Interactions among mineral, water and biomolecule by shock wave: morphological changes of olivine grains reacted with amino acid solutions by impact process

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Early oceans on Earth might have contained a certain amount of biomolecules such as amino acids, and were subjected to meteorite impacts, especially during the late heavy bombardment. When hypervelocity meteorites impact to oceans on Earth, some minerals contained in meteorite may react with solutes in oceans under high pressure and temperature conditions and subsequent pressure release processes induced by impact process. We performed shock recovery experiments to simulate shock reactions of marine meteorite impacts among olivine as meteorite components, water and biomolecules as oceanic components. Olivine is one of the most typical minerals in ordinary chondrites that represent about 90% of flying meteorites to Earth. In the present study, we investigate reactions between olivine and amino acids in water during impact process. We present the results of changes of olivine grains. We conducted shock recovery experiments by using a propellant gun at National Institute for Materials Science. Shock recovery experiments were performed that a metal flyer as projectile accelerated by a propellant gun impacted to the metal sample container after sealed with two screws as targets. Amino acid solutions (130 µl) were set with olivine powders (200 mg) and air gap in the sample room in sample containers. Impact velocities measured by using the magnetoflyer method were about 0.9 km/s. Shock pressure was calculated with the measured impact velocity using the impedance match method. After experiments, experimental products were collected from holes drilled on the impact surfaces of the recovered containers. Recovered solid samples were analyzed using X-ray powder diffraction method (XRD), scanning electron microscopy (SEM), electron probe microanalyser (EPMA), and transmission electron microscopy (TEM) with energy dispersive X-ray spectrometry (EDX). The analytical results on the shocked sample of water-amino acid-olivine mixtures demonstrated the metallic material, shocked olivine grain affected by water and carbon rich material like spike as experimental products. Analytical result of EPMA indicated the metallic material derived from stainless 304 of sample container, and a detectable decreasing deviation in the atomic ratio of Mg/Si in shocked olivine relative to that of the starting olivine. The shocked olivine was shown the traces of water molecule impacting on surface by TEM observation. The results of TEM observation and EDX analysis indicated the carbon rich material derived from amino acids. The present study suggests the water-amino acid-olivine system under shock reaction is able to interact with each other. Especially, organic compounds related to origin of life in early ocean might transform to solid state by meteorite impacts. Hence, it is necessary to consider the phase change of initial materials on pre-biotic experiments simulated natural condition.

Keywords: Meteorite impact, Olivine, Amino acid

