

## OBSERVED UPPER LIMITS FOR CLAY MINERALS ON MARS

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A magnesian clay-type mineral or other hydroxylated phase has recently been detected in the martian regolith based on a specific absorption near  $2.35\mu\text{m}$  observed in spectral reflectance data. This band is extremely weak, however, indicating that the responsible hydroxylated mineral is only a minor soil component and/or is poorly crystalline.

Near-IR (0.65-2.55 $\mu\text{m}$ ) spectral observations of regions on Mars ( $\sim 1000$  km dia.) were obtained in April 1980 using the Mauna Kea 2.2m telescope. Selected data are shown in Figure 1 for the 1.7- to 2.55- $\mu\text{m}$  spectral range. The deep composite absorption near  $2\mu\text{m}$  is due to Mars atmospheric  $\text{CO}_2$ . The features under discussion are weak but definite absorption bands centered near  $2.35\mu\text{m}$ . Their position and width is similar to those seen for terrestrial hydroxylated minerals. The 2.15- to 2.55- $\mu\text{m}$  spectral region is free from other potentially complicating absorptions, such as from adsorbed, solid, or gaseous  $\text{H}_2\text{O}$  and  $\text{CO}_2$ . Extreme care was taken in data reduction to insure the validity of these weak spectral features.

Minerals with structural OH, such as clays and amphiboles, have diagnostic absorption bands in the 2.2-2.4- $\mu\text{m}$  region produced by combined OH stretch and Mg-OH lattice modes (1,2). Laboratory spectra of some representative clay minerals, as well as a palagonite and carbonate, are shown in Figure 2. The absorptions near  $1.9\mu\text{m}$  are in all cases due to molecular  $\text{H}_2\text{O}$  adsorbed or included in various sites. For the clays and the palagonite the reflectance dropoff towards  $2.55\mu\text{m}$  is due to the wing of intense water fundamentals around  $3\mu\text{m}$ . The band near  $2.2\mu\text{m}$  in montmorillonite is highly diagnostic of the structural Al-OH bonds in this dioctohedral clay mineral. Magnesian (trioctohedral) clay minerals, as well as some Mg-amphiboles, display similar bands generally centered in the 2.3-2.35- $\mu\text{m}$  region (1,2). An example is serpentine, with a band near  $2.34\mu\text{m}$ . The most similar band position to Mars seen so far is for a scapolite. Scapolite is a framework silicate with a range of compositions - this specimen has not yet been analyzed. The palagonite spectrum is for a poorly crystalline altered basaltic glass from Mauna Kea (3). This sample and certain others which lack crystallinity by conventional tests (4) still display at least a trace of a distinct cation-OH band in this spectral region. Carbonates also have a band near  $2.35\mu\text{m}$ , due to  $\text{CO}_3$  overtones, but accompanied by a stronger absorption near  $2.55\mu\text{m}$  (2), the first half of which is apparent as a very steep reflectance drop longward of  $2.4\mu\text{m}$  in the example in Figure 2.

Based on the  $\sim 2.35\mu\text{m}$  wavelength of the bands observed for Mars, some Mg-OH mineralogy seems most likely. Measured spectra of serpentine and phlogopite seem reasonable but not perfect, while talc, saponite, and tremolite appear ruled out because of band position and/or detailed shape. Scapolite is promising and will be investigated further. There is no evidence for Al-OH minerals such as kaolinite and montmorillonite. Compared to typical clay spectra these Mars data show little or no reflectance drop out to  $2.5\mu\text{m}$ , indicating a fairly high degree of dessication (lack of molecular  $\text{H}_2\text{O}$ ). Carbonates would be the most likely non-hydroxylated source of a band at near  $2.35\mu\text{m}$ , but appear ruled out because there is no evidence of the expected stronger  $\text{CO}_3$  band near  $2.55\mu\text{m}$ .

In all Mars areas observed, the  $2.35\mu\text{m}$  absorption is extremely weak - an average of about 1.5% relative band depth. This compares to values of  $\sim 8$ -15% for relatively pure crystalline hydroxylated minerals. Band depth is known to vary in complex and nonlinear ways with mineral content, opaque content, etc. (e.g 5) and additional work is needed to establish a quantitative upper limit on crystalline clay mineral. Nevertheless these bands are much weaker than would be expected if well-crystallized hydroxylated minerals were abundant in bright soils on Mars. Two possible explanations are: 1) crystalline clays exist as a minority phase mixed with other materials (e.g. palagonites), or 2) the bright soils are more homogeneous but not well crystallized into clay minerals. As mentioned above, it is possible that the observed OH-related bands might be totally attributable to amorphous phases.

The deepest band observed was for Hellas basin, which contained some dust clouds at that time (6), and which had the longest optical path through the martian atmosphere. This implies that the  $2.35\mu\text{m}$  band may have been due largely to atmospheric dust particles. These results might indicate a compositional difference between aerosol dust and other

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weathered soils, or some regional variation in soil and dust mineralogy which has not previously been observed. In any case, these questions are ideally suited for investigation by the Visual and Infrared Mapping Spectrometer (VIMS) proposed for the Mars Observer mission.

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**Figures:** Spectra have been scaled to 1.0 at the  $\sim 2.3\text{-}\mu\text{m}$  band continuum to allow visual comparison of band depths.

