EVIDENCE FOR PRESENT DAY GULLY ACTIVTY ON THE RUSSELL CRATER DUNE FIELD, MARS.

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Introduction: Gullies have been found in several places on the slopes of Martian dark dunes in the southern hemisphere between ~65°S and ~45°S [1]. In this study, we focus on gullies of the Russell crater dune field located in the Noachis Terra region at 54.5°S and 12.7°E. Most gullies occur along the SSW-slopes of the megadune [2, 3]. Based on their morphology [2, 3] and flow rheology [2, 4] melting of near-surface or surface water ice triggering debris flows is the most likely mechanism in their formation. Recent laboratory simulations also showed that the morphology of the dune gullies can be best explained by the melting of near-surface ice in silty materials [5]. The large SSW-facing dune slope of the Russell crater dune field is a monitor site for seasonal changes and imaged sequentially (23 images) with HiRISE. Here, we report evidence for present day gully activity.

Present day activity: A selection of 8 images of the same slope area is shown in Fig. 1 in chronological order. The image sequence starts at L_S ~136° (mid winter) of the first year (Fig. 1A). A small ~2 m wide gully channel is incised into the dune surface, located west of a partly filled larger channel. The small channel stopped directly after dissection of the larger channel (Fig. 1A, 1). At L_S ~182° (early spring) an increased number and larger dark patches occur (Fig. 1B). At L_S ~198° (early spring) defrosting of the dune surface proceeded, bright frost only occurs on the rippled surface (Fig. 1C). Changes in gully morphology in the first year are visible at L_S ~218° (mid spring) (Fig. 1D). The small channel grew between L_S ~198° and ~218° about 50 m downslope within the partly filled larger channel (Fig. 1D, 2). The distal part of the new channel part is with a width ~1 m narrower than its upper part and shows a sinuous course. Additional changes can be observed upslope of the grown channel. Several new, small (~1 m width) pristine channels accompanied with spreading lateral deposits showing a fingering pattern formed during the same time span (Fig. 1D, X). One of these channels seems to be responsible for the changes further downslope. It coalesces but also cuts off (Fig. 1D, Y) the small channel in the east (see also Fig. 1A). In the second year at L_S ~144° (mid winter) small dark patches again occur on the dune surface indicating the start of CO_2 defrosting (Fig. 1E). At L_S ~192° defrosting proceeded indicated by larger dark patches (Fig. 1F). Changes in gully morphology in the second year are visible at L_S ~221° (mid spring) (Fig. 1G). The same channel, which grew ~50 m in the first year (Fig. 1G, 2), grew another ~120 m in the second year between L_S ~192° and ~221° (Fig. 1G, H, 3). Again, the distal part of the new channel part is with a width ~1 m narrower than its upper part. As in the first year, several new, small (~1 m width) pristine channels accompanied with spreading lateral deposits formed during the same time span as the gully changes occurred (Fig. 1G and H, X). Smaller changes include the enlargement of the narrower, sinuous channel part from the last year (Fig. 1D, 3H, Z).

Spectral and thermal observations: Hyper- and multispectral CRISM data around the time span of the observed changes were used to track the defrosting sequence of region. At L_S ~179° and ~182° there are strong absorptions of CO_2-ice at the 1.43 µm bands. At L_S ~198° the CO_2-ice absorption band at 1.43 µm is still existent. At L_S ~215° the flat spectra show that the dune is completely defrosted. H_2O-ice signatures at the 1.5 µm bands were not found in the spectral data. Within the time range between L_S ~198° and ~215° no spectral data is available to date. These results are in agreement with the analysis of the defrosting sequence of the Russell crater dune field by [6]. Thermal modeling as well as measured values from TES indicate that the maximum surface temperatures between L_S ~205° and ~210° are close to the melting point of water ice (~260–270 K). Minimum surface temperatures within these times are with ~200 K far in excess of the CO_2-frost point of ~148 K.

