RECENT GULLY ACTIVITY IN KAMNIK AND NARUKO CRATERS. Tanya N. Harrison, Malin Space Science Systems, P.O. Box 910148, San Diego, CA, 92191-0148, USA (harrison@msss.com).

Introduction: Kamnik Crater (37.52°S, 161.89°W; Fig. 1) is the site of a new gully flow that formed on the crater's eastern wall sometime between August 2003 and April 2008 [1]. Kamnik lies only ~50 km southwest of Naruko Crater (36.56°S, 161.80°W; Fig. 2), the site of a new gully flow that formed sometime between December 2001 and April 2005 [2]. The new light-toned flows in both craters are pictured in Fig. 3. A high number of light-toned gully flows occur in this region near the Sirenum Fossae relative to the rest of the planet [1], making it of particular interest because it may indicate that the gullies in this area are presently active. Whether gully formation and ongoing activity are due to mechanisms requiring liquid water (i.e. [3,4,5]) or entirely dry mechanisms (i.e. [6,7,8]) has been a subject of debate. If they are indeed formed and presently active due to liquid water (or brine), sites of recent gully activity provide prime landing sites, fitting NASA's previous "follow the water" theme, as well as its shift to "habitability."

In addition to a new gully flow, Kamnik provides the opportunity to investigate the nature of mid-latitude "fill" material, which is present in a great number of craters in the southern mid-latitudes of Mars and has been hypothesized to be partially comprised (or formerly partially comprised) of ice based on morphologic evidence that the material has been partially removed [refs 9-13]. The walls of many of the gully channels also display clear exposures of light-toned layered material within the material mantling the crater wall (Fig. 4). This mantling material is pervasive across the mid-latitudes of Mars and has been hypothesized to consist of dust and snow [14,15]; therefore, determining its composition is of considerable interest.

Naruko crater hosts not only a new light-toned gully flow on its northeastern wall, but also an older flow on its northern wall (no image of sufficient resolution exists before the flow formed to date it). It also has mid-latitude "fill" material on its floor, and exposures of light-toned material in gully walls on the northern wall of the crater, where the gullies have incised into mantling material. Therefore, either Naruko or Kamnik would provide valuable information on gullies, present-day gully activity, and the nature of the mid-latitude "fill" and mantling material, all of which are present in thousands of locations on Mars.

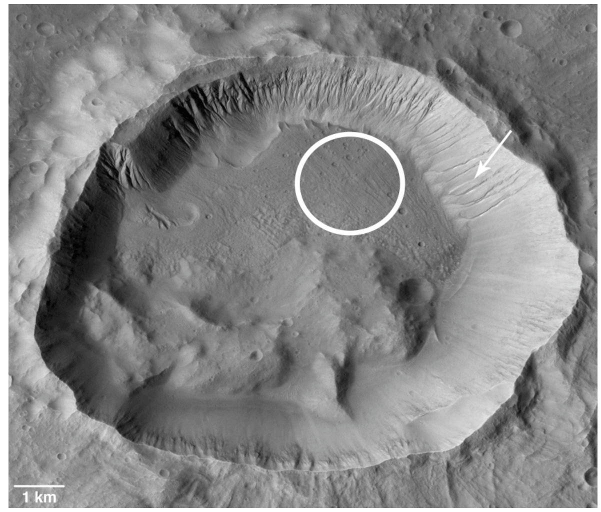

Figure 1: Kamnik Crater. The ellipse is centered at 37.49°S, 161.87°W at an elevation of 2.3 km with respect to the MDIM 2.1 ellipsoid in MOLA planetographic coordinates. The prime science targets are the new light-toned gully flow to the east of the ellipse, marked with an arrow, as well as the mid-latitude "fill" within the ellipse. North is up.

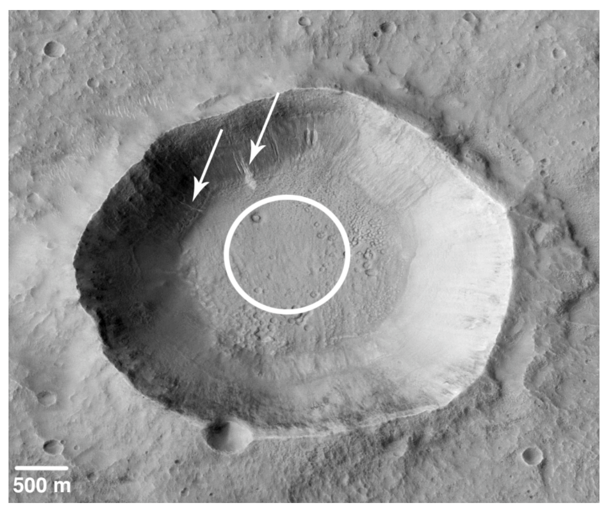

Figure 2: Naruko Crater. The ellipse is centered at 36.55°S, 161.80°W at an elevation of 2.7 km with respect to the MDIM 2.1 ellipsoid in MOLA planetographic coordinates. The prime science targets are the two light-toned gully flows marked with arrows, as well as the mid-latitude "fill" within the ellipse and the mantling material on the northern wall of the crater. North is up.

