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Reconnaissance geological mapping and thematic studies of northern Brock Inlier, Northwest Territories

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Foreword

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the summer 2014, GEM's new research program has been launched with 14 field activities that include geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, northerners and their institutions, academia and the private sector. GEM will continue to work with these key collaborators as the program advances.

The **Brock Inlier project** is an activity within the **Shield to Selwyn geo-transect: studying the evolution of sedimentary rocks of the northern mainland NWT to improve exploration success:** This activity will initiate the first regional integrated effort to place Proterozoic to Cenozoic strata of Mackenzie Platform, Selwyn Basin, and adjacent regions into a fully modern tectono-stratigraphic and metallogenic framework, and will better enable industry and northerners to responsibly find and develop energy and mineral natural resources, maximizing their economic and societal impact (Figure 1).

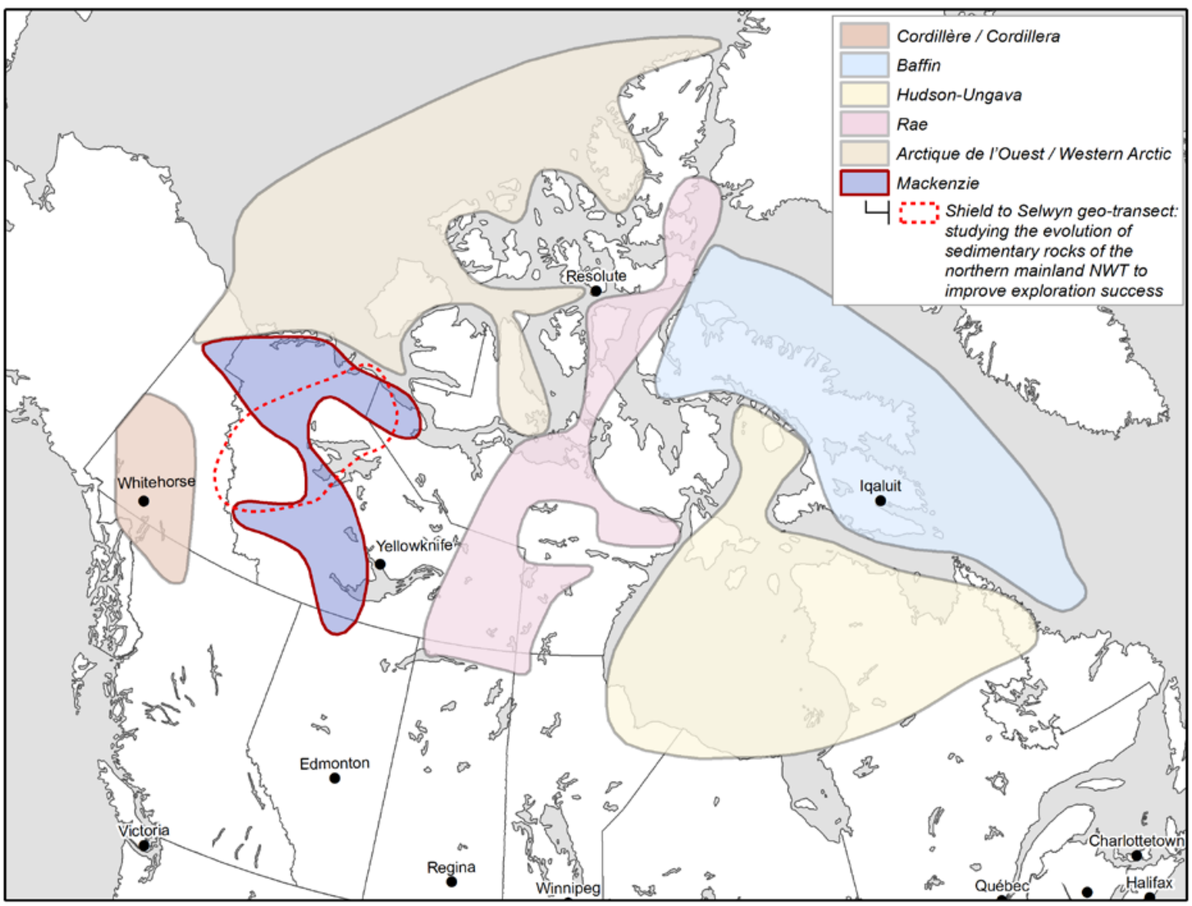

Figure 1. GEM2 Program areas of interest. Brock Inlier is at the northern extremity of the area enclosed by the red dashed line.

