

**TYPE 2 TERRAIN: COMPOSITIONAL CONSTRAINTS ON THE MARTIAN LOWLANDS** S. K. Noble and C. M. Pieters, Brown University, Dept of Geological Sciences, Providence RI 02912. noble@porter.geo.brown.edu

**Introduction:** The Mars Global Surveyor Thermal Emission Spectrometer (TES) team has identified two distinct Martian terrains, Type 1 and Type 2 [1,2]. Type 1 is interpreted as basaltic. It is found throughout the southern highlands, particularly in the Syrtis Major region. Type 2, is interpreted as a basaltic andesite and is most strongly concentrated in the Amazonian age northern lowlands.

Possible andesites on Mars have been discussed previously in the literature. The Pathfinder team identified their "sulfur-free rock" as having a basaltic andesite composition [3]. Even as far back as Viking, terrestrial andesite was used as a spectral analog in modeling the surface rocks near the Viking 1 lander [4]. There have also been basaltic andesite compositions suggested from flow rheology [5,6].

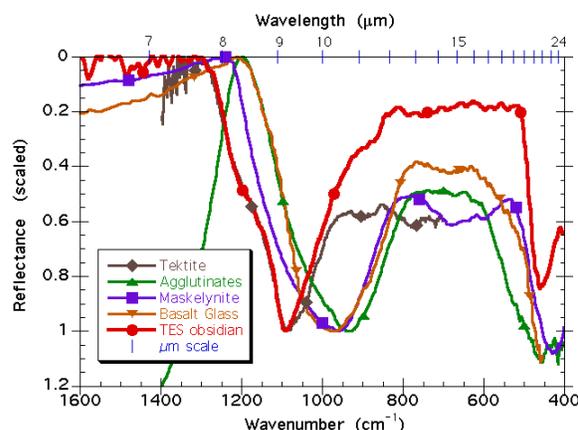
The interpretation of basaltic andesite has caused considerable discussion since it was put forth as an explanation for the TES data. Andesites on Earth are relatively rare, found mostly in subduction zones. If Mars does not have plate tectonics, then Martian andesites would have to form by a different mechanism. More silicic magma compositions can be obtained through fractional crystallization. This requires extracting small amounts of melt, a difficult way to produce such large amounts of andesite. However, adding even small amounts of water to a melt can produce andesitic magmas. Minitti and Rutherford [7] have found that an andesite of the "sulfur-free rock" composition can easily be created from a SNC parental magma with the addition of just 1 wt % H<sub>2</sub>O.

**Interpretation of TES Type 2 terrain:** Deconvolving TES spectra is not an easy task. Global dust and atmospheric components must first be estimated [8]. The TES team uses a spectral deconvolution program to determine the modal composition of their residual surface spectra [9]. This process involves fitting the spectra with endmembers from a spectral library [10]. This deconvolution method has proven itself to be rather successful for determining modal mineralogy of known samples to within ~10% error for major minerals, though it does not appear to be reliable for minor minerals present at <10% [9,11]. The method however, is highly dependent on several assumptions: 1) The minerals present occur in exposed rocks or as large particles [12,13]. 2) Mixtures behave as a linear combination of individual components [13,14]. 3) The correct endmembers are present in the spectral library [11].

**Glass Issues:** The TES team's spectral deconvolution of Type 1 terrain gives a solution of 50% plagioclase, 25% clinopyroxene, and 15% sheet silicates (concentrations of 15% or less are considered to be at or below the detection limit [9]). Type 2 terrain gives 35% plagioclase, 10% clinopyroxene, 15% sheet silicates, and 25% obsidian-like (high silica) glass [1]. However, the TES

spectral deconvolution library used contained no pigeonite and one glass sample, an obsidian-like high-silica glass. The TES team recognizes that these missing library endmembers may affect interpretations [15,16].

