#1304

Elemental Distributions of Bennu samples using a Stigmatic LG-SIMS

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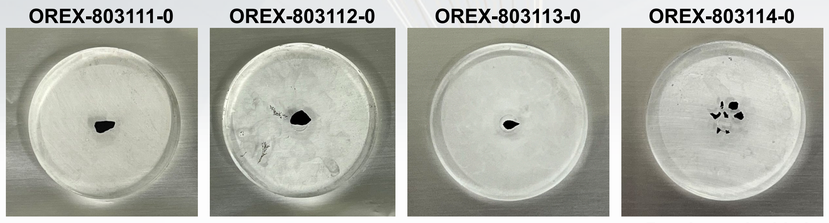
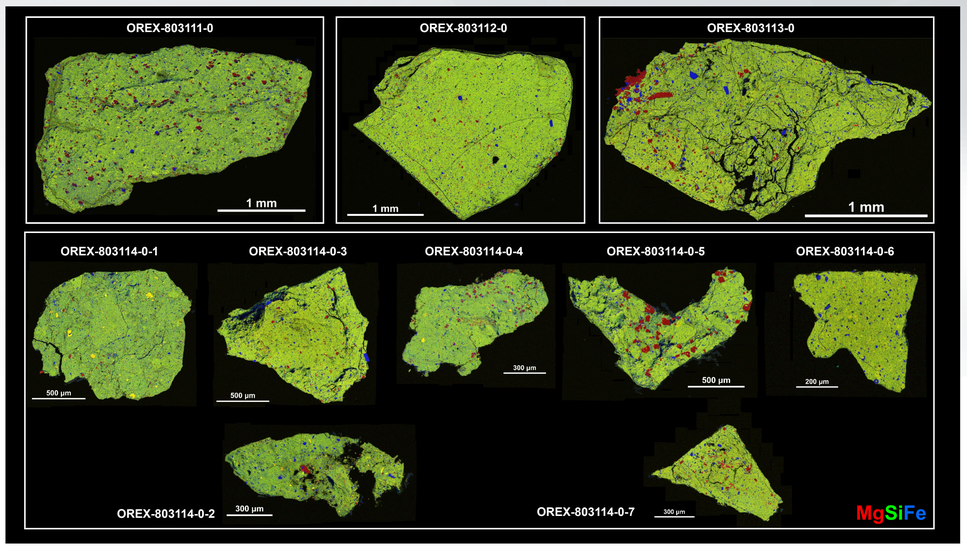
The surface of a material is sensitive to most recent events. Meteorites are the most abundant extraterrestrial materials, but their surface information is lost during atmospheric entry. In this study, we focused on the surface of Bennu particles and the cracks prone to alteration, obtaining elemental maps using Secondary Ion Mass Spectrometry (SIMS).

Samples



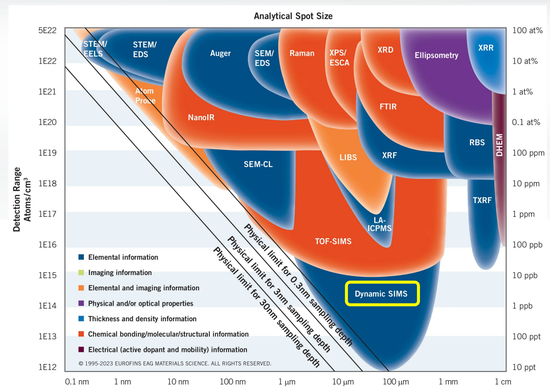
EpoxiCure 2 Resin & Hardener (BUEHLER)
Diamond slurry (MUSASHINO DENSI, Ethylene Glycol $C_2H_6O_2$)
Ethanol wash, No water

The analyzed samples include OREX-803111-0, OREX-803112-0, OREX-803113-0, OREX-803114-0-1, OREX-803114-0-2, OREX-803114-0-3, OREX-803114-0-4, OREX-803114-0-5, OREX-803114-0-6, and OREX-803114-0-7. Each sample was embedded in 1-inch resin disks using Buhler EpoxiCure2 and polished using diamond slurry with an automatic polishing machine (Musashino Denshi MA-200e), with the procedures described in Kawasaki+ (2022) Sci. Adv. The disks were cleaned using a minimal amount of ethanol (> 99.5%) to avoid the use of water. A conductive coating was applied to the polished sections for scanning electron microscopy–energy-dispersive X-ray spectroscopy (SEM-EDS) and SIMS analyses.

