**Introduction:** One of the most significant results to emerge from the Mars Global Surveyor Thermal Emission Spectrometer (TES) is the observation of two distinct thermal infrared (TIR) spectral units in the low albedo regions of Mars [1]. One of these units has the spectral characteristics of a plagioclase- and pyroxene-rich flood basalt and is found mostly in the southern highlands (Syrtis-type). The second unit, which is concentrated in the northern lowlands but is distributed across the highlands as well, has been characterized as a plagioclase- and glass-rich basaltic andesite (Acidalia-type). While the basaltic identification for the Syrtis-type spectrum is accepted widely, the andesitic characterization of the Acidalia-type spectrum is the source of considerable debate. One reason for this debate is the argument that the production of voluminous andesite requires plate-tectonic subduction [2], which is lacking on Mars. Several alternative hypotheses have been presented to explain the apparent andesitic character of the Acidalia-type spectrum. These include: oxidation and recrystallization of a SNC-type basalt [3]; weathering of basalt to produce clay minerals [2]; silica coating on basalt [4]; and palagonitization of basalt [5]. In all of these cases it has been shown that alteration of a precursor basalt can yield a spectrum that resembles the Acidalia-type spectrum. While such explanations dispense with the idea of large volumes of basaltic andesite on Mars, they require a process by which some of the basaltic materials on Mars become altered while some remain relatively pristine.

The basis for the ambiguity in the basaltic andesite identification lies in the fact that mineral glasses, both volcanic or authigenic, and some clay minerals have significant spectral overlap in the TIR wavelengths [2]. Recently it has been shown that some zeolites [6] and palagonites [5] also have overlapping spectral features. While it may be impossible to differentiate unambiguously between some of these candidates because their spectral differences are so subtle, in other cases it may be more feasible. As was noted by [2] and [6], some of the candidate clay minerals for Mars have distinctive spectral characteristics in a portion of the TIR spectrum that has been excluded in atmospherically-corrected TES spectra because of the absorption of atmospheric CO₂. The excluded region is wider than necessary in an effort to avoid the confounding effects of CO₂. However, CO₂ opacity remains relatively low in the region of the critical distinguishing features between clay minerals and glasses. Careful scrutiny of non-atmospherically-corrected TES spectra may serve to distinguish between the two. This work presents an initial assessment of whether montmorillonite and some other clay minerals are present on the martian surface. While such work is not sufficient to settle the andesite debate, it does shed light on the viability of some of the alternative hypotheses.

**Spectral Details:** The Syrtis- and Acidalia-type spectra identified by [1] are shown in Figure 1. It is clear that the Acidalia-type spectrum has fewer spectral features than the Syrtis-type spectrum, which is part of the reason it lacks an unambiguous lithological identification.

![Figure 1](image-url) The two volcanic-unit spectral classes identified by [1]. The 465 cm⁻¹ feature is described in the text.

Figure 2 shows the Acidalia-type spectrum along with a set of laboratory spectra of candidate materials with similar spectral characteristics. The common features are the prominent V-shape centered at ~1100 cm⁻¹ and a secondary feature centered at ~465 cm⁻¹. The montmorillonite spectrum has an additional feature at ~530 cm⁻¹ that readily distinguishes it from the glass and zeolite spectra. However, this feature is within the CO₂ exclusion region of the atmospherically-corrected TES spectrum and thus is not available for spectral deconvolution analysis. As shown by a typical non-atmospherically-corrected TES spectrum (Figure 3), in the region between the current lower limit of CO₂ exclusion at 508 cm⁻¹ and 560 cm⁻¹, the absorption by CO₂ is limited to a “hot band” at ~545 cm⁻¹. The strong absorption of surface radiance by atmospheric CO₂ begins at wavenumbers > 560. Because of this, the presence of a spectral feature attributable to clay minerals should be discernable in TES spectra.
Searching for Clay Minerals: A series of candidate clay mineral spectra is shown in Figure 4. In an effort to match the general spectral characteristics of the Acidalia-type spectrum, these laboratory spectra were selected based on the presence of a V-shaped feature in 1100 cm$^{-1}$ region and a second feature at $\sim$465 cm$^{-1}$. The latter feature is especially important because it serves as a proxy for the identification of Acidalia-type spectral regions on Mars. This is shown in Figure 5b which represents a global map of a spectral index developed to identify the $\sim$465 cm$^{-1}$ feature in non-atmospherically-corrected TES spectra. For comparison, the “andesite” map of [1] also is shown (Fig. 5a). From this comparison it can be seen that the $\sim$465 cm$^{-1}$ feature maps out the same regions of Acidalia-type spectral character as does the spectral deconvolution technique employed by [1] but with the benefit of improved signal to noise. An obvious mismatch is the inclusion of the hematite-rich locations at Meridiani Planum and Aram Chaos in the index map. This is due to the overlap of a hematite spectral feature in the same spectral region as the index.

