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Foreword

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in northern Canada. The Program provides modern public geoscience that will set the stage for long-term decision making related to responsible land-use and resource development. Geoscience knowledge produced by the GEM program 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 2017 field season, research scientists from the GEM program successfully carried out 27 research activities, 26 of which will produce an activity report and 12 of which included fieldwork. Each activity included 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 partners as the program advances.

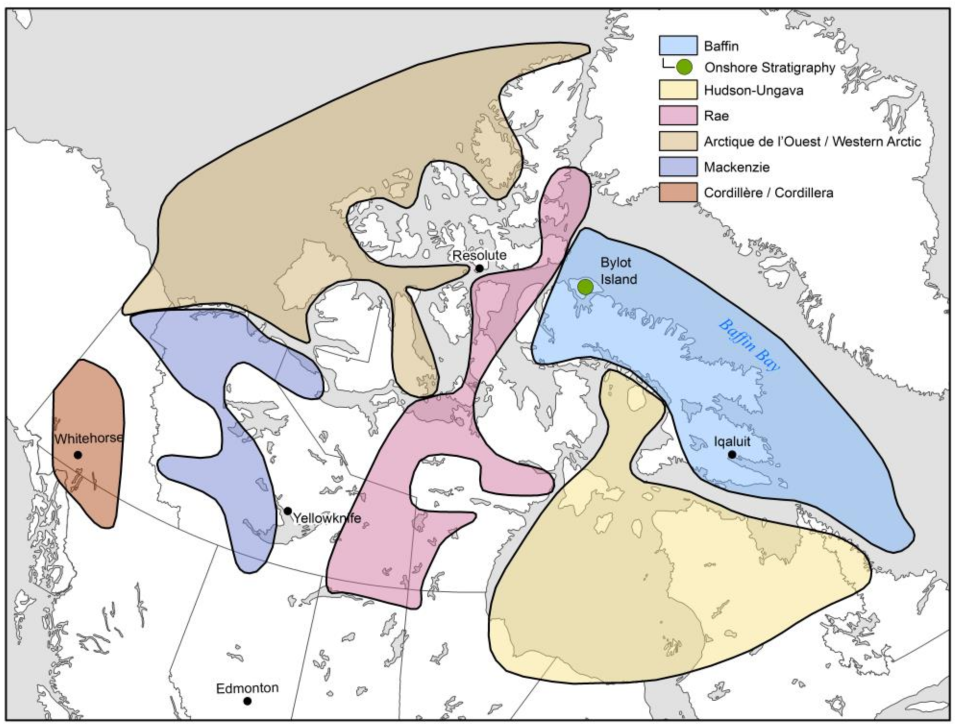

Figure 1. Location of the GEM-2 Baffin project area and activity associated with this report.

Project Summary

Extensive Cretaceous-Paleogene sedimentary basins are known along the western side of Baffin Bay from southern Davis Strait to southern Nares Strait and it is hypothesized that the region may contain significant hydrocarbon deposits, particularly within the vast basin at the mouth of Lancaster Sound and along the continental shelf of eastern Baffin Island. A persistent oil seep offshore of Scott Inlet, Baffin Island, demonstrates that petroleum systems are present in the region. Only limited geological data exist for the offshore region in this area, with only a few shallow drill holes and dredge samples and an ODP well near the Baffin Shelf. Understanding the correlative onshore sequences can serve as a ready analogue for the offshore deposits. Such onshore sequences are limited to only a few localities, however, including Bylot Island and adjacent areas of Baffin Island (Fig. 1).

Limited geological and paleontological surveys of the onshore strata were undertaken by industry and university personnel in the 1970s-1980s, and a preliminary, mostly unpublished, litho- and biostratigraphic framework was established at that time. Reconnaissance fieldwork undertaken under the GEM-1 program determined that the basic elements of a petroleum system are present in the Bylot Island region, but subsequent field studies necessary to fully describe the succession and to provide detailed insights into the geology of the offshore region were postponed. Undertaking these activities under GEM-2 will finally provide an extended data set valuable for better understanding depositional systems of Baffin Bay.

