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Nunavut, Canada: A Field Report**

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The 2013 Isachsen Expedition to Axel Heiberg Island, Nunavut, Canada: A Field Report

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INTRODUCTION

The poster presents the results of field work carried out in July 2013 for the Geological Survey of Canada's Arctic Gossans Activity. The poster was presented at the Annual Meeting of the Geological Society of America held in Denver, Colorado, USA, on September 27, 2013 (Kingsbury et al., 2013).

The report describes each section of the poster. The list of references includes publications cited in both the poster and report.

BACKGROUND INFORMATION

Gossans consist of highly weathered, Fe-rich soils overlying sulphide-rich materials that can be used as exploration targets for base metal deposits. The Arctic Gossans activity was approved in 2011 as a proof of concept to investigate the fate of toxic metals in a permafrost environment. The 3-year activity was funded by the Environmental Impact Assessment project (Northern Environment) of the Environmental Geoscience Program¹. Field work on gossans located in central Victoria Island, Northwest Territories, confirmed the underpinning scientific hypothesis:

Arctic gossans constitute analogs 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 mineralogical occurrences; metal recycling; deposition, sorting and burial; oxidation rates; distribution and effect of ice lenses; seepage flow-paths; etc.

Gossans that react with the permafrost environment are a rare occurrence on Victoria Island. The 2011 field team mapped and sampled gossans at two localities (Peterson et al., 2012; Williamson et al., 2012). Mineralogical studies showed that evaporite beds in the sedimentary succession contribute to the formation of gossans and that their origin is complex (Williamson et al., 2013). However, the databases collected on Victoria Island provided only partial information to propose a genetic model. This is because the environment is *static* - the acid permafrost containing pyrite sands at Gossan Hill, for example, has been preserved in this state since the last glaciation but the acid generation process is poorly understood (Peterson et al., in press).

On Axel Heiberg Island, the environment is *dynamic*: evaporite diapirs intruding the Mesozoic succession of the Sverdrup Basin show evidence of rising since the last glaciation (Zentilli et al., 2006; Jackson and Harrison, 2006; Harrison and Jackson, 2010). There are dozens of perennial springs and gossans or alteration zones associated with evaporite domes in the Strand Fiord-Expedition Fiord area (e.g. Battler et al., 2013; Williamson et al., 2011). The rationale for a field campaign in the final year of the activity was based on the necessity to document real-time, measurable geologic events that could be the cause of the formation of gossans encased in acidic permafrost on Victoria Island and Axel Heiberg Island. In both areas, the host rocks consist of continental flood basalts and associated intrusive rocks. As a result, a better understanding of the origin and evolution of gossans in such environments also carries important implications for Ni-Cu-PGE prospectivity (Bédard et al., 2012; Williamson et al., 2014; Jowitt et al., 2014).

¹ <http://www.nrcan.gc.ca/earth-sciences/about/current-program/environmental-geoscience/11989>

POSTER CONTENTS

Remote Predictive Mapping

The small size of most gossans (15 m to less than 1 km in length) requires careful search and analysis through remote predictive mapping (RPM) prior to any field work. RPM reduces the risk and cost of field work in remote areas of Canada's North by enabling the detailed planning of foot traverses in geologically complex areas (Harris, 2008; Harris et al., 2012). As was the case for central Victoria Island, the volcanic terrain on Axel Heiberg Island was ideal for conducting a remote predictive mapping exercise to detect and map gossans using various optical imagery (Behnia et al., 2012). The results of the RPM exercise are pertinent to spectral reflectance studies (Froome et al., 2012) and provide a tool for the selection of earth observation data that could reveal the presence of gossans in advance of field mapping.

Igneous Rocks

The poster highlights mafic igneous rocks that were mapped and sampled in the study area as part of a PhD thesis project carried out at Carleton University (Kingsbury, 2013). The objectives were to (1) document the style of eruption in the Early Cretaceous Isachsen Formation, and compare the results with previous work in other parts of Axel Heiberg Island, and Ellef Ringnes Island in particular; (2) conduct geochemical and geochronological studies; and (3) compare the results with previous work on mafic rocks from the circum-arctic High Arctic Large Igneous Province (HALIP). Important discoveries made during bedrock mapping included the complex field relationships between volcanic rocks, sills and dykes in the Isachsen Formation; and evidence for the presence of ultramafic sills.

