AREALLY EXTENSIVE OLIVINE-ENRICHED BEDROCK EXPOSURES ON MARS: MANY ARE CLASTIC ROCKS, NOT LAVAS. A.D. Rogers[1]*, N. H. Warner[2], M. P. Golombek[3], J. W. Head[4], and J. C. Cowart[1], [1]Stony Brook University, Stony Brook, NY, [2]SUNY Geneseo, Geneseo, NY, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [4]Brown University, Providence, RI, *deanne.rogers@stonybrook.edu

Introduction and significance: Degraded impact craters and intercrater plains in the Martian highlands commonly contain flat, relatively high thermal inertia (TI) surfaces ("bedrock"). These units: exhibit maximum TI values above ~500 J m^{-2} K^{-1} $s^{-1/2}$ in THEMIS images, occur in dozens of isolated exposures ranging from ~2x10^2 to ~3x10^4 km^2 in area, and commonly show modest enrichments in olivine compared to surrounding materials [1-7]. These olivine-bearing bedrock plains may be the product of Noachian/Hesperian resurfacing processes, and are widespread, thus understanding their petrogenetic origin(s) is important. Also, olivine-bearing bedrock is observed at/near all of the Mars2020 candidate landing sites, increasing the importance of understanding these materials.

The petrogenetic origin(s) of these units is uncertain. An effusive volcanic origin was generally favored in past studies on the basis of the relatively high TI, distinctive composition, and the difficulty of spatially concentrating olivine over such large scales through sediment transport and sorting [1-6]. However, the degraded nature of these units, limited vertical exposure, and lack of volcanic morphologies (e.g. flow lobes, source vents), makes their origin(s) uncertain.

In this work, we first present evidence that many of these units are not lavas, but instead are clastic rocks. Next, we discuss possible clastic origins for these materials, as well as a mechanism of olivine enrichment.

Observations: ***1. The bedrock units have not followed the same degradation and regolith development path as known volcanic plains.*** Hesperian volcanic plains have a notable lack of bedrock exposure compared to Noachian cratered terrains [8], and have developed a thick regolith [9-10] (unlike the olivine-bearing bedrock). In locations where olivine-bearing bedrock is found subjacent to Hesperian volcanic plains, a striking difference in TI and regolith cover is observed, such that Hesperian plains are more mantled than the older bedrock ([8], **Fig. 1**). One explanation for this is that the older bedrock was rapidly buried before the emplacement of the Hesperian plains, and then recently exposed [8]. However, an alternative explanation is that the Noachian bedrock units are mechanically weak/friable materials compared to the Hesperian lavas. Comminution products developed on these materials would likely be dominated by finer particulates [e.g. 11,12] that are more susceptible to eolian transport (e.g. fine- to medium-sands, [16]). Conversely, high shear-strength lavas would break down into blocks and coarser-particulate materials. Over time, this would lead to buildup of thick regolith dominated by less mobile materials (coarse sands and larger, plus trapped dust) on the Hesperian lavas, whereas the friable bedrock would experience constant deflation and exposure of a lithified surface.

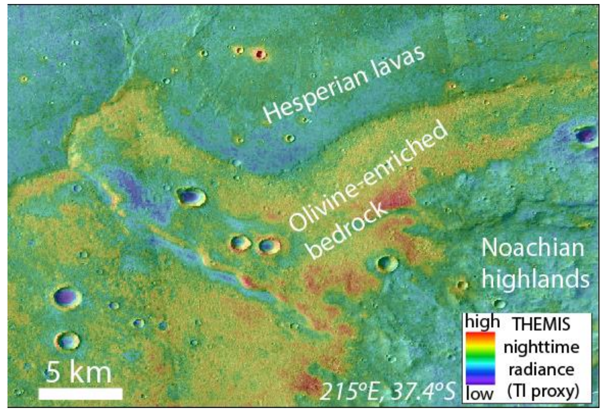

Fig. 1. Hesperian lavas exhibit low-TI and overlie higher-TI, olivine-enriched bedrock in Terra Sirenum.

Additional examples of Hesperian lavas superjacent to higher-TI (less mantled) units are observed in Gusev crater [13] and NE Syrtis (**Fig. 2**). In those locations, significantly mantled Hesperian lavas directly contact older, less mantled rock units. In Gusev crater, these rock units may represent olivine-bearing basaltic tephras, similar to the Algonquin-class rocks investigated by the Spirit Rover [14]. At NE Syrtis, the older, higher-TI rocks contain sulfates and aqueously altered basaltic materials [15]. Tephras and altered basaltic materials would likely be mechanically weak compared to unaltered basaltic lavas, such as those present in the Hesperian volcanic plains [e.g. 17].

