【Grant-in-Aid for Transformative Research Areas（A）】

Geochemistry of CO worlds

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Research Area Information	Number of Research Area : 22A206　Project Period (FY) : 2022-2026 Keywords : Planetary Environment, Chemical Evolution, Protometabolism, Biomarker

Purpose and Background of the Research

●Outline of the Research

This research area aims to elucidate the planetary environment necessary for emergence of life, through the interdisciplinary research on the "CO world" in which organic molecules are generated from carbon monoxide CO.

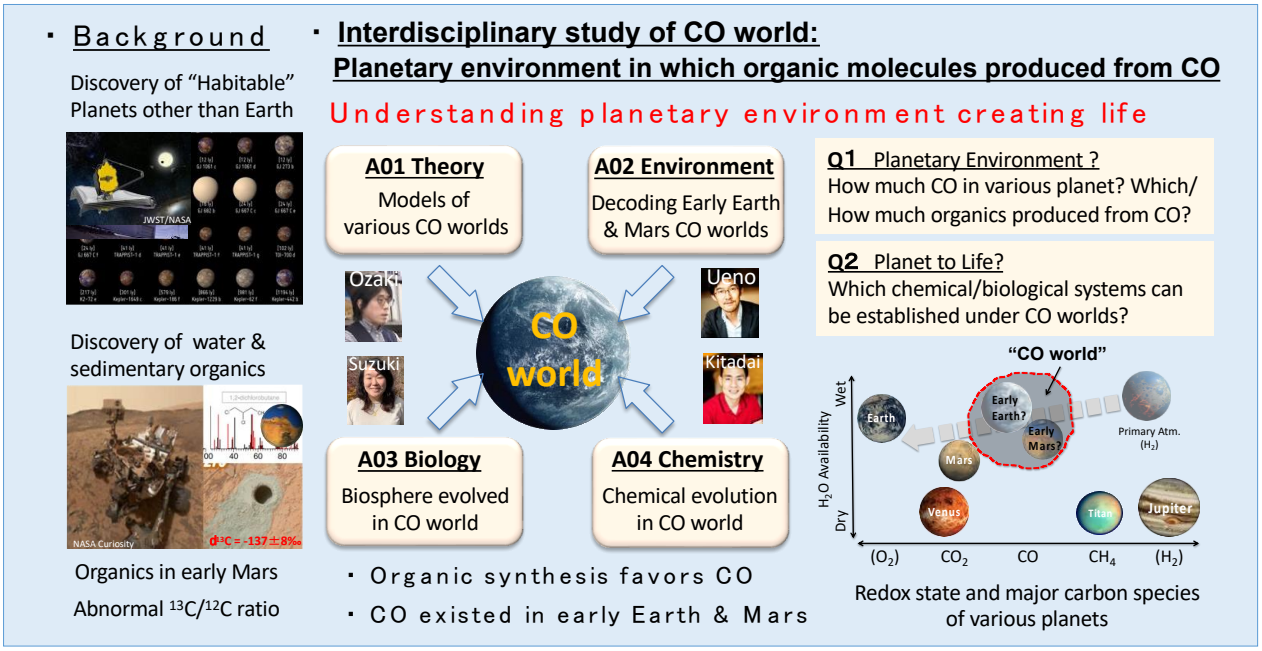

Figure 1. Background and outline of the CO world Research.

Recent astronomical observations and planetary exploration missions have been discovered habitable environment beyond planet Earth, however, we still do not understand what kind of planetary environment is necessary for the emergence of life. In this research area, we investigate the diversity of the planetary environment systematically focusing on major carbon species (CO_2/CO/CH_4) according to the redox state. Particularly the environment rich in CO is suitable for synthesizing various organic molecules. Also, it is interesting that the earliest carbon fixation of Earth's can use CO as a carbon source. Furthermore, recent geochemical and theoretical studies have provided evidence for the presence of CO in the atmosphere of the early Earth and Mars.

Based on this situation, this research area will promote the research of CO world by integrating four research fields. Based on model calculations of planetary atmosphere and material cycling together with geochemical observations and experiments of atmospheric molecules including stable isotope species (isotopologues). Theory Group (A01) and Geochemistry Group (A02) investigate how much CO is present in the atmosphere of the early Earth, Mars and other planets including exo-planets, and characterize which organic molecules are produced in each atmosphere.

