COORDINATED ANALYSIS OF ISOTOPICALLY ANOMALOUS NANOGLOBULES AND INSOLUBLE ORGANIC MATTER IN QUICK-LOOK SAMPLES FROM ASTEROID BENNU. A. N. Nguyen[1], S. J. Clemett[2], K. Thomas-Keprta[3], L. P. Keller[1], D. P. Glavin[4], J. P. Dworkin[4], J. J. Barnes[5], T. J. Zega[5], T. J. McCoy[6], M. S. Thompson[7], P. Haenecour[5], A. J. King[8], H. C. Connolly Jr.[5,9,10], and D. S. Lauretta[5]; [1]ARES, NASA JSC, Mail Code XI3, Houston, TX, USA (lan-anh.n.nguyen@nasa.gov); [2]Oasis/ERC JETS, NASA JSC, Houston, TX, USA; [3]Barrios JETS, NASA JSC, Houston, TX, USA; [4]NASA GSFC, Greenbelt, MD, USA; [5]LPL, University of Arizona, Tucson, AZ, USA; [6]National Museum of Natural History, Smithsonian Institution, Washington, DC; [7]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, IN; [8]Natural History Museum, London, UK; [9]Department of Geology, Rowan University, Glassboro, NJ, USA; [10]Department of Earth and Planetary Science, American Museum of Natural History, New York, NY, USA.

Introduction: Spectral characterization of B-type asteroid Bennu by the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) spacecraft indicated abundant organic matter with similarities to insoluble organic matter (IOM) in meteorites [1]. IOM in chondritic samples occurs in multiple forms, including a fluffy morphology and submicron-sized rounded nanoglobules. Isotopic anomalies in H, C, and N have been observed in both morphologies and are postulated to result from low-temperature chemical reactions in the molecular cloud or outer protoplanetary disk [e.g., 2,3]. We tested the hypothesis that Bennu also contains such isotopically anomalous organic matter [4] by conducting coordinated in situ analysis of "quick-look" samples collected from the avionics deck of the OSIRIS-REx sample canister. This study expands our understanding of the fundamental nature of Bennu and its pre-accretionary environment by investigating the morphologies and isotopic distribution of presolar organic matter in Bennu.

Samples: A sample mount was produced for NanoSIMS analysis by mounting annealed and HF-cleaned Au foil onto an Al stub. The sample analyzed in this study, OREX-501018-100, was produced by transferring fragments of fine-grained material from the quick-look sample OREX-501018-0 onto the Au foil mount using a tungsten needle. The fragments were then pressed into the Au with a sapphire window.

Analytical methods: Optical and ultraviolet (UV) fluorescence microscopy was applied to identify aromatic and conjugated organics [5]. Low-angle backscattered electron (LABE) images and chemical abundances of carbonaceous material were acquired by scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX). These regions were targeted for H, C, and N isotopic analysis using the CAMECA nanoscale secondary ion mass spectrometry (NanoSIMS) 50L at NASA JSC.

Results: The SEM and UV fluorescence analyses revealed numerous nanoglobules that strongly fluoresce (Fig. 1). A total area of 8323 μm^2 was analyzed for C and N isotopes. 325 grains had anomalous N isotopic ratios, and 13 of these had anomalous C isotopic compositions. Three additional grains were ^{13}C-poor and had isotopically normal N. The δ^{15}N values ranged from -457 to +2525 ‰ and δ^{13}C values ranged from -210 to +364 ‰. All grains had low ^{28}Si/^{12}C indicating they were organic. An area of 3390 μm^2 was analyzed for H isotopes and 206 grains had anomalous δD values ranging from -480 to +10,476 ‰. Sizes of anomalous organic matter ranged from 200–2260 nm.

Discussion: The ranges of C and N isotope compositions of nanoglobules and IOM in OREX-501018-100 are similar to those observed in chondrites [2,3] and samples from Ryugu [6,7] and comet Wild 2 [8], suggesting these asteroid and comet samples inherited similar interstellar organic matter. We found the D anomalies to generally be uncorrelated with N anomalies. The highest D enrichment observed thus far (δD = 10,476 ‰) exceeds those in Wild 2 [8] and Ryugu [6]. However, some chondrites and IDPs have even greater D enrichments up to ~50,000 ‰ [5,9]. The variation in δD values may be linked to parent body hydrothermal alteration [10]. The H, N, and C isotopic ratios of the anomalous nanoglobules and IOM in OREX-501018-100 are consistent with low-temperature chemical reactions in the molecular cloud or outer protoplanetary disk (see also [11]). Isotopically normal nanoglobules and IOM may have formed on the parent body.

