THE LIFE CYCLE OF YOUNG GULLIES ON MARS: GULLIES AS A TRANSIENT PRODUCT OF ICE-RICH MANTLE EMPLACEMENT AND REMOVAL. J. L. Dickson[1], J. W. Head[1], C. I. Fassett[1], J. S. Levy[2], G. A. Morgan[1]. [1]Department of Geological Sciences, Brown University, Providence, RI (jdickson@brown.edu), [2]Department of Geology, Portland State University, Portland, OR.

Introduction: A decade after their discovery [1], gullies on Mars still attract significant attention due to the possibility of liquid water on an otherwise hyper-arid Late Amazonian Mars. An unaccounted-for property of gullies is their uniform youth: they cross-cut and/or superpose all units which they contact [1], are coeval with very young high-latitude polygonally-patterned ground [2], and appear fresh at MOC [1, 3-4] and HiRISE [5-6] resolutions. Studies of stratigraphic relationships show that gullies have been active within the last several million years [7-8], and possibly on present-day Mars [9].

Solutions for Mars' orbital parameters over the past 20 Myr [10-11] show that before this most recent era of gully activity, Mars had higher peak and average obliquity, such that ice-accumulation and melting in the mid-latitudes should have been more likely [12], yet this would predict a class of gullies superposed by more recent features like dunes and polygonally-patterned ground. These relationships, along with gullies that show a more degraded appearance, have not been reported in the numerous surveys of MOC [1, 3-4, 13-17] or HiRISE data [6].

Here, we propose that this is due to a direct relationship between gullies and Late Amazonian ice-rich mantling units that we argue provide a weak substrate that can be eroded more easily than bedrock. As these mantling units are removed under varying orbital configurations, the record of gullies that they host is removed as well.

Late Amazonian mantling units: Several ice-related latitude-dependent units have been documented since acquisition of meter-scale imagery of Mars began with MOC. Among these are regionally and locally smooth units of variable thickness that drape large swaths of the mid- to high-latitudes of each hemisphere [18-19]. This mantling is observed to be continuous at higher latitudes where ground-ice is currently stable at depths of just centimeters [20-23] and discontinuous and desiccating in the mid-latitudes (30° - 50°) [24]. In regions where ice is most stable (pole-facing mid-latitude slopes, where gullies are most common [4, 17]), thick mantling units appear "pasted-on" to steep slopes [25], and "viscous flow features" (VFF) provide evidence for coherent flow of glacial ice within the last ~10 Myr [3, 26]. Previous work has shown that gullies are found in the same regions as this desiccating mantle and VFF [3], and detailed site studies have proposed that volatiles for gully formation could be provided by "pasted-on terrain" [25] and VFF [27].

Gullies and mantling units: We investigated the global relationship between gullies and mantling units by expanding the survey of HiRISE data conducted by [6] to include 188 unique gully localities. Gullies consist of two erosional components (alcoves and channels) and one depositional component (fans). We classified gullies by the surfaces that their alcoves erode and by the surfaces that their channels erode: units that are smooth and drape surface units at HiRISE resolution were categorized as mantle, while rougher coherent units were categorized as bedrock.

We found that alcoves incise both bedrock and mantling units. Forty-one percent showed alcoves carved into mantle (Fig. 1), 32% of images showed alcoves carved into bedrock (Fig. 2), and 22% showed alcove incision into both bedrock and mantle material. Eight images showed gully channels without alcoves (Fig. 2c). In contrast to alcoves, channels almost exclusively erode mantle, with only three images showing channelized structures carved into bedrock. Of these exceptions, dry processes cannot be ruled out with present data. Channels cut into mantling units show morphologies that indicate some component of liquid water (see discussions in [5] and [28]).

Gully morphology is controlled by the material that is eroded to produce the alcove. Alcoves carved into mantling units are distinct in morphology and exhibit elongated shapes (Fig. 1). These have been proposed to form by degradation of polygonally-patterned ground at higher latitudes (usually > 40°) [2]. For these instances, the entire erosional component of the gully system is relegated to the ice-rich mantling unit at the surface.

Gully alcoves carved into bedrock (Fig. 2) have been suggested to form by dry mass-wasting on very steep slopes at mid-latitudes where steep topography has been preserved (usually < 42°), similar to non-gully alcoves at low-latitudes [5]. In these scenarios, alcove floors appear to be draped by mantling units (Fig. 2a), and in some cases are source regions for ice-rich VFF [6, 13, 27]. Channelization within alcoves is only observed within the mantling unit that occupies the alcove (Fig. 2b), not the bedrock itself.

In Figure 2, we document gullies in various stages of evolution to propose a sequence of formation and removal of gullies as a function of mantle evolution.

