Thermogenic methane: a greenhouse gas during early Earth history?

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Abstract The time envelope between the late Archaean and late Palaeoproterozoic (3.2-2.2 Ga) was characterized by a series of global-scale geological, geochemical and biological phenomena, the elucidation of whom has the potential to provide vital clues towards evolutionary trends in the early Earth system. Pyrite-rich, Au-U-rich conglomerates of the Witwatersrand Supergroup (3.1-2.7Ga) in South Africa have long been regarded as strong evidence for detrital deposition under an anoxic atmosphere. Abundant organic carbon (kerogen) contained in these sediments is also indicative of one of the earliest events of large-scale hydrocarbon migration on Earth. World-wide deposition of iron-formation, a sediment type unique to the early Precambrian, provides an unrivalled archive of sedimentological and geochemical information on the physico-chemical and biological attributes of early marine environments. Global-scale glaciation (Huronian event) punctuated the above trend at around 2.4 Ga, as evidenced by deposits of unequivocal glacial origin present in three continents (N. America, S. Africa, Australia). Parallels between this glaciation and similar, well-documented events from the Neoproterozoic, have recently been drawn under the umbrella of a Palaeoproterozoic “snowball Earth” model. Post-glacially, the exceptional deposition of mixed Fe-Mn formations for the first time in Earth history, in conjunction with a sharp carbon-isotope excursion recorded in carbonate sediments world-wide at around 2.2 Ga, probably reflect a return to greenhouse conditions and concomitant rise of the O_2 content in the atmosphere towards present levels.

Geochemical and sedimentological constraints on the maximum CO_2 levels in the early Precambrian atmosphere have led to models that use methane as the most important greenhouse gas, averting global glaciation early in the Earth’s history due to lower solar luminosity (i.e., the “faint young sun” problem). This methane is generally believed to have been largely (if not exclusively) biogenic, i.e., derived by methanogenic bacteria, variously regarded as one of the earliest forms of life. However, evidence from the geological methane budget in modern environments suggests that thermogenic methane (i.e., methane delivered to the atmosphere from the maturation and migration of hydrocarbons in the crust) is likely to be an additional reservoir capable of inducing perturbations in current and future global climate.

Based primarily on circumstantial evidence from the geological record, and specifically on hydrocarbon-derived kerogens from South Africa and elsewhere, we have embarked on an appraisal of thermogenic methane as a potential greenhouse gas in the late Archaean and Palaeoproterozoic. Importantly, we will assess the likelihood that methane released from the burial of hydrocarbon source-rocks in the Witwatersrand and Transvaal Supergroups could have contributed to the re-establishment of a greenhouse-type climate subsequent to the widespread glaciation event recorded at around 2.4Ga.