EVIDENCE FOR GLACIAL AND FLUVIAL PROCESSES ON GALE CRATER RIM – DULCE VALLIS:

H. E. Newsom[1], L. A. Scuderi[1], Z. E. Gallegos[1], J. M. Williams[1] F. D. Dimitracopoulos[1] L. L. Tornabene[2], R. C. Wiens[3]. O. Gasnault[4], [1]U. New Mexico, Albuquerque, NM 87131, USA (Newsom@unm.edu); [2]U. Western Ontario, CN; [3]Los Alamos Nat. Laboratory, NM, USA, [4]Institut de Recherche en Astrophysique et Planetologie, Toulouse, 31028, France.

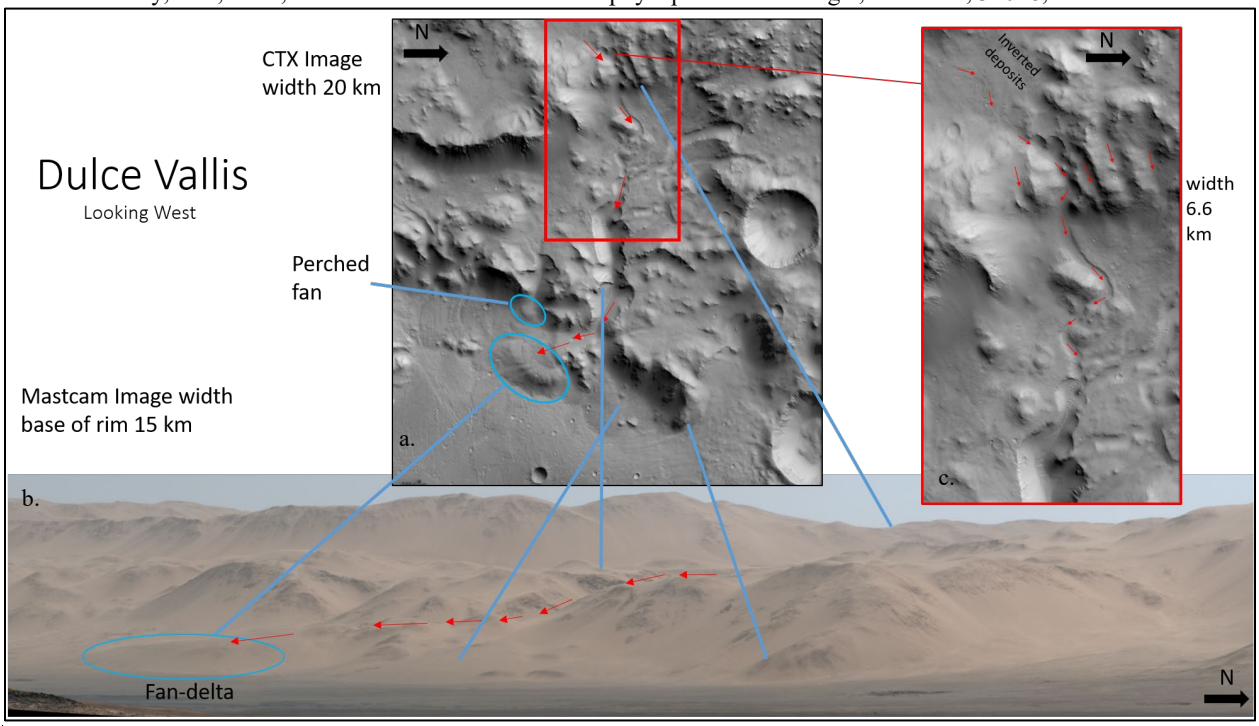

Fig. 1. Images of Dulce Vallis and adjacent valleys on the Gale crater rim **a.**) CTX image, **b.**) Curiosity M100 image. The course of the Dulce Vallis (red arrows) leads to the fan-delta (blue circle). **c.**) The eastern portion of the Dulce Vallis channel with a sinuous flat section between the lower sapping channel and a source in a valley to the east with inverted deposits. The valley drains through an eroded gap in the ridge just visible in the distance in the Curiosity panorama. North of this main channel are heavily scoured parallel U-shaped valleys on the steeper slope of the N-S ridge that are likely glacial in character.