Introduction

Cretaceous-Paleogene rocks that outcrop on Bylot Island and Baffin Island in the vicinity of Pond Inlet and Scott Inlet are being investigated in 2017-2018 to determine details of their stratigraphic succession and age. Research activities are summarized under five broad themes.

1) Geological mapping of Cretaceous-Paleogene strata to establish the overall stratigraphic succession and structural controls on rock distribution.

2) Development of a lithostratigraphic framework for the basin successions, to include local lithologic detail, biostratigraphic data, and existing and new samples summarized in measured stratigraphic sections.

3) Biostratigraphic studies to constrain the age limits of the lithostratigraphic succession and to help identify sequence stratigraphic boundaries.

4) Assessment of sedimentary environments of Cretaceous-Paleogene strata using outcrop sedimentology and analysis of trace fossil and microfossil assemblages.

5) Determination of the region's Cretaceous and younger structural history through low-temperature thermochronology studies.

Assessing stratigraphic variation across onshore basins will provide insights into basin history, and allow more accurate local and regional models of sedimentation to be developed. This knowledge will provide a basis for correlation of onshore and offshore strata, and will improve understanding of the hydrocarbon potential of the region (Brent et al., 2013).

1) Geologic Mapping

Prior to undertaking field studies, discussions with Pond Inlet community members were undertaken during 2016 and 2017 in order to present the proposed field program and to identify any issues of concern. Sensitive sites were identified and the research program developed accordingly to avoid these. The field team was based in Pond Inlet and utilized local community resources for accommodations, meals, and supplies, as well as employing a Wildlife Monitor. During the field season, community members were asked to provide Inuktitut names for local geographic features, where known, so that these might provide suitable monikers for lithostratigraphic nomenclature. Fieldwork identified several previously-undocumented cultural sites on Bylot Island and these were reported to the local community for follow-up.

Geological mapping of the Cretaceous-Paleogene succession of Bylot Island and northwestern Baffin Island was undertaken during 2017. This effort builds on previous mapping on Bylot Island and environs conducted in the 1970s (e.g. Jackson and Davidson, 1975a, b, c; Jackson et al., 1975). Principal outcrop areas (Fig. 2) of these strata include: 1) on northeastern Baffin Island in the vicinity of Pond Inlet; 2) along the southwest coast of Bylot Island and adjacent inland areas, extending to near the northwestern side of Bylot Island opposite Borden Peninsula; and 3) in the Maud Bight area on the north side of Bylot Island. The first two of these areas are a part of the Eclipse Trough while the third area comprises the North Bylot Trough of

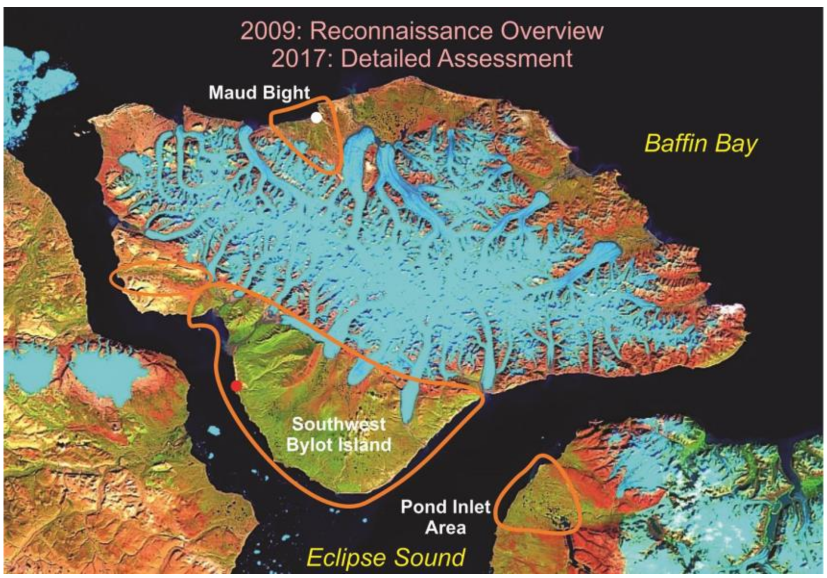

Figure 2. Principal areas of Cretaceous-Paleogene outcrop, within orange ellipses, on Bylot Island and adjacent Baffin Island.

