A Mars 2020 Perseverance SuperCam Perspective on the Igneous Nature of the Máaz formation at Jezero crater, Mars. A. Udry[1], V. Sautter[2], A. Cousin[2], R. C. Wiens[3], O. Forni[2], K. Benzerara[4], O. Beyssac[5], M. Nachon[6], G. Dromart[7], C. Quantin[7], L. Mandon[8], E. Clavé[9], P. Pinet[2], A. Ollila[3], T. Bosak[10], N. Mangold[11], E. Dehouck[7], J. Johnson[12], M. Schmidt[13], B. Horgan[14], T. Gabriel[15], S. McLennan[16], S. Maurice[2], J.I. Simon[17], C. D. K. Herd[18], J. M. Madiaraga[19]. [1]University of Nevada Las Vegas, Las Vegas, NV (arya.udry@unlv.edu), [2]IRAP, Toulouse, France, [3]LANL, Los Alamos, NM; [4]CNRS, Paris, France, [5]IMPMC, Paris, France, [6]Texas A&M, TX, [7]ENS Lyon, France; [8]CNRS, Paris, [9]CNRS, Bordeaux, France, [10]MIT, Cambridge, MA, [11]CNRS, Univ. de Nantes, France, [12]JHU/APL, [13]Brock Univ., Canada, [14]Purdue University, IN, [15]USGS, Flagstaff, AZ, [16]Stony Brook Univ., NY, [17]ARES, NASA JSC, TX, [18]Univ. of Alberta, Canada, [19]University of the Basque Country, Spain.

Introduction: The Mars2020 *Perseverance* rover landed in Jezero crater in February 2020, and first encountered the Máaz formation (or Crater floor-fractured rough (Cf-fr) unit previously mapped based on orbital data [1]). In this study, we use data from the SuperCam instrument (SCAM) to show that the Máaz formation has an igneous origin. SuperCam is a remote-sensing instrument onboard *Perseverance*, and investigates the texture, mineralogy, and chemistry of rocks and soils, as well as atmospheric features [2,3]. SuperCam comprises the Remote Micro Imager (RMI) to provide high-resolution images, laser-induced breakdown spectroscopy (LIBS) to investigate the major and minor element chemistry of materials, Raman, and passive visible-near infrared (VISIR) spectroscopy to analyze the mineralogy of targets, and time-resolved luminescence spectroscopy (TRLS) to measure organic fluorescence and inorganic luminescence. In addition, the microphone (MIC) can constrain the rock hardness through measurements of the shockwave of LIBS shots. In this study, we use LIBS-based major-oxide compositions (MOC), quantified using the calibration in [2].

The Máaz formation: The Máaz rocks were analyzed by SCAM from Sol (mission day) 11 (Máaz target) until Sol 201 (Digne target), when *Perseverance* entered Séítah after Sol 201, an olivine-rich unit mapped as Cf-f-1 by [1]. Rocks before Sol 201 were divided according to their geomorphic attributes: (i) the 'pavers' are outcropping low-standing light-toned rocks; (ii) the 'high-standing' rocks are higher-relief, darker-toned, and less dusty than the pavers. (iii) Float rocks were also recognized throughout the traverse. (iv) After Sol 177, the rover entered the Artuby ridge. Last, (v) a series of raised outcrops at the contact between the Máaz and Séítah formations. A few rocks (n=7) in Séítah with pitted texture showed similar compositions as Máaz rocks and were included in this work. In this study, we focus on the igneous nature of the Máaz formation encountered before Sol 201. In total, 11 float targets, 34 pavers, 20 high-standing rocks, 19 Artuby rocks, and 7 Séítah pitted rocks were analyzed by LIBS.

Texture: Various igneous textures were observed before Sol 201 in Jezero crater. For example, the Hastą́'áadah (Sol 87; Fig. 1) target shows elongated minerals without preferential orientation and a vesicular texture. Pahoehoe ropy texture, characteristic of basaltic lavas, was observed on the long-distance target táá'ts'áadah (Sol 110, not shown). Both abraded targets before Sol 201 (Guillaumes and Bellegarde) showed distinctive igneous textures, such as euhedral-subhedral prismatic texture (consistent with pyroxenes) aligned vesicles (Raton, Sol 130) and conchoidal fractures (tsé łibá, Sols 51–52).

