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FOREWORD

The Geo-mapping for Energy and Minerals (GEM)[1] 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 (2008-2013), GEM has been renewed for another seven years (2013-2020), with the continuing goal of producing new, publically available, regional-scale geoscience knowledge in Canada's North. 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 volcanic terrain of Cretaceous age exposed in the east-central Sverdrup Basin, known as the Canadian portion of the High Arctic Large Igneous Province (HALIP), is the focus of an activity approved for the second phase of GEM, within the Western Arctic Region Project. The main objective of the HALIP activity, from 2014 to 2017, is to identify areas on Axel Heiberg Island and Ellesmere Island that show a high potential for Ni-Cu-PGE deposits (Figure 1). Specific activities include (1) detailed mapping and documentation of sills and dykes not included in current 1:250 000 scale geological maps; (2) the collection of samples for mineralogical and geochemical studies; (3) the development of geological models and a regional stratigraphic and structural framework to identify volcanic-intrusive complexes that could host nickel (Ni) sulphide deposits; and (4) the transfer of data, maps and knowledge to decision-makers and stakeholders in northern communities, government, and industry.

Initial results, from the 2015 field season and the analysis of legacy sample collections from previous field seasons, have already been made available in several open file reports (e.g., Dewing, 2015; Williamson, 2015; Saumur and Williamson, 2016). Here, we present preliminary results and highlights from the 2016 field season, with a focus on intrusive components of the HALIP. Details on volcanic components will be discussed in a separate contribution.

[1] http://www.nrcan.gc.ca/earth-sciences/resources/federal-programs/geomapping-energy-minerals/18215

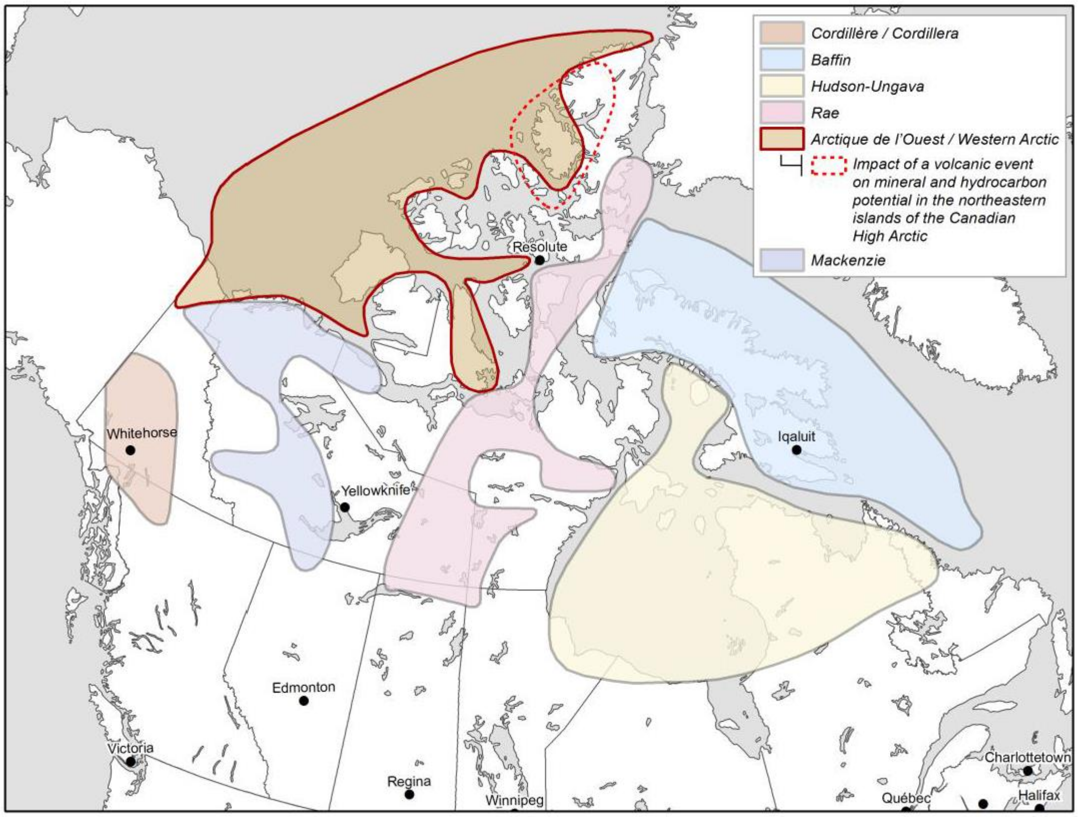

Figure 1. Regional map of the GEM 2 activities (2014-2017) showing the area covered by the Western Arctic Region Project. The HALIP activity study area is indicated by the red dashed line.

INTRODUCTION

Fieldwork by the Geological Survey of Canada was carried out on Axel Heiberg Island from July 8 to 24, 2016, as part of the GEM-2 Western Arctic Region Project, HALIP activity. This work expands upon the regional-scale work performed during the summer of 2015 (Williamson, 2015), but shifts focus towards targeted studies of volcanic-intrusive complexes at two localities on Axel Heiberg Island: Middle Fiord and Bunde Fiord (Figure 2). Additionally, diabases from localities near Rens Fiord and Otto Fiord were sampled by GSC field parties led by T. Hadlari and S.Grasby, respectively (Figure 2).

