A DELTA-LAKE SYSTEM AT JEZERO CRATER (MARS) FROM LONG DISTANCE OBSERVATIONS.

S. Gupta[1], N. Mangold[2] J. F. Bell[3], O. Gasnault[4], G. Dromart[5], J. D. Tarnas[6], S. F. Sholes[6], B. Horgan[7], C. Quantin-Nataf[5], A. J. Brown[8], S. Le Mouélic[2], R. A. Yingst[9], O. Beyssac[10], T. Bosak[11], F. Calef III[6], G. Caravaca[4], 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], M.K. Kanine, J. Martinez-Frias[19], S. M. McLennan[20], S. Maurice[4], J. I. Nuñez[21], A. M. Ollila[22], G. Paar[23], P. Pilleri[4], J. W. Rice Jr[2], M. Rice[24], J. I. Simon[25], D. L. Shuster[26], K. M. Stack[6], V. Z. Sun[6], A. H. Treiman[27], B. P. Weiss[11], R. C. Wiens[22], A. J. Williams[28], N. R. Williams[6], K. H. Williford[6].[1]Department of Earth Science and Engineering, London, UK (s.gupta@imperial.ac.uk). [2]LPG Nantes, France. [3]ASU, Tempe, USA. [4]IRAP, Université de Toulouse, France. [5]LGL, Lyon, France. [6]JPL, CalTech, Pasadena, USA. [7]Purdue University, USA. [8]Plancius Research, USA. [9]Planetary Science Institute, 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]Lund University, Sweden [17]Natural History Museum Denmark, Copenhagen, Denmark. [18]University of Tennessee, USA. [19]Instituto de Geociencias, Madrid, Spain. [20]Stony Brook University, USA. [21]JHUAPL, Laurel, USA. [22]LANL, Los Alamos, USA. [23]Joanneum Research, Graz, Austria. [24]Geology Department, College of Science and Engineering, USA. [25]Center for Isotope Cosmochemistry and Geochronology, Astromaterials Research and Exploration Science, USA. [26]Dept. Earth and Planetary Science, University of California, Berkeley, USA. [27]LPI, USRA, Houston, USA. [28]Department of Geological Sciences, University of Florida, USA.

Introduction: Orbital and rover observations of relict geomorphic features and stratigraphic architectures indicate Mars once had a warmer, wetter climate. Constraining the character, relative timing and persistence of ancient aqueous activity on Mars is possible through detailed interrogation of the stratal geometry of aqueously deposited sedimentary bodies. Such analyses inform interpretations of Martian climate evolution, potential habitability, and search strategies for rocks that might contain potential biosignatures.

A prominent sedimentary fan deposit at the western margin of Jezero crater has been inferred to be a river delta that built into an ancient lake basin during the Late Noachian-Early Hesperian epochs on Mars (~3.6-3.8 Ga) [1, 2, 3]. The Perseverance rover landed on 18 February 2021 ~2.2 km from the western fan. During the early phase of mission investigations, high-resolution images obtained from the Mastcam-Z camera and from the Remote Micro-Imager of the SuperCam instrument provided the first ground-based observations of the western fan and an associated remnant outcrop, named Kodiak. Here, we report its sedimentology, which provide new constraints on the nature of the fan deposits, and their paleoenvironmental implications (4).

Kodiak butte: Observations of a prominent butte, informally named Kodiak, located ~1 km south of the western fan, show that its stratigraphy is characterized by distinct sedimentary geometries (Fig. 1).

Kodiak butte consists of two outcrop sections on its E-face. In the northern section, the lowest visible part of consists of plane-parallel horizontal to low-angle thinly bedded strata. Overlying these is a ~10 m thick series of strata comprised of steeply inclined beds with apparently southward dips at angles up to 35˚. Individual beds, defined by variations in erosion, have apparent thicknesses from 10 to 50 cm. We infer their primary lithology to be finer-grained than a conglomerate, possibly sandstone, with scattered cobbles. Foreset strata show a downward asymptotic decrease in apparent dip angle and appear to pass gradually into bottomset facies. Foreset strata are overlain by a horizontally stratified topset strata across an apparently sharp subhorizontal truncation surface though locally sigmoidal geometry is observed showing a gradual change in dip from topset to foreset strata. A second unit of foreset strata, immediately overlies the topset strata.

In the southern portion of Kodiak (Fig. 1), a second sedimentary package that lies stratigraphically higher and is offset from the northern package is observed and shows similar stratal geometries. In its lower section, it consists of thinly bedded, gently dipping, and horizontal strata (Fig. 1. These show recessive weathering, again indicating mudstones or sandstones. These pass upwards into a distinct 7-m-thick section of inclined foreset beds that dip consistently to the south (Fig. 1). Locally, these dipping beds contain isolated boulders and cobbles (up to 40 cm in diameter). At their base, these beds show a downward asymptotic decrease in inclination and pass into lowermost horizontal strata. Overlying the inclined beds across a sharp sub-horizontal truncation surface (Fig. 1), is a unit that shows low-angle to locally cross-stratified sub-horizontal topset strata. These topsets are overlain by a boulder conglomerate, which contain boulders up to 1.5 meter in long axis.

