
Introduction: The OSIRIS-REx spacecraft arrived at near-Earth asteroid Bennu on December 3, 2018. During the Approach phase of the mission, the onboard MapCam camera, part of the OSIRIS-REx Camera Suite (OCAMS), acquired images of the asteroid using four narrow bandpass filters with a pixel scale up to 12 m/pixel. MapCam has four color filters—b’ (473 nm), v (550 nm), w (698 nm), and x (847 nm)—and a panchromatic filter [1]. Using the color images from November 4 to 9, 2018, we generated a color mosaic of the surface of Bennu. Our goal is to investigate surface color variation, quantify trends in color parameters (spectral slope, band depth), and map the distribution of potential absorption features.

Bennu Before OSIRIS-REx: Ground-based photometric measurements by [2] and spectra from [3] showed that Bennu is a B-type asteroid. Clark et al. [3] showed that Bennu’s disk-integrated spectrum has a blue spectral slope and is essentially featureless. They proposed CI or CM carbonaceous chondrites as probable meteorite analogs for the asteroid.

Data Processing: Calibrated reflectance data (I/F) was corrected for viewing and illumination effects to adjust the brightness of the images acquired during different days with different viewing conditions. This allows us to build a more homogenous image mosaic without too much discrepancy between frames (i.e., a seamless mosaic).

Color Analysis: Various color parameters were computed such as band depth, color ratios, and slopes using unprojected multi-band cubes and with the reprojected global mosaic of Approach images (10 m/pixel at best).

Color sets. Color sets consist of four color filter images acquired close to each other in time. Images were aligned to their backplanes to reduce the pointing errors and were then centered on Bennu to create a unprojected color cube with four bands (Fig. 1).

The most striking color variations are associated with a very dark outcrop, dark boulders or clusters of dark boulders that can be resolved in the approach phase images (Fig. 1). The average geometric albedo of Bennu is 0.0435, and we estimate the albedo of the dark outcrop to be 0.034 in the panchromatic filter. We can also compute other parameters such as ratio of b’/x (473 nm/847 nm) to characterize these dark surface features.

They seem to generally have a much redder spectral slope between b’ and x than the typical average terrain on Bennu, which has a blue slope (Fig. 2).

Color spectra. The dark terrain also stands out in other color ratios, for example b’/v, because they have a deeper 550-nm band depth than the average terrain on Bennu (Fig. 2).

Figure 1. RGB color image of Bennu (left) created using MapCam filters w, v, and b’ as the red, green, and blue channels. Color ratio image (right) from b’/v.

Figure 2. (Top) Average global color spectra of Bennu (red) and dark boulder (black). (Bottom) Same spectra normalized at 550 nm. Error bars are computed with one standard deviation.
Absorption features. The location of the largest dark spot is indicated on the PolyCam Approach map (Fig. 3). We used images from the Approach phase to compute the distribution of the 550-nm band depth (Fig. 4) as well as the 700-nm band depth for this dark outcrop, using a standard formula to calculate band depths as described in [4]. It allows us to visualize the distribution of the areas with deepest band depth, confirming that the dark terrains (Fig. 5) exhibit the deepest 550-nm absorption band depth (Fig. 4). At the Approach resolution and with only a preliminary photometric model, it is difficult to identify further surface features with a pronounced 550-nm absorption band in the map. In addition, a better photometric correction is required to study more accurately the distribution of surface units with this spectral signature. The 700-nm absorption was not detected.

Nature of the 550-nm Absorption Feature: CM and CI chondrites have been proposed as analogs for Bennu. The mineralogy of these meteorites reflects extensive aqueous processing and includes phyllosilicates, carbonates, and Fe oxides, notably magnetite. Magnetite reflectance spectra exhibit a local minimum in reflectance centered near ~550 nm [6], as do the related minerals ferrihydrite and maghemite [3]. Magnetite is further characterized by a low overall reflectance and has a blue spectral slope shortward of 1000 nm.


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Figure 3. Panchromatic global map of Bennu from the PolyCam imager, showing the location of the dark outcrop indicated by a white circle. Images used for this mosaic were acquired during the Approach phase.

Figure 4. 550 nm-band depth image of Bennu created using MapCam Approach phase data from November 8, 2018. The darkest spot, indicated by white arrow, and identified as an possible outcrop, has a deep 500-nm feature compared to the global average. Image has been smoothed.

Figure 5. v-band image of Bennu acquired during Approach phase (November 8). The dark outcrop is visible as the largest low reflectance unit (indicated by the white arrow). This outcrop is surrounded by smaller dark boulders also showing a relatively deep 550-nm band depth (Fig. 4). Image has been smoothed.