SIGNIFICANCE OF THE VARIATIONS IN FLUVIAL INPUT WITHIN JEZERO CRATER FROM PERSEVERANCE ROVER OBSERVATIONS. N. Mangold[1*], S. Gupta[2], G. Caravaca[3], O. Gasnault[3], G. Dromart[4], J. D. Tarnas[5], S. F. Sholes[5], B. Horgan[6], C. Quantin-Nataf[4], A. J. Brown[7], S. Le Mouélic[1], R. A. Yingst[8], J. F. Bell[9], O. Beyssac[10], T. Bosak[11], F. Calef III[5], B. L. Ehlmann[12], K. A. Farley[12], J. P. Grotzinger[12], K. Hickman-Lewis[13,14], S. Holm-Alwmark[15,16,17], L. C. Kah[18], J. Martinez-Frias[19], S. M. McLennan[20], S. Maurice[3], J. I. Nuñez[21], A. M. Ollila[22], P. Pilleri[3], J. W. Rice Jr[9], M. Rice[23], J. I. Simon[24], D. L. Shuster[25], K. M. Stack[5], V. Z. Sun[5], A. H. Treiman[26], B. P. Weiss[5,11], R. C. Wiens[22], A. J. Williams[27], N. R. Williams[5], K. H. Williford[5]. [1]LPG Nantes, France. [2]Department of Earth Science and Engineering, London, UK [3]IRAP, Université de Toulouse, France. [4]LGL, Lyon, France. [5]JPL, CalTech, Pasadena, USA. [6]Purdue University, USA. [7]Plancius Research, USA. [8]Planetary Science Institute, USA. [9]ASU, Tempe, USA. [10]IMPMC, Paris, France [11]MIT, USA [12]CalTech, Pasadena, USA. [13]The Natural History Museum, London, UK [14] Università di Bologna, Italy [15]Niels Bohr Institute, Copenhagen, Denmark [16]Department of Geology, Lund University, Sweden [17]Natural History Museum Denmark, Copenhagen, Denmark. [18]Department of Earth and Planetary Sciences, University of Tennessee, USA. [19]Instituto de Geociencias, Madrid, Spain [20]Department of Geosciences, Stony Brook University, USA [21]JHUAPL, Laurel, USA [22]LANL, Los Alamos, USA [23]Geology Department, College of Science and Engineering, USA [24]Center for Isotope Cosmochemistry and Geochronology, Astromaterials Research and Exploration Science, USA [25]Dept. Earth and Planetary Science, University of California, Berkeley, USA [26]LPI, USRA, Houston, USA [27]Department of Geological Sciences, University of Florida, USA. *nicolas.mangold@univ-nantes.fr

Introduction: The Perseverance rover landed on the floor of Jezero crater on 18 February 2021. The landing site, named “Octavia E. Butler” is located ~2.2 km from the SE-facing erosional scarp of the western fan deposits, which are of strong interest for the mission [1-2]. Images obtained using the Mastcam-Z camera and the Remote Micro-Imager (RMI) of the SuperCam instrument provided the first Mars ground-based observations of this western fan (Fig. 1). At the distance images were taken, the RMI images offer a pixel resolution of 2.2 cm, thus enabling identification of objects of typically 7-8 cm (3-4 pixels). Observations of the residual butte Kodiak confirmed the presence of a lake within Jezero crater, but also showed that the lake deduced from the deltaic architecture at Kodiak had a level ~100 m lower than expected (-2495/-2500 m), and was thus a closed system for a significant period [3]. In addition, the coarser deposits (boulder conglomerates and pebbly sandstones) observed near the top of all of the scarps are typical of fluvial floods with high energy, reflecting a change in hydrology of the fluvial system. Here, we focus on the hydrological characteristics of fluvial deposits observed within the scarps of the delta, both as topsets and as boulder conglomerates.

Observations: Sub-horizontal topset beds at Kodiak are homogenous deposits, likely sandstones, as highlighted by numerous cross-bedding relationships. Beds are typically 20-30 cm in thickness and display various depositional directions suggestive of meandering [4]. These observations are consistent with the deposition of sand/gravel material within relatively regular flows. The presence of occasional boulders 20-30 cm in long axis within the Kodiak butte topsets and foresets points to locally higher intensity flow conditions, but no clast-supported coarse conglomerates are observed in topsets, although gravel conglomerates with pebble sizes mostly limited to 6 cm cannot be discarded at this distance. No obvious channel fills are observed, suggesting progressive truncations of each bedset before deposition of the next one.

Massive deposits are observed at or close to the top of all scarps observed. They display faint layering, irregular shapes and blocks up to 1.5 m in length, a geometry consistent with fluvial floods from relatively ephemeral activity. In five scarps, these deposits display a discontinuity against a base of finer-grained topsets that is interpreted as a truncation, except in the northernmost case where the transition seems more regular but largely hidden by erosional debris [3]. The rounding of many clasts indicates that they have undergone abrasion by fluvial processes. The rounded to subrounded shape as well as the lack of apparent internal bedding in these clasts suggests an igneous lithology. The overall geometry of the sedimentary body suggests that it is a channel deposit. The boulder-rich conglomerates are present at elevations higher than -2495 m. Thus, most of their occurrences take place at an elevation above that deduced from Kodiak deltaic architecture (-2490/-2500 m), confirming an origin as subaerial flood deposits rather than gravitational slide deposits below water. The persistence of a lake at the time of these deposits is currently unknown.

