Olivine promotes amino acid synthesis under alkaline conditions at 60 C°

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Carbonaceous chondrites, which have primitive chemical compositions in the Solar System, contain a diverse suite of extraterrestrial amino acids. The degree of aqueous alteration on meteorites appears to have correlation to the amino acid distribution (e.g. α-aminoisobutyric acid and β-alanine) and L-enantiomeric excess (Lee) of isovaline. Although these results suggest that aqueous alteration have influence on amino acid synthesis on the meteorite parent body, the detailed formation mechanisms remains unclear. In this work, we performed the amino acid synthesis experiments simulating the condition of meteorite parent body to investigate their distribution and enantiomeric composition to infer the formation mechanism of meteoritic amino acids: aqueous solution (300 μL) containing ammonia /formaldehyde/acetaldehyde or ketone (100/10/1 by mol) was heated at 60 °C for 6-28 days in a N_2-purged glass ampoule with or without olivine powder (San Carlos, 27.0 mg).

As a result, totally 16 amino acids up to C_5 were identified, in which glycine was the most abundant (up to approximately 3500 ppm relative to carbon amount of reactants). Other amino acids are composed mainly of serine, isoserine, alanine, β-alanine, β-(aminomethyl)succinic acid, β-aminobutyric acid, homoserine, aspartic acid and glutamic acid. In the absence of olivine, small amounts of some amino acids were detected from the hydrolyzed fraction. In contrast, in the presence of olivine, the concentration of most of the amino acids increased significantly in the hydrolyzed fraction. The amino acid concentration increased significantly after hydrolysis, which is similar to the occurrence of meteoritic amino acids.

The amino acid distribution (e.g. absence of α-aminoisobutyric acid and isovaline) implies a different formation pathway from the Strecker-type reaction, which has been proposed for meteoritic amino acid synthesis. We propose other formation mechanisms: iminium cation produced from aldehydes and ammonia is subjected to nucleophilic addition by formyl anion followed by chemical oxidation, giving α-amino acids detected in this experiment. In addition, larger amino acids ($>C_3$) are synthesized through aldol condensation, explaining the occurrence of α-, β-amino acids detected.