GLOBAL DOCUMENTATION OF OVERLAPPING LOBATE DEPOSITS IN MARTIAN GULLIES: IMPLICATIONS FOR THE ROLE OF DEBRIS-FLOW PROCESS IN GULLY FORMATION. Rishitosh K. Sinha[1,2], Dwijesh Ray[1], Tjalling De Haas[3], Susan J. Conway[4], [1]Physical Research Laboratory, Ahmedabad 380009, India (rishitosh@prl.res.in), [2]Indian Institute of Technology, Gandhinagar 382355, India, [3]Faculty of Geoscience, Universiteit Utrecht, Princetonlaan 8a, 3584 CB Utrecht, the Netherlands, [4]CNRS, UMR 6112 Laboratoire de Planétologie et Géodynamique, Université de Nantes, France.

Introduction: Gullies on Mars are kilometre-scale sediment transport systems comprising an alcove, channel and debris apron [1]. In some gullies lobate deposits have been observed [2-6], implying a debris-flow-like process, but uncertainty remains as to the importance of this process in the gully-population and whether lobate deposits are related to a specific context or are widely representative of gully-processes.

In this work, we conduct an extensive morphological study utilizing the Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) image archive to: (1) document evidence of overlapping lobate deposits on gully-fan surfaces within craters emplaced between 30˚-75˚ in both hemispheres, and (2) infer whether the lobate deposits found in gullies stem from aqueous flows, dry flows, or both.

Observations and Results: We identify gullies as steep-sloped drainage systems over crater wall typically consisting of an alcove, a channel and a depositional apron. Overlapping lobes are recognized as stacking of relatively small-sized individual lobes or laterally elongated lobes at the gully fan termini or at the fan surface. In total, we analyzed 1726 craters (988 in the northern hemisphere and 738 in the southern hemisphere). In the northern hemisphere, we find morphological evidence of lobate deposits in 8 gullied craters, of which 2 were previously reported [6]. In the southern hemisphere, 18 gullied craters show evidence of lobate deposits, of which 4 were previously reported [2-5]. This results in a total of 26 craters in which lobate deposits occur in gullies, which corresponds to 3.39% of the 765 gullied craters studied using 1004 HiRISE images.

We find that overlapping lobate deposits occur in craters with diameters ranging from ~2 – 30 km and ~3 – 36 km in the northern and southern hemispheres, respectively. We observe morphological features which are associated with terrestrial wet-debris flows including: overlapping convex-up, tongue shaped terminal lobes, levees, channel backfilling, plug formation and avulsion. The lobate deposits are emplaced at slope gradients at the foot of the fans that range from 18-25° in the northern and 7-19° in the southern hemisphere. Similar to gullies in general, gullies with lobate deposits are generally poleward-facing. Gullies with lobate deposits are found in craters with and without Latitude Dependent Mantle (LDM) and/or

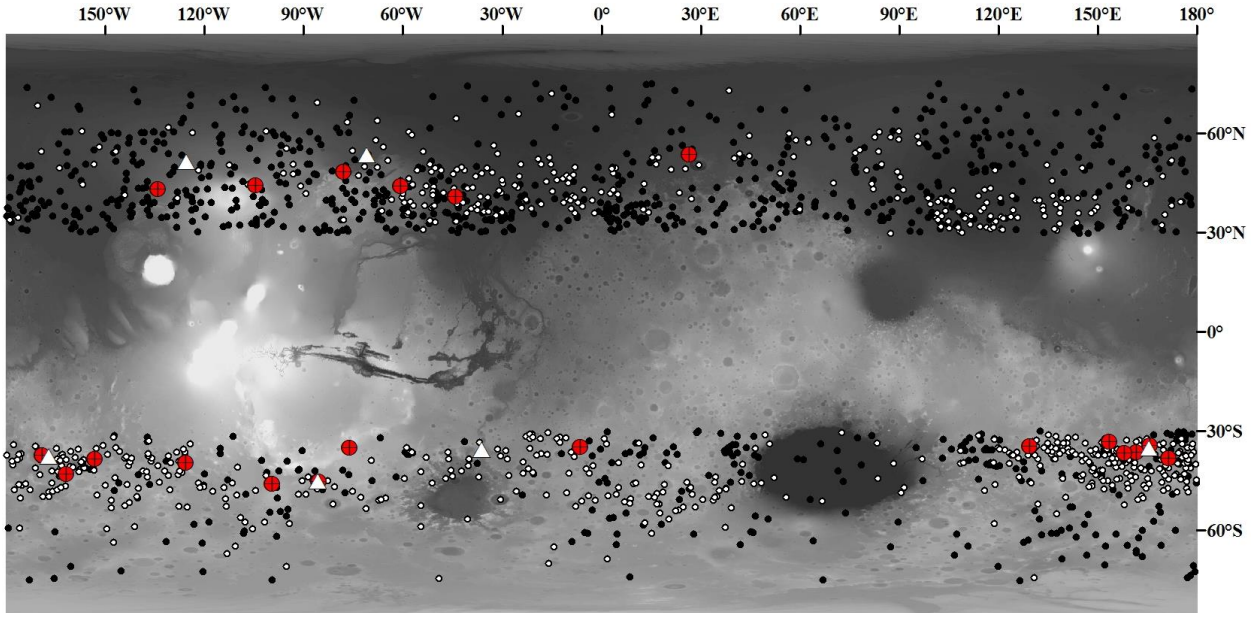

Figure 1. Distribution of overlapping lobate deposits in gullied craters between 30˚-75˚ N and S plotted over the Mars Orbiter Laser Altimeter topographic data (MOLA; white is high elevation and black is low elevation) superposed on the Mars Odyssey THEMIS daytime thermal infrared global mosaic (100 m/pixel). The colours of the symbols indicate: white circles – craters with gullies in HiRISE, black circles – craters without gullies in HiRISE, red circle with plus – gullied craters with overlapping lobate deposits, and white triangles – previously reported gullied craters with overlapping lobate deposits. Basemap image credit: MOLA/GSFC/USGS.