We observed solid and hollow nanoglobules and nanoglobule clusters, consistent with TEM analysis of cross-sections of Bennu samples [12]. The hotspots in the UV fluorescence images correlated with N-rich grains in the NanoSIMS ^{12}C^{14}N isotope images. Many nanoglobules that fluoresced were isotopically anomalous, but some were not. Moreover, some isotopically anomalous nanoglobules did not fluoresce. Additional studies are required to assess whether these differences are related to the chemistry and morphology of the nanoglobules, and to understand the nature and origin(s) of organic matter in Bennu.

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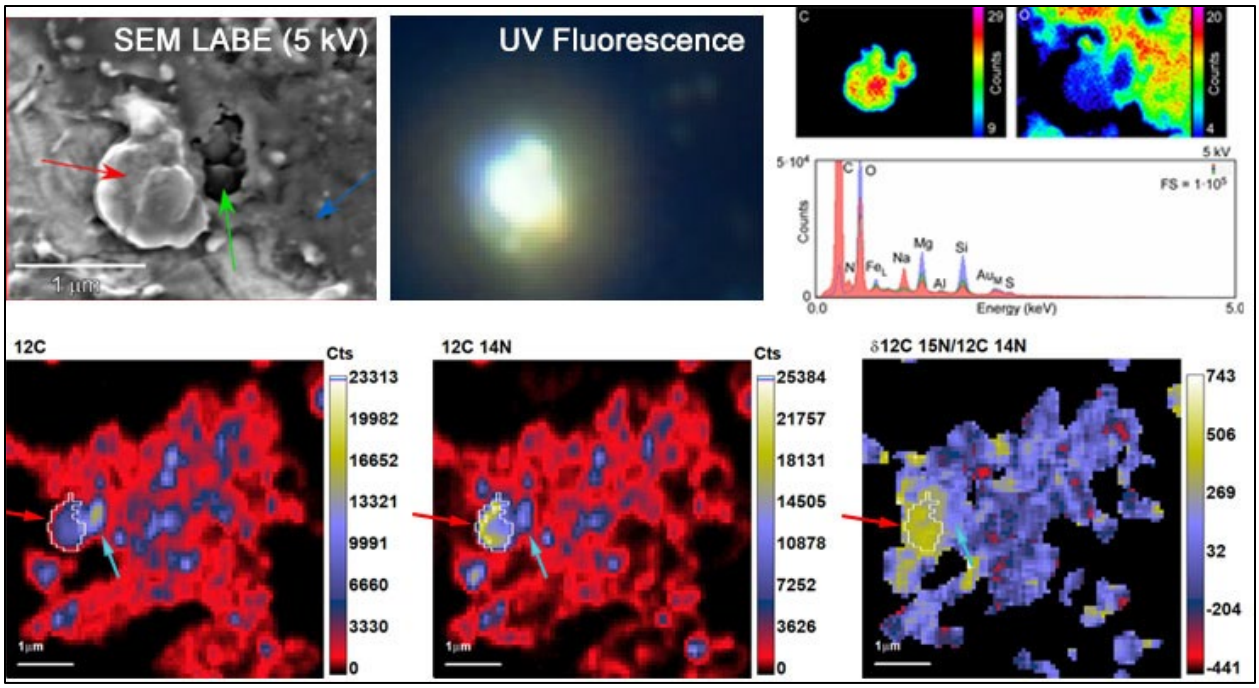

Figure 1. SEM LABE image of a region containing a fluorescent nanoglobule (red arrow) and adjacent nonfluorescent carbonaceous matter (green arrow). C and O EDX maps and spectra of the nanoglobule, carbonaceous matter, and silicate matrix. On the bottom are the NanoSIMS ^{12}C and $^{12}C^{14}N$ ion images, and $\delta^{15}N$ ratio map showing the nanoglobule (outlined in white) is ^{15}N-rich and the adjacent organic matter is isotopically normal.