EFFECTS OF SURFACE TEXTURE AND OBSERVATION GEOMETRY ON THE NEAR-INFARED WATER-OF-HYDRATION ABSORPTION BANDS.
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Introduction: Reflectance spectroscopy in the range of near-infrared (1–5 µm) can be used to detect and characterize mineral hydration on Solar System surfaces through the observation of strong absorption bands around 1.9 µm and between 3 and 4 µm (« 3 µm band »). The relationships between the hydration bands strength and the minerals water content have been experimentally studied ([1] and [2]), providing empirical equations that can be used to estimate Solar System surfaces water content. Unfortunately, parameters such as surface texture and observation geometry are known to have a strong influence on reflectance spectra and could introduce severe bias in the water content estimation. Thus, the qualitative and quantitative effects of these parameters on the hydration bands strengths have to be clearly understood. The aim of this study is to determine the effects of grain size, mixtures of materials with different albedos and measurement geometry on the criteria commonly used to estimate the strength of the water-of-hydration absorption bands.

Methods: We compare results from laboratory measurements and radiative transfer modeling.

Laboratory experiments. Laboratory measurements of minerals reflectance spectra (0.4 - 4.6 µm) were obtained on the LPG spectro-gonio-radiometer [3]. We measured bidirectional reflectance spectra of phyllosilicates (smectites STx-1 and SWy-2 and kaolinite KGa-1, all from Source Clay Repository), an altered volcanic tuff (from the career of Corant, Puy-de-Dômes, France) and coals (especially anthracite, a spectrally neutral and absorbing coal). Measurements were made under various incidence and emission angles on pure and mixed materials separated in different grain size fractions. Materials water content was estimated by measurements of loss on ignition.

Radiative transfer modeling. Bidirectional reflectance spectra have been modeled for one material (SWy-1 Smectite) using a radiative transfer model [4] and optical constants for a SWy-1 smectite from [5]. We also modeled reflectance spectra of this smectite mixed with a synthetic material, spectrally neutral and highly absorbing (model for anthracite).

Estimation of absorptions intensities. Criteria designed to estimate the intensity of the absorptions due to water of hydration are calculated in the same way on laboratory-measured spectra and synthetic (modeled) spectra. A simple reflectance ratio (Band depth) is used for the 1.9 µm band whereas integration methods are

used for the 3 µm band. These integration methods imply the definition of an arbitrary continuum above the wide absorption band. All these criteria are directly calculated on reflectance spectra and on spectra converted to apparent absorbance: -ln (Reflectance) and single scattering albedo.

Results: Figures 1 to 3 show examples of evolutions of the 3 µm band strength as a function of material mean grain size (fig.1), proportion of anthracite in a binary mixture : anthracite-smectite (fig.2) and measurement geometry (fig.3). In these figures, the criterion used to estimate the 3 µm band strength is the Normalized Integrated Band Area (NIBA) calculated after definition of a linear continuum above the absorption band (following the definition proposed by [6]).
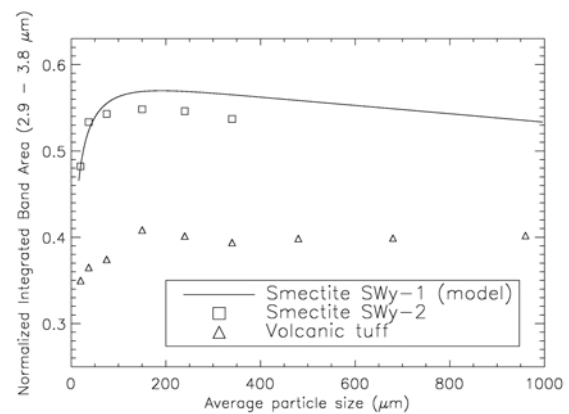

Figure 1: Effect of particle size on the NIBA. This criterion strongly decreases for the smallest particles but variations with particle size are very small for fractions with mean particle size larger than 150 µm. The same kind of evolution is observed for the 1.9 µm band but relative variations of band strength are even larger. Conversion of reflectance to apparent absorbance or single scattering albedo increases the effects of particle size.

