INVESTIGATION OF BIOSIGNATURES IN CANADIAN ARCTIC GOSSANS USING PORTABLE FIELD REMOTE SENSING INSTRUMENTS. G. Belleau-Magnat[1] , M. Lemelin[1] and E. Cloutis[2], [1]Department of applied geomatics, Université de Sherbrooke, Québec, Canada, J1K 2R1 (Gaelle.Belleau-Magnat@usherbrooke.ca, Myriam.Lemelin@usherbrooke.ca), [2] Department of Geography, University of Winnipeg, Manitoba, Canada, R3B 2E9.

Introduction: Orbital and robotic Martian missions have successfully determined that Mars once had a warm and wet climate, which could have allowed early forms of life to survive. One of the goals of the Mars 2020 Perseverance rover currently on Mars is to find traces of such life. The rover is using its onboard remote sensing tools to identify geologic sample that could hold biosignatures and is caching them on the Martian surface. A follow-up mission will collect these samples and bring them back to Earth for further analysis. The return of Martian samples in the coming years will be key to confirm the presence of past life forms. However, as the quantity of material that will be returned to Earth is limited, it is essential to prioritize the samples to be collected.

The instruments such as PIXL, ChemCam, CheMin, SHERLOC, and SuperCam, onboard the rovers currently in operation on Mars make it possible to identify a wide range of minerals and organic molecules (e.g., organic carbon, chlorophyll, and lipids). Various studies have highlighted the effectiveness of rover-like tools for identifying biosignatures, on Earth, in Martian analogue environments such as locations where inverted fluvial sediments were found [1] or in perennial hypersaline spring complexes [2]. The use of such methods makes it possible to simulate the approaches used by rover vehicles to identify biosignatures and thus, guide the selection of Martian sampling sites as part of in situ missions.

Gossans are the superficial and oxidized portion of a massive sulfide deposit. They form though the alteration of sulfide-rich bedrock by acidic fluids, and thus contain abundant alteration minerals which require the presence of water during their formation. Different strata can generally be identified using the color of the sediments which is associated to the oxidation level, ranging from grey to dark orange [3]. If present on Mars, these geological formations would be key places to search for biosignatures. Indeed, the presence of biosignatures, such as hydrous ferric oxide filaments, in terrestrial gossans have already been identified [4]. While gossans have not yet been identified on Mars, their presence has been hypothesized [5], and the alteration minerals they contain (e.g., jarosite, hematite, goethite) have been identified by orbital or surface instruments. Reactive gossans in the Canadian Arctic are thus considered good analogues to paleo-hydrothermal systems on Mars [3].

The protocols used to identify biosignatures using remote sensing instruments differ according to the environmental setting of the samples. The protocols used to identify biosignatures in iron-rich environments, such as gossans, generally include manipulations in the laboratory, which can not be executed in the field. This leads us to consider the possibility of experimenting with a combination of fine-resolution and rover-mountable spectroscopy methods to identify biosignatures in Mars-like gossans. The development of such a methodology on Earth would make it possible to apply it to similar terrains on Mars.

The project aims (1) to determine the potential of five spectroscopy techniques (reflectance, X-ray diffraction, X-ray fluorescence, Raman spectroscopy, light-induced breakdown spectroscopy), to identify biosignatures and (2) to determine the spectral characteristics as well as the stratigraphic distribution of biosignatures in Canadian Arctic gossans.

Figure 1: Gossans found at Colour Ridge on Axel Heiberg Island, Nunavut.

Study area: The study area is located on Axel Heiberg Island in Nunavut, Canada (Fig. 2). This island in the Canadian Arctic Archipelago is part of the High Arctic Large Igneous Province (HALIP). It is an area with a complex relief of hills and valleys. Areas of interest for this project are the Expedition Fiord and South Fiord areas due to the potential association of gossans found in the region with paleo-hydrothermal systems [6]. They are located in the south center of the island, where South Fiord is located further west and

Expedition Fiord further east. A field campaign will take place in the summer of 2023 to acquire data and collect samples. The team base camp will be located near M.A.R.S. (the McGill Arctic Research Station, 79°24'55" N 90°44'53" W), at Expedition Fjord. The sampling sites will be defined within a radius of a few kilometers around the research station so that they are accessible by foot. Helicopter trips will make it possible to travel to South Fjord to carry out additional measurements.

