ORGANIC MATTER IN "QUICK-LOOK" RETURNED BENNU SAMPLES REVEALED BY COORDINATED UV FLUORESCENCE, SEM-EDX AND TWO-STEP LASER MASS SPECTROMETRY.
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Introduction: The parent bodies of carbonaceous meteorites are generally unknown. However, on September 24, 2023, NASA's OSIRIS-REx mission successfully returned samples from the B-type asteroid (101955) Bennu, enabling coordinated laboratory analyses of pristine surface material from a carbonaceous asteroid with a well characterized geological context.

One of the driving mission hypotheses, addressing the fundamental nature of Bennu, is that it contains prebiotic organic compounds [1]. To evaluate this hypothesis, we conducted coordinated UV fluorescence, two-step laser mass spectrometry (μ–L^{2}MS), and scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDX) analyses of "quick-look" (QL) Bennu samples collected from the return capsule avionics deck.

Samples: Three QL mounted samples were studied. OREX-501006-0 and OREX-501018-100 both consisted of aggregate fines (<100 µm); the former pressed onto a KBr window and the latter onto Au foil. OREX-501018-100 was composed of four coarse particles (>500 µm) mounted on an Al SEM stub using C-tape.

Methods: All samples were documented using large-area optical photomosaics. High-resolution optical and ultraviolet (UV) fluorescence images (330–385 nm excitation / 420 nm long-pass emission) of selected particles were then captured, at a pixel resolution ≥2× diffraction limit, using a Nikon BX-50 microscope. For μ–L^{2}MS analyses, both point spectra and 2-D maps were acquired at a spatial resolution of 5 µm using either resonant multiphoton (λ, 266 nm) or nonresonant single-photon (λ, 118 nm) post ionization. The former provides selective detection of polycyclic aromatic hydrocarbons (PAHs), and the latter enables broad detection of most organics. SEM analyses were performed using either a JEOL 7600F or 7900F, equipped with Oxford Instruments Ultim Max EDX detectors. Samples were analyzed uncoated except for OREX-501018-100 that was sputter coated with C.

Results and Discussion: Our results suggest organic matter in Bennu samples can be described into four categories, three discrete (Fig. 1) and one diffuse. The discrete phases occur, in order of size: plates/veins (10s µm); carbonaceous-mineral aggregates (≤ few µm); and nanoglobules (0.1–1 µm). The diffuse phase is heterogeneously distributed through the mineral matrix.

μ–L^{2}MS probed the molecular components of the diffuse phase. Sample off-gassing was so significant that PAHs could be observed above the sample. PAHs were observed to be heterogeneously distributed, both in abundance and composition, throughout the fine-grain matrix (Fig. 2). The overall mass envelope is dominated by three-ring (phenanthrene) and to a lesser extent four-ring (pyrene / fluoranthene) aromatics along with their alkylated homologues (Fig. 3). While the PAH distribution is broadly similar to other carbonaceous chondrites, lower-mass species such as benzene and naphthalene are depleted, possibly due to aqueous remobilization or sample off-gassing. Using nonresonant single-photon ionization, simple carbonyls such as formaldehyde and acetaldehyde were detected, along with a small but continuous source of ammonia.

UV fluorescence and SEM-EDX were used to probe the discrete phases. Under UV illumination the fine-grained matrix exhibits native fluorescence dominated by prominent µm to sub-µm hotspots exclusively associated with nanoglobules (Fig. 4). This fluorescence was demonstrated to be thermolabile, indicating that: (1) nanoglobules were not heated after formation; (2) they are structurally and/or compositionally distinct from the other discrete phases; and (3) UV fluorescence might serve as an organic geochronometer. SEM-EDX analyses of the organic–mineral assemblages also revealed the mineral component was dominated by Fe-sulfides, which may have played a role in formation of the organic component [2]. Furthermore, the majority of nanoglobules contain N in their EDX spectra [3].

Conclusions: Bennu samples contain a rich and complex reservoir of organics which are manifested in a variety of structural forms. It is arguable that these phases derived from both pre- and post-accretionary processes occurring in a diverse range of isolated environments.

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References: [1] Lauretta D.S. et al. (2023) arXiv [astro-ph.EP] 2308.11794. [2] Heinen W. and Lauwers A.M. (1996), *Orig. Life Evol. Biosph.*, *26*, 131–150. [3] Thomas-Keprta K.L. et al. (2024) this conference.

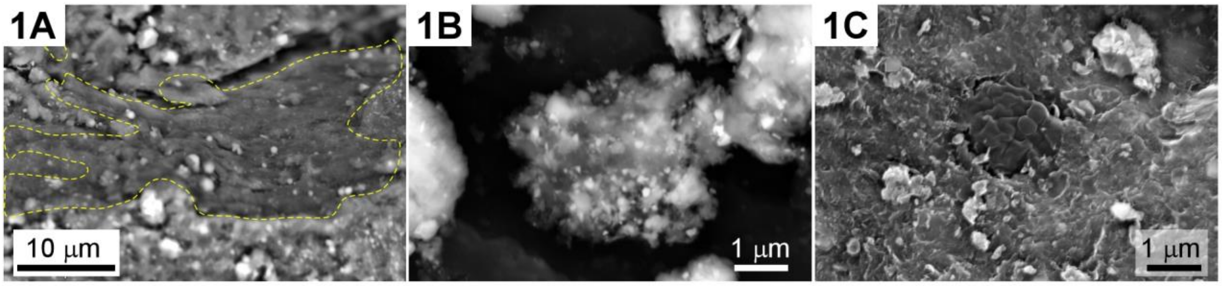

Figure 1: Discrete carbonaeous phases, (**A**) plate, (**B**) organic-mineral aggregate, (**C**) nanoglobules.

