DERIVATION OF THE VNIR (0.4-4.0µm) OPTICAL CONSTANTS OF NONTRONITE AND AN APPLICATION TO MARS: MODELING SINGLE SCATTERING ALBEDO OF CANDIDATE MARTIAN DUST GRAINS.

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Introduction: As part of a project to derive the VNIR optical constants of a range of planetary materials, we have concentrated on deriving the optical constants of a phyllosilicate that is thought to be present on Mars [1-2]. As a demonstration application of the use of optical constants, we examine the optical properties of nontronite and compare them to palagonite grains, using Mie theory. This application demonstrates the importance of deriving optical constants to enable accurate albedo and to derive accurate energy budget models on Mars.

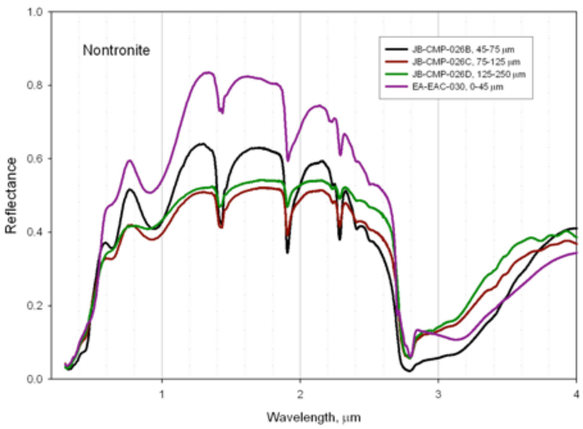

Figure 1. VNIR reflectance spectra of nontronite samples from the RELAB library.

Nontronite on Mars: The first spectral evidence for nontronite was extracted from data from the OMEGA instrument on Mars Express [1]. Since that time, it has been invoked as a possible explanation for OH absorbtion bands detected by CRISM [2]. As an Fe-bearing phyllosilicate, it is thought to be a breakdown product from altered iron rich basaltic materials. If it is a large component of the soils and dust on Mars, it is possible it may be an important mineral to consider when constructing radiative transfer models of the surface and dust clouds on Mars.

Methods: Our intention is to derive the optical constants for nontronite based on laboratory reflectance spectra. Figure 1 shows the reflectance spectra of various nontronite samples; some with varying grain size. These illustrate the natural variability in spectral behaviour that should be included in derivation of the optical constants of a material. We will derive the optical constants using two techniques, so we can examine the different approaches, assumptions and uncertainties inherent in the inversion approaches.

Sample #	Grain size (µm)	Origin
JB-CMP-026D	125-250	J. Bishop RELAB
JB-CMP-026C	75-125	J. Bishop RELAB
JB-CMP-026B	45-75	J. Bishop RELAB
EA-EAC-030	0-45	E. Cloutis RELAB

Table 1. Nontronite $[Na_{0.3}Fe^{+3}{}_2Si_3AlO_{10}(OH)_2.4H_2O]$ samples used in this study.

Shkuratov Inversion Method: Shkuratov developed a method for finding the imaginary index of refraction using an easily invertible radiative transfer model [4]. This has been used to develop complex mixture models for OMEGA and CRISM spectra and determine quantitative rock/soil mixture models for various locations on Mars [5]. This method requires knowledge of the real index of refraction, which we initially estimate for nontronite as an average from [6] (= 1.598).

Hapke Inversion Method: Hapke's radiative transfer model for particulate surfaces [7] is used in an iterative approach to derive the imaginary index of refraction from reflectance measurements [8-10]. Using spectra of a material at different grain sizes makes this process more reliable and self consistent [9,11]. An intial determination of optical constants for nontronite (using the spectra of the two finest grain sizes from Figure 1 and Table 1) assumes a constant real index of refraction and median diameters (22.5 and 60 µm respectively) for the two particle size fractions. The real index is iteratively estimated using a subtractive Kramers-Kronig approach [11].

Results: The initial application of the Hapke approach, without optimizing grain parameters, produces imaginary index values that agree within a factor of two of much of the 0.3-4µm range (Figure 2). Using the Shkuratov inversion model, and assuming a grain size of (S=50 µm) and pore filling parameter of 70% (q=0.7) , we came up with qualitatively similar results to the Hapke approach (Figure 3). Future work will compare the two approaches more closely, including the effects of changing grain sizes.

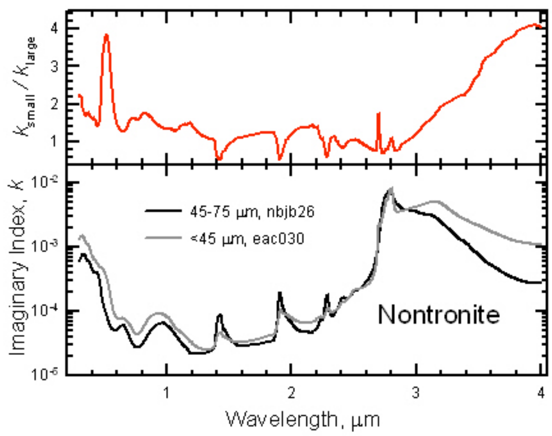

Figure 2. Hapke estimates of the imaginary index for nontronite (bottom) using spectra of the two finest grain size samples, assuming a constant real index and median grain diameters. The ratio of the derived k-values agree to within a factor of 2 over much of the wavelength range (top).

