Effects of minerals on the formose reaction: implication for the potential ribose formation on ancient Mars

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DNA, RNA, and proteins work together to support the essential system of the present life. RNAs catalyze biological reactions as well as have nucleotide sequence transcribed from DNA. Therefore, abiotic RNA formation has been regarded as an essential step of the origin of life. Ribose is an essential constituent of RNA and is known to form in the formose reaction in which a series of condensation and polymerization of formaldehyde under alkaline condition forms many sugar molecules. Thus, formose reaction on prebiotic Earth has been investigated intensively. On the other hand, chemical evolution might have happened on the other planets in some extent. Mars, one of the candidates of past habitable planet, is shown to have liquid water on the surface and/or subsurface and had CO_2-rich atmosphere. Thus, photochemical formaldehyde formation would have been possible on ancient Mars. However, ribose formation on ancient Mars has not been investigated. Therefore, this study investigates effects of ancient Martian environments to the formose reaction and evaluated potential ribose synthesis on ancient Mars. In particular, this study investigates effects of minerals potentially presented on ancient Mars. Phyllosilicates such as saponite distribute widely in Noachian sediments. Carbonates such as magnesite, siderite, and calcite have been found from sediments close to the Noachian phyllosilicate-rich sediment. The Gale crater sediments suggests a neutral pH of the lake water on Noachian Mars. On the other hand, sulfides such as jarosite and gypsum were known to present in Hesperian sediments and suggest the presence of acidic aquatic environments on Hesperian Mars.

The formose reaction experiments were conducted with formaldehyde and glycolaldehyde with minerals. Ribose formation was accelerated in neutral solution with several minerals. The residual amount of formaldehyde was decreased with increasing reaction. Ribose formation was not seen in acidic solution (pH: ~4) with/without minerals, although tetroses were formed.

These results suggest that ribose was spontaneously formed from formaldehyde and glycolaldehyde in neutral aquatic environments implying that ancient Mars promoted sugar-forming chemical evolution.

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