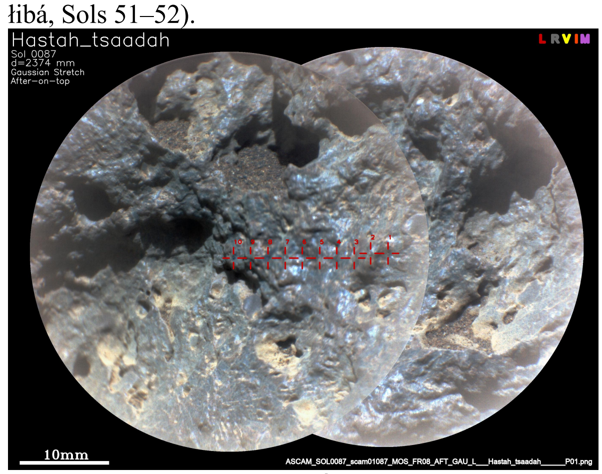

Fig. 1. RMI mosaic of Hastą́'áadah (Sol 87), showing elongated grains. Red crosses correspond to individual LIBS measurements.

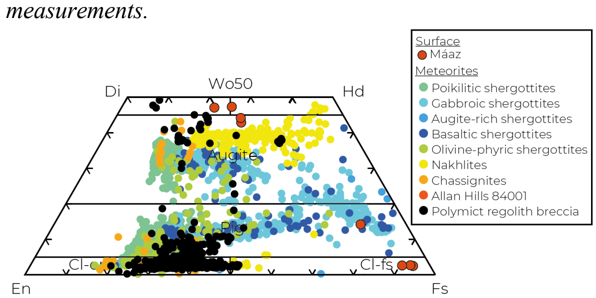

Fig. 2. Pyroxene compositions found in the Máaz formation using stoichiometry (meteorite compositions from [3]).

Mineralogy: The rocks in the Máaz formation show a basaltic mineralogy. Several pure mineral LIBS analyses were determined using different stoichiometric conditions. Minerals of pyroxene have been recognized through LIBS analyses (4 (±0.2) total cations with 6 O; 0<Ca<0.55; 0.85< (Fe+Mg+Ca)/Si <1.15); Al/Si < 0.1; 2 (±0.15) = Si^{4+} + Ti^{4+}; 2 (±0.15) = Ti+Fe+Mg+Ca+Na+K; Totals = 82 – 105 wt.%, Al_2O_3

< 5 wt.%, Na_2O < 1.5 wt.%; K_2O < 0.5 wt.%) with relatively Fe-rich composition, including augite grains ($Wo_{43-48}En_{25-30}Fs_{22-31}$) and Fe-rich grains ($Wo_{3-15}En_{4-11}Fs_{74-93}$) (Fig. 2). A few possible plagioclase grains were observed (using $0.2 < (Ca + Na)/(Al + Si) < 0.3$, $(Fe + Mg)/Si < 0.1$, and $(0.45/0.55 < Al/(2Ca + Na) < 0.55/0.45)$. However, these grains display a low Al_2O_3 content (≤ 18 wt.%) for stochiometric feldspar, while martian meteorites contain plagioclase with an average Al_2O_3 of 26 wt.%, consistent with andesine composition [4]. Due to the polymineralic nature of these rocks and due to grain size versus LIBS spot size (~350 µm), it is likely that the LIBS beam hit a mixture of plagioclase and other minerals (plagioclase grains are possibly too small) and/or felsic glass composition. Olivines have not been analyzed through LIBS, Raman, nor VISIR analyses in the Máaz formation. Minor minerals such as Fe-oxides have possibly been recognized in the Máaz formation.

