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7486
GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA
2014

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ENVIRONMENTAL AND ECONOMIC IMPACT OF OXIDE-SULPHIDE GOSSANS, NORTHWEST TERRITORIES AND NUNAVUT

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THE ARCTIC GOSSANS ACTIVITY

Natural Resources Canada's **Environmental Geoscience program** focuses on the assessment of the environmental impacts of natural resource development and use, and on the development of solutions that will help mitigate risks to ecosystems and health.

The **Environmental Impact Assessment in the Northern Environment project** has the following objectives:

1. Environmental research to support sustainable development in the North.
2. Evaluating the risk of environmental impact related to mineral development.
3. Defining new methods to support the evaluation of environmental assessments.
4. **Evaluating the impact of metals in the environment e.g. potential toxic metals associated with mineralization; their phase, concentration and remobilization; and mitigation measures.**

The Arctic Gossans activity contributes to **Objective #4** as a proof of concept approach that reduces the knowledge gap between the Exploration and Environmental Assessment cycles in the North.

SCIENTIFIC HYPOTHESIS

Arctic gossans constitute analogues of how mine waste will behave in a permafrost environment. They are natural laboratories that record the processes leading to potentially acid generating mine tailings and mine waste rock in a permafrost environment, such as oxidation, metal recycling, deposition, sorting and burial.

OBJECTIVES OF THE ARCTIC GOSSANS ACTIVITY (2011-2014)

1. Locate oxide-sulphide gossans using Remote Predictive Mapping (RPM) techniques.
2. Measure the spectral signatures of surficial materials at key locations to improve the accuracy of remote predictive maps.
3. Map and sample surface materials of alteration zones and protoliths.
4. Determine the stratigraphy, mineralogy, and geochemistry of deposits to document facies and origin.
5. Integrate the results from 1-4 with stream sediment geochemical data.

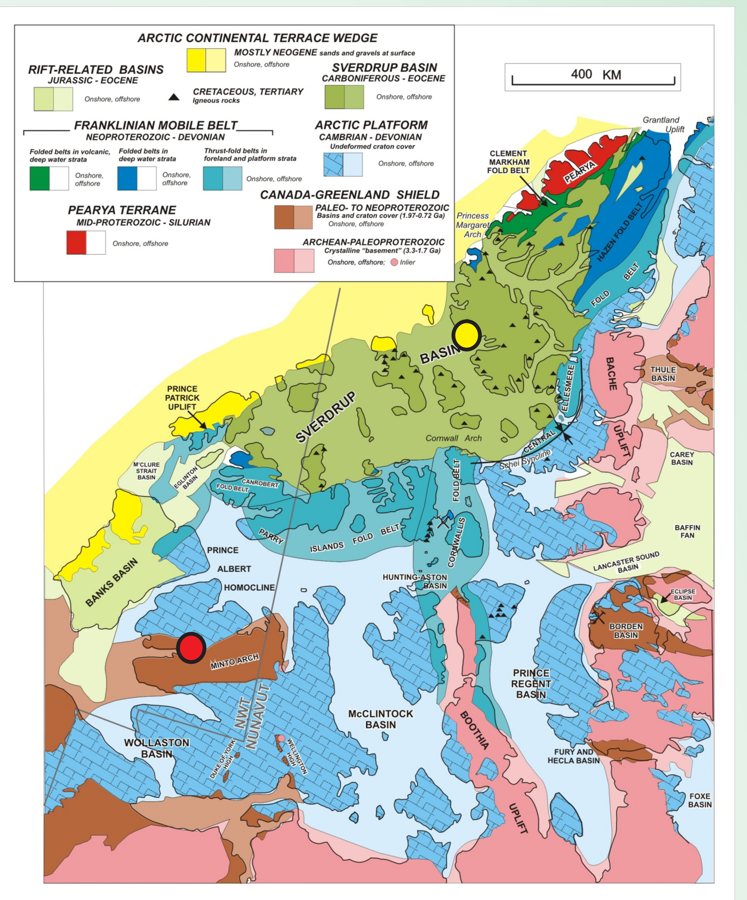

Figure 1. Location of the study areas (filled circle): red, Victoria Island, Northwest Territories; yellow, Axel Heiberg Island, Nunavut.

