Investigating the organic compounds in the asteroid Ryugu

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Organic compounds in meteorites provide insights into the carbon chemistry present in the interstellar medium and solar nebula and on their alteration on the parent bodies. Further, delivery of these organic compounds could have contributed to Earth's habitability and life. However, studying these compounds in meteorites is complicated by their exposure to terrestrial organic contamination after entering the Earth's atmosphere. As such, one of the goals of the Hayabusa2 sample return mission (asteroid (162173) Ryugu) is to understand the nature, origin, and evolution of organic compounds in the early solar system but from samples free of terrestrial organic contamination. Here, we examine further samples from asteroid Ryugu that were collected during the first touchdown (Chamber A, samples A0079 and A0169; allocated in first Ryugu AO). The goals of our research are to understand diversity, origin, and formation mechanisms of the macromolecular material that dominates Ryugu organics, as well as the secondary processes involved in their modification, such as heating and aqueous alteration.

Fragments of the two Ryugu samples up to a few 10s of microns in size were pressed into Au foils for H, C, and N isotope analysis with the Carnegie NanoSIMS 50L ion microprobe. We used a ~0.4 pA, ~100-nm Cs^+ primary beam and acquired data for C and N isotopes, including $^{12}C_2$, $^{12}C^{13}C$, $^{12}C^{14}N$, and $^{12}C^{15}N$, as well as ^{16}O, ^{32}S, and secondary electrons. The prepared samples were then analyzed for ^{1}H, D, and ^{12}C and secondary electrons with a slightly more intense primary beam. C-rich regions of interest (ROIs) were defined in the C-N images and subsequently located and analyzed in the H-D images.

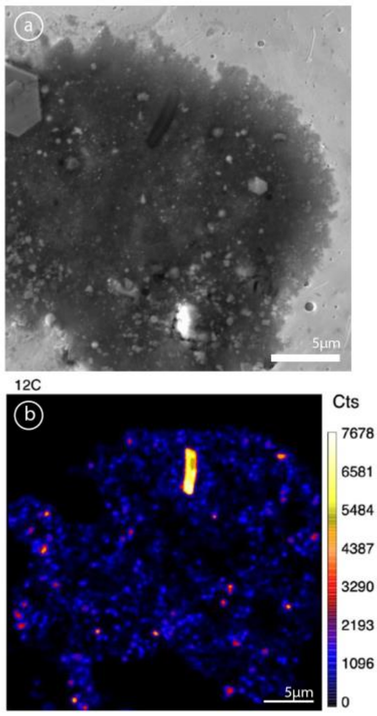

Figure 1. (a) Secondary electron (SE) image of a Ryugu particle from chamber A (A0079) pressed into gold foil. (b) D and ^{15}N-enriched lath-like (whisker) detected in same particle.

We have analyzed a total area of ~9,000 μm^2 across the two samples. Data reduction is in progress. The majority of C-rich ROIs appear rounded in the ion images and range from ~100 to 900 nm with some to up to a few µm (e.g., Fig.1). Consistent with previous measurements [2-6], our data shows that the organic material is on average enriched in D and ^{15}N with most ROIs having compositions consistent within error with average values of δD of a few 100 ‰ and $\delta^{15}N \sim +50‰$. However, one lath-like rectangular grain was identified in a particle within A0079 (Fig. 1), similar in shape to a grain previously reported in Chamber C [5; Fig.3], but larger. This 4.5 × 1 µm grain has an extreme isotopic composition: δD ≈10,000 ‰ and $\delta^{15}N \approx +800‰$. In order to clarify the nature and origin of this unusual grain and other select C-rich ROIs, we are currently extracting focused ion beam (FIB) lift-out sections of D and ^{15}N hotspots. The FIB sections will be studied with transmission electron microscopy, scanning transmission electron microscopy, energy dispersive spectroscopy and electron energy loss spectroscopy at Arizona State University. Results from these investigations will be presented at the symposium.

References: [1] Huss G. R. and Draine B. T. 2006. Highlights of Astronomy 2: 353–356. [2] Busemann H. et al. 2006. Science 312, 727–730. [3] Nittler L. R. et al. 2019. Nat. Astron. 3, 659–666. [4] Nittler L. R. et al. 2018). GCA 226, 107–131. [5] Barosch J. et al. 2022. Abstract#2050. 53rd LPSC; [6] Yabuta, H. et al. 2023. Science 379, eabn9057.