

THE EFFECTS OF SMALL AMOUNTS OF CHEMICAL WEATHERING ON THERMAL INFRARED SPECTRAL MODELS: IMPLICATIONS FOR MARTIAN SURFACE MINERALOGY. E. B. Rampe¹, M. D. Kraft¹, T. G. Sharp¹, J. R. Michalski² ¹Arizona State University, School of Earth and Space Exploration, PO Box 871404 Tempe, AZ 85287-1404, Liz.Rampe@asu.edu, ²California Institute of Technology, Jet Propulsion Laboratory.

Introduction: The presence of recent gullies and ancient channels, hydrated minerals, ice deposits, and hydrogen in the near surface indicate water has been present on Mars for billions of years [1-4]. Spectral data from Mars, *in situ* chemical data, and SNC meteorites show that the martian surface is primarily composed of basalt [5-7]. Intermittent interactions between basalt and water over billions of years can cause the formation of chemical weathering products, such as amorphous silica and clay minerals.

Linear deconvolution is the primary method for modeling the mineralogy of TIR spectra, including spectra from the Thermal Emission Spectrometer (TES) on Mars Global Surveyor and Mini-TES on the Mars Exploration Rovers. It has been demonstrated that linear deconvolution is a valid technique for modeling the mineralogy of fresh igneous and metamorphic rocks, SNC meteorites, and coarse-grained mixtures of primary minerals [8-13]. However, the effect of small amounts of weathering products on modeled mineralogy is not straight forward. Previous studies have shown that chemical weathering can cause difficulties in modeling TIR spectra. For example, TIR spectra of basalt slabs coated with amorphous silica could not be modeled accurately as a mixture of the basalt substrate and silica coating because of nonlinear mixing [14]. Additionally, studies on the mineralogy of fresh and weathered surfaces of Columbia River Basalts showed that the primary mineralogy did not differ between the fresh and weathered surfaces, but TIR spectral models showed a change in primary mineralogy between the fresh to the weathered surfaces [15, 16]. Therefore, it is important to understand how different chemical alteration products affect TIR spectra and linear deconvolution models. The experiments presented here investigate the effects of small amounts of chemical alteration products on the modeled mineralogy of TIR spectra from simple physical mixtures.

Methods: We created physical mixtures of one or two primary minerals and one secondary alteration material. The primary minerals included andesine (plagioclase feldspar), augite (clinopyroxene), and a 50:50 wt% mixture of andesine and augite. The size of the primary minerals was 75-106 μm . To these primary minerals, we added a secondary alteration

material in 2.5, 5, 10, and 20 wt% abundances. The secondary materials included montmorillonite clay, synthetic amorphous silica, and synthetic aluminous amorphous silica in the $<2 \mu\text{m}$ size fraction.

To mimic the texture of loose soil, we created loose particulate mixtures and to mimic the texture of rock, we created pressed pellet mixtures. TIR spectroscopy was performed on the mixtures and the spectra were modeled by linear deconvolution over the range 200-2000 cm^{-1} with two libraries: one library contained the starting materials in the mixtures, and the second library contained the starting materials in the mixtures, other primary minerals commonly found in basalts, three types of primary glass, and a variety of clay minerals.

Results: The presence of small amounts of secondary materials caused non-linear mixing effects that could not accurately be modeled by linear deconvolution. Models of montmorillonite-bearing mixtures consistently overestimated the montmorillonite contents. Models of amorphous silica-bearing mixtures generally underestimated the abundance of amorphous silica, especially in the particulate mixtures.

The presence of secondary products resulted in inaccurate models of primary mineralogy in mixtures that contained 50:50 weight % andesine and augite. For example, the modeled plagioclase-to-pyroxene ratio was less than the actual plagioclase/pyroxene ratio when montmorillonite was present in the mixtures, while the modeled plagioclase/pyroxene ratio tended to be greater than the actual plagioclase/pyroxene ratio when amorphous silica was present in the mixtures (Fig. 1).

A final result is that primary glass (basaltic glass and high-silica glass) is commonly modeled (as high as 40 volume %) in mixtures that contained amorphous silica or montmorillonite, but no primary glass (Fig. 2).

Discussion: The results of these experiments have important implications for martian surface mineralogy as determined by TIR spectroscopy and linear deconvolution. First of all, it appears that the type of secondary alteration product present can affect the modeled abundances of primary minerals in the mixtures. Small amounts of weathering products on the surface of Mars may result in modeled primary mineral abundances that differ from the actual primary

mineral abundances, resulting in a possible misinterpretation of the igneous history of the martian surface. For example, spectral models from TES identify basalt at low latitudes (Surface Type 1) and andesite at mid-to-high-latitudes (Surface Type 2) [5]. Surface Type 1 models identify predominantly plagioclase and pyroxene, while Surface Type 2 models identify plagioclase and a high-silica phase commonly identified as high-silica glass, with little pyroxene. The high plagioclase/pyroxene ratio modeled in Surface Type 2 may be a result of coatings of amorphous silica produced by chemical weathering. Similarly, the primary glass identified in Surface Type 2 spectral models could be a result of the presence of a secondary silicate, like amorphous silica. Therefore, Surface Type 2 could have a basalt composition, containing plagioclase and pyroxene, but small amounts of amorphous silica could cause a lack of pyroxene and high amounts of primary glass in spectral models. The presence of secondary silicates may also explain the disagreement between the *in situ* APXS chemical data and modeled mineralogy from Mini-TES spectra of Clovis class rocks in Gusev crater. Chemical data indicate that Clovis rocks are chemically altered [17]. However, Mini-TES spectral models identify significant amounts of primary glass [18]. These conflicting data can be reconciled by the presence of secondary silicates because they form as a result of chemical alteration and can cause primary glass to be identified in spectral models.

