

HYDROTHERMAL MARS “THROUGH THE CRISM”: WHICH HYDROXYL BAND AND WHY. A.J. Brown¹, ¹Australian Centre for Astrobiology, Macquarie University, NSW 2109, Australia, email:abrown@els.mq.edu.au website:http://aca.mq.edu.au/abrown.htm

Introduction: The Compact Reconnaissance Infrared Spectrometer for Mars (CRISM) is scheduled to launch on Mars Reconnaissance Orbiter in August 2005. CRISM will view radiation from Mars in the ultraviolet to mid wavelength infrared (0.383-3.960 μm) [1]. A commandable subset of wavelengths covering key mineralogic absorption bands will be examined during the preliminary mapping phase of the mission. In order to search for Al-OH bearing hydrothermal minerals such as muscovite, kaolins and pyrophyllite, absorptions due to vibrations of the hydroxyl (OH) molecule will be targeted [2]. The spectral region covered by CRISM contains several OH absorption bands. The subject of this report is: Which of the available OH absorption bands should be targeted during CRISM preliminary mapping?

Wavelength/Frequency: CRISM operates primarily in the Visible to Near Infrared (VNIR), and following the literature dealing with this region of the spectrum, wavelength in μm is used instead of frequency in wavenumbers (cm^{-1}). $f(\text{cm}^{-1}) = 10000/\lambda(\mu\text{m})$.

Muscovite: Muscovite was chosen for this study because it is a typical mineral found in the sericitic zone of hydrothermal systems [3], is stable once formed [4] and its presence in mafic volcanic terranes such as Mars would be highly suggestive of aqueous alteration and movement of potassium.

Hydroxyl bands covered by CRISM: Three relatively strong Al-OH bands are covered by CRISM – one is the fundamental stretching (v) band at 2.75 μm , one is the overtone band of this stretching band (2v) at 1.4 μm and one is a combination of the stretching and bending fundamentals (v+ δ) at 2.2 μm [5]. The band at 1.4 μm is directly overlapped by a broad band due to adsorbed H₂O and is not considered further. Being a fundamental band, the absorption at 2.75 μm is inherently stronger than the combination band at 2.2 μm .

The detection of absorption bands in the region 2.0-3.0 μm is complicated by the following factors:

- a.) relatively low incident solar radiation, compared to the visible region,
- b.) effects of thermal emission from Mars,
- c.) proximity of a broad, deep absorption at 3.0 μm due to adsorbed H₂O, and
- d.) narrow atmospheric absorption lines due to CO₂ and H₂O.

Each of these points is dealt with briefly below. In addition, the effects of particle size on volume scattering may serve to mask absorption bands [6]. The results of this study are valid for fine grained muscovite typical of hydrothermal alteration zones. Muscovite in

a dust form and the effects of Martian dust coatings are not addressed here.

Incident solar radiation: CRISM is designed to acquire images in the Martian day using reflected sunlight. It has a planned sun-synchronous orbit with a mean local solar time of 3PM [1]. Treating the Sun as a Lambertian blackbody radiator at 5880K, and mean distances and temperatures of the Earth and Mars of 1.5x10⁹m and 2.3x10⁹m, we can calculate total incident flux curves arriving at the atmosphere of each planet. Without considering atmospheric effects which will reduce the flux of photons at the surface still further, the incident sunlight on Mars at 2.0-3.0 μm is approximately 40% that arriving at the Earth in this spectral region. At 2.75 μm it is approximately 50% of the flux at 2.2 μm . This favors relative detection of the 2.2 μm band.

Thermal Emission at Mars: Assuming maximum Mars daytime temperatures of 280K and mean of 245K, and that Mars is a Lambertian blackbody radiator, idealized thermal emission curves for the Mars surface can be obtained. Thermal emission for 280K Mars at 2.75 μm is less than 2nW/cm² μm , compared to incident radiation at the top of the atmosphere of approximately 1500 nW/cm² μm . In the absence of a duststorm the incident solar radiation will dwarf emission from Mars at this wavelength. These results indicate that thermal emission from the Martian surface will not substantially reduce the depth of the 2.75 μm absorption band.

Nearby bands and superimposed background continuum: The OH band at 2.2 μm is situated on a high reflectance plateau that is relatively free of atmospheric effects and overlapping bands. The whole reflectance continuum in this region is decreased by the proximity of the adsorbed H₂O band at 3.0 μm . Figure 1 shows that the OH band for muscovite at 2.75 μm is much deeper and sharper than the broad H₂O band and therefore should be discernable. Mixing of muscovite with other minerals such as kaolins and other phyllosilicates will complicate detection but for simplicity it is assumed here that muscovite is the only Al-OH bearing mineral in the target rock.

