EVIDENCE FOR GLACIAL PROCESSES ON GALE CRATER RIM SURFACES FROM NEW HIRISE OBSERVATIONS: H. E. Newsom[1], L. A. Scuderi[1], Z. E. Gallegos[1], L. L. Tornabene[2], R. C. Wiens[3]. [1]U. New Mexico, Albuquerque, NM 87131, USA (Newsom@unm.edu); [2]U. Western Ontario, CN; [3]Los Alamos Nat. Laboratory, NM, USA.

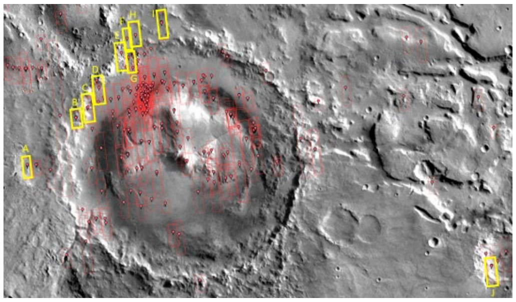

Fig. 1. HiRISE images (yellow) relevant to this abstract.

Introduction: Gale Crater has received great attention due to the proximity to the MSL (Curiosity) landing site [1-2 and prior references]. However, high-resolution imaging by HiRISE has focused on the area of the rover traverse. Until recently, only a very limited number of HiRISE images of the crater rim and surrounding region were available and even fewer stereo pairs. The recent acquisition of new HiRISE images in the last four years has led to a reexamination and, in some cases, reinterpretation of detailed features on the crater rim, especially in the watershed of Peace Vallis (PV) and its fan, and along other channels and valleys depositing material on the floor of Gale Crater and nearby highlands [3]. The available images (Fig. 1) suggest a long history of multiple geomorphic processes that included the early lacustrine sedimentation event with a recent glacial interval followed by a very late fluvial episode. These observations are consistent with features sometimes visible in the lower resolution CTX images. The central uplift surrounded by mound material and other portions of Mt. Sharp (Aeolis Mons), also of interest for glacial valleys and deposits is summarized by Fairén et al. [4] but as with the crater rim, there are still only limited stereo observations and high-resolution DEM data for quantitative analysis.

Observations: A. The crater rim watershed surface standing as much as 1300 m above the crater floor is bounded by an elevated ridge next to the large scarp into the crater, consists of weakly interconnected basins, separated by ramps with multiple parallel channels and/or inverted channel deposits leading in a few locations, like Peace Vallis, to the crater floor. Erosion of the watershed surface produced a mottled scoured appearance where smooth material has filled depressions in the size range of meters to tens of meters that may be small craters whose rims have been removed (Fig. 2). The mottled scoured terrain surprisingly includes the surface of several alluvial fans on the crater rim (Fig. 3) and nearby uplands (Fig. 4).

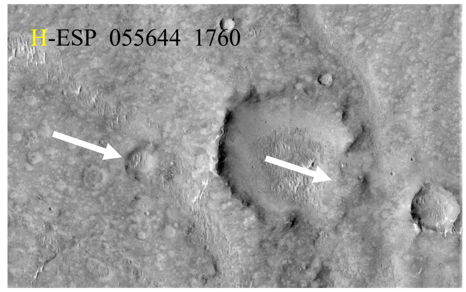

Fig. 2. PV watershed surface with breached crater, pitted surface and channels, ~2 km across. The white arrows point to craters with scoured rims.

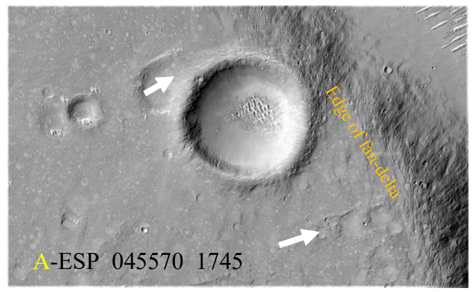

Fig. 3. Surface of fan-delta on westernmost Gale rim. Surface is mottled and scoured like the other surfaces above the crater rim, ~2 km across.

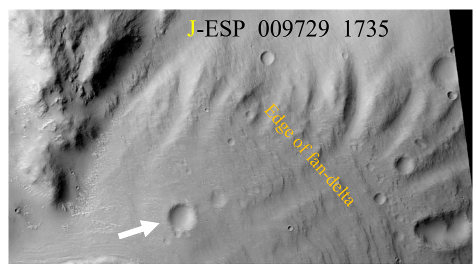

Fig. 4. Fan-delta in crater on the highlands East of Gale crater. Broad channels, with no sharp fluvial incisions, have dramatically scoured the surface of the fan, ~5 km across. White arrow points to crater with scoured rim.

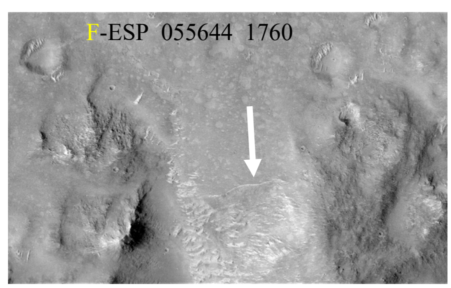

Fig. 5. Breach through the crater rim wall. There is no incised fluvial channel in the broad shallow valley, ~2 km across. The high point on the saddle is ~ 20 m above the low channel area just above the top of the image. White arrow points to scarp within the channel. The slope in the direction of the white arrow is 10% or ~6°.

B. Numerous shallow valleys that do not show incised fluvial channels penetrate the rim wall ridge (e.g. Fig. 5). The elevated saddles where the valleys cross the ridge crest are often only a few tens of meters above the rim basins. The valleys therefore appear to have no access to any fluvial supply from the main watershed.

