HAMP (Hydrated Ammonium-Magnesium-Phosphorus-rich) grains in Ryugu samples with major biochemical potential

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Introduction: The Ryugu samples are stored and curated in an ultra-clean and controlled N_2-purged environment in the JAXA-ISAS Curation Center and have thus remained unexposed to the terrestrial atmosphere since their collection [1]. In this facility, a global non-destructive and non-invasive characterization of these samples is being performed. In particular, the MicrOmega near-infrared (NIR) hyperspectral microscope has identified inclusions and grains, some with sizes up to a few hundreds of micrometers of a variety of composition: organics, NH-rich and OH-rich phases, as well as minerals such as carbonates [2,3] all embedded within a dark matrix (near-IR reflectance factor of 2-3% [1,2]) primarily made of phyllosilicates [1,4-8]. One specific class of grains/inclusions uniquely exhibits a reflectance factor about 4-10 times higher than the matrix and a singular broad and deep '3 µm' absorption feature. We report here the results of a collaborative work led by IAS, Ph2K Curation and OU teams to investigate the physico-chemical properties of these peculiar grains [9].

Methods: In order to complement the NIR characterizations performed within the Curation Center, two grains displaying these specific spectral properties were extracted from aggregate samples, one from C0209 and the other from A0218 for further investigation. Combined analyses were then performed at the Kochi Institute for Core Sample Research of Japan Agency for Marine-Earth Science and Technology (JAMSTEC, Japan), Institut d'Astrophysique Spatiale (IAS, France), Synchrotron SOLEIL (France) and Open University (OU, UK). These analyses include SEM-EDS (both directly on the extracted grains and on a fraction pressed on a gold foil), SXRD and MIR micro-spectro-imagery.

Results: The deep and broad '3 µm' feature observed by MicrOmega in the Curation Center is attributed to O-H stretching vibrations of H_2O molecules, implying that this compound is hydrated and that the H_2O molecules are endogenous. SEM-EDS analyses revealed an elemental composition primarily made of phosphorus, oxygen and magnesium with almost no silicon, nor calcium (Ca/Mg is below the percent level). Additionally, this phosphorus-based compound appears poorly crystalline from XRD analyses. Further analysis by mid-IR micro-spectro-imagery (2.5-12 µm) have shown the presence of correlated features at 3 µm, 6.9 µm and a broader one centered around 9.5 µm on the P-O-Mg-rich areas. The ~9.5 µm spectral feature is attributed to P-O stretching vibrations and the 6.9 µm band is attributed to the out-of-plane bending vibration in NH_4^+. Put together, these combined analyses thus reveal that Ryugu

contains Hydrated Ammonium-Magnesium-Phosphorus-rich (thus labelled "HAMP") grains in which phosphorus is oxidized, plausibly as phosphate.

The discovery of such compounds in Ryugu samples has major implications. First, it supports the scenario that Ryugu's material initially accreted and evolved in the Outer Solar System [3,4,6,10-12]. Secondly and most importantly, it delivers a critical outcome of biochemical relevance, with respect to the role such grains may have played when they were brought to the inner Solar System and then immersed in the ancient terrestrial water reservoirs, thanks to their specific physico-chemical properties. We will present and discuss these different results during the conference.

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