TOF-SIMS ANALYSIS OF PREBIOTIC ORGANIC COMPOUNDS IN THE MURCHISON METEORITE.

D. N. Simkus¹ (simkus@ualberta.ca), Y. S. Goreva², T. J. McCoy³, and C. D. K. Herd¹, ¹Dept. of Earth & Atmospheric Sciences, University of Alberta, Edmonton, Canada, ²Dept. of Mineral Sciences, NMNH, Smithsonian Institution, Washington, D.C.

Introduction: The Murchison meteorite, and other carbonaceous chondrites, have been thoroughly investigated for their prebiotic organic content via bulk solvent extractions and analyses using GC-MS and HPLC techniques [1-4]. These studies have detected a wide range of prebiotic organic compounds that are indigenous to the meteorites, including amino acids, carboxylic acids, polycyclic aromatic hydrocarbons (PAHs), nucleobases, alcohols, aldehydes and ketones. A key question that remains is whether the types and concentrations of prebiotic organic compounds vary spatially across a meteorite section. Identifying associations between prebiotic organic compounds and specific minerals or lithologies within the meteorite requires alternative techniques but promises to yield information about the chemical reactions (e.g. Strecker amino acid synthesis) that were involved in their formation.

Time-of-flight secondary ion mass spectrometry (ToF-SIMS) offers a unique opportunity to examine the spatial distribution of organic compounds across a meteorite sample. The method exhibits high spatial resolution, and the ability to detect a very large range of elemental and molecular species, inorganic and organic, up to masses > 1000 amu.

Although ToF-SIMS has recently been used for several space science applications [5], there have been very few ToF-SIMS investigations of organic compounds in meteoritic materials [6-8]. A range of PAHs within the Murchison meteorite have been observed using ToF-SIMS [6]; however, other key prebiotic organic compounds, such as amino acids and carboxylic acids, have not yet been reported in this study. In this study, we carried out a ToF-SIMS analysis of the prebiotic organic content of the Murchison meteorite to determine whether other prebiotic compounds, such as amino acids and carboxylic acids, can be identified using this method, as well as to examine potential spatial variations across the meteorite sample.

Methods: The Murchison meteorite fragment used in this study was fully enveloped by a fusion crust and had been stored in a sealed jar since 1971. The sample was removed from the jar in a laminar flow hood and wrapped in combusted aluminum foil. A small corner of the rock was split off using a clean, miniature rock splitter exposing a fresh meteorites surface and introduced into ToF-SIMS.

Ion imaging was done using an ION-TOF GmbH TOF-SIMS IV instrument at the Smithsonian Institution. A 25 keV Bi⁺ beam at a pulsed current of 0.3 pA was rastered over an area of ∼500 x 500 µm² for 180–600 s. The accumulated primary ion dose never exceeded the static limit. Analyses were performed with the instrument optimized for high mass resolution (bunched mode: m/∆m of at least ∼5,000 at m/z 30). Seven 500 x 500 µm² areas of the fresh Murchison fracture surface were analyzed via ToF-SIMS in this study. The two areas that yielded the best signal (Fig. 1) are described in this abstract.

Results and Discussion: Positive secondary ion images generated for each of the two Murchison sample areas are shown in Fig. 2 and 3. Each frame in a series represents the ion distribution for a specific mass. The last frame of each series is an optical image of the area. Major mineral phases can be deduced from the distribution of major elements. The thermal scale reflects relative ion intensity, increasing from blue to red. Common terrestrial contaminants, including siloxanes, plasticizers and Teflon, were not observed in any of the five samples, reflecting the pristine nature of the meteorite sample.

Ion fragments that are characteristic of organic compounds, including carboxylic acids, amino acids, and PAHs, were identified in each sample area, and
examples of ion distribution images for these fragments are shown in Fig. 2.

In the first sample area (Fig. 2), the ion fragments for amino acids, carboxylic acids and PAHs all followed the same general pattern as Fe⁺, Mg⁺, Na⁺ and K⁺, characteristic of the matrix, but appeared to differ slightly in their relative abundances across the various mineral grains. For example, amino acids appeared to be slightly less abundant in the center left hand feature in comparison to the carboxylic acids and PAHs.

![Figure 2](image)

**Figure 2**: Secondary ion distribution images (500 x 500 µm²) and an optical image for Sample 1. The three bottom left frames represent summations of secondary ions that are characteristic fragments of A) amino acids, B) carboxylic acids, and C) PAHs.

The second area analyzed (Fig. 3) also yielded ion fragments that are characteristic of amino acids, carboxylic acids and PAHs (data not shown) but these compounds did not appear to vary spatially across the sample area. All of the ions included in frames A and B were specifically chosen as they either appeared to correlate (A) or anticorrelate (B) with a chondrule present in the lower left corner of the field of view. The molecular origin of these ion fragments is currently not clear; however, these images demonstrate that there is some variability in the distribution of organics across the meteorite sample.

**Conclusions**: Overall, despite the difficulty of the analysis of rough (fresh fracture) surfaces, this study illustrates the applicability of ToF-SIMS as a tool to map the distribution of organic compounds within meteorite samples. Characteristic fragments of amino acids, carboxylic acids and PAHs were identified, and some spatial variations between different types of organics were observed.

![Figure 3](image)

**Figure 3**: Secondary ion distribution images (500 x 500 µm²) and an optical image for Sample 2. The two bottom left frames represent summations of ions that (A) correlate and (B) anticorrelate with the presence of a chondrule.

**Tagish Lake meteorite – A key next target**: The Tagish Lake meteorite, an ungrouped type 2 carbonaceous chondrite, landed on the frozen surface of a lake, was collected shortly after its fall without direct hand contact, and has been stored at sub-zero temperatures since its collection. As such, this meteorite is believed to be the most pristine meteorite collected to date. Tagish Lake is further unique in that different samples of the meteorite vary in lithologies and types and concentrations of organics, likely indicating varying degrees of aqueous alteration across the parent body asteroid [9]. A key question remaining is whether this variability also occurs on a sub-millimeter scale. The results of this abstract show that ToF-SIMS can be used to address this question and potentially elucidate the chemical processes that took place during aqueous alteration on the Tagish Lake parent body asteroid.

**Acknowledgements**: Funding for this project was provided by the Smithsonian Graduate Student Fellowship program, an NSERC CGSD awarded to D.N.S. and Carnegie DCO funding (Y.S.G.).