References: [1] Sharp R. P. and Malin M. C. (1975) *GSA Bull.*, 86, 593-609. [2] Bibring J.-P. et al. (2006) *Science*, 312, 400-404. [3] Thomas P. et al. (1992) in *Mars*, Univ. Arizona Press, 767-795. [4] Feldman W. C. et al. (2002) *Science*, 297, 75-78. [5] Bandfield J. L. (2002) *JGR*, 107, E6. [6] Gellert R. (2004), *Science*, 305, 829-832. [7] McSween H. Y., Jr. (2002) *Meteoritics and Plan. Sci.*, 37, 7-25. [8] Ruff S. W. (1998) Ph.D. Dissertation, Arizona State University. [9] Hamilton V. E. et al. (1997) *JGR*, 102, 25,593-25,603. [10] Ramsey M. S. and Christensen P. R. (1998) *JGR*, 103, 577-596. [11] Wyatt M. B. (2001) *JGR* 106, 14,711-14,732. [12] Hamilton V. E. and Christensen P. R. (2000) *JGR*, 105, E4. [13] Feely K.C. and Christensen P. R. (1999) *JGR*, 104, 24,195-24,210. [14] Kraft M. D. et al. (2003) *Geophys. Res. Lett.*, 30, 24. [15] Michalski J. R. et al. (2006) *EPSL*, 248, 822-829. [16] Kraft M. D. et al. (2006) *Geochim. Cosmochim. Acta Supp.*, 70, 335. [17] Ming D. W. et al. (2006) *JGR*, 111, E02S12. [18] Ruff S. W. et al. (2006) *JGR*, 111, E12S18.

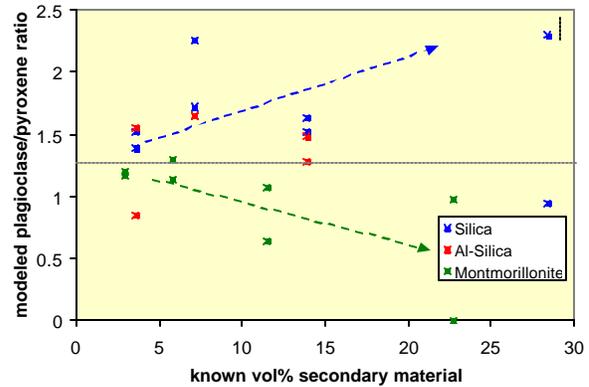


Figure 1. The modeled plagioclase/pyroxene ratio vs. the known volume % of the secondary phase in mixtures containing amorphous silica (blue points), aluminous amorphous silica (red points), and montmorillonite (green points). The actual plagioclase/pyroxene ratio in the mixtures is denoted by the horizontal gray line. If the models identified the exact plagioclase/pyroxene ratio in the mixtures, all points would plot on the horizontal line. Instead, the addition of amorphous silica in the mixtures tends to increase the modeled plagioclase/pyroxene ratio (blue line), and the addition of montmorillonite results in a decrease in the modeled plagioclase/pyroxene ratio (green line). The blue point with the black arrow at the upper right-hand corner of the graph indicates a measured point plotting at a plagioclase/pyroxene ratio of 7.9.

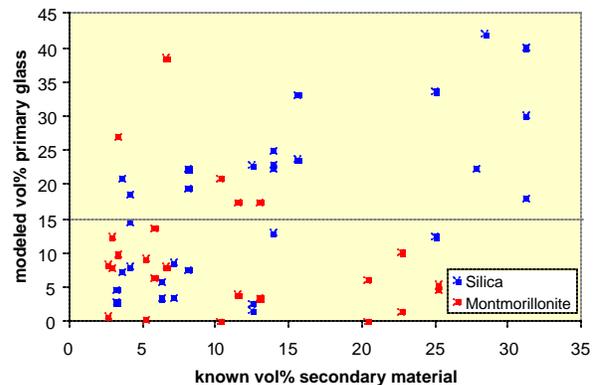


Figure 2. The modeled vol% of primary glass (basaltic glass + high-silica glass) vs. the known vol% of the secondary material for mixtures containing amorphous silica (in blue) and montmorillonite (in red). Mixtures that contained amorphous silica or montmorillonite modeled primary glass in significant abundances (15 vol% is the approximate detection limit and is denoted by the horizontal gray line). No primary glass was present in the mixtures, but some models identified 40 vol% primary glass.