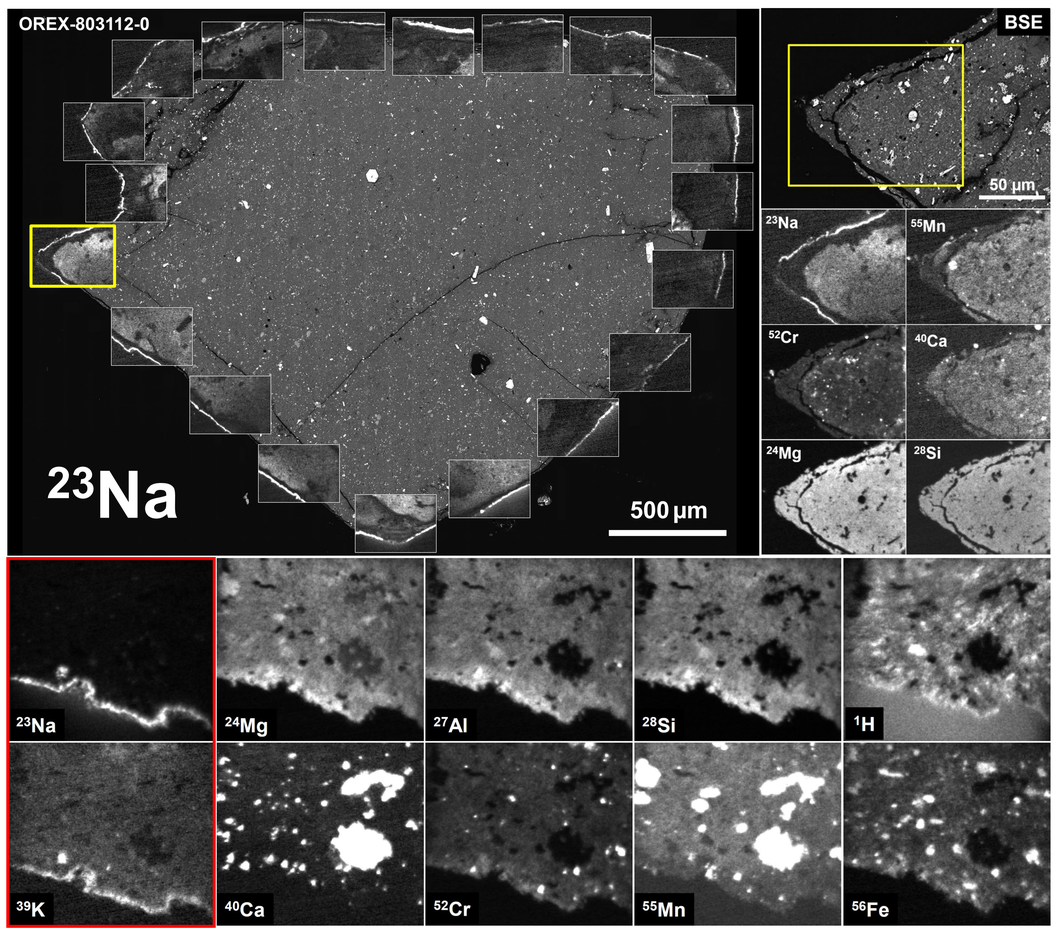


Method

The analytical technique used in this study belongs to Dynamic SIMS, which offers the highest sensitivity among various surface analysis methods shown in the figure below. Within Dynamic SIMS, the stigmatic ion optics system and the large geometry sector-type magnet (Stigmatic LG-SIMS) enable us to produce elemental maps with the highest sensitivity in the world.