REMOTE PREDICTIVE MAPPING

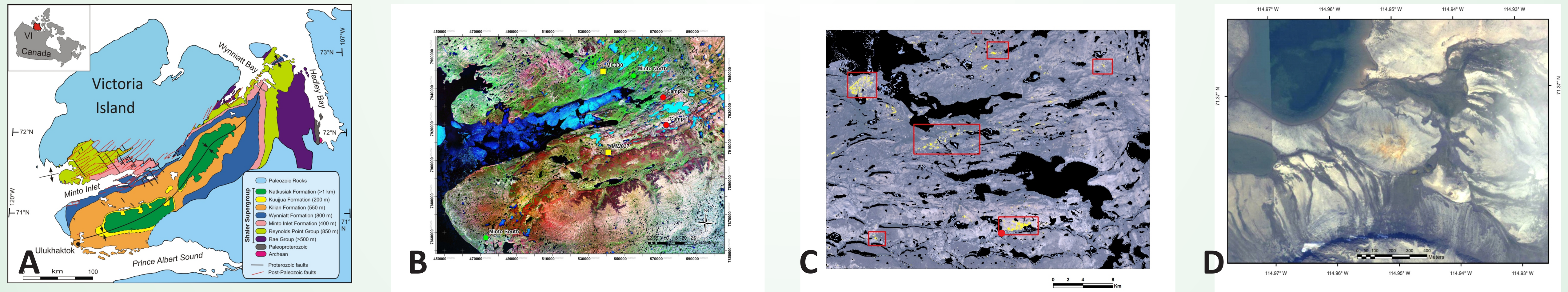

Figure 2. A. Geological map of the Minto Inlier, Victoria Island (after Thorsteinsson and Tozer, 1962; Bédard et al., 2012). **B.** Landsat-7 mosaic of the study area (Behnia et al., 2012). Note the location of Camp 1 (red dot). **C.** Close up of map [B] where yellow areas were identified using a combination of a Principal Component Transform and a 3/1 band ratio to highlight the presence of ferric iron. Camp 1 location shown as red dot. **D.** WorldView-2 (WV-2) natural composite showing Gossan Hill at the Camp 1 location (Photos NT-1, NT-2). The gossan shows up as a yellowish colour anomaly due to the high reflection of the red wavelength (Band 6) on the WV-2 optical sensor (Froome et al., 2012). The alteration zones are mappable (Williamson et al., 2011; see report).

RESULTS

1. Oxide-sulphide gossans in volcanic terrain are best detected and mapped using high-resolution WorldView-1 and -2 images.

2. Frozen pore waters in gossan pyrite sands at Gossan Hill, Victoria Island, are extremely acidic, with a pH of 2, confirming our working hypothesis that oxide-sulphide gossans could provide analogues of mine waste in a permafrost environment.

3. The mineralogy of gossans at Gossan Hill and Sill Gossan, Victoria Island, consists predominantly of gypsum, jarosite, and goethite, implying an important role for sulphate-evaporite rocks of the Kilian Formation in the genesis of these deposits.

4. The activity results suggest that the geochemistry of stream sediments and water could be modified by the presence of gossans on a local scale.

MINERALOGY

Gossans are highly weathered, iron-rich soils overlying sulphide-rich materials that can be used as exploration targets for base metal deposits. Typical gossan mineralogy: ***Goethite, Jarosite, Gypsum***.

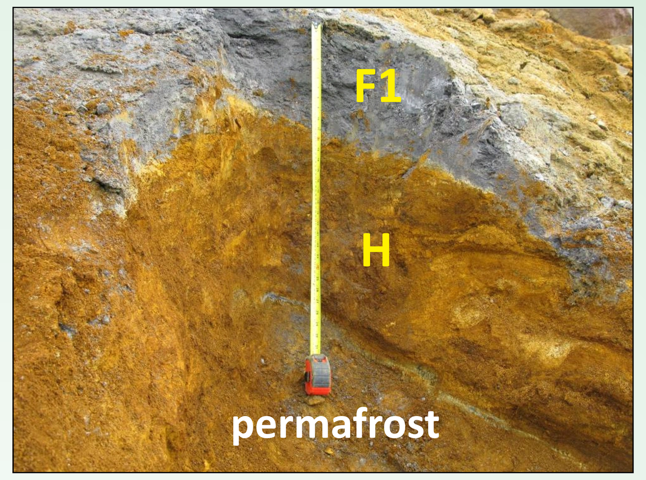

Figure 3

Figure 3. Stratigraphy at the Sill Gossan locality, Minto Inlier, Victoria Island (Photos NT-3 to NT-6; Percival and Williamson, 2013). Sample **F1** was collected at the top of the trench and is the most sulphide-rich. Sample **H** was collected at the bottom of the trench and is the most oxidized. The depth to permafrost is 80 cm at this locality.

