Nucleobases in Bennu, Ryugu, and carbonaceous meteorites

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The presence of all canonical nucleobases (cytosine, uracil, and thymine, which are classified as pyrimidine bases, and adenine and guanine, which are classified as purine bases) in extraterrestrial materials has been recognized recently [1]. Given that organic molecules delivered by extraterrestrial materials may have played a pivotal role in chemical evolution on the early Earth [2], understanding the distribution of nucleobases in various kinds of extraterrestrial materials is a prerequisite for deciphering chemical evolution toward the emergence of genetic functions in that environment.

We had precious opportunities to analyze nucleobases in primitive materials of the Solar System collected at the carbonaceous asteroids (162173) Ryugu and (101955) Bennu by the Hayabusa2 and OSIRIS-REx missions, respectively, through the initial analyses of these samples, as well as JAXA's 3rd Announcement of Opportunity. In the present study, we will present the distribution of canonical nucleobases in Bennu and Ryugu samples and various classes of carbonaceous meteorites and discuss their formation pathways in relation to the concentration of ammonia (NH_3) in each parent body.

Samples: Samples returned from the asteroids Ryugu (A0106, C0107, A0480, C0370) and Bennu (OREX-800044-101, OREX-800107-108) were used for the analysis of nucleobases [3-5]. In addition, various classes of carbonaceous meteorites, including Murchison (CM2) [6], Yamato (Y)-791198 (CM2), Y-793321 (CM2), Aguas Zarcas (CM2), Orgueil (CI1), Oued Chebeika 002 (CI1), Kolang (CM1/2), Asuka-881828 (CR2), Y-002540 (CR2), and Tarda (C2-ung), were also analyzed. Detailed analytical conditions are referred to refs [1,3-7].

Results: All canonical nucleobases were detected in both Ryugu (A0480 and C0370 [4]) and Bennu samples (OREX-800044-101, OREX-800107-108 [5,8]). The distribution of nucleobases in carbonaceous meteorites varied between samples; except for Y-793321, Y-002540, Kolang, and Oued Chebeika 002, all canonical nucleobases were detected. These results strongly indicate that nucleobases are common in the primitive materials of the solar system. In addition to canonical nucleobases, various kinds of non-canonical nucleobases, such as isocytosine and hypoxanthine, were detected in the same extracts from the return samples and meteorites. The abundance of purine nucleobases relative to that of pyrimidine ones (Pu/Py) detected in the samples seems to have correlations with their NH_3 concentrations: CMs showed high Pu/Py (>1.7, except for Y-793321) with low NH_3 (<2 μmol g^{-1}), CRs moderate NH_3 (~6 μmol g^{-1}) with low Pu/Py (<0.2), and C2-ung Tarda very high NH_3 (49 μmol g^{-1}) with very low Pu/Py (0.1). We found that CIs, Bennu, and Ryugu are distributed in relatively low Pu/Py (<~1 or less) with the wide variations of NH_3 (0.2-43 μmol g^{-1}) regions, suggesting that the availability of NH_3 in each parent body may be one of the key factors to constrain the observed differences in nucleobase distributions.

References

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