Chemical History of Organic Macromolecules in the Early Solar System: Scientific Strategy and Expected Insights from Asteroid Ryugu. H. Yabuta[1] and Organic macromolecules initial analysis sub-team[2], [1]Department of Earth and Planetary Systems Science, Hiroshima University (1-3-1 Kagamiyama, Higashi-Hiroshima, 739-8526 Hiroshima, Japan. E-mail: hyabuta@hiroshima-u.ac.jp)

Introduction: Since the arrival of the JAXA's Hayabusa2 spacecraft at asteroid Ryugu on June 27, 2018, observations by onboard remote-sensing instruments, MASCOT and MINERVA landers have provided interesting insights into the features of asteroid Ryugu [1-4]. The two-times of successful touchdowns have enabled collections of both surface and interior samples of the asteroid, which is an advantage to investigate origin and evolution of the Solar System as well as the surface processes of the asteroid. After the sample return in the end of 2020, curatorial work on the Ryugu sample will be conducted at JAXA for the first 6 months. Afterward, initial sample analysis will be performed during the following 12 months.

The presence of organic compounds is unknown at this stage, although the low albedo at 0.55 μm may be related to the presence of organic carbon [5]. Thus, the initial sample analysis will be the first opportunity to unveil the distributions and compositions of organic molecules on a C-type asteroid, which lead to our understanding of the Solar System formation and volatile delivery to the Earth.

Significance of investigating organic macromolecules in solar system small bodies: Organic macromolecules have been identified from various types of small body materials, such as chondritic meteorites, interplanetary dust particles (IDPs), cometary dusts, and Antarctic micrometeorites (AMMs), indicating that they enables our comprehensive understanding of chemical history of the early Solar System. Organic macromolecules from chondritic meteorites have been often characterized as an acid-insoluble organic matter (IOM). The intact chemical structure of IOM in primitive carbonaceous chondrites (CCs) is still unknown, while a number of previous studies have suggested that it is composed of aromatic network crosslinking with short-branched aliphatic chains and various O-bearing functional groups [6, 7]. Elemental, molecular and isotopic variations of IOM within and across meteorite groups and petrologic types sensitively record the chemical history of the meteorite parent bodies [6, 7]. Distributions of IOM are often related to those of phyllosilicates in primitive CCs, implying that meteoritic IOM could have been a product from parent body aqueous alteration of precursor molecules.

On the other hand, organic macromolecules in IDPs, cometary dusts, and AMMs, may not be necessarily "insoluble", according to their diverse compositions. In particular, comet 81P/Wild2 dust particles collected by Stardust as well as anhydrous IDPs and AMMs which are thought to be cometary origin, contain high abundances of organic macromolecules consisting of N- and/or O-bearing functional groups, and/or aliphatic carbon compared to chondrites [8]. These chemical features are also comparable with those of comet 67P/Churyumov Gerasimenko observed by Rosetta [8]. The organic macromolecules often coexist with GEMS, implying that they could have been formed prior to parent body aqueous processes [8].

Deuterium and ^{15}N enrichments have been commonly observed from organic macromolecules in meteorites, IDPs, cometary dusts and AMMs. The isotopic features indicate that their precursors may have a common origin in extremely cold environments, such as outer solar nebula and interstellar clouds [6], while there have been also other hypotheses that organic macromolecules may have been formed from inner nebula gas or during parent body processes [6].

Comparison of organic chemistry in association with mineralogy between meteorites and cometary materials have revealed a blurred boundary between carbonaceous chondrites and comets, as observed in an ultracarbonaceous AMM [9] and a ultracarbonaceous microxenolith of primitive CC [10]. The findings imply the material mixing in the early Solar System (e.g. [11], [12]). Investigation of organic macromolecules in asteroid Ryugu samples will verify the hypothesis and constrain the origin and chemical evolution of building blocks of planets and life as well as the formation of asteroid Ryugu.

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