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Space weathering formation of glassy layers at the surface of Ryugu: a STEM-EDX study

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On December 6, 2020, Japan Aerospace Exploration Agency (JAXA)'s Hayabusa2 mission brought back 5.4g of material from the surface of the carbonaceous asteroid Ryugu. Some of these grains show evidence of a modified surface attributed to space-weathering [1]. Such phenomena result from solar-wind irradiation and/or micrometeoroid bombardment. The study of these modified surfaces should allow to better understand how a C-type asteroid surface evolves when subjected to space weathering. Here, we present spatially resolved characterization by S/TEM of modified surfaces and underlying matrix of several small Ryugu grains, in collaboration with the Hayabusa2-Initial-Analysis Min-Pet Fine Team and the Hayabusa2-Initial-Analysis core.

JAXA allocated us grains from touchdown sites A and C [2]. Space weathered surfaces were identified with a SEM. This recognition was based on the occurrence of smooth, vesiculated surfaces and melt splashes. Thin section from these areas were prepared by FIB and were studied by STEM-HAADF imaging and STEM-EDX using a FEI-TITAN-Themis300-S/TEM at the University of Lille (France).

The interior of the grains is composed of a phyllosilicates-rich matrix containing numerous Fe-sulfides. The grains surfaces are made of an amorphous layer of variable thickness, ranging from a hundred nanometers to few micrometers. These layers consist of a Mg-rich silicate glass embedding numerous rounded Fe-Ni-sulfides and vesicles of various sizes. The smallest sulfides inclusions and vesicles are located at the boundary with the underlying matrix while larger ones lie next to the surface. The presence of rounded Fe-sulfides and vesicles reflects a rapid cooling of a melted material, that prevented their coalescence and growth. STEM-EDX results show that the silicate glass composition can be enriched in Fe compared to the composition of the underlying phyllosilicates. For some grains, the Mg/Si ratio is slightly lower in the glass layer than in the underlying phyllosilicates matrix. These observations show that the glassy layers were formed from molten silicate which cooled rapidly. It might be consistent with micrometeorite impacts and could have affected Ryugu's optical properties [3].

[1] Noguchi and the Hayabusa2-Initial-Analysis Min-Pet Fine Team (2022) *in prep*

[2] Yada et al. (2021) Nature-Astronomy, ISSN-2397-3366

[3] Thompson et al. (2020) Icarus, 346, 113775.