Introduction

The goal of this project is to upgrade geoscience knowledge in the Brock Inlier, a large window of mainly late Mesoproterozoic to early Neoproterozoic sedimentary rocks with affinities to the Minto Inlier on Victoria Island (GEM1 activity) and the Mackenzie Mountains to the southwest (e.g. Rainbird et al. 1994; 1996). The inlier overlaps the eastern edge of the largest coincident gravity and magnetic anomaly in North America (Darnley Bay Anomaly; Figure 2), which has long-been speculated by the mining industry as being due to a deeply buried Ni-Cu-PGE magmatic sulphide deposit on the scale of Sudbury or Noril'sk. Our work is, in part, intended to decrease potential exploration investment risk by increasing the level of detail of scientific information in the surrounding region.

Prior to the 2014 field season, our intention was to: 1) Acquire magnetotelluric data along an E-W transect to see how strata exposed in the Brock Inlier continue westward into the region over the geophysical anomaly, which is covered by younger sediments (Figure 2). These data would also potentially image the top of the anomaly, thereby providing a more accurate assessment of its depth. 2) Measure and describe unstudied stratigraphic sections of the Rae Group along the Brock River. Stratigraphic information from these sections will contribute greatly to our understanding of geological linkages between, and evolution of the Mackenzie Corridor and Arctic Islands. 3) Assess the accuracy and density of previous geological mapping/observations in the Brock Inlier and address the feasibility of mounting a field mapping program there for 2015 and 2016.