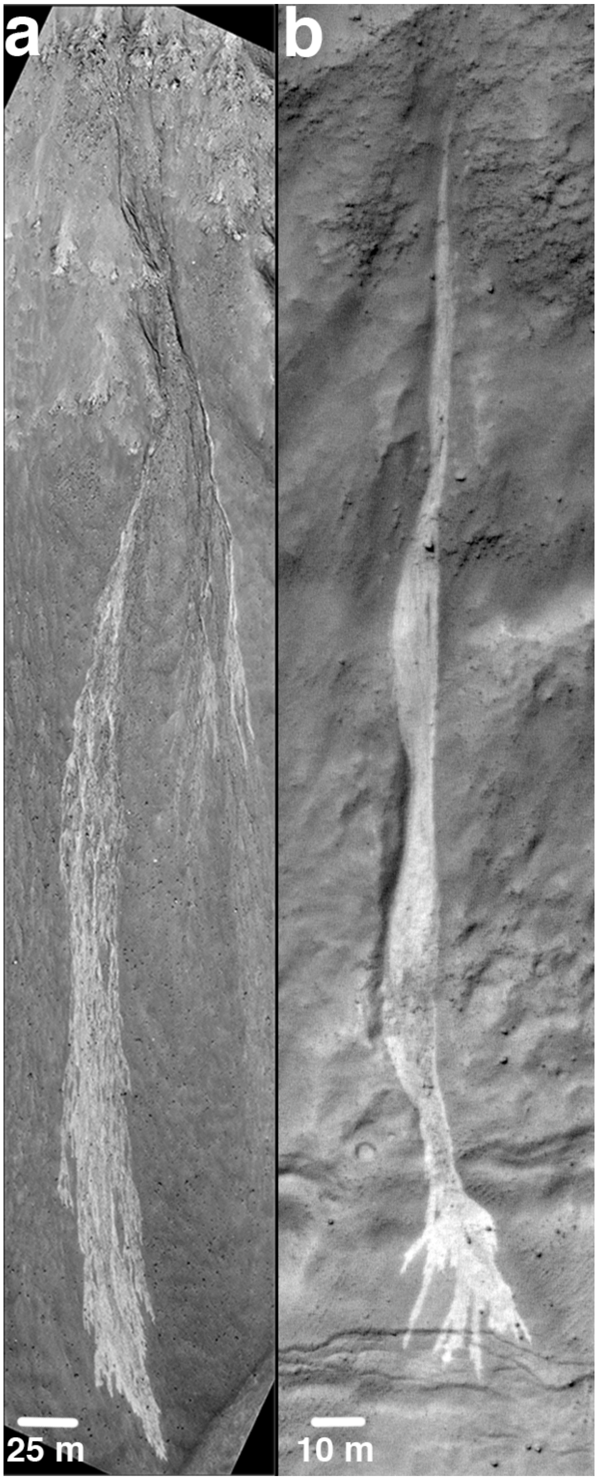

Figure 3: **(a)** Subframe of HiRISE ESP_012338_1425 showing the new light-toned flow in Kamnik Crater. North is to the left. **(b)** Subframe of HiRISE PSP_004229_1435 covering the new flow in Naruko Crater. North is to the upper right corner.

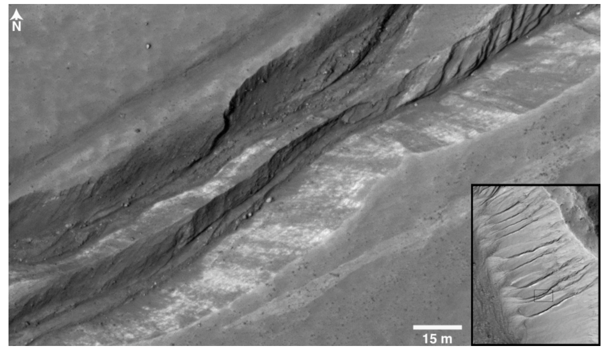

Figure 4: Subframe of HiRISE ESP_012338_1425 showing light-toned layered material exposed in a gully wall where a gully has incised through mantling material. CTX B04_011283_1424_XI_37S161W in the lower right corner shows the context of the HiRISE subframe.

Mission Description: A rover sent to either Kamnik or Naruko would require instrumentation to determine the composition and grain size of the various units within the crater. To avoid driving up the crater walls 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. Both craters are in the Sirenum Fossae region, which has been subjected to multiple episodes of tectonic activity in the past [16]. If tectonic activity plays a role in the concentration of gullies in this region, an instrument capable of detecting seismic activity would provide insight on Mars' present-day internal activity.