Due to the highly disordered nature of glass, the spectral features of all glasses are generally broad and amorphous. Spectral variation of glasses are shown in figure 1 for a wide range of compositions. In fitting the TES spectra, broad or glassy spectra tend to act as convenient "fillers" as the program tries to minimize the error in its fit. Thus, if glass is indeed a major component of terrain Type 2, its derived silica content depends directly on the glasses available as endmembers in the spectral library.



**Figure 1.** Scaled spectra for glasses of diverse compositions: The TES spectral library's obsidian (TES obsidian), an unweathered basaltic glass from Hawaii (from Crisp et al [19]), a shocked lunar plagioclase (maskelynite), lunar soil agglutinates and a tektite. The spectra have been scaled to allow comparison by setting the maximum reflectance to 1.0 and the minimum to 0.0.

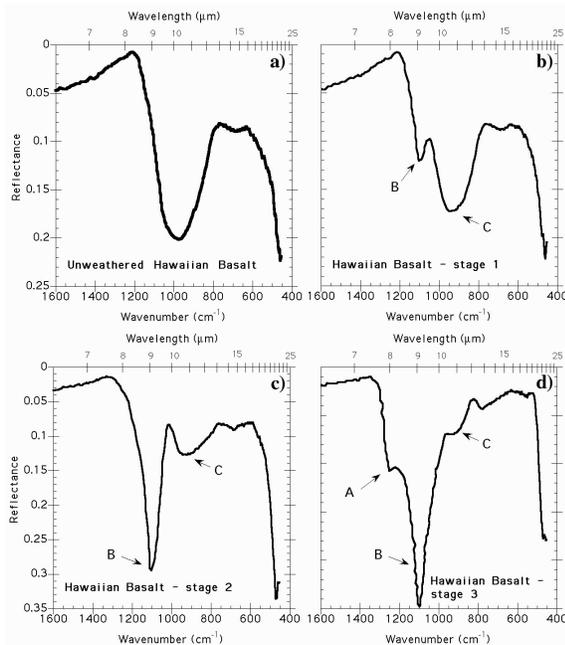
**Weathering Issues:** Deconvolving TES spectra of the surface is particularly difficult given the unknown effects of weathering in Martian conditions.

The effects of terrestrial weathering on thermal infrared spectra of basaltic Hawaiian glasses have been well characterized [17,18,19]. Shown in Figure 2 are several spectra from Crisp et al. [19], which illustrate systematic changes observed as a glassy surface is exposed and oxidized. First the reflectance peak (emission minimum) near 10 $\mu$ m (1000cm<sup>-1</sup>) of unweathered glass evolves into a B and C feature. The B feature grows quickly and soon dominates the C feature, which becomes reduced to simply a shoulder on the B feature. (Often a separate feature labeled 'A' develops as well, but this feature is the result of a different mechanism, silica coatings on the surface, which are not expected to form on Mars in the absence of rainfall [3].) The B feature is associated with sheet-like silicate structures and the C feature with chain-like struc-

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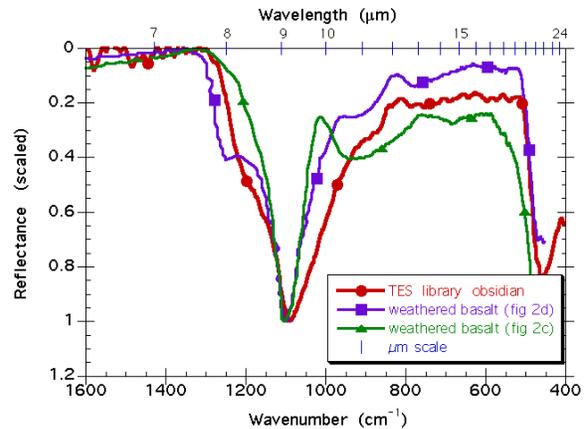
tures. The B and C features appear to be a result of divitrification of the glassy surface [19]; as the glass becomes increasingly ordered the more highly polymerized sheet-like tetrahedral structures replace the chain-like tetrahedral structures. The basalts used in the Crisp et al. study [19] are from the semi-arid regions of Hawaii and do not yet show any signs of palagonization. However, they do show signs of oxidation on their surface. By enhancing the degree of polymerization, iron oxidation may contribute to the spectral changes observed [19].

