GOING WITH THE FLOW: SEDIMENTARY EVOLUTION OF THE JEZERO WESTERN FAN, MARS.

S. Gupta[1*], K. Stack Morgan[2], N. Mangold[3], L. R. W. Ives[2], S. Gwizd[2], G. Caravaca[4], R. M. E. Williams[5], N. Randazzo[6], A. J. Williams[7], P. Russell[8], B. H. N. Horgan[9], K. L. Siebach[10], M. M. Tice[11], J. Hurowitz[12], R. Barnes[1], C. Tate[13], J. I. Núñez[14], S. Scholes[2], L. C. Kah[15], M. E. Minitti[16], G. Dromart[17], J. F. Bell III[18], J. Maki[2], G. Paar[19], A. Annex[20], B. P. Weiss[21], O. Beyssac[22], J. Frydenvang[23], M. Nachon[11], R. Kronyak[2], V. Sun[2], A. J. Jones[1], D. L. Shuster[24], J. I. Simon[25], M. P. Lamb[20], J. P. Grotzinger[20], S. Le Mouélic[3], O. Gasnault[4], R. C. Wiens[9], S. Maurice[4], and K. A. Farley[2]. [1]Imperial College London, UK, [2]JPL, Pasadena, USA, [3]LPG, Nantes Univ., CNRS, France, [4]IRAP, Université de Toulouse, France, [5]PSI, Tucson, AZ, [6]University of Alberta, Edmonton, Canada, [7]University of Florida, [8]UCLA, Los Angeles, CA, [9]Purdue U., West Lafayette, IN, [10]Rice U., Houston, TX, [11]Texas A&M, College Station, TX, [12]Stony Brook U., Stony Brook, NY, [13]Cornell U., Ithaca, [14]Johns Hopkins U. Applied Physics Laboratory, Laurel, MD, [15]U. Tennessee, Knoxville, TN, [16]Framework, [17]LGL, Lyon, France, [18]ASU, Tempe, AZ, [19]Joanneum Research, Graz, Austria, [20]Caltech, Pasadena, CA, [21]MIT, Cambridge, MA, [22]IMPMC, Paris, France, [23]U. Copenhagen, København K, Denmark, [24]UC Berkeley, Berkeley, CA, [25]NASA Johnson Space Center, Houston, TX. and the NASA Mars2020 Science Team *s.gupta@imperial.ac.uk

Introduction: Sedimentary fans developed at the mouths of Martian valleys have been interpreted as the deposits of sustained surface water flow on early Mars building either fluvial fan systems or deltas into standing bodies of water [1]. Whilst much insight has been gleaned from orbital observations, it is only possible to constrain the character, relative timing and persistence of ancient aqueous activity on Mars through detailed on-the-ground interrogation of sedimentary successions built during fan growth. A prominent sedimentary fan deposit at the western margin of Jezero crater – the Western fan – has been interpreted from orbital data/observations to be a river delta that prograded into an ancient lake basin during the Late Noachian-Early Hesperian epochs on Mars (~3.6-3.8 Ga) [2]. The Western fan deposit forms a point-sourced depositional system developed at the mouth of Neretva Vallis, a valley system that is incised across the crater rim and has an extensive extra-crater catchment draining over diverse ancient geological units in Nili Planum [4]. The mechanism of crater rim breaching remains unconstrained. Between 2022 and 2023, the Mars 2020 Perseverance rover explored the Western fan, with the objective of characterizing its paleoenvironmental context and collecting a diverse suite of sedimentary rock samples for return to Earth via the Mars Sample Return mission. Perseverance has now completed her traverse across the Western fan having commenced in the distal downstream sectors exposed at the erosional front of the fan and then crossing across its upper exposed surface toward the fan apex region near the mouth of Neretva Vallis. This transect provides a unique window into a Martian sediment routing system at a time when climate conditions permitted the flow of surface water. In this contribution, we review the overall sedimentary architecture of the fan and develop a model for its evolution based on detailed mapping of lithofacies changes across the fan. A first-order synoptic overview is presented.

Fig. 1. ~10 m tall foresets at Pinestand Mountain (zcam08726)

Early alluvial fan to lake evolution at fan front: Strata exposed at the base of erosional scarp at the SE margin of the fan preserve evidence of the earliest history of the fan. Here, a ~25 m thick stratigraphic succession, informally named the "Shenandoah formation" comprises a lowermost unit of laminated and soft sediment-deformed fine- to coarse-grained sandstones interpreted as deposition in a distal alluvial fan setting [5]. Overlying this we observe an abrupt transition into sulfate-bearing mudstones (Hogwallow Flats member) inferred to have been deposited in a widespread lake records a transgression of the early alluvial realm. These thin lacustrine deposits can be traced along strike for several kilometers along the edge of fan erosional scarp suggesting a lake-level rise that was spatially extensive at a kilometer scale.

