

EXPERIMENTAL STUDY OF SERPENTINIZATION AND ABIOTIC CH₄ PRODUCTION IN MARTIAN CONDITIONS. V. Fortier^{1,2}, V. Debaille², V. Dehant^{1,3}, B. Bultel⁴, D. Debecker⁵, P. P. Melo Bravo⁵, Y. Sekine⁶, S. Tan⁶; and Natsumi Noda⁶. ¹ELI, UCLouvain, Louvain-la-Neuve, Belgium (valentin.fortier@uclouvain.be); ²Laboratoire G-Time, ULB, Brussels; ³Royal Observatory of Belgium, Brussels, Belgium; ⁴CEED, UiO, Oslo, Norway; ⁵MOST/IMCN, UCLouvain, Louvain-la-Neuve, Belgium; ⁶ELSI, Tokyo Institute of Technology, Tokyo, Japan.

Introduction: The presence of methane on Mars remains highly debated in particular with contrasted detection results from Curiosity rover [1] and TGO [2]. In addition, the possible methane cycle is also poorly known: source(s) and removal process(es) remain currently undefined and it is not known yet if methane emissions might possibly be related to biological activity. Because of orbital detection of serpentine on Mars [3], and of the mafic-ultramafic nature of Mars ancient crust, it is important to understand first abiotic sources of methane on Mars. As such, a putative abiotic candidate source is serpentinization associated with Sabatier reaction (Fig. 1).

The aim of this work is to experimentally study the production capacity of H₂ and mainly CH₄ by those abiotic processes (Fig. 2) in martian conditions to determine the viability of this origin.

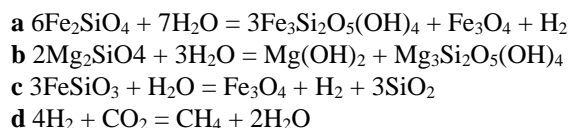


Fig. 1. Serpentinization of fayalite (a); forsterite (b); and ferrosilite (c). Sabatier reaction (d).

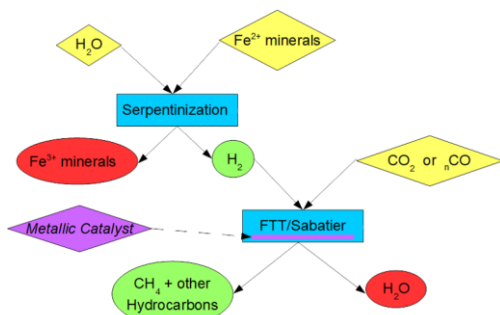


Fig. 2. Schematic representation of serpentinization and Sabatier reaction and their relation in CH₄ formation.

Methodology: Two different experimental setups are used in this work and will be presented.

The first one is a flexible gold-cell type setup [4] (Fig. 3) nicknamed “Wet” in this study, running at ELSI, Tokyo, Japan [5]. This type of setup, used in several previous similar studies, focuses here on serpentinization and CH₄ production by Sabatier reaction

in presence of liquid water. For this setup, two nearly identical experiments have been realized with the following parameters: a version of the Synthetic Shergottite Powder (SSP) [6] for the solid phase; pure MilliQ water for the liquid phase; starting Water:Rock ratio of 4:1; 75-150µm grain size; 280°C; and 70MPa. The only difference between the two experiments is the addition of CO₂ in one of them by incorporation of ¹³C marked NaHCO₃, giving a traceable carbon source for possible CH₄ formation. Experiments lasted respectively 2545 hours for the no-CO₂ one, and 3592 hours for the CO₂ one.

The second setup, nicknamed “Dry” in this study, is a gas reactor running at the IMCN, Louvain-la-Neuve, Belgium [7]. This setup focuses on CH₄ production by Sabatier reaction in absence of liquid water. The same version of SSP used in the “Wet” setup has been used here for a wide range of temperature.

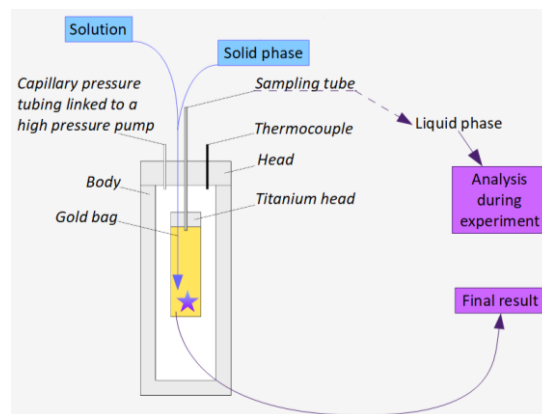


Fig. 3. Scheme of the flexible gold-cell setup used.

