ISOTOPE DISTRIBUTIONS AND ANOMALOUS MATERIALS IN RETURN SAMPLES FROM THE ASTEROID RYUGU. N. Sakamoto[1], The Hayabusa2-initial-analysis chemistry team, The Hayabusa2-initial-analysis core, [1]Hokkaido University.

Introduction: The objective of the Hayabusa2 mission that sampled the C-type asteroid Ryugu in two touchdown sites is to clarify the origin and evolution of the Solar System, especially the origin of organic matter and water [1], important constituents of Earth's life. The asteroid Ryugu is believed to contain abundant organic matter formed in the early Solar System. Isotopic imaging allows us to observe distributions of organic matter, presolar grains, and minor elements. Here we report the preliminary results on isotope imaging of the Ryugu samples returned by the Hayabusa2 spacecraft.

Experimental: Polished sections from A0058-C1001 and C0002-C1001, samples from 1st and 2nd touchdown sites, respectively, were used. Their isotopic distributions were collected using the Hokudai isotope microscope system consisting of a stigmatic secondary ion mass spectrometer (SIMS, Cameca ims-1270e7) and a stacked CMOS active pixel sensor (SCAPS) [2].

A 20 nA primary $^{16}O^-$ ion beam accelerated to 23 keV was focused onto the sample surface over 100×80 μm^2 through a square aperture. Secondary ion images of $^1H^+$, $^7Li^+$, $^{11}B^+$, $^{23}Na^+$, $^{24}Mg^+$, $^{27}Al^+$, $^{28}Si^+$, $^{39}K^+$, $^{40}Ca^+$, and $^{56}Fe^+$ were projected onto the SCAPS. Analyzed areas include 11 and 37 maps in A0058 and C0002, respectively, totaling ~384,000 μm^2. Detailed analytical conditions are described in [3].

Secondary ion images of $^1H^-$, $^{12}C^-$, $^{13}C^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$, $^{16}O^-$, $^{17}O^-$, $^{18}O^-$, $^{19}F^-$, $^{28}Si^-$, $^{31}P^-$, $^{32}S^-$, and $^{35}Cl^-$ were collected using Cs^+ ions at 2 nA and 15 keV impact energy. Each map corresponds to a 50×50 μm area on the sample surface. The exit slit was narrowed to avoid interferences of $^{11}B^{16}O^-$ on $^{12}C^{15}N^-$ and $^{16}OH^-$ on $^{17}O^-$. Analyzed areas include 132 maps in C0002, ~330,000 μm^2 in total. Candidates of chemically and isotopically anomalous materials were analyzed repeatedly for confirmation. Most of the isotopically anomalous materials were not completely sputtered away, allowing their identification by electron microscopy.

Results and Discussion: The images show abundant carbonaceous materials in matrices of the Ryugu samples. These include globules and a large C- & N-rich object (Fig. 1). We also observed isotopically anomalous carbonaceous materials, including ^{13}C-rich SiC and ^{15}N-rich grains (Fig. 2). Based on BSE images, three lithologies in the Ryugu samples can be tentatively identified: white, gray, and black. Light elements (C, N, F, Cl, and Na) are heterogeneously distributed among these lithologies. We also identified several B-rich objects, and a Na-rich rim along the original surface of A0058 sample (Fig. 3).

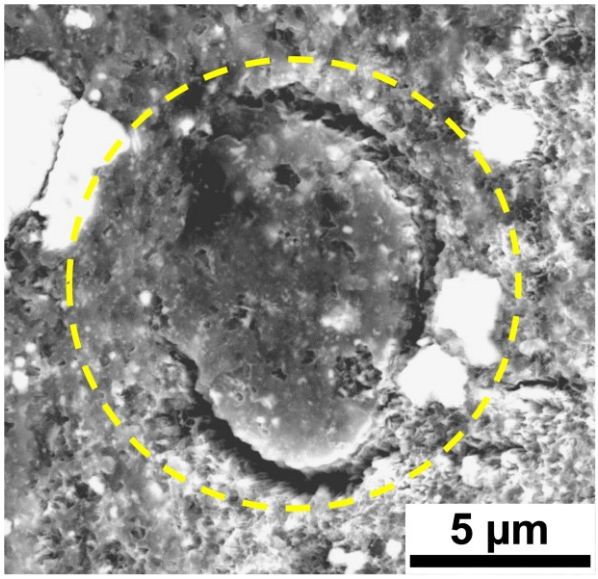

Fig. 1. Backscattered electron (BSE) image of C- and N-rich material in the C0002.

The chemical distributions and the presence of isotopically anomalous materials in the Ryugu samples indicate that the asteroid Ryugu was not chemically and isotopically homogenized; some primordial materials survived during the extensive aqueous alteration it experienced. Carbon- and N-rich materials are important ingredients of life and will be further studied in detail.

References: [1] S. Tachibana (2021) In *Sample Return Missions* (Ed. A. Longobardo), Elsevier, pp 147–162. [2] H. Yurimoto et al. (2003) *Appl. Surf. Sci.* **203–204**, 793–797. [3] S. Tagawa et al. (2021) *Nat. Commun.* **12**, #2588.

