ORIGIN OF THE SOLUBLE ORGANIC MATTER OF RYUGU, AND CARBONACEOUS CHONDRITES.

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Introduction: Meteorites and comets bear organic molecules ranging in size from one single to an arbitrarily large number of carbon atoms. This diversity contrasts with the limited size of free molecules detected in space environments. Understanding the organic matter cycle in the galaxy requires to identify the time and place where the molecules were formed[1].

The Ryugu regolith sample brought to Earth by the Hayabusa 2 mission is a unique instance of the material of a C-type asteroid and can be compared to carbonaceous chondrites. For this sample, contamination is under control. The travel from the parent body extraction to the surface of the Earth included collection in situ followed by ~15 months of storage in a very protective environment in the spacecraft sampling module. This mitigates against organic contamination or modification during atmospheric entry[2].

The High Resolution Mass Spectrometry technique has been used for almost a decade to characterize extraterrestrial material. The technique only accesses the soluble part of the samples and is used both with and without liquid chromatography for molecular identification. Several scenarios have been proposed for the soluble organic matter in extraterrestrial samples.

In this study, we focused on the distribution of masses observed by mass spectrometry and associated with molecular formulas. We highlighted a peculiar pattern in meteorite extracts that can be only reproduced by gas phase polymerization experiments simulating reducing planetary atmospheres or nebular environements[3], [4].

Method: Solvent extractions were performed at Kyushu University. A small aggregate sample of Ryugu grains from the first touchdown site (A0106) were used in this study. The aggregate sample of A0106 (17.15 mg) was extracted sequentially with hexane, dichloromethane (DCM), methanol and H_2O. All extraction procedures were performed on an ISO 5 (Class 100) clean bench inside an ISO 6 (Class 1000) clean room. All glassware used in this study were heated in an oven at 500°C for 3 h prior to analysis to remove possible organic contaminants. Baked serpentine powder (500°C for 3h) was analyzed as a procedural blank. We did comparable extractions for several carbonaceous chondrites including Orgueil (CI), Murchison (CM) and 4 CR chondrites. Laboratory experiment residues produced from ionized gas, photon irradiated ices or reactive liquids were also analyzed to provide comparison to well constrained synthesis environments.

Results: The organic compound complexity of the Ryugu methanol extract is, to first order, similar to extracts from Murchison samples. Specifically, the chromatographic separation resulted into two broad peaks: water soluble and water insoluble compounds, as described for the homologous series of 1-N bearing molecules.

In every sample, CH_2 elongation patterns are detected. A CH_2 family has only molecules with R-$(CH_2)_n$ formula. From each CH_2 family, the free parameters of the Wesslau model for polymerization can be adjusted to match the distribution[5]–[7].

The mass distribution of various classes of compounds in the Ryugu extract is among the broadest ever measured in laboratory experimental analogues simulating gas phase synthesis, liquid phase polymerization or UV irradiation of ices. This means that to-date, the complexity pattern found in Ryugu extracts is dissimilar from those in any prior terrestrial experiments. We discuss a potential nebular origin on the basis of comparison with highly reduced gas phase experiments.

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