Secondary SOM produced through aqueous alteration on carbonaceous chondrite parent bodies: anomalies from mass distributions

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Introduction: The differences in bulk elemental compositions, stable-isotope ratios, mineralogy, and structures of chondrites demonstrate the variations in time/space of their formation regions in the solar nebula and the subsequent evolution of their parent body. Naturally, one may expect to find some variations in chondritic organics reflecting their different reservoirs in the solar nebula and the secondary modifications on asteroids [1]. Chondrite soluble organic matter (SOM) is complex, and the aqueous reactions on asteroids are thought to be where it was synthesized [2]. Also, thermal alterations could have produced organo-metallic complexes [3]. Our previous study of Tagish Lake meteorite showed that the primordial SOM could be distinguished from the parent body's secondary alteration through mass distribution. Also, we concluded that the complex nature of the primordial SOM was established before severe alteration on the asteroid and later became simplified on the asteroid [4]. However, it is still unclear if the secondary processes recorded in the Tagish Lake SOM can be generalized and applied to other chondrite groups.

Recently, organic extracts from the asteroid Ryugu regolith materials brought to Earth by the JAXA Hayabusa 2 mission were analyzed and revealed the nature of terrestrially uncontaminated CI organic materials [5]. Although Ryugu extracts and other chondrite extracts are not identical, it appears to have only subtle variations in their parameters to explain their overall alkyl homologous series' mass distribution [6]. Relative to this first-order similarity, the secondary modifications we observed in the Tagish Lake meteorite are indeed minor. In this study, we focused on the relatively small variations/ potential specific chemical differences among different chondrite groups and petrologic types using the model from our previous study to further clarify the secondary processes on the asteroids.

Sample and Methods: Tarda (C2 ungrouped), Orgueil (CI), Murchison (CM2), EET 96029 (CM2), GRO 95577 (CR1), EET 92159 (CR2), GRA 06100 (CR2), GRO 03116 (CR2), and MIL 090657 (CR2) meteorite SOM were compared with experimental products from mineral-organic co-alteration under hydrothermal conditions [7]. We analyzed the methanol/toluene extract from meteorites with the high-resolution Orbitrap mass spectrometer located at the Institut de Planétologie et d'Astrophysique de Grenoble (IPAG). We directly injected and ionized the SOM and its solvent by using an Electrospray Ionization (ESI) source. After spectra acquisition, post-processing data analysis tools with the name Attributor [8], which were developed in-house, were employed.

Results and Discussion: Tarda and the other type 2 chondrites' SOM mass distribution were well fit by using the model interpreted as the primordial SOM distribution in Tagish Lake. This match among the distribution patterns from different chondrite types implies the presence of a common organic reservoir or a common mechanism for SOM formation, as discussed in Orthous-Daunay et al.'s abstract at the same conference [6]. The model fits better to Tarda SOM distribution than Tagish Lake ones; this implies that Tarda was less altered in the parent body than Tagish Lake, consistent with their studies of inorganic matter [9]. Orgueil and GRO 95577 (CR1) share the common shape in their mass distribution of a few alkyl homologous series, and these unique features are apparent in Orgueil, CR1. Such characteristic mass-distributions were not reported by the Ryugu extract studies (analyzed by the HPLC) [5], or other type-2 meteorites (analyzed by direct infusion). However, its similar bimodal distribution appeared in the organic extracts from the hydrothermal mineral-organic co-alteration experimental products.

In contrast to the mass distribution, SOM's elemental abundance was distinct among the different chondrite groups. In this presentation, we will discuss standard features of SOM among the chondrite groups based on the Wesslau model [6] and chemical formulae of detected ions. We discuss the organic chemical processes that are unique to the small bodies by listing stoichiometric formulae and mass distributions that are recognized as anomalies from the Wesslau model [6]. Finally, we hope to discuss the mechanisms of chemical reactions that produced specific organic compounds in the context of chemical evolution in the early solar system.

References: [1] Naraoka and Hashiguchi (2019) Geochemical Journal, 53, 33-40, [2] Cronin and Chang, (1993) The Chemistry of Life’s Origins pp 209-258 [3] Ruf et al. (2017) PNAS, 114(11), 2819-2824. [4] Isa *et al.* (2021) ApJL, [5] Naraoka et al. (2022) Science (in press). [6] Orthous-Daunay, F. R. *et al.* (2022) this MetSoc abst. [7] Zandanel, A. E. 2021, Doctoral dissertation, Univ. Grenoble Alpes. [8] Orthous-Daunay, F. R. *et al.* (2019) Geochemical Journal, 53(1), 21-32. [9] Marrocchi et al. (2021). ApJL, *913*(1), L9.