Various alkylpyridine homologs in the Murchison meteorite

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Many types of organic compounds including amino acids and carboxylic acids have been identified in the water extract of carbonaceous chondrites. In contrast to the water extract, the polar organic solvent (e.g. alcohol) extract has not been characterized well in spite of relatively high content of organic matter with D- and ^{15}N-enrichment, which may imply an interstellar origin. Recently, ultrahigh-resolution mass spectral analysis on polar solvent extracts of Murchison was performed by electrosplay ionization (ESI) using Fourier transform-ion cyclotron resonance/mass spectrometry (FT-ICR/MS) to reveal significant chemical diversity up to hundreds of thousands of different mass peaks having CHO, CHOS, CHNO and CHNOS elemental compositions [1]. With the assumption for molecular formulae calclation and no chromatographic separation, however, the detailed chemical structures cannot be determined. In particular, the organic compounds with their elemental compositions of CH and CHN were not discussed.

In this study, we performed detailed analysis of organic compounds in polar solvent extract of Murchison by high-performance liquid chromatography/high resolution mass spectrometry (HPLC/HRMS) using an LTQ Orbitrap XL with an amide column. The positive ions by ESI show a suite of saturated- and unsaturated-alkylated (C_1 to C_{21}) pyridine homologs (mainly $C_nH_{2n-5}N$ and $C_nH_{2n-7}N$ series), which could be produced by aldehyde and NH_3 through aldol condensation and Chichibabin-type synthesis. Relatively simple aldehydes such as formaldehyde and acetaldehyde are found in molecular clouds, and possibly present in primordial solar nebulae [2]. Ammonia is observed much in molecular clouds as well as coments, and abundant in carbonaceous chondrites [3]. In addition, chemical oxidation processes could be significant by OH radicals and/or aqueous alteration, where methylene bonds in unsaturated alkylpyridines seems easily to be oxidized to yield alkylpyridine carboxylic acids [4]. The alkylpiperidines were also identified, probably resulting from H_2 addition of alkylpyridines. This study shows importance of alkaline environment with ammonia for the chemical evolution of meteoritic organic matter.

[1] Schmitt-Kopplin *et al Proc. Natl. Acad. Sci.* **107**, 2763 (2010). [2] Dutrey *et al Astron. Astrophys.* **317**, L55 (1997). [3] Pizzarello and Williams, *Astrophys. J.* **749**, 161 (2012). [4] Pizzarello *et al Science* **293**, 2236 (2001).