SEARCHING FOR HYDROUS CARBONATES ON MARS: INVESTIGATION OF CRISM SPECTRAL SUMMARY PARAMETERS. Anna E. Baker[1,2] and Martha S. Gilmore[3], [1]Dept. of Earth & Planetary Sciences, Washington University in St. Louis, MO 63130; [2]U.S. Geological Survey, Earthquake Science Center, Menlo Park, CA 94025; [3]Dept. of Earth & Environmental Sciences, Wesleyan University, Middletown, CT 06459, USA. (Contact: annabaker@wustl.edu)

Introduction: Carbonates have long been predicted to be abundant on Mars as a product of the aqueous weathering of basalt under a dense CO_2 atmosphere early in the planet's history [1]. This dense atmosphere is thought to be necessary for the planet to have warmed via the greenhouse effect enough for liquid water to flow on the surface around 4 billion years ago [2]. However, to date, carbonates have only been found in several small, localized deposits scattered across the surface of the planet (Fig. 1), as well as in low concentrations in Martian meteorites (<1 vol. %) and dust (2-5 wt. %) [2]. The apparent absence of carbonates presents a problem for our climate models of ancient Mars, and its implications could change our understanding of the evolution of the planet. In addition to climate history, understanding Martian carbonates is crucial to understanding Mars' ancient geochemical processes and acidic aqueous environments [2].

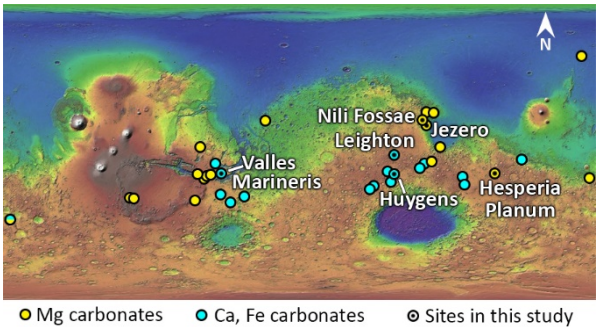

Fig. 1. *Locations carbonates have been found on Mars, with the 6 sites examined in this study labeled. Modified from [3].*

Spectral Identification of Carbonates: Spectral summary parameters are calculated measures of spectral variability designed to take advantage of the unique spectral features of different materials for use in their identification [4, 5]. In a 2015 study, Harner and Gilmore [6] developed a spectral library of hydrous carbonates and found that some of the characteristic spectral features used to identify carbonates on Mars, such as absorption bands at 2.3 and 2.5 µm, are diminished or absent in hydrated carbonates. If there are hydrous carbonates on Mars, they may be missed using the traditional combinations of summary parameters, which could partially explain why few carbonates have been found thus far. Here, we evaluate new potential spectral summary parameter combinations for targeting hydrous carbonates and apply the laboratory findings of Harner and Gilmore to hyperspectral imaging of Mars.

Methods: We applied a variety of spectral summary parameters defined by Viviano-Beck et al. (2014) [5] to laboratory spectra for hydrous and anhydrous carbonates and other minerals. We also applied a new spectral parameter, A1200, suggested by Harner and Gilmore for use in identifying hydrous carbonates [6]. The A1200 parameter measures the band depth and asymmetry of an absorption feature at 1.2 µm:

$$\left(\frac{\mathrm{R1110}}{\mathrm{R1240}}\right) * \left(1 - \frac{\mathrm{R1215}}{a * \mathrm{R1110} + b * \mathrm{R1240}}\right) \qquad a = 1 - b \qquad b = \frac{\lambda C - \lambda S}{\lambda L - \lambda S}$$

where C is the center wavelength and S and L are the shorter and longer endpoints, respectively [6, 5].

To apply these summary parameters to CRISM hyperspectral imaging data of Mars, we used ENVI's CRISM Analysis Tool (CAT) and Band Math function. We examined six locations on Mars where carbonates have been found that also show evidence of the presence of water (Fig. 1, Table 1).

Table 1. *Sites of Martian carbonates examined in this study.*

Location	Image	Carbonate Type	Reference
Nili Fossae	FRT00003E12	Mg	[7]
Jezero Crater	HRL000040FF	Mg	[7, 8]
Leighton Crater	FRT0000A546	Ca/Fe	[9]
Huygens Basin	FRT0000B5AF	Ca/Fe	[3]
Hesperia Planum	FRT00007DF8	Mg	[3]
Valles Marineris	FRT00008112	Ca/Fe	[10]

Results & Discussion: Graphical comparison of laboratory spectra confirmed that the standard spectral summary parameter combinations recommended in *The MICA Files* [4] for anhydrous carbonates are ineffective in isolating hydrous carbonates (Fig. 2). Instead, we recommend using the A1200 parameter along with parameters BD1750_2 and BD2100_2 [5] when targeting hydrous carbonates (Table 2).

