BRECCIAS AND GOSSANS ASSOCIATED WITH SHALLOW IGNEOUS INTRUSIONS ON EARTH AND MARS: CASE STUDIES AT TWO ANALOGUE SITES IN THE CANADIAN ARCTIC ISLANDS

M.-C. Williamson[1], M. Lemelin[2], C. L. Marion[3] and B.M. Saumur[4]. [1]Geological Survey of Canada, 601 Booth St., Ottawa, ON, K1A 0E8, Canada, marie-claude.williamson@nrcan-rncan.gc.ca; [2]Département de géomatique appliquée, Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, QC, Canada, J1K 2R1; [3]Canada Aviation & Space Museum, 11 Aviation Pkwy, Ottawa, ON, Canada, K1K 2X5. [4]Département des Sciences de la Terre et de l'atmosphère, Université du Québec à Montréal, 201 av. du Président-Kennedy, Montréal, QC, Canada, H2X 3Y7.

Introduction: Comparative studies of habitable environments on Earth and Mars have focused primarily on regional-scale deposits, structures and landforms that provide favorable conditions for microbial life to develop and persist through geological time [1]. Martian landforms such as impact structures, volcanic edifices and shallow igneous intrusions could have provided the necessary heat for hydrothermal systems to develop in the presence of groundwater [2-5]. However, investigations of acidic alteration in terrestrial basaltic subvolcanic systems also suggest that the targeted geochemical signatures can be generated on a local scale [6]. These observations open new avenues for research on small-scale hydrothermal systems associated with shallow intrusions as analogues for Mars.

Sills, Breccias and Gossans: We report the results of a comparative study of breccias and gossans associated with mafic sills from two Large Igneous Provinces (LIPs): the Franklin LIP, of Neoproterozoic age, and the High Arctic LIP (HALIP), emplaced in the late Cretaceous (Fig. 1). In both cases, the sill is associated with a breccia and gossan at the contact with sedimentary rocks.

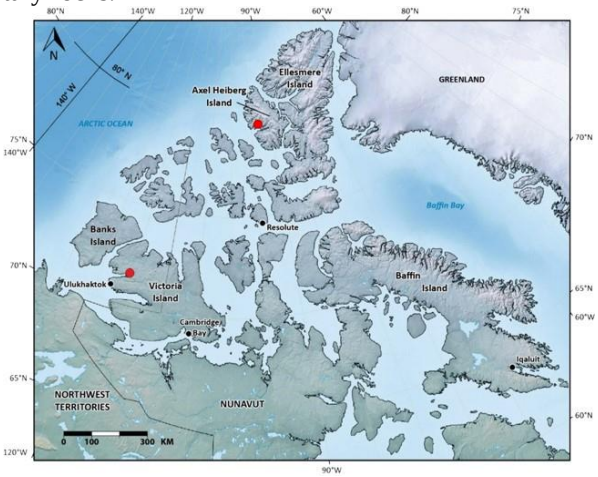

Figure 1. Map showing the location of the two analogue sites (red dots) on Victoria Island, NT, and Axel Heiberg Island, NU.

Our objectives were to (1) characterize the mineralogy and geochemistry of the gossanous soils, and (2) investigate the genetic link between the gossans and locally derived breccias.

Analogue Site 1 – Franklin Sill. Four distinct lithological units are present at this locality: the mafic sill exposed along a ridge (Fig. 2, Fig. 3A), the basal breccia (Fig. 3B), a thin layer of massive sulphides (Fig. 3C), and the gossan (Fig. 3D). The spectral signatures, mineralogy and geochemistry of the gossan have been documented [e.g., 7] and the generation of a detailed map from Worldview2 imagery is forthcoming.

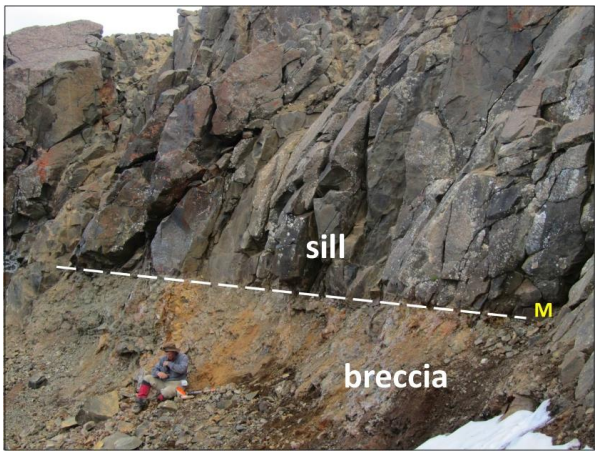

Figure 2. Photograph of the Franklin sill showing the contact with the underlying breccia (dashed line). M = massive sulphides.

