DIAGENETICALLY ALTERED FINE SEDIMENTS AT NEREVTA VALLIS, MARS. L. Mandon[1,2], O. Forni[3], N. Mangold[4], R. C. Wiens[5], H. T. Manelski[5], Z. U. Wolf[6], E. Dehouck[7], P. Beck[1], O. Beyssac[8], J. R. Johnson[9], E. Clavé[10], C. C. Bedford[5], S. Schröder[10], C. Royer[11], S. Connell[5], A. Udry[12], J. I. Simon[13], A. Cousin[3], [1]IPAG (lucia.mandon@univ-grenoble-alpes.fr), [2]Caltech, [3]IRAP, [4]LPG, [5]Purdue, [6]LANL, [7]LGLTPE, [8]IMPMC, [9]JHUAPL, [10]DLR-OS, [11]LATMOS, [12]UNLV, [13]ARES, NASA-JSC.

Introduction: The *Perseverance* rover landed on Mars in 2021 in Jezero crater, which contains evidence of an ancient lake. Deltaic deposits are preserved at the inlet of this paleolake, connected to an ancient fluvial network via a valley dissecting the crater rim, named "Neretva Vallis". Between Sols 1169 and 1244, the rover explored light-toned deposits in Neretva Vallis, known as the "Bright Angel formation", at two main sites: "Bright Angel" in the North and "Masonic Temple" in the South (Fig. 1). Sedimentary bedrock at both sites is fine-grained, light-toned, and crosscut by white veins [1,2], with darker bedrock observed overlying the light-toned bedrock at Masonic Temple, and sandstones of the "Fern Glen Rapids member" in contact with above fine-grained strata at Bright Angel. In the fine-grained levels, potential organic compounds and Fe/P-rich reduction spots provided clues for past habitability and "potential biosignature" [3,4]. Here, we synthesize the geological results on the Bright Angel fm. from the SuperCam instrument perspective, and implications for past environments at Neretva Vallis.

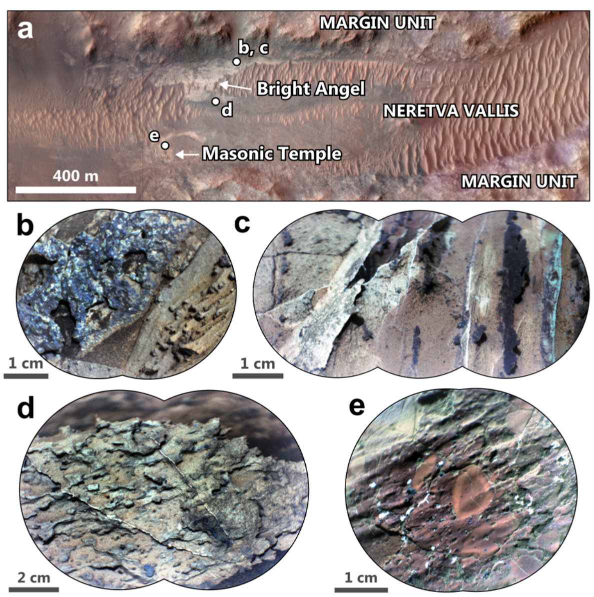

Fig. 1: (a) HiRISE orbital mosaic. **(b-e)** Color-enhanced RMI images of bedrock targets in: (b) the Fern Glen Rapids mb., (c, d) the fine-grained facies at Bright Angel and (e) at Masonic Temple.

Dataset: We used data collected at Bright Angel and Masonic Temple by the SuperCam instrument suite onboard *Perseverance*, including color Remote Micro-Imaging (RMI), elemental compositions from laser-induced breakdown spectroscopy (LIBS), mineralogy from remote green pulsed Raman spectroscopy, and 0.4-0.8 and 1.3-2.6 µm visible and near-infrared (VISIR) reflectance spectroscopy [5,6]. In the close (~2-8 m) environment of the rover, the analysis footprint is on the order of 0.2-0.5 mm for LIBS, 1.5-6 mm for the VIS and Raman and 2-10 mm for the IR. At these distances, the RMI has a field of view of 4-14 cm and can resolve sub-mm features. Calibration procedures follow standardized pipelines, presented in [7] for LIBS, in [8] for Raman, in [9] for VIS and in [10] for IR data.