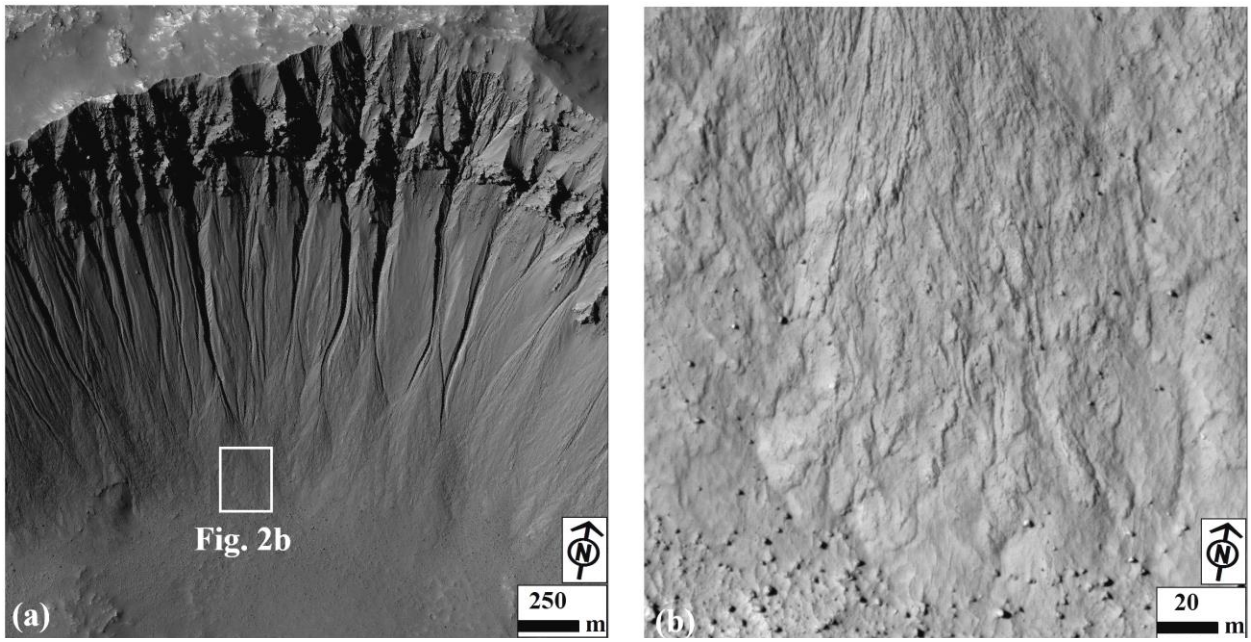

Figure 2a. Subframe of HiRISE image ESP_020774_1445, which shows a part of the pole-facing wall of Los crater (dia.: ~7.8 km; best-fit age: ~7.9±3 Ma) cantered on 35.08˚ S, 76.22˚ W. These gullies have slope gradients at the top, middle and bottom of ~35˚, 28˚, and 14˚, respectively. **2b.** Detail of the gully fan surface within Los with overlapping lobate deposits, including convex-up and tongue shaped terminal lobes with lateral levees. Image credit: NASA/JPL-Caltech/University of Arizona.

glacier-like-forms. Best-fit age estimates from crater size frequency distribution implies that lobate deposits form in gullies with host craters of all ages. Our observations show that lobate deposits become progressively obscured over time, by a combination of post-depositional processes. Their relatively young age is supported by a pristine clast-rich surface texture. We have not observed any significant present-day changes in the morphology and topography of gullies and lobate deposits in this study.

Discussions and Implications: There is a lack of particular spatial, orientation or landscape context for the lobate deposits which suggests that the presence of lobate deposits is not due to a specific process occurring in any given context, but rather a result of preservation of the deposits. It is likely that the process forming lobate deposits has been active more widely, but that its morphological expression has been hidden by post-depositional processes. Further, our results signify the importance of debris-flow-like processes for the formation of the lobate deposits and by extension gully-fans on Mars and therefore the transport of sediment through gullies. To produce deposits that resemble those produced by debris flows on Earth, implies the involvement of a fluidizing agent, which is most likely to be CO_2 and/or liquid water. At present, our data do not allow us to determine if these processes are continuing at the present day, but the observation of new lobate deposits in Istok crater in winter suggests these processes could be ongoing [7]. If substantiated by future observations, this would imply that sublimating CO_2 is capable of producing debris-flow like lobate deposits. Recently, a modelling study has revealed that even small volumetric fractions of CO_2 frost (<1%) within mass flows can generate gas fluxes adequate to fluidize present-day flows in gullies [8]. However, there are important physical differences between gas-supported granular flows and liquid supported ones, which should result in morphological differences, but detailed numerical or laboratory investigations would be needed to unravel these. We conclude that a debris-flow-like process is likely responsible for the majority of sediment transport in gully-landforms, but whether the fluidizing agent is liquid water or CO_2 sublimation remains unknown.

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