DISCOVERY OF LIGHT-TONED FLOAT ROCKS IN JEZERO CRATER: A TALE OF AQUEOUS ALTERATION AND HIGH-TEMPERATURE METAMORPHISM.

C. C. Bedford[1], C. Royer[1], R. C. Wiens[1], J. R. Johnson[2], B. H. N. Horgan[1], A. Broz[1], O. Forni[3], S. Connell[1], L. Mandon[4], B. S. Kathir[5], E. M. Hausrath[6], A. Udry[6], J. M. Madariaga[7], E. Dehouck[8], R. B. Anderson[9], P. Beck[10], O. Beyssac[11], É. Clavé[12], S. M. Clegg[13], E. Cloutis[14], T. Fouchet[15], T. S. J. Gabriel[9], B. J. Garczynski[16], A. Kildaras[1], H. T. Manelski[1], L. Mayhew[17], J. Nuñez[2], A. M. Ollila[13], S. Schröder[12], J. Bell[18], J. I. Simon[19], U. Wolf[13], K. M. Stack[16], A. Cousin[3], and S. Maurice[3]. [1]Purdue University, USA (cbedford@purdue.edu), [2]John Hopkins University Applied Physics Laboratory, USA, [3]IRAP, CNRS, Université de Toulouse, UPS-OMP, France, [4]California Institute of Technology, USA, [5]Western Washington University, USA, [6]University of Nevada, Las Vegas, USA, [7]University of the Basque Country UPV/EHU, Spain, [8]Université de Lyon, UCBL, ENSL, CNRS, LGL-TPE, France, [9]U.S. Geological Survey, USA, [10]Université Grenoble-Alpes, CNRS, IPAG, France, [11]IMPMC, Sorbonne Université, MNHN, CNRS, Paris, France, [12]Deutsches Zentrum für Luft- und Raumfahrt, Germany, [13]Los Alamos National Laboratory, USA, [14]University of Winnipeg, Canada, [15]LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Université de Paris, France, [16]Jet Propulsion Laboratory, California Institute of Technology, USA, [17]University of Colorado, USA, [18]Arizona State University, USA, [19]NASA Johnson Space Center, USA.

Introduction: Since Landing in Jezero crater, the Mars 2020 *Perseverance* rover has encountered light-toned float rocks ("float") scattered across the crater floor and Jezero delta (Fig. 1), with recent observations suggesting that they may also be present on the crater rim. In total, over 4,000 candidate light-toned float have been identified in Mastcam-Z images as mostly gravel to pebble grain size, but occasionally present as sand and small boulders. To date (Sol ~1000), no outcrop of these light-toned float has been found. Here, we report on their discovery and use imaging, chemical, and mineralogical data from the SuperCam and Mastcam-Z instruments onboard the *Perseverance* rover to constrain the potential origins of these unusual float.

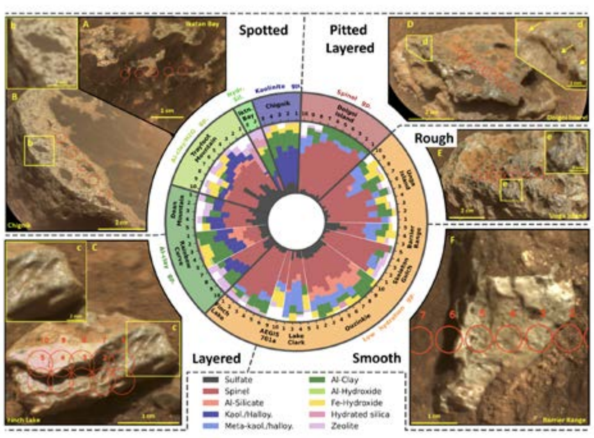

Figure 1: *A plot of IR mixing coefficients for each target up to sol 800 alongside RMI images highlighting the textural classes in the light-toned float (see [4] for more details on the spectral modelling).*

Methods: In this study, Mastcam-Z images [1] were used to characterize the distribution of light-toned float and to measure grain sizes. SuperCam [2,3] analyzed 19 light-toned float targets in total: 18 using RMI, LIBS and VISIR; 2 targets with Raman, and 1 target is RMI-only. We used RMI images to classify the float based on textural characteristics, then applied these textural classes to the chemical and mineralogical data gathered using LIBS and VISIR. See [4] for a detailed methodology of the spectral unmixing used on the SuperCam IR data.

Results: The light-toned float plot along a SiO_2-Al_2O_3 trendline from LIBS data, with most showing very high (35 wt% avg) Al_2O_3 abundances relative to other rocks in Jezero crater and Mars (Fig. 2). Likewise, they exhibit very low abundances of FeO_T, MgO, CaO, and Na_2O suggesting that feldspar, a common cause of high-Al_2O_3 and SiO_2 abundances on Mars, is an unlikely mineral in these rocks. Only one float has high SiO_2 abundances (>70 wt%) and little Al_2O_3 (target AEGIS_0910A, see also [5]) but is situated at the end of the negative Al_2O_3-SiO_2 regression line, possibly representing the high-SiO_2 endmember. The rocks also displayed variable high Cr and some Cu abundances, and some have ore-grade (> 1 wt%) Ni abundances [6]. Mn is not particularly enriched, and Co, Zn, and Pb were not detected. The light-toned float can be placed into 5 textural categories (Fig. 1) that align with chemical and mineralogical variations detected with SuperCam LIBS and IR spectroscopy:

