THE PETROGENETIC HISTORY OF THE JEZERO CRATER DELTA FRONT FROM MICROSCALE OBSERVATIONS BY THE MARS 2020 PIXL INSTRUMENT.

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Introduction: On ~sol 370 of the *Perseverance* rover mission, the Mars 2020 Science Team completed its investigation of igneous units of the Jezero crater floor [1] and directed *Perseverance* to drive towards the topographic scarp that marks the interface between the crater floor and Jezero's western delta. The "Delta Front Campaign" consisted of close-up investigation and sampling of lithologies located there.

Here, we report on the major findings relevant to the provenance and diagenetic history of these lithologies deduced from measurements made by the Planetary Instrument for X-ray Lithochemistry (PIXL), a micro-focus X-ray fluorescence (XRF) microscope [2]. Data were collected from two sections at Cape Nukshak and Hawksbill Gap; outcrop and member names are from [3]. Lithologies are described here in order from base to top of each section. For investigation locations, see: https://mars.nasa.gov/mars2020/mission/.

Cape Nukshak, Amalik Outcrop*:* PIXL analyzed two targets: the first was on a Supercam LIBS-cleaned natural surface called "Chiniak" (on sols 558 and 560) and another three scans were collected on the target "Novarupta" (sol 567, cleaned natural surface; sols 570 and 573, abraded surface). Novarupta is composed of well-sorted, very fine sand grains. Compositional data indicate that the grains are predominantly of intermediate Fo# olivine and its silicate alteration products [4]; there is also a carbonate component, possibly cement, with a composition similar to ferrodolomite. Both targets also contain planar lags of Ca-phosphate, Cr-spinel, and zircon or baddeleyite [5]. Such enrichments lags and nearly monomineralic coarser layers require efficient repeated sorting without significant re-suspension, (e.g., as in in a beach swash zone or fluvial bar).

Cape Nukshak, Yori Pass Outcrop*:* PIXL analyzed the abraded target "Uganik Island" on sols 614, 617, and 618. This target is a poorly sorted clastic rock with silt to fine sand-sized grains, large (≤ 2 mm diam.) chemical domains, possibly clasts of at least three types: two varieties rich in phyllosilicate and a third consistent with being a ferric sulfate. The bulk of the rock consists of a mixture of $(\sim Fe_{0.5}Mg_{0.5})SO_4$ and a Fe-Mg-silicate phase, likely a phyllosilicate (**Fig. 1**). Sulfate compositions indicate precipitation from high-salinity fluids. The rock is cut by mm-scale veins and former void spaces filled with anhydrite [6]. The stoichiometry and lack of Fe-Mg fractionation between matrix minerals indicates the likely presence of ferrous sulfate, consistent with precipitation under anoxic conditions, while a ferric sulfate clast could indicate oxidation and reworking of related sediments that were then incorporated into Uganik Island during deposition.

Hawksbill Gap, Devil's Tanyard Member: Because this part of the section could not be successfully abraded, limited compositional information is available from PIXL. Scans collected from natural surfaces on "Buzzard Rocks" (sol 445) and Rose River Falls (sol 450) indicate poorly-sorted fine-sand sized basaltic sediment and associated alteration products, likely including Fe-Mg phyllosilicates. Elevated SO_3 (6-9 wt. %) could derive from a surface coating, the rock interior, or both. The color properties of fines from an attempted abrasion at Rose River Falls are distinctive and indicate the presence of ferric-oxide, suggesting more extensive syn- or post-depositional oxidation than observed elsewhere [4, 7-9].

Hawksbill Gap, Hogwallow Flats Member*:* PIXL analyzed a LIBS-cleaned natural surface called "Pignut Mountain" (sol 463) and another pair of scans were collected on the abraded target “Berry Hollow” (sols 505 and 507). These targets are dominated by silt and mud sized particles that are nearly identical in composition to the fine-grained matrix of Uganik Island, suggesting a genetic relationship. Again, the observed variations are consistent with a mixture of $(\sim Fe_{0.5}Mg_{0.5})SO_4$ and a probable Fe-Mg-phyllosilicate (**Fig. 1**); this mixture invites comparison with the Burns Formation at Meridiani Planum [e.g., 10]. Cross-cutting veinlets are composed of anhydrite [6].

Hawksbill Gap, Lower Rockytop Member*:* A single boulder, shed directly from in-place cliff forming strata above, was analyzed by PIXL in two locations: Shop Hollow (sol 480, natural surface) and Thornton Gap (sols 484 and 490, abraded surface). The abraded surface analyses of Thornton Gap indicate a highly heterogeneous, poorly-sorted medium- to coarse-grained sandstone containing mm-scale rounded to subangular granules. Sand and granules include monomineralic grains (pyroxene, Ca-phosphate, feldspar, spinels) and lithic fragments with a wide range of compositions, including: carbonated feldspar, Fe-Mg carbonate, and Fe-Mg silicate (probably serpentine). Salt phases, including Mg- and Ca-sulfate, Fe-Mg carbonate, and a one with K + Cl (possible sylvite or K-oxychlorine) are found in the matrix, as well as within and around granules. The diversity of compositions (**Fig. 2**) indicates this rock has a highly heterogenous provenance and a complex history of cementation by an evolving fluid or multiple fluids.