Miall et al. (1980); the two basins are separated by the Byam Martin Mountains of central Bylot Island, a suite of uplifted Archean to Mesoproterozoic rocks (Jackson and Davidson, 1975a, c).

Important geological observations arising from the recent mapping include:

1) Outcrop strata of Eclipse Trough dip very gently (< 10°) in most areas, becoming steeper closer to the eastern basin margin, or along local fault traces.
2) The eastern margin of the Eclipse Trough appears to be faulted against the Archean to Mesoproterozoic basement in most areas, although depositional onlap of Cretaceous strata on basement rocks is noted locally.
3) Distinctive lithological marker units have been identified, which allow lithostratigraphic correlations along Eclipse Trough and in North Bylot Trough.
4) Lithological variation of the Cretaceous-Paleogene strata in Eclipse Trough is in part a function of lateral facies changes in stratigraphic units across broad areas of the trough.

2) Cretaceous-Paleogene Lithostratigraphy

The lithostratigraphic succession of Bylot Island was assessed in detail during the 1980s in a series of student theses and associated publications (Sparkes, 1989; Waterfield, 1989; Benham and Burden, 1990; Benham, 1991; Wiseman, 1991). Results presented in these contributions were never integrated into a comprehensive stratigraphic framework. One aspect of the current GEM project is to assess and build upon the stratigraphic results presented in these contributions.

The Cretaceous-Paleogene succession exposed along the southwest coast of Bylot Island was studied in detail in its coastal exposures and along inland river and stream valleys. The base of the succession consists of marginal-marine to locally non-marine sandstone, siltstone, mudstone, and coal, of Albian-Cenomanian age. These strata have been referred previously (e.g. Miall et al., 1980) to the Hassel Formation, a lithostratigraphic name applied to characteristic strata of the western Arctic. These rocks can be mapped along the northeastern margin of Eclipse Trough, but their preserved thickness varies greatly, due to stratigraphic thinning and structural disruption. They also comprise the unique stratigraphic unit found on Baffin Island in the vicinity of Pond Inlet (see Jackson and Davidson, 1975b). The succession is exposed poorly along the southwest coast of Bylot Island and a newly recognized section farther inland can serve as type locality for a new stratigraphic unit appropriate to the northwest Baffin Bay region.

Overlying strata on Bylot Island consist of alternating sandstone and mudstone units. Palynological data indicate the strata range in age from early Late Cretaceous (Turonian?) through Selandian. The extent of unconformities within the succession is unknown at present, although some stratigraphic levels (e.g. Campanian, Maastrichtian, Selandian) are more widely represented than others (e.g. Turonian, Coniacian, Santonian). Sedimentary structures, ichnofossils, and palynological assemblages suggest these strata accumulated in coastal settings from shoreface to mid- to outer shelf environments.

An unusual lithofacies within the succession includes lenticular conglomerates interstratified with medium- to coarse-grained sandstones (Fig. 3).

Figure 3. Lenticular conglomerate and sandstone facies, interpreted as fan-delta deposit.

Clasts within the conglomerates range from small cobbles to boulders > 5 metres in diameter and represent almost exclusively Archaean lithologies present in the adjacent uplifted Byam Martin Mountains. The unit is interpreted tentatively to have accumulated in a fan-delta setting adjacent to steep topography.

Field mapping of geological relationships, supported by biostratigraphic studies, demonstrate that several stratigraphic units proposed by earlier workers (i.e., Miall et al., 1980; Sparkes, 1989; Waterfield, 1989; Wiseman, 1991) represent lateral facies variants, rather than stratigraphically successive and younger strata.

3) Basin Biostratigraphy

Correlation of the Cretaceous and Paleogene rocks in Eclipse Trough and North Bylot Trough has proven difficult using macrofossils and inorganic-walled microfossils; they are very scarce and degraded. However, one macrofossil collection of *Sphenoceramus* cf. *lundbreckensis* (McLearn) (Fig. 4) made in 2017 helps to constrain the latest Santonian/earliest Campanian age of enclosing strata.

