OSIRIS-REx
ASTEROID SAMPLE RETURN MISSION

Distinguishing carbonates and organics on OSIRIS-REx target asteroid Bennu using the 3.4-micron feature

Salvatore Ferrone sferrone@Ithaca.edu

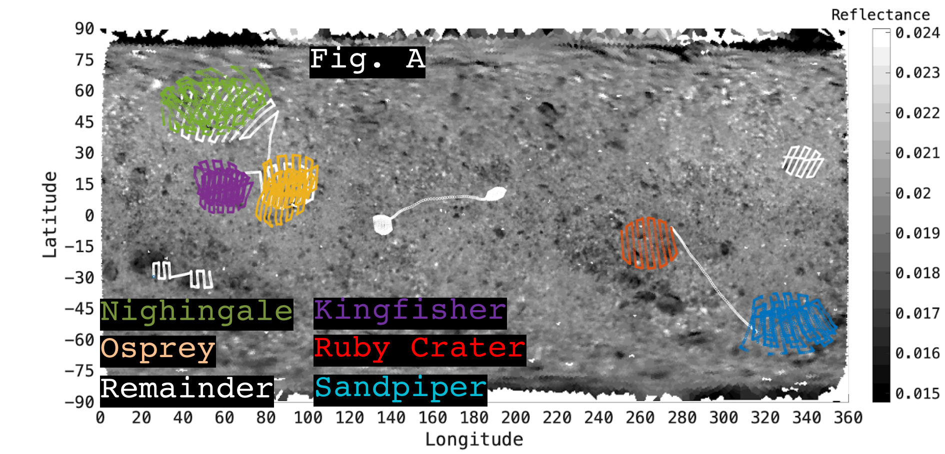
Beth Clark bclark@Ithaca.edu

September 2020

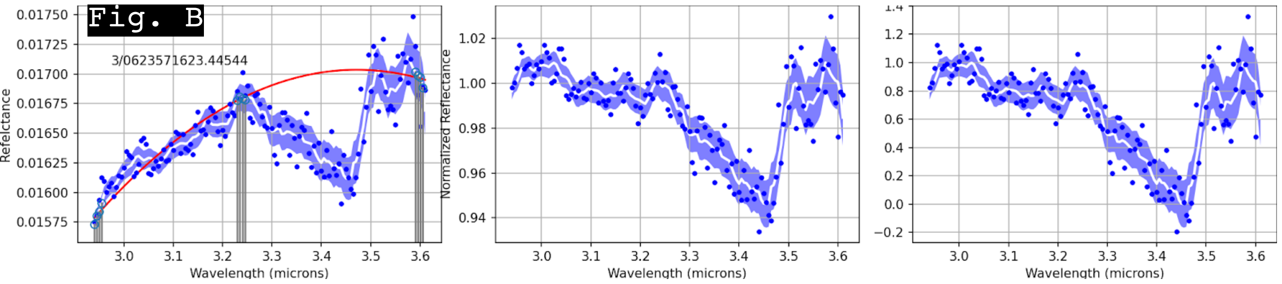
Abstract

- We apply a Kolmogorov-Smirnov similarity test to OVIRS spectral observations of Bennu and laboratory spectra of minerals to categorize 3.4-micron features as detecting either carbonates (calcite, dolomite, magnesite, siderite) or organics (meteoritic aliphatic hydrocarbons, asphaltite, graphite, carbon black, coals of various ranks). Of the 15,585 Bennu spectra measured by OSIRIS-REx during the Recon-A mission phase, we find 544 spectral matches with carbonates and 245 spectral matches with organics (i.e. top 5%), using the Kolmogorov ranking. We map the locations of these excellent matches and characterize features of Bennu's surface from corresponding image data. Image data are used to quantitatively characterize the scene within each spectrometer footprint. Results are that we find no significant trends between spectral classification and surface morphological expression, and we find no correlation between carbon species classification and other spectral properties (such as slope or band depth). This suggests that either carbonates and organics are ubiquitous across the surface of Bennu, independent of surface features (consistent with studies of carbonaceous chondrites), or that we do not achieve the spatial resolution required to resolve differences. We do, however, find that more organic spectral matches occur in the Nightingale sampling site, Osprey secondary sample site, and at Ruby Crater than other locations observed during Recon-A. Higher concentrations of organics at Nightingale, Osprey, and Ruby craters may be explained if these materials have been more recently exposed to surface alteration processes, perhaps by recent crater formation.

