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Synthesis of organic molecules by ocean impacts on the early Earth

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1. Introduction
Heavy impacts of extraterrestrial objects at 4.0-3.8 billion years ago have been suggested by many previous studies. The heavy impacts most likely introduced substantial amounts of carbon and metals to the early Earth. A part of minerals in meteorites may have reacted with seawater and atmosphere during its hypervelocity impact to ocean which covered most of the surface of the Hadean Earth. This impacts probably produced variety of organic compounds including amino acids (Nakazawa, 2008). Locally-reducing conditions were suggested by previous studies concerning about the redox state in the impact-induced plume (Hashimoto et al., 2007). Formation of ammonia and several organic compounds including glycine have been reported in experimental simulations of meteorite impact (Nakazawa et al., 2005; Furukawa et al., 2009). However, numbers of organic compounds detected in the previous shock experiments were limited because of analytical difficulties. Therefore, detection of variety of organic molecules formed in the shock-recovery experiments was set to be the purpose of the present study by improving the analytical methods. Those organic molecules might greatly influence to the surface environments of the early Earth and the course to origin of life.

2. Experimental
Experiments were demonstrated using single-stage propellant gun with stainless-steel gas-tight container and stainless-steel flyer. The samples were enclosed in the container with nitrogen gas and impacted by flyer with approximately 0.9 km/s. The samples were composed of water and mixed powder of iron, nickel and ¹³C (amorphous). After the shock experiment, the container was recovered and volatile organic compounds in products were collected from the container. For this purpose, an organic-gas collector was specially constructed. Analyses were performed using gas chromatography-mass spectrometry (GC-MS).

3. Results
Formation of 12 kinds of ¹³C-based organic molecules were confirmed with GC-MS analyses. They contain hydrocarbons (ethane, propane, butane, hexane, and benzene), alcohols (methanol, ethanol, and isopropanol), a nitrile (acetonitrile), an aldehyde (acetaldehyde), and carboxylic acids (formic acid and acetic acid). ¹³C-organic compounds clearly distinguish the products from contaminants.

4. Discussion
Our results suggest that variety of organic compounds could be synthesized by ocean impacts of meteorites on the early Earth. 29 organic species were synthesized in the present and a previous impact experiments in total (Mukhin et al., 1989; Furukawa et al., 2009). Those products were likely to affect the composition of early ocean and atmosphere. Subsequent impacts during the late heavy bombardment might further promote to produce more variable and complex organic molecules.

References

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