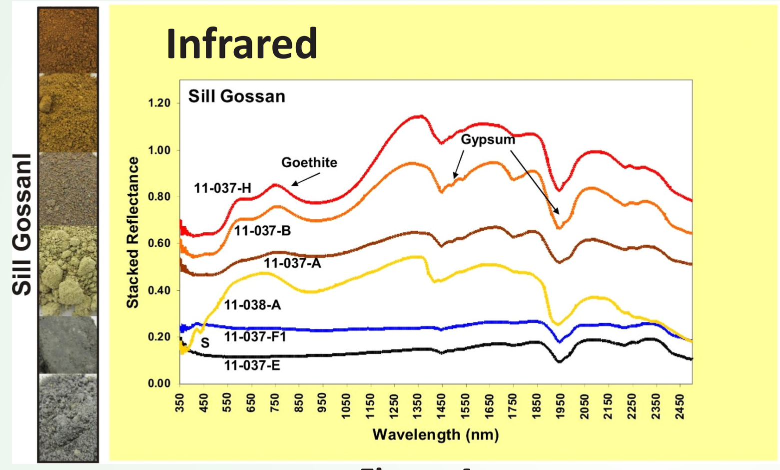

Figure 4

Figure 4. Stacked spectral reflectance profiles showing VIS-NIR-SWIR signatures of representative samples from the gossan arranged from least oxidizing to most oxidizing (samples as depicted on left hand side). Dark samples produce flat spectra; highly coloured samples improve the reflectance characteristics.

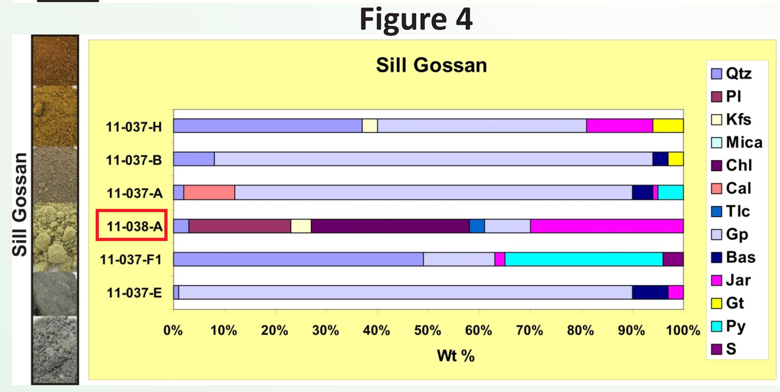

Figure 5

Figure 5. Quantitative mineralogy (X-Ray Diffraction) of samples arranged from least oxidizing to most oxidizing (left-hand side). Note the presence of sulphur in sample **11-038-A** (red square); and of gypsum and goethite as the samples become more oxidized. Remarkably, the most sulphide-rich sample (11-037-**F1**) is located at the top of the pit whereas the most oxidized sample (11-037-**H**) occurs at the bottom of the trench just above permafrost. This sequence is the opposite of what is expected in a classic gossan profile (Fig. 6).

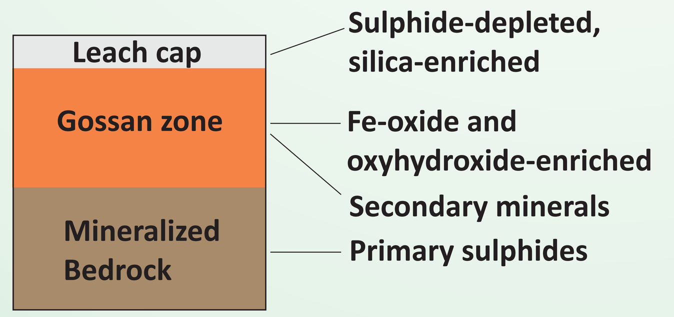

Figure 6. Schematic diagram of a classic gossan profile.

Recommended Citation
Williamson, M.-C., Percival, J.B., Behnia, P., Harris, J.R., Peterson, R.C., Froome, J., Fenwick, L., Rainbird, R.H., Bédard, J.H., McNeil, R.J., Day, S.J., Kingsbury, C.G., Grunsky, E., McCurdy, M.W., Shepherd, J., Hillary, E.M., and Buller, G., 2014. Environmental and economic impact of oxide-sulphide gossans, Northwest Territories and Nunavut; Geological Survey of Canada, Open File 7486, 10 p. and poster. doi:10.4095/293922

