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Analysis of spectral indices for fast mineralogical interpretation of Bennu reflectance spectra

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Abstract

The OSIRIS-REx Visible-Infrared Spectrometer will map the surface of asteroid 101955 Bennu from 0.4 to 4.34 µm. The spectrometer is sensitive to a large number of minerals that have features in this wavelength range. In this study, we analyze the efficiency of detection software with spectra of pure minerals with the goal of providing guidance for **fast** spectral map analysis and confidence in mineral detection during operations at Bennu.

1. Introduction

NASA's Asteroid Sample Return Mission OSIRIS-REx (**O**rigins, **S**pectral **I**nterpretation, **R**esource **I**dentification, and **S**ecurity **R**egolith **Ex**plorer) was launched in September 2016, and reaches its target late in 2018. The mission will map and study the Near-Earth asteroid 101955 Bennu and select two possible sampling sites. If there is mineralogical variation across the surface of Bennu, then one region will have a higher science value than another region [1]. We are focused on developing fast mineralogical mapping with data from the OSIRIS-REx Visible-Infrared Spectrometer (OVIRS) [2]. For quick analysis, spectral index (SPINDEX) calculation software has been developed, and is now part of an automated data processing pipeline. For each spectrum of Bennu, SPINDEX calculates 103 spectral indices (absorption band depths and regional continuum slopes). The goal of this study is to calibrate each index with pure mineral spectra in order to select the best spectral indices for mapping Bennu. The mission requires a map of all minerals showing band depth of 5% or more.

2. Data Analysis

Initially, our focus is on oxides (chromite and magnetite) and sulfates (epsomite). Pure mineral reflectance spectra are gathered from the RELAB (Reflectance Laboratory) online database (hosted by Brown University) and the PSF (Planetary Spectrophotometer Facilities) database (hosted by the University of Winnipeg). We then wrote software to resample the laboratory spectra to OVIRS spectral resolution and format them for input to SPINDEX. Additional programs were developed to visualize SPINDEX results, and perform careful analysis of absorption band positions. Magnetite is of particular interest as it has been suggested to be present on Bennu [3].

3. Results

For SPINDEX, each spectral index is numbered and associated with a specific mineral. Based on SPINDEX results, we can separate these bands into strong and weak bands, according to depth. For chromite ($FeCr_2O_4$ Bands 15-20), a total of 15 spectra from the RELAB database were analyzed. Band 15 is the strongest but is not specific to chromite. Hence, a positive detection is required for at least one of the other four weak bands (bands 17, 18, 19, or 20). We find that band 18 is too weak to be of any use (its depth is always below the 5% threshold even for pure minerals), hence to detect chromite on Bennu, we must observe both Bands 15 and 20, the next strongest band. One outcome of our analysis is an improvement of the three wavelengths defining band 20. In Figures 1 and 2, we present band 20 strength after continuum removal according to the old definition (Fig. 1) and according to our new proposed definition (Fig. 2). In Figures 1 and 2, the black dashed line symbolizes the 5% threshold and the dotted line is the wavelength center of the band. This is an example of the type of improvements we are making to SPINDEX.

As for magnetite, only one band index exists in SPINDEX: Band 16. Our analysis of 33 pure magnetite spectra enables us to propose a new definition of the band, shown in Table 1, to better take into account the absorption feature centered at 0.52 µm. With this improvement, 30% of the magnetite spectra showed positive detection at Band 16, as compared to only 12% previously.

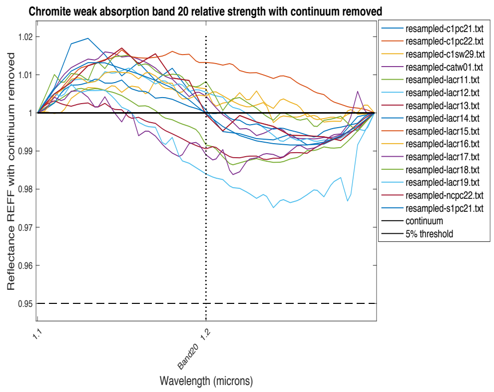

Figure 1: Old definition of Band 20 relative strength with continuum removed.

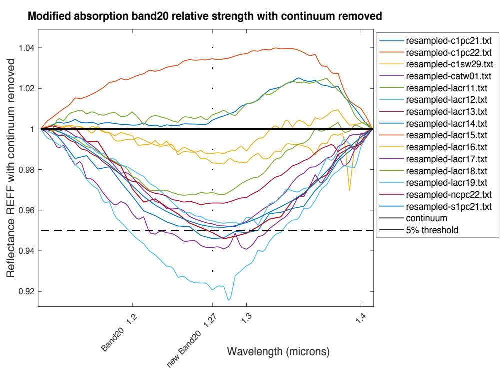

Figure 2: New definition of Band 20 relative strength with continuum removed.

Epsomite is one of the two sulfates detectable with OVIRS (gypsum is the other). Two specific bands (30 and 31) are dedicated to Epsomite. The results of analysis of 6 pure epsomite spectra (from the PSF database) show that both bands can be qualified as strong if we make an improvement to Band 31, shown in Table 1, to better take into account the shape of the absorption feature centered at 1.95 µm. Because it has two strong bands, epsomite, if present on the surface of Bennu, is very likely to be detected.

Table 1: Old and new proposed definition of the SPINDEX bands tested in this study

Band number, and mineral detected	Old definition (left, center and right wavelengths in µm)	New definition (left, center, and right wavelengths in µm)
Band 15 (Chromite)	1.5-2.1-2.7	\
Band 17 (Chromite)	0.55-0.58-0.61	\
Band 18 (Chromite)	0.64-0.67-0.7	\
Band 19 (Chromite)	0.8-0.9-1.0	\
Band 20 (chromite)	1.1-1.2-1.3	1.12-1.27-1.41
Band 16 (Magnetite)	0.45-0.5-0.55	0.41-0.52-0.64
Band 30 (Epsomite)	1.3-1.45-1.75	\
Band 31 (Epsomite)	1.8-1.95-2.25	1.83-1.95-2.25

4. Future Work

In future work, we will analyze SPINDEX results for silicates and hydrated silicates. Ultimately, our work will provide a ranking of the most useful SPINDEX indices in terms of band strength and science value. This will constitute a "Guide to spectral indices" that OSIRIS-REx science team members can use for fast and confident interpretation of OVIRS spectral maps.

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