AN AQUEOUS WEATHERING MODEL FOR MIDDLE AND HIGH LATITUDE REGIONS OF MARS.

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Introduction: Middle and high latitude regions of Mars are compositionally and morphologically distinct from other areas of the planet and are dominated by near-surface water ice. These observations suggest the uniqueness of these areas of Mars is linked to the recent climate. The morphologic properties are linked to ground ice, and the compositional properties are linked to chemical alteration. Here, we present a geochemical/mineralogical model based on these observations. This model is intended to serve as hypothesis against which to further examine current datasets and data returned from the upcoming Phoenix lander. In contrast to other martian alteration schemes, this model proposes that liquid water is a necessary component of a pedogenic weathering system that has been active in recent Martian geologic history, and which may operate into the present day.

General model description: It has been suggested that high-latitude regions of Mars have been chemically altered in response to an aqueous system related to recent climate [1]. We have suggested that weathering occurs in higher latitude soil environments in the presence of water ice [2]. In this model, small amounts of liquid water form within ice-rich soils in response to temperature change, pressure changes associated with ice expansion and contraction, and configurational freezing-point depression caused by the presence of fine-grained dust particles [3]. Thus, liquid water forms periodically as small pockets or thin films along mineral surface contacts, creating a situation in which aqueous dissolution may occur. Liquid water is transient and decoupled from the atmosphere. Dust-size particles that are incorporated into soils are most susceptible to aqueous attack due to a high specific surface area, and because they create the small pore spaces where configurational freezing-point depression occurs. Dissolved constituents, derived mainly from silicate dust grains, are precipitated as authegenic high-silcia mineraloids and poorly-crystalline Fe-hydroxides in this low-temperature, low-energy system. Where a pocket of liquid water connects sand or rocks to a dissolving dust grain, these mineraloids could be precipitated onto the larger particles. Thus, over time and many such events, thin mineraloid coatings would form on sand grains and rocks [4]. Because liquid water is transient and limited in this system, chemical mobility is also limited. We, therefore, predict that mineralogical changes to the bulk soil system are limited and that weathering is more or less isochemical.

Mars data: Our model for high-latitude weathering is consistent with mineralogical and geomorphological observations and interpretations:

Mineralogical properties. TES Surface Type 2 (ST2) occurs at middle to high latitudes in both hemispheres [5,6]. The high-silica nature of ST2 is consistent with the presence of a high-silica mineraloid [7]. Occurring as particle or rock coatings, the high-silica mineraloid would exhibit a strong influence on thermal-infrared TES spectra [2] while having little impact on GRS data [8], consistent with Mars observations. Near-infrared OMEGA data from northern high-latitude regions lack hydration features, have a negative (blue) slope between 1-3 μm, and show a weak pyroxene band [9,10]. The blue slope suggests a Fe-bearing coating on basaltic particulates. Despite the lack of hydration absorptions, OMEGA spectra are consistent with the presence of thin coatings of hydrous high-silica material, where hydration bands have been shown to be absent [2].

Geomorphological properties. Although the northern and southern high latitudes differ from each other [11-13], they share certain commonalities that distinguish them from equatorial regions. Analysis of MOLA data has shown the high latitudes to be smoother than low latitudes in kilometer-scale roughness [11]. Analyses of the MOC dataset have detailed the extent of volatile-rich and permafrost-related features, which occur in both hemispheres [12-14]. Patterned ground terrains include the extensive "basketball terrain," which HiRISE images show to have distinctive textures due to small polygons and rocks [15]. All of these data indicate ice is present in the soil and that the soil layer is dynamic.

Water ice distribution. GRS neutron spectrometer results indicate the presence of water ice near the surface of higher latitude areas in both the northern and southern hemispheres [16].