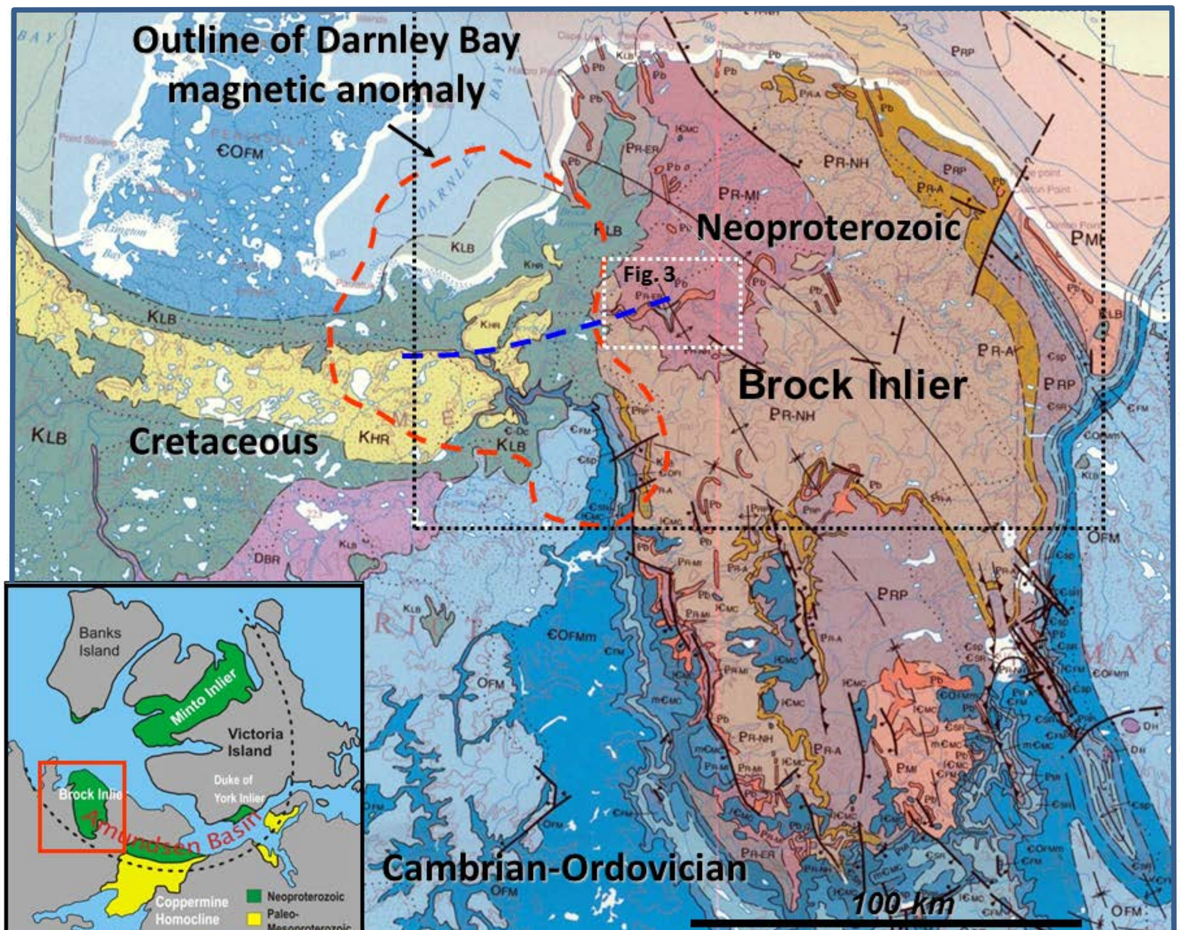

Figure 2. Geology of Brock Inlier (Okulitch, 2000); blue dashed line is location of proposed magnetotelluric survey and fine dashed black line is outline of NTS 97D (Brock River) map sheet. Geology from. Inset shows location of the Brock Inlier relative to other Proterozoic inliers of northwestern Canada.

Methodology

Detailed Stratigraphic and Sedimentological studies

Strata of the Mikkelsen Islands Fm., exposed along approximately 13 km of the Brock River canyon (Figure 3), were measured in detail at eight overlapping sub-sections. A range pole was used to measure increments at decimeter- to metre-scale. Lithofacies and stratigraphic patterns were described in the same level of detail. Samples collected at ~ 2 m intervals will be used to evaluate regional correlations using carbon isotope stratigraphy. The formation's stratigraphic succession is seemingly monotonous at outcrop scale and, aside from several conspicuous diabase sills, generally lacks obviously distinctive layers that can be used to link the almost flat-lying subsections to one another; successfully doing so was the most challenging part of documenting this formation's lithostratigraphy.

