

Supercritical CO₂ Environment in the Seafloor Drives Prebiotic Synthesis of Nucleic Acid Building Blocks

*Shotaro Tagawa¹, Kohei Morino^{2,3}, Kosuke Fujishima^{2,4}

1. Institute for Extra-cutting-edge Science and Technology Avant-garde Research (X-star), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2. Earth-Life Science Institute (ELSI), Institute of Science Tokyo, 3. School of Life Science and Technology, Institute of Science Tokyo, 4. Graduate School of Media and Governance, Keio University

In the study of the origin of life, the synthesis of prebiotic biomacromolecules in water-rich environments, such as deep-sea hydrothermal systems, remains a major unresolved challenge. The abundance of water inhibits dehydration-condensation reactions necessary for polymerization while simultaneously promoting macromolecule hydrolysis.

To address this issue, recent observations of liquid CO₂ bubbles leaking from the seafloor have suggested the presence of benthic CO₂ pools, leading to the liquid/supercritical CO₂ (Lq/ScCO₂) hypothesis as a potential solution to the water problem. This hypothesis proposes that the ScCO₂-water two-phase environment could facilitate the dehydration-condensation of organic molecules during prebiotic chemical evolution. However, experimental validation of how this environment functions remains limited. In order to investigate its role, we have used a hydrothermal reactor that simulates the ScCO₂-water two-phase environment to study the synthesis of nucleotides, the building blocks of nucleic acids, and their molecular precursors. Our research has demonstrated that this environment can dissolve phosphate from phosphate minerals and promote the prebiotic phosphorylation of nucleosides to synthesize nucleotides. These findings suggest that the ScCO₂-water two-phase environment provides a relatively dry setting, similar to terrestrial hot spring environments, where both phosphate acquisition and phosphorylation can occur within the same location.

Currently, we are also working on the prebiotic synthesis of uracil, a nucleobase and a precursor of nucleotides. Possible synthetic pathways for uracil involve reactions using urea or amino acids, which may potentially be synthesized from CO reduced from CO₂. We look forward to sharing with you the results of our research to date as well as latest findings.

Keywords: Origin of life, Supercritical carbon dioxide, Nucleotide, Prebiotic chemistry