In-depth analysis of the single grain from the C-type asteroid Ryugu utilizing linkage microanalytical instruments planed by Phase 2 curation "Team Kochi"

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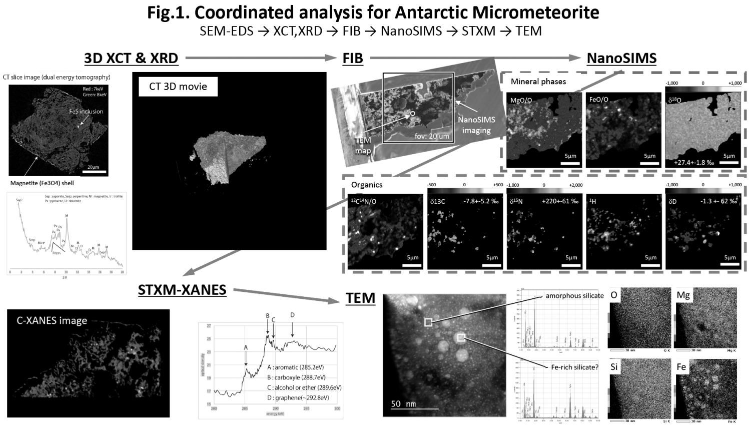
On-going missions of JAXA Hayabusa2 (the C-type asteroid Ryugu [1]) and NASA OSIRIS-REx (the B-type asteroid Bennu [2]) are to understand the Solar System evolution in the point of view of organics, water, and associated minerals (i.e., hydrous minerals). Both are asteroid-sample return missions in addition to the series of studies by different types of spectrometers (thermal emission, infrared and visible spectrometers). The Hayabusa2 space craft was thought to be successfully obtained the Ryugu samples from surface and subsurface on Feb. and Apr. 2019 and will return to the Earth on late 2020. These sample may contain organics and hydrous minerals especially in subsurface samples. For the Ryugu sample analysis, six initial analysis team (chemistry, fine-grained minerals, coarse-grained minerals, soluble organic matter, insoluble organic matter and volatiles) was organized by the Hayabusa2 project. Phase 2 curation team were also organized by the Astromaterial Science Research Group (ASRG) of JAXA and was authorized two institutes by the steering committee of the ASRG in 2017. One of the Phase 2 curation team was proposed by Kochi Institute for Core Sample Research (KOCHI), JAMSTEC in collaboration with JASRI/SPring-8, UVSOR Synchrotron Facility/National Institutes of Natural Sciences, Institute for Molecular Science, National Institute of Polar Research (NIPR) and Tokyo Metropolitan University. We are going to conduct an in-depth analysis of a few grains by the *state-of-the-art* instruments/techniques and nationwide collaborative research activities. We will conduct on analyses in parallel with the initial analysis team in the first year of arrival of the Ryugu samples.

For the best analytical results from the Ryugu samples, we have designed a Kochi grid and a Kochi clamp for FIB, TEM, and NanoSIMS and then designed an Okazaki cell for STXM minimizing possible terrestrial contaminations and sample lost [5]. Another development is a sample transport vessel (FFTC: facility to facility transfer container) under vacuum or inert gas [6]. We, then, have established coordinated synchrotron based-XCT (SPring-8) – XRD (SPring-8) – FIB (JAMSTEC KOCHI) – STXM-XANES (UVSOR Synchrotron Facility) – NanoSIMS (JAMSTEC KOCHI) – TEM (JAMSTEC KOCHI) analysis. This coordinated analytical procedure is promising to obtain complex characteristics inside of the sample; light element isotopes with their spatial distributions, speciation of elements (type of bonding, chemical species) and ultra-fine textural structure (mineralogy and crystallography in fine-grained mineral and organic assemblage) from few tens to hundreds of micrometer-scale sample. We have tested the procedure using Antarctic micrometeorites provided by NIPR as an analogue of the Ryugu grain because of size (50 to 800 μm) and chemical properties (Fig .1). Our coordinated analysis procedure with KOCHI grid, Okazaki cell and FFTC was successfully performed.

Fig.1. Coordinated analysis for Antarctic Micrometeorite



The degree of thermal metamorphism and aqueous alteration of the asteroid Ryugu is still unknown. Our next plan before the analysis of the Ryugu sample is to make analysis of Antarctic meteorites (preferably primitive chondrite) experienced with various degree of thermal metamorphism and aqueous alteration. One of candidate is the primitive Antarctic meteorite A12169 having a low degree of thermal and aqueous alterations [7, 8]. We will explore A12169 as a unique analogue utilizing the coordinated analysis to obtain comparative analytical data between most primitive carbonaceous chondrite and the sample from the asteroid Ryugu which is either CM chondritic materials or shocked/heated carbonaceous chondrites [3-4].

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