Effects of particle size (fig.1). This effect has been experimentally tested on two materials: a smectite (SWy-2) and an altered volcanic tuff. Particle size fractions were isolated by dry sieving directly from the original material (smectite) or after grinding (volcanic tuff). Effects of particle size variations were also studied thanks to radiative transfer modeling for a smectite (SWy-1). Variations of the mean particle size always induce large variations of the band strength but quantitative effects are dependant on the criterion chosen to estimate band strength. We always observe a strong decrease of the 1.9 and 3 µm bands strength for the

smallest particle size fractions (previously observed by [7] and [8]) but variations of the 3 µm band strength estimated by integration on reflectance spectra become negligible for the largest particle size fractions.
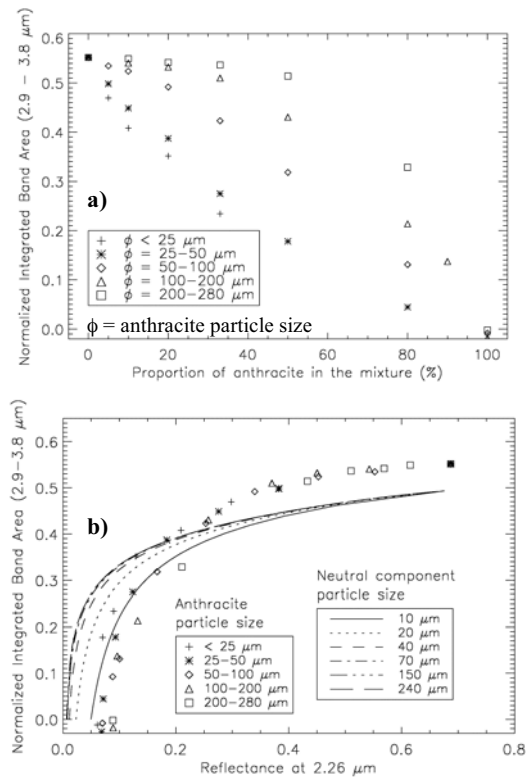

Figure 2: Effects of mixtures on the NIBA criterion. a) Only experimental results are presented here. For a given value of anthracite proportion in the mixture, the NIBA value seems highly dependent on the anthracite particle size. b) Results from experiments (symbols) and radiative transfer modeling (lines) are now plotted versus the value of reflectance in the spectrum continuum, highlighting the strong correlation of NIBA with continuum reflectance despite the applied normalization.

Mixtures of materials with different albedos (fig.2). We mixed in various proportions a very fine smectite (STx-1) powder and anthracite powders with different particle size (from less than 25 µm to 250 µm). Corresponding synthetic spectra were also produced using optical constants for SWy-1 smectite and a neutral absorbing component. Results show a very poor correlation between hydration band strength and proportion of smectite in the mixture (and thus water content). However, hydration band strengths at 1.9 and 3 µm are highly correlated with the value of reflectance in the spectra continuum generating an artificial correlation of band strength with albedo. The same effect had been previously observed by [9] in an experiment where the neutral component particle size was very small.

Effects of measurement geometry (fig.3). Bidirectional reflectance spectra have been measured and modeled under various incidence and emergence angles for most of our materials. Variations of incidence and emergence angles induce non negligible variations of the hydration bands strengths for high phase angles. We also observe that relative variations of band strength between two given geometries are highly dependent on grain size, macroscopic roughness and other surface texture parameters.
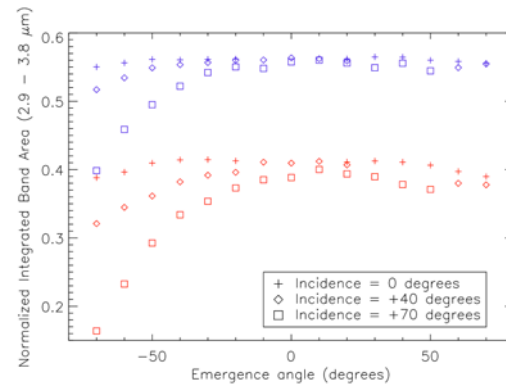

Figure 3: Effects of incidence and emergence angles on the NIBA criterion. Values of NIBA are plotted versus emergence angle (position of the detector) for three values of incidence angle (position of the light source) and two different samples: STx-1 smectite (blue symbols) and altered volcanic tuff (red symbols).

Implications: Laboratory measurements and radiative transfer modeling give globally consistent results. They show that particle size, surface albedo and measurement geometries strongly influence the water-of-hydration bands strengths. Therefore, these parameters have to be taken into account to interpret the spatial variations of band strength on planetary surfaces or to compare the hydration state of different bodies (asteroids, moons…). In a separate abstract [10], we use the OMEGA (Mars Express) dataset to characterize the effects of the mentioned parameters on the Martian surface and try to determine the origins of the spatial variations of the hydration bands.

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