EVIDENCE OF WATER-RICH SNOW DEPOSITS WITHIN MARTIAN GULLIES. A. R. Khuller[1], P. R. Christensen[1], [1]Arizona State University, Tempe, AZ, 85281 USA (akhuller@asu.edu)

Introduction: Evidence for near-surface water ice in the mid-latitudes from past obliquity cycles [1] has been described by several authors [2-4]. Subsurface ice can be permanently stable at latitudes poleward of 25° due to slope effects, especially on pole-facing slopes [5]. Numerous examples of 'pasted-on', smooth volatile-rich mantle units are observed on these cold, pole-facing slopes that can also host gullies (from ~30°-poleward) [6-10]. It has been proposed that the melting of these water-rich mantles can cause the formation of some gullies [7, 11-13]. However, direct evidence of water ice in mid-latitude mantling units proposed to be sources of water for the erosion of these gullies is lacking. Here we present novel visible, spectral, and thermal evidence of decameter-scale, water-rich snow deposits being exhumed within mid-latitude gully alcoves.

Methods and Observations: Decameter-scale partially exposed, lighter-toned materials are observed within summertime HiRISE near-infrared imagery over mid-latitude gully alcoves within pasted-on materials (Fig. 1). The bright materials are present solely within alcove walls cut into pasted-on mantles and are absent over underlying and nearby lithic regions.

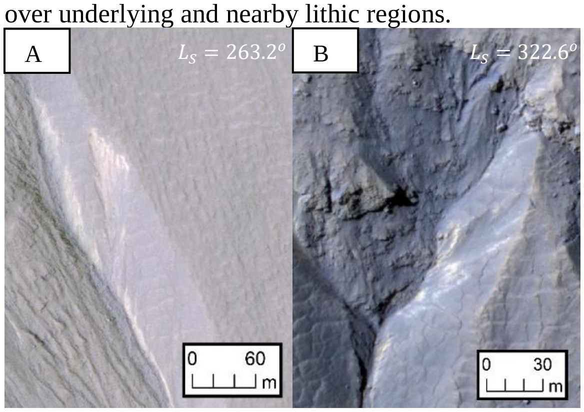

Figure 1. *Partially exposed lighter-toned materials with evidence of slumping within mid-latitude gully alcoves. A, HiRISE image ESP_013067_1470 (-32.93N, 93.2E), b, HiRISE image ESP_014329_1435 (-36.03N, 199.47E).*

Context Camera (CTX) observations (Fig. 2) document the exposure and evolution of lighter-toned material seen in Fig. 1a over 3 Mars Years (MY). This activity possibly represents the largest scale change observed within a Martian gully, with most recent activity [14-17] documented at relatively smaller scales.

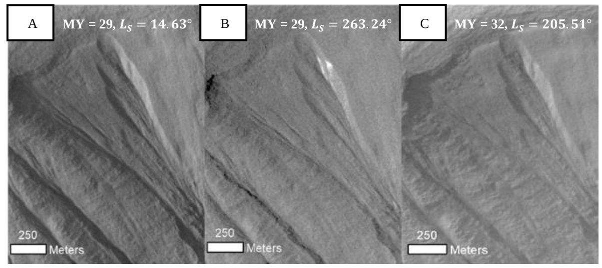

Figure 2. *No evidence of bright material is seen in A, and is exposed in B, but appears to have faded in C. Portions of CTX images (~5 m/pixel) A (P15_006804_1484), B (B09_013067_1468) and C (F06_038332_1466) are shown here.*

CRISM spectra obtained concurrent to the exposures were atmospherically corrected using the CRISM Analysis Toolkit [18] and examined for spectral signatures of water ice. The light-toned materials only cover about ~5% of a CRISM pixel. Spectra (red: ~18 m/pixel, local solar time (LST): 14.4 and green: ~180 m/pixel, LST: 15.2) obtained around southern summer show H_2O-ice absorption features (black dashed lines; [19]) associated with light-toned materials, but not over adjacent terrain. The spectra are indicative of a mixture between water ice and dust/sediment (see Fig. 12 in [20]), with absorptions appearing to be dampened (relative to clean water ice).

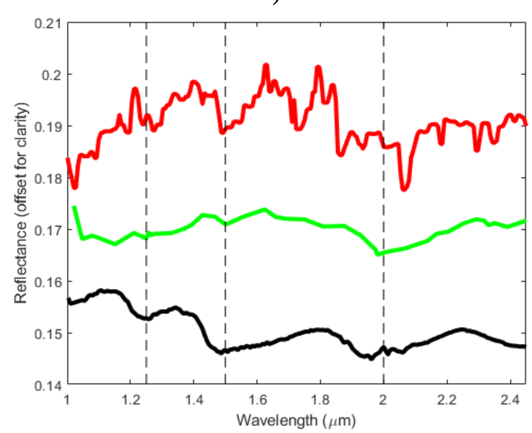

Figure 3. *Red: unratioed spectra ('despike', median filters applied) from FRT000146D8, (L_s = 322.5). Green: unratioed, continuum-removed median spectra from MSP00012969 (L_s = 263.24). Black: laboratory water-ice spectra [21] multiplied by a factor of 0.2.*

Nighttime THEMIS temperatures (Fig. 4) highlight bands of finer-grained materials (greenish hues) up to ~10 km downslope of mantled, gullied walls (Fig. 1a) that are interspersed by rockier, warmer temperature materials (reddish hues).