1. *Spotted*: contains abundant, dark-toned, spots among an otherwise, light-toned, smooth matrix. Small (<1 mm) and large (>4 mm) pits are present. These targets have more SiO_2 and a greater degree of compositional scatter in FeO_T, MgO, CaO, Na_2O relative to the other groups. IR spectral modelling suggests kaolinite, Al-smectites, hydrated silica and alumina, zeolites, sulfates. This class has the deepest hydration bands.
2. *Layered*: wavy, inconsistent, cm-scale layering present. Can have some small pits that do not

disrupt the layers. Layered targets have lower to intermediate Al_2O_3 abundances, and exhibit IR spectral signatures indicative of hydrated phases such as kaolinite, Al-smectites and zeolites.

3. *Smooth*: has a smooth textural, aphanitic/vitreous appearance, with some small, spherical pits. Luster ranges from pearlescent to dull. Rarely, small, dark features interpreted as grains are visible. Smooth targets have an intermediate SiO_2-Al_2O_3 chemistry. Spinel (Cr?), metakaolinite, and cordierite dominate the models of IR spectra (Fig. 1).
4. *Rough*: has abundant small and large pits. In this class, the IR-derived mineralogy of AEGIS_0910A [5] is consistent with hydrated silica, while for Unga-Island and AEGIS_0912A the spectra are indicative of spinel and metakaolinite.
5. *Pitted Layered*: has abundant small and large asymmetrical pits that distort the layers. Dark-toned mm-scale, cubic grains are visible but were not targeted with the SuperCam raster. This is the most Al_2O_3-rich textural class with an IR-spectra mostly dominated by spinel and metakaolinite and negligible hydration (Fig. 1).

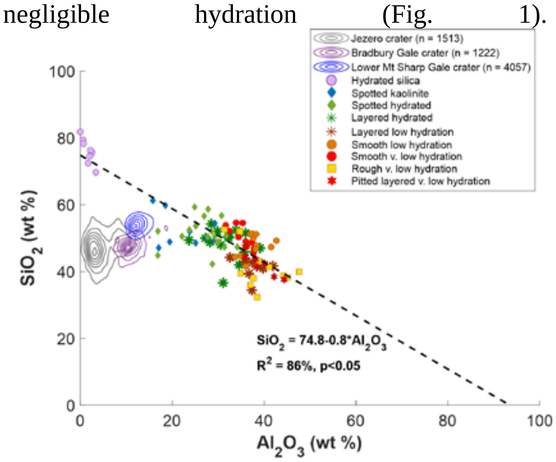

Figure 2: *SiO_2 versus Al_2O_3 for the light-toned float. Hydrated float are in blue/green, float with the least hydration are in yellow/red. Different shapes relate to different textural classes. Density contours show the Jezero crater bedrock and ChemCam data for Gale crater [e.g., 7] geological units for comparison.*

Discussion: Nearly all targets have a chemical and mineralogical signature indicative of intense aqueous alteration and leaching, followed by dehydration associated high-temperature metamorphism. The high-Al_2O_3 abundances with abundant kaolinite and Al-clays suggests extensive leaching perhaps similar to that found in some terrestrial tropical weathering soil profiles (e.g., bauxite) or associated with hydrothermalism [e.g., 8]. Tau modeling of the depletion of Fe, Mg, Ca, and Na indicate they are between 65 and ~100% leached. The Nilli Fossae region of the Jezero crater watershed has several sections of exposed Noachian crust envisaged as deep tropical weathering profiles (kaolinite at the top, followed by Fe/Mg phyllosilicates) [5]. As such, it is possible that the mineralogy of the hydrated classes (Spotted and Layered) and Al_2O_3-enrichment are derived from a similar Noachian crustal source.

The light-toned float that have evidence of dehydration, greater Al_2O_3-enrichment, and mineral assemblages containing metakaolinite, cordierite, and spinel suggests extensive leaching by aqueous alteration processes, followed by heating. Kaolinite heating experiments show that metakaolinite forms at temperatures between 500°C to 980°C, and continued heating forms a spinel phase up to 1150°C [10]. High-temperature contact metamorphism studies on the Earth also show that at temperatures of ~1000°C, hydrothermally altered basalt rich in Al_2O_3 and SiO_2 can create assemblages with cordierite, mullite/metakaolinite, and spinel [11,12]. Such high-temperature metamorphic rocks can also exhibit variable degrees of pitting/vesiculation that can disrupt layers due to the release of volatiles as a hydrated protolith is melted [11,12].

Two possible sources of heating may be responsible for metamorphosing these rocks: contact metamorphism from a large igneous intrusion/lava flow or impact metamorphism. The Jezero crater watershed has several large impact craters similar to ones that are associated with kaolinite weathering horizons in [9]. There are also large linear features with fractured, light-toned margins in north-east Syrtis Major that may relate to contact metamorphism by igneous intrusions [13]. As such, both are possible and both would likely be associated with hydrothermalism that can produce silica-rich rocks such as AEGIS_0910A [e.g., 5]. The distribution of these rocks within Jezero as float scattered on the surface of the delta top and crater floor, suggests that they were transported late in Jezero crater's geological history, either as impact ejecta or by late-stage flood or fluvial processes.

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