**LITHOFACIES, FLOW DIRECTIONS, AND PRELIMINARY DEPOSITIONAL INTERPRETATIONS OF LEDGE-FORMING SANDSTONES AT ALAGNAK, JEZERO CRATER, MARS.** L.R.W. Ives[1], K.M. Stack[1], R. Barnes[2], S. Gupta[2], G. Caravaca[3], P. Russell[4], A.M. Annex[5], [1]Jet Propulsion Laboratory, California Institute of Technology, USA (elizabeth.r.ives@jpl.nasa.gov), [2] Department of Earth Science and Engineering, Imperial College London, UK, [3]IRAP, Toulouse, France, [4]Earth, Planetary and Space Sciences, UCLA, USA, [5]Division of Geological and Planetary Sciences, California Institute of Technology, USA

**Introduction:** The Mars 2020 *Perseverance* rover is exploring a sedimentary deposit interpreted to be the remnants of a delta within Jezero crater, a 45 km diameter Late Noachian-aged crater. During its exploration of the "lower delta" exposure of the western delta/fan in Jezero crater, Mars (Fig. 1), Perseverance acquired image and composition data from Alagnak, a ~2 m thick, well-exposed outcrop of clastic sedimentary rock located at Cape Nukshak (Fig. 1).

This outcrop was thoroughly documented from multiple angles at a cm-scale by the Mastcam-Z camera system [1] and the Supercam Remote Micro-Imager (RMI) [2] on the *Perseverance* rover. Dip and strike measurements of sedimentary beds were collected from 3D reconstructions of Mastcam-Z stereo-images collected using the Planetary Robotics software tools PRoViP and PRo3D [3].

In this study, we examine the physical sedimentology and stratigraphic context of the Alagnak outcrop. The preliminary depositional interpretation of Alagnak is as a prograding, subaqueous fan built through the deposition of many, meter-scale, gravity-driven, sediment-rich flows. Flow directions ranged between NNE and SW, with principal directions toward SE and E.

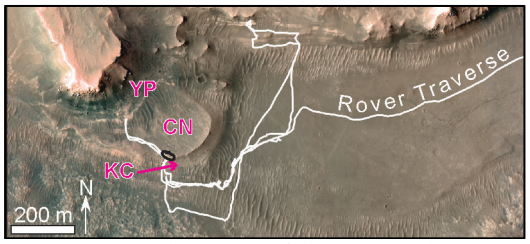


***Figure 1.*** *HiRISE color image of the "lower delta" area of Jezero Crater [4]. The white line shows the* Perseverance *rover traverse. The black ellipse indicates Alagnak. CN = Cape Nukshak, YP = Yori Pass, KC = Knife Creek.*

**Physical Sedimentological Observations:**

*Grain Characteristics.* The Alagnak outcrop contains coarse- to very coarse-grained sandstones with rare pebble beds (Fig. 2, Fig. 3). Visual estimation of the grain size distribution for grains >1 cm in diameter indicates these sandstones are moderately to very-well sorted. Pebbles range in size between 1 – 25 cm, with ~ 3 cm being the most abundant. Clasts have angular to sub-rounded shapes. Pebbles and small cobbles become less common upward in the succession.

*Facies Associations (FA) Descriptions.*

FA1 is predominately made up of dipping, planar thin beds of pebbly sandstone (Fig. 2, Fig. 3B,C). Beds > 1 cm thick tend to be normally graded, have sharp, planar upper and lower contacts, and appear to thin and fine in the direction of bed dip. Beds ≤ 1 cm thick have irregular thicknesses and contacts. Beds have a dip range between 4° and 23°.