Fortunately, palynomorphs are preserved in the finer grained facies and these fossil types are thus being assessed to provide more refined biostratigraphic and paleoenvironmental control. Quantified documentation of proportions of marine (dinoflagellate cysts) and non-marine (spores and pollen) palynomorphs can help to interpret the sea level history recorded in the sections and hence facilitate inter- and intra-basinal correlations.

Palynomorph assemblages recognized on Bylot Island (Fig. 5) can be compared with assemblages described previously from Bylot Island by Ioannides (1986), as well as from the Labrador-Baffin Seaway and from elsewhere in the Canadian Arctic by Nøhr-Hansen et al. (2016). Data from other fossil groups will also be integrated into comprehensive 'events plot' summaries, and help to address problems of provincialism, diachronism, and paleoenvironments.

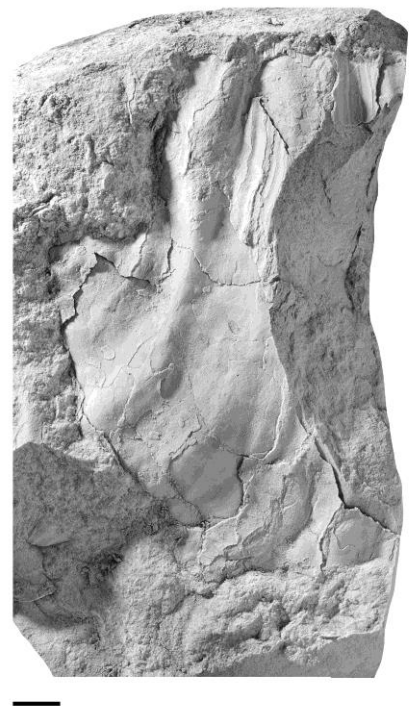

Figure 4. *Sphenoceramus* cf. *lundbreckensis*, collected from Eclipse Trough. Scale bar = 1 cm.

Stratigraphic sections from Eclipse Trough that are the focus of biostratigraphic study include the south coast and Twosnout Creek regions; those from the North Bylot Trough are all from the Maud Bight area. A comparison of the principal stratigraphic section in the Twosnout Creek area (the 'Q' section) has suggested some preliminary similarities in the events plot of this section with sections described in Nøhr-Hansen et al. (2016). Relative percentage plots showing miospores (pollen and spores), dinocysts, acritarchs, and others (such as the fresh-water *Pediastrum*) are being compared for all stratigraphic sections studied on Bylot Island. Such plots allow recognition of changing paleoenvironments, such as transgressive and regressive episodes and fluctuations in water depths.

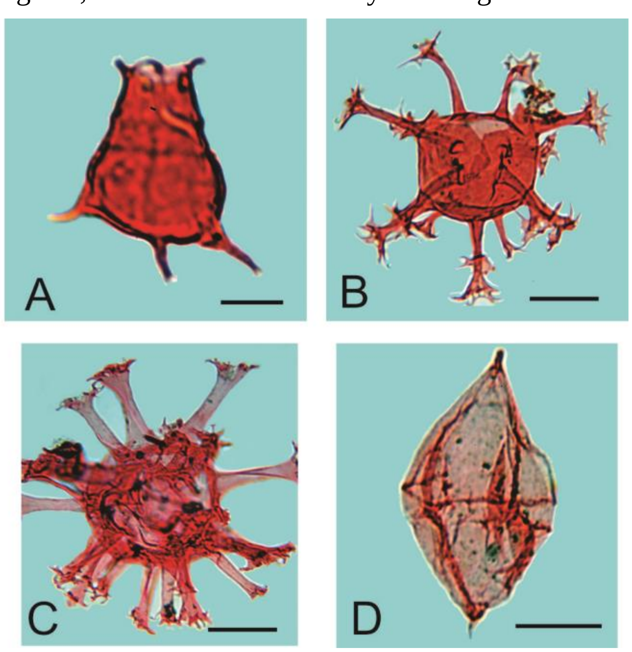

Figure 5. Dinocysts from Eclipse Trough. **A**. *Dorocysta litotes*, P5148-3B. **B**. *Oligosphaeridium complex*, P5148-2C. **C**. *Kleithriasphaeridium loffrense*, PP4148-4C. **D**. *Laciniadinium arcticum*, P5148-4D. Scale bar = 20 µm; all south coast Bylot Island.

