CARBONATES FROM RYUGU: EVIDENCE OF PARENT BODY AQUEOUS ALTERATION IN SAMPLE A0112

A. Van den Neucker[1], E. Bonato[1,2] , A. Maturilli[1], S. Schwinger[1], J. Helbert[1], M. Baqué[1], M. Hamm[3], G. Alemanno[1], M. D'Amore[1], [1]German Aerospace Center (DLR) – Institute of Planetary Research, Rutherfordstrasse 2, 12489 Berlin, Germany, [2]Museum für Naturkunde - Invalidenstraße 43, 10115 Berlin, Germany, [3]Freie Universität Berlin – FB Geowissenschaften – Institut für Geologische Wissenschaften Planetologie and Fernerkundung – Malteserstr. 74 – 100 – 12249 Berlin, Germany.

Introduction: The Japanese Hayabusa2 sample return mission retrieved fragments of the near-Earth C-type carbonaceous asteroid Ryugu 162173, that exhibit similarities in composition to the Ivuna meteorite. The high carbon content and presence of volatile-rich materials, suggests it could potentially be categorized as a primitive CI-type asteroid. [1] Among the collected samples, the piece A0112 was sent to Planetary Spectroscopy Laboratories (PSL) at the German Aerospace Center (DLR) for spectral analysis. Micro infrared spectroscopy and Raman microspectroscopy measurements were carried out on sample A0112, when the grain was still sealed within its sample holder. The analysis of the sample, allowed the determination of its bulk composition and its mineralogy under glass, without it being affected by terrestrial alteration. Carbonates could be identified, which provided significant evidence of the aqueous alteration processes that occurred in the parent body of Ryugu.

Materials and Methods: The A0112 sample, which weights 5,1 mg and is 3046x1823 µm in size, was contained in a nitrogen-filled sample holder, free of any form of terrestrial contamination after its retrieval from the asteroid. In order to preserve the sample from external contamination, such as the atmosphere, the first set of analyses were performed with the grain sealed within its sample holder. High-resolution 3D images were taken of multiple sides of the grain with the digital microscope Keyence VHX-7000 and VHX-7100 observation system, which allowed a global view of its surface morphology and topography. From the processed images, the sample can be described as a mostly dark fragment with a few micron-sized, bright inclusions on most of its faces. More than 50 point-localized infrared spectroscopy measurements were performed on the A0112 grain with the Hyperspectral Bruker Hyperion 2000 Micro-FTIR to assess the general mineralogy of the fragment through the glass window of the sample holder. MIR (1.3 – 5 µm) reflectance point measurements consisted of 1000-2000 scans at an optical magnification of 15x and a resolution of 4cm^{-1}. VNIR reflectance spectra were also taken for a few spots to cover the full spectral range. Raman spectroscopy under neutral atmosphere with the WiTec Alpha 300 confocal Raman microscope [2] was used for organic matter and mineral identification, and to generate elemental maps of the grain. With the FTIR spectrometers (three identical Bruker Vertex 80V) and a special manufactured sample holder it was possible to measure bi-directional reflectance bulk sample spectroscopy of sample A0112 completely under vacuum in the whole spectral range from UV to FIR (0.25 µm to at least 25 µm spectral range).

Results and Discussion: The in-situ Micro-FTIR measurements revealed an abundant presence of secondary minerals such as phyllosilicates throughout the sample and a localized area of around 30 µm rich in carbonates, which could be identified as dolomite due to the absorbance bands at wavelengths of 1.90, 2.21, 2.73 and 4.4 µm, as well as two distinctive sets of doublets at 3.33, 3.47 µm and 3.81, 3.95 µm. [1, 3] The presence of dolomite was reconfirmed by the Raman spectroscopy measurements with spectral bands at 175, 300, 727 and 1098 cm^{-1}. The dolomite inclusion seems to be associated with a vein in the grain. By investigating the hydrated minerals formed through aqueous alteration that took place in the parent body, it is possible to get a better understanding on the evolution of materials characterizing Ryugu and the protoplanetary disk. The presence of carbonates is of significant importance as these findings suggests the presence of liquid water within the asteroid, which could potentially play a role in water delivery to Earth or other planets. [4] Furthermore, these results allowed us to confirm that in-situ point measurements, to localize hydrated minerals and organic matter, are still possible through the glass window of a sample holder.

References: [1] Nakamura, T. et al. (2022) *Science.* [2] Böttger, U. et al. (2013) *LPS XVIV*, Abstract #2092. [3] Loizeau, D., et al. (2023) *Nat Astron. 7*, 391-397, [4] Ito, M. et al. (2022) *Nat. Astron. 6*, 1-9.

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