PHYSICAL MODIFICATION OF SYNTHETIC BASALTIC SEDIMENT COMPOSITIONS: IMPLICATIONS FOR INTERPRETING THE GEOCHEMISTRY OF MARTIAN SOILS.

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Introduction: Impact shattering of bedrock, wind-driven transport, and sorting have been identified as the primary processes modifying the size, shape, and roundness of basalt-derived sediment "soils" at the Mars Exploration Rover (MER) landing site at Gusev Crater [1, 2] and these processes are recognized as being important for shaping the surface of Mars [3]. In addition to the physical modification of sedimentary grains, bolide impacts, transport dynamics, and hydrodynamic sorting can also be major sources for compositional modification. Chemical compositions of sediments in Gusev Crater are in part controlled by mixing sediment from multiple sources and by the selective sorting of dense FeO_T+MgO-bearing minerals (*e.g.,* olivine, pyroxene) from basaltic lithic fragments [2]. With the potential for active aeolian environments [4, 5], it is critical to explore the fractionation effects of hydrodynamic sorting of sediments on Mars. The purpose of this study is to demonstrate the possibility that compositional changes in martian sediment [2] may result from the redistribution of mineral species by physical processes, rather than chemical weathering.

Sample Selection and Analysis: Two basalt samples were selected provide a range of protolith compositions and igneous textures. The first sample is a porphyritic trachybasalt (yellow square, Fig. 1) from the Cima volcanic field, Mojave Desert, CA, containing olivine, plagioclase, and clinopyroxene megacrysts, and a groundmass of olivine, clinopyroxene, plagioclase, and equant opaque minerals. The second sample is a highly porphyritic vesicular basalt (blue square, Fig. 1) from Kilauea volcano, HI, with abundant olivine phenocrysts and a groundmass of olivine, clinopyroxene, plagioclase, and equant opaque minerals. To produce analog sediments that mimic impact comminution and aeolian sorting conditions on Mars, bedrock samples were crushed and sieved into 0.5 ϕ fractions from -2.0 to 4.0 ϕ. Chemical, mineralogical, and textural characterizations of rock and sieved sediment samples were conducting using point-counting, electron microprobe, and ICP analyses.

Compositional Modification by Hydrodynamic Sorting: Plotting major oxides of analog protolith and derived sediment samples (Fig. 1) in a total alkali-silica diagram (TAS) provides a way to compare the compositional variations from sorting to the compositions of basalt bedrock and "soil" sediment from geochemical data collected from the Mars Exploration Spirit (MER) Alpha Particle X-Ray Spectrometer (APXS). Cima trachybasalt (yellow square, Fig. 1) and Kilauea basalt (blue square, Fig. 1) represent high- and low-alkali compositions, bracketing most Gusev rocks and soils. The range and trajectory of Cima analog sediment (yellow points, Fig. 1) are indicated by arrows extending away from the Cima trachybasalt composition. Sediment compositions plot in along the tephra-trachybasalt boundary away from the rock in both directions. The trend of Kilauea analog sediment (blue points, Fig. 1) is show by arrows originating from the Kilauea basalt. Note that Cima and Kilauea sediment compositions show similar patterns to the trajectory and range of sediment in Gusev Crater (diamonds, Fig. 1). Such a pattern formed by Kilauea sediment occurs from the redistribution of olivine phenocrysts removed and concentrated by sorting.

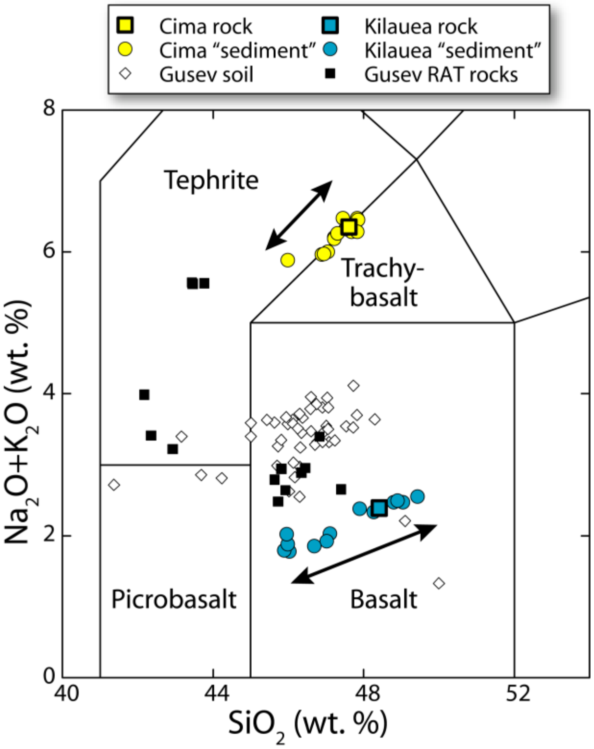

Figure 1. Total alkali content (Na_2O+K_2O) vs. SiO_2 classification plot for volcanic rocks. Cima and Kilauea sediment diverge from the protoliths. Kilauea sediment has a compositional spread similar to most soils in Gusev Crater, demonstrating the potential importance of hydrodynamic-driven compositional changes.

Implications for the Interpretation of Soil Compositions: Accurate characterization of martian sediment weathering pathways necessitates a distinction between compositional changes resulting from the progressive alteration of unstable mineral species associated with chemical weathering [*e.g,*. 6, 7] and from the redistribution of mineral species associated by abrasion and hydrodynamic sorting [*e.g.,* 2].

