FILL HISTORY OF JEZERO: VOLCANIC FLOOR UNITS AND THEIR RELATIONSHIPS TO THE MANY LAKES OF JEZERO CRATER.

A. M. Annex[1] and B. L. Ehlmann[1], [1]Division of Geological and Planetary Sciences, California Institute of Technology, MC 150-21, 1200 E. California Blvd., Pasadena, CA 91125, USA (annex@caltech.edu).

Introduction: The Mars 2020 Perseverance rover landed in Jezero crater due to interest in collecting rock samples from an ancient lacustrine environment to assess the habitability of ancient Mars. Prior works have interpreted differing geologic histories for units within and outside of Jezero using orbitally-derived datasets available prior to the landing. With the additional context of nearly two years of operation by the rover, it is now possible to re-examine these orbital datasets from a new frame of reference to maximize the science return of samples collected and returned.

Fassett and Head first proposed Jezero once hosted an ancient fluvial-lacustrine environment, supported by two fan deposits in the West and North and the outlet channel on the eastern side, indicating a minimum open-basin lake extent level of -2395 m [1]. Goudge et al. 2015 identified distinct volcanic crater floor units extending across the interior of the crater and proposed a chronology of filling events in the basin: a “light-toned floor” (LTF) unit predates the two fan deposits, which both predate a “volcanic floor” (VF) that covers much of the floor of Jezero [2]. Stack et al. then refined the unit mapping close to the landing site [3]. The LTF unit, aka Cf-f-1 in [3], is expressed as polygonal blocks interspersed among bedforms, while the VF unit, aka crater-floor fractured-rough (Cf-fr) in [3], is a rough, crater-retaining surface in places covered by a smooth undifferentiated unit, interpreted as a lag accumulated by local bedrock deflation. Finally, the Western and Northern Fan deposits (WF & NF respectively) extend out into the crater interior for kilometers and exhibit a complicated relationship with each other. Perseverance measurements of the western fan established a -2490 m level corresponding to a closed-basin lake phase [4].

The VF unit is of particular interest because, pre-landing, its sedimentary vs. igneous nature was not determined; post-landing, the Cf-fr portion of the VF was established to be igneous, either a lava flow or less-mafic component of intrusive igneous rock that predates the fan deposits [5]. However, certain geologic contacts provide contradictory constraints for the relative chronology between these three major units, necessitating further study of the floor units in areas inaccessible to the Perseverance rover.

Data & Methods: Several new HiRISE DTMs of the crater floor units in Jezero were produced using the Ames Stereo Pipeline from the PDS EDR products [6-8]. Previously published CTX and HiRISE DTMs and ortho images from Fergason et al. 2020 and Mangold et al 2021 were also used in this work [4,9].

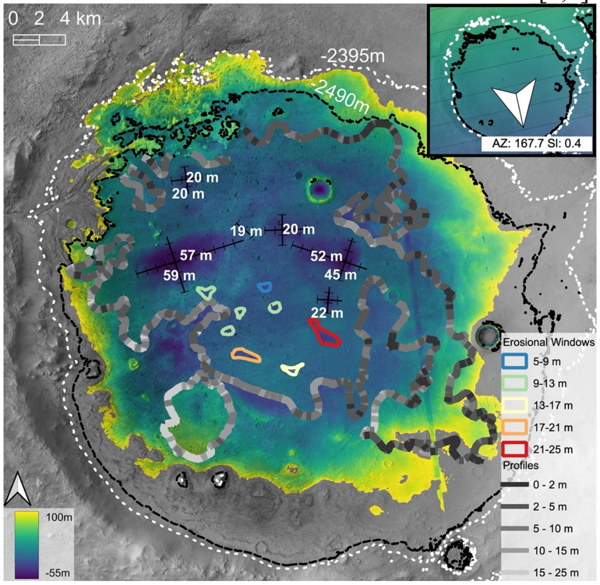

Figure 1: CTX orthoimage contextual map of Jezero Crater with subset of detrended topography below -2395 m and trend surface and fit in upper right corner. Depression depths in meters (white labels). Erosional window outlines shaded according to colormap, and elevation deltas of VF margin profiles in grayscale. Lake level contours from [1] and [4].

To accentuate subtle topographic features the DTMs were detrended using OLS regression to fit a linear trend surface to VF. Pixelwise differences from the mean elevation over multiple length scales were also used to make RGB maps of terrain variations at multiple scales (501 m, 301 m, and 151 m) without a trend surface [10]. Finally, the geologic map and units defined by Goudge et al. 2015 were utilized to sample unit thickness at contacts using profiles and min-max elevation differences [2].

Results: Detrending VF topography revealed a dip of 0.4° (0.7 %) with a 167° azimuth (SSE) (Fig 1), consistent with findings in [11]. Detrended topography emphasizes the signature of two multi-kilometer-scale depressions that are over 50 m deep (Fig 1) relative to the VF unit without obvious slope breaks or cliffs. The largest depression is just east of the Octavia E. Butler landing site and appears connected to the second largest depression by wide, but subtle, channel impressions connecting the depressions (Fig 1 & 2).