Cretaceous-Paleocene palynological taxa have been identified from Bylot Island that have stratigraphic or paleoenvironmental significance; many of these taxa are new. Taxa have been identified that define the palynological assemblages of late Albian-Cenomanian, Cenomanian, Turonian, Coniacian, Santonian, Campanian, Early Maastrichtian, Late Maastrichtian, Danian, and Selandian ages. As well, important taxa have been recognized which appear to be restricted to coastal to marginal marine, inner neritic, outer neritic, and open-ocean paleoenvironments, aiding in assessing depositional settings of stratigraphic units.

Detailed stratigraphic sampling for marine microfossils (primarily foraminifera, but also radiolarians, diatoms, and nannofossils) was also undertaken at three localities of Eclipse Trough, in an attempt to enhance the local record of these groups in the Bylot Island succession. A total of 142 mudstone samples were collected from three different stratigraphic sections. Variable preparation techniques will be undertaken on these samples to hopefully improve recovery of these heretofore poorly-represented faunal groups. Subsamples will be analyzed for carbon isotope content at Frankfurt University. If fruitful, analysis of these collections may provide additional age and paleoenvironmental control on critical marine sections within Eclipse Trough. In addition, a possible bentonite was sampled for geochronological age determination.

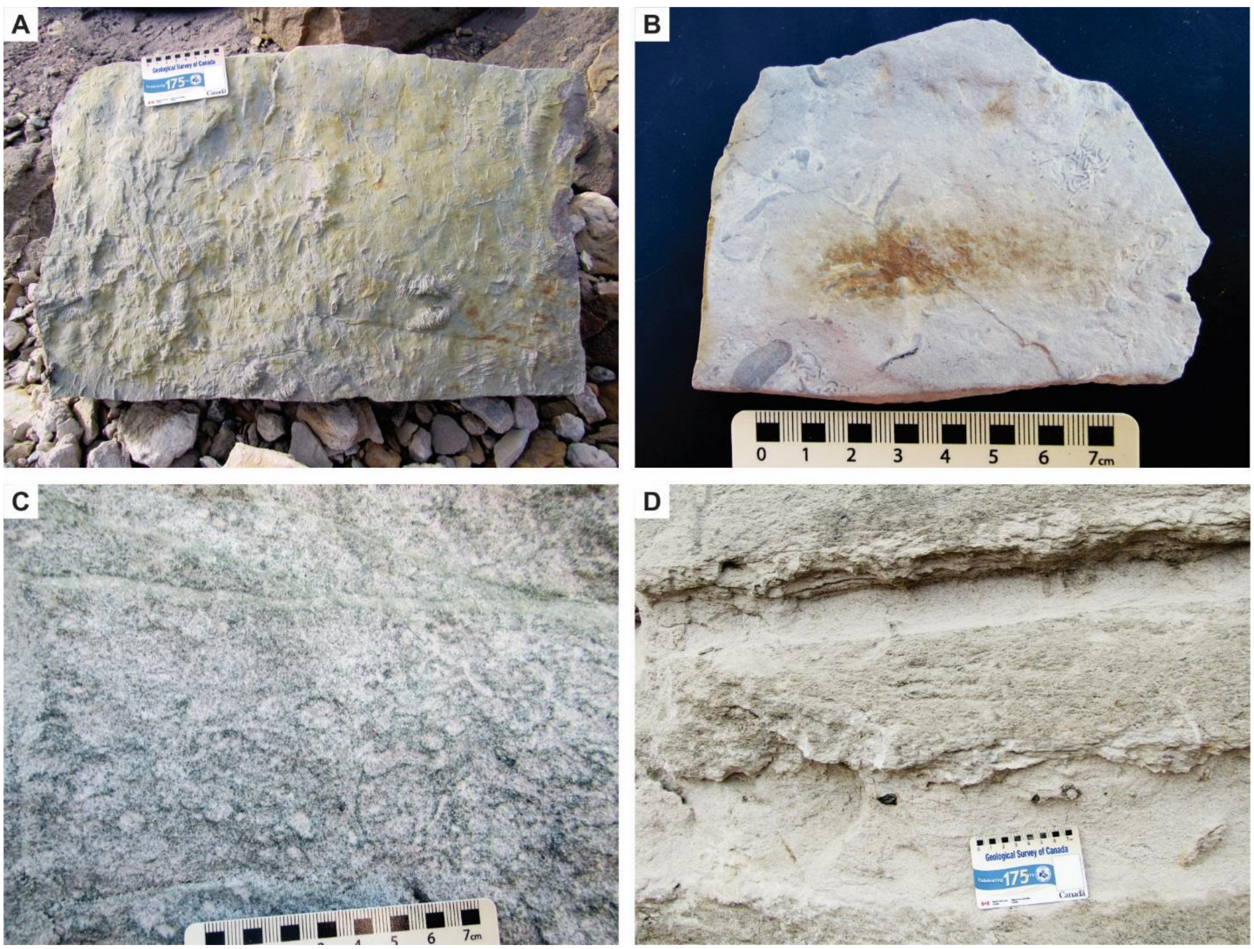

Figure 6. **A**. Surface trails from the basal Cretaceous sandstone, Baffin Island. **B**. Grazing trails, including *Phycosiphon* from mudstones overlying basal Cretaceous sandstone, Bylot Island. **C**. Pervasive *Macaronichnus* from sandstone unit, Maud Bight, Bylot Island. **D**. Interbedded sandstone and bioturbated silty sandstone, south coast Bylot Island.

4) Paleoenvironmental Analysis