Data



1) **The OSIRIS-Rex data:** data were collected from the OVIRS visible and infrared spectrometer and images were collected with the MapCam instrument in the Reconnaissance A mission phase from 09-September-2019 to 28-October-2019. The OVIRS observations are shown in Fig A. The size of the spectrometer Field's of view are roughly drawn to scale.
2) **Laboratory Data:** The laboratory spectra were obtained from the RELAB, Ecospeclib, and USGS spectral libraries. The 14 organic matter spectra contain meteoritic aliphatic hydrocarbons, asphaltite, graphite, lampblack, coals. Carbonate mineral spectra contain (44 calcites, 25 dolomites, and 15 magnesites)



3) **Preparation:** The OVIRS observations were photometrically corrected to viewing geometry of (incidence, emission, phase) = (30,0,30) using a McEwen photometric model, whose parameters were constrained using reflectance data taken from the global survey mission phase. The MapCam images were also corrected to (30,0,30) using a ROLO photometric model. Observations and pixels whose incidence angles above 70 degrees were omitted.

Overview: Spectrometer data from the OVIRS instrument and laboratory reflectance data of Calcites, Dolomites, Magnesites, and Organic matter are continuum removed with a second order polynomial, as shown in Fig. B.

Methods

Fig. A

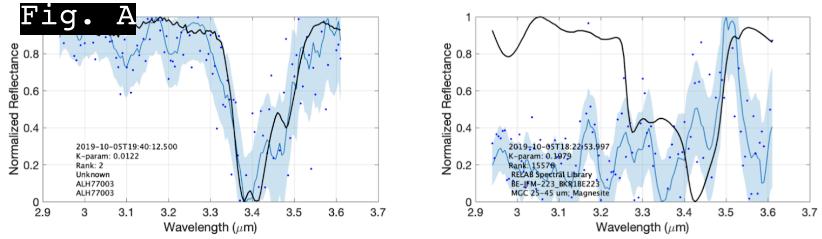


Fig. B

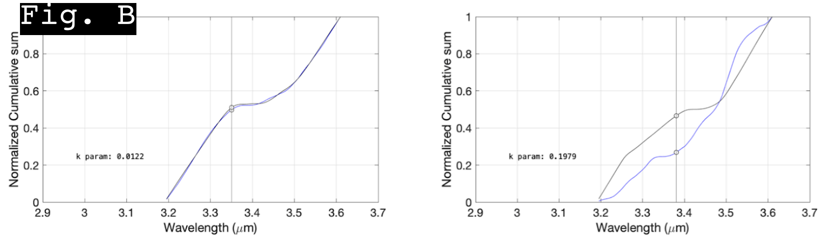
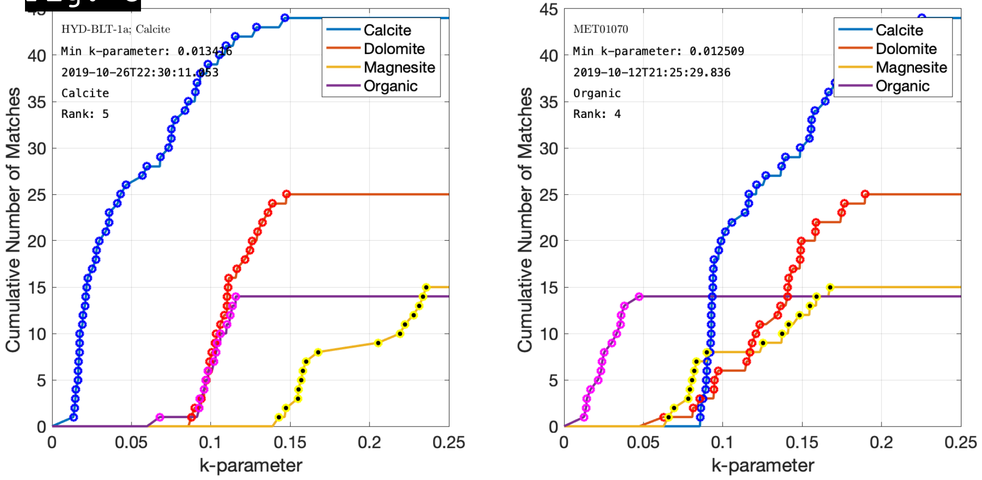


