Abiogenic methane formation in arc magmatic-hydrothermal systems

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Methane (CH_4) may have contributed to the origin of life, both directly, i.e. as an educt for the synthesis of complex organic molecules (1), and indirectly, i.e. as a greenhouse gas that kept temperatures comfortable for early life (2). Biogenic generation of CH_4 by microbes or by thermal decomposition of organic matter is well documented (3). It is still a matter of debate if CH_4 can be produced abiogenically within the Earth's exosphere. Fluids discharging from ultramafic environments often contain CH_4 whose carbon isotopic composition is different from that of biogenic CH_4 (4). However, it remains unclear if the CH_4 released from such settings derives from the mantle or from the inorganic reduction of CO_2 under hydrothermal conditions provided by the oceanic crust (4).

We have investigated the chemical and isotopic composition of gases emanating from some subduction-related volcanic-hydrothermal settings of the Mediterranean. For the systems of Nisyros, Vesuvio and Ischia temperatures reflected by carbon isotope partitioning between CO_2 and CH_4 agree with those derived from a gas concentration geothermometer that is mainly based on CO/CO_2 ratios. Chemical and isotopic equilibrium pattern, CH_4/CO_2 concentration ratios as well as the carbon isotopic signature of CO_2 rule out both a biogenic and a mantle origin of CH_4. Instead, our results imply that CH_4 was generated by a Fischer-Tropsch type mechanism, i.e. the reduction of CO_2 under hydrothermal conditions.

The present-day flux of CH_4 from arc magmatic hydrothermal settings is negligibly small compared to the total input of CH_4 to the atmosphere. However, this flux strongly depends on the redox conditions of the rock matrix. CH_4 fluxes might have been orders of magnitude higher during the early Archean, provided that arc volcanism occurred on a global scale and that the upper arc-related crust was more basaltic in composition.

References

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