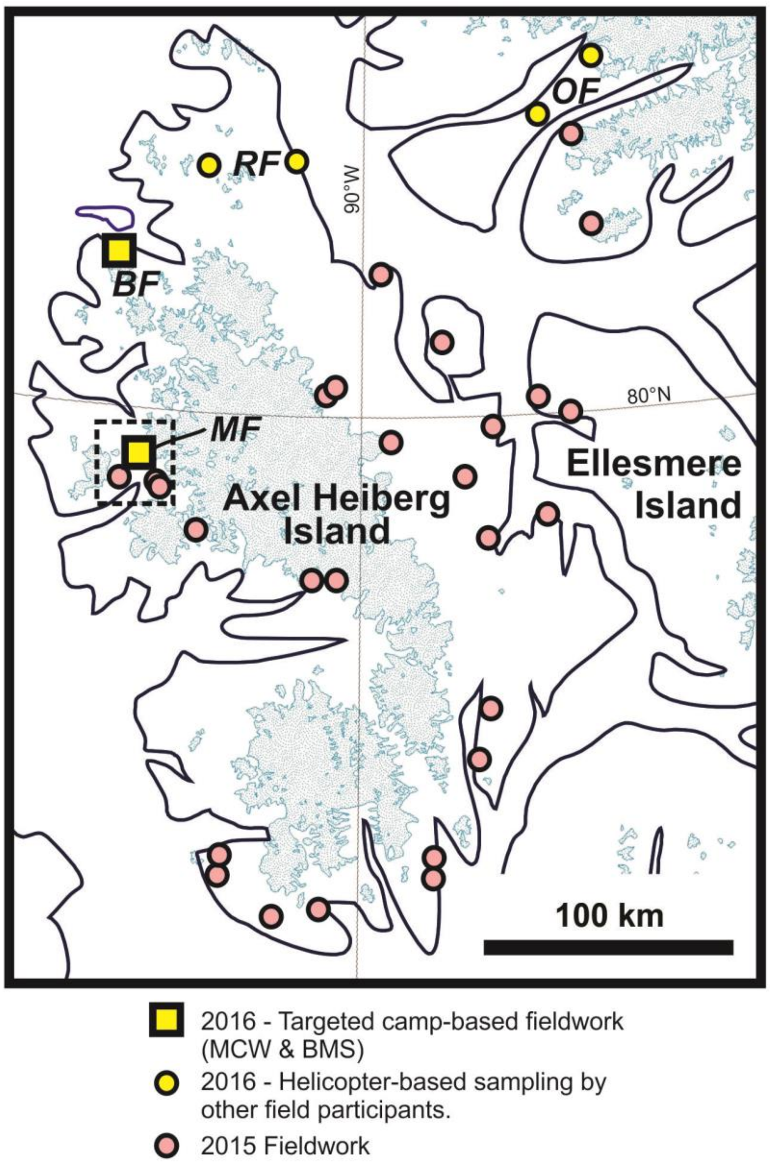

Figure 2. Axel Heiberg Island and Ellesmere Island, highlighting sites visited during the 2016 Fieldwork, and showing sites of 2015 Fieldwork (Williamson et al., 2015; Bédard et al., 2015). Sites of fieldwork are named after nearby bodies of water MF: Middle Fiord (this report); BF: Bunde Fiord; RF: Rens Fiord; OF: Otto Fiord.

1) MIDDLE FIORD

The intrusive complex exposed at Middle Fiord was first visited during the 2015 field season (Williamson et al., 2015). Fieldwork was concentrated in the portion of the complex located on the south side of Middle River (Fig. 3), leaving the northeast side unexplored. However, remote predictive mapping, field photographs and Gigapan© images from the south bank of the river suggested that multiple intrusive elements with complex geometries occur in the north. Further work focused on the north bank of Middle River was deemed necessary to adequately define the architecture of the intrusive system exposed at Middle Fiord.