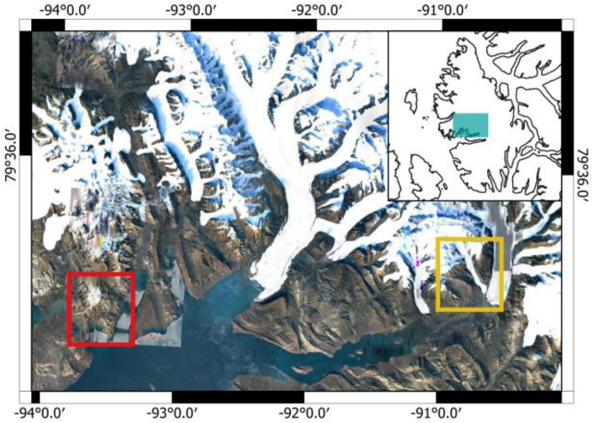

Figure 2: Location of Expedition fjord (yellow) and South fjord (red) on Axel Heiberg Island, Nunavut.

Methodology:

Preliminary experiment. Prior to the field work of 2023, laboratory tests will be carried out on the samples collected during the 2022 field campaign in the Expedition Fiord area in order to identify the appropriate parameters to be used for the different instruments.

Field work. A first phase of data acquisition in the field will focus on the surface of gossans which will make it possible to simulate the data acquired by remote sensing instruments mounted on rovers. Reflectance measurements and several LIBS acquisitions will be performed at each sampling site. Then, a vertical cross section will be dug to obtain information of the near subsurface which will provide intel on the potential stratigraphic distribution of biosignatures. For each stratum identified, acquisitions of reflectance, light-induced breakdown spectroscopy and Raman spectroscopy will be carried out. Samples will finally be collected on each target measured, on the surface and for each stratum to perform laboratory analyses on the same material.

Laboratory work. Samples collected in the field will be used to acquire additional or confirmation data in a controlled environment, in the laboratory. The results of this project will be based on the field data, while laboratory data will be used to validate what has been observed in the field. In order to know the mineralogical composition of the samples, X-ray fluorescence and diffraction measurements will be taken. Then, the elemental composition will be acquired through X-ray fluorescence, light-induced breakdown spectroscopy and Raman spectroscopy measurements.

Interpretation and validation. A literature review will be carried out and classification and linear unmixing algorithms will be used to interpret the spectra obtained from the different techniques. It will aim to identify the elements, molecules or minerals potentially representing biosignatures in the gossans. It will also be used to identify the validation criteria useful to confirm the biological origin of the signatures potentially found.

Expected results: The expected results at the end of this project are (1) a method for remote sensing of biosignatures in Mars-like gossans combining various fine-resolution spectroscopy techniques, (2) a description of the types of biosignatures observed in the study region and (3) an analysis of the stratigraphic distribution of the biosignatures found in these geological formations.

Benefits of the study: The development of a fine-resolution remote sensing method will make it possible to highlight the effectiveness of spectroscopy and the complementarity of the different techniques for the study of biosignatures. Then, the stratigraphic analysis of the biosignatures will provide information on the factors influencing the vertical distribution of microorganisms in this type of formation. The fact that this project is carried out in a Mars-like environment will make it possible to acquire expertise in anticipation of future planetary exploration missions and contribute to extracting scientific information from current Mars rover missions. Indeed, the biosignatures found in the gossans of the Canadian Arctic are expected to be similar to traces of past life potentially present on Mars. The biosignature detection method could be relevant to guide the types of analysis carried out and the choice of samples collected by rover

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