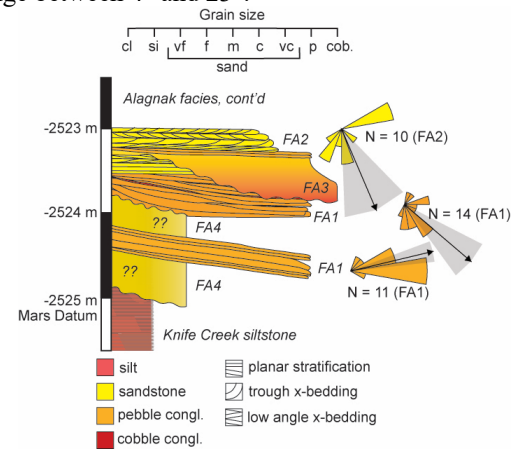


***Figure 2.*** *Stratigraphic column showing the lithofacies present in the Alagnak outcrop. Flow directions displayed as rose diagrams were inferred from sedimentary structures and measured with 3D models. Rose diagram bins are 20°. Black arrows show mean direction and their length = 50% radius. Grey bins show ± 1 std. dev. of mean direction.*

FA2 is characterized by sandstones that appear relatively finer-grained (do not contain pebbles) and better sorted than FA1 (Fig. 2, Fig. 3D,E). Stratal bounding surfaces are near-horizontal. Planar beds, low-angle cross-bedding, and trough cross-bedding are common. Sand bodies in this FA have generally sharp, planar basal and upper contacts. Within individual sand bodies of this FA, sedimentary structures transition from planar beds at the base to cross-stratification at the top, suggesting a decrease in flow strength upward.

The FA3 sandstone is normally graded but otherwise appears structureless (Fig. 2; Fig. 3D,F). There is a single occurrence of FA3 in Alagnak, as a 0.5 m thick and ~ 1 m wide sand body that overlies an erosional surface [Fig. 2]. Directly overlying the basal erosion surface is a cobble bed with clasts up to ~ 25 cm in diameter. The upper contact of FA3 is sharp and planar.

FA4 weathers recessively and the outcrop is very poor to non-existent (Fig. 3A,C). This unit mostly

occurs in the lower half of Alagnak (Fig. 2, Fig. 3B). This FA can be differentiated from the underlying Knife Creek unit because of its color and weathering character. This FA may be more fine-grained and/or thinly-stratified than the rest of Alagnak.

*Stratal Orientations:* Strike and dip measurements were collected from two FA1 sand bodies and one FA2 sand body (Fig. 2).

*Geometries and Stacking Trends of Sand Bodies.* Alagnak is composed of coarse-grained sand bodies (FAs 1, 2, and 3) that are interstratified with a recessive, fine-grained unit (FA 4) (Figs. 2 and 3). These sand bodies range in thickness from 0.25 – 0.5 m, and have meter-scale widths. Each sand body is composed of a single FA. The dipping beds of FA1 suggest that these sand bodies overlie some relief and indicate a more channel-like shape. In one of the FA1 sand bodies, the magnitude of bed dips gradually decreases upward, which suggests that that the beds are aggrading to fill the underlying topography. The sand bodies of FA2 exhibit a lenticular shape.

**Preliminary Interpretations:** The sedimentary structures in the coarse-grained, ledge-forming sedimentary rocks that make up most Alagnak were most likely deposited by gravity-driven downslope transport in an unconfined, subaqueous system.

Massive, fining upward beds (FA1, FA3) most likely resulted from subaqueous flows similar to a high-density turbidity current [5,6] or concentrated density flow [7,8]. Since beds in FA1 fine and thin in the direction of dip, their dip direction is inferred to be their flow direction (Fig. 2). Sand bodies with planar- and cross-bedded sandstone (FA2) were most likely deposited by unchannelized or poorly channelized waning flows within a turbidity current or a transitional concentrated density flow [7].

Each sand body in Alagnak was deposited through distinct processes. The plano-concave-up channel-form sand bodies were created either by the contemporaneous erosion and deposition during a single density-flow event, as in FA3, or through the filling of antecedent scour by multiple, subsequent, and much smaller density flow events, as in FA1. Lenticular-shaped bodies composed of current-transported sands (FA2) appear to not have significant erosion associated with them.

