SPECTRAL MINERAL UNMIXING EXPERIMENTS IN ERIDANIA BASIN, MARS.  S. M. Corrigan1 and M. S. Gilmore1, 1Dept. of Earth and Environmental Sciences, Planetary Science Group, Wesleyan University, 265 Church St. Middletown, CT.

Introduction: A large global carbonate rock reservoir on Mars is one expected consequence of a possible thick CO₂-rich atmosphere early in the planet’s history [1]. The study of carbonate-bearing outcrops can help constrain environmental conditions on early Mars.

Carbonate minerals are identified in CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) [2] spectra by absorption features at 2.3, 2.5, and 3.9 μm. The major cations in carbonate minerals can be identified, as the cations determine the exact position of absorption minima at 2.3 and 2.5 μm [3].

The two most useful carbonate absorption features at 2.3 and 2.5 μm are not unique, and are shared with some silicates, particularly phyllosilicates. In some locations on Mars, the relative depths and positions of carbonate absorption features appear inconsistent with pure carbonate [4,5,6]. Instead, these outcrops are likely mixtures of carbonates and silicates.

In this study we develop software to aid in the identification of mineral mixtures that can better recognize carbonate spectra observed in CRISM images. We then test this software through analysis of martian carbonate outcrops with well constrained compositions, and finally analyze carbonate spectra of unknown compositions.

Methods: Spectra were taken from CRISM observations and processed using standard photometric and atmospheric corrections [2, 9]. Spectra from multiple pixels were averaged and divided by spectra from a spectrally “neutral” region, where spectra are relatively featureless.

Mineral mixtures are created using our own spectral analysis software written in Python. This program uses two different methods for generating and testing modeled mineral mixture spectra against an observed CRISM spectrum. Mixture models are calculated as linear combinations of lab spectra converted to single-scattering albedo, as in [7]. Lab spectra are taken from the RELAB spectral library, USGS spectral library version 7, and a set of hydrous carbonate spectra measured by [8]. Our spectral library consists of minerals included in the MICA Files [10], as well as hydrous carbonates from [8].

The first round of spectral analysis is done in an “equal combinations” mode, where spectral mixtures are created of all possible unique combinations of the spectral library minerals including 1 to 5 endmembers. In this mode areal abundances of each endmember are assumed to be equal. The program calculates a spectral angle [11] between the observed CRISM spectrum and each modeled mixture. Library endmembers are ordered by their frequency of occurrence in mixtures that yield spectral angles in the bottom one percentile. The 20 most commonly occurring minerals move to the second round of analysis.

The “all combinations” mode is the second round of spectral analysis, where all possible combinations of up to 5 endmembers of the most commonly occurring minerals are mixed in various proportions. This analysis is similar to the first-round equal combinations mode, except that it does not assume that endmembers are mixed in equal proportions. Again, a spectral angle is calculated in order to compare each mixture-and-abundance combination to the observed CRISM spectrum.

Results: Here we report results for two test images: "known" carbonates, which includes a Mg-carbonate-bearing outcrop in Nili Fossae [4] and a Ca/Fe-carbonate outcrop in Leighton Crater [5]. We also run the analysis on an outcrop in Eridania recognized to have mixed carbonates and phyllosilicates by [6].

Nili Fossae. Previous analyses [4] report the presence of olivine, magnesite, and nontronite in Nili Fossae. In the 1.0-2.6 μm wavelength range, all bottom-1-percentile combinations include fayalite in some nonzero abundance, while forsterite appears in half of these combinations. Chlorite and siderite also tend to occur at higher abundance than other minerals in the library. All four of these minerals show the broad 1.0 μm absorption feature that dominates the observed spectrum.

Analysis of the 2.2-2.6 μm wavelength range can further constrain the compositions of clays and carbonates present in the observed spectrum. For the Nili Fossae outcrop, magnesite occurs more often and in higher concentrations in bottom-1-percentile mixtures than any other mineral. In this range, talc is the preferred clay mineral, occurring in 40.07% of mixtures. The identification of olivines and magnesite is consistent with published compositions, while the identification of talc is not [4].

Leighton Crater. The central peak of Leighton Crater contains outcrops of Ca/Fe-carbonates, kaolinite minerals, and hydrated Fe/Mg silicates [5]. Analysis in the 1.0-2.6 μm range identifies hematite, diopside, and fayalite, with each occurring in most bottom-1-percentile mixtures. The 2.2-2.6 μm analysis identifies prehnite and three hydrous carbonates: brugnatellite,
coalingite, and pokrovskite. All three of these hydrous minerals contain Mg as a major cation, while brugnatellite and coalingite both contain ferric iron (Fe$^{3+}$).

Eridania Basin. An unnamed crater near Simois Colles in Eridania Basin contains carbonate outcrops near the crater rim, some of which have been mobilized in a gully system [6]. Previous analysis [6] reports the presence of ankerite and silicates.

Analysis of a carbonate outcrop, located in a gully within Eridania, in the 1.0-2.6 μm wavelength range identifies fayalite, diopside, forsterite, and hematite. Analysis in the 2.2-2.6 μm range identifies chlorite as the main clay mineral, occurring in 89.73% of bottom-1-percentile mixtures. Calcite and siderite are the two main carbonates selected, beating 7 hydrous carbonates. Magnesite was not included in the all combinations analysis, as it was not one of the top 20 minerals in the equal combinations analysis. However, calcite is still the preferred carbonate in this wavelength range even when magnesite is inserted artificially into the spectral library.

Discussion: Analysis of the two test cases shows that our software can identify carbonate minerals when they are present in the observation. With particularly strong signals, it can identify the type of carbonate as well, as with magnesite in Nili Fossae. The results from Eridania will help to identify mineral mixtures that can be studied in greater detail, for comparison to the Eridania CRISM spectrum.