VOLCANIC PLUME ORIGIN FOR WIDESPREAD, INDURATED SURFACE COATINGS IN JEZERO CRATER. M. E. Schmidt1 A. Allwood2, M. L. Cable2, B. C. Clark3, E. M. Hausrath4, J. Henneke5, J. A. Hurowitz6, T. V. Kizovski1, D. A. Klevang3, A. Knight1, A. Shumway8, M. Tice8, S. VanBommel7, C. C. Bedford10, A. Brown11
1Brock U. (St. Catharines, ON, L2S 3A1, Canada, mschmidt2@brocku.ca), 2JPL-Caltech (Pasadena, CA 91109), 3Space Sci. Inst. (Boulder, CO 80301), 4Univ. NV Las Vegas (NV 89154-4010) 5DTU Space, Tech Univ. of Denmark (Kongens Lyngby, Denmark), 6NY Stony Brook (NY 11794), 7Wash. U. (St. Louis, MO 63130), 8Univ. WA (Seattle, WA), 9Texas A&M (College Station, TX 77843), 10Purdue U. (W. Lafayette, IN 47906), 11Planckian Research, MD

Introduction: Since landing in Jezero crater, the Mars 2020 Perseverance rover has encountered maroon indurated coatings [1,2] that are variably distributed on surfaces of nearly all rock types along its traverse. Here we present chemical, textural, and spectral data for coatings examined in natural surface scans by the Planetary Instrument for X-ray Lithochemistry (PIXL). We interpret chemical homogeneity and volatile element enrichments identified in PIXL scans as well as the widespread occurrence of the coatings to be the result of a single, externally derived formation event, such as a volcanic eruption plume or impact.

Methods: PIXL is an X-ray fluorescence (XRF) spectrometer that maps fine-scale (~120 µm spot, PMC) elemental compositions of martian surface materials. Elements reported for individual spots include Na to Fe. For bulk sums of XRF spectra, some trace element concentrations (e.g., Zn) may also be reported when detected [3]. X-ray diffraction (XRD) peaks on individual XRF spectra (PMCs) provide textural information [4], but along with surface roughness are corrected out of XRF spectra. We use the PIXLISE [3] data visualization software to interpret X-ray spectral, spatial, and compositional variations.

Images by SHERLOC (SRLC) Watson and ACI (Autofocus Context Imager) cameras [5] and PIXL’s multispectral (near infrared, green, blue, ultraviolet) MCC (Micro Context Camera) [3] provide context for PIXL scans. For several natural surface (unabraded) targets, the gas Dust Removal Tool (gDRT) or the SuperCam laser was used to remove surface airfall dust.

Results: Of the 10 natural rock surfaces examined by PIXL, 7 contain maroon coatings (Fig 1). They appear smooth and continuous (e.g., Novarupta, Sol 567) or patchy with step margins (Cavetown, Fig 2). Coatings are also seen around edges of some abraded patches in microscopic images (e.g., Dourbes, Sol 257). Many similar coatings have been identified in Mastcam-Z images and by SuperCam [1] along the traverse.

The coatings are found on nearly all rock types and display uniform properties regardless of substrate lithology, including the igneous Crater Floor and sedimentary Jezero delta and margin, as well as on an exotic boulder on the Delta Top and possibly on regolith clasts [6]. Maroon coatings were notably not observed on light-toned, sulfate-rich sediments of the Delta Front (Fig 1; Hogwash Flats [7]).

Coatings imaged by PIXL MCC are spectrally distinct with Near-IR/G and Near-IR/UV band ratios, consistent with ferric oxides and Mastcam-Z observations [1].

Coatings are compositionally distinct from underlying rocks, indicating they range to thicknesses greater than PIXL interrogation depths (>50-100 µm) [3, 8]. XRD peaks are generally not identified in X-ray spectra of coated regions in PIXL scans, indicating they are fine grained (<50 µm) and potentially amorphous.

