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CH_4 and NH_4^+ generation by peridotite hydrothermalism: An experimental study of the cradle of life

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Geologists have been investigating environments and geochemical processes that could have contributed to the primordial synthesis and sustainability of primordial life and their implications for planetary habitability [1]. Thus, hydrothermal reactions, considered a source of chemical reduction and energy, capable of producing CH_4 and NH_3 from H_2O and CO_2 [1] [2] [3] [4], has been focus of experimental studies that tried to investigate abiogenesis of hydrocarbons and ammonia in hydrothermal environments [3] [4]. Considering the still fringe field of testing gas mixes to try synthesizing ammonia and methane through hydrothermal reactions [4], and the Cr-spinel known participation in the formation of hydrocarbons [3], our research explored the abiotic synthesis of hydrocarbons and ammonia through experimental simulation in hydrothermal reactors. In total three experiments were devised, coded CNPXX-Yd (X being the experiment number and Yd the length in days). They were run in a hydrothermal reactor at conditions of 210°C and with total pressure of 102 bars with N_2/CO_2 0.03 ratio, under varying time lengths of 5, 10 and 20 days. A peridotite rock composed of 70% olivine, 17.5% enstatite, 9.5% diopside and 3% Cr-spinel was produced to react with a saline water solution with sodium chloride and bicarbonate under pre-experimental pH of 8.4. XRD and TGA Results show dominant carbonatation of the peridotite with presence of magnesite and amorphous silica indicating silica release. Whole rock Fe speciation analysis shows oxidation did happen by the increase in Fe^{+3} and MEV-EDS investigations suggest spinel reacted to form hydrothermal derived Cr-Fe species. Gas chromatography detected the highest quantity of dihydrogen and methane by 20 days (281.43 and 1810 ppm respectively), while NHx colorimetric analysis of the solution with Uv-Vis spectrometer detected the highest amount of 22.2 ppm in 5 days, decreasing within 20 days.

1 Martin et al. (2008), Nature Reviews Microbiology 6, 805–814.

2 Russel et al. (2010), Geobiology 8, n. 5, 355–371.

3 Janecky & Seyfried (1986), Geochimica et Cosmochimica Acta 50, 1357-1378.

4 Shang et al (2023), Science Bulletin 68, 1109-1111.