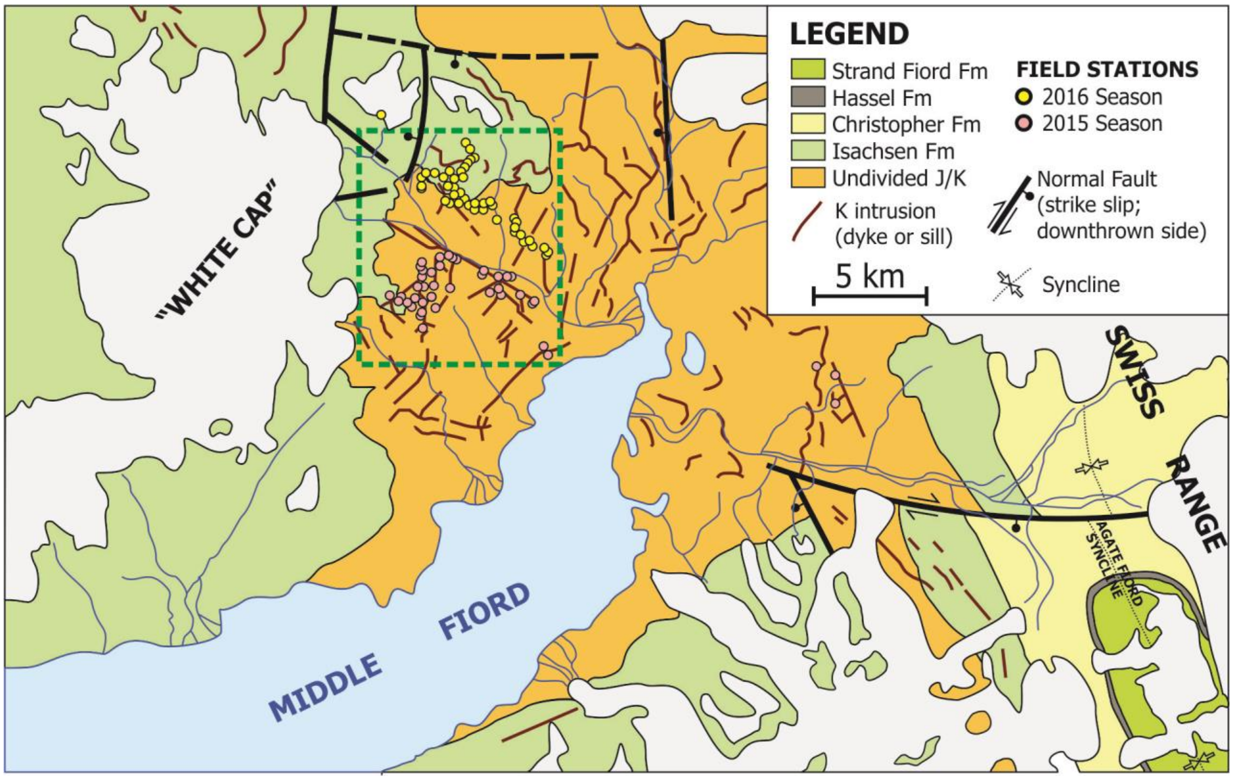

Figure 3. Preliminary map of the Middle Fiord area (modified from Thorsteinsson, 1971). Field stations from the 2015 and 2016 are indicated, as are the positions and the directions of photos provided in figures of this report. The area highlighted in green shows the footprint of Figure 5.

Strata exposed at Middle Fiord are gently dipping to sub-horizontal, defined by regional scale broad gentle folding. This is in stark contrast to the "wall-and-basin" structure occurring southeast of Middle Fiord, within the well-studied Strand Fiord/Expedition Fiord area, where structure is characterized by NE-SW trending open folding associated with salt diapirism (Harrison and Jackson, 2011).

In contrast to South Middle River, which is relatively flat and shows only few visually distinct geological or geomorphological features, North Middle River exhibits accentuated landscapes and distinct topographic and geological elements that were easily visible from the ground and distinguishable from airphotos. The names of the localities used in the text are provided in Figure 4. These names were attributed colloquially by the authors in the field and remain unofficial, but are useful here for the purposes of this report.