On the other hand, the Biology Group (A03) and Chemistry Group (A04) will clarify what kind of ecosystem, metabolism and chemical reaction system are established under such a planetary environment. The presence of organic molecules is not enough to create life. Rather, the chemical system itself is necessary to be in the environment for providing building blocks of life. By focusing on CO, this research area plans to demonstrate that a chemical system capable to evolve into life (Protometabolism) can be established in the actual planetary environment. Through the interdisciplinary research, we aim to revolutionize the astrobiology research field, and provide more concrete methods for discriminating traces of life (biosignature) in future astronomical observations and planetary explorations.

Expected Research Achievements

●Goal 1: Elucidating the planetary environment necessary for emergence of life

What kind of planetary environment would be necessary to create life? Chemical systems similar to the central metabolism of present-day organisms could have been driven initially by inorganic catalysts provided by the Earth, instead of enzymes. Such chemistry is called as “protometabolism”. In the CO world, one would expect the protometabolism to be continuously driven by the aldehydes and organic acids that are continually produced from atmospheric CO. When this reaction system generates the molecules that make it up itself, an autocatalytic cycle is established and molecules such as amino acids are produced more efficiently. If these further polymerize and become active, they can replace the inorganic catalyst and this chemical system itself can gradually become self-sustaining from the environment. In this project, we will approach the origin of life by constructing a chemical system that can be established in a planetary environment and can be evolved into biological metabolism.

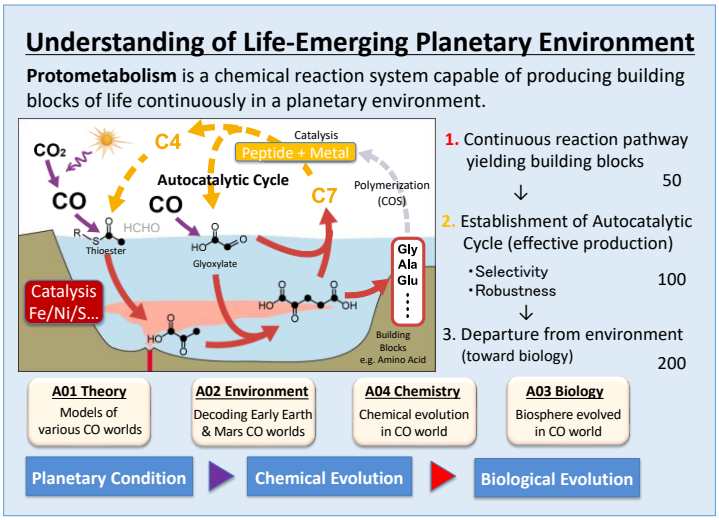

Figure 2. Working model of the Protometabolism.

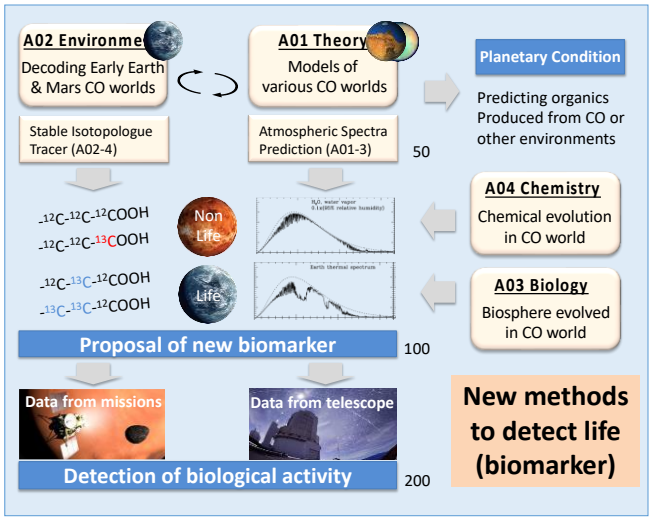

Figure 3. Biomarker established in this research.

●Goal 2: Establishing new methods to detect life in the universe

Through the co-operation of theory, geochemistry, biology and chemistry groups, we will propose several new methods to distinguish biological or non-biological molecules using stable isotopologues (i.e., molecular species consist of substitution of stable isotopes) and others. Also, we will predict key feature of atmospheric spectra of the planets hovering life. These new technologies will be fundamental for search for life in the universe using data from near future planetary exploration missions and astronomical observations using next generation telescopes.

Homepage Address, etc.	https://co-world.jp