Discharge rates estimations: Boulder size distribution and geometry of the channel helps to estimate discharge rates. The Darcy-Weisbach equations are usually applied to estimations of discharge rates (hereafter Q), where estimations of channel width W, water height H, and slope s can be made in association with measurements of clast size distribution that help to fix the friction factor f [5]. This relation has been modified for Mars conditions enabling the use of local martian gravity g_m (3.72 m.s^{-2}):

$$Q=A(8g_mRs/f)^{1/2} \qquad \text{(Equation 1)}$$

Used on the boulder conglomerates, this equation gives results from 1.63 to 8.64 m s^{-1} for velocities and 76 to 3000 m^{3}s^{-1} for discharge rates assuming channel depths of 3-10 m as seen from the channel fill shape of this body. This method does not enable measurements of flow velocities in sandstone topsets in which no grain size distribution can be determined and no typical shape of channel fill has been observed. Another approach to estimate velocities and discharge rates is based on the largest clast lifted up by the flow. Several studies have developed methods taking gravity into account [6] by estimating the critical force necessary to initiate the motion of a spherical boulder:

$$V= (4/3\ Dg(p_r/p_f-1)\mu-0.5a/g)^{0.5} \qquad \text{(Equation 2),}$$

where D is the boulder diameter. This equation helps to estimate the velocity of the large boulder in Figure 1b (1.25 m in average diameter) as 1.91 m s^{-1}. Used on the largest boulders of the Kodiak topsets (0.25 m in average), the corresponding velocities is of 0.85 m s^{-1}, which gives a strict maximum flow velocity for all the topsets where no such boulders are observed. The most energetic topset flows were thus >2 times less energetic than the boulder conglomerates.

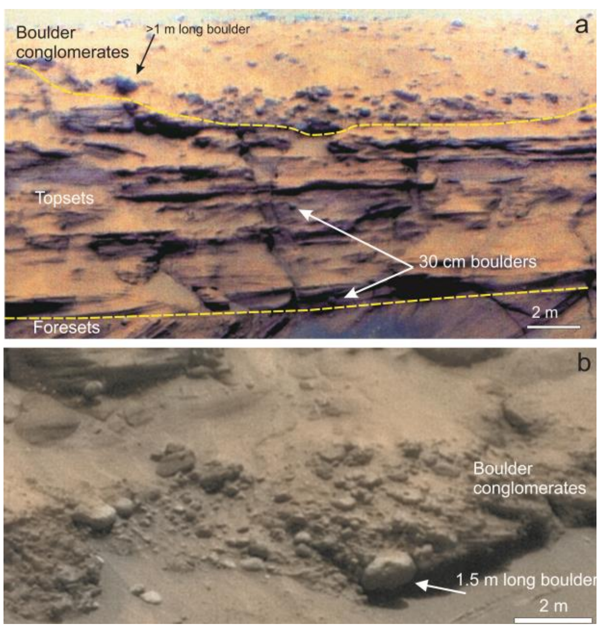

Figure 1: (a) Close-up on the RMI image of Kodiak butte showing, from bottom to top, foresets, topsets and boulder conglomerates. (b) Close-up of the RMI image of the delta front. Topsets include a few 20-30 cm in long axis clasts while boulder conglomerates include many boulders some of them being >1 m.

Origin of the hydrological change: Flood episodes illustrated by boulder conglomerates could have formed by a variety of processes such as rainfall events, snowmelt episodes (from climatic origin or heating by volcanism or impact), or through progressive building of glaciers and (sub)glacial lakes that could have generated episodic surges. Although not understood yet, this transition in flow intensity at Jezero crater may be related either to paleoclimatic shifts, or changes in watershed hydrology (new craters, building of glaciers…). It is currently unknown whether these floods occurred during the presence of a lake at lower elevation (-2500 m or below), or after a complete loss of water from Jezero crater floor.

Conclusions and implications: The hydrological regime observed in the fluvial topsets point toward regular, low to medium energy fluvial flows consistent with meandering or sinuous braiding streams assessed at Kodiak [4] and the curvilinear deposits observed from orbital data in erosional windows of the delta [5]. The boulder-rich conglomerates observed ontop of the sequence are present stratigraphically above all topsets deposits. They usually consist of high-energy floods with a difference in flow velocity by a factor of two, at minimum. The future rover traverse includes an access to the top of the delta where it should cross the transition from topsets toward conglomerates. Thus, it should enable more precise calculations of discharge rates and a better understanding of the origin of this transition toward a more ephemeral river activity. Boulders also present an opportunity to analyze and sample crustal rocks sourced from outside Jezero before leaving the crater.

Acknowledgments: The authors acknowledge the M2020 project's management, engineering and scientific teams for their diligent efforts in making this mission as effective as possible. The authors are grateful to M2020 team members who participated in tactical and strategic science operations.

References: [1] B. L. Ehlmann et al., *Nat. Geo.*, 1, 355-358 (2008). [2] T. A. Goudge et al., *J. Geophys. Res.*, 120, 775-808, 2015. [3] N. Mangold, et al., *Science*, 374, 711-717, 2021. [4] G. Caravaca et al., *53th LPSC*, 2022. [5] J. C. Bathurst, *J. Hydrol. Eng.*, 111, 625-643 (1985) [6] J. Alexander and M.J. Cooker, *Sedimentology*, 63, 1582-1595 (2016). [7] K. M. Stack et al., *Space Sci. Rev.*, 2020.