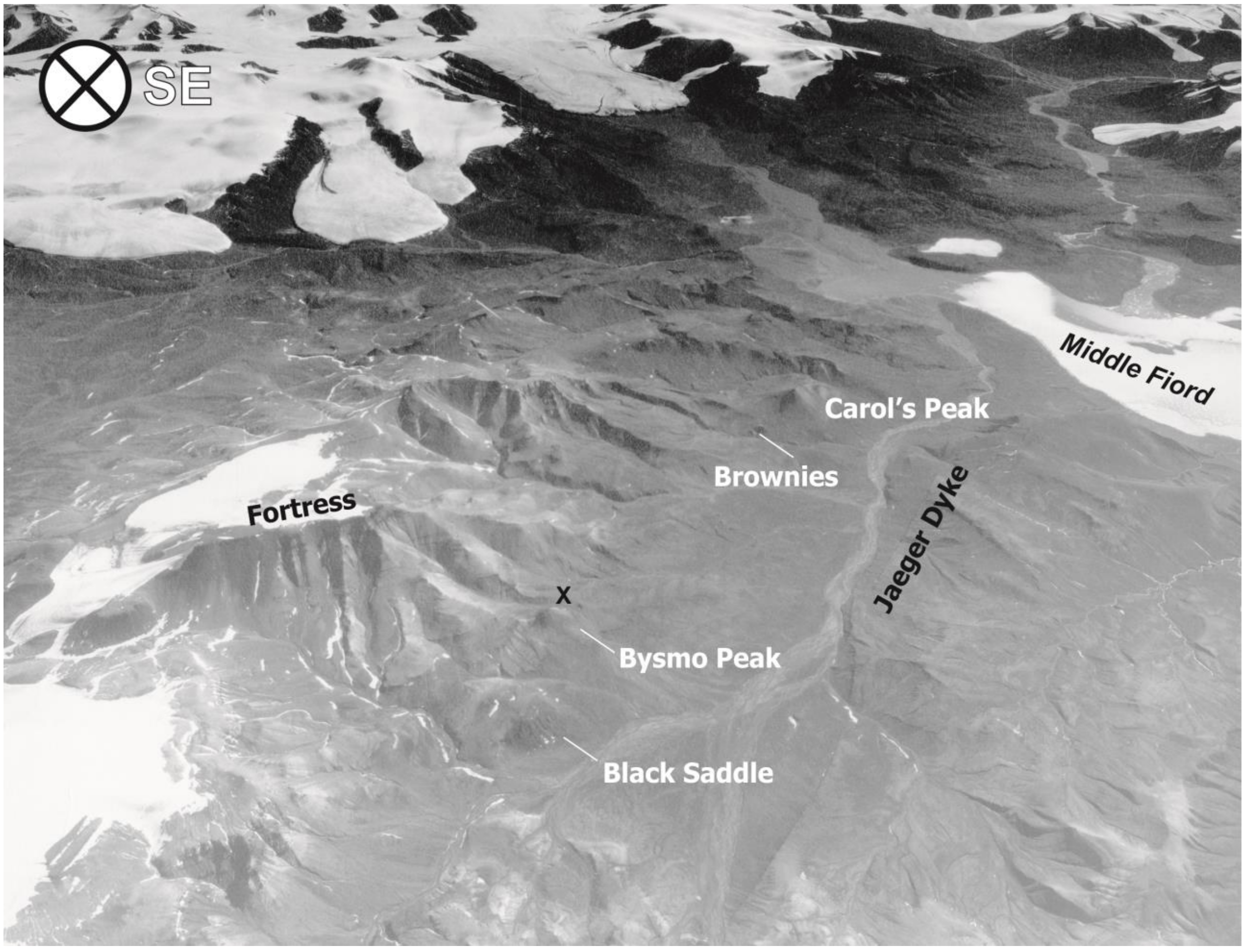

Figure 4. Annotated oblique air photo (T412L-54) of Middle Fiord, facing SE. X marks the location of our camp (near "Chopper Hill", see Fig 5). Black Saddle and Bysmo Peak are in the Northwest Field area; Brownies and Carol's Peak in the Southeast Field area; and the Fortress is the dominant feature in the Northern Field area. The "Jaeger Dyke" is a dominant NW-SE dyke that was visited in 2015.

1.1) NORTHWEST FIELD AREA (BYSMO PEAK – BLACK SADDLE)

The Bysmo Peak – Black Saddle area (Figure 5) highlighted intrusive relationships that were more complicated than anticipated. Nevertheless, at least two intrusive units are exposed on Bysmo Peak: a southwest-dipping, thick, fine grained diabase to coarse grained gabbro or troctolite, which is cross cut by a steeply dipping, NW striking dyke (~325°/80°) roughly 10 m thick, and broadly sub-parallel to the Jaeger dyke (although a relationship between the two is unclear). Despite being a major feature of Bysmo peak, the NW-trending dyke itself is only exposed on the crest of the peak, and no equivalent exposures or evidence of this intrusion are observed parallel to strike on either side of the peak. This lack of lateral continuity suggests that the dyke pinches out within 100-200 m of Bysmo peak, and geometrically could be characterized as a pipe-like intrusion or an irregular intrusion (i.e., "chonolith"; Daly, 1905) that may have a rectangular, oval or lens-shaped cross-section.

Diabases and gabbros exposed on the Black Saddle (Figure 6) occur within a thick tabular body which likely has a shallow dip towards the southwest. The quality of exposure is poor, however, mafic intrusive rocks project laterally eastwards towards the SW-dipping intrusive unit exposed on Bysmo Peak, suggesting that they form a single intrusion rather than a series of distinct intrusions.

A rheomorphic breccia often occupies the area near contacts between the intrusive units. It consists of hydrothermally altered, autobrecciated host rocks and hornfelsed diabase. Such rocks are commonly observed at the margins of intrusive units throughout North Middle River, specifically where the host rock consists of shale beds of the Deer Bay Formation.