Gossans

The poster highlights three types of gossans that were mapped and sampled in the study area: (1) a gossan associated with volcanic and sedimentary rocks in the Isachsen Formation; (2) a gossan associated with sill emplacement that is comparable to one of the gossans investigated on Victoria Island (Williamson et al., 2014); and (3) gossans closely associated with evaporite diapirs. Two of the three types of gossans displayed reactive zones with permafrost but in all cases the stratigraphy is complex, and the soils, acidic. Field relationships provided important clues on the origin of gossans associated with mafic sills rafted in evaporite diapirs.

Stream Sediments

The stream sediment study on Axel Heiberg Island represents a benchmark survey for future research and exploration concept development in this area. Two types of studies were carried out: (1) a detailed study was aimed at evaluating the downstream dispersion of a known gossan; (2) a regional survey of the area provided new stream-sediment and water geochemistry coverage to yield indicator mineral samples for the evaluation of the region's bedrock geology and mineral potential.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the scientific and technical support of the Arctic Gossans team (Environmental Geoscience Program, Earth Sciences Sector) and HALIP research team (Carleton University). Aircraft and logistics support was provided by the Polar Continental Shelf Program, Natural Resources Canada (Project 003-13). Special thanks to G. Hartery for helicopter support. Cole G. Kingsbury acknowledges thesis supervisors Richard E. Ernst and Brian L. Cousens for financial support through an NSERC-CRD Grant “A new tool for Canada’s exploration industry: using the large igneous province record to reconstruct supercontinents back to 2.7 Ga”. Rob Rainbird provided a critical review of the poster and report.

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UNIVERSITY



OBJECTIVES

Remote Predictive Mapping

An important goal of the field campaign was to test the use of satellite images and remote predictive mapping techniques in advance of bedrock mapping (RPM; Harris, 2008). Satellite images used for the 2013 Isachsen Expedition include Landsat-7, Aster, and Spot-5 integrated with air photographs and other base maps into a Geographic Information System.

Igneous Rocks in the High Arctic Large Igneous Province (HALIP)

1. Style of eruption in the Isachsen Formation.
2. Comparison with the stratigraphy in other parts of the Sverdrup Basin.
3. Lithochemistry of mafic rocks.
4. U-Pb geochronology to resolve the age of intrusive rocks in the Canadian component of the HALIP.

Gossans

1. Remote Predictive Mapping (RPM) to detect gossans.
2. Measure the spectral signatures of surficial materials at key locations to improve the accuracy of RPM.
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.

Stream Sediments

1. Detailed Study: Identify the geochemical and physico-chemical signatures of (a) gossanous zones and evaluate the downstream dispersion; and (b) an evaporite dome by sampling/analyses of stream sediment and water.
2. Regional Survey: New regional stream sediment and water geochemistry coverage combined with indicator mineral samples for evaluation of the region's bedrock geology and mineral potential.

REMOTE PREDICTIVE MAPPING

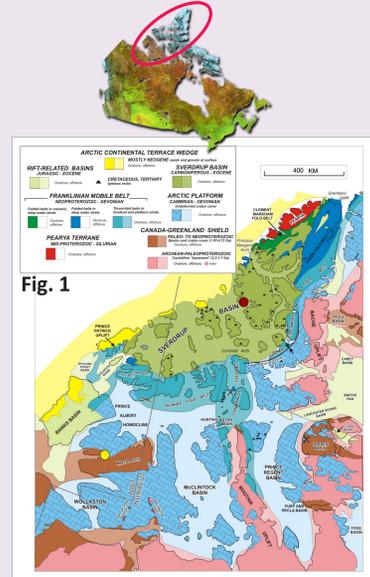


Fig. 1 Simplified geology of the Queen Elizabeth Islands (contributed by C. Harrison) showing the location of 2011 (yellow dot) and 2013 (red dot) study areas on Victoria Island, NT, and Axel Heiberg Island, NU.
Fig. 2 [A] Team logistics involved a 2-hour flight from PCSP Base Resolute to the Strand Fiord airstrip by Twin Otter aircraft. **[B]** Camp personnel, equipment, instruments and supplies were flown by helicopter from the Strand Fiord airstrip to Expedition Fiord.
Fig. 3 View of base camp on July 10, 2013.

