The Petrologist’s Guide to the Study of Soluble Organic Matter

*Junko Isa[1], François-Régis Orthous-Daunay[1], Pierre Beck[1], Christopher D. K. Herd[2], Véronique Vuitton[1], Laurène Flandinet[1]

1. Institut de Planétologie et d’Astrophysique de Grenoble, 2. Department of Earth and Atmospheric Sciences, Edmonton, AB, Canada.

The solar system origin and the subsequent evolution of organic matter have been widely studied and yet they are still not well understood. Inorganic chondritic components, bulk elemental compositions, and the petrography of the chondrite groups reflect different accretionary components. Also, the petrological observations of alterations/metamorphism in the chondrites shows evidence of the geological evolution since accretion and of the parent body processes that result in the variety of rock types we see today across chondrite groups. The chondritic rock components, including both organics and inorganics, experienced geological processes. Thus, the vast majority of organic compounds are subject to reactions that lead to synthesis, degradation, and alteration due to their nature to be reactive. The modifications that occur due to geological processes help to explain why the overall picture of the organic compound distribution is still unclear. We targeted small organic compounds that are likely more sensitive to the parent geological environment on their parent body as compared to the macroscopic molecules called insoluble organic matter, IOM.

In order to comprehensively study the accretionary remnant and the effect of parent body processes on soluble organic matter, SOM, in meteorites, we have applied non-targeted analyses on solvent extracts from chondrites. They were analysed by using either Heated Electrospray Ionization (HESI) or nano-ESI direct-infusion with a high-resolution Orbitrap mass spectrometer. We studied Tagish Lake (C2-ungrouped) chondrites from different lithologies together with Orgueilas (CI) for a comparison of aqueous alteration, an Antarctic CM2 for aqueously altered oxidized chondrite, an Antarctic CR2 as a reduced chondrite, an Antarctic R3 as an oxidized thermally metamorphosed chondrite, and the relatively well-studied Murchison (CM2) as a reference. Petrographic textures of the Antarctic meteorites were determined by using SEM images.

Each Antarctic meteorite and the Murchison meteorite were subsequently extracted by solvent (hexane, dichloromethane, methanol, and 100°C water). The methanol extracted organics were analysed using the high-resolution Orbitrap mass spectrometer at Kyushu University. Tagish Lake, Orgueil, and another Murchison were analysed at the University of Grenoble Alps. For the extraction solvent, we used a mixture of methanol:toluene equal to 2:1 by volume. The methanol/toluene extracted organic compounds were also analysed using the high-resolution Orbitrap mass spectrometer at the University of Grenoble Alps. The SOM, together with the solvent, was injected into the Orbitrap and ionized by using the HESI source.

We found that the mass spectra of methanol extracts vary according to the redox conditions and thermal history of the extracted rocks. In the spectra, there are significant differences in organic composition and inorganic ions that were detected together with organic molecules. We have not yet found a major stoichiometric difference in CHNO organic compounds among Murchison and most of Tagish Lake lithologies. However, some portion of Tagish Lake SOMs are significantly enriched in sulfur. In the presentation, we will summarize the common denominator and individual characteristics in organic compound distributions amongst the different chondrite groups. Also, we will discuss potential formation mechanisms based on the polymerization pattern evident in the observed mass spectra.

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