

Interaction of Methanogens and Early Earth Environment

*Duo Cui¹, Feng Tian¹

1. Department of Earth Science System Tsinghua University

The luminosity of the Sun was 20-25% lower during the Archean (3.8~2.5 Ga) but geological records indicate a generally warmer climate than those of today. The common consensus is that the Archean warm climate was supported by greenhouse effect from CO₂, CH₄, and/or H₂-N₂ collision-induced absorption. It is generally accepted that H₂-using methanogens evolved early. In this work we developed a coupled ecosystem model to study the dynamic relationship between methanogens and their environment on early Earth.

The model shows prior to the development of biological nitrogen fixation, the methanogens biosphere would have little impact on the environment because of limited Net Primary productivity (NPP). After the invention of biological nitrogen fixation, there could be 2 types of interaction patterns. In the case of low hydrogen escape efficiency and high CO₂ weathering rate, both the biomass of methanogens and the environmental variables (temperature, greenhouse gas concentrations, etc.) show cyclic variations around the freezing point. Activities of methanogens are limited by environmental temperature in this case, which is in turn regulated by atmospheric CO₂ and H₂. In the case of high hydrogen escape efficiency and high CO₂ weathering rate, low hydrogen escape efficiency and low CO₂ weathering rate and high H₂ escape efficiency and low CO₂ weathering rate, both the biomass of methanogens and the environmental variables are stable, with the activities of methanogens limited by the availability of H₂, which does not directly influence environmental temperature. We will compare the NPP and atmospheric concentrations of greenhouse gases in the coupled model with results in previous works (Kharecha et al. 2005, Canfield et al. 2006, Wordsworth et al. 2013). We will also discuss the impact of biological nitrogen fixation on the interactions of methanogens and the Archean environment.

Keywords: Early Earth, Methanogens, biological nitrogen fixation