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doi:10.4095/293922

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GEOCHEMISTRY

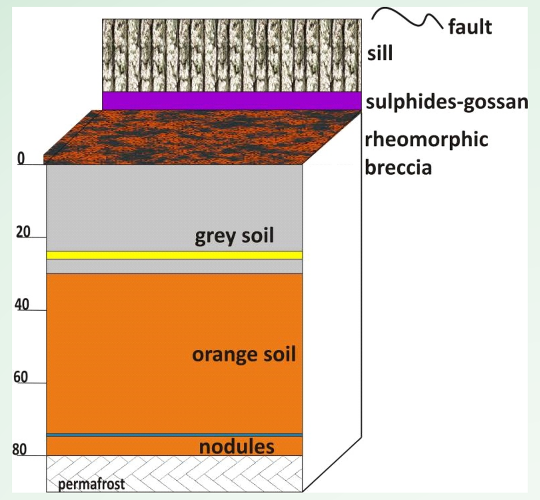
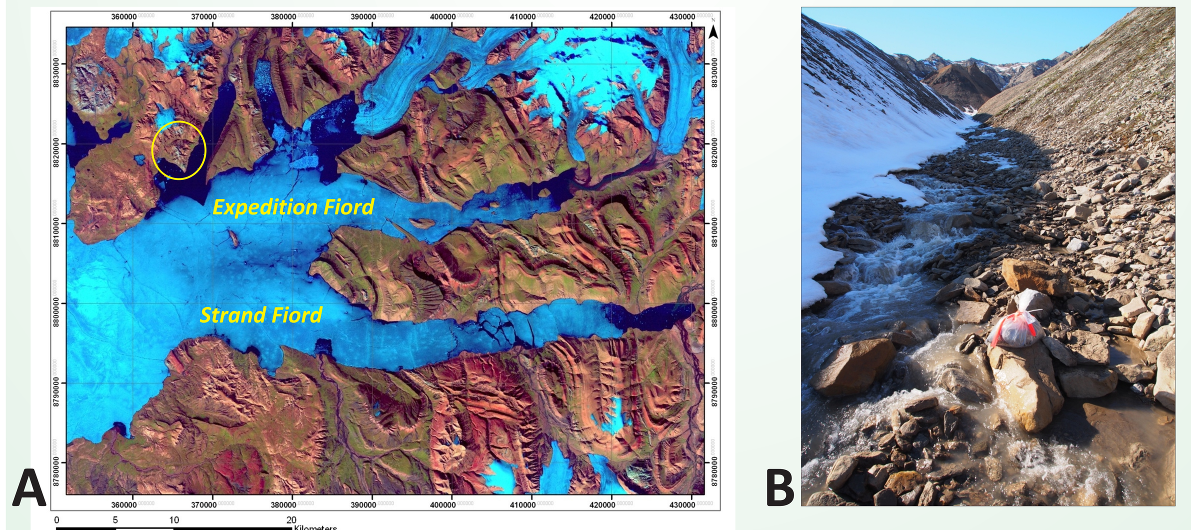


Figure 7. Schematic diagram of the field relationships at Sill Gossan. The soils at this locality uniquely record the development of an inverted gossan profile (photo NT-6). The concentrations of Cu, Ni, Co, Cr, S and Au in (a) the sill protolith, (b) a fault-related gossan, and (c) the soils analysed for this study (Fig. 3) are shown in Table 1. These preliminary results suggest a complex origin and significant economic potential. The geochemical data will be compared to results obtained for a sill gossan on Axel Heiberg Island (photos NU-7 and NU-8).

GEM-Victoria Assay / This Study	/ ĵ (ppm)	Ni (ppm)	Co (ppm)	Cr (ppm)	S wt%	Au (ppb)
nearby fault in sill rock	147	92	40	226	0.45	< 2
lower chilled margin sill	125	73	29	175	0.61	6
sulphides - gossan	16	19	**92**	9	**> 20.0**	**30**
rheo breccia 1	**414**	**125**	35	**331**	2.93	< 2
rheo breccia 2	82	98	14	298	2.33	< 2
grey soil	17	11	13	13	4.61	nd
orange soil	74	19	19	110	5.37	nd
nodules	125	**109**	39	**394**	2.31	nd

STREAM SEDIMENTS



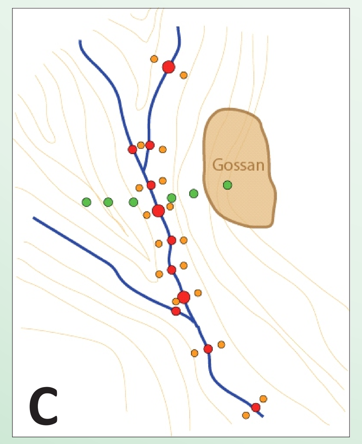


Figure 8. A. Enhanced Landsat-7 mosaic of the Strand Fiord-Expedition Fiord area showing the location of the study area on Axel Heiberg Island, Nunavut (see Open File report for details). **B.** Photograph of stream sediment/heavy mineral concentrate sampling site. **C.** Idealized sampling plan of a detailed drainage study to identify the areal extent, mineralogical and geochemical signatures, and dispersion down drainage of a known gossan. Filled circles designate samples of stream heavy mineral concentrates (red, large dot); stream silt (red, small dot); base of slope regolith (orange); and till/soil (green).