Relationship between spatial distribution of organic compounds and minerals in the Murchison meteorite

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[Introduction]

Primitive meteorites contain a wide variety of organic compounds. More than 600 species of CHN compounds were identified in the methanol extract of the Murchison meteorite (CM2), in which saturated- and unsaturated-alkylated pyridines ($C_nH_{2n-4}N^+$ and $C_nH_{2n-6}N^+$) as well as alkylimidazoles ($C_nH_{2n-1}N_2^+$) are predominant (Naraoka et al., 2017). Interaction between organic matter and minerals during aqueous alteration is very important in the chemical evolution (e.g. Kebukawa et al., 2010), therefore, it is necessary to investigate the spatial distribution of the organic matter and minerals in the meteorites. In the previous studies, chemical imaging of soluble organic matter (SOM) was performed on the Murray and Murchison meteorites (CM2) by desorption electrospray ionization/high-resolution mass spectrometry (DESI/HRMS), and the different spatial distribution was observed among the different CHN species and/or their alkylated homologues (Naraoka & Hashiguchi, 2018, Hashiguchi & Naraoka, 2018). However, the relationship between the organic compounds and minerals is still unresolved. In this study, the DESI-HRMS imaging and detailed mineralogical observation were performed on fragments of the Murchison meteorite.

[Sample & Method]

Two fragments designated as “np15" (2x3 mm^2) and “np16” (2x2 mm^2) were obtained by chipping from different large fragments of the Murchison meteorite. These fragments were embedded in indium or metal with low-melting point for DESI-HRMS imaging. The DESI-HRMS imaging was performed on each sample for three times. Methanol was used as a spray solvent with the flow rate of 2 μL/min. The electrospray voltage was set to 3 kV. The nebulizer N_2 gas pressure was ~100 psi. The positive ions were collected in a full scan mode (m/z 50-500) with mass resolution of about 140,000 ($m/\Delta m$ at m/z 200) on the sample surface of np15 (4x4 mm^2) and np16 (3.8x3.8 mm^2). For the fragment np16, dry polishing was performed on the sample to remove ~250 μm from the surface and the imaging was performed again, because no signals of CHN compounds were obtained by the 1st set of DESI-HRMS imaging. After the DESI-HRMS imaging, the same sample surface was used to obtain backscattered electron images (BSE) and X-ray elemental maps using SEM/EDS.

[Results & Discussion]

Some alkylated homologues of CHN compounds were detected from np15 by DESI-HRMS imaging. Their exact masses correspond to alkylimidazole ($C_nH_{2n-1}N_2^+$) and saturated- or unsaturated-alkylated pyridine ($C_nH_{2n-4}N^+$ or $C_nH_{2n-6}N^+$) within 3 ppm of mass precision. The spatial distribution was different between $C_nH_{2n-1}N_2^+$ and $C_nH_{2n-4}N^+$, which is consistent with the previous study (Naraoka & Hashiguchi, 2018). On the other hand, no CHN compounds were detected from np16. After removing ~250 μm of the surface of np16 by polishing, some CHN compounds corresponding to $C_nH_{2n-1}N_2^+$ and $C_nH_{2n-6}N^+$ were detected in 3rd DESI-HRMS imaging finally, however, these compounds were not detected by 1st and 2nd analyses. These results indicated that the CHN compounds might have been volatilized from the sample surface

during its storage, and that repeated DESI-HRMS imaging is important to obtain clear signals of SOM from inside of meteorite. The detected CHN compounds showed heterogeneous spatial distribution in the sample surface, which indicate that dry polishing does not affect the spatial distribution of SOM significantly.

In both np15 and polished np16 samples, the CHN compounds distribute mainly in the matrix region (~ few hundreds of square meters) of the meteorite. Although the X-ray elemental mapping showed that CHN compounds-rich region seemed to contain abundant Ca-containing minerals in both fragments, no clear relationship was observed between the averaged chemical compositions of matrix region and the spatial distribution of the CHN compounds. Further detailed analysis will be performed on tiny minerals in the matrix.

Keywords: carbonaceous chondrite, chemical imaging , soluble organic compounds

