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Rock weathering as a source of metals to promote biotic methanogenesis

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Evolution of atmospheric methane concentration affects the rise of oxygen in geological history. The transition of the upper continental crust from a mafic to felsic composition during the Archean coincides with a gradual decrease of methane concentration in the atmosphere, but their correlation remains elusive. To test if rock composition affects the methanogen activity and methane production, a model methanogen Methanosarcina Acetivorans C2A was cultured with three types of silicate rocks, peridotite, basalt and granite. These silicate rocks contain varying amounts of trace metals, including iron (Fe) and nickel (Ni), cobalt (Co), zinc (Zn) and molybdenum (Mo), which are essential cofactors of metalloenzymes in methanogens. We found that weathering of peridotite and basalt significantly promoted the growth and methanogenesis of methanogen. The released trace metals from peridotite and basalt, especially Fe, Ni and Co, accounted for the promotion effect. Granite, on the other hand, showed a limited promoting effect owning to its low trace metal contents. Observation at different spatial scales showed a close association between rocks and cells. Proteomic analysis revealed that rock amendment significantly enhanced the expression of core metalloenzymes in the methylotrophic methanogenesis pathway. The study provides important insights on how rock-microbe interactions affect the evolution of atmospheric methane concentration through geological history.