Comparison Study of Macromolecular Organic Matter between Asteroids Bennu and Ryugu: Mainly from the perspectives of C, N, O, and S-XANES

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Introduction: Hayabusa2 and OSIRIS-REx spacecrafts collected and returned samples from the asteroids Ryugu and Bennu, respectively. The comparative study on the two asteroid samples is expected to unveil the evolutionary relationship between the asteroids. The earliest papers on the Bennu sample analysis revealed that elemental compositions and mineralogy are similar among the asteroids Bennu and Ryugu, and CI chondrites, while bulk hydrogen and nitrogen isotopic compositions were different between the two asteroid samples [1].

Macromolecular organic matter, as known as acid-insoluble organic matter (IOM), accounts for the largest part of total organic carbon in samples from a wide variety of small bodies. As part of the Ryugu-Bennu Comparative Study, this study aimed to unveil the chemical compositions and distributions of macromolecular organic matter in the asteroid Bennu samples by the same analytical protocols that we applied to the Ryugu samples [2].

Samples and Methods: We studied (i) intact grains, (ii) the residues after water and solvent extraction, (iii) the residues after HCl treatment, and (iv) IOM residues isolated by HF/HCl treatment, of Bennu samples. Strong absorptions of N-H bonds were detected at ~3.1 μm in the infrared spectra of a yellowish grain by MicrOmega. The analytical procedures included a combination of μ-FTIR, micro-Raman spectroscopy, STXM-XANES, ToF-SIMS, and SEM-EDS.

Results and Discussion: The μ-FTIR and Raman spectra of the Bennu grains were very similar to those of the Ryugu grains and CI chondrites [3, 4]. On the other hand, the fluorescence background in Raman showed differences in intensities. This appears to be related to the variations in NH^+ ions intensities from the ToF-SIMS spectra [5], as well as the variations in ammonia concentrations among the asteroid and meteorite samples [6].

The Bennu grains contained organic nanoparticles and unstructured diffuse carbon, similarly to Ryugu [2]. The C-XANES spectra of the Bennu grains mainly included peaks of aromatic carbon, carboxyl and aliphatic carbon with a lack of aromatic ketone peak. This spectral shape corresponds to Highly-aromatic and/or alkyl-aromatic types known from Ryugu samples [2]. Unlike carbonaceous chondrites, the IOM-type spectra were rarely observed. Molecular carbonate was only locally observed. Low abundances of these O-bearing functional groups imply that Bennu experienced lower degree of oxidation during aqueous alteration relative to Ryugu. From the grain with strong N-H absorptions, organic nanoparticles were not abundant, while halites were observed [7].

The C-XANES spectra of the residue after water/solvent extraction were aromatic poor relative to the intact grains, while the spectra of the residues after HCl treatment and IOM residues were roughly similar

to the intact grains. Some IOM residues showed rather more heterogeneous compositions relative to the intact grains. N-XANES spectra of the Bennu grains showed as weak absorption as Ryugu.
S-XANES of the Bennu IOM showed two different spectral shapes which were likely related to the morphology of Bennu grains. Most of the IOM particles from angular and mottled Bennu grains exhibit the highest intensity at ~2472 eV corresponding to reduced organic sulfur such as disulfide, similarly to Ryugu IOM [6]. In contrast, the IOM particles from hummocky Bennu grains often showed similar spectra to Murchison IOM exhibiting two intense peaks of disulfide and oxygenated organic sulfur at ~2482 eV, such as organic sulfate. The difference in S-XANES spectra is possibly reflected by heterogeneous aqueous alteration on the asteroid parent body.

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