Fig. C



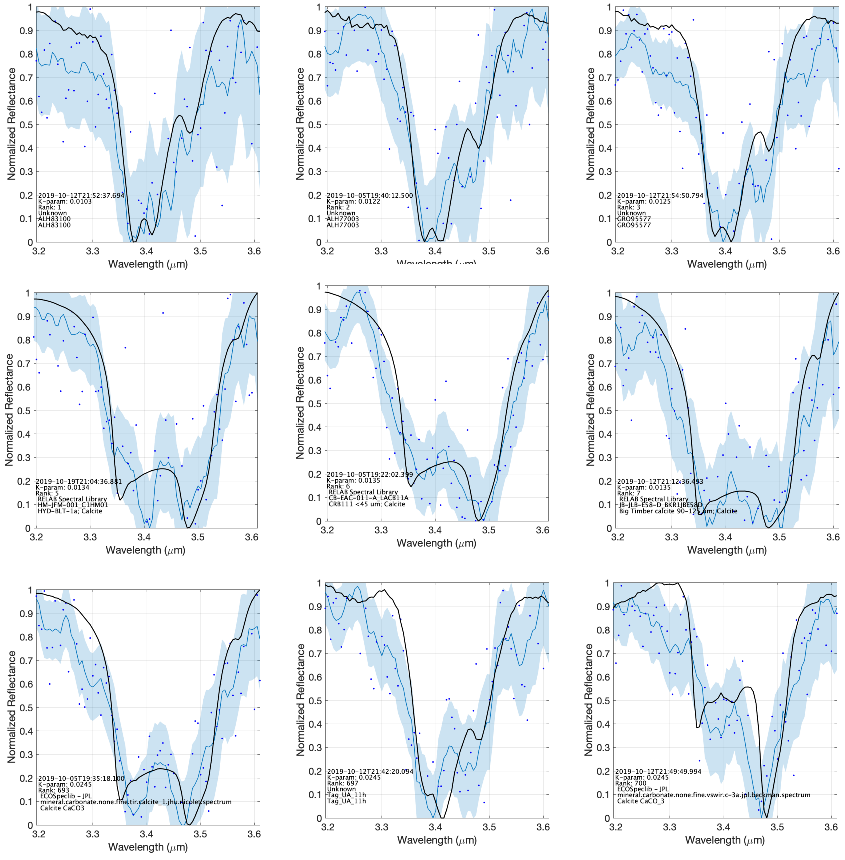
Overview: The goodness of fit of each OVIRS spectrum is evaluated against each of the 98 laboratory spectra (44 calcite, 15 dolomite, 17 magnesite, and 14 organics). An OVIRS observation is matched with the laboratory spectrum with the lowest goodness of fit value. The spectral matches are shown in Fig. A. The goodness of fit parameter is the maximum vertical distance between each of the cumulative distribution functions of the spectra as shown in Fig. B. We assign the best matching laboratory spectrum to an OVIRS spectrum. A spectral match is generally repeatable if the smallest goodness of fit value is below .05 as shown in Fig. C.

Fig. A: spectral matching of one of the best spectral matches and one of the worst matches in the data set. Blue represents an OVIRS observations, while black is a laboratory spectrum

