INTERACTION BETWEEN GULLIES AND LOBATE DEBRIS TONGUES ON MARS AND IN THE ANTARCTIC DRY VALLEYS. G. A. Morgan[1], J. W. Head[1], D. R. Marchant[2], J. Dickson[1], and J. Levy[1]; [1]Dept. Geol. Sci., Brown Univ., Providence, RI 02912 USA (gareth_morgan@brown.edu), [2]Dept. Earth Sci., Boston Univ., Boston MA 02215 USA.

Introduction: The discovery of martian gullies in 2000 attracted significant attention due to the apparent role of liquid water and because of the very youthful nature of the appearance of the gullies [1,2]. The existence of such gullies has raised the question of the role liquid water has played in the hydrological cycle operating throughout the late Amazonian, a period otherwise thought to be cold and very dry [3].

The high resolution images (~30 cm/pixel) of the martian surface by the HiRISE camera allow for the most detailed studies of martian gullies to date [4-7] and in addition permit direct comparisons to be made with features investigated at terrestrial analog field sites. Surveys of HiRISE images of gullied sites were made with specific attention being paid to those that also included other landforms potentially generated by the action of water (both in its liquid and solid phase). This is deemed important as it can shed light on the climate history of that particular region and the conditions under which the gullies formed. Here we report on a lobate debris tongue that is found in association with gully systems within a crater depression located at 40°S, 5°E (Fig. 1a). We interpret this feature to be a unique class of landform previously unreported in the literature. To aid our analysis of the landform and gather insights into gully formation and the hydrological systems in operation within a terrestrial analog environment, we drew upon field work conducted in the Antarctic Dry Valleys (ADV) during the austral summer of 2006-7. The ADV are a hyperarid, cold polar desert in which sublimation exceeds precipitation [8] and has thus long been held to provide one of the closest terrestrial analogs for the current Martian conditions [9-10].

Mars: The lobate debris tongue feature extends for ~4 km within a 3 km wide valley that forms the eastern portion of the annular crater depression. Other examples of lobate debris tongue features exist within the depression crater complex, but this was the only example which had HiRISE coverage. Gullies are observed on the slopes surrounding the lobate debris tongue, and the termini and fans of many of these gullies are found to curve in the downslope direction of the lobe (Fig. 1a). The lobe appears heavily deflated and exhibits 200 m wide troughs running along the central axis of the lobe (Fig.1c). Troughs may be a product of deflation processes and might represent the loss of ice through sublimation. Linear indentations tens of meters in width are common along the edge of the tongue and are interpreted to be the result of strain encountered within the lobe during its deflation.

Lineated Valley Fill/Lobate Debris Aprons (LVF/LDA) deposits found + 30° in both hemispheres also exhibit lobe-like morphology and have been interpreted to be the remains of debris covered glacial deposits [e.g. 11,12]. However, unlike such deposits this lobe displays a very different surface texture consisting of large boulders, patterned ground and linear troughs. In addition the largest boulders are found to be surrounded by moats with raised rims (Fig. 1d), which could have been formed by the sublimation of near surface ice due to the thermal inertia properties of the rock. LVF/LDA deposits, in contrast, have surfaces that consist of pits and buttes [13, 12]. The occurrence of large numbers of gully networks within the vicinity of the tongue is another trait not typically shared by LVF/LDA deposits. The tongue is also unlike arcuate ridge features found in the vicinity of gullies [e.g. 14, 4] elsewhere on the planet. These features are consistently found along the lower internal walls of craters that contain crater fill and not within valley settings.

The sweeping nature of the termini of the gullies suggests that they were formed when the tongue was active as their curvature could have been generated by the downslope movement of the tongue. However, the occurrence of gully fans that have infilled and cross cut the strain indentations along the periphery of the lobe argues that a number of the gullies were active after the tongue ceased movement. This suggests that both landforms can exist contemporaneously and therefore gully activity may influence the formation of lobate debris tongues. However, the continued activity of gullies after the cessation of tongue suggests that they are less sensitive to climatic changes than the lobate debris tongue.

ADV: Based on elevation and distance form the Ross Sea, the climate of the ADV can be broadly subdivided into three microclimate zones which are defined by their own unique assemblages of landforms [8]. The *Stable Upland Zone* (SUZ) which is characterized by ground temperatures which never exceed 0°C is the most representative of the current martian climate, but the other two zones may have been close to previous martian conditions. Comparing martian features with those of the ADV thus provides an insightful means by which to assess the conditions that have prevailed in the history of Mars.

The SUZ contains slow moving (<~40 mm/yr [15]) integrated systems of debris covered glaciers. These have been used as an analog for LVF/LDA systems [e.g. 16] and thus are morphologically distinct from the martian tongue. However, because of the persistent sub-zero temperatures, any snowfall sublimates rather than forming surface runoff and so gully systems are absent within this zone. In contrast the *Intermediate Mixed Zone* (IMZ), experiences sufficient summer runoff to produce gully systems from both the melting of perennial snow banks (within the gully alcoves) and from the melting of windblown snow banks, collected annually within the gully channels [e.g. 7]. Our field work was concentrated within South Fork in upper Wright Valley which marks the transition between these two climatic zones and thus most closely resembles Mars during periods of higher obliquity in which conditions were sufficient to enable limited surface runoff and gully formation.