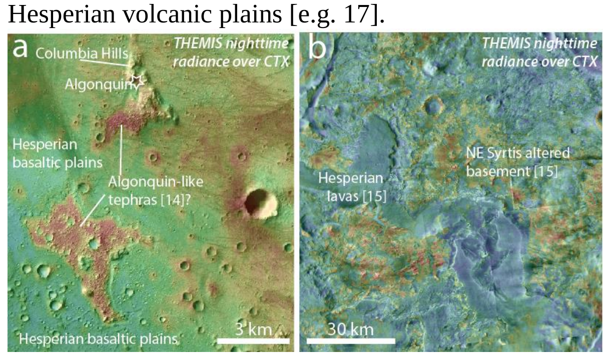

Fig. 2. Examples where Hesperian lavas abut older, likely mechanically weak materials (see text). (a) Gusev (b) NE Syrtis. The differences in surface TI expression may result from differences in friability.

2. The bedrock units do not preserve small craters as well as superjacent Hesperian lavas or adjacent low-TI surfaces. We determined the cumulative size frequency distributions and spatial density of craters with D > 200 m for nine bedrock regions and adjacent low-TI surfaces within the same (or younger, in one case) global chronostratigraphic unit [18] (**Fig. 3**). In this exercise, we assumed that the adjacent low-TI surfaces represent regolith derived from dense crystalline rocks. Bedrock and low-TI regions of interest were chosen from areas of similar elevation and slope, reducing the possibility of differences in wind activity. The bedrock regions showed between 18-78% lower crater density than their adjacent low-TI surfaces, suggesting that small craters are more easily removed from the bedrock. This is consistent with differences in material properties between the bedrock and Hesperian lavas.

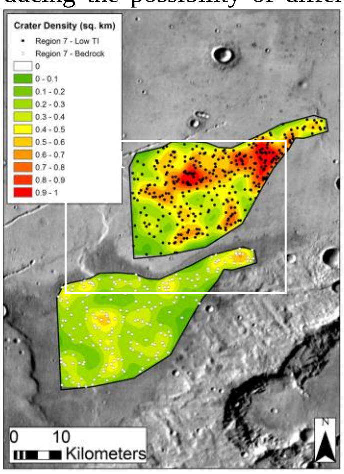

Fig. 3. Crater density is higher on Hesperian lavas (top polygon) than on olivine bedrock (bottom polygon).

3. The bedrock units exhibit surface morphologies consistent with wind-eroded landforms in friable rock. Mars Reconnaissance Orbiter Context Camera (CTX) images show that many olivine-bearing bedrock surfaces exhibit parallel or sub-parallel striations, which we interpret as yardangs. In addition, craters within the bedrock commonly appear shallow, with degraded or scalloped rims.

Discussion: The observations discussed above indicate that *some* olivine-bearing bedrock units may represent mechanically weak materials, which is inconsistent with dense, crystalline rock such as basalt. Alternative petrogenetic origin(s) are discussed below.

Explosive volcanism could produce olivine-enriched friable rocks. For the intercrater plains and crater-filling units, the volcanism would need to be localized, because we do not observe draping deposits over pre-existing topography. Alternatively, draping deposits could have been removed or resurfaced.

Basin scale impacts (e.g. Isidis, Hellas, Argyre) could potentially also form these materials, in the form of suevites, or perhaps as silicate condensates from vaporized crust (which could range from porous/unconsolidated to strongly welded) [19,20]. For example, [20] suggest silicate condensate from the Isidis impact this as a potential origin for the circum-Isidis olivine-bearing bedrock in Nili Fossae and Libya Montes. For intercrater plains and crater-filling units, the timing of deposition would need to be better constrained to determine if their formation times were consistent with the ages of these large basins.

Sediment transport and deposition in topographic lows is a likely origin for the intercrater plains and crater-filling materials. We suggest that the observed olivine enrichment in the bedrock arises through deflation, after the sediments have been transported, deposited, and lithified. As the basaltic bedrock is eroded and deflated, plagioclase could be preferentially transported away from the bedrock and coarser and/or denser olivine-bearing grains could accumulate in lag deposits. The lag deposits may have then organized into bedforms and/or become trapped in small topographic lows in the bedrock (both observed in HiRISE images), allowing portions of the basaltic bedrock to remain free of the lag. This could allow the high-TI signature to persist, and the spectral datasets to be dominated by the finer particulate and daytime-warmer olivine-enriched sediments. Additional sedimentary mechanisms for olivine-enrichment are discussed in [7].

Conclusions: We present evidence that many olivine-bearing bedrock plains are not effusive volcanics. For the intercrater plains and crater-filling olivine bedrock units, which are isolated and concentrated in topographic lows, the simplest explanation is detrital sedimentation. Olivine enrichments likely formed over time, through slow deflation of the bedrock, preferential eolian removal of plagioclase, and accumulation of olivine-bearing sediments in patchy lag deposits.

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