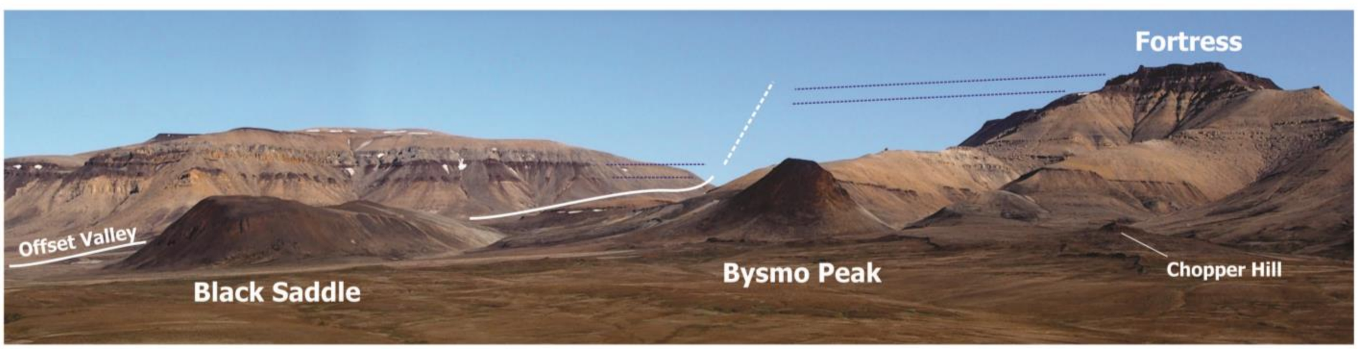

Figure 5 View towards the north (from Middle Fiord) of Black Saddle, Bysmo Peak, the Fortress and Offset Valley. Field of view is roughly ~3 km.

1.2) SOUTHEAST FIELD AREA **(BROWNIES – CAROL'S PEAK)**

Geometrically complex dykes were well documented in South Middle River (Williamson et al., 2015), with dykes showing marked surface trace offsets due to their anastomosing and stepped geometry. Yet perhaps the best example occurs in the southeastern portion of the field area: the "Squiggly dyke" as viewed from the south bank of Middle Fiord (Fig. 6A) exhibits a complicated surface trace that is independent of topography. Orientation measurements confirm a generally shallow to moderate east dip and confirm its changes in orientation along strike. Several dykes occur here intruding the Deer Bay Formation shales, including a dyke of intermediate composition that appears to cross-cut the diabasic Squiggly dyke.

The prominent isolated peaks in the southeastern-most portion of the field area are both attributable to diabasic intrusions (Fig. 6B). The Brownies are a pair of peaks in close proximity consisting of resistant diabase. They appear to correlate with flat lying diabasic units subcropping to the west, and may therefore represent sills within the Deer Bay Formation (Fig. 6C). The base of the units, near the diabase sandstone contact, consist of rheomorphic breccia similar to that observed at Bysmo Peak. At Carol's Peak, the most prominent hill near the mouth of Middle River, a10m-thick diabase dyke and associated rheomorphic breccia occurs in contact with shale hornfels and sandstone.

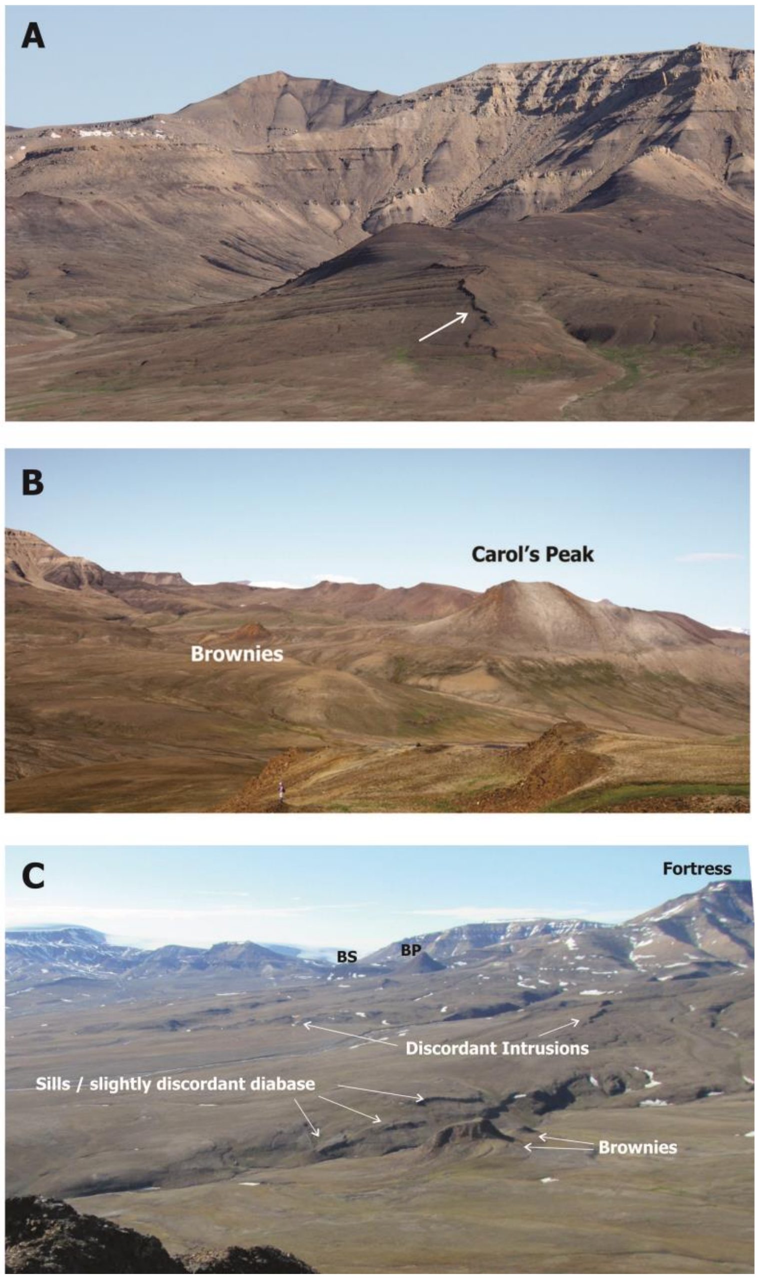

Figure 6. Southeastern Intrusions. **A)** Squiggly Dyke (viewed from South Middle Fiord towards the east, field of view ~ 500 m; dyke is 1-2 meters thick; **B)** Brownies and Carol's Peak (viewed from South Middle Fiord towards the southeast, field of view ~2 km); **C)** View towards NW from Carol's Peak (BS = Black Saddle; BP = Bysmo Peak; Black Saddle is ~ 5 km away).