The weathering environment on Mars, of course, is different than Hawaii, but a similar process may be operating. We know that oxidation occurs on Mars, its visible red color is testament to that. If the Martian surface contains basaltic glass, perhaps weathering processes comparable to those on Hawaii occur causing the glass to divitrify. The result of increased polymerization would cause the weathered spectra of basaltic glass to exhibit characteristics similar to those of SiO<sub>2</sub>-rich glass.



**Figure 2.** Sequence of weathering in Hawaiian basalt. As these glassy Hawaiian basalts are exposed at the surface, the reflectance peak in the unweathered basalt (a) splits into two separate peaks (b). Then the feature near 9 μm, B, intensifies (c). Finally the altered basaltic glass mimics the spectral properties of high-silica obsidian glass (d). Modified from Crisp et al. [19].

The TES library obsidian spectrum is compared in Figure 3 to the weathered basalt from Figure 2c and d [19]. Despite their basaltic composition, weathering has caused these glasses to take on many of the spectral properties of high silica obsidian. If such a weathered basaltic glass fits Type 2 terrain as well as the obsidian glass originally used, then the estimated silica content of the terrain would fall within the basaltic range at about 50 wt % SiO<sub>2</sub>.



**Figure 3.** The TES spectral library's obsidian sample compared to the stage 2 and 3 weathered Hawaiian basalts from figure 2 [19].

**Conclusions:** Possible interpretations of TES spectra for Type 2 terrain in the northern plains of Mars include: (1) The material is basaltic andesite as originally hypothesized [1]. (2) The bulk composition of Type 2 material cannot be distinguished from Type 1. Lack of certain endmembers, particularly low-silica glasses in the TES spectral library may have caused the silica content of Type 2 terrain to be overestimated. In this scenario, the spectra of Type 2 terrain looks different from Type 1 terrain because it has a larger glass component. They may or may not differ compositionally, depending on the composition of the glass. (3) Type 2 material is not crystalline basaltic andesite. Weathering processes have altered the surface to resemble the spectral properties of andesite. In this scenario, the spectra of this terrain look different from Type 1 because the weathering products are different in some form. Again, the terrains may or may not differ compositionally.

**References:** [1] Bandfield et al (2000) *Science*, **287**, 1626-1630. [2] Christensen P.R. et al (2000) *JGR*, **105**, 9609-9621. [3] Mcsween Jr. H.Y. et al (1999) *JGR*, **104**, 8679-8715. [4] Adams J.B. et al (1986) *JGR*, **91**, 8098-8112. [5] Hulme G. (1976) *Icarus*, **27**, 207-213. [6] Zimbelman J.R. (1985) *16<sup>th</sup> PLPSC*, 157-162. [7] Minitti M. and Rutherford M. (2000) *GCA*, **64**, 2535-2547. [8] Smith, M.D. et al (2000) *JGR*, **105**, 9589-9607. [9] Hamilton V.E. and Christensen P.R. (2000) *JGR*, **105**, 9717-9733. [10] Christensen P.R. et al (2000) *JGR*, **105**, 9735-9739. [11] Feely K.C. and Christensen P.R. (1999) *JGR*, **104**, 24195-24210. [12] Mustard J.F. and Hays (1997) *Icarus*, **125**, 145-163. [13] Ramsey M.S. and Christensen P.R. (1998) *JGR*, **103**, 577-596. [14] Lyon R.J.P. (1965) *Econ. Geol.*, **60**, 715-736. [15] Hamilton V.E. and Wyatt M.B. (1999) *5<sup>th</sup> Intl Mars Conf*. [16] Wyatt M.B. et al (1999) *LPSCXXX*, ab#1754. [17] Kahle A.B. (1988) *JGR*, **93**, 15239-15251. [18] Bartholomew, M.J. et al (1989) *Intl J. Remote Sensing*, **10**, 529-544. [19] Crisp J. et al (1990) *JGR*, **95**, 21657-21669.

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