COMPARATIVE GEOLOGIC MAPPING OF GOSSANS ON EARTH AND MARS

M. Lemelin[1], M.-C. Williamson[2], R.J. Léveillé[3], and F.R. Doucet[4]. [1]Département de géomatique appliquée, Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, QC, Canada, J1K 2R1, Myriam.Lemelin@USherbrooke.ca; [2]NRCan-Geological Survey of Canada, 601 Booth St, Ottawa, ON, Canada, K1A 0E8, marie-claude.williamson@canada.ca; [3]Department of Earth and Planetary Sciences, McGill University, 3450 University St, Montreal, QC, Canada, H3A 0E8, richard.leveille@mcgill.ca; [4]ELEMISSION inc., 3410 Thimens blvd., Montréal, QC, Canada, H4R 1V6, fdoucet@elemission.ca.

Introduction: One of the main goals in the field of planetary exploration is to document the geological record and processes that have shaped the surface of the rocky planets, their moons and asteroids. Remote sensing measurements acquired by orbital spacecraft are the first component by which this information is obtained. Spaceborne remote sensing instruments acquire data in different regions of the electromagnetic spectrum and typically provide information on the properties of planetary surfaces at the meter to kilometer scale. They are a crucial tool to establish the global to regional context of geologic processes and the precursor to discoveries made by landers, rovers and astronauts at the local scale. Landers and rovers on Mars, the Moon or comets have also relied, most of the time, on the use of remote sensing instruments to characterize the surface at such fine scale. Follow up analyses of samples, either in situ or once returned to Earth, in turn provide the most detailed information. They allow thorough mineralogical, elemental and isotopic analyses in a laboratory setting.

In this paper, we outline a project to study gossans in permafrost in the White Glacier (WG) area of Axel Heiberg Island, Nunavut, as analogues for gossans on Mars that may be linked to paleo-hydrothermal systems. Our project objectives include (1) the identification and mapping of gossans on a regional scale using high-resolution satellite imagery, and (2) laboratory analyses to further investigate the composition and biosignatures of samples collected during fieldwork.

Geological context: Gossans are highly weathered, iron-rich soils overlying bedrock (Fig. 1). On Earth, these deposits form in a wide range of geologic settings but outcrops are generally a few meters to kilometers in size. Gossans underlain by permafrost in sparsely vegetated areas of the Canadian Arctic are natural laboratories for the study of sulfates and iron oxides identified on Mars [1-2]. A recent study of gossans in two different areas of the Canadian Arctic islands (Victoria and Axel Heiberg) suggests a complex origin for deposits that form in a permafrost environment [3-4]. A key aspect of the study was the identification and mapping of gossans using WorldView-2 (WV-2) images, such as done for Gossan Hill (Fig. 2-3).

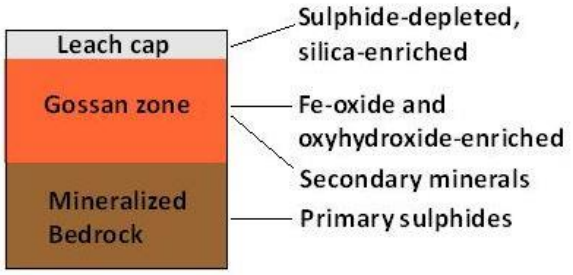

Figure 1. Schematic cross-section of a classic gossan.

Figure 2. Field photograph of Gossan Hill, Victoria Island, Northwest Territories, looking North. The structure is 400 m at the base and ~75 m high [2].

Figure 3. WorldView-2 natural composite showing Gossan Hill, Victoria Island, Northwest Territories, at centre (71.36697° N, 114.9515° W).

On both Victoria and Axel Heiberg Islands, regional mapping of igneous intrusions emplaced in a Large Igneous Province (LIP) led to the discovery of gossans [2]. Locally, the morphology and stratigraphy of gossans vary widely, but their mineralogy always includes goethite, jarosite, gypsum and silica [5]. These alteration minerals have also been identified on Mars, either from orbit or from rover-based instruments [e.g., 6]. On a local scale, the discovery of sulfate-rich sediments by the Mars Exploration Rovers led to a renewed interest in jarosite as key indicator of potentially habitable aqueous acidic conditions [7].

Analogue site: Minerals such as goethite, jarosite, gypsum and silica are thought to have formed when hydrothermal systems were active. The potential association of gossans with paleo-hydrothermal systems on Mars led us to the selection of the WG area, on central Axel Heiberg Island, Nunavut, as the analogue site for this project (Figs. 4 and 5). At the WG site, the close spatial association of perennial cold springs with paleo-hydrothermal deposits suggests that both systems were fed by fluids originating in and around evaporitic structures [8]. We hypothese that gossans are linked to the hydrothermal system at depth [9].