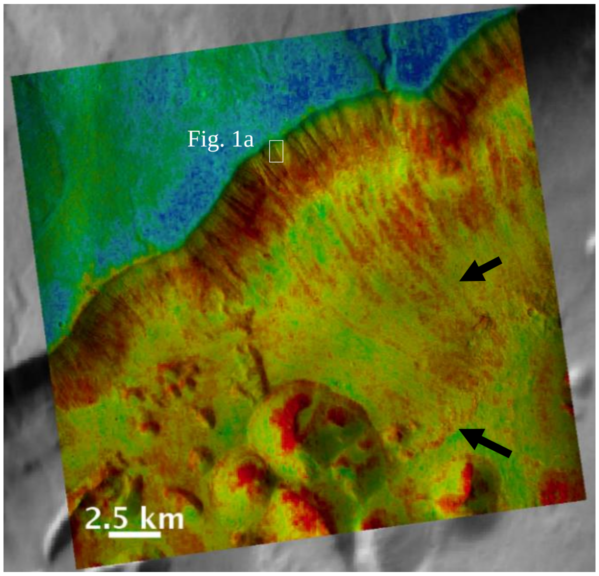

Figure 4. *Icy flow features (black arrows) downslope of gully features are highlighted by nighttime THEMIS IR image I17752021 overlaid on CTX image B09_013067_1468 and the global THEMIS daytime IR mosaic [22]. The location of Fig. 1a is also shown.*

Discussion: One hypothesis for the spectral detection of H_2O-ice absorption features within mid-latitude gully alcoves is the presence of seasonal H_2O frost. [23] attributed the presence of lighter-toned materials present in and around gully alcoves in winter/spring imagery to surface frosts or particulate ice. However, the exposed lighter-toned materials are unlikely to be persistent H_2O frosts due to several factors. HiRISE and CRISM data indicative of water ice were obtained during southern summer, when frost is not expected at these latitudes [24-26]. Additionally, the morphologies of the exposed, bright materials (Fig. 1) are reminiscent of exhumation rather than surficial frosts. THEMIS IR data indicates that the gully alcoves containing exposed bright materials have late-afternoon summertime temperatures that are greater than the predicted atmospheric frost point (for the region in Fig. 1b/red spectra in Fig. 2, at L_s = 314.9, LST: 14.9, the temperature is ~ 271 K; THEMIS observation I42200002). Ice-rich soils highlighted by nighttime THEMIS data are likely to have flowed down gullied walls (Fig. 4), transporting finer-grained materials downslope.

We interpret these observations to indicate that the light-toned materials are exposures of subsurface, water-ice mantle materials that are very similar to those seen in the LDM [4], being exhumed due to slumping caused by sublimation or seasonal frost processes. The spectral reflectivity, albedo and appearance of snow can vary tremendously with crystal size, structure and the incorporation of dust [27, 28]. This effect is pronounced at wavelengths beyond 0.8 μm [28], close to the HiRISE filter wavelengths. Bright white material can be masked in HiRISE imagery with as little as 17 μm of dust [29]. The bright white/yellow appearance of these materials in HiRISE near-infrared imagery (Fig. 1) is consistent with the presence of dust (relatively clean water ice typically appears relatively blue [4, 17]) that partially covers, or is mixed in with ice deposited as snow, within the pasted-on materials.

A dust content of 1,000 parts per million by mass (p.p.m.m.) is sufficient for melting to occur for a wide range of snow properties and atmospheric pressures, and can occur under current conditions in the mid-latitudes [30]. Modeling suggests that a 5-cm dust lag layer is enough to 'protect' the underlying snow from the Sun, and that for melting to occur, rapid exposure of the preserved snowpack is necessary [13].

A major argument against the formation of gullies by melting occurring today is the very presence of this protective dust mantle. The observation of active exposure of the subsurface ice provides the mechanism by which snow can be exposed and melt, lending support to the theory that some gullies can form by the melting of dusty, water-rich snowpacks, with melting potentially occurring today [7, 13, 30]. The presence of liquid water in the near subsurface is key to the evolution of Martian geology, with implications for the potential for past or extant life, and for the future of robotic and human exploration on Mars.

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