

PAST VARIATIONS OF WATER LEVEL OF JEZERO PALEOLAKE. N. Mangold^{1,*}, G. Caravaca², S. Gupta³, R.M.E. Williams⁴, O. Gasnault², S. Le Mouélic¹, E. Dehouck⁵, G. Dromart⁵, A. Annex⁶, J. Hurowitz⁷, L.R.W. Ives⁶, L. C. Kah⁸, N. Randazzo⁹, J. I. Simon¹⁰, K. Stack⁶, M.M. Tice¹¹, J.F. Bell III¹², A. Cousin², S. Maurice², R.C. Wiens¹³. ¹LPG, Nantes Univ, CNRS, France; ²IRAP, CNRS, CNES, Univ. Toulouse, France; ³Imperial College, London, UK; ⁴PSI, Tucson, AZ, USA; ⁵LGL-TPE, Univ. Lyon 1, France; ⁶Caltech-JPL, Pasadena, CA, USA ; ⁷Stony Brook University, Stony Brook, NY, USA; ⁸Earth and Planetary Sciences, University of Tennessee, ⁹Univ Alberta, Edmonton, AB, Canada, ¹⁰NASA Johnson Space Center, Houston, TX, USA ¹¹Texas A&M, College Station, TX, USA; ¹²ASU, Tempe, AZ, USA ; ¹³Purdue Univ. West Lafayette, IN, USA. *nicolas.mangold@univ-nantes.fr

Introduction: The western fan of Jezero crater displays features interpreted as fluvial and deltaic sedimentary rocks from orbital data [1,2]. Images obtained using the SuperCam Remote Micro-Imager (RMI) and the Mastcam-Z camera provide in-situ observations of Jezero crater's western fan in various locations along the Perseverance traverse. In the last two years, the rover analyzed the fan front from a distance using these imaging tools and at close range using its entire payload. Then, in 2023, the Perseverance rover explored the top of the western Jezero sedimentary fan. Here we show that fluvial topsets and deltaic foresets dominate sedimentary rocks. Determining the boundary between fluvial and prodelta deposits enables us to draw the evolution of the lake level through time.

Observations at the fan front: The fan front has been examined using distant imaging on several hillslopes, along its eastern and southern sides. Despite scree covering large sections of some of the hillslopes studied, our observations highlight a systematic stratigraphy of the fan front (Fig. 1)[3]: (i) The bottom of hillslopes displays recessive, light-toned deposits that are best explained as lacustrine deposits at the delta toe (bottomsets and toesets), part of the Shenandoah fm. [4]. (ii) The central part of the fan front hillslopes corresponds to dipping foreset beds developed most of the time over 20 to 25 m of vertical extension. They usually display sigmoidal geometry with steeply dipping sandstones and some conglomerates. (iii) Above the foresets various types of fluvial deposits (sandstones and conglomerates) are present, with frequent cross-beddings interpreted as topset beds deposited from rivers feeding Jezero Lake. The transition between topsets and foresets varies from -2470 to -2500 m, corresponding to earlier lake levels, in agreement with what has been deduced at the Kodiak butte, i.e., -2490 and -2500 m [5,6]. (iv) Above these bedded sedimentary rocks are massive, poorly-sorted boulder conglomerates that truncate the underlying strata. They represent an energetic last stage of fluvial floods which truncates underlying beds and for which the relationships to the Jezero Lake is unclear, i.e.

potentially deposited subsequently and without any link to the paleolake.

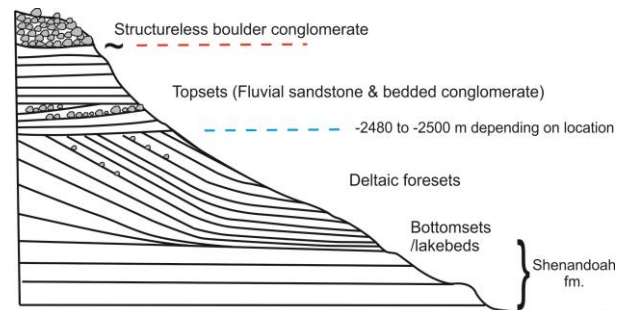


Fig. 1: Synthetic sketch of the observations made on the fan front [3].

Observations at the fan top: From orbital observations the fan top displays sedimentary layering interpreted mostly as fluvial deposition [1,2]. However, in-situ observations by Perseverance show many outcrops that we interpret as pro-delta deposits. For instance, Pinestand Mountain is a ~22 m high butte exposed east of the rover's traverse (Fig. 2). It displays two ~14 and ~22 m bed sets with up to ~30° dipping sigmoid strata. No pebble or cobble has been observed at this scale, suggesting the rock texture is sandstone. From the lack of cross-stratification and the planar bedding with steep dip, we interpret these beds as due to gravity-induced avalanches of material deposited onto the slope of a delta, namely foresets. In planview, Pinestand Mountain shows a lobate shape consistent with a deltaic lobe [7]. In contrast to locations at the fan front, topsets are absent here (likely eroded), so the tops of these beds mark the minimum water level during their deposition, at -2448 m. Further up, images within Belva crater enabled the localization of the uppermost foresets observed so far at an elevation of -2410 m (Fig. 2).