Previous and ongoing analysis of stratigraphic sections from Bylot Island has provided a framework for understanding the overall nature of the Cretaceous and Paleogene stratigraphy. The previous studies focused primarily on the lithostratigraphy and biostratigraphy of the units, providing a broad regional context for the strata. This earlier work has laid the groundwork for an initial observation of trace fossils found within a number of stratigraphic intervals of the Cretaceous-Paleogene, but these structures were generally described as burrows without a specific ichnotaxonomic designation. In this part of the study, we conducted detailed sedimentological and ichnological analysis on previously measured sections to provide high-resolution interpretation of depositional environments (Fig. 6). A total of 15 sections were studied during the 2017 field season, which included analysis of most of the lithstratigraphic units from both the Eclipse Trough and North Bylot Trough regions. Sedimentological analyses included the assessment of lithology, sedimentary structures, and overall stacking patterns of facies. The trace fossil analyses included identification to generic level (where possible) and overall degree of bioturbation, although some lithologies did not permit clear identification of ichnogenera. By integrating trace fossil interpretation with sedimentology and stratigraphic stacking pattern, robust paleoenvironmental interpretations of units are possible. In addition, this detailed component of the study will aid in understanding the lithostratigraphy and variations within the Eclipse Trough and North Bylot Trough, as well as between them.

5) Low Temperature Thermochronology and Structural History

During the 2017 field season, 32 samples were collected for apatite fission track and apatite and zircon (U/Th)/He analysis from the Bylot Island - northeast Baffin Island area. The samples were collected as part of a low temperature thermochronology study that addresses the structural response of this portion of Canada's eastern margin to the opening of Baffin Bay. Apatite and zircon separates from samples collected for other purposes (e.g. U/Pb zircon age determinations) as part of the GEM Northern Baffin Bedrock Mapping project (Saumur et al., 2017) may also be used in this study.