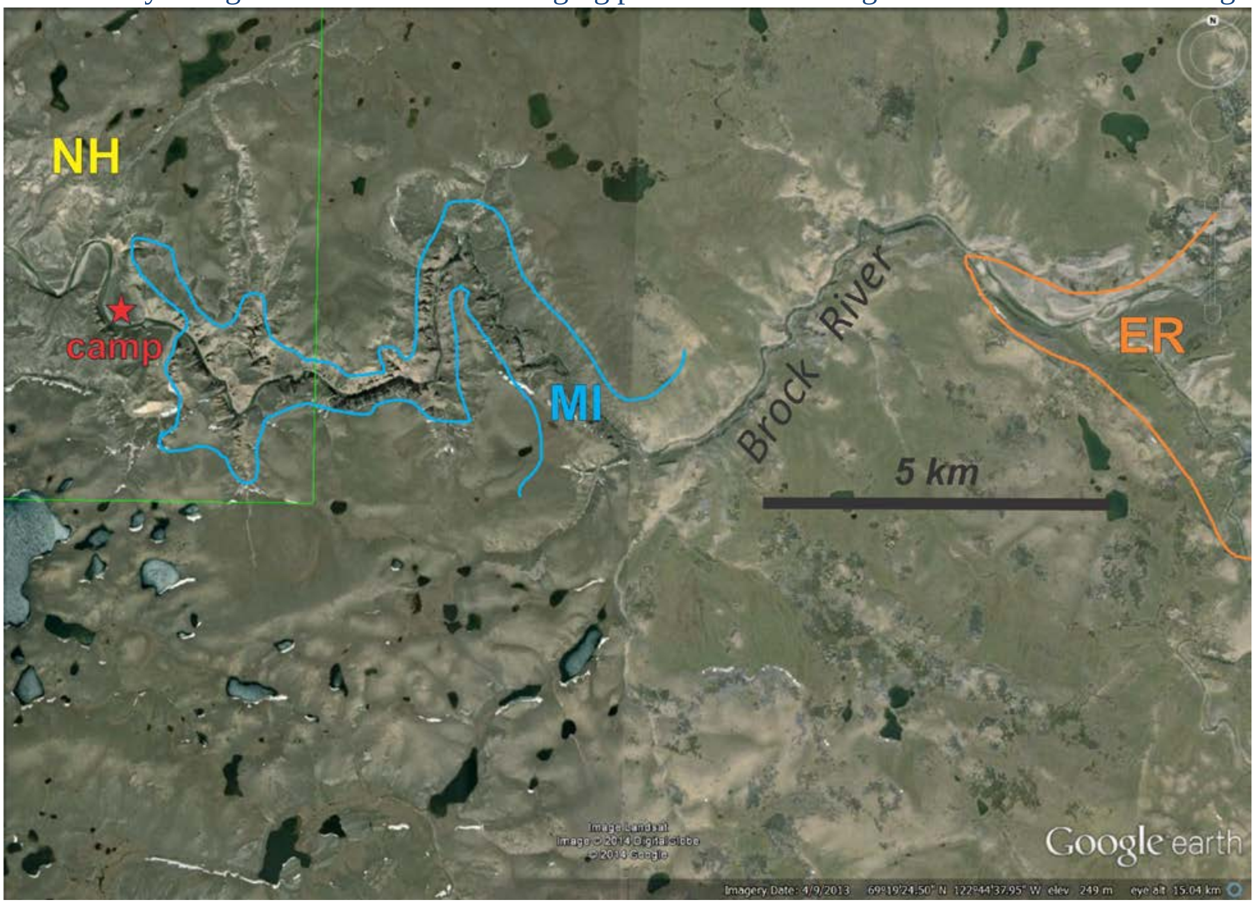

Figure 3. Google Earth image showing location of camp site and distribution of main geological units in the Brock River canyon. NH=Nelson Head Formation, MI=Mikkelsen Islands Formation and ER = Escape Rapids Formation. See Figure 2, for location.

Strata of the Nelson Head Formation are exposed along a 3 km-long segment of the Brock River canyon immediately to the west of the westernmost exposure of the Mikkelsen Islands Formation (Figure 3), which it sharply but conformably overlies. Bedding dips toward the west with the base of the section being steeper (up to 50 degrees), then progressively flattening up-section and westward (down to 10 degrees).

Stratigraphic sections were measured via bed-by-bed logging of superb cliff-side exposures. Depositional architecture assessments were performed through line drawing and measurement of relative dip of inclined depositional surfaces with respect to bounding surfaces (e.g. bedding). Two main exposures were used to collect data on depositional architecture: the first is oriented parallel to the regional bedding and has a lateral extent of some 300 m; the second one is oriented perpendicular to the regional bedding and has a lateral extent of some 800 m. Stratigraphic correlation between the two was aided by the limited deformation of the deposits and by the occurrence of a laterally extensive dark-red interbed. Detailed paleoflow analysis of architectural elements was conducted by measurement of crossbed foreset inclination and primary current lineation.

Geochronological Studies

Samples of heavy-mineral bearing sandstone were collected from the base and the top of the Nelson Head Formation and from the top of the Mikkelsen Islands Formation for detrital zircon U-Pb geochronology (Rayner and Rainbird, 2013). Samples of organic-rich shale from the top of the Escape Rapids Formation and from the base of the sharply overlying Mikkelsen Islands Formation were collected for Re-Os geochronology at the University of Alberta (van Acken et al., 2013). Shale samples will also be used for micropaleontological studies by E. Javaux (Université de Liège).

