BENNU: AN AQUEOUSLY ALTERED AND MILDLY HEATED CM CARBONACEOUS ASTEROID.

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Introduction: The OSIRIS-REx mission is currently observing asteroid (101955) Bennu to prepare for sampling in 2020. Spectra acquired with the OSIRIS-REx Visible and InfraRed Spectrometer (OVIRS) and Thermal Emission Spectrometer (OTES) during the Approach and Preliminary Survey mission phases indicate that hydrated materials, similar to aqueously altered CM chondrites, dominate Bennu's surface [1]. Here we present the results of a laboratory spectral study of a suite of CMs with variable degrees of aqueous alteration and heating to correlate and characterize spectral changes associated with petrologic subtype. This will aid in the interpretation of OVIRS and OTES spectral data and help assess the degree of alteration and heating across Bennu's surface and at the sampling site.

Methods: We analyzed a group of 13 CMs representing a range of aqueous alteration (2.0–2.7; [2]) and degree of natural heating (stages II–III/IV; [3]) as well as one CI (Alais). In addition, we experimentally heated chips of CM 2.1 ALH 83100 to observe the mineralogical and spectral modification resulting from the heating of a highly aqueously altered CM. For the initial experimental heating, small chips of ALH 83100 were placed in platinum crucibles and heated in a tube furnace under vacuum for 24 hours at 400°C. We collected mid-infrared (4,000–400 cm^{-1}; 2.5–25 µm) reflectance spectra of all samples in thin section with a Thermo Scientific iN10 FTIR microscope (µFTIR) at a spectral resolution of 4 cm^{-1}[4]. We performed complementary mineralogical and textural analysis of the sample sections using backscattered electron (BSE) imagery and energy-dispersive (EDS) x-ray analysis.

Results and Discussion: We observe several spectral trends correlated to both the degree of aqueous alteration and heating among the CMs. With increased aqueous alteration, the Christiansen feature (CF) moves to smaller wavenumbers, the SiO stretching (~950 cm^{-1}) and SiO bending (~440 cm^{-1}) bands move to larger wavenumbers, and the depth of the MgOH deformation band (~625 cm^{-1}) increases. With increased degree of natural heating, the SiO stretching band first broadens and then, with higher heating (stage III+), becomes sharp with bands that can be attributed to secondary olivine formation [3]. The SiO bending minimum also moves to smaller wavenumbers with heating, forming strong olivine bands as well at higher stages (III+). The MgOH deformation band is absent from all naturally heated samples. The main spectral modifications of the experimentally heated ALH 83100 are lowered emissivity due to formation of sulfides [5], a broadening of the SiO stretching band, and decreased depth of the MgOH band.

Analysis of a globally averaged OTES spectrum acquired during a Preliminary Survey equatorial pass confirms the initial interpretation that Bennu resembles a highly aqueously altered CM [1]. The positions of its CF (1117 cm^{-1}), SiO stretching minimum (950 ± 8 cm^{-1}), and SiO bending minimum (442 ± 9 cm^{-1}) are most consistent with a CM of subtype 2.5 or below. However, Bennu's spectrum lacks a detectable MgOH band, which is prominent among all aqueously altered CMs, and its SiO stretching band has a long wavelength broadening that is markedly different from that of unheated CMs. While the latter could be caused by the presence of fine particles, an MgOH band should still be observable (e.g., Fig. 4 in [1]). Both of these features could be attributed to heating of CM material however, as evidenced by both our naturally and experimentally heated CMs. Because the heating did not lead to the formation of secondary olivine typical of stage III+ CMs, we conclude that temperatures remained below 500°C [3]. Other evidence for heating of Bennu's surface include the presence of magnetite [1], which is found in mildly heated (stage II–III) CMs [6], in-situ breakdown of boulders that may be thermally induced [7], and particle ejection that may be related to volatile release, perhaps from the breakdown of hydrous minerals [8]. Despite this evidence for mild heating, we cannot rule out the presence of unheated materials on Bennu, especially in forthcoming higher-spatial-resolution data.

Conclusions and Ongoing Work: Our analysis of the globally averaged OTES spectrum suggests that the best spectral match to Bennu may be an aqueously altered (subtype ≤ 2.5) CM that has been mildly heated (< 500°C). We are currently heating chips of ALH 83100 for longer durations at lower temperatures to further constrain the nature of heating on Bennu's surface. We are also analyzing the 2.74-µm feature in OVIRS data to search for evidence of heating in the 3-µm region, which should be sensitive to heating as has been found for asteroid Ryugu [9].

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