

A MODEL FOR GENERATION OF MARTIAN SURFACE DUST, SOIL AND ROCK COATINGS: PHYSICAL VS. CHEMICAL INTERACTIONS, AND PALAGONITIC PLUS HYDROTHERMAL ALTERATION. J. L. Bishop¹, S. Murchie², C. Pieters³, and A. Zent⁴, ¹SETI/NASA-ARC, MS-239-4, Moffett Field, CA 94035 (jbishop@mail.arc.nasa.gov), ²Applied Physics Lab, Laurel, MD, 20723, ³Brown Univ. Box 1846, Providence, RI 02912, ⁴NASA-ARC, MS-245-3, Moffett Field, CA 94035.

Introduction: This model is one of many possible scenarios to explain the generation of the current surface material on Mars using chemical, magnetic and spectroscopic data from Mars and geologic analogs from terrestrial sites. One basic premise is that there are physical and chemical interactions of the atmospheric dust particles and that these two processes create distinctly different results. Physical processes distribute dust particles on rocks, forming physical rock coatings, and on the surface between rocks forming soil units; these are reversible processes. Chemical reactions of the dust/soil particles create alteration rinds on rock surfaces or duricrust surface units, both of which are relatively permanent materials. According to this model the mineral components of the dust/soil particles are derived from a combination of “typical” palagonitic weathering of volcanic ash and hydrothermally altered components, primarily from steam vents or fumaroles. Both of these altered materials are composed of tiny particles, ~1 μm or smaller, that are aggregates of silicates and iron oxide/oxyhydroxide/sulfate phases.

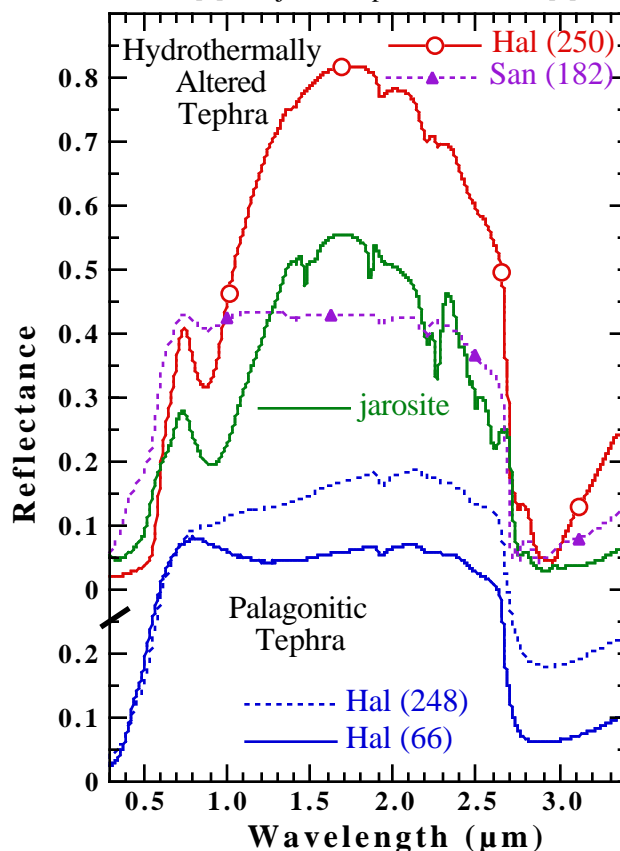
Composition of Martian Surface Rocks and Soils: The chemical and mineralogical compositions of the rocks near the Pathfinder lander indicate that they are andesitic-basaltic, are covered with alteration rinds, and are locally derived [1,2]. Analysis of the Pathfinder soil units showed that they are chemically and mineralogically distinct from the rocks, and that they may contain goethite, maghemite or other iron oxyhydroxides, but do not show the expected evidence for crystalline hematite [2,3]. The magnetic tests indicate the presence of maghemite and/or magnetite in the dust and soils and suggest that this magnetic component must be intimately mixed with the silicates and other components [4].

Terrestrial Alteration of Volcanic Tephra/ Ash: A recent study of the fine-grained fractions of volcanic tephra indicates that there are at least two kinds of alteration processes taking place: the “typical”, long-term palagonitic weathering of volcanic tephra in a dry environment, as well as more rapid and/or intense alteration in the vicinity of steam vents and cinder cones [5]. These hydrothermally altered tephra often contain significant amounts of crystalline iron oxides/oxyhydroxides and jarosite/alunite, while the palagonitic tephra tend to contain poorly crystalline and/or nanophase (np) minerals. A bright red tephra sample (250) collected from a cinder cone in the Haleakala crater basin is particularly interesting because it is extremely fine-grained, magnetic and contains both jarosite and iron oxides/oxyhydroxides [5]. Additional jarositic tephra from Mauna Kea have been

analyzed in other studies [7]. Many of these jarosite-bearing “soils” formed via hydrothermal alteration of glassy tephra in the presence of sulfur-bearing volcanic gases. Reflectance spectra of selected sulfate minerals formed in terrestrial steam vents or fumaroles are presented by Calvin et al. [8]. Potential factors contributing to ferric oxide/oxyhydroxide formation along with jarosite in such soils include the temperature and composition of the volcanic gases, duration of hydrothermal exposure, and oxidation following hydrothermal alteration.