We interpret the distinct tripartite geometry as a deposit of a steeply fronted Gilbert-type delta that prograded into an ancient lake basin in Jezero crater. The foreset strata represent deposits formed by gravity-driven flows on steeply dipping delta fronts. Bottomset strata represent finer-grained sediments deposited in areas immediately lakeward of the delta front. Topset

strata are fluvial deposits formed in delta top environments, however, may also be overlain by transgressive, deeper lake facies deposited during lake level rise. The transition from topset to foreset (the topset breakpoint) provides a lower bound on the lake level at the time of deposition. 3-D reconstructions of these deposit geometries from stereo-imaging provide quantitative constraints on delta evolution (5;6).

Gilbert-type deltas are highly sensitive recorders of base-level changes (ie., lake level change) (7). Mapping of topset-foreset clinoform architecture – in particular, the transition from oblique to sigmoidal geometries – records short-term variations in baselevel. In eastern face of Kodiak, a N-S transition from oblique to sigmoidal stratal geometry indicating a lake-level rise. The progradational delta package on the southern side of Kodiak east face shows a marked erosion surface separating topset from foreset strata that indicates an oblique toplap geometry. This geometry is interpreted as the result of progradation of the delta during stationary or falling lake level.

At a larger-scale, the stacking both vertically and laterally of 3 Gilbert delta packages in Kodiak indicates longer term changes in base level that resulted in stacking of successive deltas. Elevation of the topset-foreset transition gives the elevation of -2490/-2500 m for the lake level at the time of deposition, thus 100 m below the lake elevation inferred from the breach toward the east of Jezero crater.

The western fan: A Mastcam-Z mosaic acquired on sol 275 at the highest vantage point in the South Séitah region provides new views of the SE-facing erosional front of the western Jezero delta showing sections of the delta previously not visible (Fig. 2). This mosaic provides the first direct evidence of delta geometries in the main western delta.

The central and upper parts of the western fan scarps show clear evidence of large scale inclined bedding that we interpret as delta foreset strata similar to that observed in Kodiak (Fig. 2). The foreset strata are largely inclined to the south, but locally more complex patterns are observed and in one example, bivergent inclined strata are preserved indicative of a complex delta geometry, perhaps a highly lobe-shaped prograding delta. Where the base of the scarps can be observed, subhorizontal bottomset strata are present. These vary in style. Thick-bedded, dark toned subhorizontal tabular packages likely represent coarser-grained delta toe deposits formed by gravity flow processes. However, at the proposed entry point for *Perseverance* to ascend the delta, a distinct light toned layer is observed in both the HiRISE image and in the Mastcam-Z mosaic (Fig. 2). A plausible interpretation of this layer is that it represents fine-grained delta bottomset beds, potentially mudstones (Fig. 2), formed by decantation processes in a prodelta environment.

The uppermost part of the scarps comprise tabular, cliff forming blocky beds that comprise horizontally stratified rocks that we interpret to be delta topset deposits (Fig. 2). Overlying these strata at or close to the top of all scarps observed are massive boulder conglomerates, which are commonly poorly exposed but form boulder-strewn surfaces (8). The character of these deposits is consistent with deposition from ephemeral fluvial flood activity (4; 8).

Summary: The delta architecture at Kodiak indicates deposition in a closed-lake system, under fluctuating water levels and changing styles of flow during later stages. Close-range investigation of these deposits by *Perseverance* will permit fine-scale quantitative reconstruction of delta facies architecture and stacking patterns providing constraints on lake level evolution, and targets for the search for ancient biosignatures and organic matter.

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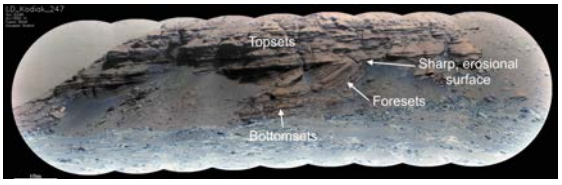

Fig. 1 SuperCam RMI of Gilbert delta architecture in Kodiak butte showing foresets, bottomsets and topsets.

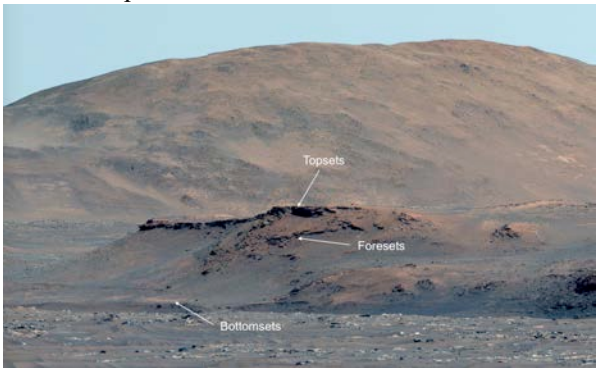

Fig. 2 Portion of Mastcam-Z of western fan. PIA25022 showing Gilbert delta geometry.