Table 2. *Recommended spectral summary parameters for targeting different types of carbonates. Equations from [5].*

	Anhydrous [4]		[This work]
	Ca/Fe *(Fig. 3A)*	**Mg**	**Hydrous** *(Fig. 3B)*
R	MIN2295_2480	OLINDEX3	BD1750_2
G	MIN2345_2537	MIN2295_2480	BD2100_2
B	CINDEX2	MIN2345_2537	A1200

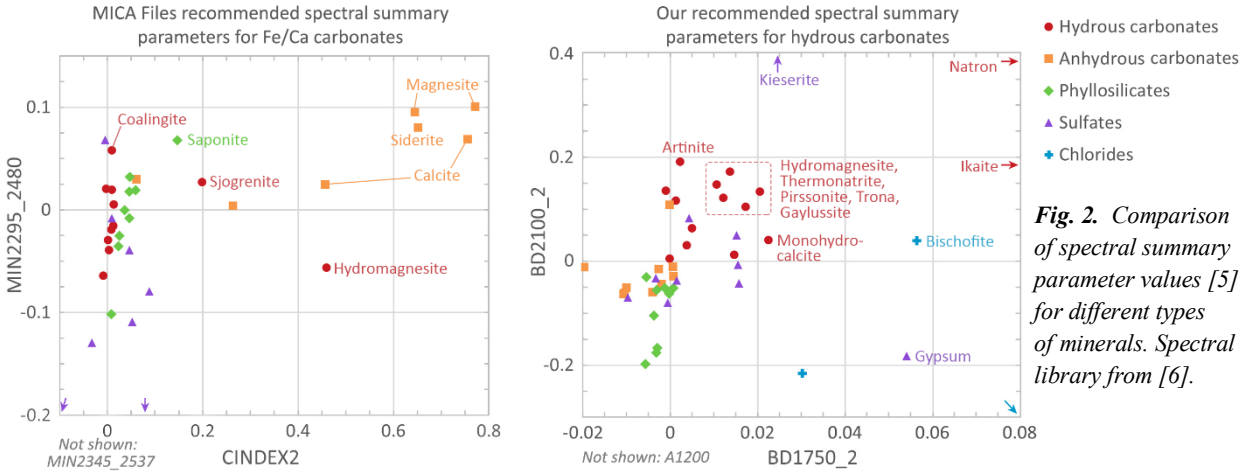

Fig. 2. *Comparison of spectral summary parameter values [5] for different types of minerals. Spectral library from [6].*

When this new spectral summary parameter combination was applied to six locations of known carbonates and water on Mars (Table 1), it was unsuccessful in identifying the carbonates (Fig. 3). Our laboratory findings suggest this indicates that those carbonates are most likely anhydrous. This is supported by comparing ratioed CRISM spectral profiles of those locations to a reference spectral library. The CRISM spectra match the profiles of anhydrous carbonates most closely, aside from absorption features at ~1.9 and 1.4 µm caused by the presence of water. This spectral signature could be caused by anhydrous carbonates that occur in assemblage with some other hydrated phase.

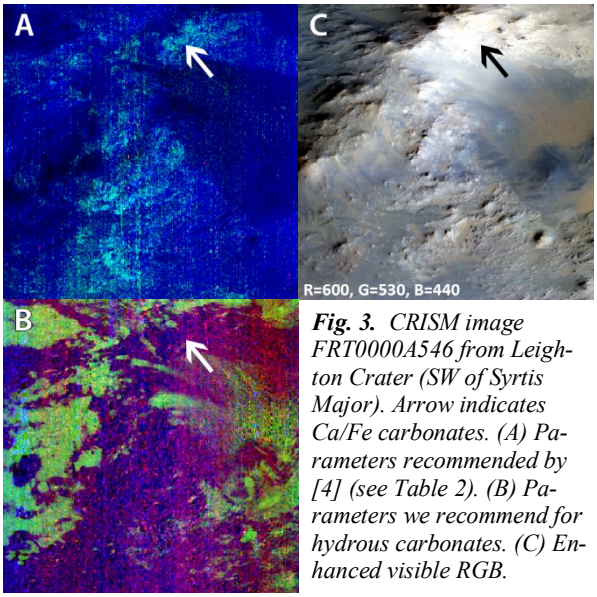

Fig. 3. *CRISM image FRT0000A546 from Leighton Crater (SW of Syrtis Major). Arrow indicates Ca/Fe carbonates. (A) Parameters recommended by [4] (see Table 2). (B) Parameters we recommend for hydrous carbonates. (C) Enhanced visible RGB.*

Initial applications of the A1200 spectral parameter were highly noisy. We determined the noise was not due to the relatively low spectral resolution of the CRISM instrument (6.55 nm/channel) by reducing the laboratory spectra generated by Harner and Gilmore [6] to match CRISM. In these reduced-resolution spectral profiles of hydrous carbonates, the 1.2 µm feature was still clearly discernable, suggesting that it should also be discernable in CRISM spectra if present. The noise may improve if the A1200 parameter is applied to sites that include minerals with the 1.2 µm feature.

Conclusion: If hydrous carbonates are present on Mars, it is plausible that they may have gone undetected by past studies of Martian mineralogy. In the six locations studied here, the carbonates are likely predominantly anhydrous, but further research will be necessary to determine if there are hydrated carbonates elsewhere on the planet. Laboratory data indicate that the spectral summary parameter combination of BD1750_2, BD2100_2, and A1200 may be useful for targeting hydrous carbonates in those future studies. Either the presence or the absence of hydrated carbonates on Mars will be useful in further constraining its mineralogy and ancient environments and could inform us about the evolution of the planet.

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