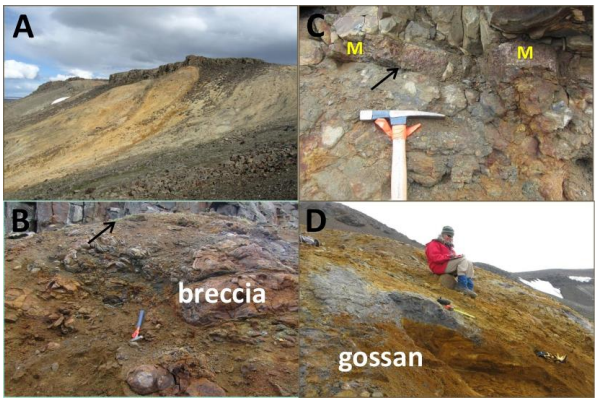

Figure 3. A. Panoramic view of the Franklin sill (ridge crest) and gossan. **B**. Basal rheomorphic breccia. The arrow points to the contact. **C**. Close up of the massive sulphides along the basal contact (arrow). **D**. Reactive gossan in permafrost showing reverse stratigraphy [7].

Analogue Site 2 – HALIP Sill: Minerals such as goethite, jarosite, gypsum, and silica are thought to have formed when hydrothermal systems were active. The potential association of gossans with the White Glacier (WG) paleo-hydrothermal system (Fig. 1) [8], led us to select this locality as the analogue site for the T-MARS project [9, 10]. Fieldwork carried out in July 2022 revealed a close spatial association between the breccia and gossan (Fig. 4). Remarkably, the two units occur alongside each other but there is no clear evidence of compositional mixing. Many of the structures within the breccia suggest an origin by fluidization during sill intrusion at shallow depths. Multi-scale studies are underway to map the geology of the area in detail [11], investigate the spectral and compositional signatures of the gossans [12], and characterize biosignatures [13]. North of the WG exposure, gossans form a linear trend that suggests a link with regional structures [e.g., 14]. These features suggest that (1) the chaotic breccia and gossan were generated during the emplacement of the HALIP sill into country rocks, and that (2) the resulting hydrothermal system was then activated on a local scale. These observations do not preclude the existence of deep faults acting as fluid conduits in and around the evaporite structures exposed in the Strand Fiord-Expedition Fiord area [15].

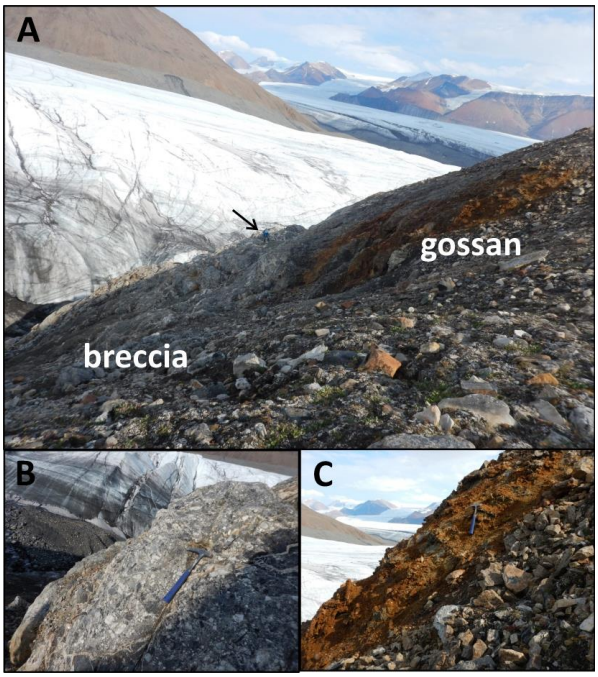

Figure 4. A. Panoramic view of the HALIP sill, breccia and gossan at the WG analogue site located at the head of Expedition Fiord, on central Axel Heiberg Island, Nunavut. The arrow points to C.L. Marion for scale. **B**. and **C.** Close up views of the breccia and gossan, respectively.

Conclusions: The search for geomorphic, structural, lithological and compositional evidence linking gossans, breccias and hydrothermal deposits in the two study areas described here is comparable to the approach used for mapping chaos terrain and/or hydrothermal deposits on Mars [e.g., 16-18]. Work is underway to compare geological maps of sills in the Franklin LIP and HALIP to estimate the range of intrusion depths and emplacement styles. Detailed mapping and sampling of these units and associated breccias and gossans on Earth may improve our understanding of the complex processes that could have led to the formation of regionally extensive hydrothermal systems on Mars.

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