Science Merit Related to Mission Objectives: Assessing whether martian gullies formed via a process requiring liquid (with the most likely candidate being water, including brines) is of great geological and astrobiological interest, particularly due to the sheer number of gullies planetwide. 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 [17] (coarse gravel-sized grains and larger (>16 mm [18]), with mobility increasing with volume [19]) and therefore if the gully fans are predominantly comprised of finer-grained material then it would support formation mechanisms requiring liquid. Determining the composition of both the mid-latitude "fill" material and mantling material on the crater walls will provide insight into Mars' climatic history, as the presence of both has been hypothesized to be linked to the last period of high obliquity (i.e. [14,15]).

Engineering Constraints: The somewhat high elevation of Kamnik and Naruko craters (~2.3 and 2.6 km, respectively) provide an engineering challenge. While current airbag and skycrane technology would not be adequate for these sites, a new appropriate landing system would need to be devised. This is a measure that should be undertaken regardless of what future landing sites are chosen, as the majority of the southern hemisphere outside of the Argyre and Hellas basins lies well above the +1.0 km MOLA datum that is the elevation limit of current landing systems. If the rover is to land inside the crater, greater landing precision will also be necessary. However, with expanded HiRISE coverage, suitable landing ellipses outside of the craters may be found.

Due to the presence of gullies and their possible water-involved origin, both Kamnik and Naruko are "special regions" 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) and HiRISE stereo coverage of Naruko Crater has been acquired, but not complete HiRISE stereo coverage of Kamnik. Therefore, stereo coverage of Kamnik is required in order to create high-resolution DEMs of the landing site. To look for potential landing ellipses outside of the craters, additional HiRISE coverage of the surrounding terrain is also needed. CRISM has already acquired multiple full-resolution targeted observations of both craters.

Landing Ellipse: The proposed landing ellipses lie on the mid-latitude "fill" material within both craters. Tables 1 and 2 list the landing site characteristics for both sites. Larger landing ellipses outside of the craters would be more appropriate for utilization of current EDL technology, and with expanded HiRISE coverage around the craters, new landing ellipses can be evaluated.

Summary: Kamnik and Naruko both provide features of interest both geologically and astrobiologically. Gullies, mantling material, and "fill" material present at these locations is also present in many other locations on Mars, and hence a rover mission to one of these sites would provide invaluable data applicable to thousands of other locations planetwide.

Table 1: Landing site characteristics for Kamnik.

Site Name	Kamnik
Center Coordinates Latitude, longitude	37.49°S, 161.87°W
Elevation	+2.3 km
Ellipse Size	2 km
Prime Science Targets	Gullies, mantling material, mid-latitude "fill"
Distance of Science Targets from Ellipse Center	New gully flow – 1.88 km to E Layered exposures in mantling material– 2.3 km to SE Mid-latitude "fill" – inside ellipse

Table 2: Landing site characteristics for Naruko.

Site Name	Naruko
Center Coordinates Latitude, longitude	36.55°S, 161.80°W
Elevation	+2.7 km
Ellipse Size	1 km
Prime Science Targets	Gullies, mid-latitude "fill," mantling material
Distance of Science Targets from Ellipse Center	New gully flow – 953 m to NW Older gully flow and mantling material exposures – 840 m to NW Mid-latitude "fill" – inside ellipse

References: [1] Harrison T. N. et al. (2009) *DPS 41*, Abstract #57.03. [2] Malin M. C. et al. (2006) *Science, 314,* 1573-1577 [3] Malin M. C. and Edgett K. S. (2000) *Science, 288*, 2330-2335. [4] Hartmann W. K. et al. (2002) *LPSC XXXIII,* Abstract #1904. [5] Costard F. et al. (2002) *Science, 295,* 110-113. [6] Pelletier J. D. et al. (2008) *Geology, 36,* 211-214. [7] Treiman A. (2003) *JGR, 108,* 8031. [8] Shinbrot T. et al. (2004) *PNAS, 101,* 8542-8546. [9] Mangold N. (2003) *JGR, 108,* 8021. [10] Pierce T .L. and Crown D. A. (2003) *Icarus, 163,* 46-65. [11] Chuang F. C. and Crown D. A. (2005) *Icarus*, *179,* 24-42. [12] Li H. et al. (2005) *Icarus, 176*, 382-394. [13] Levy J. S. et al. (2009) *Icarus, 202,* 462-476. [14] Mustard J. F. et al. (2001) *Nature, 412,* 411-414. [15] Christensen P. R. (2003) *Nature, 422,* 45-48. [16] Wilson L. and Head J. W. (2002) *JGR, 107,* 5057. [17] Hungr O. et al. (2001) *Env. Eng. Geosci., VII,* 221-238. [18] Krumbein W. C. and Sloss L. L. (1963) *Stratigraphy and Sedimentation (2nd ed),* Freeman and Company, San Francisco, 660 p. [19] Heim A. (1932) *Landslides and Human Lives (Bergsturz und Menschenleben)*, Bi-Tech Publishers (ed. Skermer, N.), Vancouver, B.C., 196 p.