SUMMARY OF ROCK COATING OBSERVATIONS ON MARS FROM PAST ROVER MISSIONS.

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Introduction: Rock coatings form when externally-derived materials accrete and are cemented onto rock surfaces through water-rock-atmosphere interactions with the original surface [1]. On Earth, coatings record information about past climate and weathering conditions, and in some cases have previously been shown to provide important microhabitats for microbial life [2,3]. Such characteristics make rock coatings on Mars important targets for constraining past surface alteration processes, paleoenvironments, and habitability. Here, we summarize previous rover observations of rock coatings on Mars. We first present findings made by the Perseverance rover at Jezero crater and review previously reported observations of potentially similar coatings at other landing sites. By integrating findings from multiple missions, this work aims to highlight the implications of rock coatings for understanding surface alteration and environmental evolution on Mars for previous and future missions.

Jezero crater: The NASA Mars 2020 Perseverance rover has been exploring the ~45 km wide impact crater in Nilli Fossae since Feb 2021, and most recently completed its climb up the western crater rim [4]. Smooth, discontinuous coatings have been commonly observed on eroded natural rock surfaces throughout the rover's traverse, suggesting a widespread surface alteration process [5,6] (*Fig 1)*. The coatings are easily distinguished from the underlying rock with purple hues when viewed in visible wavelength enhanced color and decorrelation stretch images. Some coatings appear more muted in hue and range from mauve to gray, likely reflecting variable degrees of oxidation [7]. Coating compositions are similar to dust and fine regolith (which are potential progenitors), and coating enrichments in SO_3 and Cl suggest induration by S- and Cl-bearing salts [8]. Faint H_2O spectral absorptions and S/H-enrichment reported by the SuperCam instrument suggest minor hydration within the coatings attributable to hydrated sulfates [9,10]. Ferric absorptions in coatings observed in Mastcam-Z multispectral data and SuperCam visible spectra suggest a variable component of ferric oxides [7]. Previous studies have hypothesized that coating formation in Jezero is a result of atmospheric water-rock interaction related to diurnal changes in relative humidity, frost events, meltwater, or other near surface aqueous activity [7]. Volatile element enrichments reported by the PIXL instrument have been hypothesized by [8] to be associated with a single volcanic eruption plume or impact. Other potential rock coatings rich in Mn have also been described in Jezero, but such coatings are rare and likely unrelated to formation of the purple-hued coatings [11].

Gusev crater: A dark multilayer coating on basaltic rock target *Mazatzal* was observed by the NASA *Spirit* rover at Gusev crater. Previous studies reported that the coating contained Fe-oxides, including crystalline hematite, and S- and Cl- enrichments that were hypothesized to be associated with alteration of the silicate component of the soil or rock itself, Fe-oxidation, and incorporation of S and Cl [12]. The widespread occurrence of coatings at Gusev crater have not previously been reported, but a preliminary review of images acquired by *Spirit's* Pancam instrument has revealed potential candidate coatings on other rocks along the traverse (*Fig 1)*.

Meridiani Planum: Discontinuous patches of purple-hued surface coatings were observed on Fe-Ni meteorites investigated by the NASA *Opportunity* rover. Pancam reflectance and Mössbauer data suggested a mixture of ferric materials dominated by nanophase hematite, while APXS data showed enrichments in Mg, Br, and Zn relative to the underlying meteorite. The coatings were hypothesized to have formed during episodes of burial and exhumation that were partially eroded by subsequent erosion [13]. At Endeavor crater, *Opportunity* also investigated a sulfate-rich (~21 wt%) coating with high abundances of Si, Fe, Ca, Mg and an assemblage of Fe oxides and/or oxyhydroxide phases [14]. Similar features were reported by [15] as 'dark veneers' that showed large enrichments in S, Cl, Zn, and Br and smaller enrichments in K and Ca. Like in Gusev crater, the widespread occurrence of such coatings have not been reported but a preliminary review of *Opportunity's* Pancam images also reveal candidate coatings (*Fig. 1*).

Gale crater: Since 2012, the *Curiosity* rover has been investigating sedimentary rocks deposited in a paleolake environment. Until recently, purple-hued coatings have not been previously described in Gale crater. However, more recent occurrences of potentially similar coatings have been noted on darker toned float rocks investigated by Mastcam [16] (*Fig 1.*).