1.3) THE FORTRESS: VOLCANIC ROCKS OF THE ISACHSEN FORMATION

The two mafic units exposed at the top of the Fortress (Fig. 7A), within the Walker Island Member (late Barremian – Aptian), were considered as possible sills based on remote observations during the summer of 2015. New fieldwork instead suggests that these are lava flows. The units measure 17 m and >25 m in thickness, respectively. They exhibit pronounced columnar jointing (Fig. 7B), are variably amygdaloidal (Fig. 7C, D), contain pumaceous clasts (Figure 7C) and exhibit flow top breccias (Fig. 7D). Lava flows have been well documented within the Walker Island Member (Embry and Osadetz, 1988); however, they had not been identified in the Middle Fiord Area. As viewed from atop the Fortress, it is clear that Walker Island Basalts form a resistant cap on mountains surrounding Middle Fiord, upon which several glaciers rest.

The potential link between intrusive units within the Deer Bay formation and these flows remains hypothetical; this will be confirmed or rejected based on follow-up geochemical analyses.

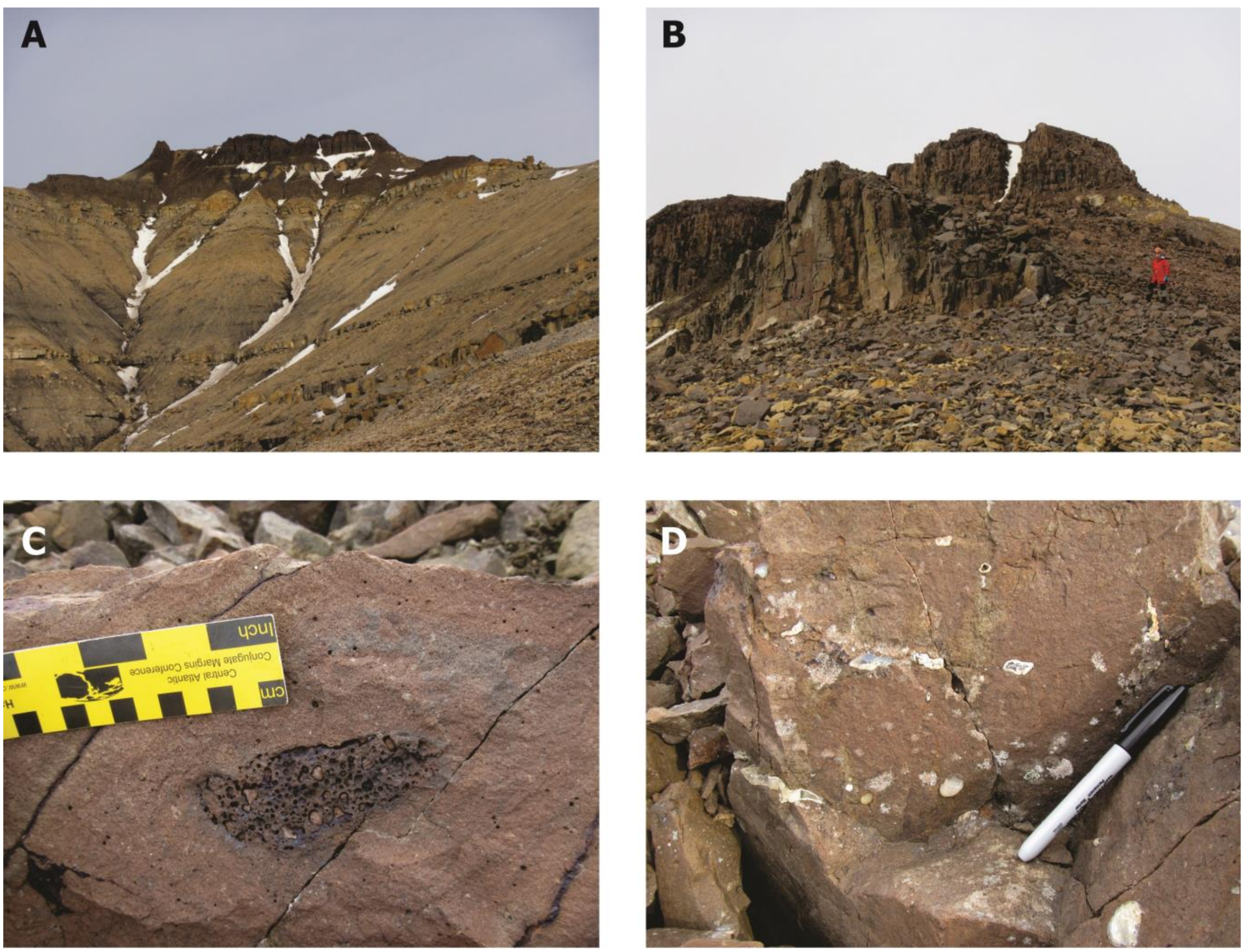

Figure 7. Flows of the Walker Island Member exposed on "the Fortress" A) View from the bottom of the mountain, with two flows exposed near the crest; B) Flow #1 of the Walker Island Member; 3) Clast of scoria within flow #1; 4) Amygdules of flow #1.

2) BUNDE FIORD