Application for Mars: Single scattering albedos of dust grains of differing compositions: As an application of our derived optical constants, we have used them to model single scattering albedos in potential Martian dust clouds. Assuming the dust grains are well separated (i.e. their mutual shadowing is negligible) we can use Mie theory to predict the single scattering albedo (ω - the probability that a photon encountering the grain will be scattered) of a cloud of dust of differing composition [12]. We used a grain size of 2μm, thought to be a typical size for Martian dust grains [13].

The optical constants of palagonite are often used in modeling the effect of dust on Mars [eg. 14]. It is widely acknowledged that palagonite is not a perfect analog for Martian dust, however the optical constants of palagonite are readily available and thus are often used by default [15]. Here we investigate the errors this approach introduces into atmospheric models.

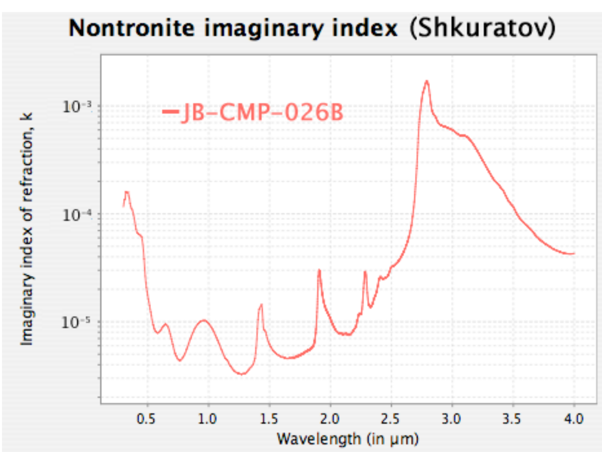

Figure 3. Initial estimates of the imaginary index for nontronite JB-CMP-026B using Shkuratov inversion method.

Results: Directly comparing single scattering albedo results for palagonite and nontronite dust clouds, it is clear that nontronite is inherently brighter across the VNIR spectrum than palagonite (Figure 4). In addition, the water-related absorption band near 3μm appears in the spectra of both materials, but is far stronger in palagonite. These effects are exacerbated with larger grain sizes. Even at these small grain sizes, palagonite is clearly inadequate to describe nontronite-bearing dust clouds, (and vis versa) particularly when deriving albedos for Mars energy balance applications.

Conclusion: We have used two methods to derive the optical constants of an iron rich phyllosilicate thought to be important for Mars. A simple Mie scattering model comparing potential dust grain materials has shown the importance of knowing the optical contants of planetary materials in relevant regions of the VNIR, for the benefit of interpreting CRISM spectra.

References: [1] Poulet, F. et al., (2005) Nature **438**, 623 [2] Mustard, J. et al., (2007) *7th Mars*, #3240 [3] Shkuratov, Y. et al., (1999) *Icarus* **137**, 235-246. [5] Poulet, F., (2007) *AGU* P11E-07 [6] Deer, W. et al., (1966) *An introduction to the rock forming minerals*, Longman, London 528pp. [7] Hapke, B. (1993) *Theory of Emittance and Reflectance Spectroscopy*, Cambridge Uni Press. [8] Clark, R. and T. Roush (1984) *JGR* **89**, 6329 [9] Calvin, W. (1990) *JGR* **95,** 14743 [10] Lucey, P. (1998) *JGR* **103**, 1703 [11] Roush, T. et al., (2007) *JGR* **112** E10003 [12] Bohren, C. and D. Huffman (1983) *Absorption and scattering of light by small particles*, Wiley, NY [13] Snook, K. et al., (2000) *DPS* 32, 1094 [14] Brown, A.J. et al. (2008) *Icarus* in press [15] Roush, T. et al., (1991) *Icarus* 94, 191.

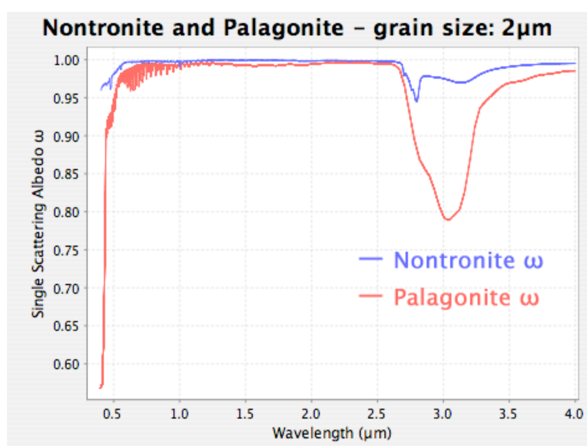

Figure 4. Mie-derived single scattering albedo of nontronite eac030 and palagonite from [15], grain radius 2μm.