

THE EFFECTS OF OXIDATION ON SPECTRA OF SNC-LIKE BASALTS: APPLICATIONS TO MARS REMOTE SENSING. M. E. Minitti, M. J. Rutherford and J. F. Mustard, Brown University, Department of Geological Sciences, Providence, RI, 02912 (Michelle_Minitti@brown.edu).

Introduction: Recent results from the Thermal Emission Spectrometer (TES) on the Mars Global Surveyor mission reveal two broad categories of spectra associated with dark, low thermal inertia regions on the Martian surface. One category of spectra correlates well with fully crystallized terrestrial basalt spectra while the second set of spectra correlates well with glassy terrestrial basaltic andesite [1].

The modal mineralogies of the basaltic and basaltic andesite compositions measured by TES were estimated by a linear mixing model [e.g. 2]. A mode of 45-53 vol% plagioclase, 19-26 vol% pyroxene and potentially 10-15 vol% olivine and sheet silicates yield the best fit to the basaltic spectra [2]. The terrestrial basaltic andesite that provides the best match to the Martian basaltic andesite spectra has 45 vol% volcanic glass, 40 vol% plagioclase, and 10 vol% pyroxene [1]. The plagioclase/pyroxene ratios that best reproduce the basaltic and basaltic andesite TES spectra, however, differ markedly from the plagioclase/pyroxene ratios measured and calculated for the basaltic SNC magmas. All calculated modes for the basaltic TES spectra have plagioclase/pyroxene ratios (vol%) between ~1.3-2.8 [2] and the terrestrial rock with the best fit to the Martian basaltic andesite data has a plagioclase/pyroxene ratio (vol%) of 4 [1]. In contrast, the range of plagioclase/pyroxene ratios (vol%) for basaltic shergottites is 0.38-0.88 [3], which correlates with the low Al_2O_3 contents of calculated shergottite parent melts [4]. Low Al_2O_3 compositions are also indicated by quantitative modeling of pyroxene compositions in NIR spectra of dark terrains [5].

The contrast between the mineralogy determined from TES spectra, that determined from NIR measurements and the mineralogy of the SNC meteorites raises interesting possibilities. Is TES detecting plagioclase-rich materials, possibly the missing Al_2O_3 -rich complement to the SNC source? Do our only samples of Mars not originate from the planet-wide dark regions of Mars observed by TES? Or, could a surface process such as oxidation mask a SNC-like composition of the surface materials? The red color of Mars testifies to its oxidized nature and direct observations of nanophase hematite on the Martian surface have been made [e.g. 6]. In addition, [7] demonstrated that oxidation affects the spectra of Fe-bearing minerals including Ca-rich and Ca-poor pyroxenes. In light of these studies, it is possible that surface oxidation on Mars might preferentially affect Fe-bearing pyroxene minerals, leading to an elevation of detected

plagioclase/pyroxene ratios. One goal of this study, therefore, is to understand the effect of oxidation on spectra of SNC-like basalts with varying crystallinities and mineralogies as a potential tool in understanding TES results. A second goal of this study is to determine the effects of variable amounts and compositions of glass on spectral properties.

Experimental: In order to study the effects of oxidation on the spectra of Martian basalts, we are synthesizing a series of basaltic materials from a variation of the A* composition [8]. This starting composition is a high-FeO, low- Al_2O_3 basalt that represents common SNC parent melt compositions. All basalts are crystallized dry at one atmosphere and at the QFM oxygen buffer. Experimental temperatures range from 1130 °C to 980 °C which yields crystallinities from ~10% to ~90% [9].

After a fresh synthesized basalt is fully chemically and spectrally analyzed (see *Analytical*), it is ground and subjected to an initial oxidation step. The oxidation step involves heating the ground basalt to elevated (> 500 °C) temperatures and exposing the basalt to air for various lengths of time. Once oxidized, the basalt is cooled in air. After chemical and spectral analysis of the oxidized basalt, additional oxidation steps are conducted in order to understand the effect of varying degrees of oxidation on a single sample.

Analytical: Both the unoxidized and oxidized versions of a synthesized basalt are analyzed for their chemical and spectral characteristics. Chemical analyses include measurement of glass and phenocryst compositions on the Cameca Camebax electron microprobe at Brown University. The electron microprobe results are utilized in the PETMIX program [10] to determine the mode of each basalt. Spectral analyses are conducted at the RELAB facility at Brown University. Reflectance spectra between 0.32 μm and 2.55 μm are obtained by the bi-directional spectrometer with a 30° incidence angle and a 0° emergence angle. Biconical reflectance spectra between 1.8 μm and 26 μm are obtained on the FTIR spectrometer with a 30° incidence angle and a 30° emergence angle. Ultimately, we plan to attempt deconvolution of the unoxidized and oxidized basalt spectra into component mineral spectra in order to investigate changes in the predicted mode produced by the oxidation process.

