003) *Icarus, 163,* 46-65. [14] Chuang F. C. and Crown D. A. (2005) *Icarus*, *179,* 24-42. [15] Li H. et al. (2005) *Icarus, 176*, 382-394. [16] Levy J. S. et al. (2009) *Icarus, 202,* 462-476. [17] Wilson L. and Head J. W. (2002) *JGR, 107,* 5057. [18] Hungr O. et al. (2001) *Env. Eng. Geosci., VII,* 221-238. [19] Krumbein W. C. and Sloss L. L. (1963) *Stratigraphy and Sedimentation (2nd ed),* Freeman and Company, San Francisco, 660 p. [20] Heim A. (1932) *Landslides and Human Lives (Bergsturz und Menschenleben)*, Bi-Tech Publishers (ed. Skermer, N.), Vancouver, B.C., 196 p.