Delta Front Petrogenetic History: Sediment provenance ranges from relatively homogeneous, altered olivine-dominated sources at the base of the section at Cape Nukshak, to highly heterogeneous and altered (likely serpentinized) mafic to ultramafic sources at the top of the section at Hawksbill Gap. The presence of Fe-bearing carbonate at both locations indicates precipitation from anoxic, alkaline, waters of moderate pH. The finest-grained rocks of the delta front contain abundant sulfates and phyllosilicates, with compositions that indicate at least one period of deposition under anoxic, hypersaline conditions. The preservation of the Fe-Mg sulfate component of these rocks is remarkable, given its extreme solubility and susceptibility to oxidation. Fluids that precipitated the cross-cutting veinlets of anhydrite apparently had little effect on the rocks’ bulk compositions. At present, it is uncertain whether observed evidence for oxidation results from ~syn-depositional variability in atmospheric and aquatic redox state, or later diagenesis or weathering [e.g., 11, 12]. A major finding of this investigation is that delta front sedimentary rocks are compositionally and mineralogically diverse, which bodes well for sample return science, and indicates that paleo-environmental conditions were variable in space and/or time during delta deposition and diagenesis.

References: [1] Farley, K. et al. (2022) *Science, 377* [2] Allwood, A. et al. (2020) *Space Sci. Rev., 216* [3] Stack K. et al. *LPSC 2023* [4] Dehouck E. et al. *LPSC 2023* [5] Kizovski T. et al *LPSC 2023* [6] Jones M.W.M. et al. *LPSC 2023* [7] Mandon L. et al. *LPSC 2023* [8] Nunez J. et al. *LPSC 2023* [9] Johnson J. et al *LPSC 2023* [10] Cino C. et al. (2017), *Icarus, 217*, 137-150 [11] Broz A. et al. *LPSC 2023.* [12] Kalucha et al. *LPSC 2023* [13] Tice M. et al. (2022), *Science Adv. 8*

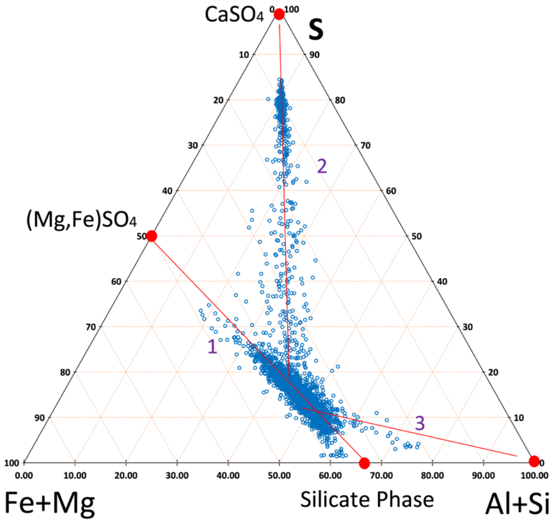

Fig. 1: Molar proportions of the indicated elements for the sol 614 PIXL XRF scan of Uganik Island. Vector 1: mixing between $(\sim Fe_{0.5},Mg_{0.5})SO_4$ and Fe-Mg-silicate; vector 2: cross-cutting anhydrite; vector 3: Distinct Al-silicate clasts. Hogwallow Flats data fall along V1 & V2.

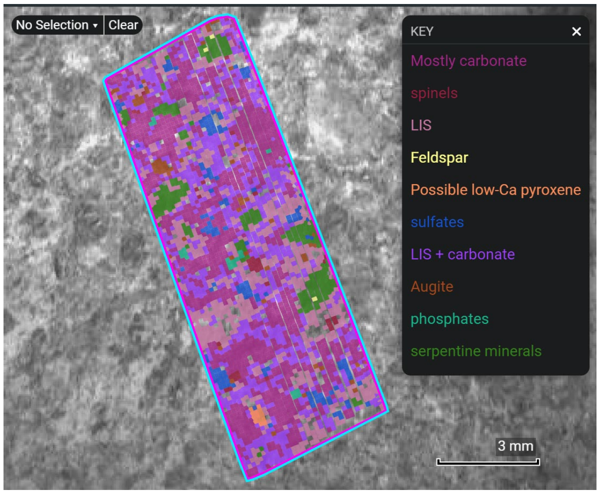

Fig. 2: Assignment of grains, matrix and cement to chemically distinct regions of the sol 484 PIXL XRF scan of Thornton Gap. “LIS” = low Fe-Mg silicate, described in [13].