THE IMPORTANCE OF AN INVESTIGATION OF THE NORTHERN PLAINS. E. B. Rampe[1], M. D. Kraft[1], and T. G. Sharp[1], [1]Arizona State University School of Earth and Space Exploration, P.O. Box 1404 Tempe, AZ 85287-1404, Liz.Rampe@asu.edu.

Introduction: Thermal infrared (TIR) spectral models of low-albedo areas of the martian surface show a broad, global-scale compositional dichotomy in which the low latitudes are dominated by pyroxene and plagioclase and high latitudes are composed of plagioclase and a high-silica phase [1-3]. Initially, the high-silica phase was identified as primary volcanic glass [1], so basalt dominated low latitudes (termed surface type 1, or ST1) and andesite dominated mid to high latitudes (surface type 2, or ST2). However, spectral similarities between volcanic glass and silicate chemical weathering products led others to suggest the presence of alteration phases at ST2 [4-8] so that the compositional dichotomy was a result of chemical weathering of ST2. The nature of the high-silica phase is still unknown and its composition has important implications for the history of liquid water on the martian surface. For example, while evidence supporting the presence of weathering products over volcanic glass is growing, if glass is present, it suggests a lack of liquid water at high latitudes because glass is highly susceptible to aqueous alteration. Additionally, it necessitates an igneous origin for the compositional dichotomy, rather than chemical weathering. However, if alteration products are present in the northern plains, the nature of the alteration products can elucidate details of the history of liquid water on the surface, such as amount of liquid water present and duration of wet conditions, pH of the solution, minerals being weathered, and mechanisms for soil development. Research has also shown that alteration phases can affect igneous mineralogic interpretations from remote sensing measurements [5-7,9-13]. Therefore, a sample return mission to the northern plains is important for explaining the compositional dichotomy and the petrologic evolution of the surface.

Evidence for Water in the Northern Plains: The identification of volcanic glass in TIR spectral models from the martian surface [1,14] is evidence for a lack of liquid water in the northern plains. However, there is a wealth of evidence from Mars for a possibly habitable environment in which liquid water existed. For example, gullies, proposed to be formed by melt water from snow and/or ice, are widespread at mid to high latitudes [15-21]. Mantled terrains, attributed to the presence of surface ice and/or permafrost, are also prevalent in these regions [22-24], and the Vastitas Borealis Formation has been suggested to have formed by permafrost-related activities [25]. GRS data also show high levels of hydrogen, attributed to near-surface water ice [26]. GRS and TES analyses support the formation of a silica-rich rind or coating on ST2 because derived chemistry from TES shows a higher SiO_2 content for ST2 than ST1, while GRS data show essentially no change between ST1 and ST2 SiO_2 abundances. This is attributed to a difference in sampling depth, where TES samples the upper tens of microns so that the weathering rind/coating has a large effect on derived chemistry and GRS samples the upper tens of cm so that the weathering rind/coating does not affect derived chemistry [27].

Interpretations from Remote Sensing Experiments: It has been suggested that chemical alteration of the martian surface resulted in the formation of amorphous to poorly crystalline aluminosilicates, rather than crystalline clay minerals [5-7,28]. Our research is concerned with the ways in which chemical weathering and authigenic phases affect remote sensing measurements and interpretations. We have presented research on TIR and visible near-infrared (VNIR) spectra of natural weathering rinds of Columbia River basalts (CRBs), synthetic silica coatings on basalt, and TIR spectra and spectral models of physical mixtures of igneous and alteration phases [5-7,9-13].

Our research shows that TIR spectra and spectral models are greatly affected by relatively small amounts of weathering, while VNIR spectra are not. For example, TIR spectral models of CRB weathering rinds identify significant amounts of glass and/or clay minerals [6,9-10]. These materials are not present in the rinds (igneous minerals and poorly-crystalline, Si-Al-Fe-enriched phases are the only phases present), and their identification in spectral models increases the derived silica content of the surfaces. This is apparent in spectral models of ST1 vs. ST2, where ST1 models have lower silica than ST2 [1-3]. VNIR spectra of CRB rinds are brighter than fresh surfaces, but do not contain absorptions to indicate a greater extent of weathering [6]. VNIR data from the northern plains of Mars also do not contain absorptions that indicate chemical weathering [29,30]. Additionally, TIR spectra and spectral models of silica-coated basalt slabs show that thin coatings (~1 µm) have a large effect on the underlying basalt spectrum. Linear deconvolution modeling, a linear least squares algorithm used to interpret martian surface mineral abundances from TIR spectra, is unsuccessful for silica-coated basalts [7]. However, VNIR spectra of silica-coated basalt particulates do not show evidence for thin silica coatings [11].

Our research also shows that the presence of alteration phases can affect the interpreted igneous mineral abundances from TIR spectra. TIR spectral models of CRB weathering rinds indicate a higher plagioclase-to-pyroxene ratio than is actually present in the rocks [13]. TIR spectral models of physical mixtures of one or two basaltic igneous minerals and a secondary silicate (silica or smectite clay) also show the presence of a secondary silicate can affect how we interpret primary igneous mineralogy. The presence of silica in a 1:1 wt% mixture of plagioclase and pyroxene cause an increase in the interpreted plagioclase-to-pyroxene ratio from spectral models, while smectite causes a decrease [12]. With the mounting evidence for chemical weathering in the northern plains, plans for sample return missions must include samples from the northern plains.

What a Sample from the Northern Plains Can Tell Us: There are two important questions that such a sample can help us answer: 1) How did the martian surface evolve petrologically? 2) What is the history of liquid water in the northern plains and was the area habitable?

Although research by us and others has helped explain the effects of chemical weathering on remote sensing interpretations of igneous mineral abundances, the effects are still not completely understood. Rampe et al. (2007) suggested that if amorphous silica is present, it may mask the identification of pyroxene in TIR spectral models. Consequently, TIR models from ST1 contain pyroxene while models from ST2 do not [1-3], possibly indicating silica is present in ST2 and obscuring the observation of pyroxene. If a sample is returned from the northern plains, we can determine igneous mineral abundances to compare to TIR spectral models and investigate whether apparent ST1 and ST2 compositional differences are due to igneous variability, disparities in authigenic phase abundances, or a combination of the two. This information will help constrain the petrologic history of the crust.

To characterize the alteration phases and determine the igneous minerals that are chemically altering, we must have a hand sample for analysis. In the rocks of the northern plains, where liquid water is limited, alteration phases are expected to be amorphous or poorly crystalline [5-7,9-12,28], and therefore require microscopy, such as transmission and scanning electron microscopy, for their characterization. The types of secondary alteration phases present and the igneous minerals that are dissolving to produce alteration phases can tell us how much liquid water was present, the duration of liquid water, and the pH of the solution. Since soil develops from the alteration of rocks, understanding the phases within the weathering rinds will help explain soil formation processes on Mars.

A major goal of a sample return mission is to target a habitable area with the hopes of finding evidence for life. Martian data and analog studies support the presence of liquid water in the northern plains. It has been proposed that near-surface environments in the northern plains may have been and still may be able to support chemoautotrophic microbes [31,32]. Martian data and analog studies also support the presence of amorphous silica in the northern plains. On Earth, the oldest microfossils are preserved in silica (chert) [33], rather than clay-rich sedimentary rocks, as are present in the Noachian highlands. The northern plains are a prospective place to find evidence for life because of its habitability and potential for microfossil preservation.

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