Reconnaissance geological mapping

A regional reconnaissance geological survey was undertaken to assess the need for, and feasibility of, future regional geological mapping. Helicopter traverses were conducted mainly to the north, northeast and south of our field camp, located at the mouth of the Brock River canyon (Figure 3). Traverses were confined to NTS 97A (Brock River) map sheet.

Results

Magnetotelluric Survey

Our planned magnetotelluric survey was postponed due to potential disturbance to caribou in the proposed transect area. The local Hunters and Trappers Council recommended all-terrain vehicles be used for deployment of our instruments; however, it was determined that this was not feasible as it might compromise the integrity of the instruments and would increase the time required to move the instruments between stations. It is anticipated the survey will be conducted in 2015 after receiving endorsement to do so by the Inuvialuit Land Administration (ILA).

Stratigraphic analysis of the Mikkelsen Islands Formation

The Mikkelsen Islands Formation in Brock Inlier is approximately 575 m thick (Figure 4). Its lower contact is abrupt and undulatory, cross-cutting layering in underlying siltstone of the Escape Rapids Formation. Its upper contact with Nelson Head Formation sandstone is abrupt but non-erosive, unlike in the northern Minto Inlier, where it is unconformable with features of paleo-weathering (Rainbird et al., 1992).

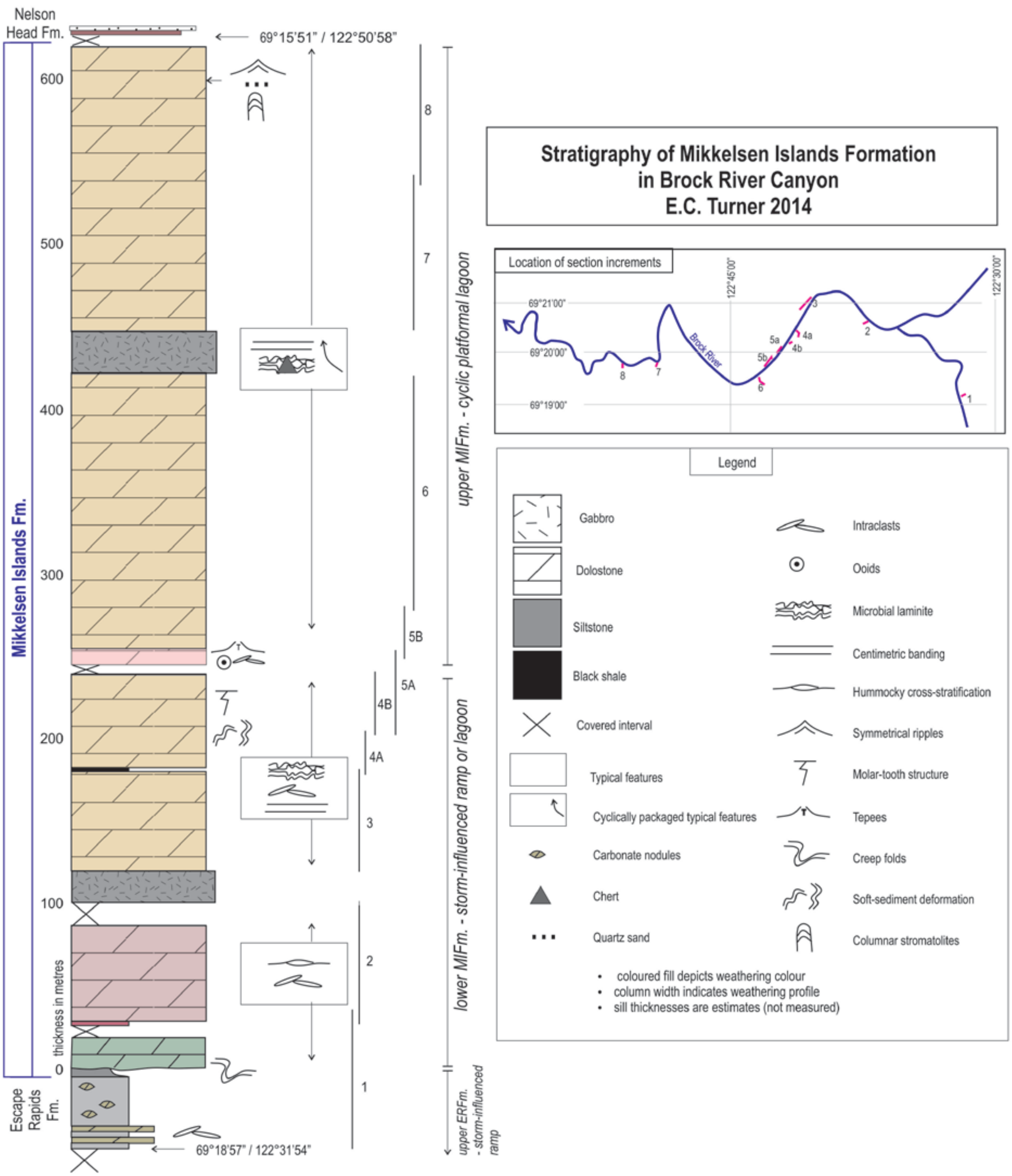

Figure 4. Mikkelsen Islands Formation section from the Brock River Canyon.

The lowest 100 m of the formation consist of intraclastic, ripple-cross-laminated, quartz-silty dolostone with local hummocky cross-stratification and intraclast rosettes, and is predominantly red-weathering owing to minor argillaceous content. The remainder of the formation is generally grey-, yellow-, buff-, and black-weathering. The lowest 60 m of strata consist of banded and microbially laminated dolostone, and are