MELT ZONES IN RYUGU SURFACE SAMPLES: XANES AND STEM-EELS CHARACTERISATION OF SPACE WEATHERING

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Introduction: C-type asteroid Ryugu grains returned by the JAXA Hayabusa2 mission show a variety of space weathering (sw) effects overprinting a CI chondrite like mineralogy [1]. Notably, the Fine Grained Mineralogy team demonstrated that sw on the asteroid's surface included amorphization and partial melting of phyllosilicate [2]. In previous work on sw samples from the Itokawa S class asteroid we used Fe K XANES, STEM, TEM to demonstrate changing $Fe^{3+}/\Sigma Fe$, vesicular blistering, and $npFe^0$ growth associated with that style of sw. Here, and in [2], we use the same techniques to provide accurate $Fe^{3+}/\Sigma Fe$ and mineral-textural identifications on sw Ryugu grains to help characterise a different set of SW processes, likely associated with micrometeorite bombardment [2].

Samples and Methods: We have analysed FIB-TEM wafer samples A0058-C2001-08, A0104-00200502, and A0104-01700602 prepared from Hayabusa2 near surface samples (Chamber A) by Noguchi at Kyushu University [2]. As part of a Hayabusa2 consortium of complementary analytical work, we conducted Fe-Kα XAS measurements using the I-14 X-ray Nanoprobe Beamline at Diamond Light Source. To achieve XAS mapping, a series of maps were obtained over regions of interest, each map measured from 7050 to 7350 eV with a higher energy resolution over the XANES features (~7100-7150 eV). Similar to Itokawa asteroid samples [3], mineralogical identity can be constrained, including oxidation states in Fe-oxides and Fe-silicates, by observing increased energy shifts in the 1s→3d pre-edge peak centroid positions, and comparing to reference minerals of known $Fe^{3+}/\Sigma Fe$. EELS was performed using the JEOL ARM200CF instrument at ePSIC in the Diamond facility, using an accelerating voltage of 200 keV, current 15 µA, and measuring 0.25 eV/ch. Additional TEM imaging, calibrated STEM-EDX have been performed using JEOL 2100 FEG and LaB_6 TEM's at the University of Nottingham, UK.

Results: The interior of these samples are a fibrous phyllosilicate and magnetite rich (Fig. 1) with lesser amounts of phosphate and sulfides. The phyllosilicate has two layered lattice spacings of 0.75-0.78 nm and $100*(Si+Al)/(Mg+Fe_{tot})$ atomic of 48-60. Its $Fe^{3+}/\Sigma Fe$ varies considerably on the 3 wafers we have analysed from 20-50%. However, the melt zone, as shown by vesicularity and less crystalline nature, has $Fe^{3+}/\Sigma Fe$ of 15%.

Discussion and Future Work: The reduction of the phyllosilicate-rich Ryugu grains associated with micron scale surface melt zones is in contrast to the $>Fe^{3+}/\Sigma Fe$ associated with sw nm-thick zones in Itokawa samples returned by Hayabusa [3,4]. The latter is thought to be a result of the implanted solar wind H^+ ions reacting with the segregated ferrous Fe in the surface material [3]. The Ryugu results are demonstrating the diversity of processes associated with sw that act to alter the spectral characteristics of airless bodies. This report forms part of our study into the origin of the phyllosilicate in Ryugu Chamber A grains and the conditions of space weathering that have altered them.

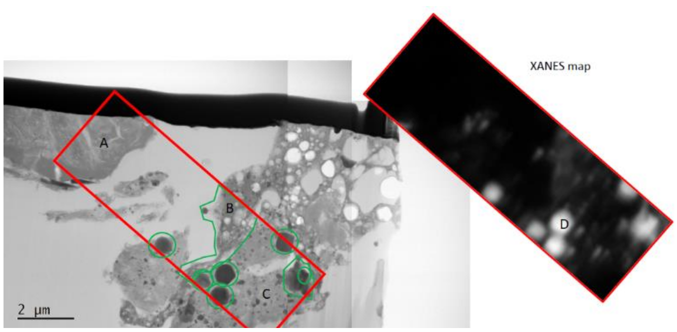

Figure 1. STEM image and Fe K XANES map of sample A0058_T8. A Mg phosphate, B vesicular melt zone, C phyllosilicate, D magnetite. The melt zone has a more reduced Fe^{2+}-rich composition than the phyllosilicate-magnetite rich interior.

References: [1] Yokoyama T. et al. *Science* (subm.). [2] Noguchi T. et al. (2022) *Nature Astronomy* (subm.). [3] Hicks, L. et al. (2020) *Meteorit. Planet. Sci. 55*, 2599–2618. [4] Noguchi T. et al. (2014) *Meteorit. Planet. Sci. 49*, 188–214.