THE RARITY OF SPACE WEATHERED GRAINS FROM RYUGU: REGOLITH ABRASION?

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Introduction: JAXA's Hayabusa2 mission successfully retuned 5.4 g of regolith from asteroid 162173 Ryugu, a water-rich C-type asteroid, in December 2020 [1]. Analysis of Ryugu grains indicate that the sample is consistent with CI chondrite [1]. One of key goals of the Hayabusa2 mission is to understand how C-type asteroid surfaces are modified by space weathering. However, reflectance spectra of returned samples are different to the spectra acquired from the Hayabusa2 probe [1,2], while only ~6 % of Ryugu grains studied so far exhibit space weathering features [3]. The frequency of space weathered grains observed from Ryugu is much lower than asteroid Itokawa [4] and the Moon. This study aims to determine why space weathered grains are so rare on asteroid Ryugu.

Methods: Two Ryugu grains were mounted on Cu tape. Their surfaces were imaged by Low (2 keV) kV scanning electron microscopy (SEM) using a Zeiss Sigma variable pressure field emission gun (VP-FEG)-SEM at the ISAAC facility at the University of Glasgow (UofG). Ryugu grains were then sputter coated with a 200nm protective layer of Cr and Transmission electron microscopy (TEM) and Atom Probe Tomography (APT) samples were extracted using a FEI Nova Nanolab 200 Ga-Focused ion beam (FIB)-SEM in the KNC at UofG, following the approach of Daly et al. [5]. TEM analysis and imaging were undertaken on the JEOL ARM 200cF TEM in the KNC at UofG. APT samples were analysed on a CAMECA LEAP 5000XS at the University of Oxford.

Results: Low kV SEM imaging shows that the grains are angular-subrounded. Low kV SEM, TEM and APT analysis provide no evidence of space weathering. Low kV SEM imaging indicate that crystals of magnetite, carbonate and sulphide exposed at the grain's surface exhibit rounded facets and stand proud of the fine grained phyllosilicate matrix, while TEM imaging reveals that these same crystal facets are angular at depth.

Discussion and Conclusion: The rarity of space weathered grains on asteroid Ryugu could indicate that only the very surface of C-type asteroids is space weathered and that the kinetic sampling mechanism used by Hayabusa2 preferentially collected material from depth. However, regolith gardening processes would result in overturn of the surface burying space weathered grains and exposing fresh grains. Thus even a sample from depth should contain space weathered grains. Alternatively, the rounded grain morphology, and crystal facets combined with the nano-topography of competent minerals relative to soft minerals is consistent with abrasion. This could be caused by collisions and fracturing during sampling by the Hayabusa2 probe or by natural abrasion and erosion within the regolith of Ryugu. If kinetic sampling was the cause we would expect angular grains and grains with space weathered surfaces on one grain face – inconsistent with observations. In contrast, natural agitation of the regolith during impacts or regolith gardening would slowly erode and destroy space weathered surfaces on grains at depth, particularly weak minerals like phyllosilicates and produce rounded grains. Thus, the scarcity of space weathering features on Ryugu is likely due to natural abrasion of grains in the asteroid's regolith.

References: [1] Yada T., et al., (2021) *Nat. Astro.* 1-7. [2] Kitazato K., et al., (2019) *Sci.* 364, 272-275. [3] Noguchi T., et al., (submitted) *Nat. Astro.* [4] Noguchi T., (2011) *Sci.* 333, 1121-1125. [5] Daly L., et al., (2021) *Nat. Astro.*