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Production of thermogenic CH_4 by 2.7 Ga submarine hydrothermal activities and its importance to late Archean carbon cycle

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Significant enrichment of ^{12}C is found in 2.7 Ga sedimentary organic matter. Such enrichment is often considered as evidence of the rise of methanotrophy under CH_4-rich environments (1). On the other hand, it has been unclear how to produce large amounts of CH_4 in 2.7 Ga marine environments. In order to examine CH_4 production processes on the 2.7 Ga ocean floors, geological and geochemical studies were performed on fossilized petroleum (pyrobitumen) in volcanogenic massive sulfides (VMSs) from the Potterdoal and Matachewan areas in the Abitibi Greenstone Belt, Canada.

Geological survey revealed that VMSs at both areas interbed with black shales, which were the source rocks of petroleum. Pyrobitumen mainly appears in sulfide/quartz veins in footwall lavas. Sulfide crystals also contain pyrobitumen inclusions. HR-TEM observation, Raman spectroscopic and vitrinite reflectance data showed different maturation patterns of pyrobitumen even in a single rock specimen. Carbon isotope compositions of pyrobitumen range from -46 to -25 per mil (V-PDB), changing systematically with alteration degrees and fluid chemistries. Such isotope shift is explained by production of CH_4 and petroleum by the interaction of sedimentary organic matter with submarine hydrothermal fluids.

In addition, carbon isotope compositions of organic matter around the paleo-vent area range from -45 to -32 per mil at the Potterdoal area, differing from those of organic matter in distal shales (-35 to -20 per mil). This suggests the difference in microbial communities between distal zone and venting area, and activities of methanotrophs were surprisingly limited around the vent.

It is known that large masses of VMSs were formed on 2.7 Ga seafloor in global scale with sedimentation of shales (2, 3). This suggests that the flux of thermogenic CH_4 into 2.7 Ga oceans was most likely high, and such thermogenic CH_4 could contribute to operate unique carbon cycles at 2.7 Ga.

References: (1) Hayes JM (1994) in Early Life on Earth, Columbia U.P.; (2) Gloves and Barley (1994) in Archean Crustal Evolution, Elsevier; (3) Rasmussen et al. (2012) Nature, Vol.484, 498-501.