Europlanet TA Scientific Report

PROJECT LEADER

Project number: 20-EPN-003
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Home Institution: McGill University, Quebec, Canada
TA Facility visited: Iceland Field Sites (IS)

Project Title: Production and Early Preservation of Biosignatures in Glaciovolcanic Lakes: A Biogeochemical Analogue for Mars

Scientific Report Summary.
(plain text, no figures, maximum 250 words, to be included in database and published)

The search for extraterrestrial life, either extinct or extant, on Mars is a key objective for several international space exploration programs. To maximize the likelihood of success for these programs, we must first study ecosystems on Earth that resemble those on Mars and investigate both the kinds of organisms that can survive there and the processes that control their ultimate preservation/fossilization in the rock record.

We proposed that the geothermally-heated lake Gengissig, located in the Highlands of Iceland, represented an ideal natural laboratory within which to conduct a Mars-centric taphonomic study. Geologically, this setting provides an excellent analogue for Mars because the basaltic bedrock has a bulk chemical composition that is similar to the rocks measured on Mars by past and current rovers, thereby allowing us to study how signs of life may be preserved by the rock types common on Mars. Furthermore, this remote location is nearly devoid of multicellular life-forms and is isolated from anthropogenic input, providing a pristine ecosystem to study the fossilization processes expected to be encountered on Mars – those operating on microbial life.

We collected water, rock, and lake sediment samples to investigate the site. We intentwill use a combined genomic, stable isotope, and geochemical approach to investigate the indigenous microbial communities and their ultimate fossilization in this Mars-like terrain. the results of which will be immediately relevant towards directing current and upcoming Mars rovers towards sites on Mars most likely to retain signs of ancient extraterrestrial life.

Full Scientific Report on the outcome of your TNA visit

We encourage you to add figures to your report, which should be approx. 1 page of text plus figures.

The question of whether we are alone in the Universe has been a source of wonder for humanity for millennia and has become a key motivator for modern space exploration efforts. Mars is a particularly compelling target to address this fundamental question both because of its proximity to Earth (accessibility) and because its surface retains tantalizing evidence for habitable environmental conditions in the ancient past. The scientific challenge of our time is to address this question with rigour and determine whether this other habitable world was indeed *inhabited.*

Although Mars is thought to have been amenable to life as we know it in the past, planetary-scale climate models suggest that these conditions were only sustained for a short period of time and at discrete localities. Therefore, if life did emerge on the red planet it likely remained in a primitive state of evolution (in most cases probably not achieving photosynthesis) and likely did not proliferate across the entire surface. The Martian fossil record is thus expected to be sparse and dispersed, which highlights the difficulty faced by current and upcoming astrobiology missions. Mars exploration sites will have to be chosen judiciously to maximize the chance of success and should only focus on environments that were both habitable *and* conducive to the concentration and preservation of primitive fossils. This foundational knowledge of biology and taphonomy is guided by the investigation of analogous ecosystems on Earth. Unfortunately, the ecology of modern Earth is so dominated by photosynthesis that it is difficult to study natural chemosynthetic ecosystems (and their associated fossilization) in isolation and we currently lack a clear understanding of how these communities are structured, distributed, and how they become fossilized.

The goal of our TNA visit was therefore to collect environmental and biological samples from a Mars-like ecosystem where photosynthesis is not the dominant form of primary production. We selected lake Gengissig in the Highlands of Iceland because it boasts several key parameters that make it uniquely well-suited for a Mars-centric taphonomic study. Specifically, the location is nearly devoid of multicellular life-forms, is isolated from anthropogenic input, and the extrusive basaltic flows that underlie lake Gengissig are geochemically and mineralogically analogous to the basaltic crust of Mars. This combination of features affords us the opportunity to study chemotrophic microbial communities that are sustained by nutrients and energy sources derived from a Mars-like substrate. In brief, this ecosystem is a modern geological and biological analogue to past habitats on early Mars.

Because the site is so remote, we partnered with the Icelandic Glaciological Survey to help facilitate access and joined a pre-planned expedition across the Vatnajokull ice-cap, scheduled for 31-05-2022 – 05-06-2022. We arrived in Iceland on 27-05-2022. In the three days preceding the expedition (pre-analytical preparation), we purchased food and collected specialized equipment from our hosts at Matis and from collaborators at the University of Iceland. During the analytical phase, we collected a comprehensive suite of environmental measurements, water samples, and sediment samples from the Gengissig lake and surrounding environment. It is important to note that we had brought a boat to the site and were able to collect water samples from both the lakeshore and the lake interior, which has not been attempted by previous researchers who have visited the area for astrobiology investigations. We anticipate that this comprehensive sampling strategy will allow us to investigate how the biological community is structured and how fossil remains are transported throughout the system. Upon our return to Reykjavik (06-06-2022), we spent two days performing chemical measurements of redox-sensitive elements in the water samples using a field-portable chemistry kit; these measurements need to be performed with 7 days of collection.

Moving forward, the goal is to conduct a thorough assessment of the energy sources available to life in this environment and establish a baseline understanding of how Mars-like organisms have adapted to survive. We will also use a combination of genomic, stable isotope, and organic geochemical analyses to characterize what happens to the microbial community members after they die – ie. what fossil remains are left behind, where are they concentrated, and what preservation biases may exist? We will specifically look for any correlations between the fidelity of the fossil record and environmental gradients, like pH, temperature, salinity, etc., as these relationships could help guide future exploration missions towards samples most likely to retain evidence of Mars' past biosphere, if it ever existed. We expect our results to be immediately relevant to the Mars 2020 mission, which is seeking signs of life in an ancient lakebed environment, as well as any future Mars life detection missions.

Photos:

Our research team just before arriving at the remote TNA site.

Our field research station on the shores of Gengissig

- Give details of any publications arising/planned (include conference abstracts etc)

3 possible publications planned:

1. *Title*: Production and Early Preservation of Biosignatures in a Glaciovolcanic Lake: A Biogeochemical Analogue for Mars.
    - Target journal: Astrobiology
2. *Title*: Lipid Preservation in Modern and Relict Mud Pots in Iceland, with Implications for Organics Detection on Mars.
    - Target journal: Astrobiology
3. *Title*: Energetics of Chemolithoautotrophy in a Glaciovolcanic Lake.
    - Target journal: Geobiology

The above topics will also likely be presented at the 2023 Lunar and Planetary Science conference as well as various in-team meetings of the Mars 2020 Perseverance rover Science Team.

- Host confirmation

Please can hosts fill in/check this table confirming the breakdown of time for this TA project:

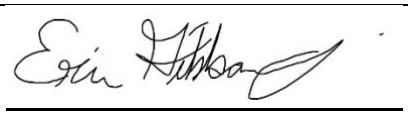
Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
Departed: 27-05-2022 Arrived: 27-05-2022	28-05-2022	3	6	2	08-06-2022	Departed: 09-06-2022 Arrived: 09-06-2022

The host is required to approve the report agreeing it is an accurate account of the research performed.

Host Name	
Host Signature	
Date	

- Project Leader confirmation

Do you give permission for the full version of this TA Scientific Report (in addition to the 250 word summary) to be published by Europlanet 2024 RI on its website and/or public reports? YES

Project Leader Name	Erin Gibbons
Project Leader Signature	
Date	25-07-2022