**THE DELTAIC DEPOSITIONAL ENVIRONMENTS AND STRATIGRAPHY OF THE KODIAK BUTTE (JEZERO CRATER, MARS).**

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**Introduction:** For two years, the *Perseverance* rover has been exploring the Jezero crater floor. A lot of remote observations have been made on the delta front and its remnants, and notably toward the Kodiak butte, situated about 1 km south of the main delta front (Fig. 1). There, morphologies typical of a Gilbert-type delta have been identified [1] using long-distance observations carried out by SuperCam's Remote Micro-Imager (RMI) and Mastcam-Z (Fig. 2). In this work, we use high-resolution 2D images, as well as 3D Digital Outcrop Models [2;3], to document and characterize the sedimentary succession observed up the cliffs of Kodiak. We divide the Kodiak butte into 3 units (0 to 2) with further sub-facies divisions described below.

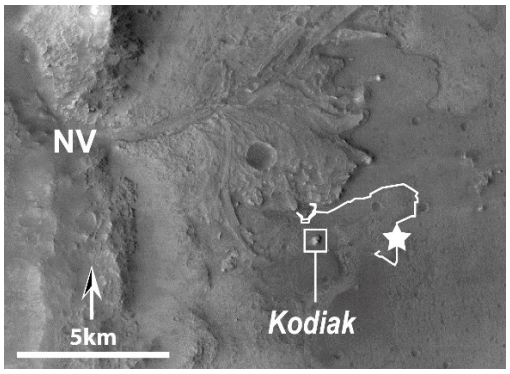


**Fig. 1** Orbital view of the western fan in Jezero crater (CTX basemap), and position of the Kodiak butte, relative to the Octavia E. Butler landing site (white star). The white line indicates the traverse of the *Perseverance* rover. NV: Neretva Vallis.

**Facies associations and depositional settings:** We identify 11 facies and sub-facies, representing 5 facies associations which we will use to illustrate a polyphase 4D history of the deltaic deposition at Kodiak and in Jezero at a larger scale.

The bottomset association (blue in Fig. 3) is present at the base of all sections. It is mostly made of coarse sandstones, locally up to pebble conglomerates, with planar and cross-bedded stratifications. It likely represents deposits of gravity-driven turbulent currents under low energy settings, distally to the main delta front.

The toeset association (grey in Fig. 3) is observed in every section but #3. It is made of sandstones structured in thinly-laminated planar beds. Those correspond to tangential ends of foresets, and result from low-energy waning of gravity-influenced avalanches at the very end of the prograding foresets.

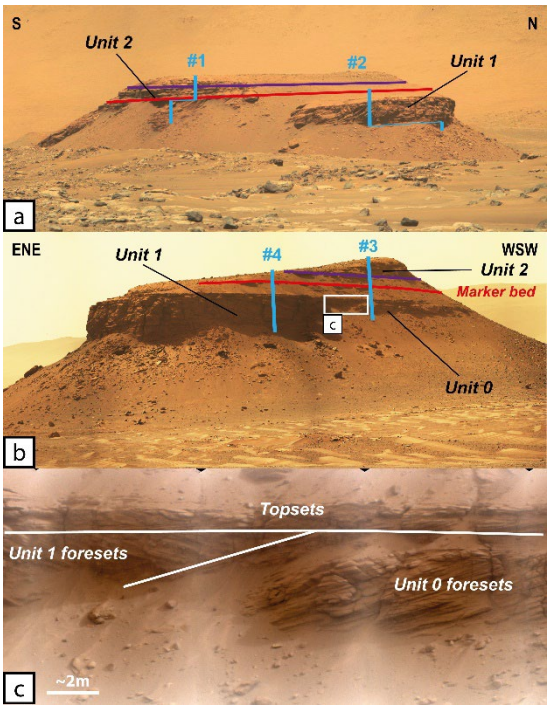


**Fig. 2**: General views of Kodiak butte, with Delta Units 0 to 2, positions of the log sections #1 to #4 (light blue bars), and traces (red and purple) of laterally continuous correlation beds (cf. Fig. 3). a) View of the east-facing part of the butte (zcam08103). b) View of the north-facing part of the butte (zcam08425). c) RMI mosaic of the north-facing part of the butte, showing the conformable contact of Units 0 and 1 foresets, overlain by a common set of topsets (scam01580).

The foreset association (green in Fig. 3) is present in all sections. It is composed of decimeter-scale steeply inclined (~20 to 30°) strata of sandstones to pebble conglomerates. It represents medium energy deposition of prograding avalanche fall of sediment on the slope of the delta. Those strata locally show scours, cross-stratifications, and normal grading, highlighting possible occurrence of episodic fluvial surges in the system.

The topset association (yellow in Fig. 3) is present in all sections. It is composed of decimeter-scale beds of sandstones and pebble conglomerates (locally up to cobble conglomerates), arranged in planar parallel and cross-stratified strata, deposited in a medium to high energy setting. Those topsets also exhibit channelizing

bodies indicating recurrent variations of the direction of transport [4], suggesting deposition on the upper fluvial deltaic plain.