Results: *Bedrock texture.* The RMI reveals that the light-toned bedrock exhibits thin depositional bedding with homogeneous textures but shows variability in post-depositional features such as concretion occurrence, vein size and vein density (Fig. 1c-e). A notable variation within the bedrock is its hue, ranging from light beige to tan at Bright Angel (Fig. 1c, d) and transitioning to a redder tone at Masonic Temple (Fig. 1e; [11]). The grain size of the light-toned bedrock is below the RMI's resolution, suggesting silt and/or clay-sized particles. At Masonic Temple, the matrix is fine-grained, and centimetric clasts of similar fine material are embedded within the bedrock (Fig. 1e). In contrast, the coarser bedrock of the Fern Glen Rapids mb. contains poorly sorted millimeter-sized greenish grains embedded in a dark-toned matrix (Fig. 1b).

Elemental composition. The light-toned bedrock has an Al/Fe/K-rich silicate composition. It is notably low in Mg (MgO = 2 ± 1 wt.%) compared to bedrock previously analyzed at Jezero crater, which typically exhibited MgO values >10 wt.% [12]. Individual LIBS shots allowed us to identify (Fig. 2a): 1) a K-rich aluminosilicate such as illite, associated to Chemical Index of Alteration (CIA) values up to 80%; 2) a high Fe-phyllosilicate such as nontronite; 3) higher Fe phases with composition close to Fe-oxides and 4) a high Ca, low Si phase. The latter is more often associated with veins and detection of S emission lines, indicating Ca-sulfates. In the veins, SiO_2 values are modelled as low as 0 wt.%, and H lines are relatively weak, suggesting poorly hydrated sulfates are the major constituents. Ca-sulfates are also present as mixture in the rock matrix, indicating sulfate cement or veinlets smaller than the LIBS analysis footprint. The coarser bedrock of the Fern Glen Rapids mb. exhibits a similar range of composition as the light-toned bedrock, with addition of lower Si and higher Mg points, consistent with the greenish grains being olivine. F and Ni [13,14] are detected in bedrock targets at >1 wt.%. At Bright Angel, F is frequently associated with P, likely forming fluorapatite. At Masonic Temple, F is not associated with P and more likely present as fluorite. Ni and Mn are most often associated in diagenetic features (veins, coatings) in the Fern Glen Rapids mb. The more massive, darker bedrock at Masonic Temple is enriched in Fe compared to the fine-grained bedrock. Here, a target has 84 ± 1 wt.% FeO_T and Cl above detection limit (>~0.7 wt.%; [15]) [16]. The two other targets analyzed here have 46 ± 24 wt.% FeO_T, with Fe correlated to S.

Mineralogy. VISIR spectra of the light-toned rocks reveal (Fig. 2b): 1) a weak H_2O band at 1.9 µm (band depth = 6 ± 1% on abraded surfaces), 2) a reflectance drop near 2.4 µm, possibly due to contributions from hydrated sulfates, 3) an absorption at 2.22 µm from Si-OH or Al-OH, consistent with phyllosilicates such as illite, 4) a weak but recurring absorption at 2.28 µm, consistent with nontronite, 5) a red slope in the VIS and 0.55 µm absorption, indicative of Fe^{3+}-oxides, with an enhanced signal at Masonic Temple. Raman and VISIR confirm the presence of olivine in the Fern Glen Rapids mb. and poorly hydrated Ca-sulfates in veins [17]. South of Masonic Temple, target with high Fe and Cl has VISIR spectra consistent with akaganeite, while those with high Fe and S align with jarosite [16].

Discussion: *The Bright Angel fm. stands out for its composition*, distinct from the olivine-rich units previously observed at Jezero crater, and more akin to rocks from Gale crater [18]. The fine-grained material that makes most of the formation is composed of clay-minerals and Ca-sulfates, strongly oxidized at Masonic Temple and lacking olivine and its alteration products. Given the abundance of olivine-bearing material in the watershed [19] and on the valley flanks [12], the Bright Angel fm. could be a late deposit leached of Mg through oxidative weathering [4], or an early deposit, derived from the erosion of the Noachian basement underlying the regional olivine unit.

This fine-grained bedrock captures a mosaic of diverse aqueous environments. Concretions, sulfate veins, and fluorite and Ni enrichments in the bedrock reveal diverse and prolongated fluid activity, potentially associated with an enhanced diagenesis or hydrothermal system. The bedrock shows variable enrichment in Fe^{3+}-oxides and illite phases, with CIA values indicative of leaching in an open aqueous system, possibly from pedogenesis at Neretva Vallis, or in its watershed and subsequent detrital deposition at Neretva Vallis. Akaganeite and jarosite in the upper Masonic Temple points to saline, low-pH fluids, potentially stemming from oxidative weathering of sulfides detected by the PIXL instrument [4,16]. The Bright Angel fm. offers a compelling record of Mars' aqueous environments, and the sample retrieved from this site is poised to provide exceptional scientific insights upon return to Earth by the MSR mission.