1. Mantle emplacement. In Fig. 2a, pasted-on terrain has exploited pre-existing bedrock topography to form polygonally-patterned units on the pole-facing wall of Dao Vallis [25]. This texture is absent from the equator-facing wall of the valley at this location.

2. Channel formation. In Fig. 2b, a bedrock alcove is observed with polygonalized mantle accumulated on its floor. This mantling unit, however, has a channel incised into it. The channel clearly incises the mantle and not the bedrock at this location.

3. Mantle removal. In Fig. 2c, channels are only preserved along this crater wall downslope from the exposed bedrock at the crest of this crater rim. These channels downslope are incised into a polygonally-patterned mantling unit that appears to have been removed from the upper reaches of the slope. Evidence for channels within the upslope bedrock alcoves is not observed.

In Fig. 2d, CTX data show a fan at the base of a slope that hosts several gullies. This fan, however, has had nearly all of its channel and any alcove removed. We hypothesize that this fan is a remnant from a previous era of gully formation, and that the channel that sourced this fan has been almost entirely removed.

Future work will involve documenting further examples of fans abandoned by their host channel and the mantle which it incised.

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Fig. 1. Multiple gullies on the pole-facing slope of a crater at 43.8°S, 222.6°E. Alcoves are entirely incised into polygonally-patterned mantle, distinct from alcoves carved into bedrock (Fig.2). HiRISE ESP_012759_1360.

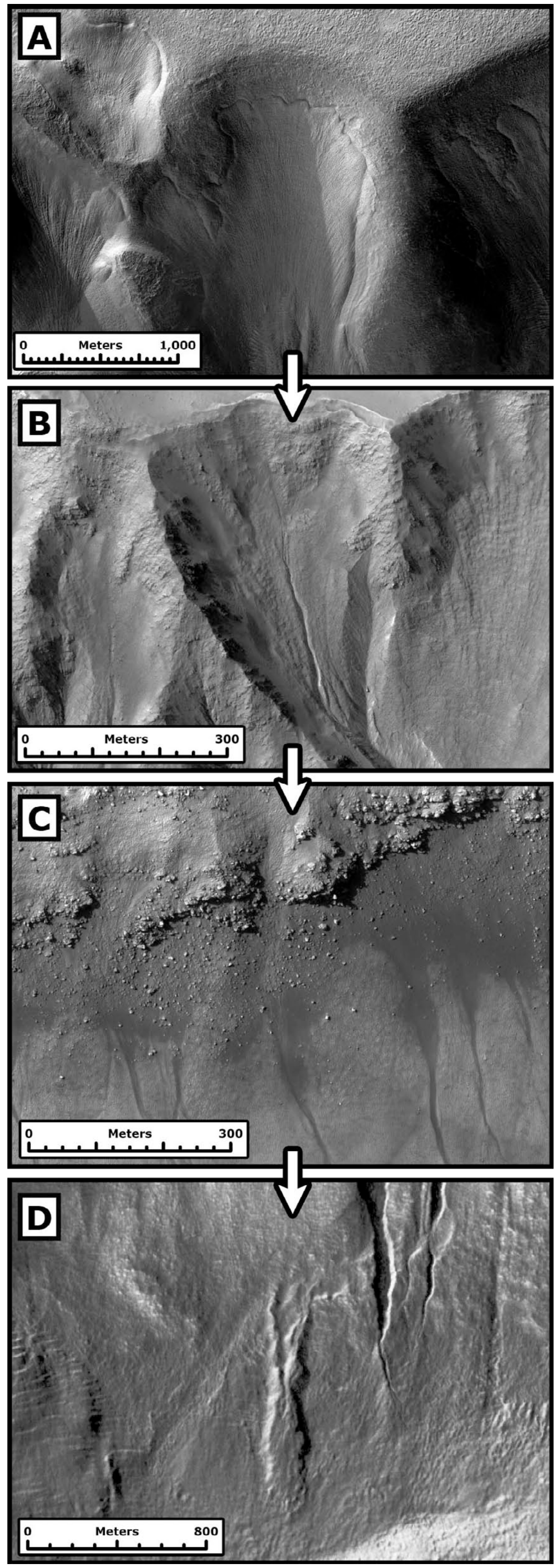

Fig. 2. Proposed sequence of mantle emplacement, channelization of mantle material, and eventual removal of mantle. (A) Bedrock alcove with pasted-on terrain draped over the floor. HiRISE PSP_001635_1445. (B) Mantled alcove with channel incised into the mantle. HiRISE PSP_003583_1425. (C) Crater wall with channels incised into polygonally-patterned mantle. Mantle appears to have been removed upslope from where the channels are preserved. HiRISE ESP_013202_1220. (D) Fan with truncated channel at its head at the base of a crater wall. We hypothesize that the majority of the channel that sourced this fan has been removed. CTX B03_010651_1398.