overlain by a 7 m-thick recessive interval that contains a 0.5-metre-thick black shale layer (Re-Os sample). The overlying ~60 m are dominated by banded and mechanically laminated dolostone with HCS, minor intraclasts in rosettes and lenses, three one-metre-thick layers containing molar-tooth structure, and two one-metre-thick layers containing soft-sediment deformation structures ("seismites"). Approximate thickness of this lower, storm-influenced part of the formation is 220 m (subsections 1 to 5a).

The section passes upward into a succession exhibiting conspicuous cyclicity (subsections 5b to 8). The lowest ~10 m are dominated by pink-weathering, ooid-intraclast dolograinstone alternating with intercalated layers of centimetrically banded dolostone and white-weathering tepee dolostone layers. The overlying ~345 m consist of alternating pale grey-weathering and medium brown-weathering dolostone in cycles that are typically 1-2 m thick. The lower part of each cycle consists of brown-weathering microbial laminite, commonly silicified with grey (rarely black) chert, and an upper part consisting of centimetrically banded dolostone, which in some layers contains ooids and intraclasts. Very rare, decimetre-thick layers of cross-laminated intraclast dolograinstone are present. One layer of symmetrical, ripple cross-lamination approximately 15 m below the top of the measured section contains fine quartz sand (detrital zircon sample); this layer is immediately underlain by the only columnar stromatolites in the formation (layer ~2.5 m thick). No other changes in lithostratigraphic patterns or lithofacies are present in the uppermost part of the formation. Strata exposed below the contact in a different location with better exposure show no evidence of change in lithostratigraphic patterns or lithofacies below the contact, and no obvious evidence of karstification or other meteoric diagenesis. Approximate thickness of the upper, cyclic part of the formation where measured is 355 m.

