Allophane on Mars: Significance for chemical weathering and soil development

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It has been suggested that allophane or related poorly crystalline aluminosilicates are present on Mars, and that they comprise the high-silica phase detected by the Thermal Emission Spectrometer (TES) in Surface Type 2 materials (Michalski et al., 2005). Using new laboratory spectra of allophanic materials, we (Rampe et al., this meeting) have detected allophane on the Martian surface via spectral modeling of TES data. We find that ST2 materials in the Northern Plains are consistent with a significant amount of high-silica allophane-like materials. In addition, we find that allophane may be present in some areas of ancient highlands (TES surface type 1), but spectra of those regions are more consistent with aluminous allophane. The presence of allophane and its chemical variability have important implications for chemical weathering and soil development on Mars.

Allophane-like materials are amorphous or poorly crystalline hydrous aluminosilicates formed from chemical weathering of glasses, feldspars, and other silicates (cf. Parfitt, 2009). True allophane is a combination of SiO_2, Al_2O_3 and H_2O where Al:Si ranges from ~0.5-2. Aluminosilicate gels are amorphous and chemically similar to allophane but can have higher SiO_2 contents. The presence of allophane indicates low-temperature chemical weathering and provides constraints on alteration conditions, limiting pH to circum-neutral (~4.5-8).

Our model results indicate that weathering occurred in the relatively young northern plains of Mars. The high-silica allophane-like material present there implies little silica mobility through the soil column, which suggests that weathering involved small amounts of liquid water, consistent with our previous models of weathering in ice-rich soils (Kraft et al., 2007). The aluminous allophane indicated by our spectral models to be present in the highlands suggest that those regions experienced greater amounts of SiO_2 leaching and weathering in those soils may have involved much larger amounts of water. The presence of allophane-like materials suggests that these weathering regimes were not influenced by the acidic weathering that appears to have affected other areas of Mars and has been proposed as a planet-wide alteration process (Hurowitz and McLennan, 2007).

Soil development in basaltic material (typically tephra) on Earth usually leads to formation of andosols. Although we do not suggest a one-to-one analogy between dark basaltic Martian soils and andosols, there may be important similarities, as andosols are typified by significant production of allophane as well as poorly crystalline Fe-hydroxides. The detection of allophane on Mars suggests a positive utility of an andosol model for Martian soils, particularly when coupled with the ubiquitous presence of Fe-oxide materials on Mars. An andosol model of soil formation is mineralogically consistent with palagonite models for the formation of Martian dust (cf. Banin et al., 1992; Morris et al., 2001), which suggests a possible genetic relationship of dust and bright soils to the broader soil layer of Mars.