

In-situ analysis of Mg-containing organic compounds in carbonaceous chondrites.

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Introduction: Recent compound analyses using high-resolution mass spectrometry (HRMS) reported various CHO, CHNO, CHOS and CHNOS compounds [1] and ~600 alkylated homologues of CHN compounds [2] from the solvent extracts of the Murchison meteorite (CM2). In addition, recent studies have identified Mg-containing organic compounds (Mg-OC) from methanol extracts of various meteorites by using HRMS [3], or from the Tagish Lake meteorite by in-situ analysis using desorption electrospray ionization (DESI) with HRMS [4]. Such metal-containing organic compounds seemed to be one of the important key for chemical evolution of organic matter preserved in primitive meteorites. This study investigated the Mg-OC in primitive meteorites to reveal the relationship of these compounds with surrounding minerals by *in-situ* analysis and to understand their formation pathways.

Experimental: Samples used in this study are 3 fragments of the Tagish Lake meteorite (Ung-C2), 2 fragments of the Murchison meteorite (CM2) and 1 fragment of the Nogoya meteorite (CM2). Fragments of these meteorite with a flat surface of each meteorite were embedded in indium or alloy with low melting point (60 °C). The DESI/HRMS imaging was performed using a 2D DESI ion source equipped with an Orbitrap MS. A spray solvent was 100% methanol with a flow rate of 2–3 $\mu\text{L}/\text{min}$. Electrospray voltage was set at 3 kV. The positive ions (m/z 50–500) were collected with mass resolution of 140,000 ($m/\Delta m$ at m/z 200) on the surface of a few square mm of the samples. After the DESI/HRMS imaging, the samples were observed using FE-SEM/EDS without coating and polishing.

Results and Discussion: No CHN compounds were detected from all the fragments of Tagish Lake by DESI-HRMS imaging, whereas several alkylated homologues of CHN compounds were identified from Murchison, similar to the previous study [5]. Abundant Mg-containing organic compounds were identified with high mass precision (<1.5 ppm) from the Tagish Lake meteorite. Those compounds have several families of $\text{C}_n\text{H}_m\text{O}_x\text{Mg}^+$ ($n=0-10$), which was partly consistent with the result by [3], and $\text{C}_n\text{H}_m\text{N}_y\text{O}_x\text{Mg}^+$ ($n=1-7$), which were assigned using Kendrick mass defect plots in addition to isotope simulation of ²⁴⁻²⁶Mg for several compounds with high intensities.

Even though the Mg-OC were also detected from Murchison, abundance was much less by an order of magnitude than those from Tagish Lake. From the Nogoya meteorite, the Mg-OC were also detected and the CHN compounds were little detected. Such characteristics were similar to Tagish Lake rather than Murchison. This observation suggests a relationship between the Mg-OC occurrence and aqueous alteration degree of meteorite (Murchison < Nogoya [e.g. 6]).

These CHOMg and CHNOMg compounds showed a similar spatial distribution with varying intensities among the different families in the meteorites used in this study. In the Tagish Lake meteorite, they were probably concentrated in the matrix with less framboidal magnetite and relatively saponite/serpentine-rich region. Such spatial distribution of those compounds was always observed in the three fragments of Tagish Lake. In Nogoya meteorite, the Mg-OC also distributed in matrix region similar to Tagish Lake. In Murchison meteorite, both Mg-OC and CHN compounds were distributed in the matrix, however, their spatial distributions were distinct. The present study indicates that the Mg-OC might have been formed by ion exchange between organic species and clay minerals during aqueous alteration [7],

and also suggesting different sources between those compounds and CHN compounds.

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