Sedimentological Analysis of the Nelson Head Formation

The lower Nelson Head Formation comprises ~150 m of sandstone capped by a thick mudstone-dominated unit and records the vertical and lateral alternation of: (1) coarse-grained, tan-yellow sandstone with scattered floating pebbles and, (2) subordinate, recessive, maroon-red, fine-grained silty sandstone. Sandstones are quartz arenite with common concentrations of heavy minerals defined by dark laminae. Bedsets are 2 to 8 m thick and laterally continuous for >800 m along strike and >300 m down-dip. Trough cross-bedding is the dominant structure, forming sets with decimetric to metric thickness; grain-size grading was not observed. Subordinate planar cross-bedded deposits form sets up to 50 cm thick. Plane-parallel stratification is preferential to the upper parts of bedsets. Soft-sediment deformation structures, exemplified by ball-and-pillow, convolute bedding, and fluid-escape conduits are common throughout. Bedsets typically comprise large, cross-beds in their lower parts; cross-cutting lithosomes with planar to concentric fill predominate upward. Coarser units are somewhat thinner but laterally more homogeneous up-section. Paleoflow patterns are complex: lower in the section, most units tend to have northwestern to northeastern indicators of paleodrainage, high dispersion within individual bedsets and upward flow rotation observed in some cases. Upward in the section, paleoflow is less dispersed with transport mainly to the northwest.

Finer units are quartz-dominated with white mica, commonly along lamination surfaces. Maroon-red colouration reflects an abundance of iron oxide cement. Bedding units are 10 to 70 cm thick, planar-bedded, and laterally continuous for >600 m along strike and >300 m down-dip. A very fine-grained, parallel-laminated, dark-red sandstone layer is continuous through the both logged exposures, serving as local correlation marker. Finer units are normally graded, with lower, medium-grained sandstone to upper, silt and very fine-grained sandstone. These units are thicker and laterally more continuous lower in the section; their thickness and prominence diminishes upward. Ripple-cross lamination, climbing in places, is the most common structure and typically alternates with minor wavy plane-parallel lamination. Trough-cross bedding is rare, occurring in decimetric sets in the lower parts of thicker units. Paleoflow is consistently toward the north-northwest with low dispersion.

Reconnaissance Geological Mapping

Reconnaissance geological mapping of NTS 97D revealed that there are extensive areas of bedrock that are mapped incorrectly as belonging to the Shaler Supergroup. Specifically, along the Amundsen Gulf coast between Albert Bay and Dease Thompson Point, the region mapped as Nelson

Head and Aok Formation (Balkwill and Yorath, 1971), is largely underlain by strata of lower Cambrian age (Mount Clark and Franklin Mountain (?) formations). The Franklin Mountain (?) is an orange-weathering dolostone, identical in lithology and stratigraphic position to the recently defined Uvayualuk Formation of western Victoria Island (Dewing et al., 2014). This lithological unit could easily be mistaken for the similar-looking (orange-weathering) Aok Formation, except that the Aok is characterized by distinctive digitate stromatolites (Jefferson and Young, 1989), which are not present in the orange-weathering dolostones of the area described. As on Victoria Island, these dolostones directly overlie crossbedded quartz arenites containing the characteristic trace fossil *Skolithos* (Mount Clark Formation). This unit has been mistakenly mapped as the lithologically similar, cross-bedded quartzarenite of the Nelson Head Formation of the Rae Group (Rainbird et al., 1994). Similar relationships and stratigraphic mis-assignments were observed in the vicinity of the Roscoe River canyon, approximately 40 km to the southeast. A large region of the central and eastern part of the map area is covered by thick Quaternary glacial deposits that have recently been mapped by Veillette et al. (2013). The quality of bedrock exposures in the south-central part of the map area is also poor owing to a *lack of* glaciation, which has promoted development of extensive felsenmeer. The most informative bedrock exposures are confined mainly to river cuts draining the coastal plain of the Amundsen Gulf, including spectacular canyon sections along the Brock, Hornaday and Roscoe rivers.

Conclusions

The results of thematic studies, including sedimentological, stratigraphic, paleontological, geochronological and geochemical analyses of the Rae Group (Shaler Supergroup) are forthcoming. Regional geological reconnaissance has identified several regions of NTS 97D that should be re-mapped owing to misidentification of Cambrian sedimentary units as belonging to the Proterozoic Rae Group. We recommend that the Brock River area, originally mapped by helicopter reconnaissance in 1968, be remapped using current stratigraphic knowledge and terminology. It is recommended that the magnetotelluric survey, originally proposed for 2014, be carried out in 2015.

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