Chemistry: Cavetown (Fig 2) is a representative Delta Top natural surface that was cleared of dust by the gDRT and examined by PIXL; regions identified in the PIXL scan include the sedimentary lithology (Mg-rich carbonate + silica) and a patchy maroon coating that is relatively enriched in ZnO and other volatiles. Coating compositions across the traverse are remarkably uniform and similar to Mars global dust [9] and average...
crust [10], but with higher SO$_3$ and Cl (Fig. 3), suggesting they may be consistent with airfall dust indurated by added S- and Cl-bearing salts.

Total oxide abundances give insight to the amount of light elements invisible to XRF (H, C, O) present. Rock interior total oxides vary and range to <90% when carbonate minerals are present [4,6]. The coatings generally have higher total oxides (95-100%), which suggests they are relatively anhydrous and free of CO$_2$.

**Figure 3.** Mars dust-normalized [9] element abundance diagram with all maroon coating compositions and Novarupta abrasion.

Pre- (cleared of dust by SuperCam laser) and post-abrasion PIXL maps of the Novarupta target examined at the Amalik outcrop allow comparison of the coatings and rock interior (Fig 3). Novarupta is a bedded siltstone largely composed of altered olivine and chromite grains. Bulk PIXL XRF analyses of the abraded rock are extremely poor in K$_2$O (0.001 wt%). P$_2$O$_5$ and SO$_3$ in the abraded scans occur in ~100 μm phosphate (likely apatite) and Mg-sulfate grains. In contrast, the coating is homogeneous with enrichment factors for volatile elements relative to the abraded rock of ~2x SO$_3$, ~1.5x Cl, ~14x P$_2$O$_5$, >400x K$_2$O, and ~4x ZnO. In addition, fluid immobile AI$_2$O$_3$ is ~4x enriched in the surface coating. The K and Zn could not possibly derive from the underlying rock and point toward an external origin (i.e., not a weathering rind). The coatings have ~0.5x MnO relative to the abrasion, indicating aqueous fluids did not mobilize Mn [e.g., 11].

**Discussion:** The maroon coatings appear pasted onto rock surfaces and do not derive constituents from the underlying rock. Their homogeneity across a wide area indicate they did not form by soluble element mobilization and evaporation of ephemeral thin films of liquid water [e.g., 12], which would have resulted in highly variable compositions depending on water activity and substrate lithology. The coatings’ patchy distribution on many of the rock surfaces and apparent lack of layering suggest they are variably eroded and likely formed by a single formation event in the relatively recent past which is not ongoing.

The distinct volatile element enrichments, uniform, and widespread nature of the maroon coatings is most consistent with deposition from a vapor plume during a volcanic eruption [e.g., 13], intrusive degassing, or impact event. Chloride and sulfate salts (containing Na, K, Zn, Cu) are common volcanic vapor precipitates on terrestrial volcanic deposits but are highly soluble in water and not preserved in the rock record [e.g., 14]. The plume model is also consistent with fumarole experiments using Mars-relevant compositions by [15,16] that have formed Na, K, Zn, and Ge-bearing phases, including chlorides, sulfides phosphates, oxides, and silicates.

As Perseverance continues its traverse out of Jezero crater, the distribution of coatings will be tracked to give insight to the extent of their formation in this region of Mars. At other Mars landing sites, similar enrichments in Cl, Zn, K, P (and Ge) are observed at rock surfaces in Gale crater by the Mars Science Laboratory (MSL) [17] and in coatings on the rock Mazatzal in Gusev crater examined by the Mars Exploration Rover Spirit [18]. These observations point toward a planet-wide process.

**Implications for Mars Sample Return (MSR):** While the coatings are thin (~50 μm), they are likely found on some of the core samples collected for MSR. Samples of interest include those from the Crater Floor Rockette outcrop (Montdenier and Montagnac; Bellegarde abrasion) and from the Delta Front Amalik outcrop (Shuyak and Mageik; Novarupta abrasion). Earth-based analyses of the coatings would yield micro-textural, trace elemental and isotopic data to test the hypothesis of vapor deposition, as well as to characterize one of the youngest geologic processes that has acted on the Mars surface.

**Acknowledgments:** M2020 and PIXL are supported by NASA. Schmidt is funded by a Canadian Space Agency M2020 PS grant.