ARPHA Conference Abstracts 6: e108122
doi: 10.3897/aca.6.e108122

OPEN ACCESS

Conference Abstract

Exploring Biomarker Signatures in Glaciovolcanic Environments: Implications for the Search for Life on Mars

Erin F. Gibbons[‡], Richard Leveille[‡], Greg Slater[§], Kim Berlo[‡]

‡ McGill University, Montreal, Canada
§ McMaster University, Hamilton, Canada

Corresponding author: Erin F. Gibbons (erin.f.gibbons@gmail.com)

Received: 16 Jun 2023 | Published: 13 Oct 2023

Citation: Gibbons EF, Leveille R, Slater G, Berlo K (2023) Exploring Biomarker Signatures in Glaciovolcanic Environments: Implications for the Search for Life on Mars. ARPHA Conference Abstracts 6: e108122. https://doi.org/10.3897/aca.6.e108122

Abstract

Glaciovolcanic systems, where hydrothermal heat interacts with ice, offer favorable conditions for life by providing liquid water, nutrients, and physicochemical gradients (Cousins and Crawford 2011). Despite significant climate change, evidence for glaciovolcanism is widespread through Mars' history. Such sites may have offered refugia for life after Mars lost much of its surface water, representing some of the most recent habitable areas and promising sites to recover biomarkers. We examined a terrestrial glaciovolcanic site to study the indigenous biological community structure, the supporting physicochemical parameters, and the distribution of biomarkers within the geologic context. The insights will help refine Mars exploration of analogous sites.

Method: We studied a partially subglacial hydrothermal area at the summit of the active Kverkfjöll volcano, Iceland. The heated ground has created a large ice-damned meltwater lake with shoreline hot springs, thermal streams, and mud pots of variable activity. We collected water and sediment samples aseptically across the breadth of features, including the lake (surface & depth). Samples were kept at -4°C. Environmental parameters were measured at each sample site. Sediment samples were split for mineralogical and organic analysis. Mineralogy was measured by X-ray Diffraction. Organic samples were freeze-dried and extracted with a Bligh & Dyer method (Bligh and

© Gibbons E et al. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Dyer 1959). Extracts were divided into hydrocarbons, neutral lipids, glycolipids, and phospholipid fatty acids (PLFA) with hexane, dichloromethane, acetone, and methanol. Gas Chromatography/Mass Spectrometry was used to analyze hydrocarbons and PLFA as fatty acid methyl esters.

Results:

Environmental: Fluids ranged from acidic to alkaline (pH 3-9), low to high temperature (8-87°C), and severely dysoxic to oxic (0.5-5 mg/L dissolved O). Mineralogy comprised a dioctahedral swelling clay, heulandite, and minor quartz, anatase, and pyrite. The assemblage suggests argillic-grade alteration at 100-140°C (Fulignati 2020), confirming that the glaciovolcanic conditions were within theoretical boundaries for life (<150°C (Merino et al. 2019)), and formed minerals capable of protecting organic matter (e.g., swelling clay).

Lipids: PLFA are essential components of cell membranes and degrade rapidly upon cell death. PLFA profiles thus provide insight into the composition and distribution of the viable community. Results revealed a diversity of PLFA with low molecular weights and several bacterial-diagnostic structures, indicating an active prokaryote-dominated biosphere. Molecular patterns correlated ($p<0.05$) with pH, temperature, and oxygen, suggesting homeoviscous adaptations or community composition variations. In either case, microbes demonstrate adaptability to extreme conditions in glaciovolcanic settings.

Hydrocarbons are inert and used as molecular fossils. We detected multiple patterns attributable to microbial biosynthesis, including abundant C_{17} (straight and branched) diagnostic of cyanobacteria; high concentrations of short-chain n-alkane/alkene doublets ($<C_{22}$) with an even carbon preference (CPI<1) indicating diverse microbial input; and a narrow unresolved complex mixture with elution parameters characteristic of microbial heterotrophy (Finkel et al. 2023). The pattern of even-numbered alkane/alkene pairs has been scarcely reported and offers insight into rare hydrocarbon distributions. Interestingly, the hydrocarbon and PLFA patterns do not align. Thus, PLFA are not a significant source of hydrocarbons here and we suggest direct microbial synthesis dominates. Implications of this hypothesis will be discussed in the context of palaeobiological reconstruction.

Conclusion: Our site provides an array of physicochemical niches for diverse life modes and a mineral assemblage amenable to organic preservation. Analogous sites on Mars should be explored, but more work is needed to understand preservation biases of hydrocarbon sources and the implications for interpretation.

Keywords

Astrobiology, Mars, lipid

Presenting author

Erin F. Gibbons

Presented at

Prefer oral presentation in the theme: "Part 3: Astrobiology and Earth Analog Settings"

Acknowledgements

This project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149. We acknowledge support of the Canadian Space Agency (CSA) [21EXPCOI1].

Conflicts of interest

The authors have declared that no competing interests exist.

References

- Bligh EG, Dyer WJ (1959) A RAPID METHOD OF TOTAL LIPID EXTRACTION AND PURIFICATION. Canadian Journal of Biochemistry and Physiology 37 (1): 911-917. https://doi.org/10.1139/y59-099
- Cousins C, Crawford I (2011) Volcano-Ice Interaction as a Microbial Habitat on Earth and Mars. Astrobiology 11 (7): 695-710. https://doi.org/10.1089/ast.2010.0550
- Finkel P, Carrizo D, Parro V, Sánchez-García L (2023) An Overview of Lipid Biomarkers in Terrestrial Extreme Environments with Relevance for Mars Exploration. Astrobiology 23 (5): 563-604. https://doi.org/10.1089/ast.2022.0083
- Fulignati P (2020) Clay Minerals in Hydrothermal Systems. Minerals 10 (10). https://doi.org/10.3390/min10100919
- Merino N, Aronson H, Bojanova D, Feyhl-Buska J, Wong M, Zhang S, Giovannelli D (2019) Living at the Extremes: Extremophiles and the Limits of Life in a Planetary Context. Frontiers in Microbiology 10 https://doi.org/10.3389/fmicb.2019.00780