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Amino acid formation by asteroid impacts on ammonia-free oceans

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Introduction: Impacts of extraterrestrial objects on the early Earth have potential to have provided organic compounds and inorganic reductants (e.g., metallic iron and carbon) to the prebiotic Earth[1,2]. Hypervelocity impacts initiate reactions between meteoritic reductants and surrounding materials to form organic compounds. Our previous study, demonstrated the formation of amino acids and nucleobases from iron-bearing meteorite simulants, water, and ammonium bicarbonate[3]. High CO_2 fugacity in the early Earth's atmosphere has been suggested in literature. However, high NH_3 concentrations in the early oceans has not been supported, although low NH_3 concentration is probable[4]. This study shows the results of shock-recovery experiments and flow-reaction experiments simulating post-impact reactions between asteroid minerals, ammonia-free ocean, N_2-CO_2/N_2 atmosphere.

Experiments: Shock-recovery experiments were conducted with a single stage propellant gun at NIMS, providing impact between a stainless steel disc and a container at approximately 0.9 km/s. Starting materials are composed of Fe, Ni, $NaH^{13}CO_3$, N_2, water/NH_3-water. The flow-reaction experiments are conducted at 1000°C with a glass flow line using Fe, Ni, SiO_2, N_2, and H_2O as the starting materials. Products are analyzed with ultra high performance liquid chromatography/tandem mass spectrometry.

Results and Discussion: In the shock-recovery experiments, glycine and β-alanine were formed from Fe, Ni, $NaH^{13}CO_3$, N_2, and ammonia-free water whereas at most 4 additional amino acids including alanine, sarcocine, α-aminobutyric acid, and β-aminoisobutyric acid were formed in experiments with ammonia water. The flow-reaction experiments with ammonia-free starting materials also yielded glycine. These results indicate that formation of amino acids with meteoritic inorganic reductants are possible on the prebiotic Earth. Although the yields of amino acids are lower than products of reaction with ammonia, the present results show a process to form amino acids from an almost infinite source of nitrogen (N_2) and carbon (CO_2) on the prebiotic Earth.

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