Chemical weathering of sediment is commonly characterized using an A-CNK-FM plot (Fig. 2), and is used here to compare compositional trends from analog sediment with sediment from the MER landing sites. Cima (yellow points, Fig. 2) and Kilauea (blue points, Fig. 2) sediments plot subparallel to the olivine-feldspar join. As shown with arrows, sieved sediment samples diverge away from their respective bedrock sources, with an increase and decrease in FM compositions. Accumulations of olivine in Kilauea sediment, and of olivine and pyroxene in Cima sediment, are shown by movement towards the FM apex. The removal of FM-bearing minerals causes sediment to move away from the FM apex. Pyroxene and olivine are present primarily in the groundmass of Cima sediment, and have minor compositional variation when sorted by grain size (Fig. 3a-c). A greater range in FM chemistry (blue points, Fig. 2) for Kilauea sediment (Fig. 3d-f) is attributed to the redistribution of abundant olivine phenocrysts. Coarse sediment (0 ϕ, Fig. 3d) resembles the composition of the protolith, while liberated olivine grains are concentrated at 2 ϕ (Fig. 3e), and are also present at 4 ϕ (Fig. 3f).

Despite different initial basalt compositions, Cima sediment match the trajectory, and Kilauea sediment match the general range and trajectory of sediment in Gusev Crater and Meridiani Planum (Figs. 2, 3). Such trends can be produced from the sorting of shattered basalt bedrock and do not require chemical weathering. This experimental approach provides a starting point to understand surface processes active on Mars. These results demonstrate the capability of compositional modification from physical sorting, link textures with sediment compositions, and must be considered when interpreting the composition and weathering pathways of sediments examined by the Mars Science Laboratory (MSL) Curiosity Rover at Gale Crater.

References: [1] McGlynn I. O. et al. (2011) *JGR, 116,* E00F22. [2] McGlynn I. O. et al. (2012) *JGR, 117,* in press. [3] Grotzinger J. P. et al. (2011) *The Sedimentary Record, 9,* 4-8. [4] Chojnacki M. et al. (2011) *JGR, 116,* E00F19. [5] Bridges N. T. et al. (2012) *Geology, 40,* 31-34. [6] Tosca N. J. et al. (2004) *JGR, 109,* E05003. [7] Hurowitz J. A. and McLennan S. M. (2007) *EPSL, 260*, 432-443.

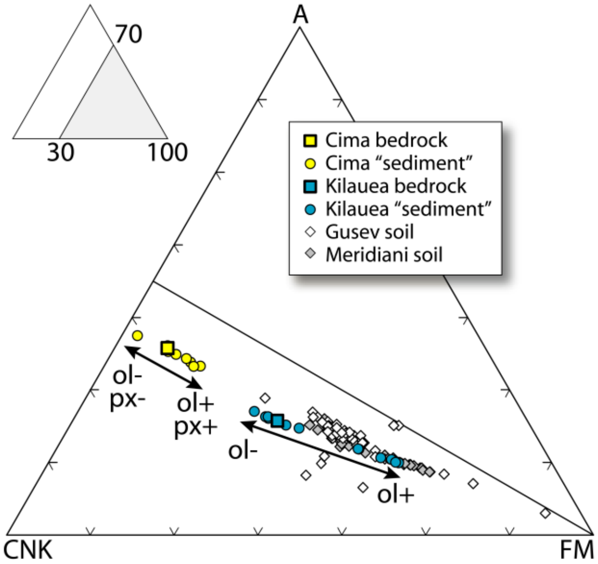

Figure 2. Molar proportions of A (Al_2O_3), CNK ($CaO+Na_2O+K_2O$), FM (FeO_T+MgO) for Cima and Kilauea sediment, extending from bedrock, towards and away from the FM apex, with the accumulation and removal of olivine and pyroxene in the absence of chemical alteration, with a trajectory that resembles Gusev Crater and Meridiani Planum soil.

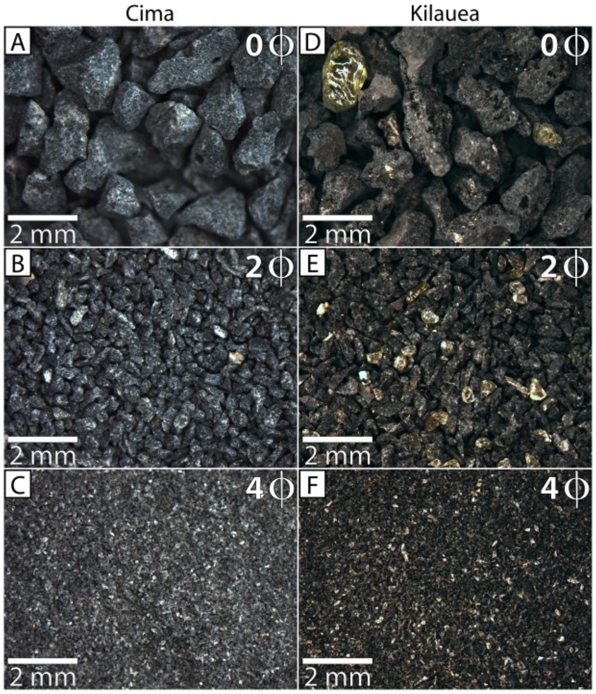

Figure 3. Comminuted and sieved sediment. Cima samples have few isolated minerals in A) very coarse and B) medium sand C) but pyroxene and olivine grains are abundant in very fine sand. In Kilauea samples, a small number of isolated olivine grains are visible in D) very coarse sand, but grains are concentrated in E) medium sand, F) and very fine sand samples.