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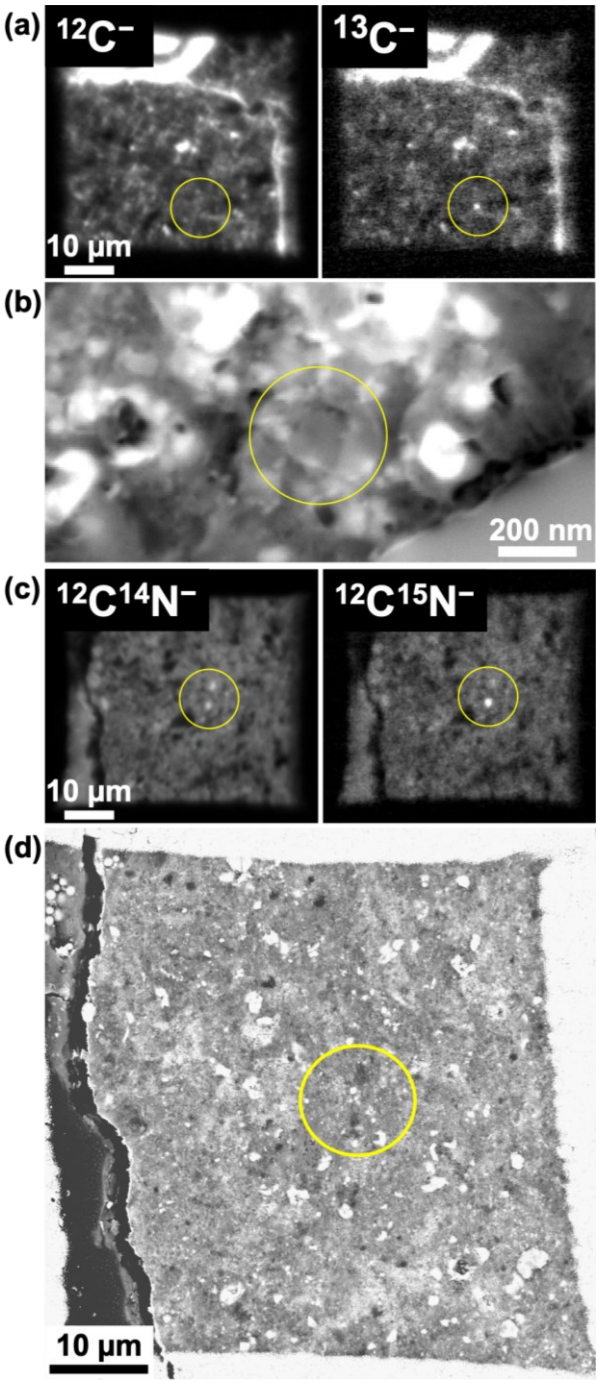

Fig. 2. Isotopically anomalous objects in C0002. (a) $^{12}C^-$, $^{13}C^-$ and (b) BSE image of ^{13}C-rich SiC grain ($\delta^{13}C$ = +4,000‰), about 150 nm in size. (c) $^{12}C^{14}N^-$, $^{12}C^{15}N^-$ and (d) BSE image of ^{15}N-rich grain ($\delta^{15}N$ = +700‰).

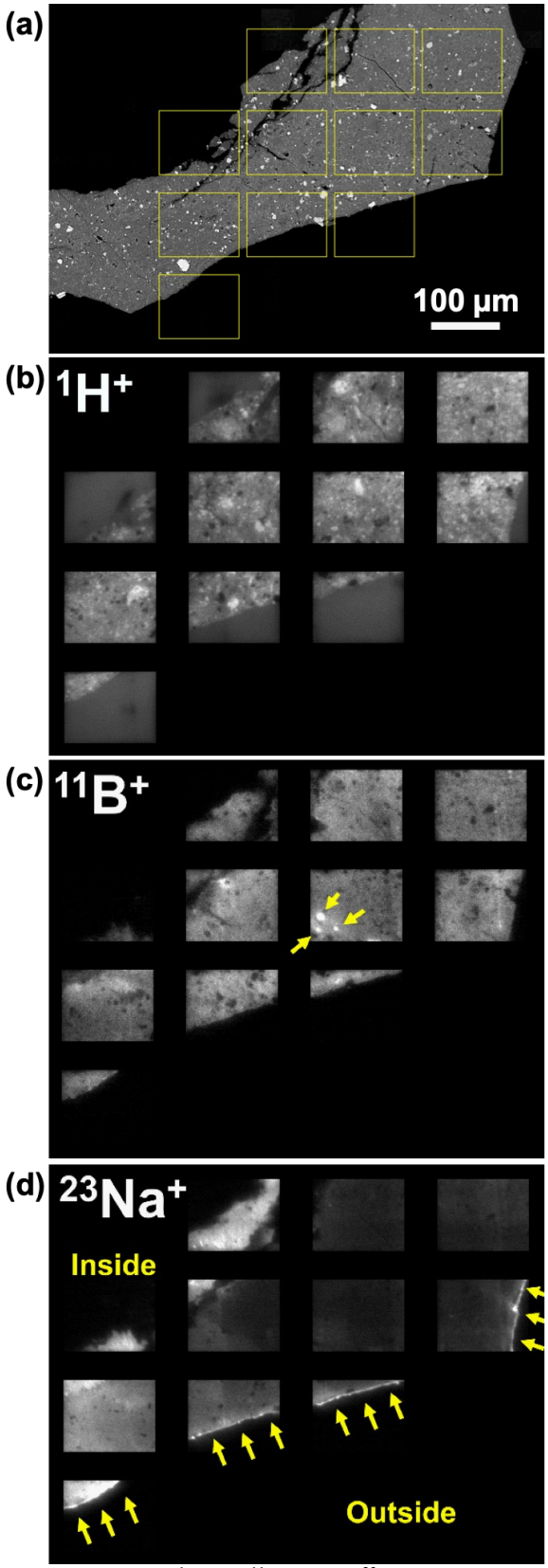

Fig. 3. (a) BSE, (b) $^1H^+$, (c) $^{11}B^+$ and (d) $^{23}Na^+$ images obtained in A0058.