

EFFECTS OF CHEMICAL WEATHERING ON THE DETECTION OF IGNEOUS MINERALS IN THERMAL INFRARED SPECTRAL MODELS. E. B. Rampe¹ M. D. Kraft¹, A. D. Rogers², T. G. Sharp¹

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Introduction: Remote and *in situ* chemical and mineralogical data from the martian surface show evidence for chemical weathering in the form of chemical mobility [1-3] and the presence of minor amounts of chemical alteration products [4,5], such as clay minerals and a high-silica phase at high latitudes which has been interpreted as volcanic glass or a weathering product [6-8]. It has been shown that igneous mineral abundances of terrestrial rocks and physical mineral mixtures can be accurately determined through thermal infrared (TIR) spectral modeling [9-14]. However, small amounts of chemical alteration products can have a large effect on the identification of primary igneous minerals through remote sensing measurements [15]. For example, TIR spectral modeling of weathered terrestrial basalts has shown that the relative igneous mineral abundances in weathering rinds cannot be determined accurately [16,17]. One of the problems in studying naturally weathered rocks is the hodgepodge of crystalline and amorphous alteration products which may be difficult to characterize. Here, we measured TIR spectra of physical mixtures of primary igneous minerals and well-characterized alteration products to investigate how weathering can affect the ability to accurately identify plagioclase, clinopyroxene, and olivine abundances in TIR spectral models.

Experimental Procedure: We created simple physical mixtures containing one or two igneous minerals (in a 1:1 ratio by weight) and one alteration phase. The igneous minerals in the mixtures were 76-105 μm in size and included olivine (Fo91), plagioclase (andesine, An30), and clinopyroxene (augite, $\text{Wo}_{48.4}\text{En}_{49.2}\text{Fs}_{2.4}$). The alteration phases were $<2\ \mu\text{m}$ in size and included smectite clay (montmorillonite) and synthetic amorphous silica. The alteration phases were present in small to moderate amounts: 2.5, 5, 10, and 20 wt% of the mixtures. To explore the effects of texture on TIR spectra and spectral modeling, we created loose particulate we compressed pellet mixtures in which we attempted to coat the primary igneous grains with the alteration phase.

We performed TIR spectroscopy on the mixtures at the Mars Space Flight Facility at Arizona State University on a Nicolet Nexus 670 spectrometer, configured to measure emitted energy [9,18]. We

measured over a 200-2000 cm^{-1} wavelength range. We used linear deconvolution spectral modeling over a 350-1300 cm^{-1} wavelength range to determine model-derived mineral abundances. Linear deconvolution is a linear least squares algorithm that uses a library of mineral spectra to create a modeled spectrum that looks most like the measured spectrum. Our library was made up of minerals commonly found in fresh and weathered basalts, including multiple plagioclase and clinopyroxene compositions, forsterite and fayalite, four volcanic glass compositions, and many secondary silicates, including montmorillonite and other clay minerals, synthetic amorphous silica, and opal-A.

Results of TIR Spectral Modeling: In general, the spectral models correctly identified the igneous minerals in the mixtures. However, for the mixtures that contained two igneous minerals and an alteration phase, models often incorrectly identified the relative abundances of the igneous minerals.

For mixtures containing plagioclase and clinopyroxene in a 1:1 ratio by weight and small to moderate amounts of montmorillonite, the modeled plagioclase-to-pyroxene ratio was less than the actual ratio in the mixtures. Conversely, the modeled plagioclase-to-pyroxene ratio was greater than the actual ratio when amorphous silica was present in the mixtures (Fig. 1).

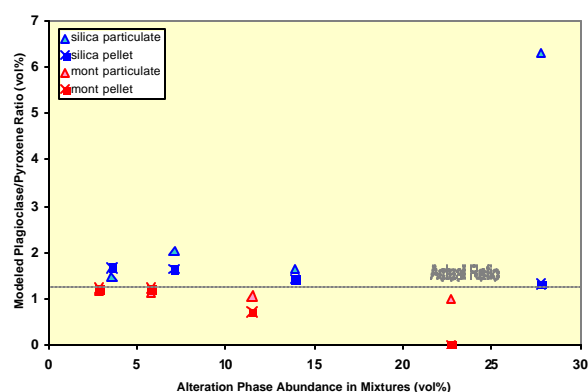


Figure 1. The modeled plagioclase-to-pyroxene ratio vs. the known vol% of the alteration phase in mixtures containing amorphous silica (blue points) and montmorillonite (red points). The actual plagioclase-to-pyroxene ratio in the mixtures is denoted by the horizontal dashed line.

