

SPECTRAL PROPERTIES OF Ca-, Mg-, AND Fe-BEARING CARBONATES AND IMPLICATIONS FOR MARS. S. J. King¹, J. L. Bishop^{1,2}, and A. J. Brown^{1,2}, ¹SETI Institute (Mountain View, CA, sking@sco.ca.gov), ²NASA-ARC (Moffett Field, CA).

Introduction: This study builds on previous work [1] and provides further analysis of the reflectance spectra for Ca-, Mg-, and Fe-bearing carbonates. Carbonate band centers near 2.3 μm , 2.5 μm , and 3.4 μm were determined from continuum-removed spectra and compared in order to distinguish the differences each cation had on the exact wavelength of the band center. The results of this study will provide baseline data to help determine carbonate chemistry of remote sensing spectral images from the Mars orbiters. We compared our full range of carbonate data to CRISM data from a few carbonate-bearing outcrops from [2].

Samples: Many of the samples from prior work [1] and the band center data associated with them were included in this study. Additional samples processed here include: two calcites (from Big Timber, Montana, USA and Mazada, Israel), two aragonites (from Minglanilla, Cuenca, Spain and Compton Martin, Somerest, England), one dolomite (Selesvann, Norway), and two siderites (Antigonish Co., Nova Scotia, Canada and Litchfield Co., Connetticutt, USA). These additional samples were analyzed across multiple grain sizes with ranges from <45 μm , 45-75 μm , 75-90 μm , 90-125 μm , 125-250 μm , and >250 μm .

Spectral Measurements: Reflectance spectra for all samples were taken from 0.3 μm to 50 μm . The near-infrared (NIR) data was processed using a continuum removal procedure [3] to enable comparison of the band centers with changes in composition.

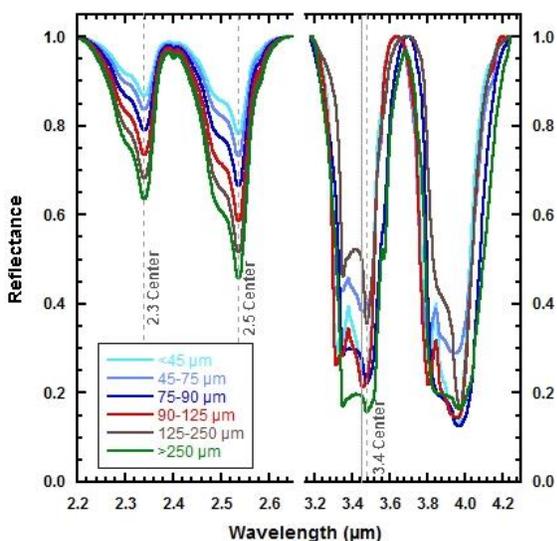


Figure 1: Continuum-removed NIR spectra of the grain size separates for the Big Timber, Montana calcite sample.

NIR Spectral Analyses: Band centers near 2.3, 2.5, and 3.4 μm are shown in Figure 1 for a calcite sample. These bands are useful for identifying carbonates in spectral data and also provide information about the type of cation present in a carbonate [4]. Band depths increase with increasing grain size at 2.3 and 2.5 μm , and some changes in band shape were also observed near 3.4 and 4 μm . Similar spectral features are observed for the other carbonates in the study. These continuum-removed data were used to determine the exact band center near 2.3, 2.5, and 3.4 μm for each sample and for each grain size. We observed that the band centers near 2.3 and 2.5 μm appear extremely consistent across grain sizes for each sample, but that variations were often observed for the 3.4 μm band center across particle size ranges.

Band Center Comparisons: After identifying the 2.3, 2.5, and 3.4 μm band centers for all the samples we generated scatter plots that compare the 2.3 μm to the 2.5 μm band centers (Figure 2), the 2.3 μm to the 3.4 μm band centers (Figure 3), and 2.5 μm to the 3.4 μm band centers (Figure 4).

2.3 μm to 2.5 μm Comparison: Because of the consistency of the 2.3 μm and 2.5 μm band centers, Figure 2 displays very clear cluster regions that can be broken down into five separate zones: a CaCO_3 region (aragonite and calcite), a FeCO_3 region (siderite), a MgCO_3 region (magnesite), a mixed region containing dual cation materials influenced heavily by either iron or magnesium (dolomite, Fe-dolomite, Mg-siderite, Mg-aragonite), and a $\text{Ca}(\text{Fe},\text{Mg},\text{Mn})\text{CO}_3$ region (ankerite).

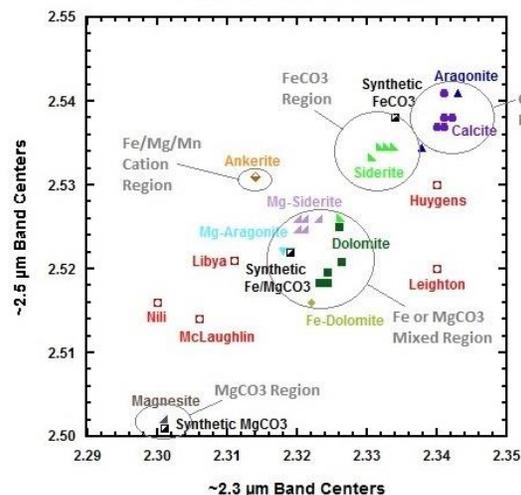


Figure 2: Band center comparison between the 2.3 μm band center and 2.5 μm band center of all samples.

