REMOTE SENSING AND COMPOSITIONAL ANALYSIS OF GOSSANS IN THE CANADIAN ARCTIC AS MARTIAN ANALOGUES.

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Introduction: Gossans are rust-coloured surficial deposits that are generally a few dozen metres in size. They are the product of weathering in an aqueous environment of sulfide and oxide minerals in host rocks, and if large enough, can be detected using satellite imagery [1]. More than eight hundred gossanous exposures have been mapped in the Canadian Arctic [2]. Some of the gossans located on Axel Heiberg Island (Nunavut) and Victoria Island (Northwest Territories) have been studied by the Geological Survey of Canada through the years [e.g., 3,4]. These studies focused, in part, on determining their composition and spectral properties, and revealed that they can be studied as Martian analogues [3].

Indeed, as postulated by Burns (1988) [5], gossans may also exist on Mars since the environmental conditions were once favorable for their formation. Past geological activity on the red planet may have created an iron-rich bedrock vulnerable to aqueous chemical weathering at the surface. Moreover, the higher temperatures that were encountered in the past could have resulted in active oxidation reactions in the presence of liquid water [5]. The analysis of data acquired by sensors orbiting Mars such as CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) and OMEGA (*Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité*) have revealed the presence of jarosite and hematite, minerals also found in terrestrial gossans [7]. These alteration minerals, which require water during their formation, corroborate the presence of ancient hydrothermal systems on Mars. Jarosite is of particular interest as it is a biosignature: it can preserve traces of past microbial life as organic matter in its crystalline structure [8]. Martian hydrothermal systems, and potentially gossans, are thus targets of interest in the search for ancient traces of life.

Here we aim to improve knowledge on the composition and spectral properties of Canadian Arctic gossans as analogues to their Martian counterpart to assess their detection potential using satellite imagery. This study is part of the T-MARS project (Terrestrial Mineral Analysis by Remote Sensing), based at Université de Sherbrooke, QC, Canada.

Study Area: The study area is located near Expedition Fiord on central Axel Heiberg Island, Nunavut, Canada (Fig. 1). The hydrological cycles of the coldest and most arid regions on Earth are the best analogues to Mars in terms of hydrology [9]. Studies of the geological setting of the Arctic volcanic terrain alteration zones show that the region is comparable to some areas on Mars where hydrothermal systems could have existed [6,3].

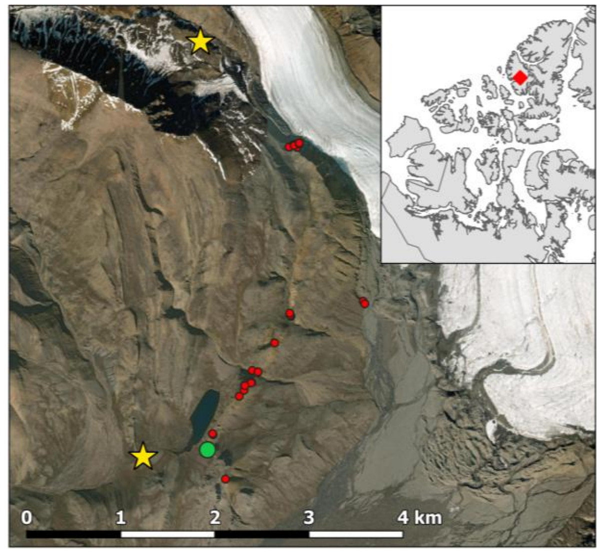

Figure 1. Gossan sampling sites (red dots) from the 2022 field campaign on central Axel Heiberg Island, Nunavut, Canada. The stars show the locations of the T-MARS base camps, and the green dot shows the location of the McGill Arctic Research Station (N 79°24’55”; W 90°44’53”).

Data and Methods: This study is based on (1) fieldwork carried out in July 2022, (2) follow up laboratory studies of the sampled gossans, and (3) remote mapping of terrestrial gossans and experimentation using Martian imagery acquired from orbiters.

