MicrOmega detections of carbonates in Ryugu returned samples within the Hayabusa2 JAXA Extraterrestrial Curation Center

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The Ryugu samples brought back by the Hayabusa2 spacecraft in December 2020 have been delivered to the JAXA Extraterrestrial Curation Center [1, 2]. Bulk samples and then sub-bulks and individual grains have been picked up and stored into sapphire dishes, weighted, and analyzed with an optical microscope, FTIR spectroscopy, and MicrOmega hyperspectral imaging [3] for initial description within the curation facility [2]. The MicrOmega instrument used in the JAXA Extraterrestrial Curation Center is a NIR hyperspectral microscope. This configuration allows a mineralogical characterization of pristine Ryugu samples, as they have never been exposed to terrestrial environment.

MicrOmega has a total field of view of 5 mm x 5 mm, with resolution of ~22.5 µm/pixel in the focal plane. It covers the spectral domain from 0.99 µm to ~3.6 µm. Its capabilities enable the identification of organic matter and of different minerals in the returned samples [4]. Initial analyses with MicrOmega were first made on the bulk samples from chambers A and C of the Hayabusa2 returned capsule, and then on extracted individual grains and sub-bulks, each stored in their sapphire dishes. For this study, we analyzed MicrOmega data of ~180 extracted individual grains (a few mm in size) and 14 sub-bulks (all observed with MicrOmega within the Curation Center in 2021). This is a unique opportunity for mapping mineral and organic species over a very large set of samples from Ryugu.

In the spectral domain of MicrOmega, carbonates have a strong characteristic double absorption band in the 3.3-3.5 µm area, accompanied by two other weaker bands around 2.5 and 2.3 µm. The exact spectral position of these bands varies with the cation content of the carbonate. Iron-bearing carbonates also show a strong absorption below 1.5 µm.

Detections of carbonates were made in grains included in the bulk samples from both chambers A and C. In the bulks, some small detached grains seem to be entirely carbonate-rich and are up to ~450 µm, down to <50 µm in size. In larger, extracted grains, carbonate inclusions are also detected, with sizes up to >500 µm in a 3mm-sized grain, and down to <50 µm.

Spectrally, two carbonate populations are detected: many detections, mostly <100 µm in size, have spectral bands centered at 2.30, 2.50, and 3.30-3.43 µm, similar to $CaMg(CO_3)_2$ dolomite; and few detections, mostly >100 µm, have bands at 2.32, 2.51, 3.31-3.45 µm together with a strong absorption <1.5 µm, similar to $(Mg,Fe)CO_3$ breunnerite. We also report 3 small detections (<50 µm in size) with spectra with bands at 3.35-3.48 µm, similar to CaCO3 calcite. Both dolomite and breunnerite-like areas are detected in samples from both chambers, but we record more detections from chamber C than from chamber A.

The largest detection was made on grain C0041, covering ~0.25 mm², or ~10% of the visible surface of the grain. This grain is one of the grains with "White regions" as described in [5]. The carbonate inclusion shows a complex morphology with three branches, 100s µm long, around a main area. Spectra of this detection are breunnerite-like.

Another large and complex carbonate inclusion was detected in grain C0181. In this example, bright carbonate detections surround a darker, 300 µm long carbonate inclusion that seem to correspond to a single crystal where both bright and dark carbonates correspond to breunnerite-like spectra.

Carbonates detected by MicrOmega are distributed in two main populations both different in composition and size/morphology, questioning the formation process or processes that led to this two populations. We did not detect any spatial transition from dolomite to breunnerite, that would have indicated a possible gradient during a single formation event. We propose two distinct formation processes: dolomites may have formed within small pores in the precursor material, limiting their size, very early in the solar system [6], while breunnerite may have formed in fractures between grains, possibly after an impact on Ryugu's parent body, or even triggered by the impact. At what scale these processes were distinct in time is still questionable.

References

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