Introduction: Evidence is growing for possible glacial and fluvial processes on the rim of Gale Crater [1-3]. Possible glacial features were described in other areas of Gale crater including on and around Mt. Sharp (Aeolis Mons) [4,5], in addition, inverted features on the floor of Gale that could be glacial eskers are also being investigated [6]. For studies of the Gale Crater rim, the acquisition of new HiRISE images in the last four years has improved the study of detailed features on the crater rim, especially in the watershed of Peace Vallis (PV) and its fan, which is partly visible from the Curiosity rover location [2]. Extending this examination, we have turned our attention to another substantial channel draining the Gale crater rim, the adjacent Dulce Vallis (DV) that is also visible from the Curiosity rover (**Fig. 1**). The Dulce Vallis watershed area (~1200 km^2) is similar in area to the Peace Vallis watershed (~1500 km^2) (**Fig, 2**). Precise delineation of these areas and their boundaries is difficult due to low-resolution topography and channels that appear to flow up and over elevated saddles or ridges. The crater rim watershed lies on a series of terraces (**Figs. 1, 3**) from the upland surface to the crater floor, consists of weakly interconnected basins, with multiple parallel channels and/or inverted channel deposits leading, like Peace Vallis, to the crater floor. The available images of both drainage areas suggest a long history of multiple geomorphic processes that include a recent glacial interval followed by a late fluvial episode.

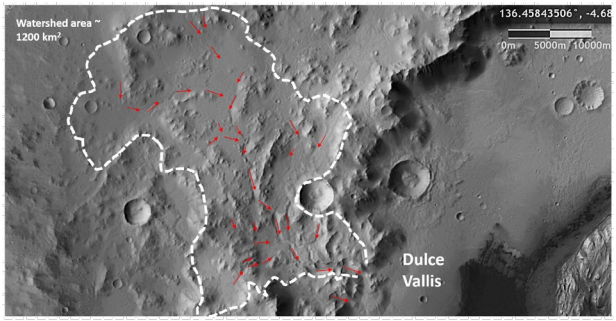

Fig. 2 The Dulce Vallis watershed, ~ 1200 km^2, and associated drainage channel system. Oriented with north at the top.

Evidence for glacial processes: U- or parabolic shaped channels are common in the Dulce Vallis and PV watersheds with little sinuosity, and many channels are often parallel to each other with little disruption of the interfluves. The channels are more deeply scoured in the steeper sections of the watershed (**Fig 1b**). There is evidence for directional scouring that leads over small hills and obstructions with accompanying plucking of the downhill sides of the obstructions (roche moutonné?)(**Fig. 4**). Many of the U-shaped valleys are headed in cirque-like, bowl-shaped alcoves against the higher ridges of the Gale Crater rim.

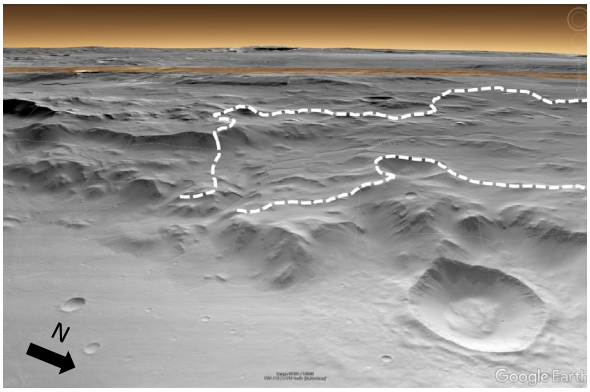

Fig. 3 Oblique view of the southern portion of the Dulce Vallis watershed, emphasizing the contrast between the steep scarps of the rim terrace edge and the flat rim terrace surfaces.

