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Investigating mineral-organics interactions in a simulated hydrothermal vent high flow environment using microfluidics

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We present a microfluidic system to mimic alkaline hydrothermal vent's minerals, with the mineral being precipitated within a Y shaped channel, at the interface of two laminar flows. This technique allows us to investigate mineral-organic interactions on ancient Earth [1] and aqua-planet site analogs. While most used microfluidic devices visualise only the surface of the mineral [2,3], we propose a new device that enables the visualisation of the mineral's depth, giving access to investigate the interactions occurring at the cross section.

Batch experiments have shown that protocells composed of undecanol and undecanoic fatty acids (on a 1:10 ratio respectively, which has the ability to self-aggregate into compartments) can aggregate in bilayer vesicles or worm-like-micelles in the presence of magnetite and mackinawite, while greigite and pyrite promote crystallisation. The microfluidic system was used to test if the fatty acids could also self-aggregate in a high flow and dynamic environment, resembling the one found in hydrothermal vents. By synthetising green rust [OH–]/{[Fe(II)]+[Fe(III)]} and mackinawite (FeS) within the chip, two types of experiments were conducted to investigate mineral-organics interactions:

1. The mineral is first precipitated inside the chip, and after a vesicle or micelle solution is injected;
2. Simultaneous injection of the mineral and fatty acids micelle solutions.

The experiments were conducted on a fluorescence microscope to analyse the mineral formation and interaction with the different fatty acid solutions. To visualise the interactions, rhodamine 6G dye was added to the fatty acid solution, allowing us to track the movement and possible morphological changes in these protocells.

[1] Hudson, et al. (2020), *PNSA,* 117 (37) 22873-22879.

[2] Lerin-Morales, et al. (2022), *Life,* 12(10):1665.

[3] Bronwyn, et al. (2025), *Earth-Science Reviews,* 271, 105311.