Discussion: Rock coating and duricrust formation has long been speculated for Mars [17, 18]. The evidence summarized and presented here further underscores the significance of these features as a potential global phenomenon. Observations of similar coatings

across multiple landing sites, spanning a wide range of geologic and environmental contexts, suggest a widespread surface alteration process on Mars. The occurrences of coatings on eroded natural surfaces indicates that the formation of coatings is relatively young and possibly represent some of the most recent episodes of alteration on Mars.

Ongoing work is focused on more systematically constraining the distribution of such coatings across rover landing sites, and using available datasets to conduct more detailed comparisons and characterization. This also includes exploring previous datasets and studies from other landed missions such as Mars Pathfinder and Viking to investigate potentially similar coatings. These efforts will help address key outstanding questions about the environmental or geochemical factors that contribute to coating formation and attempt to explain the seemingly higher abundance of coatings identified at Jezero crater compared to other sites. Overall, this work aims to provide critical insights into surface alteration across Mars.

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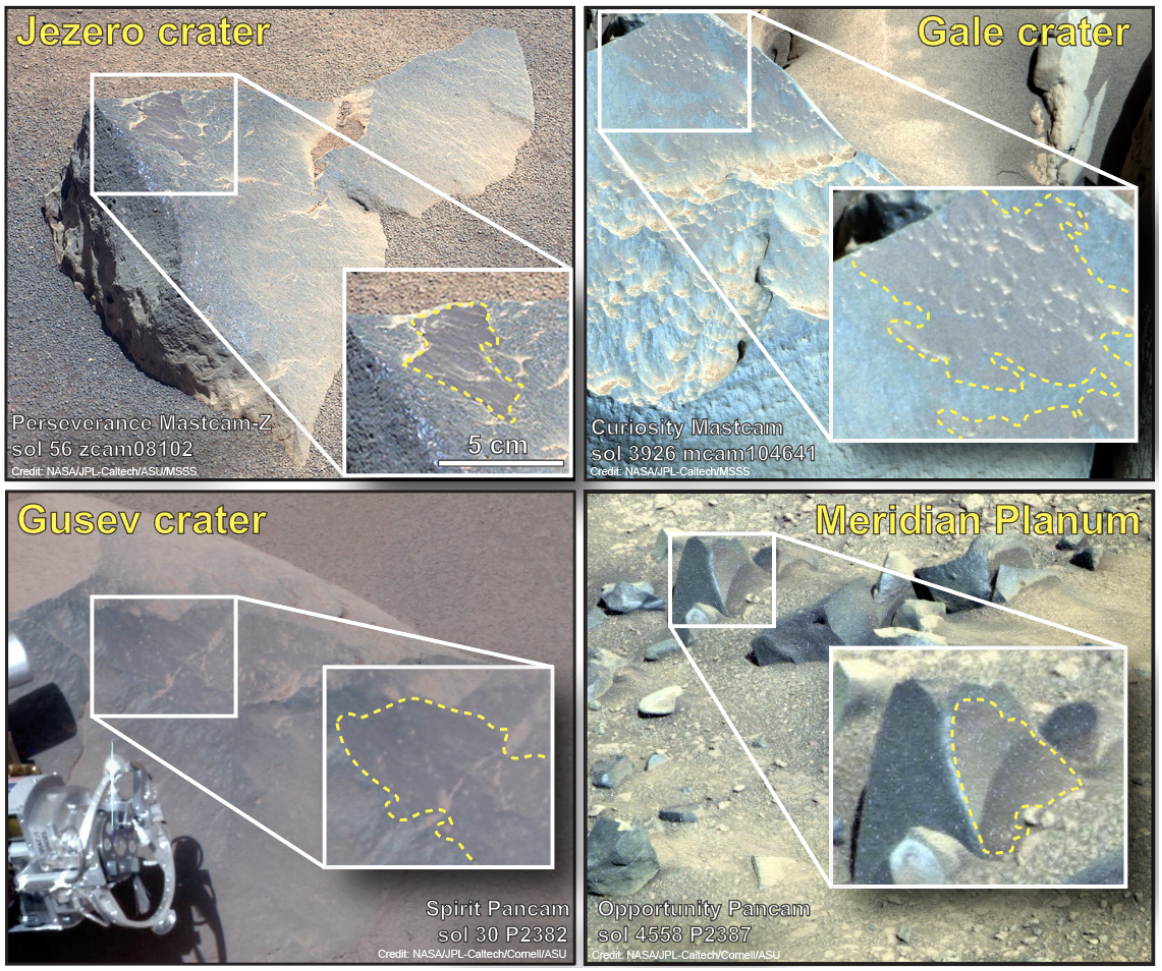

Figure 1*: Examples of similarly appearing rock coatings observed at various landing sites on Mars.*