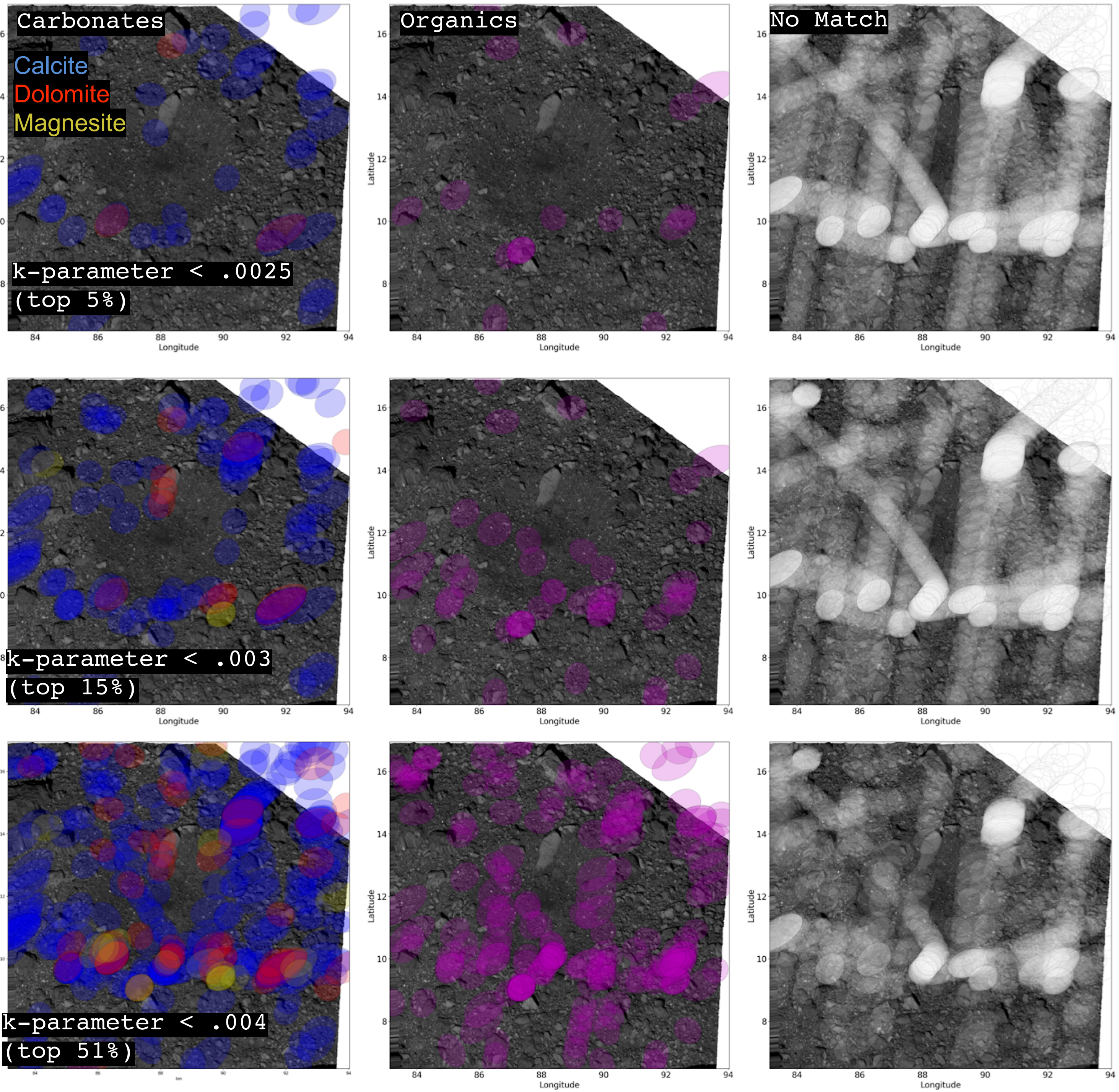
Fig. B: an example of the Kolmogorov-Smirnov statistic for spectral matching. The plots are cumulative density functions of the corresponding spectra of Fig. A. The value of the maximum discrepancy is between the two distributions is the goodness of fit parameter. The smaller the maximum discrepancy, the better the fit (left), the larger the value, the worse the fit (right).

Fig. C: The number of matches of each laboratory spectrum to a single OVIRS spectrum as a function of the goodness of fit parameter. Each marker represents a new match, the x-value indicates the goodness of fit value for that spectral match. As shown in the left panel, this OVIRS observation is matched with half of the calcite laboratory spectra before it matches a non-calcite spectra. For the right, the observation matches with all the organics before one of the carbonate spectra. This plot demonstrates the repeatability of the spectral mapping parameter.

Spectral matching



- We demonstrate that the spectra observed on Bennu have band minima positions and band widths consistent with organics and carbonate spectra. The doublet shapes associated with carbonates are also observed on Bennu.



Mapping

- The image of this region of interest is the osprey former candidate sample site.
- The colored ellipses represent the fields of view of the OVIRS instrument. We color areas within the FOVs corresponding to the match of the OVIRS spectrum to the laboratory spectra. The left column show carbonates, the middle shows matches to organics, while the right shows spectra that we do not consider to be a high-quality match. Each row we impart a different threshold for weather or not the OVIRS spectrum matches the laboratory spectrum, where the top row are the highest quality fits.
- We find no significant correlation between surface expression (craters, boulder shapes, boulder free areas, ecc) with classification of the 3.4-micron feature as either carbonates or organics.

Conclusions

- Organics and carbonates are found at all Recon-A target locations studied to date on Bennu. The carbon-species classifications of spots on Bennu do not seem to correlate with quantitative metrics of surface properties measured with either OVIRS or OCAMS. Specifically, we find no statistical associations between organics and spectrally red or dark locations on Bennu. We find no statistical relationship between carbon species category and any of the spectral parameters we measured (continuum slope, band minimum position, band depth). This could be telling us that either (1) carbonates and organics are ubiquitous across the surface or (2) our spectral data do not have sufficiently high spatial resolution to draw meaningful associations between surface features and carbon species (in other words, the connections may occur at spatial scales smaller than the 4-9 meter scale we observed). This finding could help to constrain future work in terms of areal mixing studies.