

WATER- AND ACID-SOLUBLE COMPONENTS IN THE ASTEROID RYUGU: INSIGHT FROM PRIMORDIAL SALT WITH AQUEOUS ALTERATION. T. Yoshimura^{1*}, Y. Takano^{1*}, H. Naraoka², T. Koga¹, Y. Oba³, N. O. Ogawa¹, N. Ohkouchi¹, S. Sakai¹, J. P. Dworkin⁴, S. Tachibana^{5, 6}, The Hayabusa2-initial-analysis SOM team, The Hayabusa2-initial-analysis core, ¹Japan Agency for Marine-Earth Science Technology (JAMSTEC), 2-15 Natsushima, Yokosuka 237-0061, Japan (yoshimura@jamstec.go.jp), ²Department of Earth and Planetary Sciences, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka, 819-0395, Japan, ³Institute of Low Temperature Sciences (ILTS), Hokkaido University, N19W8, Kita-ku, Sapporo, 060-0189, Japan, ⁴NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, U.S.A., ⁵UTokyo Organization for Planetary and Space Science, University of Tokyo, Bunkyo-ku, Tokyo, 113-0033, Japan, ⁶Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (ISAS/JAXA), Sagami-hara, Kanagawa, 229-8510, Japan, * equal contribution

Introduction: The Hayabusa2 spacecraft provided the first opportunity to investigate the diversity and chemical states of prebiotic molecules from a carbonaceous asteroid. Sequential organic solvents, water, and acid extraction of Ryugu samples were conducted to reveal the molecular diversity of CHNOS species [1]. Soluble ionic compositions in the Ryugu and other carbonaceous chondrites are attributed to different aqueous alteration effects in their parent bodies. Soluble ions act as bulk electrolytes that stabilize surface charge and potentially serve a specific structural or catalytic role. In addition, astrobiology-relevant organic molecules potentially present as salt forms which are less likely to be lost to evaporation from the parent body. Therefore, quantifying the major and trace ion compositions in water-, acid-, and solvent-extracts of the surface material of C-Type asteroid Ryugu would be critical to expand our knowledge of the origin and alteration history of prebiotic molecules in the solar system.

For this study, we conducted a sequential solvent extraction of the samples collected at the first touchdown site (A0106) and at the second touchdown site (C0107), the latter of which may contain ejecta from the artificially-made impact crater. We aim at quantifying soluble components: salts (via hot H₂O); ions bound to soluble organic matter (via dichloromethane and methanol, DCM/MeOH); exchangeable ions and highly soluble minerals such as carbonates (via formic acid, HCOOH); clays and residual soluble minerals (via hydrochloric acid, HCl) [2]. In addition, four meteorites (CI1 Orgueil, C2_{ung} Tarda, CM2 Aguas Zarcas, and CM2 Jbilet Winselwan) were selected to compare a range of aqueous alteration conditions.

Methods: Samples were extracted sequentially with the solvents above. After the extraction processes, anion and cation concentrations were measured by an ion chromatograph Metrohm 930 Compact IC Flex (Metrohm AG, Herisau) [3]. For cations, the samples were eluted through a Metrohm Metrosep C6-250/4.0 column with HNO₃ (TAMAPURE AA-100, Tama Chemical). Anions were measured with a Metrohm

Metrosep A Supp4-250/4.0 column with a chemical suppressor module with the mobile phase consisted of a mixture of Na₂CO₃ and NaHCO₃ (Kanto Chemical, Tokyo). The chemical suppressor module (Metrohm MSM) was used to decrease the background conductivity of the eluent and to transform analytes into free anions. The column temperature was set at 35 °C throughout the analysis. Detection of cations and anions was accomplished by electrical conductivity.

Trace element concentrations were measured by quadrupole inductively coupled plasma mass spectrometry (iCAP Qc, Thermo Fisher Scientific, Waltham). 0.3 M HNO₃ was added to each vial to dilute the samples. The HNO₃ used in this study were commercially supplied high-purity TAMAPURE AA-100 reagents (Tama Chemical, Japan). We added internal standards (Be, Sc, Y, and In) to correct the instrumental drift to HNO₃.

Results and Discussion: The major cation of Ryugu H₂O extracts are composed mainly of Na. The H₂O extracts of Orgueil have a Mg concentration of >22 times those of the Ryugu samples, which is also characterized by its high sulfate concentration. These characteristics likely reflect a clear difference in salt mineralogy and different degrees of aqueous alteration. The DCM/MeOH fraction had much less solutes for all samples. A considerable variation in solute compositions was found in the HCOOH extracts of the Orgueil, Tarda, and Aguas Zarcas, and Jbilet Winselwan, suggesting the variable extent of precipitation of highly soluble minerals and ion exchange processes. The Ryugu HCOOH extracts are characterized by intermediate composition. The HCl extracts were generally more enriched in Mg and Fe. Their Mg, Ca, Na and K compositions lie close to that of the cosmic abundance. In addition, the solute concentrations in the Ryugu HCl extracts are generally smaller among our meteorite samples, probably due to less abundant HCl-soluble minerals in the Ryugu samples.

There is increasing interest in the role of minerals and metals in the evolution of meteoritic organic matter [4] and in the role of salts in primitive bodies [5]. From this point of view, elucidation of the inorganic

constituent released during organic extraction steps is key information for catalytic effects, stabilization of macromolecules via metallic elements.

References: [1] Naraoka, H. *et al.* (2022) *LPSC Abstract* (this meeting). [2] Yoshimura, T. *et al.* (2020) *LPI Contribution* 2326, 1971. [3] Yoshimura, T. *et al.* (2018) *J. Chromatogr. A* 1531, 157–162. [4] e.g., Ruf, A. *et al.* (2017) *PNAS* 114, 2819-2824. [5] Altwegg, K. *et al.*, (2020) *Nature Astron.* 4, 533-540.

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