VNIR-TIR spectroscopy of (101955) Bennu

V. E. Hamilton (1), A. A. Simon (2), H. H. Kaplan (2), C. A. Goodrich (3), D. S. Lauretta (4), and the OSIRIS-REx Spectral Analysis Working Group; (1) Southwest Research Institute, Boulder, CO, USA (hamilton@boulder.swri.edu). (2) Goddard Space Flight Center, Greenbelt, MD, USA. (3) Lunar and Planetary Institute, Houston, TX, USA. (4) Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA.

1. Introduction

We present visible to near infrared (VNIR) and thermal infrared (TIR) spectral data for asteroid (101955) Bennu collected by the OSIRIS-REx Visible and InfraRed Spectrometer (OVIRS) [1, 2] and the OSIRIS-REx Thermal Emission Spectrometer (OTES) [3]. The data discussed here were collected during the 12:30 pm Equatorial Station of the Detailed Survey mission phase and Reconnaissance A (varying local times). Constraints applied to the selection of data are described by [4-6].

2. OVIRS results

Early results [7] revealed that an unambiguous "3-µm" band is present, consistent with the presence of hydrated (phyllo-)silicates. The specific position of this band in OVIRS spectra, 2.74 µm ± 0.01, is consistent with the positions observed in low petrologic subtype CM2 meteorites [8]. The global distribution of this feature is described by [9].

Since the acquisition of global mapping data at ~20-30 m/spot, we have identified a complex of features in the 3.2–3.6 µm region that we attribute to the presence of C-bearing compounds (organics and carbonate minerals) [4, 5]. Absorption band positions, widths, and relative strengths appear to be associated with a variable mixture of organics and multiple carbonate minerals. The varying shape and depth of a 3.4-µm absorption feature across Bennu's surface spans the range seen among disk-averaged spectra of main-belt carbonaceous asteroids. Bennu's distribution of carbon-bearing materials does not correlate with the distribution of hydrated minerals, surface brightness, or geologic features. Carbonate features identified in this spectral region are interpreted as having a variety of cation compositions. The organic features are consistent with aromatic and aliphatic C-H bonds like those of insoluble organic matter in meteorites and other primitive objects [10, 11]. The deepest 3.4-micron absorptions occur on individual boulders, and surface variation may be attributable to differences in abundance, fresh exposure by processes such as thermal fracturing, or differences in space weathering. There is no definitive spectral evidence of either organics or carbonates outside of the 3.2–3.6 µm region.

Several weak absorption bands also have been observed [4]. These are consistent with phyllosilicates (e.g., the 1.4-µm region), Fe-bearing phases (e.g., 1.05-µm region), and magnetite (0.55 µm).

3. OTES results

OTES spectra acquired during the Preliminary Survey mission phase are broadly consistent with carbonaceous chondrites (CCs) in the CI/CM groups [7]. Potential evidence of magnetite is present in features at 555 and 346 cm^{-1} [1] and is consistent with aqueous alteration. Detailed Survey measurements at ~40 m/spot exhibit spectral variability, primarily in the shape of the silicate stretching feature and the depth of the silicate bending feature. These variations can be described by two endmember spectral types, T1 and T2, which appear to primarily represent differences in the amount of fine particulate (<~65–100 µm) dust across the surface of Bennu [6]. The dust appears to be up to ~10–15 microns thick and does not exhibit the spectral characteristics of typical fine-particulate materials. Thermal inertia data also constrain the thickness of any dust layer to <50 µm [12]. The locations of T2 spectra, inferred to have a slightly greater proportion of dust cover, tend to correspond with those of boulders having rough surfaces, suggesting that dust may be trapped preferentially on these rocks.

Analysis of the shape of the silicate bending feature complex centered at ~440 cm^{-1} (~22.7 µm) indicates that anhydrous silicates are likely to comprise less than ~10 vol.% of the bulk silicate mineralogy.

A CC (C1) clast, 91A_1, from the Almahata Sitta meteorite (Ur-ung) exhibits a strong similarity to the T1 spectrum, particularly in the silicate stretching region. This sample exhibits signs of mild heating [13], with ~10 vol% recrystallized olivine.

We cannot rule out that portions of Bennu's surface lithology(-ies) have been heated but such heating is likely to be limited to temperatures <400°C [e.g., 14].

4. Implications for the returned sample

The material collected from Bennu's surface will be constrained by the design of the sampling mechanism to particles less than ~2 cm in diameter [15]. Imaging [16] and spectral data suggest that particles smaller than the maximum sampleable size are present and should be collected. It is probable that the sample will be dominated volumetrically by phyllosilicate minerals, with anhydrous silicates unlikely to comprise more than ~10 vol.% of the silicate mineralogy. Magnetite is expected to be in the returned sample, as are carbonates and organics. VNIR and TIR spectral features imply that at least some of Bennu's surface materials may differ from those of typical CC meteorites.

Acknowledgements

This material is based upon work supported by NASA under Contract NNM10AA11C issued through the New Frontiers Program. We are grateful to the entire OSIRIS-REx Team for making the encounter with Bennu possible.

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