Reworking and Diagenesis of Martian Soil: Pathway to Murray Formation Sediments?

In Gale crater, the Curiosity Mars rover has climbed over 300 meters of the Murray formation from the base of the Pahrump Hills to the crest of Vera Rubin Ridge. We discuss the possibility that fine-grained mudstone of the Murray formation is a diagenetic product of sediments with a chemical and mineralogical composition similar to present-day martian soil.

Typical (low Ca-sulfate) Murray samples have Na_2O, Al_2O_3, SiO_2, SO_3, TiO_2 and FeO_T concentrations within 10% (relative) of average martian soil. These oxides constitute ~85% of each sample. The Al/Si and Ti/Si ratios of Murray samples are comparable to average martian soil but distinct from other martian geologic units. Percentage difference in P_2O_5, Cl, K_2O, Cr_2O_3, MnO, Ni, Zn, Br, and Ge between soil and Murray samples generally exceed 10%, but these elements and oxides amount to less than 4% of the samples. These constituents are highly variable in Murray mudstone and may reflect mobility in fluid interactions. Large discrepancies in MgO and CaO with ~50% lower concentrations in the Murray samples (~2% absolute differences) are indicative of open-system alteration if the Murray mudstone originated from soil-like material.

Mineralogically, martian soil is dominated by plagioclase feldspar, pyroxenes, and olivine with minor hematite, magnetite, and Ca-sulfate. In comparison, Murray samples generally have less feldspar and pyroxene, little to no olivine, more iron oxides and Ca-sulfates, and Fe-containing phyllosilicates. If Murray mudstone originated from a Mars soil composition, aqueous alteration could have converted olivine and pyroxenes to iron oxides and phyllosilicates. Intermixed or zoned plagioclase feldspars could have lost a larger portion of calcic constituents, consistent with susceptibility to weathering, resulting in a change from ~An55 (soil) to ~An40 (Murray). This alteration could be consistent with the major element chemistry, including the small decrease in MgO and CaO. A subsequent influx of minor/trace elements and Ca-sulfate, e.g. from groundwater, would be required.

In this diagenetic scenario, the bulk of the alteration would have been nearly isochemical, suggesting limited mineral segregation and aqueous alteration during transport from the drainage basin or a significant direct aeolian contribution to the Murray sediments.

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