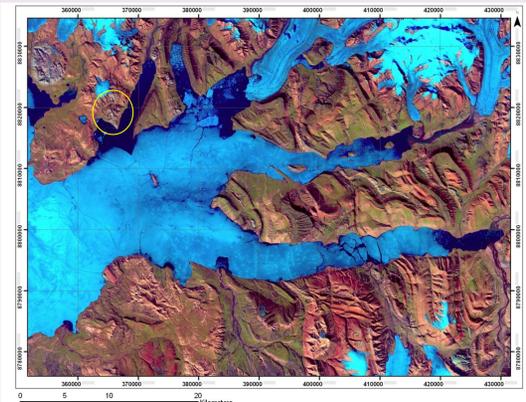


Fig. 4 Landsat-7 mosaic of the Strand Fiord-Expedition Fiord region showing the location of the study area (yellow circle; Lyon et al., 2006). Classification methods comparable to those described by Behnia et al. (2012) were applied for RPM prior to deployment.

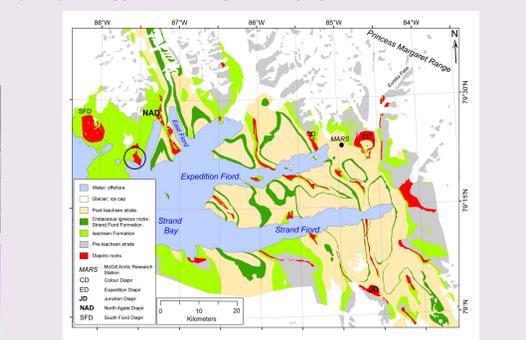


Fig. 5 Bedrock geology of the Strand Fiord-Expedition Fiord area (Harrison and Jackson, 2010). The black circle shows the location of the study area.

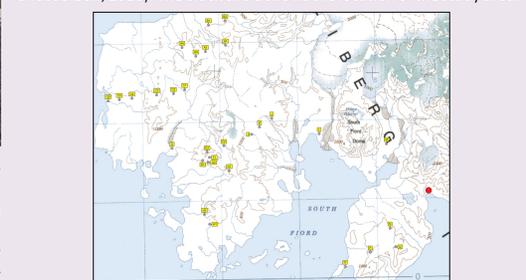


Fig. 6 Map of the study area showing the flight plan for helicopter-supported sampling of igneous rocks on the South Fiord peninsula. The map was produced on site using OziExplorer software. The red dot shows the location of base camp.