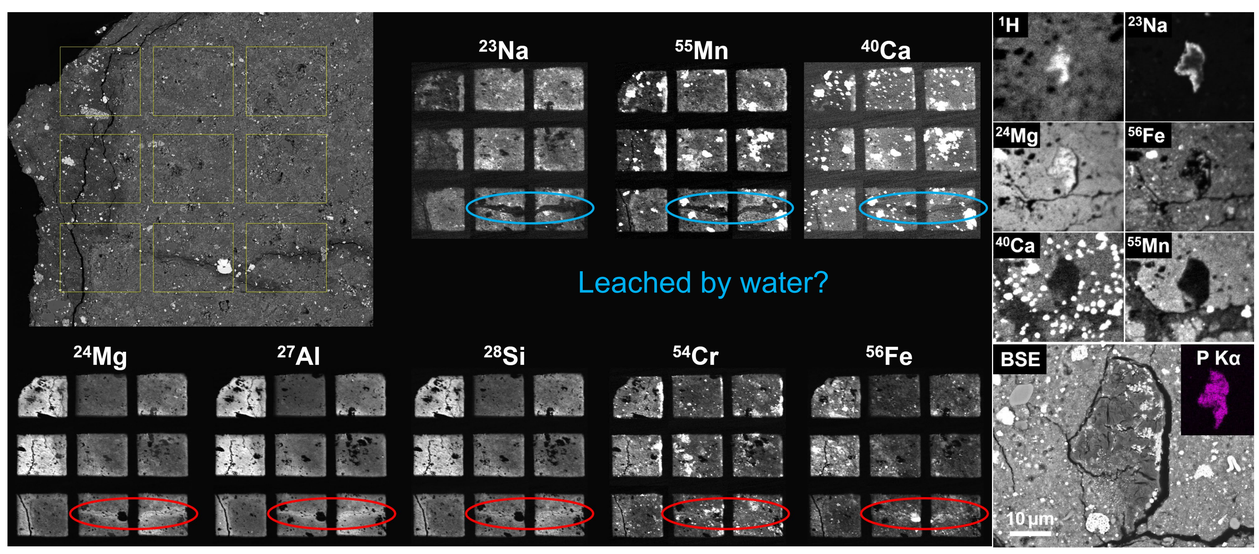


Entirely Surrounded by Na, K-rich Layer



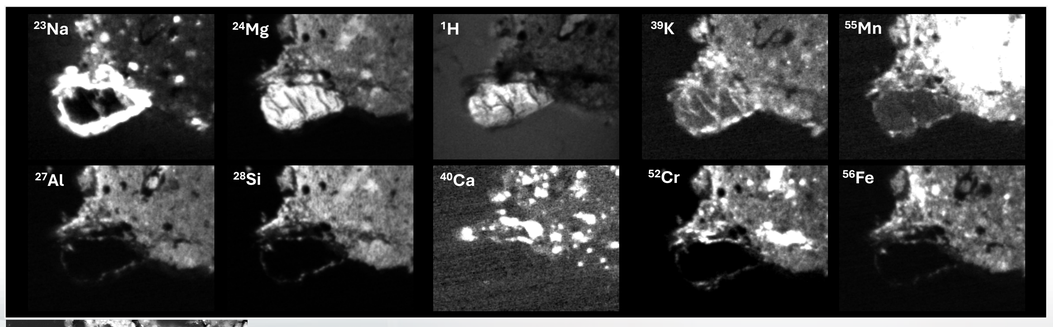
The elemental maps focusing on the outer rim of the OREX-803112-0 (upper) and OREX-803114-0-3 (lower) particles reveal that sodium (^{23}Na) is enriched across the entire surface of the particles. Inside the Na-enriched layer, another distinct layer depleted in Na and Mn is observed, with patchy depletion of Ca as shown in the upper right figure. The localized enrichment of chromium (Cr) seen in the inner regions is not present in the outer layers. Similar to Na, potassium (K) is also enriched at the particle rim, as shown in the lower left figure (red box). The contrast difference with the interior clearly highlights the stronger enrichment of Na in the rim compared to K.