Field data acquisition. The 6-person T-MARS crew established two base camps near the McGill Arctic Research Station (Fig. 1). The team was able to collect different types of gossan samples and spectral reflectance data. Sampling sites were selected to optimize the collection of samples of gossans showing differences in surface colour, degree of weathering and texture. The spectral reflectance signature of gossans was also acquired at the sampling sites when weather permitted, with an ASD FieldSpec 4 Hi-Res NG Portable Spectroradiometer. Overall, 43 surface samples were collected at 16 different gossan outcrops.

Characterization of the samples. Back in the laboratory, the samples were catalogued, air-dried, photographed, and grouped according to colour and texture. Each sample was divided into 4 sub-samples: (A) original, (B) sieved at 5 mm to remove big rocks, (C) sub-sample B lightly crushed by hand to homogenize it, (D) sub-sample C sieved at 2 mm for further analysis. The spectral reflectance signature was acquired with the portable spectroradiometer used on the field for the sub-samples A, C and D with an incidence angle of 30° and emergence angle of 0° [10]. A part of sub-sample D was used to measure the pH in a 0.01 M $CaCl_2$ solution [11]. Another part will be pulverized to characterize the mineralogical and elemental composition of the samples, in further X-ray diffraction and X-ray fluorescence analysis following the methods in Cloutis *et al*. (2015) [10].

Remote mapping of terrestrial and Martian gossans. Spectral and compositional data acquired in the laboratory will be used to create a spectral library of Martian analogue gossans. It will be used in spectral unmixing algorithms to locate gossans on a WorldView-2 multispectral image (2 m/pixel) and a PRISMA hyperspectral image (30 m/pixel). Linear and non-linear spectral unmixing will be performed using ENVI and IDL or Python programming, respectively. Despite the difficulties of using a nonlinear approach, it is more adequate for homogeneous mixture of minerals like gossans, where multiple scattering interaction occurs, and could lead to up to 30 % improvement in measurements [12,13]. The results will be validated using a database of known location of gossans in the Canadian Arctic [2]. The algorithm giving the best results will be experimented on CRISM hyperspectral images (18.4 m/pixel) of the Martian surface to explore the potential of detecting gossans on Mars.

Results: The samples were sorted by colour as a qualitative estimate of their oxidation state, from light gray (unoxidized) to yellow to brown (highly oxidized) [4]. Preliminary results show that the colour of the samples, and thus their oxidation state, has an influence on the reflectance features, which are more apparent for yellow and orange samples (Fig. 2). Of the 29 samples selected for pH measurement, 23 have been processed so far. pH ranges from 1.85 to 7.51 with two clusters: around 2.50 and 7.00. These preliminary results are consistent with those obtained in similar studies, such as Percival and Williamson (2016) [4].

Conclusions: A successful field data acquisition campaign was completed in July 2022, which resulted in the collection of 43 gossan samples. Laboratory studies in progress will characterize the mineralogy of the samples and these results will be presented at the LPSC conference. Future work will refine mapping techniques to detect terrestrial gossans with the goal of testing the same approach on Mars surficial deposits. The results could be applicable to space exploration missions as well as have implications in the search for ancient traces of life.

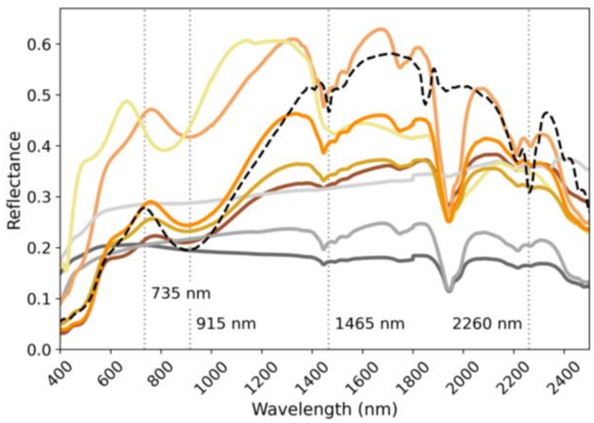

Figure 2. Laboratory-acquired spectral signatures of 8 representative gossans sampled in the study area, covering the Visible-Near Infrared (400-950 nm) and Short Wave Infrared (950-2500 nm) regions of the electromagnetic spectrum. The colour of the spectra corresponds to the natural colour of each sample. The dotted black line is the reference spectrum for Jarosite from the RELAB spectral library [14], with its main absorption feature shown by vertical lines.

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