For mixtures containing small to moderate amounts of montmorillonite or amorphous silica and olivine and plagioclase or olivine and clinopyroxene in 1:1 ratios by weight, the modeled olivine-to-plagioclase and olivine-to-pyroxene ratios were greater than the actual ratios in the mixtures. The type of secondary silicate present in the mixtures does not seem to affect the modeled olivine-to-plagioclase and olivine-to-pyroxene ratios (Figs. 2 and 3).

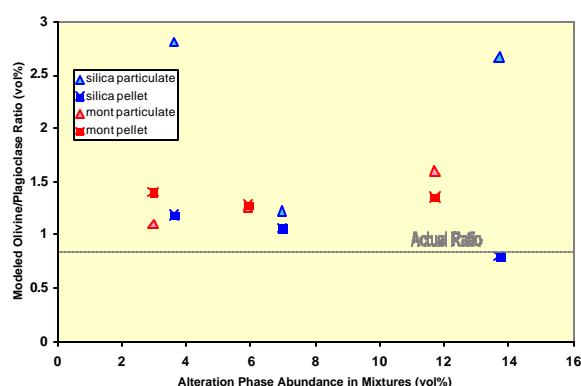


Figure 2. The modeled olivine-to-plagioclase ratio vs. the known vol% of the alteration phase in mixtures containing amorphous silica (blue points) and montmorillonite (red points). The actual olivine-to-plagioclase ratio in the mixtures is denoted by the horizontal dashed line.

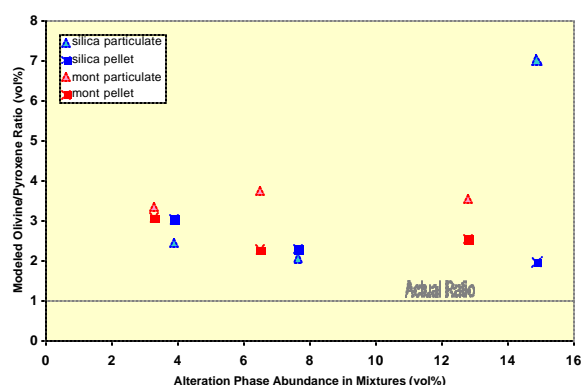


Figure 3. The modeled olivine-to-pyroxene ratio vs. the known vol% of the alteration phase in mixtures containing amorphous silica (blue points) and montmorillonite (red points). The actual olivine-to-pyroxene ratio in the mixtures is denoted by the horizontal dashed line.

Discussion: We believe that the issues in correctly identifying relative igneous abundances in spectral models may be due to the absorption positions of the alteration phases relative to the absorption positions of the igneous phases. For example, andesine, augite, montmorillonite, and amorphous silica all have absorptions due to Si-O stretching vibrations over a similar wavelength region. Conversely, the Si-O stretching absorptions in olivine occur at slightly

longer wavelengths. Because the alteration products absorb in the same wavelength region in which andesine and augite absorb, they may cause non-linear spectral mixing effects and make it more difficult to detect plagioclase and clinopyroxene than olivine. This may lead to the higher modeled olivine-to-plagioclase and olivine-to-pyroxene ratios in mixtures with small to moderate amounts of montmorillonite or amorphous silica.

The effects of small amounts of chemical alteration on the identification of primary igneous phases in TIR spectral models have important implications for martian surface geology. TIR spectral models are used to determine igneous rock types and petrologic history of the crust [6,19]. If small amounts of chemical alteration products are present on the surface, they may impede the ability to accurately determine martian petrologic history. TES and THEMIS show a broad global dichotomy in igneous mineral distributions, with plagioclase- and pyroxene-rich surfaces at low latitudes and plagioclase-rich and pyroxene-depleted surfaces at high latitudes [6,19]. We suggest chemical weathering as a possible explanation for these global igneous mineral trends observed in TIR data. If the high-silica phase identified at high latitudes is amorphous silica, our experimental data show that the relative igneous mineral abundances modeled from TIR data of these surfaces will show a deficiency in pyroxene and enrichment in plagioclase.

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