IGNEOUS ROCKS

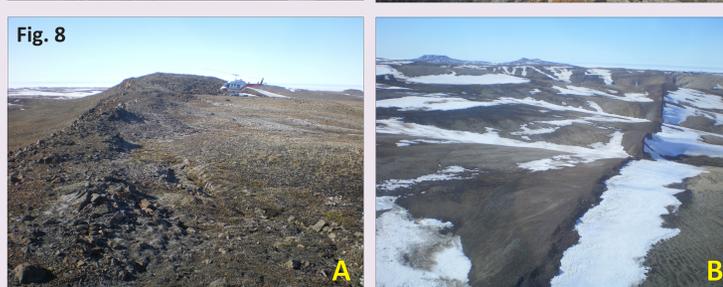


Fig. 7 [A] View of the stratigraphic succession that will form the basis of our understanding of the eruptive style in the Isachsen Formation. At this location, the section consists of alternating beds of black shale and tan-coloured sandstone. Two basaltic flows are visible in this image: (1) a ~2 m thick flow displaying crude columnar jointing crops in the centre of the succession; and (2) a ~10 m thick flow that forms a prominent cap, and extends laterally over several kilometers. Cole Kingsbury is standing at the site where gossanous soils were sampled for mineralogical and geochemical analysis (photos 10A, 10B). **[B]** Close up view of thin, glassy flow in the Isachsen Formation. Hammer is 30 cm in length.
Fig. 8 [A] Dyke sampled on South Fiord peninsula (Fig. 6) for a PhD thesis project on geochemical and geochronological studies of the Canadian HALIP (High Arctic Large Igneous Province; Kingsbury, 2013) **[B]** Aerial view of a dyke intruding the Isachsen Formation. Dykes appear to be typically thin (< 5 m) when compared to sills.
Fig. 9 Perspective showing the outcrop characteristics of a ~40 m thick coarse grained sill which may be ultramafic in composition. **[A]** Columnar jointing in the upper 2-3 m of the sill and spheroidal weathering. **[B]** Close up of the outcrop at the top of the unit showing the coarse grained character of the sill. U-Pb geochronology, whole rock, and radiogenic lithochemistry will be performed on samples collected from this location in order to elucidate tectonic significance, mantle source chemistry, crustal contamination processes and prospectivity of sills and dykes as host rocks for Ni-Cu-PGE mineralization.

GOSSANS



Fig. 10 [A] Gossan associated with the basal portion of the volcanic and sedimentary succession illustrated in Fig. 6 A. The gossan appears homogeneous at the surface but trenching reveals a complex stratigraphy and acidic soils. **[B]** Cross section of the gossan from the surface layer to permafrost showing the cyclic nature of the stratigraphy. Each layer is exquisitely preserved. Careful sampling and analysis of individual layers will clarify the processes that led to the formation of this unique occurrence.
Fig. 11 [A] Gossan developed at the base of a mafic sill (Cole Kingsbury for scale). Black shales are associated with the sill and gossan but the contact relationship is unclear. This type of gossan was also found in the Minto Inlier of central Victoria Island in 2011 (Williamson et al., 2014). **[B]** A cross section of the gossan revealed poorly-developed stratified layers and acidic soils.
Fig. 12 [A] A third type of gossan occurs in close association with evaporite domes. The photograph shows the conical features that were investigated during field work (yellow arrows). **[B]** These features could represent mafic sills that are deformed, segmented, and altered by fluids circulating in and around the evaporite dome as it rises over time.

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STREAM SEDIMENTS

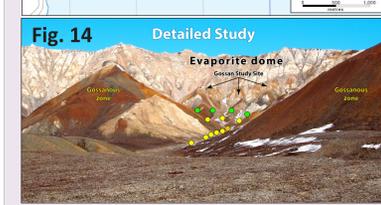
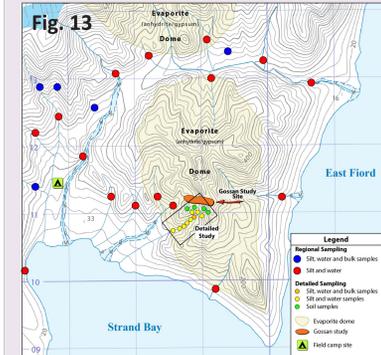


Fig. 13 Location map showing regional stream sample sites and sample locations in the study area.
Fig. 14 Detailed stream study sites within the evaporite dome and associated gossanous zones. These evaporite domes form topographic highs and represent drainage divides between catchment basins.
Fig. 15 Filtering water sample with 0.45um filter into 60ml HDPE bottle.
Fig. 16 Approximately 2 kg of silt and clay were collected from the lower energy part of streams into a cloth bag.
Fig. 17 ~ 12 kg of bulk sediment for heavy minerals were collected by wet-sieving with a 12-mesh sieve in higher energy part of streams into large plastic bags.
Fig. 18 Field equipment used and samples collected at a typical stream site.
Fig. 19 Schematic diagram illustrating an idealized sampling plan of a detailed drainage study to: (1) identify the areal extent of the geochemical and mineralogical signatures and (2) the dispersion down drainage of a known gossan. The resulting dataset will be an important tool in interpreting the regional datasets and identifying unknown gossanous areas.
Fig. 20 Typical moderately flowing immature stream intermixed with boulders, cobbles, gravel and fines. The shovel shows the location of bulk sample collection.