Figure 1 VIS/NIR Reflectance Spectra of Jarosite, Hydrothermally Altered Tephra and Palagonitic Tephra

These hydrothermally altered samples are from Haleakala and Santorini and the palagonitic tephra are from Haleakala [5]; the jarosite spectrum is from [6].



Possible Alteration Scenarios on Mars: Our model is based upon two components contributing to the dust/soil particles: a palagonitic weathering component and a hydrothermally altered product. The dust particles are a combination of iron oxide/oxyhydroxide phases intergrown with silicate material (glass, amor-

phous, proto clays, clays, poorly-crystalline feldspar & pyroxene grains). A number of hydrothermal processes have been considered for Mars [9]; our model is distinct from others presented recently, including “acid-fog” weathering [10] and hydrothermal fluids from geothermal hot springs [9].

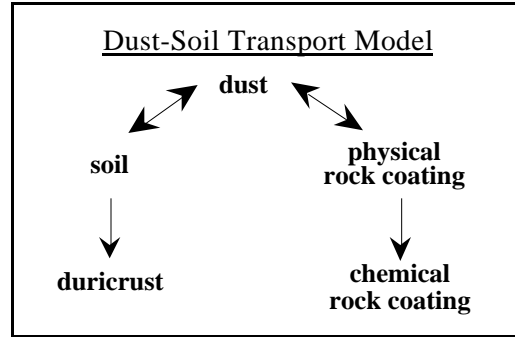
In our model volcanic steam vents are primarily responsible for the production of hematite, maghemite/magnetite, and jarosite/alunite. These minerals form in high concentrations (half of the composition of the altered ash) in specific locations – abundant, yet not ubiquitous. In contrast, palagonitic alteration of volcanic ash is more common and ubiquitous, and results in np-Fe oxide phases, poorly crystalline clays and/or protoclays (e.g. allophane and imogolite), poorly crystalline grains of feldspar and pyroxene, and perhaps some tiny glass particles. Aeolian mixing of these two alteration materials produces a non-homogenous but regionally similar, fine-grained material.

Physical Interactions. Evidence for aeolian distribution of dust particles on Mars continues to surface in nearly every measurement/experiment [11]. According to our model these dust particles cover the rocks to form physical coatings and cover the surface in between rocks to form soils. The physical coatings and soil units in our model are compositionally identical to the atmospheric dust particles; in fact, the primary difference is that these may contain larger aggregates of dust particles, held together by electrostatic or physical forces. Spectral and chemical evidence from Mars Pathfinder revealed that many of the surface soil units are compositionally similar; differences for many units are thought to be due to grain size and compaction [2,3].

Localized dust devils were identified on Mars through Pathfinder surface images, pressure changes and calculations of dust loading [12]. The idea that these local dust devils could be kicking up soil particles and redistributing them as 1-3 μm sized dust particles was presented recently [13]. Here we suggest further that there is a reversible interaction between these dust particles suspended in the atmosphere and the soil particles covering the surface. As long as the particles are kept in motion and are prevented from forming chemical bonds, they can be readily disaggregated and/or redistributed (as outlined in the diagram).

Chemical Interactions. Sulfate species are particularly reactive because of their polar nature, as are Fe^{3+} bearing phases because they readily accept electrons. For these reasons dust/soil particles containing ferric oxides/oxyhydroxides and jarosite/alunite would be particularly reactive. If these dust particles are allowed to remain undisturbed on the surfaces of rocks sufficiently long to enable chemical reactions between the ferric, sulfate and salt species and the primary rock minerals, then alteration rinds would form that would be resistant to dust devils or wind storms. Only minimal water is required for these chemical reactions, and this would be provided via atmospheric water ice

particles. Evidence for these exists through diurnal variations in the atmosphere [14].



Summary: This model was designed to explain the chemical, magnetic and spectroscopic properties of the surface material on Mars and is based on a combination of palagonitic weathering and hydrothermal alteration from steam vents as observed at terrestrial volcanic sites. This model involves both physical interactions, such as aeolian winds and electrostatic charges on dry particles, and chemical interactions including reaction of the sulfate phases and salts with molecular water provided by the diurnal moisture variations. These chemical reactions would solidify soil particles to form duricrust and “chew” through the surface of the rocks to form alteration rinds.

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