ORGANIC MATTER AND NANOGLOBULES IN BENNU SAMPLES REVEALED BY COORDINATED UV FLUORESCENCE, SEM-EDX, AND TWO-STEP LASER MASS SPECTROMETRY.

S. J. Clemett[1,2], K. L. Thomas-Keprta[1,3], L. Le[1,4], L. P. Keller[1], D. P. Glavin[5], J. P. Dworkin[5], H. C. Connolly Jr.[6,7,8] & D. S. Lauretta[7]; [1]NASA JSC, Houston, TX, USA(simon.j.clemett@nasa.gov); [2]ERC, Inc. / [3]Barrios / [4]Jacobs, NASA JSC, Houston, TX, USA; [5]NASA GSFC, Greenbelt, MD, USA; [6]Rowan University, Glassboro, NJ, USA; [7]LPL, University of Arizona, Tucson, AZ, USA; [8]Museum of Natural History, New York, NY USA.

Introduction: Carbonaceous meteorites are derived from asteroids, although specific parent bodies are generally unknown. However, on September 24, 2023, NASA's Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission delivered regolith from the carbonaceous B-type asteroid (101955) Bennu, enabling coordinated laboratory analysis of pristine samples, with a well characterized geological context, from an asteroid of known provenance. One of primary mission goals [1] was the identification and characterization of primordial organic matter present in the returned samples. We report results from the coordinated analyses of Bennu samples using UV fluorescence, two-step laser mass spectrometry (μ-L^{2}MS) and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX).

Samples: OREX-501006-0 and OREX-501018-100 consisted of aggregate fines (< 100 μm) collected from the return canister's avionics deck. For sample mounting, the former was dispersed and pressed onto a KBr window and the latter onto annealed Au foil. OREX-501017-0 (from the avionics deck) and OREX-803080-0 (from inside the sample collector) consisted of intermediate-sized grains (<500 μm); the former was mounted on an Al SEM stub using C-tape, and the latter was sectioned in epoxy.

Methods: All samples were initially documented using optical and ultraviolet (UV) fluorescence imaging (330–385 nm excitation / 420 nm long-pass emission) using a Nikon BX-60 microscope. Selected regions of interest were subsequently analyzed by μ-L^{2}MS with both point spectra and 2-D maps acquired at a 5 μm spatial resolution using either resonant multiphoton (UV; λ = 266 nm) or non-resonant single photon (vacuum UV; λ = 118 nm) post ionization. The former allows selective detection of polycyclic aromatic hydrocarbons (PAHs), while the latter enables broad detection of most small organics. Subsequent SEM analyses were performed using either a JEOL 7600F or 7900F, equipped with Oxford Ultim Max EDX detectors; the aggregate fines were uncoated, and the intermediate particles sputter-coated with C.

Results and Discussion: Organic matter in Bennu can be separated into four categories: a diffuse phase heterogeneously distributed throughout the mineral matrix and three discrete, condensed phases. In order of decreasing size, the discrete phases appear as plates/veins (10s of μm), carbonaceous-mineral aggregates (≤ few μm), and nanoglobules (0.1–1 μm).

Diffuse Phase. Freshly disaggregated samples (*i.e.*, on KBr / Au) exhibited significant off-gassing of H_2O and simple organics when *in vacuo* during μ-L^{2}MS analysis. Using UV photoionization, we observed PAHs, ranging in size from 1- to 4-ring species, distributed throughout the fine-grained matrix. The PAHs exhibited spatial heterogeneities in both composition and abundance, with the latter at scale lengths on the order of 10s to 100s of microns. The overall PAH mass envelope, dominated by phenanthrene ($C_{14}H_{10}$; 4-ring) and its alkylated homologues, is broadly consistent with that observed in C1/C2 carbonaceous chondrites, albeit at higher abundances. Under vacuum UV photoionization, the wealth of species detected complicates identification; nevertheless, simple carbonyls such as formaldehyde ($H_2C{=}O$) and acetaldehyde ($CH_2CH{=}O$) were positively identified, along with ammonia (NH_3).

Condensed Phases: The fine-grained matrix exhibited a weak dispersed native fluorescence punctuated by a myriad of prominent μm to sub-μm hotspots; these were exclusively associated with nanoglobules or aggregates thereof. This fluorescence was thermolabile, implying that (i) the nanoglobules were not heated after formation; (ii) they are distinct from the other condensed organic phases, neither of which fluoresces; and (iii) such fluorescence might serve as an organic geochronometer. Although nanoglobules are ubiquitous, local density variations on the scale of 10s to 100s of microns are observed and correlate with matrix S abundance. A significant fraction of nanoglobules show the presence of organo-N [2] and H, C, and N isotopic anomalies [3]. Organic–mineral assemblages, while considerably less abundant, are notable in the intimate association of Fe-sulfides with organic matter, which may have played a role in formation of the organic component [4].

Conclusions: Bennu samples contain a rich and complex reservoir of organics in both structured and unstructured phases, suggesting both pre- and post-accretionary processing of organics in a range of spatially and/or temporarily isolated environments. Organic nanoglobules constitute a major reserve of organic matter in Bennu.

References: [1] Lauretta D.S. et al. (2023) *arXiv* [astro-ph.EP] 2308.11794; [2] Thomas-Keprta K.L. et al. (2024) *LPSC LV* #1119; Nguyen A. N. et al. (2024) *LPSC LV* #2500; [4] Heinen W. and Lauwers A.M. (1996) *Orig. Life Evol. Biosph.* 26:131–150.

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