Preliminary Results: We have conducted chemical and spectral analyses on an initial set of unoxidized and oxidized basalts. For this initial experi-

ment, we crystallized two separate basalts at the same conditions (1130 °C, dry, 1 atm, QFM) and oxidized only one of them (rather than analyzing an unoxidized and oxidized version of the same sample). Chemical analyses of both basalts prior to oxidation indicate that they consist of 86 wt% basaltic glass (50% SiO₂, 20% FeO) and 14 wt% pigeonite. For the oxidation step, the basalt sample was ground to a 75-500 μm particle size and exposed to air at 600 °C for 7 days. Initial spectral analyses were conducted on the unoxidized and oxidized samples with particle sizes between 75-500 μm. Further spectral analyses were conducted on both samples after they were reground to particle sizes of <45 μm.

After undergoing the oxidation step, very fine (< 1μm), uniformly dispersed crystalline phases appear throughout the glass. The small size of the phases prevents their compositional analysis and the presence of these phases precludes analysis of the glass. At the petrographic scale, the amount of pyroxene in the oxidized basalt appears relatively unchanged and the pyroxenes appear unrimmed by oxides and intact overall.

Figure 1 illustrates the biconical reflectance spectra of the unoxidized and oxidized basalts with 75-500 μm particle sizes from 400 to 1400 cm⁻¹. The unoxidized basalt spectrum (Fig. 1) resembles the Martian basaltic spectra reported in [2], most notably between 800-1200 cm⁻¹. The unoxidized basalt spectrum shows a broad, featureless restraehlen band between 800-1200 cm⁻¹ and a distinct Si-O bending absorption near 500 cm⁻¹. The spectral properties are apparently dominated by glass, as no distinct features typical of pyroxene are observed. The oxidized basalt spectrum (Fig. 1) differs from the unoxidized spectrum, but the complexities of the spectrum are not well understood.

Figure 2 more clearly demonstrates the effect of oxidation on the basaltic spectra. The unoxidized spectrum exhibits clear pigeonite absorptions at ~ 0.92 μm and ~1.82 μm. The broad diffuse band between 0.9 and 1.5 μm is likely due to the glass within the sample. In the oxidized spectrum, both pyroxene features have completely disappeared, leaving a reflectance peak at ~0.79 μm as the only feature. This is most likely due to the presence of nanophase hematite, created by the thermal oxidation of pigeonite in air [7]. The spectrum of the oxidized basalt suggests that even though pyroxene is still present, the optical properties of the sample mask the presence of pyroxene in the spectrum.

Implications: The results of the initial synthesis experiment show strong similarities to Martian spectral properties from the visible through the thermal IR.

This implies that glass of SNC composition is an important component of the Martian surface. Glass of SNC composition could result from volcanic or impact processes [11]. The initial oxidation experiment may represent an upper limit of the degree of oxidation relevant to current Martian spectral data. However, the oxidation experiment convincingly demonstrates that oxidation affects the spectra of SNC-like basalts containing Fe-bearing minerals and the results will guide future oxidation experiments.

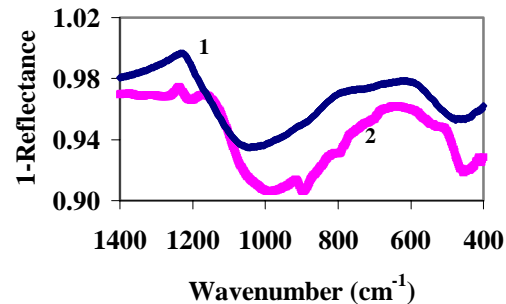


Figure 1: Spectra of unoxidized (1) and oxidized (2) SNC-like basalts crystallized dry at 1 atm, 1130 °C and QFM (crystallinity = 15 wt% pigeonite). Particle sizes of the crushed basalts range between 75-500 μm.

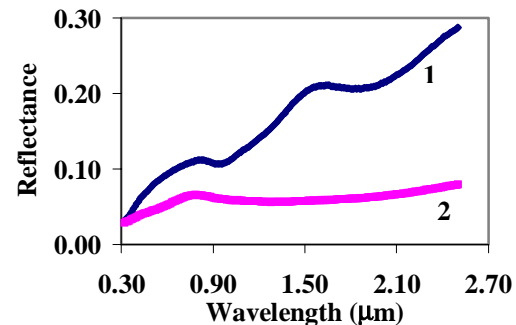


Figure 2: Spectra of unoxidized (1) and oxidized (2) SNC-like basalts with particle sizes <45 μm.

References: [1] Bandfield J.L. et al. (1999) *Fifth Intl. Conf. Mars*, #6036. [2] Christensen P. R. et al. (1999) *JGR-Planets*. In press. [3] Lodders K. (1998) *Meteoritics & Planet. Sci.* 33, A183-A190. [4] McSween H.Y. (1994) *Meteoritics* 29, 757-779. [5] Mustard J.F. and Sunshine J.M. (1995) *Science* 267, 1623-1626. [6] Singer R.B. (1982) *JGR* 86, 7967-7982. [7] Straub et al. (1991) *JGR* 96, 18819-18830. [8] Johnson et al. (1991) *GCA* 55, 349-366. [9] Minitti M.E. and Rutherford M. J. (1999) *GCA*, submitted. [10] Wright T.L. and Doherty P.C. (1970) *Bull. Geol. Sci. Amer.* 81, 1995-2008. [11] Schultz P.H. and Mustard J.F. (1998) *LPSCXXIX*, #1847.