

## **Project Description:**

### **Identifying Putative Microbial Drivers of Methane Flux on Earth and Mars**

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Methane plays a critical role in climate change on Earth and observations of methane on Mars may suggest the presence of life. Understanding the relationship between subsurface microorganisms and methane in the Arctic will help predict the influence of climate change on methane concentrations in permafrost environments and inform our understanding of methane on Mars. The following are required to assess methane-microbe relationships: i) diversity and metabolic potential; ii) physical architecture and spatial relationships between microorganisms and minerals, organic substances, and elements; iii) geochemical parameters of the environment. We will investigate three environments on Axel Heiberg Island: i) hypersaline cold spring hosted methane seeps (Colour Peak, Gypsum, and Wolf springs); ii) cryosols from polygonal terrain known to be both methane sources and sinks; and iii) glacial ice not known to be associated with methane release (Crown and White glaciers). We will test 4 prototype spectroscopy instruments to assess near surface methane in the atmosphere as well as mapping of organic molecules, minerals, and elements. Physical samples will also be acquired to assess the microbial community diversity and environmental geochemistry. Testing this instrumentation help with monitoring of remote ecosystems sensitive to environmental change and is also a crucial step in developing this instrumentation for future Mars missions.

- Can new spectroscopy instruments be used to detect methane emissions from natural methane seeps and map organics, minerals, and elements?
- What is the subsurface microbial community structure and near surface methane profile in each environment?
- Are subsurface microbial communities capable of oxidizing methane and how do they influence methane cycling?

***Objective 1: Characterize the subsurface sediment-hosted microbial communities and their capacity for active methane oxidation demonstrating their significance to methane cycling.***

***Objective 2: Characterize the near surface methane establishing a local record of methane flux linked to microbial methane oxidation rates.***

Field research (26/06/2023 – 31/07/2023) with active on Axel Heiberg Island based out of the McGill Arctic Research Station (July 2 – 19). A pump will draw atmospheric samples into the methane spectrometer. The mapping spectroscopy instruments use non-destructive LEDs. The spectroscopy instruments pose no environmental hazards or risks. Manual scooping and sediment push cores (30-50 cm) will be used to collect <5 L of sediment. Manual syringes will be used to collect <2 L / spring of water from each site. Given the water refresh rate and seasonal re-modelling, no environmental damage or risk is anticipated. Hand coring will collect <3 meters of ice core and <1.5 m of cryosol. Given the low volumes and the summer glacial surface melt, no environmental damage or risk is anticipated. All instruments will operate using Li-ion batteries.

Atmospheric, geochemical, and biological data will be stored on university servers, available on request. Published data will be publicly available through GitHub repositories or long-term

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databases such as NCBI. As funding for the project advances, we plan to hire local wilderness guides in addition to developing bi-directional outreach initiatives to share our science results with the Hamlet of Resolute Bay and other Nunavut residents through engaging with local SAO offices.

### Samples and instruments:

#### Sample types:

**Sediment cores:** Sediment cores will be acquired using 30 cm or 50 cm polypropylene tubes that will be manually pushed into the sediment within the spring sites. Pore water will be extracted from the sediment in the core tube. Sediment will be sub-sectioned. Pore water and sediment samples will be processed at MARS for downstream geochemical and biological analyses. As a result of the seasonal filling and re-modelling of the springs, no long term damage or environmental risk is expected.

**Cryosol cores:** Cryosol cores will be collected using a Kovacs Mark II corer (7.25 cm diameter) down to 50 cm. Cores will be extracted from the borehole and imaged with the Spec1 and Spec2 imagers. The borehole wall will be scanned with the down-hole miniature probe (Spec3). All three instruments acquire non-invasive measurements. Cores will be stored in sterile Whirlpak bags and transferred to MARS for downstream geochemical and biological analyses. No long term damage or environmental risk is anticipated.

**Ice cores:** Ice cores will be acquired using a Kovacs Mark II corer (7.25 cm diameter) down to 50 cm. Cores will be extracted from the borehole and imaged with the Spec1 and Spec2 imagers. The borehole wall will be scanned with the down-hole miniature probe (Spec3). All three instruments acquire non-invasive measurements. Cores will be stored in sterile Whirlpak bags and transferred to MARS for storage until returned to York University for downstream analyses. No long term damage or environmental risk is anticipated.

**Atmospheric samples:** An Off-axis integrated cavity output spectrometer (OA-ICOS) will use a lithium ion battery to power an internal pump to draw air into the internal analytical chamber where a class 1 laser will analyze methane and carbon dioxide concentrations. The air is then passively released. Interlocks prevent the laser from engaging unless the instrument is sealed. There is no stray laser light when the instrument is sealed. The non-destructive nature of this instrument prevents any environmental risk or damage.

### Instruments:

#### Spectroscopy instruments:

**OA-ICOS:** Off-axis Integrated cavity output spectrometer. Microportable instrument developed by ABB Inc. to non-destructively analyze methane and carbon dioxide atmospheric concentrations.

**Spectroscopy suite:** Fieldable suite of three in situ geochemical prototype instruments including: 1) *Spec1*: Multi-band spectral imager incorporating ultraviolet and visible multi-excitation and UV-VIS-NIR emission imaging to spatially detect and characterize organic matter (protein-like, humic-like, and pigments); determine coarse mineralogy; and detect select rare-earth elements. 2) *Spec2*: In situ microscopic ultraviolet imager incorporating simultaneous multi-spectral imaging for in situ excitation-emission spectroscopy. 3) *Spec3*: down-hole miniature

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probe for mapping and contextualization of organic matter in the near subsurface down to a 20 cm depth.

#### Coring tools and instruments:

**Push cores:** 30 cm and 50 cm long polypropylene tubes with a 7 cm diameter will be manually pushed into spring sediment to obtain spring sediment cores.

**Drilled cores:** All frozen cores (cryosol and ice) will be collected manually using a Kovacs Mark III with a 7.25 cm diameter.

#### Other instruments:

**Sonic Anemometer:** A Campbell Scientific 3-D sonic anemometer will be used to passively take measurements of the wind direction and velocity to provide metadata to interpret the methane and carbon dioxide measurements acquired by the OA-ICOS instrument. This passive, non-destructive instrument poses no risk to the environment.

Table 1: sample and data collection locations

	Push core	Cryosol core	Ice core	OA- ICOS	Anemometer	Spectroscopy suite	Drone
	Physical sampling			Passive, remote (non-destructive) sampling			
	geochemistry and/or microbiology			CH <sub>4</sub> & CO <sub>2</sub>	Wind speed and direction	Organic molecule mapping	Aerial photography
Cornwallis Island							
	PCSP			X	X	X	
Axel Heiberg Island							
	Wolf Spring	X		X	X	X	X
	Colour Peak spring	X		X	X	X	X
	Gypsum Hill Spring	X		X	X	X	X
	Crown Glacier		X	X	X	X	X
	White Glacier		X	X	X	X	X
	Polygonal terrain near MARS	X		X	X	X	X