The Carew Castle location is one of the location where beds display a sudden change in dip. At the top, the main scarp of Carew Castle displays coarse-grained beds (both sandstone and pebble conglomerate) which are subhorizontal and heavily cross-stratified, thus deposited within an energetic setting, e.g., braided river

system [7]. Below these cross-bedded beds lie steeply dipping beds (up to 22°), with apparent planar setting, thus distinct from the overlying crossbedded sedimentary rocks. We interpret this transition as being similar to those observed on the fan front between topsets and foresets. Its elevation of -2445 m, is 25 to 50 m higher than what has been determined at the fan front.

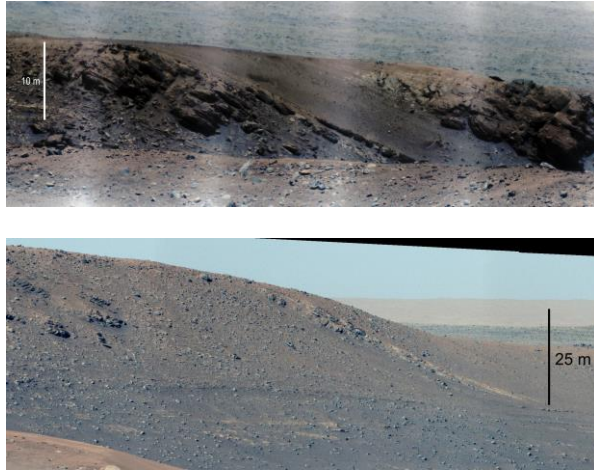


Fig. 2: (top) General view of the Pinestand Mountain butte on the fan top (SuperCam/RMI, sol 777, seq. 03777), highlighting the two series of beds of steeply dipping (up to 30°) toward SE strata interpreted as deltaic foresets. (bottom) View of Belva crater northern inner rim with dipping beds to the right and left of the Mastcam-Z 110 mm image (sol 772, seq. 08789).

Paleolake water level through the delta: Overall, observations made on the fan top agree with those made on the fan front [3] and at the Kodiak butte [4,5], but the prodelta deposits typical of subaqueous deposition are found at higher elevations. When plotting these past lake level elevations, we observe an evolution from the topmost location north of the Belva crater (-2410 m) to the lowermost elevations at Kodiak (-2500 m) that is consistent through the whole fan (Fig. 3). This evolution is related either to a progradation from top to bottom during forced regression (lake level fall from -2410 m to -2500 m) or a retrogradation from bottom to top (lake transgression from -2500 m to -2410 m). Yet, terrestrial examples of deltas formed by transgression show that the fluvial topsets are buried below the subsequent foreset beds. No observation shows such a geometry. In contrast, we observe both a truncation of foresets by fluvial topsets and a superimposition of steep foresets on gently dipping foresets that were deposited previously. Both geometries are typical of progradation during forced regression due to a rapid decrease of the water level.

Discussion and conclusion: In summary, the fan top and front both display a similar style of deposition from in-situ images, dominated by dipping beds interpreted as deltaic foreset beds. The variations of the lake level inferred from these observations are consistent with a progressive fall of the lake level, i.e. forced regression. Such evolution means that the visible part of the fan did not develop during the filling of the crater by Jezero lake, but during its progressive drying out in a closed basin below the elevation of the eastern breach toward the East (ca. -2400 m). Deposits formed during the initial stage of the lake (lake filling) may have been buried by subsequent deposits and may be hidden. Alternatively, the lake filling might have been too quick after Neretva Valles breached Jezero crater rim to allow the deposition of substantial volume of sediments [8]. Such a scenario has major implications on the chemical evolution of the lake, for instance the formation of evaporitic minerals during the drying out of the lake.

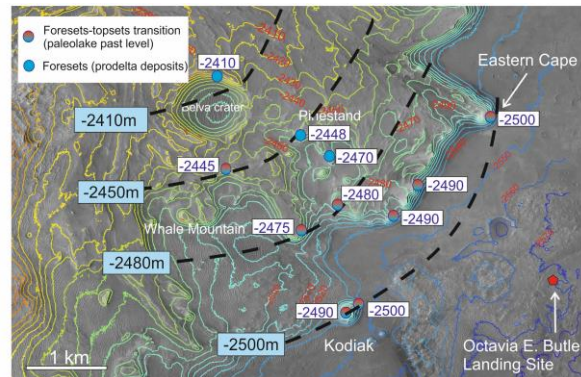


Fig. 3: Map of the western fan of Jezero with topographic contours in color. Elevations in white boxes indicate the lake level (from topset-foreset transition) or minimum lake elevation (from foresets). The elevations in blue boxes and the related black, dotted lines extrapolate these elevations showing a consistent change in elevation from -2410 m at the fan top toward -2500 m at the Eastern Cape and at Kodiak.

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References: [1] Stack *et al.* (2020) *Space Sci. Rev.* 216(8), 127. [2] Goudge *et al.* (2018) *Icarus* **301**, 58-75. [3] Mangold *et al.* (2023) *ESS Open Archive*, DOI: 10.22541/essoar.170067082.23349203/ [4] Stack *et al.*, (2023) *ESS Open Archive*, [5] Caravaca *et al.* (2024) *JGRp submitted*. [6] Mangold, Gupta *et al.*, 2021, *Science*. [7] Caravaca *et al.* (2024) *LPSC LV* (this conf.). [8] Salese *et al.*, (2020) *Astrobiology*.