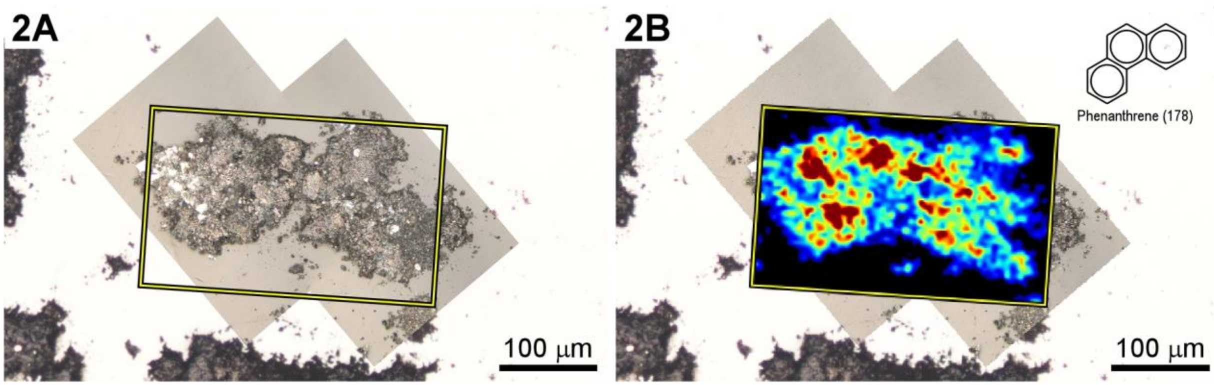

Figure 2: (**A**) Optical image of Bennu grain pressed on KBr window. (**B**) μ-L^{2}MS spatial map showing distribution of phenanthrene.

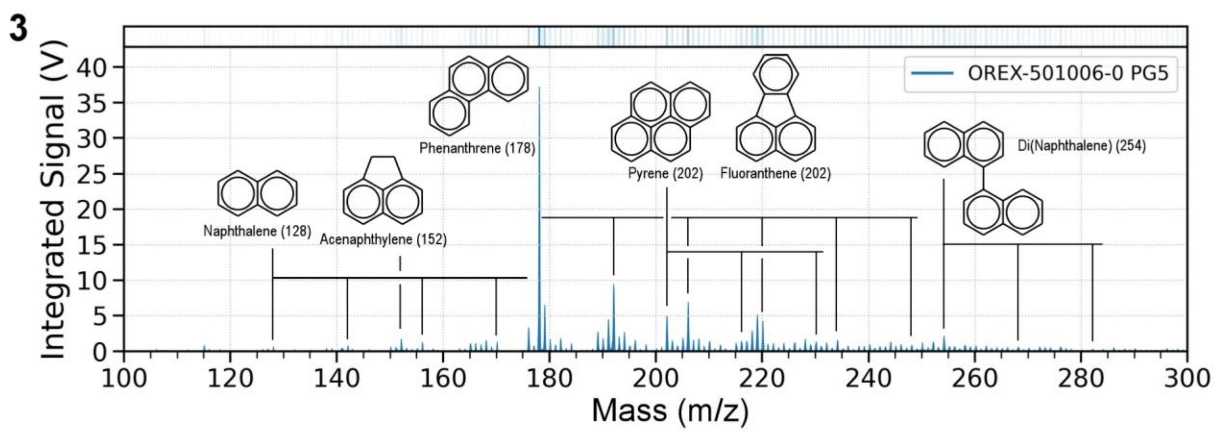

Figure 3: Summed μ-L^{2}MS spectrum acquired from particle shown in Fig. 2B. The structures of primary PAHs, along with their associated alkylation series, are overlaid.

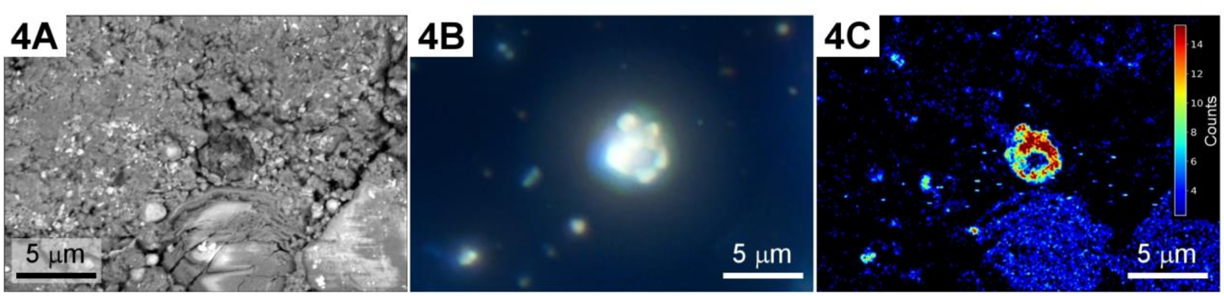

Figure 4: Prominent native fluorescence in Bennu fine grain matrix due to the presence of a cluster of organic nanoglobules. (**A**) SEM backscatter image of matrix at 5 kV (uncoated). (**B**) Fluorescence image of **A** under UV illumination. (**C**) EDX C map of **A**.