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The Discovery of New Meteoritic Amino Acids in the Murchison Meteorite: Implication for New Formation Mechanisms of Meteoritic Amino Acids

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Introduction: Carbonaceous chondrites contain a diverse suite of extraterrestrial amino acids having various structures such as α, β, γ or δ amino-group [1], while terrestrial life uses only α-amino acids. The comprehensive formation pathway that could explain the diversity of meteoritic amino acids remains unclear, even though several mechanisms have been proposed. In this study, we revisited amino acid analysis of the Murchison meteorite and performed the amino acid synthesis experiments simulating the conditions of meteorite parent body to pursue their formation mechanisms, since the distribution of meteoritic amino acids had been influenced by aqueous alteration on the meteorite parent body (e.g. α-aminoisobutyric acid versus β-alanine [2], and L-enantiomeric excess of isovaline [3]).

Materials and Methods: The Murchison meteorite powder were extracted with H_2O at 100 °C for 20 h. The supernatant and the extract residue were subjected to acid hydrolysis with 3M and 6M HCl, respectively. After desalting using an ion exchange column to purify amino acids, both fractions were reacted with isopropanol(iPrOH)/HCl and trifluoroacetic anhydrite (TFAA). The resultant TFA-amino acid-OiPr derivatives were analyzed by GC/MS with a Chirasil-L-Val capillary column. The amino acid synthesis experiments were performed with H_2O/ammonia/formaldehyde/acetaldehyde and/or glycolaldehyde ratio of 1000/10/1/0.1/0.1 (by mol) at 60 °C for 6 days in the presence or absence of olivine powder with the water/mineral ratio of 1/9 (by weight). The reaction products were analyzed by the same procedure as above.

Results and Discussion: Totally 30 amino acids between C_2 and C_6 were identified in the extract of Murchison, in which glycine was the most abundant (up to approximately 3.5 ppm). In addition to the common amino acids such as α-aminoisobutyric acid and isovaline, the nine C_3 and C_4 hydroxy amino acids (isoserine, homoserine, γ-amino-α-hydroxybutyric acid, γ-amino-α-(hydroxymethyl)propionic acid, β-homoserine, β-amino-α-hydroxybutyric acid, α-methylserine, isothreonine and allo-isothreonine) have been newly identified (~20 to ~140 ppb) from the Murchison extract. A new dicarboxy amino acid, β-(aminomethyl)succinic acid, was also detected as a relatively large amount (~90 ppb). The discovery of 10 new amino acids is striking after numerous surveys of meteoritic amino acids since the half century ago.

The simulation experiments yielded various amino acids including the new amino acids with the most abundant of glycine. Moreover, β-(aminomethyl)succinic acid was produced using formaldehyde, acetaldehyde and ammonia in the presence of olivine, but not detected in the absence of olivine. These results indicate that the formose reaction with ammonia in the presence of minerals is an important formation pathway to produce meteoritic amino acids during aqueous alteration on the meteorite parent body.

References: [1] Burton, A. S. et al. (2012) *Chemical Society Reviews* 41:5459–5472. [2] Glavin D.P. et al. (2006) *Meteoritics & Planetary Science* 41:889-902. [3] Glavin D. P. and Dworkin J. P. (2009) *Proceedings of the National Academy of Sciences of the United States of America* 106:5487-5492.