TRANSMISSION ELECTRON MICROSCOPY OF CARBONACEOUS MATTER IN BENNU AGGREGATE SAMPLES

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Introduction: Preliminary analyses of regolith samples from asteroid Bennu show high bulk carbon abundances (~4.7 wt.%) [1]. The organic matter is readily apparent in scanning electron microscopy (SEM), transmission electron microscopy (TEM), and NanoSIMS observations [2-5]. A major objective of the OSIRIS-REx mission is to understand the nature and origin of the pre-biotic organic matter inventory in Bennu samples [1]. Here we report on TEM studies of indigenous organic matter in Bennu aggregate samples.

Methods and Samples: We prepared multiple electron transparent cross sections from aggregate grains in OREX-501005-0 by focused ion beam (FIB) milling. The FIB sections were extracted using the FEI Quanta3D FIB at JSC and were analyzed using the JEOL 2500SE scanning and transmission electron microscope (STEM) equipped with a JEOL 60 mm^2 silicon drift detector for energy-dispersive X-ray (EDX) analyses.

Results and Discussion: Organic matter is abundant in the FIB sections in the form of sub-μm carbonaceous nanoglobules and concentrations or clumps of finely disseminated carbonaceous material intergrown with the fine phyllosilicates. The nanoglobules occur as individuals, typically 100–500 nm in size, and in clusters, generally < 1 μm in size. Both solid and hollow nanoglobules are observed [3]. The largest nanoglobules are hollow with thin walls (~100 nm). EDX analyses of nanoglobules show that they contain significant O, N, and S, in addition to C with an approximate composition of $C_{85}N_3O_{12}S_1$ (at%) and an average C/N (at.) ~28 (n = 13). The other major form of carbonaceous matter is diffuse and occurs in close association with clusters of fine-grained phyllosilicates and FeNi sulfides (Figure 1). The diffuse carbonaceous material is also N-bearing, but it is difficult to quantify O and S by EDX given the intimate intergrowth with the fine-grained phyllosilicates and FeNi sulfides. For the diffuse carbonaceous material the average C/N (at.) is ~12 (n = 12), about half the value observed for nanoglobules. The coarse-grained clusters of phyllosilicates have carbon abundances near detection limits. Hydrogen and nitrogen isotopic measurements show that many, but not all, nanoglobules in Bennu aggregate samples are isotopically anomalous with enrichments in D and ^{15}N [5]. Synchrotron X-ray Absorption Near-Edge (XANES) structure analyses show complex organic functionality in Bennu nanoglobules [6]. Additional coordinated TEM and NanoSIMS analyses of Bennu carbonaceous matter are underway.

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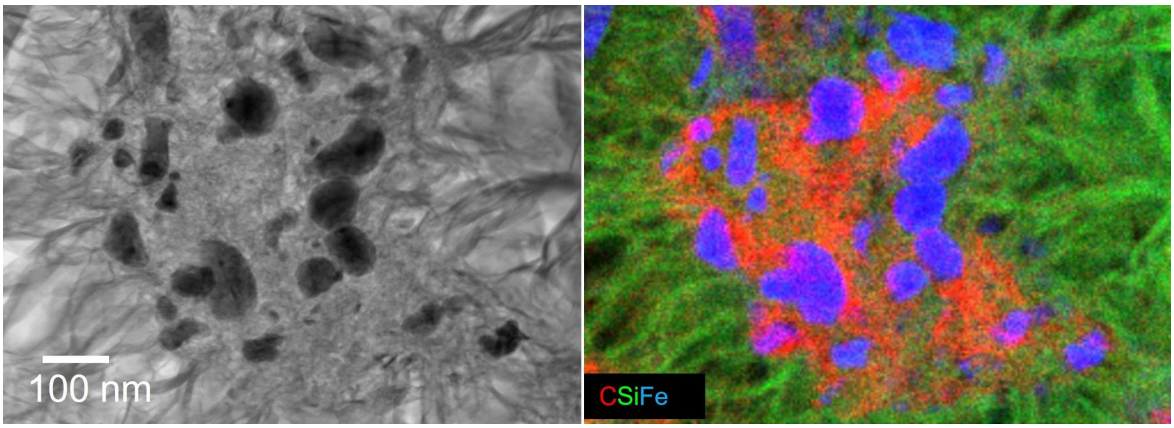

Figure 1. Brightfield STEM image (left) and corresponding RGB composite (R=C, G=Si, and B=Fe) (right) showing the diffuse carbonaceous matter associated with fine-grained phyllosilicate and sulfide clusters.