Within South Fork we encountered a lobe feature that is morphologically very similar to that of the martian lobe (Fig. 1). The feature extends from the up-valley side of South Fork and terminates along the western shore of Don Juan Pond. The snout of the tongue exhibits a convex up profile which levels off around ~20 m above the valley floor. The exact origin of the tongue remains unclear though the lack of a steep terminus and its convex-up cross sectional profile agues that the lobe is currently inactive (i.e. it has experienced viscous relaxation [17]) A seismic refraction station set at the terminus found no evidence to suggest primary ice was present, but instead the interior is interpreted to consist of interstitial ice within pore spaces [17]. This was further confirmed by a 100 m seismic line set up further up the body of the tongue; this found no evidence of a strong reflection associated with primary ice layers. The tongue may have been a previous debris-covered glacier that experienced deflation. Thus we cannot rule out the presence of clean ice in the past when the feature initially formed.

Gully systems are located along the southern wall of the valley. Several of these exhibit channel termini and fans that bend into the down-slope direction of the tongue itself in a similar fashion to those of the martian tongue (Fig. 1). Larger-scale channel systems are also present along the center of lobe; these terminate at its snout in a series of delta systems adjacent to Don Juan Pond. Shallow excavations throughout the surface of the tongue revealed that the top of the ice-cement (ice table) was present at a depth of ~30 cm. Flow from the surrounding gullies often disappeared into the upper surface along the edge of the tongue and substantial flow also occurred within the larger stream systems present on the surface of the tongue. Further excavations during the peak of summer demonstrated that a significant volume of water was migrating on top of the ice table within the central regions of the tongue. Within localized depressions water was observed to pond on the surface indicating that the ground above the ice table had become saturated. This finding challenges previous assumptions that snow melt does not provide a significant volume of melt water into Don Juan Pond [18] and that the melting of ice from within the tongue itself was a more significant input of water than gully runoff.

The gullies have clearly established a significant interplay with the surface of the tongue. We are currently assessing whether, under previous conditions, the gully formation could have contributed to the initiation of the tongue itself through ice-assisted creep. This could have occurred through solifluction effects or through the accumulation of secondary ice from the infiltration of water into the talus from the termini of the active gullies. Such considerations would allow us to address whether in the ADV and on Mars conditions favorable for the formation of gullies is also suitable for development of lobate debris tongues.

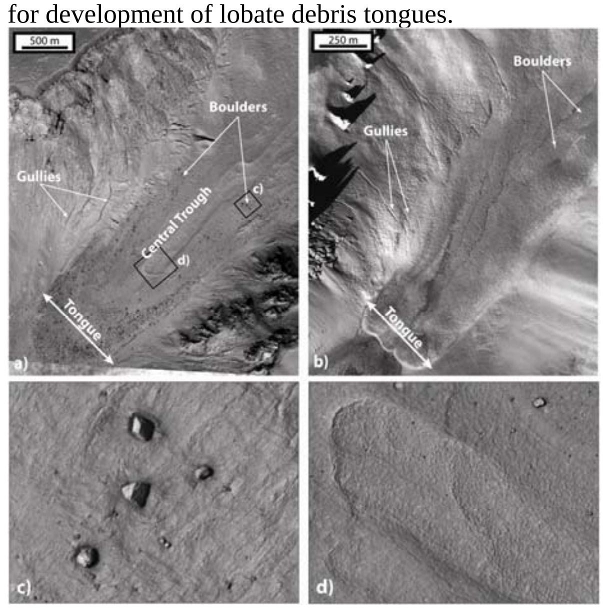

Fig. 1. *Gullies and lobate debris tongue in a depression crater on Mars (a,c,d) and in the ADV (b).*

References: [1] Malin M and Edgett K, *Science*, 288, 2330, 2000. [2] Malin M and Edgett K, *JGR*, 106, 23429, 2001. [3] Carr M, Water on Mars, 1996 Rignot et al, *GRL*, 10.1029/2001 GL013494, 2002. [4] McEwen A et al, Science, 317, 1706 [5] Head J and Marchant D, Martian Gullies Workshop, 8009, 2008. [6] Dickson J et al, MGW, 8010, 2008. [7] Morgan G et al, MGW, 8015, 2008. [8] Marchant and Head, Icarus, 192, 187. [9] Anderson, D et al, Antarctic J. of the U.S. 7, 114, 1972. [10] Gibson, E et al JGR, 88, suppl. A812-A918, 1983. [11] Head et al EPSL, 241, 663, 2006 [12] Ostrach and Head, this meeting. [13] Mangold N, JGR, 10.1029/2002JE001885, 2003. [14] Berman D et al, Icarus 178, 465, 2005. [15] Rignot E et al, GRL 10.1029 /2001GL013494, 2002. [16] Morgan and Head, LPSC, 1622, 2007. [17] Hassinger J and Mayewski, P Arctic and Apline Res, 15, 351, 1983. [18] Chinn T, Antarctic Res. Ser., 59, 1, 1993.