In areas not expressing a distinct channel there is some evidence of scouring of the rims of impact craters, but a thicker cover of late air-fall material in the Dulce Vallis area likely obscures the evidence seen in the Peace Vallis watershed.

Throughout the upper watershed is a channel network primarily of non-sinuous nature that may have subglacial and/or late fluvial character (**Figs. 1, 2**). Inverted channel deposits are present in the watershed- in one case, parallel to nearby U-shaped valleys, in another, on the floor of a larger valley (not shown), consistent with deposition in sub-ice channels as eskers.

Evidence for late fluvial activity: Unique in the lower portion of Dulce Vallis and adjacent channels is the presence of V-shaped valleys with narrow floors and deep alcoves at their heads. Their form is very different from the heads of the U-shaped valleys, suggesting an origin by sapping and fluvial erosion. The V-shaped valleys have undercut and left numerous hanging U-shaped valleys with no evidence of later fluvial incisions into the V-shaped channels, consistent with this being the final stage of major channel modification.

There is only one example of a smaller scale sinuous channel that could represent late fluvial surface flow leading into the beginning of the V-shaped sapping channel of the main Dulce Vallis (**Fig. 1b**). The sinuous channel is sourced in a higher valley with inverted deposits on the floor.

Compared to the Peace Vallis system, there is no evidence for late fan outflows (e.g. Scuderi et al. [7]) or the very small m-scale channels seen in PV area, however, the DV region appears to be buried with a thicker layer of late air-fall material than the PV area.

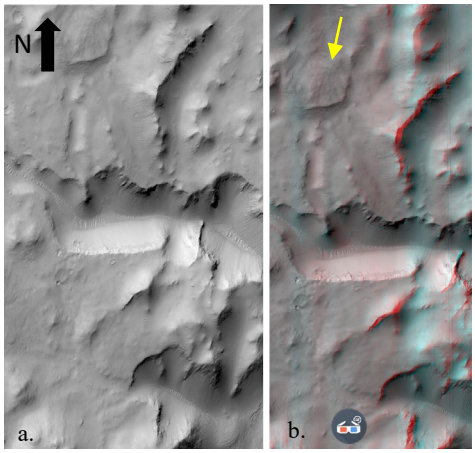

Fig. 4a. HiRISE ~ 5 km wide and **b.** stereo HiRISE of the sapping V-shaped lower Dulce Vallis channel. At the top left is a flat topped hill (yellow arrow) smooth on the upslope N-side and plucked on the S-side suggesting glacial processes.

Depositional features: Located at the base of the channels are alluvial fans and a likely fan-delta (**Fig. 1**), but the total area of the deposits is substantially smaller than the Peace Vallis fan. The V-shaped sapping valley immediately to the south of the lower Dulce Vallis has deposited a perched fan (Fig. 1) well above the crater floor, also suggestive of fluvial deposition.

Deposition of the delta into a lake is suggested by the relatively flat upper surface ~250 m above the crater floor of the most prominent fan/delta. It is possible that the base of the fan/delta is partly buried beneath the deposits on the crater floor and the fans in the Dulce Vallis area may have originally covered a somewhat larger area.

Conclusions: The Dulce Vallis area has evidence for an early resurfacing event, including the abundant U-shaped valleys and a scouring of the surface that is consistent with glacial flow. There is also evidence for a later fluvial event expressed mainly by the presence of the V-shaped sapping channels leading to a possible fan/delta on the crater floor. In contrast, features suggestive of late fluvial activity at the Peace Vallis area include outflow features on the fan [7], and thin late channels across parts of the surface [1-3].

References: [1] Newsom et al., (2019), 9th Mars #6119. [2] Newsom et al., (2020) LPSC #2609. [3] Newsom et al., (2020) AGU P038-01 [4] Fairén et al., (2014) *Planetary and Space Sci.* 93-94, 101-118. [5] Williams et al., (2020) AGU P038-02. [6] Gallegos et al., 2020, AGU P028-01. [7] Scuderi et al. (2019), LPSC #5043, and 9th Mars #6285.