Because of the significance of the $\sim$465 cm$^{-1}$ feature as related to the Acidalia-type spectral unit, it is reasonable to conclude that at least one of the components of Acidalia-type material has a prominent feature in this location. As shown by Figure 2, glass and zeolite have such a feature as does montmorillonite and to a lesser extent, nontronite and Fe-smectite (Figure 4). Each of these clay minerals also has a second absorption feature at $\sim$530 cm$^{-1}$ separated from the $\sim$465 cm$^{-1}$ feature by an emissivity peak. The $\sim$530 cm$^{-1}$ feature falls within the CO$_2$ exclusion region instituted by [1] but well outside of any significant CO$_2$ absorption. Therefore it should be discernable in non-atmospherically-corrected TES spectra. An index for this feature has been developed and a global map of the index is shown in Figure 5c.
**Results:** The combination of the index maps defined in the previous section is a necessary but not sufficient strategy to identify certain clay minerals on the surface of Mars. A positive correlation between the two indices would be good evidence for these clay minerals. As can be seen by comparing the two maps in Figure 5, the northern lowland occurrences of the Acidalia-type spectral unit are not matched by the ~530 cm\(^{-1}\) feature index. Instead, this index maps out portions of Syrtis Major, Terra Cimmerium, and other highland, low albedo regions. This distribution is attributable to a feature in Mg-rich olivine that overlaps that of the clay minerals used to define the index. For example, the prominent region of high ~530 cm\(^{-1}\) index values in the location of Nili Fossae (NE Syrtis Major) coincides with a known olivine anomaly [7, 8]. The two hematite locales also are identified with this index because of an overlapping spectral feature in hematite.

**Conclusions:** Volcanic glass and some zeolites and clay minerals are viable components of the Acidalia-type material. A spectral feature at ~465 cm\(^{-1}\) is common to all three candidates and the Acidalia-type spectrum. An index developed to identify this feature in non-atmospherically-corrected TES spectra readily distinguishes Acidalia-type spectral units from Syrtis-type. A second feature at ~530 cm\(^{-1}\) is present in some candidate clay minerals and has the potential to be used to distinguish clay minerals from zeolites and glass. An index developed to identify this feature in non-atmospherically-corrected TES spectra shows no correlation with the index of the ~465 cm\(^{-1}\) feature, diminishing the likelihood of the presence of certain clay minerals in the Acidalia-type material. This weakens the case for weathered basalt as an alternative to andesite in the northern lowlands of Mars. However, because zeolite can form as the result of weathering processes [e.g., 9, 10] and its spectral character can be so similar to volcanic glass, it may be that weathering or alteration of basalt has produced zeolites rather than clay minerals.

**Figure 5.** Global maps of TES spectral data. (a) andesite abundance map of [1]; (b) spectral index representing the feature at ~465 cm\(^{-1}\) in the Acidalia-type spectrum; (c) spectral index representing a feature at ~530 cm\(^{-1}\) found in some clay minerals, olivine, and hematite.