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Electron Microscopy of Organic Matter in Returned Samples from Asteroid Ryugu

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We will present results from the intersection of the work of the Haybausa2 Macromolecular Organics and Fine-grained Mineralogy-Petrology ("Sand") Initial Analysis teams, with a focus on transmission electron microscopy of organic matter and associated minerals. The returned Ryugu samples for these studies included whole particles, extracted focused ion beam cross-sections, microtomed slices of particles, and microtomed slices of acid-insoluble organic isolates (IOM) from both the Chamber A and Chamber C, from TD1 and TD2 collection site respectively. The different sample preparation methods enabled observation of different components; some soluble organic matter can preserved in FIB sections but is lost in microtomed samples, whereas microtomed samples allow easier study of the few-nm to sub-nm features. Scanning transmission electron microscopy of the Ryugu samples revealed that organic matter is abundant and intermixed with the mm to sub-mm mineral components, including Mg-rich phyllosilicates, magnetite, carbonates and sulfides. The most common morphologies of the organic matter are diffuse carbon and nanoglobules (typically < 400 nm). Larger nanoglobules and dense, irregularly shaped organic particles up to 2 mm in size are also present, but rare. Some secondary minerals, such as carbonate grains, contain vesicles that enclose diffuse organic matter and nanoscale minerals. Nanodiamonds with a possible presolar origin are present in clusters, surrounded by amorphous organic carbon. In addition to imaging organic-mineral relationships, we investigated the C functional group chemistry with electron energy loss spectroscopy (EELS) of the C-K near edge structure, and the elemental composition with energy dispersive x-ray spectroscopy (EDS). The results are broadly consistent with prior studies of organic matter in the Orgueil meteorite, and indicative of a parent body history that includes extensive low temperature aqueous alteration. The organic matter in Chamber A and Chamber C samples are similar in morphology, but possibly different in C:N:O:S elemental composition, as determined from EDS. However compositional differences could represent particle-to-particle variation in the measured samples, rather than overall differences in Chamber A and Chamber C grain averages. A search for space weathering signatures in the organic matter is underway, but is as yet inconclusive.