Discussion: Gully activity was observed in early spring between L_S ~198° and ~218° in the first year and between L_S ~192° and 221° in the second year. The same time range of activity in both years indicates that seasonal effects are causing the gully changes. The morphology of the grown channel with incision into the dune surface, sinuous courses and branching implies a flow behavior of the material causing the erosion. Possible mechanisms are dry flows, CO_2-based flows or flows with the involvement of liquid water. Dry flows are unlikely because of the slope of ~10°, far below the friction angle of dry granular flows. Additionally, the sinuous courses, branching, confined flow and erosion into the dune surface are characteristics which cannot be caused or are unusual for dry flows. Liquid CO_2 is unstable under the low pressures on Mars. A flow mechanism triggered by CO_2-vapor was proposed by Hoffman [7] to form gullies in polar areas. However, the morphology of possible vapor-supported flows would be consistent with terrestrial pyroclastic flows [8], which can not be observed for the dune gullies. The constrained time range of the gully changes makes the formation by CO_2 vapor supported flows also unlikely. At L_S ~198° most of the CO_2 ice is already sublimated as evidenced in high resolution imagery. Although there is still CO_2-ice detectable at this time in spectral data, weakest CO_2 signatures occur on dark spots [6], which are frequently located along the channels. Deposition of surface water-frost from the atmosphere is still possible under present climatic conditions and have been observed at the Viking 2 landing site at ~50°N [9] and in Orbiter data at latitudes up to 30°S [10]. Transient melting of small amounts of H_2O-ice is theoretically possible under current conditions on Mars [11, 12]. Redeposition in cold traps were observed at the Viking Lander 2 landing site [9] and this mechanism is also expected at sheltered regions of gully channels [11], which would enlarge the available water ice amounts for melting. Gully changes in both years occurred during a time range when CO_2-frost starts to be instable on the surface and the surface is completely defrosted. Modeled and measured surface temperatures indicate that the melting point of water can be reached within the time range of the observed gully changes. We conclude that the gully changes might be due to transient melting of small amounts of H_2O-ice around L_S ~210° triggering small debris flows. Further data acquisition by HiRISE and CRISM in the following years between L_S ~200° and ~215° are needed to constrain if the changes are related to the present day occurrence of liquid water on Mars.

References: [1] Reiss D. et al. (2007) *LPS XXXVIII*, Abstract #1993. [2] Mangold N. et al. (2003) *JGR., 108*, 5027. [3] Reiss D. and Jaumann, R. (2003) *GRL, 30*, 1321. [4] Miyamoto, H. et al. (2004) *GRL, 31*, L13701. [5] Védie E. et al. (2008) *GRL, 35*, 21. [6] Gardin E. et al. (2009) *LPS XXXX*, Abstract #2032. [7] Hoffman, N. (2002) *Astrobiology, 2*, 313–323. [8] Stewart, S.T. and Nimmo, F. (2002) *JGR, 107*, 5069. [9] Svitek, T. and Murray, B. (1990) *JGR, 95*, 1495–1510. [10] Schorghofer, N. and Edgett, K.S. (2006) *Icarus, 180*, 321–334. [11] Hecht, M.H. (2002) *Icarus, 156*, 373–386. [12] Kossacki, K.J. and Markiewicz, W.J. (2004) *Icarus, 171*, 272–283.

