ATACAMA DESERT MUDFLOW AS AN ANALOG FOR RECENT GULLY ACTIVITY ON MARS. J.L. Heldmann[1], C. Conley[1, 2], A.J. Brown[3], L. Fletcher[1], J.L. Bishop[3], C.P. McKay[1] [1]NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035 USA Jennifer.L.Heldmann@nasa.gov, [2]NASA Headquarters, Washington, DC, 20546 [3]SETI Institute, Mountain View, CA 94043.

Introduction: Evidence of recent gully activity on Mars has been reported based on the formation of new light-toned deposits that have occurred in the past decade [1]. The nature of these deposits (Figure 1a) remains enigmatic but their association with the Mars gully features may suggest that liquid water played a role in their formation. Here we discuss light-toned mudflow deposits associated with gullies in the Atacama Desert, Chile (Figure 1b), which share similar morphologic and spectral signatures as the new Mars deposits. We show that analogous recent light-toned gully features formed from flowing water in the Atacama Desert on Earth leave no mineralogical trace of water activity and only show an albedo difference. Contrary to previous belief, spectral variations indicative of differences in mineralogy between a recent gully deposit and the surrounding terrain appear not to be the relevant criteria for detecting water flow in arid environments. We suggest that, similar to the Atacama deposit, the Mars gully deposits may be remnant mudflows.

Recent Gully Activity on Mars: Malin et al. [1] recently reported the discovery of gully activity occurring within two separate gully systems within the past decade. Light-toned deposits were discovered in gullies in both the Terra Sirenum and Centauri Montes regions on Mars using the Mars Orbiter Camera (MOC) aboard the Mars Global Surveyor spacecraft (Figure 1a). The Terra Sirenum gully showed evidence of new light toned deposit which formed sometime between December 2001 and April 2005. The new deposit is ≤20% brighter than the surrounding region [1]. The Centauri Montes gully showed evidence of a new light toned deposit which was formed sometime between August 1999 and February 2004 and shares similar brightness values with the Terra Sirenum deposit [1].

The deposits in both regions are morphologically similar. The new deposits show long digitate distal and marginal branches, divert around obstacles, and have relatively low relief [1]. The material also flows slowly as it can't run over the top of obstacles. Malin et al. [1] interpret these observations as indicative of the action of a very fluid material that thins while flowing and can bud into multiple branches.

Recent HiRISE imagery covers both the Centarui Montes and Terra Sirenum sites. Even in the HiRISE images no smaller scale structure is visible within the deposits themselves. Also, neither of the new gully sites shows any discernable changes of these new light-toned deposits when compared with the earlier MOC imagery.

In addition, spectral data associated with the Mars gullies shows that in general the gully deposits are spectrally indistinct from the surrounding terrain [2]. CRISM is a visible-near infrared imaging spectrometer which takes measurements at 544 wavelengths from 0.36-3.92 microns at 15-19 meters/pixel. CRISM data suggests that gully sites are not associated with hydrated minerals [2].

The precise formation mechanism for these new deposits remains enigmatic. Malin et al. [1] suggest that the deposits are the result of fluvial activity and the observed residues may be created by a water-bearing fluid. If the new deposits are indeed formed from water activity then they may contain ice and/or frost but due to the instability of these materials on the martian surface then the deposits can retain their light tone only through replenishment of the water-based content [1]. Alternatively, the deposits could be the result of salt deposition or deposition of fine-grained sediments [1].

Atacama Gully Mudflow Deposit: The deposit in Figure 2 was imaged in a pre-existing gully in the Atacama Desert in June 2005. The Atacama deposit shows very low relief and only exists as a thin veneer over the desert surface. The deposit shows multiple flow lobes along the terminus. In Figure 2a the deposit appears as a relatively smooth feature but Figure 2b shows a close-up view of the same deposit which reveals that the deposit is actually composed of disjointed and warped pieces of cracked mud. Small-scale relief is evident in this image on the order of several centimeters.

This deposit was formed as a result of a rain event in the Atacama that occurred approximately one month prior to when these images were taken. The deposit is the result of a slurry of mud (soil and water mixture) which flowed downslope. The fluidized mixture then became desiccated in the extremely dry Atacama Desert environment and formed the cracked mud surface shown in Figure 2b. The deposit is composed of the same material as the surrounding terrain since the cracked mudflow is the remnant of soil and dust fluvially transported downslope.

Visible to near infrared (0.4-2.5 microns) reflectance spectra of both the light-toned mudflow deposit and the surrounding terrain were obtained using an ASD FieldSpec Pro (Figure 3). The samples of the mudflow deposit and the surrounding, undisturbed terrain are spectrally similar, requiring only a scaling factor in reflectance to explain the differences. This could be accomplished by a change in grain size or porosity of the two samples. This suggests that the two samples are composed of the same minerals. This interpretation is consistent with the formation mechanism of the mudflow deposit since the light-toned material in Figures 2a and 2b is simply material that has been lubricated by liquid water and flowed downslope to eventually dessicate into a cracked mud deposit on the desert surface.

