Magnesium-containing organic compounds in the Tagish Lake and Murchison meteorites.

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Introduction: Recent compound analyses using high-resolution mass spectrometry (HRMS) from the solvent extracts of the Murchison meteorite (CM2) reported various CHO, CHNO, CHOS and CHNOS compounds [Schmitt-Kopplin *et al.*, 2010] and ~600 alkylated homologues of CHN compounds [Naraoka *et al.*, 2017]. CHOMg compounds were also identified from methanol extracts of various meteorites by using HRMS [Ruf *et al.*, 2017]. To understand chemical evolution of the meteoritic organic matter, investigation of their relationship with surrounding minerals by *in-situ* analysis is necessary. Our previous studies revealed spatial distribution of alkylated homologues of CHN compounds in the Murray and Murchison meteorites using desorption electrospray ionization (DESI) with HRMS [Naraoka and Hashiguchi, 2018; Hashiguchi and Naraoka, 2019], but clear relationship with specific minerals was not found. In this study, we carried out DESI-HRMS imaging on the Tagish Lake meteorite to reveal the relationship between SOM and minerals.

Experimental: Fragments of the Tagish Lake (Ung-C2) meteorite and the Murchison meteorite with a flat surface of each meteorite were embedded in indium or alloy with low melting point (60 ºC). The DESI-HRMS imaging was performed using a 2D DESI ion source equipped with Orbitrap MS. A spray solvent was methanol 100% with the flow rate of 2–3 μL/min, and electrospray voltage was set at 3 kV. The positive ions (m/z 60–500) were collected with mass resolution of 140,000 ($m/\Delta m$ at m/z 200) on the surface of Tagish Lake (2.5×2.5 mm^2) and Murchison (4.5×4.5 mm^2). Antigorite grains was also analyzed to understand adsorption effects of organic compounds on clay minerals during storage in a clean room (Class 1000). After the imaging, FE-SEM-EDS analysis was carried out on the samples without coating and polishing.

Results and Discussion: Any CHN compounds were not detected from the Tagish Lake by DESI-HRMS imaging, whereas several alkylated homologues of CHN compounds were identified from Murchison similar to the previous study [Hashiguchi and Naraoka et al., 2019]. The distinctly different organic characteristics between the two meteorites was contrast to previous bulk analysis showing its quite low abundance of CHN compounds in Tagish Lake relative to Murchison [e.g. Pizzarello *et al.*, 2006]. Instead of the CHN compounds, abundant Mg-containing organic compounds were identified from Tagish Lake with mass precision of <1.5 ppm. Isotopomers of $^{24\text{-}26}$Mg for compounds were identified using the exact mass and Mg isotope simulation. Several families of $C_nH_mO_xMg^+$ (n=0-10) different from the compounds identified by Ruf *et al.* (2017), and $C_nH_mN_yO_xMg^+$ (n=1-7) were assigned using Kendrick mass defect plots. The Mg-organic compounds were also detected from Murchison, however, the abundance was more than an order of magnitude lower than that in Tagish Lake. By DESI-HRMS analysis on antigorite grains, some Mg-organic compounds (e.g. $C_nH_{2n+2}NO_2Mg^+$ families) showed high ion intensity after storage for 1 month, indicating their adsorption effects on the clay minerals. In contrast, other Mg-organic compounds were not found by the adsorption effect, suggesting that these compounds were indigenous in the meteorites.

The CHOMg and CHNOMg compounds showed a similar spatial distribution with various intensity among the different families in both meteorites. In the Tagish Lake meteorite, they were likely to be concentrated in the matrix with less framboidal magnetite and relatively saponite/serpentine-rich region. This indicates that the Mg-organic compounds might have been formed by ion exchange between organic species and

the clay minerals during aqueous alteration. Moreover, the Mg-organic compounds and CHN compounds were also distributed in matrix of Murchison, however, their spatial distributions were different, suggesting different origins between these compounds.

Keywords: Primitive meteorites, Magnesium containing organic compounds, Molecular imaging