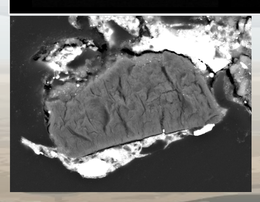
Depletion of Na, Mn, Ca along the Crack / Vein



SIMS elemental maps of OREX-803111-0 (left), the only sample without a Na rim in this study, and the matrix of OREX-803114-0-1 (right), which contains Mg-phosphate. The regions along the cracks or veins appears dark in the backscattered electron (BSE) image (upper left). Although the major elements appear slightly brighter (red circles in the lower), these regions are depleted in Na, Mn, and Ca (blue circles), which are known to be water-soluble. The Mg-phosphate grain in the matrix of OREX-803114-0-1 consists of an H-rich interior and Na-rich rim (upper right). The Fe map is useful for correlating the positions of the SIMS map with the BSE image, which indicates magnetite particles within the Mg-phosphate grain. The H-rich interior exhibits a fractured texture, while the Na-rich rim shows no clear features. The Ca and Mn maps not only show intense spots indicative of carbonates, observable in SEM-EDS, but also reveal bright and dark areas along cracks in the matrix, similar to those in OREX-803111-0, identified through high-sensitivity analysis using a stigmatic LG-SIMS.

Mg-phosphate overgrown by Na-rich Rim





The elemental maps for a Mg-phosphate found on the outer regions of OREX-803114-0-1. Sodium is highly enriched in the rim of the grain but not in the interior. This Mg-phosphate, with a Na-rich rim, is also enriched in hydrogen and contains small amounts of potassium (K) and manganese (Mn).The Na-rich rim of Mg-phosphate surrounds the fractured, H-rich interior, suggesting that the H-rich interior formed first, followed by the Na-rich rim, which likely formed through the evaporation of fluid, leading to the concentration of salts.

Salinization on Carbonaceous Asteroids?

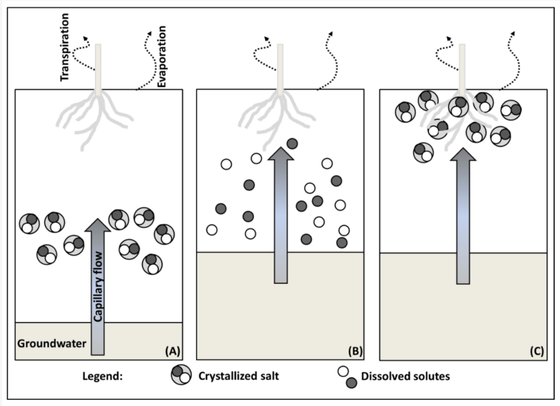
■ Solonchak — Photobooks of Drylands, Yamanaka and Toderich eds.

Solonchaks are the soil in which a large amount of salts (mainly sodium salts such as sodium chloride and sodium sulfate) have been accumulated. Typically, the soil surface is covered with precipitated white salt that have risen by capillary action from the lower layer with water. Due to excessive accumulation of salt, ordinary plants (Glycophyte) cannot grow, this selects only for halophytes (plants with strong salt tolerant and/or high salt preference). Solonchaks are artificially (secondary) formed when groundwater level rises due to poor management of irrigational system, the process of soil salinization has been a serious cause of soil degradation for over 6,000 years in irrigated farmlands of the world. (Sadahiro YAMAMOTO)

ソロンチャックの土壌断面(チュニジア、ジェリド湖)。
Soil Profile of Solonchak (Chott el Djerid, Tunisia).

Uri N., Water 2018, 10(8), 1030

Figure 2. Soil salinization by salt originating from the parent geological material. (**A**) Initial conditions with salt at deep parts of the soil profile and deep groundwater; (**B**) Elevated ground water dissolves the salt and solutes are transported upward by capillary flow towards the root zone; (**C**) Water is evaporated and consumed by the plants while the salts precipitate close to soil surface, resulting in soil salinization.



The surface enrichment of Na and K, observed throughout the Bennu particles except for OREX-803111-0, is likely to have occurred after the particles acquired their present shape. This enrichment can be attributed to a salinization process similar to that occurring in arid regions on Earth. In such a process, water moves from the ground to the surface by capillary action, accompanied by water-soluble components, and evaporates on the dry surface, concentrating elements such as Na and K. If this process occurred on the surface of asteroid Bennu, the Na and K distributions of the Bennu particles suggest the possible presence of subsurface water, since the outer surface of asteroid Bennu would have been in an environment drier than that of Earth. Similar observations on Ryugu (Sakamoto+, 2022 JpGU) imply that this phenomenon may be common on C-type asteroids. These findings underscore the importance of preserving the pristine surface conditions of asteroid regolith particles in sample return missions.