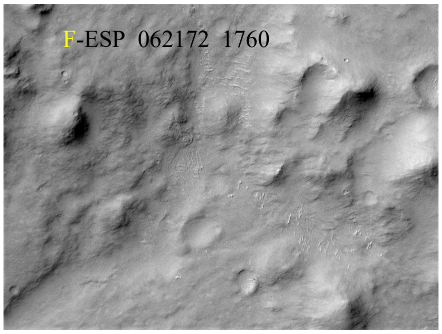

Fig. 6. The beginning of the large Peace Vallis channel, ~ 5 km across. Note the absence of an incised channel connecting the main PV watershed at the top of the image with the wide PV channel starting at the lower left.

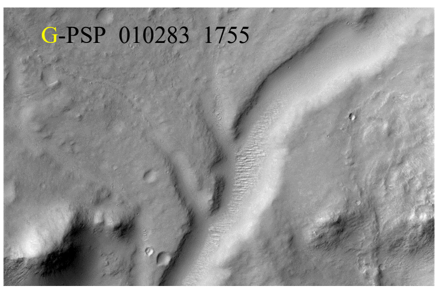

Fig. 7. PV channel, just below the section in **Fig. 6,** with tributaries on the left. The image is 5 km across with the main channel being as much as 500 m in width.

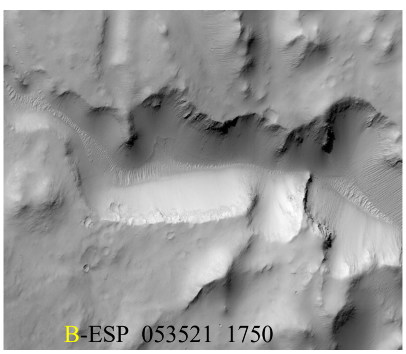

Fig. 8. V-shaped sapping channel cutting earlier broad shallow channels. Image is ~5 km across with crater floor to the right.

C. There is a surprising lack of highly integrated fluvial channel systems on the crater rim, especially for channels leading to the Peace Vallis alluvial fan. For example, the area connecting the main watershed area with the wide PV channel shows no fluvial incision (**Fig. 6**). Yet, further downslope, on a lower bench in an embayment on the rim, the main PV channel is very broad, but the HiRISE images reveal a parallel set of channels and inverted deposits (**Fig. 7**).

D. There is evidence, in some areas, for late incision in the crater rim by V-shaped sapping channels that leave hanging earlier parallel shallow channels (**Fig. 8**).

Discussion: The surface morphology of the Gale rim, e.g. scouring of small crater rims, shallow valleys lacking sinuous channels, lack of an incised integrated valley network, suggests a late glacial epoch in Gale. This epoch likely post-dated the early fluvial episode that led to lacustrine sedimentation in Gale observed by Curiosity, based on the glacially scoured surfaces of early fan-deltas (Figs. 3, 4). Gallegos et al. [5] discuss additional evidence for glacial inverted channel features with esker-like characteristics (e.g. [4]) as seen in new HiRISE images on the crater rim. The glacial epoch was limited in intensity or duration, as earlier fluvial channels were not completely eroded away in the watershed (e.g. Fig. 2). Wide shallow U-shaped valleys (e.g. Fig. 5, 8) formed that were not deeply incised, leading to limited evidence for morainal material besides hummocky outwash deposits. Terrestrial examples include ice-filled channels in the Himalayas, and glacial landforms in Scotland with limited morainal deposits.

A glacial scouring process can also explain surfaces that contain "mottled" texture with many sub-circular depressions. The circular nature of the depressions suggests impact craters, or pitted terrain from volatile-rich impact melt deposits [6]. The presence of this texture on the surface of several fan-delta fan deposits (e.g. Figs. 3, 4) makes an impact melt hypothesis for this surface less likely, leaving impact craters as the likely possibility. Of the identifiable impact craters, only a few larger craters in the 100+ m size retained their rims. Most of the circular structures have no rims or breached rims, a characteristic difficult to produce by fluvial processes.

Conclusions: New imagery suggests the presence of a late glacial epoch in Gale Crater rim and surrounding highlands, namely, scoured surfaces, a poorly integrated valley network, and shallow U-shaped valleys with no sinuous channels. The present of glaciers is further evidenced from linear inverted deposits seen in HiRISE images that have glacial esker characteristics, including parallel deposits that cut across topography [5].

A late fluvial event followed the end of the glacial epoch, possibly associated with melt back of glaciers. The late event led to fluvial erosion or sapping channel formation in the bedrock of the crater rim (e.g. Fig. 8). Light-toned material was also mobilized during the fluvial event, filling the scoured depressions of the mottled terrain and forming the smooth upper Peace Vallis fan (AF) unit with a relatively young age of ~ 1.2 AE [2]. The AF unit subsequently experienced groundwater sapping that formed depressions on the lower slopes of the fan [3]. This last fluvial episode also produced small, meter scale sinuous channels [3].

References: [1] Palucis et al., (2014) J. Geophys. Res. Planets 119:705–728. [2] Grant et al., (2014) Geophys. Res. Lett. 41:1142–1148. [3] Newsom et al., (2019), 9th Mars [4] Fairén et al., (2014) Planetary and Space Sci. 93-94, 101-118. [5] Gallegos et al., 2020, this meeting. [6] Tornabene et al. (2012) Icarus, 220, 348-368. [7] Scuderi et al. (2019), LPSC #5043, and 9th Mars.