There are eight erosional windows (EW) surrounded by VF in a restricted region south of the center of Jezero (Fig 1). The EW are ~1-2 km^2 in scale and range in depth from 5-25 m as determined by their maximum depth relative to the surrounding VF elevation. The boundaries of the EW are cliff-forming exposures of the VF unit that drop several meters then shallow dropping further towards the interior. A few EW exhibit layers in the walls; others have poorly exposed breaks in slope within their interior on the exposed vertical cliff walls of VF (Fig 2A-B). Where measured, distances between slope breaks are meter-scale.

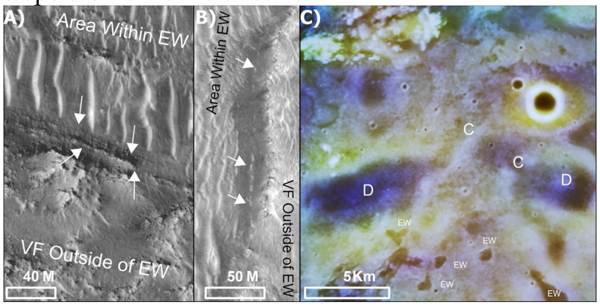

Figure 2: HiRISE imagery of EW interior and breaks in slope **(A)**, and layers **(B)** embedded within cliff walls of EW indicated by arrows. Histogram (**C**) equalized 3-length-scale (501 m Red, 301 m Green, 151 m Blue) pixelwise difference from mean elevation map showing presence of EW, depressions (D) and channel impressions (C) within VF made from CTX DTM.

Profiles sampling the elevation change along the periphery of the VF unit (Fig 1) reveal a variable height difference between VF and the units they contact. The highest differences are along the southwest quadrant that are upwards of 10-15 m and peak near 20 m in elevation change. The south margin of VF spans 100 m of detrended topography.

Discussion: We interpret the depressions as post-depositional deformation of the overlying VF unit. The depressions are more than twice the depth of the deepest EW, and prior studies constrained the thickness of VF to <10 m [2]. If the VF unit consists of extrusive lava flows, they should have filled in the depressions. The post-depositional deformation may be due to compaction of relatively unconsolidated fluvial-lacustrine sediments, formed in a chain of lakes during a closed basin stage of Jezero crater, and then overtopped by VF lavas. Alternatively, the depressions could be the result of collapse of lava tubes or magma chambers (Fig 2).

The negative relief of the EW and the expression of the margins of the VF unit likely result from the same processes. Weaker, possibly lacustrine, deposits forming topographic highs, were embayed by VF lavas, and then were preferentially eroded to fines lofted by winds, leaving pits where the topographic highs once were [12]. Alternatively, upward inflation of lavas, thickening around a topographic obstacle, can generate negative topography of the EW and margin cliffs [13].

Importantly, the depths of the EW contrast with embayed inferred-lacustrine rocks at Gusev crater [14] as well as the presence of Cf-f-1 (Séítah) rocks at Jezero as topographic highs surrounded by VF (Cf-fr) nearer to the landing site [3]. This implies either that (1) volcanic intrusive Séítah-like rocks were also in EW but the Séítah rocks near the landing site were protected from erosion and only recently exhumed or (2) that the materials in the EW were fundamentally different and more susceptible to erosion, properties consistent with sedimentary lacustrine deposits or very altered volcanics, such as might have been submerged in the deepest parts of the basin.

The variable height of the VF margin as measured (Fig 1) is also likely related to either variable exhumation or material strengths of units that are adjacent and/or underlying. At the south, the high boundary of the VF with the LTF spans most of the crater diameter and corresponds to the lowest elevations in Jezero (<-2640 m). These elevations are lower than the depressions but at similar elevations as the EW. This region could be an impression left by erosion of a large lacustrine deposit in the south of Jezero.

Both the depressions and EW imply substantial pre-existing topography and/or lithologic heterogeneity on the floor of Jezero crater at the time of emplacement of the VF unit. The characteristics observed are consistent with an eroded sedimentary flood plain with chains of lakes.

Conclusions: The volcanic floor units in Jezero remain a vital component of the geologic history within the crater. We identified the presence of large-scale depressions from detrended topography that could be the signatures of smaller lakes/channels within Jezero when water levels were ~100 m below the outlet valley elevation and below strata explored by Perseverance. Inverted topographic features may also be the signatures of lacustrine deposits near the center of Jezero now lost to surface erosion. Work remains to assess the viability of these hypotheses and to understand the filling history of Jezero crater.

Acknowledgments: EDR PDS HiRISE data available at doi: 10.17189/1520179 was used to make several HiRISE DTMs.

References: [1] Fassett and Head *GRL* (2005), [2] Goudge et al. *JGR Planets* (2015), [3] Stack et al. *SSR* (2020), [4] Mangold et al. *Sci.* (2021), [5] Farley et al. *Sci.* (2022), [6] Alfred S. McEwen doi: 10.17189/1520179, [7] Beyer et al. *ESS* (2018), [8] Annex and Lewis *5th Planetary Data and PSIDA #7003* (2021), [9] Fergason et al. (2020), [10] Lindsay et al. *Geomorphology.* (2015), [11] Sholes et al. *53rd LPSC #2641* (2022), [12] Holm-Alwmark et al. *JGR Planets* (2021), [13] Hamilton et al. *J. Geophys. Res. Planets* (2020) [14] Ruff *4th ICEM #3076* (2017),