If these interpretations of the physical sedimentology of Alagnak are applied to the rest of Cape Nukshak, then the inference becomes that the Cape is a prograding, subaqueous fan built through the deposition of many, meter-scale, gravity-driven, sediment-rich flows. This interpretation is consistent with the depositional processes and settings inferred from sedimentary rocks in other parts of the lower delta examined by *Perseverance* [9, 10, 11].

**Acknowledgments:** This work has been made possible by the hard work of the Mars 2020 operations team, and specifically the Mastcam-Z team.

**References:** [1] Bell III et al. (2022) *Sci. Adv*. [2] Maurice et al. (2021) *Space Sci. Rev*. [3] Barnes et al. (2018) *Earth & Space Sci*. [4] Fergason et al. (2020) *USGS*., [5] Lowe (1982) *J. Sed. Res.*, [6] Talling et al. (2012) *Sed*. [7] Mulder & Alexander (2001) *Sed*. [8] Sumner et al., (2008) *J. Sed. Res.,* [9] Stack et al. (2023) *LPSC*, [10] Tebolt et al. (2023) *LPSC*, [11] Stack et al. (2023) *GSA*.

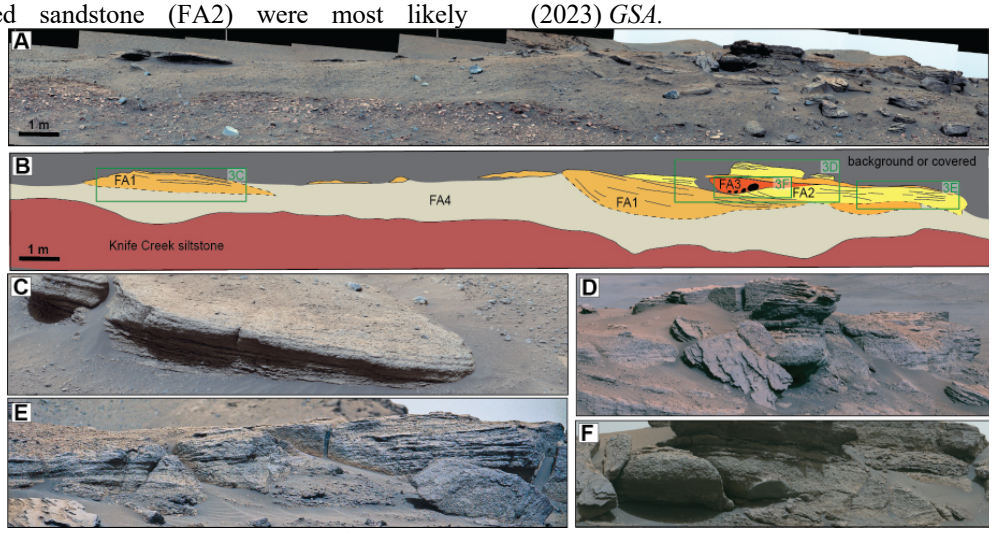


***Figure 3.*** *Mastcam-Z enhanced color mosaics of Alagnak.* ***A.*** *Alagnak outcrop (sol 604, zcam08613 L0) and* ***B.*** *its schematic facies interpretation. Green boxes show locations of 3C – 3F in outcrop. View toward northeast.* ***C.*** *Sol 632 (zcam08630 L0) showing the best-exposed outcrop of FA1.* ***D.*** *Sol 629 (zcam08628 R0) that shows portions of FA1, FA2, and FA3 including cross-stratification in FA2 and changes in bed dip angle within FA1. View is toward east.* ***E.*** *Mosaic showing FA2 in outcrop (sol 604, zcam08613 L0) with a focus on its planar- and cross-bedding.* ***F.*** *Sol 632 (zcam0631 L0) centered on the FA3 sand body. View toward northeast. All images are products of NASA/JPL-Caltech/ASU/MSSS.*