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B 会場 ：11/7　 AM1 （9:00-10:30）
09:15～09:30

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Global simulation of valley network formation by rivers and ice sheets in early Mars for various surface pressure and H2 amount

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Valley networks are dendritic feature on Mars and they are considered as evidence of prolonged water existence during the late Noachian and the early Hesperian (3.85-3.6 Ga). Early Mars at that time is thought to have had a CO_2 atmosphere of 1-2 bar in surface pressure from the constraint of the past geological studies, and a strong infrared absorption such as a collision-induced absorption of CO_2 and H_2 should be needed to warm enough to make fluvial activities. We have explained the formations of valley networks by coupling simulations between global climate model (PMGCM), global river model (CRIS), and global ice sheet model (ALICE), and suggested the possibilities of two opposite scenarios. One is that valley network was formed by rainfall-fed rivers (warm early Mars, Kamada et al., 2021), and the other is that valley network was formed by subglacial meltwater-fed rivers from ice sheets (cool early Mars, Kamada et al., 2022).

In this study, to explore the best climate scenario of early Mars, we performed a series of climate simulation of early Mars for a long timescale of over 10^5 Mars years, as an extension of our previous studies. We assumed a $CO_2/H_2O/H_2$ atmosphere with surface pressures of between 1 and 2 bar, H_2 mixing ratios of between 0% and 6%, obliquity of 40 degree, and geothermal heat flux of 55 mW m^{-2}. We defined an ancient northern ocean and lakes in our model with the amount of 500 m global equivalent layer (GEL) at the initial state, and implemented a pre-True Polar Wander topography to investigate the global water cycle of early Mars before late Tharsis formation. We iterated the runs of ALICE and coupled PMGCM-CRIS several times over the course of 10^5 Mars years to explore the long-term evolution states for each condition of surface pressure and H_2 mixing ratio.

We found that climate on early Mars should be divided mainly into 3 types. First, with high surface pressure and H_2 mixing ratio, climate on early Mars was ”warm and semi-arid”, characterized by global mean temperature of above 273 K and prolonged rainfall-fed river systems carving valleys on southern highlands where the most of valley networks are observed. These valleys were formed within a relatively short geological timescale (˜10^4 Mars years), which agrees with previous geological studies of valley network formation timescale (10^4-10^6 Mars years). Second, with middle surface pressure and H_2 mixing ratio, climate on early Mars was ”cool and wet”, characterized by global mean temperature slightly below 273 K and widespread temperate-based ice sheets. Subglacial meltwater-fed river systems carved valleys on southern highlands with a relatively longer geological timescale (˜10^5 Mars years) than ”warm and semi-arid” case. Third, with low surface pressure and H_2 mixing ratio, climate on early Mars was ”cold and icy”, characterized by global mean temperature much below 273 K and widespread cold-based ice sheets, preventing ice sheet from melting. In both cases of ”warm and semi-arid” and ”cool and wet” scenarios, our river model CRIS produced widespread valleys which are consistent with more than half of the observed ones, indicating that many of river systems in the southern highlands are likely to have been formed by either rainfall or subglacial meltwater. However, in case of ”cold and icy” scenario, there was almost no apparent surface liquid water activity, which is contradictory to observations. Even though with the scenario, there is a possibility that several valleys were produced by short-lived climatic warming, possibly through an increase of atmospheric greenhouse gas by volcanism and meteorite events.