2.3 μm to 3.4 μm Comparison: Because of the mild variation across grain sizes of the 3.4 μm band center, Figure 3 displays the same set of zones as Figure 2; however, in this case the zones of interest are less clustered and more stretched out into vertical columns.

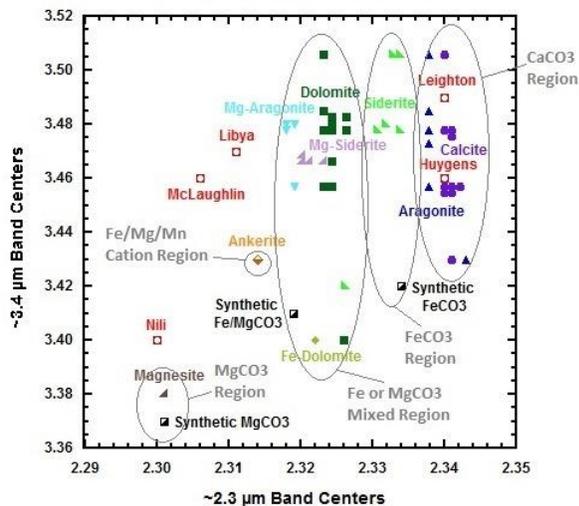


Figure 3: Band center comparison between the 2.3 μm band center and 3.4 μm band center of all samples.

2.5 μm to 3.4 μm Comparison: Figure 4 also displays vertically oriented zones because of the variation in the 3.4 μm band centers. The five zones that appear on both of the other scatter plots also appear here; however, the CaCO_3 and the FeCO_3 zones appear to overlap to a great extent. Thus, in order to distinguish Ca and Fe-rich carbonates on Mars, the visible region Fe spectral features must be used as well [2].

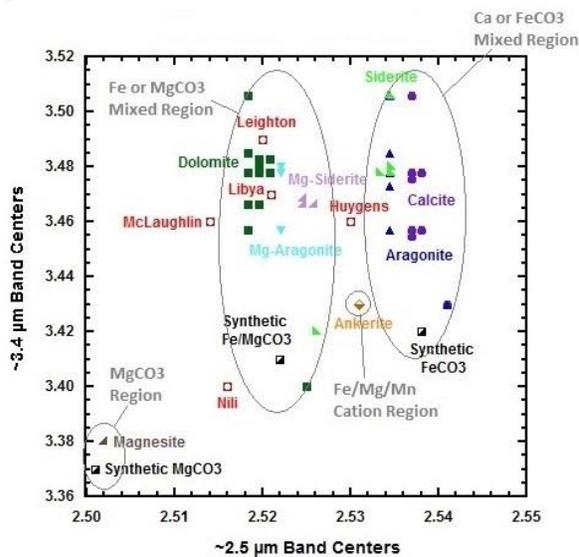


Figure 4: Band center comparison between the 2.5 μm band center and 3.4 μm band center of all samples.

Applications to Mars: Fe/Mg-carbonates are suspected to exist on Mars [e.g. 5-6] and other studies indicate Mg- and Ca-bearing carbonates as well [e.g. 7-11]. Scatter plots of band centers (Figures 2, 3, and 4) enable more accurate determination of carbonate chemistry from remote sensing data on Mars. Band centers from spectra of carbonate-bearing sites at Nili Fossae, McLaughlin crater, Libya Montes, Leighton crater and Huygens crater [2] are included in these figures. We evaluated the position of the data for each of these Martian carbonate outcrops across all three comparison plots to estimate the dominant composition of the carbonates in that location.

Nili Fossae: This site appears closest to being a pure magnesite, but it likely has minor Fe or Ca components as well which pull the data point up and to the right of the MgCO_3 zone in all three cases.

Libya Montes and McLaughlin crater: Both of these sites coordinate well with the mixed Fe/Mg cation zone but are drawn left and down toward the pure MgCO_3 zone. Thus, these sites likely represent MgCO_3 with significant components of either Fe or Ca.

Huygens crater: This site exhibits spectra closest to those of pure CaCO_3 ; however, the presence of some Mg or Fe is likely as the data are located slightly outside the pure CaCO_3 zone.

Leighton crater: This data is the most difficult to assign. For the 2.3 and 3.4 μm band positions the data-point falls well within the CaCO_3 zone, while the 2.5 and 3.4 μm comparison displays it in the Fe/Mg mixed zone. However, in the 2.3 and 2.5 μm clusters it is well below the CaCO_3 zone and far to the right of the Fe/Mg mixed zone. Additional spectral data will need to be acquired from this site for a better understanding of the carbonate chemistry here.

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References: [1] Bishop J.L. et al. (2013) LPS XLIV, Abstract #1719. [2] Bishop J.L. et al. (2013) LPS XLIV, Abstract # 2555. [3] Brown A. J., M.C. Storrie-Lombardi (2006) *SPIE, abs.*, doi:10.1117/12.677107. [4] Gaffey S.J. (1987) *JGR*, 92, 1429-1440. [5] McKay D. S. et al. (1996) *Science*, 273, 924. [6] Morris R. V. et al. (2010) *Science*, 329, 421. [7] Ehlmann B. L. et al. (2008) *Science*, 322, 1828. [8] Brown A. J. et al. (2010) *EPSL*, 297, 174. [9] Michalski J. R. & P. B. Niles (2010) *Nature Geosci.*, 3, 751. [10] Wray J. J. et al. (2011) LPS XLII, Abstract #2635. [11] Viviano C. E. et al. (2012) LPS XLII, Abstract #2682.