The Fate of Ancient Macromolecules on Mars

Artificial Maturation of Iron- and Sulfur-rich Mars-Analogues

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EVIDENCE OF LIFE ON MARS MIGHT BE OUT THERE…IF ONLY WE COULD DETECT IT

1. Surviving Mars

- **Acidic iron- and sulfur-rich streams** are analogues for periods of martian history when Mars exhibited extensive habitable environments [1]
- For organic biosignatures to remain distinguishable from abiotic carbon, they must be **rapidly buried** to be shielded from the harsh radiation flux at the Martian surface [2,3]
- Iron minerals **jarosite** and **goethite** are highly oxidising, and interfere with both the preservation of organic matter [4], and its detection by thermal extraction techniques [5]

2. Objectives

1. Can organic biosignatures survive up to **three billion years of burial** in highly-oxidising, acidic, iron- and sulfur-rich stream environments?
2. How does **mineralogy** affect preservation and detection?
3. Can we mitigate the **obfuscating effect** of jarosite and goethite?
4. Will any surviving biosignatures be **unambiguously diagnostic** of biogenic organic matter?

3. Methods

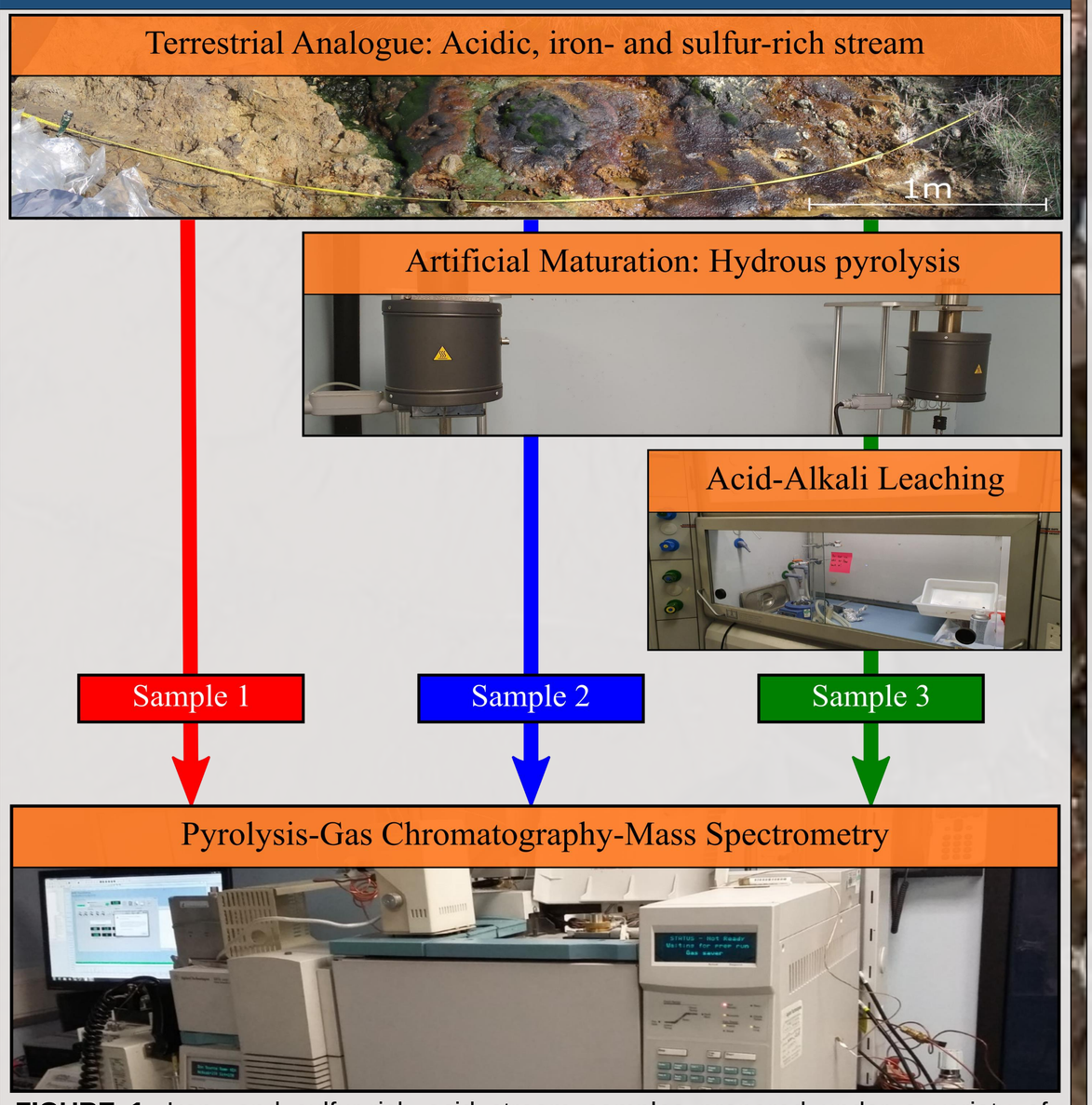

FIGURE 1. Iron- and sulfur-rich acid stream samples prepared under a variety of conditions. A clay-rich sample that included up to 36 wt% of phyllosilicates such as kaolinite and illite was also collected. Sample 1: Unheated samples from the terrestrial analogue site. Sample 2: Terrestrial analogues subjected to **hydrous pyrolysis** for 72 hours. Sample 3: Terrestrial analogues subjected to hydrous pyrolysis, followed by **leaching** using a strong alkali (24 hours), and then a strong acid (96 hours).

5. Discussion and Implications

- Macromolecular organic matter can **survive even the latest stages of diagenesis**
- **Clay minerals aid the detection of organic matter** by thermal extraction techniques
- A simple alkali-acid leaching procedure reveals the presence of a significant amount of organic matter, including **unambiguously biogenic hopanes**
- Developing **sample processing strategies** could be key for life detection in iron-rich environments on Mars