Fieldwork at Bunde Fiord focused on the physical volcanology and stratigraphy of the Strand Fiord Formation exposed in the area. This work will be detailed in a future contribution. Nevertheless, two important findings related to the architecture of the area are noted herein.

2.1) FAULT KINEMATICS IN THE BUNDE FIORD AREA

Bunde Fiord Camp was located in an area previously mapped by Thorsteinsson (1971) and Mayr et al. (2002). Figure 8 shows an update of the geology and fault kinematics of the area based on our recent field studies: a prominent NE-striking fault has its hanging wall on its southeast side (Strand Fiord Formation), since older units occur to the northwest (Christopher and Isachsen Formations). Similarly, a moderately dipping, S-striking normal fault occurs between the Christopher and Strand Fiord Formations, and is interpreted to merge with the NE-striking fault (Fig. 8).

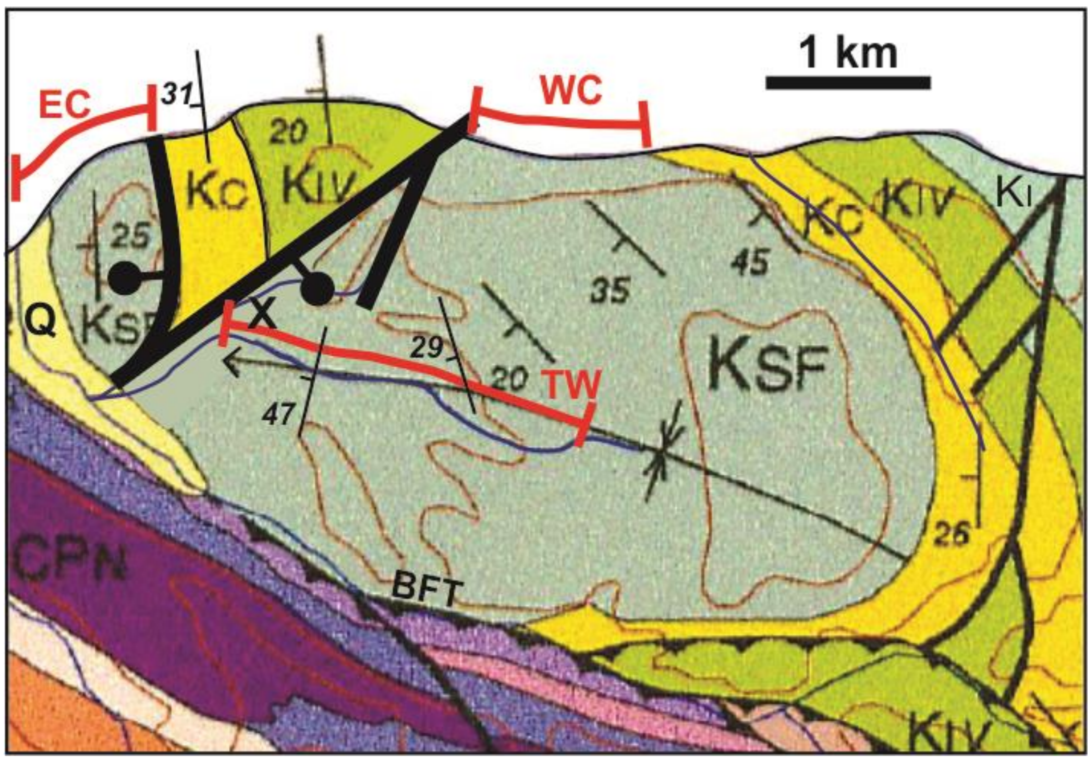

Figure 8. Preliminary map of Bunde Fiord Field area; modified from Mayr et al. (2002). The location of the camp is identified with an "X". The map includes the positions of stratigraphic sections analyzed during the 2016 field season (TW: Twilight Creek; EC: East Coastal Section; WC: West Coastal Section). We also update the fault geometry and kinematics at the northwest part of the map based on our field observations and previous mapping by Thorsteinsson (1971). Units: Q: Quaternary; K_{SF}: Strand Fiord Formation; K_C Christopher Formation; K_{IV}: Isachsen Formation Volcanics; K_I: Isachsen Formation; CP_N : Nansen Fm (and associated units in purple/pink. BFT: Bunde Fiord Thrust.