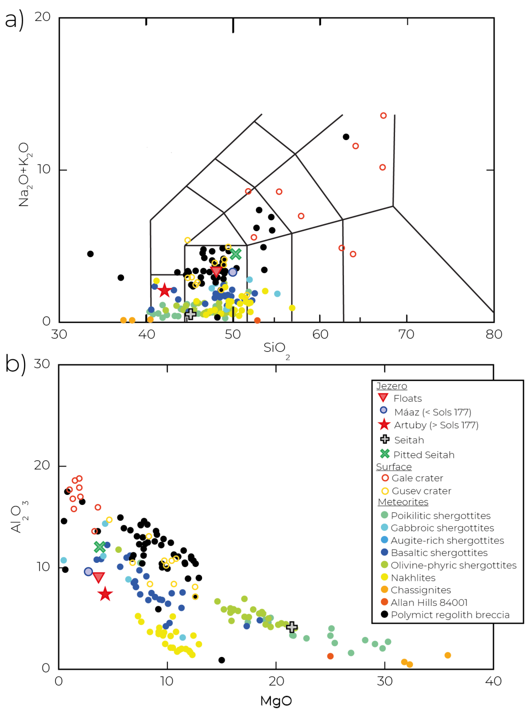

Fig 3. Average compositions of the Máaz formation, float rocks, Seitah, and pitted Séítah of a) SiO_2 versus Na_2O+K_2O, and b) MgO vs. Al_2O_3 compared to martian meteorites [4], Gale [5], and Gusev rocks [6].

Bulk rock compositions: The pavers and high-standing rocks as well as floats show similar bulk composition with 48–50 wt.% SiO_2, 9.3–10 wt.% Al_2O_3, 18–19 wt.% FeO, and Mg# of 21–25 (= molar MgO/MgO+FeO) (Fig. 3). These compositions indicate that floats rocks are likely rocks originating from the Máaz formation. The pavers, high-standing rocks and Artuby units have also similar compositions, although Artuby is more primitive with a Mg# 26, and higher Ca and Ti content. The Pitted rocks analyzed at Séítah have a very similar composition to the Máaz formation before Sol 177, with slightly higher alkaline compositions ($Na_2O + K_2O$ = 5.2 wt.%), indicating a common provenance. The bulk compositions show a trend from Artuby to Pitted Séítah (Fig. 3), likely representing a magmatic evolution trend between these different rocks. According to anhydrous MELTS calculations at 1 bar, fractional crystallization of a melt with a bulk Artuby composition could form rocks before Sol 177 and pitted Séítah compositions. The Máaz formation rocks have bulk compositions similar to the basaltic shergottites (also containing pyroxene and plagioclase) and some igneous clasts found in the regolith breccia Northwest Africa (NWA) 7034 [4]. Séítah, which is interpreted as an olivine-rich cumulate, shows a more primitive composition as rocks before Sol 177 with a Mg# of 62.

Possible formation of the Máaz formation and link to Séítah: According to the texture, mineralogy and bulk compositions, the outcropping and float rocks encountered at the Máaz formation, as well as pitted Séítah rocks, are igneous and have mineralogies and compositions comparable to basaltic and gabbroic shergottite meteorites, although less primitive. They especially resemble the basaltic and gabbroic shergottites, Los Angeles and NWA 7320 [7,8]. It was suggested that the Máaz formation and Séítah units are parallel and drape the underlying unit [9]. We propose three possibilities for formation of the Máaz formation: 1) Possible shallow sill or center of a thick lava flow; 2) Differentiated impact melt. However, Máaz and Séítah are draping the local topography, whereas melt ponding in lower topography would be expected with impact melt; and 3) Pyroclastic unit interstratified with volcanic rocks.

We will be conducting thermodynamical modeling to understand the petrogenetic link of the Máaz formation and Séítah. *Perseverance* will be roving back into Artuby in early 2022, which will possibly provide new opportunities to better constrain the formation of the Máaz formation.

References: [1] Stack et al. (2020) Space Sci Rev 216, 127. [2] Anderson et al. (2021) *Spect. Acta Part B: Atomic Spectroscopy*, Accepted. [3] Wiens et al. (2021) *SSR 217*, 4. [4] Udry et al. (2020*) JGR: Planets, 125*, e2020JE006523. [5] Sautter et al. (2015) *Nat Geosc, 8*, 605-609 [6] Ming et al. (2006) *JGR,* 111, E02S12. [7] Warren et al. (2004) *MAPS, 39*, 137-156. [8] Udry et al. (2017) *GCA, 204*, 1-18. [9] Goudge et al. (2015) *JGR: Planets*, *120*, 775–808