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FORMATION AND MARS SAMPLE**

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OBSERVATIONS OF COARSE-GRAINED FLUVIODELTAIC ROCKS IN THE JEZERO WESTERN FAN AND GALE CRATER: IMPLICATIONS FOR SEDIMENTARY ROCK FORMATION AND MARS SAMPLE RETURN. K. L. Siebach¹, M. M. Tice², J. A. Hurowitz³, E. L. Moreland¹, J. I. Simon⁴, M. E. Schmidt⁵, T. V. Kizovski⁵, G. Caravaca⁶, A. Klidaras⁷ ¹Rice University, Houston, TX (ksiebach@rice.edu), ²Texas A&M University, College Station, TX, ³Stony Brook University, Stony Brook, NY, ⁴NASA-JSC, Houston, TX, ⁵Brock Univ., Ontario, CA ⁶IRAP, CNRS, CNES, Univ. Toulouse, FR, ⁷Purdue Univ., West Lafayette, IN

Introduction: Coarse-grained fluviodeltaic sedimentary rocks preserve the history of events and environments from source to sink; clasts provide a record of provenance and weathering, rounding and sorting record transport, and cements record lithification and alteration. We have now observed coarse sandstones and fluvial conglomerates with two rover missions in different parts of Mars: Mars Science Laboratory *Curiosity* observed fluviodeltaic sandstones and conglomerates in the Bradbury formation, and Mars 2020 *Perseverance* observed and sampled fluviodeltaic sandstones and conglomerates in the Tenby and Otis Peak formations on top of the Western Fan in Jezero crater. Here, we consider what we have learned from these deposits about source-to-sink sedimentary processes on Mars and what additional information the returned samples will provide.

Curiosity. *Curiosity* traversed the Bradbury formation from its landing in August 2012 to September 2014 [1]. The conglomerates and coarse sandstones in this formation typically have dm- to m-scale cross-bedding and occasional imbrication, with clasts up to ~6-10 cm diameter [1]. We include observations from the cameras, APXS (~1.6 cm XRF-based chemistry) [2], ChemCam (~400 μ m LIBS-based chemistry) [3], and CheMin (powder XRD) [4].

Perseverance. *Perseverance* traversed the Upper Fan in a campaign between February and September 2023, including the Tenby formation, with a characteristic “curvilinear” appearance in orbital images, and the Otis Peak formation, a coarser cross-bedded deposit that creates characteristic delta lobate channel features [5, 6]. While the Tenby formation is more massive or flat-laminated, Otis Peak shows fluvial cross-bedding and occasional imbrication, including areas of boulder imbrication—although the largest grains in sampled rocks are ~2 mm. We focus on observations from PIXL (Planetary Instrument for X-ray Lithochemistry), a micro-XRF instrument mounted on *Perseverance*’s robotic arm that obtains maps of high-resolution (~120 μ m spot size) geochemical data of rock targets [7].

Source Rocks and Transport Sorting: The detrital grains in both martian conglomerates are dominantly from igneous sources, although rare recycling of sedimentary rocks has been observed in both systems [8, 9]. Sedimentary rock compositions do not perfectly

reflect those of their source rocks; sorting and weathering during transport segregate and alter grains [e.g., Putnam et al., this meeting]. When there are coarse phenocrysts in the igneous source rock, those are likely to become monomineralic coarse grains in the sediments and then be overrepresented in coarse sediments [10-12]. Interestingly, both suites of observed conglomerates are derived from at least one source with igneous phenocrysts, however in Gale crater the phenocrysts are cm-scale elongate plagioclase crystals [13-15] and in the Jezero western delta the phenocrysts are ~mm-scale olivine grains. This pattern leads to different sorting trends in the two craters.

