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The stability of amino acids in early ocean by meteorite impacts: Implication for chemical evolution of biomolecules

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Prebiotic oceans may have contained abundant amino acids, and were subject to meteorite impacts, especially during the late heavy bombardment. It has been unknown how meteorite impacts affected such dissolved amino acids in the early oceans. Experiments in the present study were performed using aqueous solutions containing olivine or hematite powders and ^{13}C-labeled glycine and alanine. In particular, the reaction products from ^{13}C-labeled amino acids are expected to compose ^{13}C, distinguishing if they are contaminants or not. Two powders of olivine and hematite help to keep the oxygen fugacity low and high during experiments, respectively in order to investigate the effect of oxygen fugacity on chemical reaction of amino acids. The run product of selected amino acids and amines in samples were analyzed with liquid chromatography-mass spectrometry (LC/MS). Some experiments were carried out in the presence of ammonia and/or benzene. The results revealed that amino acids survived partially or reacted out in early ocean through meteorite impacts. It was found that glycine changes into alanine and large amounts of methylamine and ethylamine are formed. Amine formation from alanine was increased considerably in the presence of Fe_2O_3 rather than olivine under similar impact conditions. XRD for the recovered hematite powders indicated the presence of a small amount of magnetite, suggesting that the oxygen fugacity was kept high enough to be close to the Fe_2O_3-Fe_3O_4 buffer. The formation of n-butylamine, detected as the largest number of carbon species in the recovered samples from the solutions with ammonia and benzene, suggests that chemical reactions to form new biomolecules can proceed through marine impacts. These results suggest that amino acids in early oceans can proceed further by impact-induced reactions, implying that impact energy plays a role in the prebiotic formation of various biomolecules, although the reactions depend upon the chemical environments as well.