Finally, the bouldery unit association (purple in Fig. 3) is restricted to the top of sections #1 and #3. It is composed of boulder conglomerates (with boulders up to 1 meter wide), and represents poorly sorted deposits, resulting from high-energy floods [1, 5].

**Spatio-temporal variations in the stratal pattern of Kodiak**:

All along the 4 sections, we observe a similar vertical succession of the 5 facies associations, as expected for a deltaic series. Those sections represent 3 different and laterally emplaced units (0 to 2, Figs. 2 & 3). The stratal pattern of these units indicates a probable succession over time rather than a coeval deposition. Unit 0 (illustrated by section #3, Figs. 2 and 3) would likely be the first emplaced, with a sedimentary transport toward the NE, as indicated by lowest-angled foreset strata and poorly developed topsets. Unit 1 (illustrated by sections #2 and #4, Figs. 2 and 3) would be deposited against Unit 0, as no unconformable relationship or erosive contact is observed between them (Fig. 2c). Both Unit 1's bottomsets and foresets indicate a sedimentary transport towards SW. Finally, Unit 2 (illustrated by section #1, Figs. 2 and 3) is likely to be the youngest unit in the deltaic system. All bottomsets, foresets and topsets indicate a propagation towards S/SE, with variations in direction occurring during late-stages within the topsets.

Local correlation of the sections and units is possible using a single, laterally continuous, "marker bed" occurring at ~-2490m (red line in Figs. 2 and 3). This sandstone bed is present in all sections, and is interpreted to pertain to Unit 2's topsets. This further consolidates Unit 2 as being the latest episode here, with its topsets covering all and every previous series. Another potentially continuous bed (purple line in Figs. 2 and 3) is observable on all sections but #4, just below the bouldery unit. Its occurrence at a higher, but variable elevation likely indicates a higher aggradation southward, in agreement with Unit 2's depositional pattern which it is a part of.

**Summary**:

As the *Perseverance* rover focused on studying the lower sedimentary series of the Jezero delta front [6; 7], and before it actually climbs onto the delta itself, the Kodiak butte offers a unique perspective in studying the 4D evolution of the deltaic depositional settings and environments of the Jezero crater lake. We observe five distinct facies associations showing a sustained and hydrodynamically variable deposition under influence of fluvial inputs into the lake. This deposition pattern is in agreement with the construction of a spatially prograding Gilbert-type delta system. Further work will focus on correlation with the current main delta front [5;8] and reconnecting this "window" in the broader-scale Jezero history during the soon to come ascent by the rover.

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**References:** [1] Mangold et al. (2021) *Science*, *374*, 6568. [2] Tate *et al.* (2023) *LPSC LIV* (this conf.). [3] Caravaca *et al.* (2022) *LPSC LIII* #1189. [4] Caravaca *et al.* (2022) *EPSC abstracts, 16, 345*. [5] Mangold *et al*. (2023) *LPSC LIV* (this conf.). [6] Stack *et al.* (2023) *LPSC LIV* (this conf.). [7] Williams *et al.* (2023) *LPSC LIV* (this conf.). [8] Gupta et al. (2023) *LPSC LIV* (this conf.).

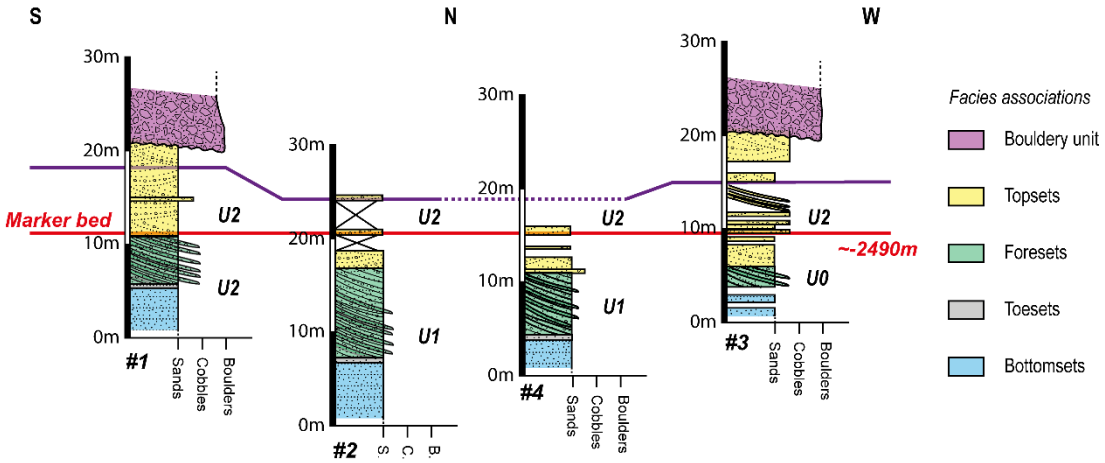


**Fig. 3**: Synthetic log sections and facies associations as observed across East and North faces of Kodiak butte (for localization of the section, refer to Fig. 2). The "marker bed" is used as a datum line for correlation between sections (cf. Fig. 2). U0-U2: Unit 0 to Unit 2.