References: [1] Barnes et al., *this conf.* [2] Jones et al., *this conf.* [3] Murphy et al., *this conf.* [4] Hurowitz et al., *this conf.* [5] Wiens et al. (2020) *Space Sci. Rev., 217* [6] Maurice et al. (2021) *Space Sci. Rev.*, 217 [7] Anderson et al. (2022) *Spectro. Acta B*, 188 [8] Clavé et al. (2023) *JGR: Plan.*, 128 [9] Mandon et al. (2023) *JGR: Plan.*, 128 [10] Royer et al. (2023) *JGR: Plan.*, 128 [11] Broz et al., *this conf.* [12] Clavé et al., *10th Int. Conf. On Mars* 128 [13] Wolf et al. (2024) *AGU Fall conf.* [14] Manelski et al. *this conf.* [15] Wolf et al., *this conf.* [16] Dehouck et al. *this conf.* [17] Manrique et al., *this conf.* [18] Dehouck et al., *JGR: Plan.* 127 [19] Mandon et al. (2020) *Icarus*, 336.

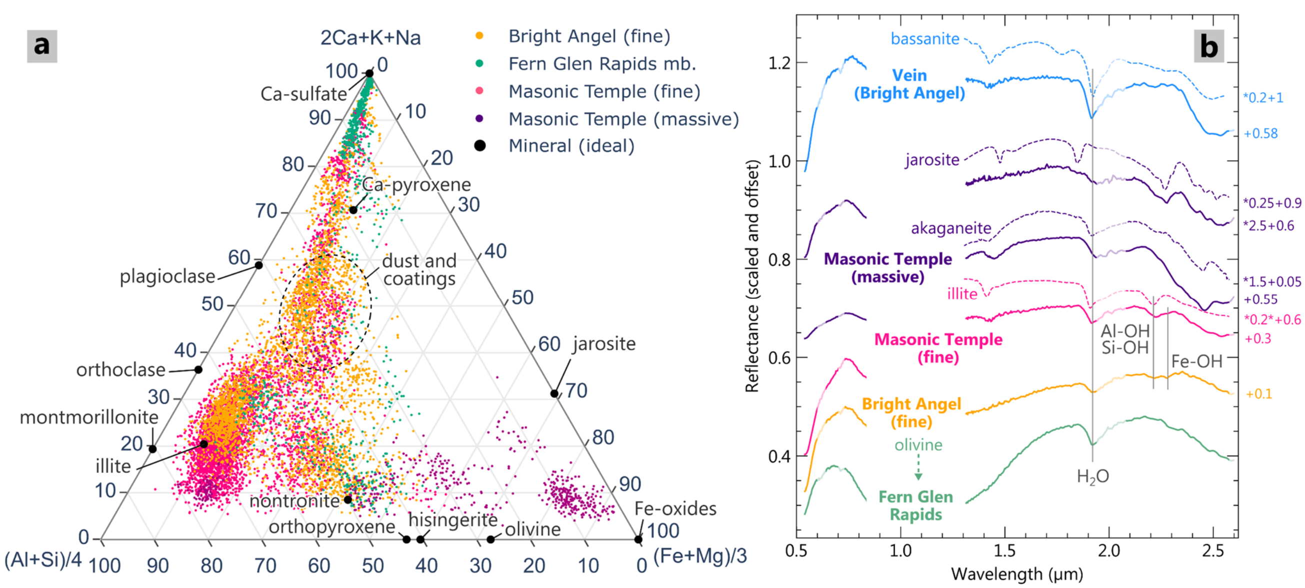

Fig. 2: (a) LIBS shot-to-shot molar compositions of the bedrock and veins of the Bright Angel fm. **(b)** Mean VISIR spectra of selected targets in solid lines (Fern Glen Rapids: abraded surf. *Steamboat Mountain*; Bright Angel: abraded surf. *Walhalla Glades*; Masonic Temple from bottom to top: abraded surf. *Malgosa Crest*, natural surf. *Phantom Creek* and *Elaine Castle* pt. #10; Vein: natural surf. *Mooney Falls*) compared to laboratory spectra in dashed lines (illite LAIL03; jarosite RELAB C1JBB82B; bassanite USGS GDS145).