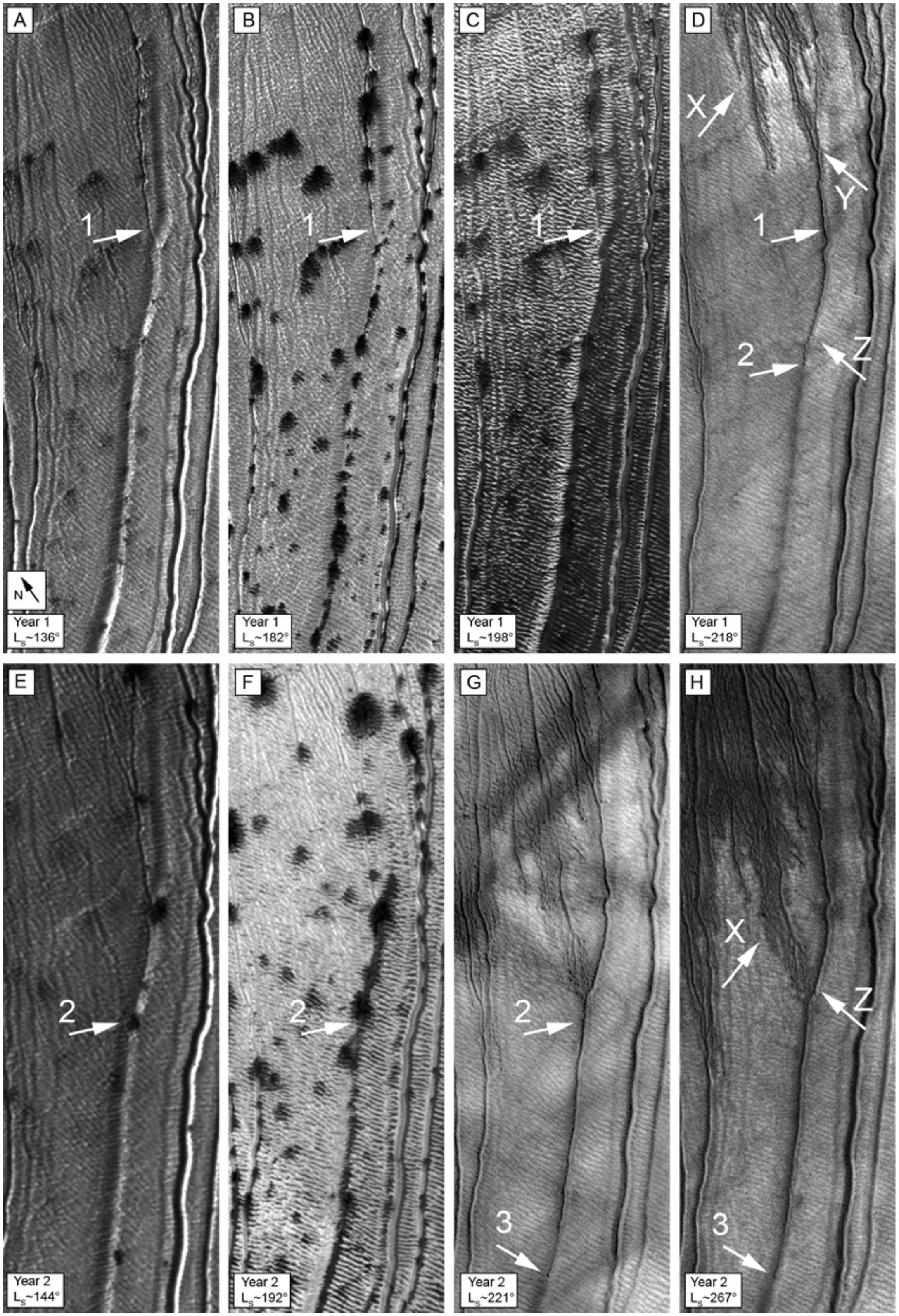

Figure 1. Selected seasonal HiRISE imagery over 2 Martian years showing gully changes. White, numbered arrows mark the stages of the growing, incised gully channel. All images have a width of 100 m. A: PSP_001440_1255, ~50 cm/pxl; B: PSP_002548_1255, ~25 cm/pxl; C: PSP_002904_1255, ~25 cm/pxl; D: PSP_003326_1255, ~25 cm/pxl; E: PSP_010446_1255, ~50 cm/pxl; F: ESP_011580_1255, 50 cm/pxl; G: ESP_012213_1255, ~25 cm/pxl; ESP_013136_1255, ~25 cm/pxl).