2.2) INTRUSIONS IN THE BUNDE FIORD AREA

Several prominent intrusions occur within the area. Intrusions are presumably of Cretaceous age and occur as concordant sills. They were most spectacularly along cliff exposures on the south shore of Bjarnason Island (Fig. 9). Such sills had been identified from remote predictive mapping described by Saumur et al. (2016). Field evidence from 2016 thus confirms the of sills prominence within strata of the Sverdrup Basin.

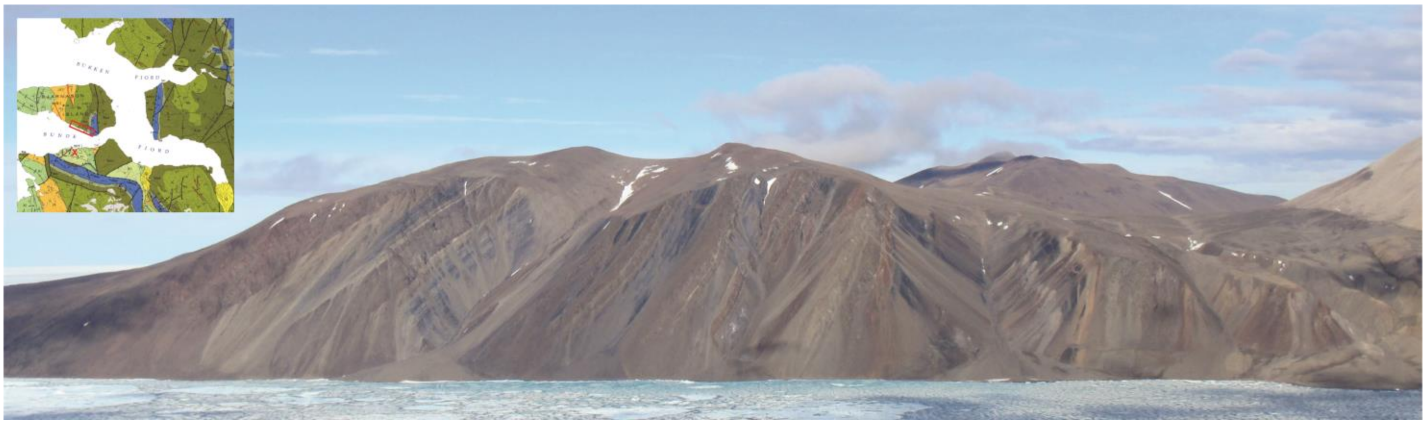

Figure 9: Panoramic view of the southern shore of Bjarnason Island (see inset, after Thorsteinsson, 1971), viewed towards the NNE from the south side of Bunde Fiord. Field of view is approximately 2 km. Brown units are concordant mafic sills within Triassic strata of the Blaa Mountain and Blind Fiord formations.

3) RENS FIORD AND OTTO FIORD

In an effort to extend the coverage of the HALIP sample database towards northern Axel Heiberg Island and Ellesmere Island, two new localities were targeted for sampling (Fig. 2). These consisted of quick helicopter stops by T. Hadlari (Rens Fiord) and S. Grasby (Otto Fiord) that were coordinated alongside various movements of field personnel.

3.1) RENS FIORD

In this area, HALIP diabasic dykes (i.e., Queen Elizabeth Island dyke swarm) crosscut Cambrian strata (Trettin, 1996), are steeply dipping and trend north. Two localities were sampled on northern Axel Heiberg Island: one southeast of Rens Fiord, the other along the Northeastern coast of the Island. Both localities are within 30 km of Rens Fiord.

A notable feature is the en-enchelon surface traces of two closely spaced (< 1 km) groups of north-trending dykes. The significance of this geometry remains unclear, although it may be indicative of syn-emplacement deformation; further detailed fieldwork in the area would be required to test this hypothesis.

3.2) OTTO FIORD

Prominent diabasic intrusions were sampled at the Head of Otto Fiord (sill, 30 m thick) and at Van Hauen Pass on Svartfjeld Peninsula (dyke, NNW trending, 25 m thick). Both units are associated with Triassic strata: the sill occurs within lower Triassic Blind Fiord Formation, whereas the dyke cross-cuts both the Blind Fiord and the middle Triassic Blaa Mountain Formation (Thorsteinsson and Trettin, 1972).

4) HIGHLIGHTS OF 2016 FIELDWORK

- Our work in the Middle Fiord area and other localities, in both 2015 and 2016, highlights the architectural complexity of subvolcanic systems that underlie flood basalt provinces. Furthermore, detailed work and reconnaissance confirm remote interpretations suggesting that intrusions, notably sills, are common throughout the stratigraphy of the Sverdrup Basin. These findings have implications for the Ni-Cu-PGE potential of the HALIP and the petroleum/energy potential of the Basin.

- Volcanic Flows of the Walker Island Member were documented at Middle Fiord, thereby extending northwards the known aerial footprint of the Barremian - Aptian eruptive event of the HALIP by ~400 km^2.

- 2016 fieldwork led to the reinterpretation of new faults at Bunde Fiord.

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