The phenocryst-bearing sources are not the only sources of the detrital grains in the conglomerates. *Curiosity* drilled a sandstone with abundant sanidine indicative of an alkali basalt source mixing with the dominant source with plagioclase phenocrysts [14, 16]. Olivine and pyroxene stoichiometries derived from *Perseverance* PIXL data over monomineralic spots show at least two populations of igneous basaltic sources upstream of Jezero crater [see Moreland et al., this meeting]. PIXL data also reveal a shifting balance between a Cr-rich and Ti-rich spinel population [9, 17].

Weathering: Coarse-grained sediments have lower surface area:volume ratios than finer-grained sediment and are therefore less likely to show signs of chemical weathering [18, 19]. However, even considering the grain sizes, both conglomerates on Mars show surprisingly little evidence for chemical weathering of detrital clasts deposited in fluviodeltaic environments.

As *Curiosity* observed, nearly all of the Bradbury sandstone and conglomerate targets have APXS chemical compositions consistent with mixtures of igneous phases [14] and ChemCam observations of individual igneous minerals do not show evidence for chemical weathering [13]. The low Chemical Index of Alteration values invoke comparisons to modern environments in Iceland or Antarctica [18].

The sandstone and conglomerate investigated by *Perseverance* are dominated by olivine grains that are only partly altered into easily-formed early secondary phases like Fe-Mg carbonate, hisingerite, sepiolite, and greenalite [Moreland et al., this meeting]. While olivine is fairly resistant to physical abrasion and can be concentrated in sand dunes [11, 20], it is extremely susceptible to aqueous alteration and does not persist in

terrestrial weathering profiles older than 10 ka [21, 22]. The Mars CO₂-rich atmosphere likely contributes to slower weathering [23], but the dominance of olivine and the nature of the alteration phases [24] point to cool temperatures and/or relatively short-term exposure to warm aqueous conditions.

Lithification and Diagenesis: Diagenesis includes all of the changes in sediment after burial and prior to surface exposure (assuming no metamorphism), including lithification and other interactions with pressure, heat, and groundwater. Sandstones and conglomerates are not expected to significantly compact under likely burial depths on Mars [1], so a higher percentage of cement materials are required to occlude porosity/permeability of coarse-grained materials on Mars. Sandstones and conglomerates observed in both craters appear to be well-cemented, as demonstrated by fracture fills that do not permeate into the adjacent rock [25] and PIXL observations [9].

The cementing agent in Gale crater is poorly understood. Carbonates were not detected in the Bradbury formation and sulfates did not permeate the sandstone, so altered silicates or glassy materials are the most likely cementing phase [16, 26, 27]. These cementing phases unfortunately appear amorphous to the CheMin instrument [28-30].

Perseverance observed Fe, Mg phyllosilicates, Fe, Mg carbonates, Fe-phosphate, and minor amorphous silica in and between detrital grains with PIXL [9, 31, 32]. At PIXL resolution, there are hints of layers in these cementing phases; with further work or at higher resolutions upon sample return, these layers could be deconvolved to describe the chemistry, and possibly the timing, of different episodes of groundwater interaction in Jezero crater.

Sample Return: Four samples were collected from coarse-grained facies in the Upper Fan, Jezero crater. Much like the regolith breccias among martian meteorites [33], these coarse grained samples have potential to be very high value for Mars Sample Return as a collection of clasts representing multiple source environments and cements representative of multiple aqueous environments [34]. Specific advantages of these coarse-grained sedimentary rocks include:

(1) Coarse grains are likely to include polymineralic, or lithic clasts, with mineral assemblages that allow us to refine our understanding of the formation conditions of their protolith.

(2) Similarly, coarse grains tend to preserve and enable recognition of more textures or microstructures that record information about their formation, erosion, transport, and deposition pathways.

(3) Large void spaces between coarse grains may contain layered cementing phases enabling cement

stratigraphy, which would reveal changing aqueous conditions in the crater over time [e.g., 35, 36].

(4) Coarser clasts enable grains to be analyzed with more high-resolution isotopic, magnetic, and radiometric techniques; polymineralic clasts may allow multiple isotope and dating systems to test concordance or sequential event timing.

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