The Atacama spectra show bands at 1.4 and 1.9 microns indicative of hydroxyl, bound, or unbound water and a weak band at 2.2 microns suggestive of an Al-rich clay. Since these bands are evident in both the mudflow and surrounding terrain samples, the presence of water is most likely due to the presence of small amounts of water found in the Atacama at this field site (primarily due to rain and fog events) and/or the fact that these samples have been exposed to a humid California environment for several years prior to this spectral analysis.

Discussion and Conclusions: The new light-toned deposits seen in association with gullies on Mars in Terra Sirenum and Centauri Montes show striking similarities in morphology with the new Atacama Desert gully deposit. The deposits on Earth and Mars are both thin deposits that are more light-toned that the surrounding terrain. The martian and terrestrial deposits both show digitate flow lobes particularly near the terminus of the deposit. Deposits on both planets also have formed in conjunction with pre-existing gully features. In addition to these geomorphic similarities, all of these features have formed in arid desert environments. Due to these myriad similarities, we believe the Atacama gully deposit is an excellent terrestrial analog for the martian deposits.

Similar to the Atacama deposit, the martian deposits were most likely formed by the action of liquid water. Similar to the Atacama case, the martian deposits were most likely formed by a soil and water fluidized slurry which flowed downslope. Due to the ambient environmental conditions on Mars, the liquid water within this slurry will evaporate and the mud-like deposit will become desiccated. As the deposit dries, the deposits will develop cracks to form a similar mud cracked appearance as shown in Figure 2b. The individual mudcracks are not visible in the Mars images likely because the camera resolution is not sufficient to resolve these small features. Instead, the martian deposits appear as relatively smooth terrains (Figure 1), just as the Atacama deposit appears as a relatively smooth deposit when viewed from a further distance with decreased resolution (Figure 2a).

Because the light-toned deposit is composed of regolith and dust material that has been transported downslope, the spectral signature shows the same composition as the adjacent terrain as shown in Figure 3. Also, because the deposit is composed of desiccated surface material, the deposit should not change in albedo, size, or shape over time, which is also consistent with the observations to date (no detectable changes have been observed for either of the martian deposits since they were first discovered). A dried mudflow provides a simpler explanation for this observation than the requirement for replenishment of ice if the deposit is composed of snow, ice, or frost. To date, no spectral signatures of water ice or hydrated minerals have been detected in association with gullies on Mars [2] which indicates that likely there is not water ice/frost at the surface of these deposits.

References: [1] Malin et al. (2006) Science 314, 1573-1577. [2] Murchie, S. (2007). GSA Annual Meeting, Paper No. 60-2.

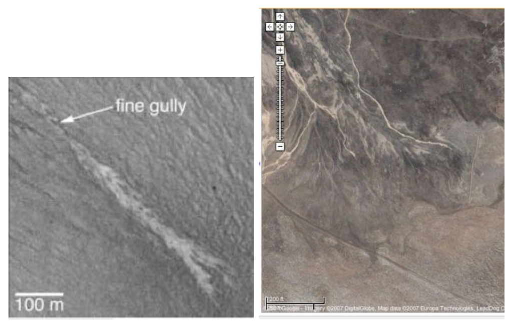

Figure 1a (left). New light-toned gully deposit on Mars [1]. Image courtesy of Malin Space Science Systems. Figure 1b (right). Aerial view of Atacama Desert mudflows (Google Maps).

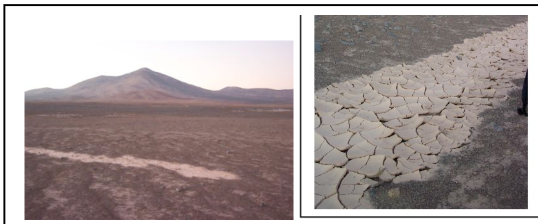

Figure 2a (left). Atacama mudflow deposit.
Figure 2b (right). Close-up view of mudcracks within mudflow deposit.

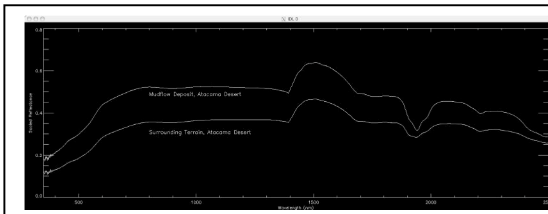

Figure 3. Atacama desert sample spectra of mudflow deposit (top spectra) and surrounding terrain (bottom spectra).