4. Results

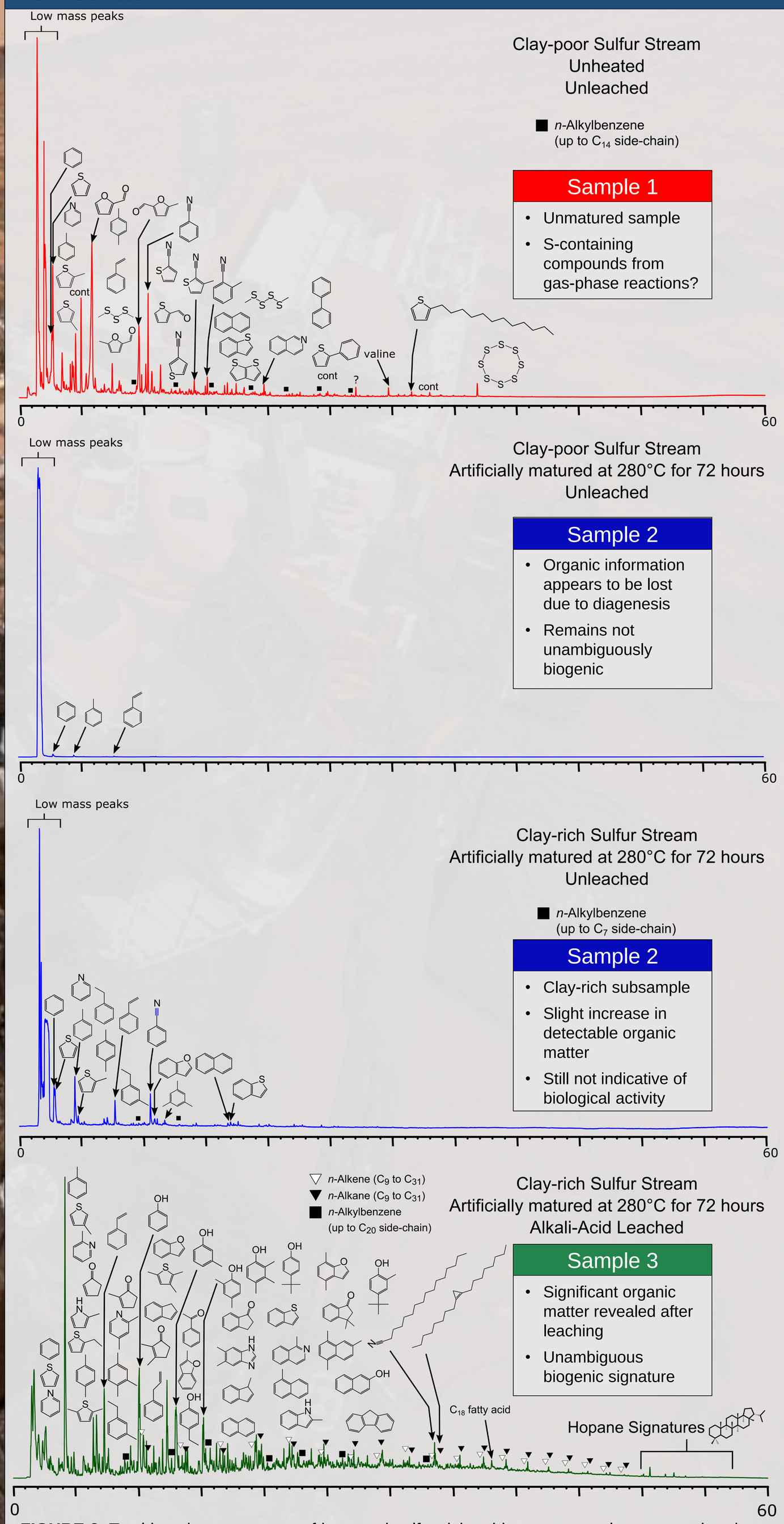

FIGURE 2. Total ion chromatograms of iron- and sulfur-rich acid stream samples prepared under a variety of conditions. Common pyrolysis products include alkylbenzenes that derived from the decarboxylation, aromatisation and thermal cyclisation of fatty acids, primarily as a function of pyrolysis rather than diagenetic effects [6]. The hopanes detected in Sample 3 are diagnostic of bacterial cell membranes [7].

S-containing compounds in Sample 1 could be derived from gas-phase reactions during pyrolysis, but S-containing compounds in Sample 3 must be due to the diagenetic incorporation of sulfur due to the sample having been leached prior to flash pyrolysis.

6. References

[1] Fernández-Remolar, D.C., et al.,, 2005. The Rio Tinto Basin, Spain: Mineralogy, sedimentary geobiology, and implications for interpretation of outcrop rocks at Meridiani Planum, Mars. Earth Planet. Sci. Lett. 240, 149–167. [2] Kminek, G., Bada, J.L., 2006. The effect of ionizing radiation on the preservation of amino acids on Mars. Earth Planet. Sci. Lett. 245, 1–5. [3] Pavlov, A.A., et al., 2012. Degradation of the organic molecules in the shallow subsurface of Mars due to irradiation by cosmic rays. Geophys. Res. Lett. 39, 5–9. [4] Tan, J., Sephton, M.A., 2019. Organic Records of Early Life on Mars: The Role of Iron, Burial, and Kinetics on Preservation. Astrobiology 20, ast.2019.2046. [5] Lewis, J.M.T., et al., 2015. Sulfate Minerals: A Problem for the Detection of Organic Compounds on Mars? Astrobiology 15, 247–258. [6] Saiz-Jimenez, C., 1995. The origin of alkylbenzenes and thiophenes in pyrolysates of geochemical samples. Org. Geochem. 23, 81–85. [7] Rohmer, M., et al.,1984. Distribution of hopanoid triterpenes in prokaryotes. Microbiology 130, 1137–1150.