Transition to delta-lake deposition: Overlying the lacustrine beds of the Hogwallow Flats member, the stratigraphic succession examined by Perseverance shows a coarsening-up sequence into dipping planar thin-bedded sand-gravel couplets that are interpreted to record deposition by sediment gravity flows in the toesets of river deltas [5]. Where Perseverance's ascended onto the Western fan, Hawksbill Gap, scarps at the margin of the Gap show complex stratigraphic geometries. On the eastern flank, Franklin Cliffs shows stratal units comprising (1) poorly sorted matrix-supported conglomerates interpreted to be debris flow deposits, (2) gently inclined pebbly sandstone bedsets, and (3) tabular large-scale inclined bedsets that are locally conglomeratic but predominantly comprise finer-than-conglomerate lithologies, likely pebbly sandstones. The inclined strata show multiple laterally stacked bedsets indicating episodic deposition from multiple flow events on the steep front of Gilbert-style deltas. The inclined strata are overlain across a sharp truncation surface by generally planar parallel thin-bedded horizontal strata that we interpret as deposition from fluvial processes in a delta top environment. The oblique clinoform geometry exhibited by the foreset-topset beds indicates delta progradation during lake level fall based on Earth field examples and experimental studies. Overall, the observation of >10 m thick, approximately southward-inclined foreset units is suggestive of steep fronted deltaic systems building into a lake environment within Jezero crater [3, 5, 6].

Fluvial-deltaic systems of Tenby formation: In the medial section of the Western fan, to the north of the fan front, Perseverance explored complex stratigraphy exposed on the upper surface of the fan. Here, outcrops comprise extensive planform exposures mapped pre-landing as the curvilinear unit dotted by isolated mesas providing vertical sections. Stratigraphic relations are complex here due to an absence of distinct marker horizons to provide correlation ties. The curvilinear unit has a distinct orbital expression of decimeter-scale sets of alternating light- and dark-toned, curved, parallel strata that occur in amalgamated and stacked sets and was interpreted pre-landing as lateral accretion sets formed by sinuous river systems [8]. However, the steeply dipping nature of bedsets observed on the ground suggests that this model may not be plausible and alternative depositional models such as accretion on downstream migrating bars or delta mouthbars/foresets need to be considered. Vertical sections in buttes adjacent to the planform curvilinear strata show variable stratigraphic geometries recording interesting variability in depositional patterns [9]. At Pinestand Mountain and Crescent Rock, >10-m-scale in height inclined bedsets record large-scale foreset units with similarities to those observed at Franklin Cliffs (Fig. 1). Their cross-sectional form is suggestive of Gilbert-type delta foresets but their planform patterns are not easily explained, though a model of delta mouth bar lobes may provide an explanation. Their occurrence on the 'fan top' at a higher elevation than observed at the fan front may be explained by a progressively downstepping deltaic system formed during lake-level fall [7, 9] or more complex stacking patterns which more detailed analysis of facies relations may reveal. By contrast at Carew Castle butte, a cross-stratified pebbly sandstone erosionally overlies the curvilinear unit and likely records a younger episode of fluvial system evolution though the stratigraphic relations at present are not constrained.

River systems of the Otis Peak formation: In the proximal areas of the Western fan, we observe a series of cross-cutting ridge- and fan-shaped deposits that are commonly capped by boulder deposits that were mapped pre-landing as the Blocky unit [4, 10]. Investigations by Perseverance reveals that the ridges are defined by elongate outcrops of medium- to coarse-grained pebbly sandstones that are planar stratified and are considered to unconformably overlie the Tenby formation deposits. These facies record deposition by rivers likely with shallow flow depths with the ridge systems perhaps representing complex patterns of avulsive sediment routing across the fan.

Late-stage boulder-transporting fluvial systems: Unconformably overlying the primary fluvial-deltaic deposits that make up the Western fan are a sequence of boulder-containing deposits that are extensive across the region of the rover traverse and represent the youngest stage of deposition on the Western fan [10]. These deposits generally occur as non-lithified units commonly forming ridges and are dominated by rounded boulders up to 2 m in diameter and of igneous origin [11, 12]. Locally, exposures of well cemented boulder conglomerates are preserved. The abrupt change in the calibre of the routing system implies a transition to higher velocity fluvial systems characterized by flood flows capable of transporting boulder-sized clasts from headwater regions over extensive areas of the fan.

Implications & Samples: The Jezero Western fan shows evidence of sustained aqueous activity and the development of fluvio-deltaic-lacustrine systems with a complex temporal and lake-level evolution. Future RSS studies will target phyllosilicate, carbonate and silica-rich cements in samples from Hogwallow Flats to search for potential biosignatures and quantify the extent of and nature of aqueous alteration of the Martian crust. RSS analyses of cements and detrital grains in samples from the Shenandoah, Tenby and Otis Peak formations will enable constraints on the earliest and latest timing of fluvial activity and its duration. Paleomagnetic studies of all the samples could constrain the locations of hiatuses through the identification of sharp stratigraphic changes in magnetization. Furthermore petrologic, geochemical, and magnetic studies of ancient detrital grains derived from the Jezero watershed will constrain the earliest history of Martian igneous differentiation, volatile evolution, and the history of the Martian dynamo.

References: [1] Morgan (2022) *Icarus, 385,* 117–137. [2] Goudge (2018) *Icarus* 301, 58-75. [3] Mangold (2021) Science, [4] Stack (2020) *Space Sci. Rev.* 216(8), 127. [5] Stack in revision JGRP. [6] Gupta (2022) AGU Fall Mtg, [7] Mangold LPSC this mtg, [8] Ives (2023), AGU Fall mtg. [9] Caravaca LPSC this mtg, [10] Gwizd LPSC this mtg. [11] Beyssac LPSC this mtg., [12] Dehouck LPSC this mtg.