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Detection and Preservation of Biosignatures in Mars Analogs Hot Spring Deposits from the Taupo Volcanic Zone, New Zealand

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Abstract

Characterizing the preservation potential of biosignatures in martian analogs is essential in the quest for biosignatures with martian rovers. Hot spring silica deposits are part of the minerals with a high preservation potential. As part of an ongoing study, we are characterizing the nature and distribution of organic molecules including lipid biomarkers in a range of analog hot spring deposits, evaluating their preservation potential, and determining the potential signals from flight-like experiments. We are focusing on various geothermal fields in the New Zealand Taupo Volcanic Zone with physical and chemical variabilities. Samples are being extracted for lipid biomarker characterization as well as analysis using flight-like experiments from the current and future pyrolyzer-gas chromatograph-mass spectrometer instruments SAM and MOMA on the Curiosity and Exomars2020 rovers. The aim of work is to improve our knowledge of the detection and preservation of biosignatures in different hot spring lithologies while simultaneously evaluating the potential limits and biases of flight experiments.

1. Introduction

The search for traces of past life is one of the driving goals of Mars exploration. On Earth, silica-rich rocks, including siliceous sinters (hot spring deposits), have been highlighted as targets with high biosignature preservation potential [3]. Similarities have been drawn between nodular, micro-digitate, and opaline silica on Mars (*e.g.* Columbia Hills) and actively forming sinters at El Tatio, Chile [5] as well as sinter fabrics in the Taupo Volcanic Zone (TVZ) in New Zealand (NZ) [1]. Hydrated silica has also been detected from orbit on Mars at Jezero Crater and around the NE Syrtis region, potentially indicative of ancient hot springs [2]. A great deal of laboratory work has been done on terrestrial analogs from various mineralogical environments using techniques from the instruments aboard these rovers [4,6], but spicular sinters remain understudied.

2. Objectives

The objectives of this study are to characterize the nature and distribution of lipid biomarkers and organic molecules, evaluate their preservation potential, and determine potential signals from flight-like experiments. A previous study has shown strong preservation of biosignatures in NZ sinters, including textural evidence of microbial communities at the micron scale [2].

3. Samples sites and mineralogy

Five geothermal fields in the TVZ around Rotorua have been selected for this study (figure 1). Siliceous spicular sinter deposits were collected in six active hot-springs from the sites in late June of 2018: Tikitere (Hell's Gate), Orange Spring, Whangapaoa Spring, Rotokawa and Te Kopia (figure 2). Digitate silica textures were precipitating and silicifying from the hot springs in various physical and chemical conditions including fluid compositions (alkali-chloride, acid-sulfate chloride, acid sulfate and bicarbonate-sulfate), temperatures (from ambient to ~80°C) and pH (1.6-8.4) (see details in Table 1). Samples dedicated to organic analysis (including lipids) were collected with solvent-cleaned and ashed material to prevent organic contamination, and placed immediately on ice in a cooler following sample collection. They were then stored in the laboratory at -80°C until processing. XRD analysis indicated they are all opal-A silica in composition.

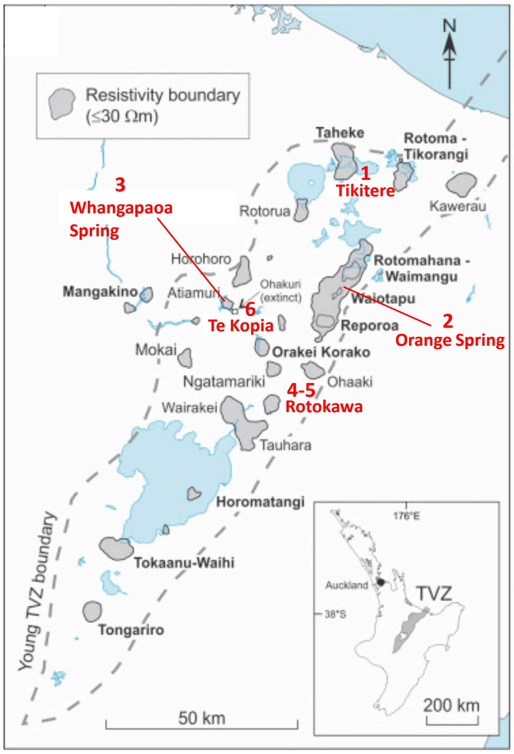

Figure 1: The five sampling sites are located in the Taupo Volcanic Zone in the Northern Island of New Zealand.

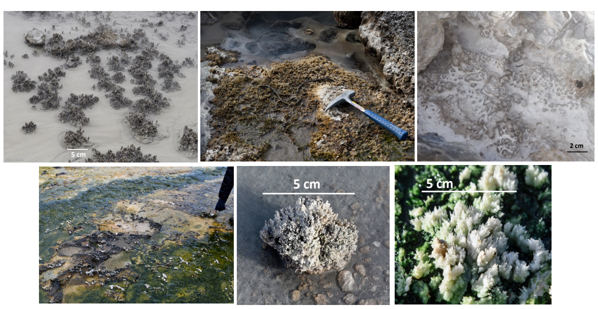

Figure 2: Detail of the six siliceous spicular digitate sinter deposits from the geothermal fields where they were collected. From left to right and top to bottom: Tikitere, Orange Spring, Te Kopia, Whangapaoa Spring, Rotokawa Lagoon and Parariki Stream.

4. Laboratory experiments

Samples were freeze-dried and crushed prior to analysis and total organic carbon (TOC) was measured. At present, these samples are being analyzed using a modified Bligh & Dyer extraction method for lipid biomarker preservation. Shortly thereafter, samples will be analyzed using flight-like experiments from the Sample Analysis at Mars (SAM) instrument currently aboard the Curiosity Rover and the MOMA (Mars Organic Molecular Analyzer) instrument that will be aboard Exomars 2020. Techniques include flash-pyrolysis, SAM/MOMA-like pyrolysis-gas chromatograph mass spectrometer (py-GCMS) experiments as well as MTBSTFA, TMAH and DMF-DMA wet chemistry experiments. This ongoing investigation will improve our knowledge on the preservation of biosignatures in a range of hot spring martian analog environments and better evaluate the potential limits and biases induced by current and future flight-like experiments.

Table 1: Temperature and pH of the pool for each sampling site

Sampling sites	Fluid composition	T of the pool (°C)	pH of the pool
Tikitere (Hell's Gate)	Bicarbonate-sulfate	41	6.8
Orange spring	Acid sulfates	70	2
Whangapaoa Spring	Alkali-chloride	25	8.4
Parakiri stream (Rotokawa)	Acid sulfate chlorides	43	1.6
Rotokawa lagoon	Acid sulfate chlorides	81	1.8
Te kopia	Acid sulfates	95	1.6

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