Data and methods: We are using WV-2 images in combination wtih the Arctic Digital Elevation Model [10] to map out small gossans closely associated with mafic intrusions of the High Arctic LIP (Fig. 4-5). Different techniques to better identify the gossans will be tested. The objective is to establish the presence of geomorphic and structural connections with the White Glacier paleo-hydrothermal system.

WV-2 is a high spatial resolution 8-band multispectral commercial satellite [10]. Since its launch in 2009, WV-2 has acquired images at a spatial resolution of 0.46 m in its panchromatic band (450-800 nm) and 1.85 m in its eight visible and near infrared bands (400-1040 nm). For the WG analogue site, we use an image that was acquired in August 2019 with minimal snow coverage and favorable illumination (Fig. 4-5).

The Arctic DEM consists in a Digital Elevation Model of high spatial resolution (2 m per pixel) that was generated by applying stereo auto-correlation techniques to overlapping pairs of high-resolution optical satellite images such as WorldView [11].

Conclusion: The search for geomorphic evidence linking gossans and hydrothermal deposits at the WG site is comparable to the approach used for mapping chaos terrain and/or hydrothermal deposits on Mars [e.g. 12, 13, 14]. Mapping of gossans at the WG site followed by ground truthing may help us understand how gossans are connected to hydrothermal systems in a permafrost environment on Earth and Mars.

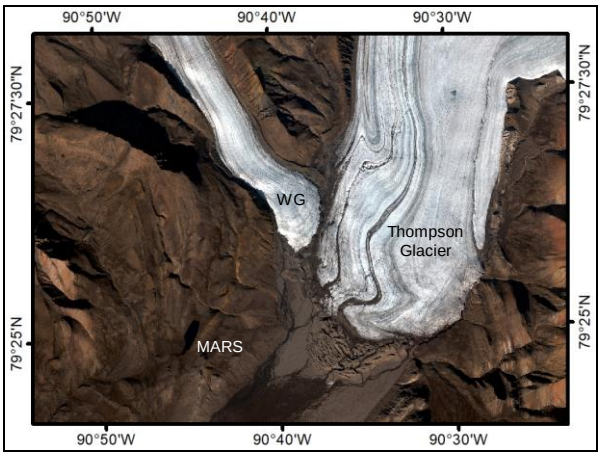

Figure 4. Location of the White Glacier (WG) analogue site at the head of Expedition Fiord, Axel Heiberg Island (WorldView-2 image). The location of the McGill Arctic Research Station (MARS) is also indicated. The image is ~12 km wide.

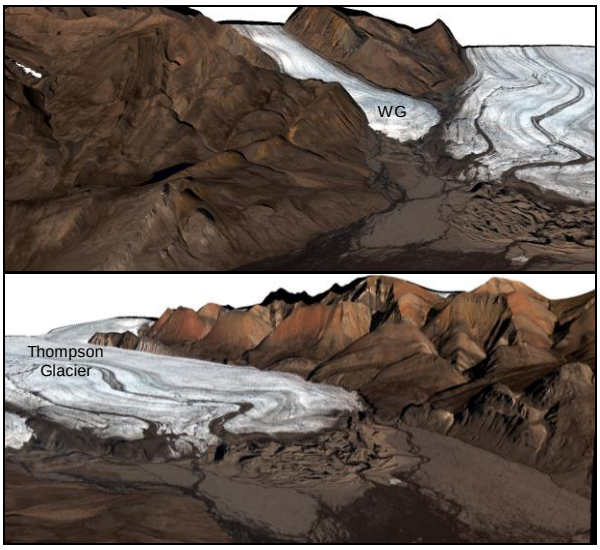

Figure 5. WorldView-2 image of the White Glacier analogue site draped over the Arctic DEM [10]. Top: Looking North. Bottom: Looking East.

References: [1] Battler et al. (2013), *Icarus*, 224. [2] Peterson et al. (2014), *EPSL*, 400. [3] Williamson et al. (2011) *GSA Special Paper* 483, 249. [4] Percival and Williamson (2016), *Applied Clay Science*, 119P2, 431. [5] Percival & Williamson (2017) *GSC Open File* 8151, 22. [6] Viviano-Beck et al. (2014), *JGR*, 119. [7] Lewis et al. *Astrobiology* 18(4), 454. [8] Zentilli et al. (2019), *Geofluids*, 9502904. [9] Wilton et al. (2019), *Can. J. Earth Sci.*, 56. [10] Ditigal Globe (2020), WorldView-2, Online. [11] University of Minnesota (2020), ArcticDEM, Online. [12] Cabrol et al. (1997), *Icarus*, 125. [13] Pedersen & Head (2011), Icarus, 211. [14] Michalski et al. (2017) *Nature Comm.*, 15978.