Atmospheric absorption: A narrow absorption doublet due to atmospheric CO₂ lies at 2.75-2.8 μm . Preliminary modeling suggests this can be removed using a radiative transfer code (informed by complementary CO₂ absorptions in other parts of the spectrum). An absorption due to atmospheric H₂O is also present in this region however due to the low water content in the atmosphere (0.03% of a 7 mbar atmos-

phere) it is likely the Martian atmospheric spectrum will not be saturated in this region as it is on Earth.

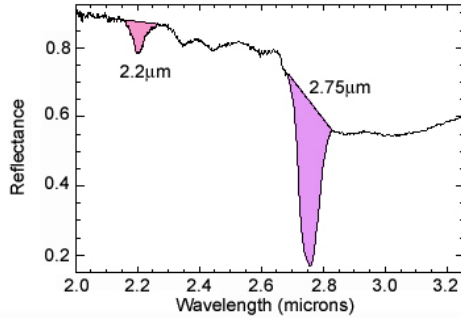


Figure 1 – Infrared Spectra of muscovite sample discussed in text. OH absorptions colored at 2.2 and 2.75 μ m.

Sample provenance, preparation and measurement: The sample analyzed was collected from a quartz porphyry hydrothermal vein in the North Pole Dome, a region in the 3.5Ga Pilbara Craton of Western Australia. A sample was taken at outcrop and the weathering rind was removed. A thin section was made and analysed using EMP - muscovite of formula $(K_{0.55}Fe_{0.27}Mg_{0.18})Al_2(Si_3Al)O_{10}(OH)_2$ was identified along with quartz and minor iron oxide phases (less than 1% by mode). The muscovite occurs primarily as fine grained sericite, with occasional large grains up to 1 mm in the longest dimension. The whole sample was crushed using a tungsten carbide ring mill. The powder was then analysed in a near-vacuum with a Bruker FTIR IFS 66v spectrometer in the mid-infrared region from 2-25 μ m using a germanium coated KBr beamsplitter and a DLaTGS detector. A Diffuse Reflectance Infrared Fourier Transform (DRIFT) accessory from Spectra Tech was used to collect light reflected from the sample [7]. The spectral resolution was 4 cm^{-1} and a Blackman-Harris apodization function was used to smooth the edges of the sampled region. The resultant spectrum (Figure 1) is significantly better than those expected from the CRISM instrument, however for the purposes of this study, the relative depth of both the 2.2 and 2.75 μ m features is the key measurement, and this setup was chosen in order to collect spectra at 2.2 and 2.75 μ m simultaneously.

Detection limit: Following Kirkland [8], a relative detection limit (DL) was calculated for the 2.2 and 2.75 μ m OH absorption bands. Using the formula:

$$DL = \frac{100 \times \text{confidence factor}}{\frac{\text{signal}}{\text{noise}_{p10p}/2} \times \sqrt{\frac{\text{band FWHM}}{\text{sampling interval}}}}$$

with sampling interval of 6.6nm, approximate signal to noise for CRISM at 2.2 μ m of 460 and at 2.75 μ m of 75 [1], and calculating band FWHM by fitting each band with an inverted Gaussian function using non linear

least squares and modeling the background using a second degree polynomial [9], it was found that DL (2.75 μ m)/DL (2.2 μ m) \sim 14. This implies the depth of the vibration at 2.75 μ m would have to be 14 times the depth of the vibration at 2.2 μ m in order to be as detectable to CRISM. Under the conditions of this experiment, depth(2.75 μ m)/depth(2.2 μ m) \sim 5. Thus we conclude that the band at 2.2 μ m would be the most sensitive band for CRISM to find muscovite on Mars.

Future Research: Future work on the detection of hydroxyl bearing minerals by CRISM will involve investigation of hydrous phyllosilicates other than muscovite, further characterization of the effects of particle size and volume scattering, effects of mixing with impurities likely in the Martian environment (such as sulfates and iron oxides/oxyhydroxides) and measurements of low temperature spectra (which would be expected to decrease the band FWHM of the OH absorption bands [10]).

Conclusion: Results of this work indicate that the absorption band at 2.2 μ m is most suitable for CRISM to localize muscovite on the surface of Mars. It should be pointed out that high spectral resolution surveys of sites of specific interest should attempt to detect the 2.75 μ m OH band, since the combination of information from both bands will reveal information on OH bending, potentially useful in determining the packing structure (1M, 2M or 3M) and hence the thermal history of hydrothermal muscovite [4].

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