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H$_2$/CH$_4$ Ratios Cannot Reliably Distinguish Abiotic vs. Biotic Methane in Natural Hydrothermal Systems

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H₂/CH₄ ratios cannot reliably distinguish abiotic vs. biotic methane in natural hydrothermal systems

In their paper, Oze et al. (1) used H₂/CH₄ ratios to assess the origin of methane in serpentinization systems on Earth and Mars, with ratios <33 indicating that “life is likely present and active.” The production of CH₄ and H₂ in oceanic and continental hydrothermal systems has been intensively studied for several decades by using numerous techniques (e.g., ¹³C, ¹⁴C, thermodynamic modeling) in conjunction with comprehensive fluid analyses. Based on this body of work, we argue that H₂/CH₄ ratios are inappropriate for determining the origin of methane on this planet and likely on others. Artificially high H₂/CH₄ ratios in benchtop hydrothermal serpentinization experiments do not place realistic constraints on the complex multiple processes affecting CH₄ and H₂ in natural hydrothermal systems, despite their claims.

Of the nine “biotic serpentinization systems” cited (1), eight have temperatures (>150 °C) that argue against biological methanogenesis [Ashadze I and II, Broken Spur, Endeavour, Logatchev, Lucky Strike, Menez Gwen, and Rainbow (2)] and four are hosted in magmatically robust basaltic crust not undergoing serpentinization (Broken Spur, Endeavour, Lucky Strike, and Menez Gwen). Furthermore, thermogenic decomposition of buried sedimentary organic matter is considered the primary source of CH₄ at Endeavour (3), which has the lowest cited H₂/CH₄ ratio (~0.1), and is therefore not directly “biotic.” Oze et al. (1) cited Ashadze II as having the highest ratio (~33), serving “as an upper bound for natural systems with dominantly abiotic CH₄ and minimal biological activity,” but fail to include higher H₂/CH₄ ratios (~46) from serpentinite-influenced systems (4), or similarly high values from other basaltic systems in which serpentinization does not influence either volatile. Also, dissolved hydrocarbons at Ashadze II show ¹³C enrichments with carbon chain length (2) consistent with a thermogenic, not abiotic, origin (5). For the remaining systems, multiple lines of evidence still argue for a dominantly abiotic origin for methane without significant biotic inputs. These include methane ³¹⁴C and Δ¹⁴C signatures, relative concentrations and ³¹⁴C signatures of C₂–C₄ hydrocarbons, a lack of sedimentary inputs, and a lack of clear evidence for significant microbial methanogenesis (2, 5). Minor contributions of magmatically degassed methane are also neglected, yet this is likely the dominant source at Broken Spur (1), where H₂ and CH₄ are low, despite “biotic” ratios according to Oze et al. (1).

Similar to CH₄, H₂ can have multiple sources, as well as sinks, and is more reactive. High-temperature reactions with mineral assemblages (aside from serpentinization), microbial oxidation, and sulfate reduction can influence H₂ production or consumption, and therefore H₂/CH₄ ratios, without impacting CH₄. Additionally, H₂ production by serpentinization of olivine-rich igneous rock is highly complex, and can vary over a wide range of conditions in nature that are often highly simplified in hydrothermal experiments. It is therefore unreasonable to apply purely experimental H₂/CH₄ ratios to diverse natural hydrothermal systems. The distinction made by Oze et al. (1) between “biotic serpentinization systems” and “abiotic serpentinization experiments” is instead better explained as a difference between the complexity of natural systems and the inability to replicate them with simple benchtop experiments.

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