Weathering model and Mars data: Data from Mars show that water ice is present in the near surface at higher latitudes and that the icy layer is dynamic. The distribution of near-surface ice is roughly linked to the present climate and corresponds roughly to the areas where high-silica ST2 materials are observed. This suggests that the formation of ST2 is linked to the occurence of ground ice. The high-silica nature of ST2 is most consistent with coatings of high-silica material, and the formation of silica coatings requires an aqueous mechanism to mobilize and redistribute silica. Thus, we suggest that liquid water forms periodically within icy soils and facilitates weathering. The corresponding oxidation and precipitation of Fe with silica would account for the near-infrared blue slope seen in OMEGA data. The dynamic nature of the soil means that dust may be cycled through the soil over time, and that rocks and particles on which silica coatings formed in the subsurface could be brought to the surface by cryoturbation.

Additional observations: Two notable observations are that (1) there are TES Surface Type 1 (basaltic) outliers that occur within the ST2-dominated northern plains [17], and (2) ST2 occurrence in the southern hemisphere are generally weaker, yet correspond to dune fields [18]. We suggest that these observations are consistent with our weathering model, and point to a pedogenetic process, in which the soil properties have a strong control over the weathering process.

In our model, weathering is linked directly to icy soils and the cycling of dust through those soils. Thus, there is likely a porosity control over where this mechanism may be active. The occurrences of ST1 in the northern plains are tied largely to knobby terrains and impact craters [17]. These are probably rocky (non-soil) units in which the soil processes are not active and, therefore, the weathering process is not active. The majority of the northern plains are deposited and reworked sediments [19] that have a porosity that enables this weathering mechanism to be active. Although this weathering mechanism is active in the south, it may be less prominent than in the northern hemisphere because southern hemisphere soils are not derived from similar sediments. Silica-coated materials that do form in the south may be concentrated in dunes after their formation.

Implications: This weathering model is a hypothesis against which to test observations of middle and high latitude regions. The products of weathering are volumetrically small, suggesting that weathering is limited and proceeds slowly. However, because high-latitude weathering principly involves silica redistribution, it requires liquid water, suggesting that other weathering models involving anhydrous reactions [20] need to be revised. The present model suggests that liquid water has formed in near-surface soils under a recent climate regime if not under the present climate.

References: [1] Wyatt M. B. et al. (2004) *Geology*, *32*, 645-648. [2] Kraft M. D. et al. (2007) 7th Internat. Conf. Mars, Abstract #3396. [3] Williams P. J. and Smith M. W. (1989) *The Frozen Earth*, Cambridge Univ. Press. [4] Kraft M. D. et al. (2003) *GRL*, *30*, 2288. [5] Bandfield J. L. et al. (2000) *Science*, *287*, 1626-1630. [6] Rogers A. D. and Christensen P. R. (2007) *JGR*, *112*, E01003. [7] Michalski J. R. et al. (2006) *JGR*, *111*, E03004. [8] Wyatt M. B. (2007) *7th Internat. Conf. Mars*, Abstract #3402. [9] Mustard J. F. et al. (2005) *Science*, *307*, 1594-1597. [10] Michalski J. R. and Kraft M. D. (2007) *GSA*, *Abstr. Prog.*, *39*, 49. [11] Kreslavsky M. A. and Head J. W. III (2002) *GRL*, *29*, 1719. [12] Mangold N. (2005) *Icarus*, *174*, 336-359. [13] Kostama V.-P. (2006) *GRL*, *33*, L11201. [14] Mustard J. F. et al. (2005) *Science*, *307*, 1594-1597. [15] Mellon M. T. et al. (2007) *7th Internat. Conf. Mars*, Abstract #3285. [16] Feldman W. (2004) *JGR*, *109*, E09006. [17] Rogers A. D. and Christensen P. R. (2003) *JGR*, *108(E4)*, 5030. [18] Ruff S. W. and Christensen P. R. (2007) *GRL*, *34*, L10204. [19] Tanaka K. (2003) *JGR*, *108 (E4)*, 8043. [20] Bibring J.-P. et al. (2006) *Science*, *312*, 400-404.