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Mapping Spectral Units on (101955) Bennu

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Abstract

Spectral data collected by the Origins, Spectral Interpretation, Resource Identification, Security–Regolith Explorer (OSIRIS-REx) mission reveal spatial variability of surface properties. We identify and map variations in albedo, slope, and absorption feature strength in data from two spectrometers: the OSIRIS-REx Visible and InfraRed Spectrometer (OVIRS) and the OSIRIS-REx Thermal Emission Spectrometer (OTES). We use these maps to define two distinct spectral units on Bennu.

1. Introduction

The OVIRS and OTES spectrometers onboard OSIRIS-REx are characterizing the global chemistry, mineralogy, and temperature of Bennu's surface, including the sample site, prior to sample collection and return. OVIRS covers visible and near-infrared (VIS-NIR) wavelengths (0.4–4.3 μm; ~25000–2304 cm^{-1}) [1], and OTES measures the thermal infrared (5.5–100 μm; ~1820–100 cm^{-1}) [2]. OVIRS and OTES data collected during the Approach and Preliminary Survey mission phases revealed evidence of hydrated minerals, consistent with CI and CM carbonaceous chondrites [3].

Diverse albedo and geologic features are seen in high-resolution OSIRIS-REx Camera Suite (OCAMS) images of Bennu's surface at the centimeter to meter scale [4], motivating the search for related spectral variability. We discuss Bennu's absorption features, their spatial distribution, and the subsequent identification of spectrally distinct regions.

2. Search for Absorption Features

We find evidence of hydrated minerals in all spectral data. In the OVIRS spectra, we observe a 2.7-μm OH^{-}/H_2O absorption feature with a band center at ~2.74 ± 0.01 μm [3]. The VIS-NIR slope in most photometrically corrected spectra is negative (blue) [5], consistent with ground-based observations [6]. OTES spectra also show evidence of hydrated minerals and, by comparison with laboratory spectra of analogue meteorites, indicate that the abundance of these phases exceeds ~55 vol.% [3]. Specifically, we observe a diagnostic phyllosilicate-dominated bending feature with a minimum at 440 cm^{-1} (~22.7 μm) and a set of features potentially indicative of magnetite at 555 and 346 cm^{-1} (~18 and 28.9 μm) [3, 7].

We continue to search for additional spectral features as we obtain data of increasing quality and spatial resolution. To date, we have not observed features at 0.55 or 0.7 μm associated with magnetite [8] and Fe-bearing phyllosilicates, respectively, in OVIRS data. The search for organics is also ongoing and will be best assessed with OVIRS data from our equatorial mapping station at 10:00 am local time, scheduled for May 2019.

3. Spatial Distribution of Spectral Properties

Global maps demonstrate that observed spectral feature variations are spatially coherent. We map reflectance factor (REFF) at 0.55 μm, bolometric bond albedo (Figure 1), spectral slope from 0.45 to 0.55 μm, band depth at 2.7 μm, band depth at 22.7 μm (440 cm^{-1}), temperature derived from both OVIRS and OTES, and thermal inertia, which each appear to show regional variation across the surface. It is unclear whether the variations are the result of space weathering, particle size, surface roughness, composition, or some combination of these properties.

3.1 Spectral Units

We recognize two distinct spectral units. Because these are associated with surface albedo, we call them the **light unit** and the **dark unit** (see Figure 1). Two

regions, each corresponding to one of these units, are identified in the Figure 1 and their spectral properties are discussed below.

The light unit is characterized by higher albedo material, with REFF at 0.55 µm of 0.0270 ± 0.0004 and bolometric bond albedo of 0.0253 ± 0.0003. Slopes in these regions are bluer, with an average slope from 0.45 to 0.55 µm of –0.0085 ± 0.0009. The absorption feature at 2.7 µm is stronger and the minimum at 22.7 µm (440 cm^{-1}) is deeper relative to those features in spectra from the dark unit. Mapping the variation in the 2.7 µm band depth [9] and separating band depth from temperature [10] is ongoing work. These materials appear to have higher thermal inertias than the dark unit [11].

The dark unit has a lower albedo with an average REFF at 0.55 µm of 0.0241 ±0.0010 and bolometric bond albedo of 0.0227 ± 0.0009. Slopes are less blue, though only rarely is there a positive (red) slope. The average slope from 0.45 to 0.55 µm in the dark region is –0.0059 ± 0.0010. The absorption feature at 2.7 µm and minimum at 22.7 µm (440 cm^{-1}) are weaker in this region than in the light unit. The type location for this material is a large ~90-m boulder that is labeled on the map in Figure 1. This large boulder has a higher than predicted temperature in data collected at local noon, interpreted to be due to lower thermal inertia [10, 11].

The geologic relationship between the dark and light units will be critical for understanding the origin of these spectral differences. Preliminary analyses tell us that (1) the two units appear to be morphologically distinct, with variations in boulder size-frequency distribution and boulder morphology, and (2) steeper terrain in the mid-latitudes may have mobilized mass movement towards the equator [12], potentially leading to differing exposure ages and space weathering effects between the two units.

4. Summary and Conclusions

We present the spatial distribution of spectral properties of Bennu's surface. Two preliminary units are identified by the OVIRS and OTES spectrometers on OSIRIS-REx based on their albedo, slope, absorption features, and thermal properties. As more data are collected during our Detailed Survey of Bennu, we expect that we may resolve further spectral and morphologic variation within each of these units.

Acknowledgements

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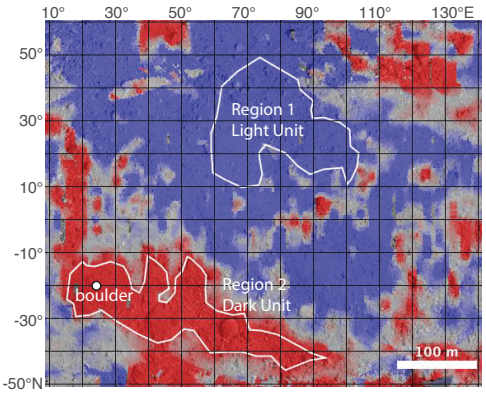

Figure 1: Regions are defined from the bolometric bond albedo map (red < 0.0232, blue > 0.0249).