Results: Preliminary results of the two experimental setups are presented Fig. 4 and Fig. 5, including variations with time of H₂ concentrations; CH₄ concentrations; CO₂ concentrations; dissolved ions concentrations, and pH. Data for XRD, SEM, and TGA of the solids resulting from the “Wet” setups will be obtained soon.

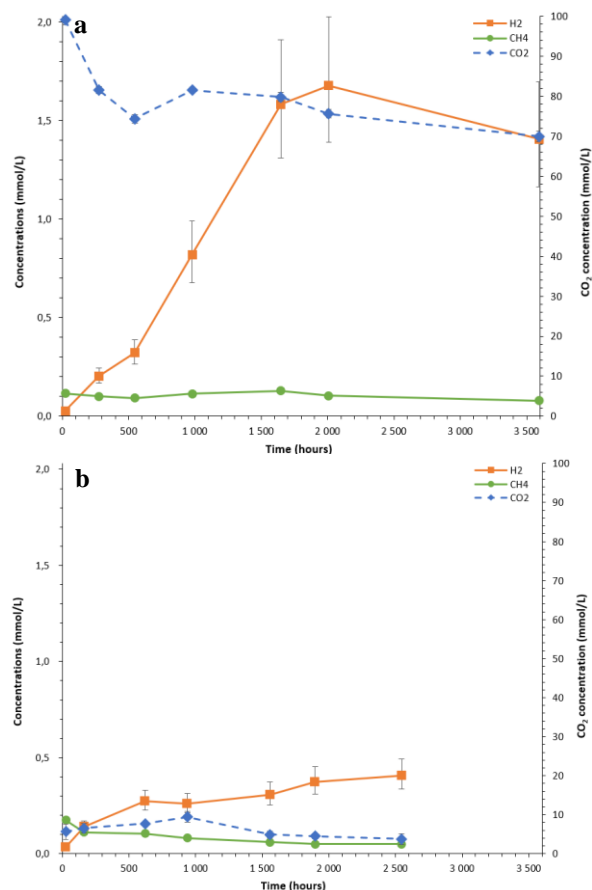


Fig. 4. H₂; CH₄; and CO₂ concentrations evolution trough time for “Wet” setup experiments “CO₂” (a) and “No-CO₂” (b).

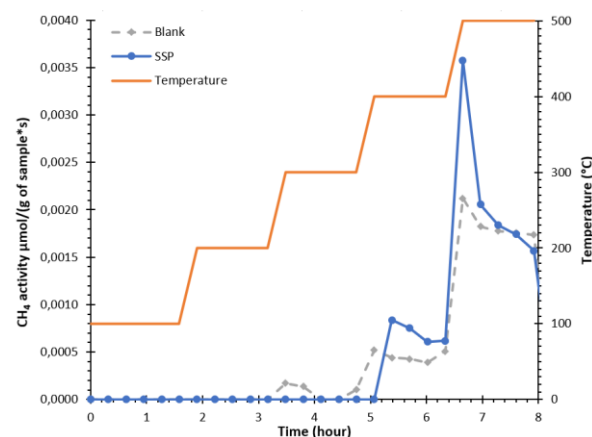


Fig. 5. “Dry” experiment with CH₄ activity versus time for 5 successive temperature steps (100°C; 200°C; 300°C; 400°C; and 500°C).

Discussion: H₂ production is witnessed in both “Wet” experiments, especially in the “CO₂” one. This H₂ production indicates that serpentinization has likely happened in our system, vigorously in presence of CO₂. XRD, SEM, and TGA data for the solid phase of both experiments should confirm it. On the other hand, no clear CH₄ production is visible. It is confirmed by the Gas Chromatography ¹³CH₄ analysis. Also, no clear CH₄ production was observed in the “Dry” experiment as the sample CH₄ activity was too close from the background CH₄.

References: [1] Webster C. R. et al. (2015) *Science*, 347, 415-417. [2] Korablev O. et al. (2019) *Nature*, 568, 517-520. [3] Ehlmann B. L. et al. (2010) *Geophys. Res. Lett.*, 37. [4] Seyfried W. E. et al. (1979) *American Mineralogist*, 64, 646-649. [5] Tan S. et al. (2021) *Icarus*, 357, 114222. [6] Fortier V. et al. (2022) *this conference*. [7] Kim A. et al. (2018) *Applied Catalysis B: Environmental*, 220, 615-625.