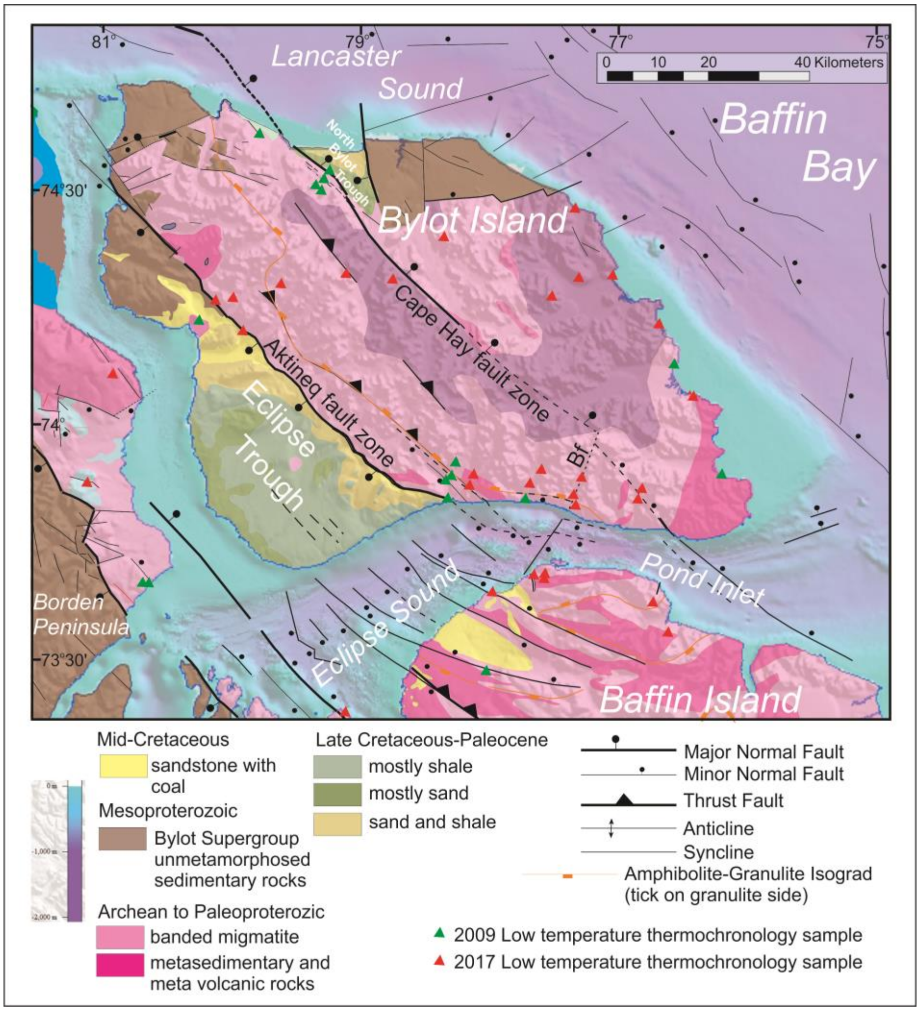

Figure 7. Generalized geology map of Bylot Island and environs (based on Jackson and Davidson, 1975a and Jackson et al., 1975), showing the locations of samples collected for apatite fission track and (U/Th)/He analysis. Bf: Bylot fault.

A number of fault-bounded structural blocks with unique cooling histories were identified on Bylot Island previously, based on thermal modelling of apatite fission track (Currie et al., 2012) and (U/Th)/He analyses for samples collected during the 2009 field season. These results clearly demonstrated the usefulness of low temperature thermal modelling for understanding the structural history of this area, but additional samples were required for a robust understanding of the location, timing, and magnitude of displacement along a number of known and possible faults.

Of particular interest are the following faults and fault zones. The Aktineq fault zone (Fig. 7) is well documented on Bylot Island. Here, Archean to Paleoproterozoic gneisses that form the basement to Eclipse

Trough on the west, cooled through temperatures between 120° C and 70° C during the Paleozoic. East of the fault, similar basement rocks that form the spectacular glaciated mountains cooled through the same temperatures during the Mesozoic. The location of Aktineq fault to the south of Bylot Island has not been convincingly established. The fault zone may continue across Eclipse Sound onto Baffin Island, or to the east beneath Eclipse Sound, as shown on Figure 7.

The Cape Hay fault zone has been mapped from beneath Lancaster Sound (based on interpretation of industry marine seismic reflection data; Harrison et al., 2011) on to northern Bylot Island, where it forms the western margin of North Bylot Trough (Jackson and Davidson, 1975a), and as far south as 73°N, 17 km north of the south shore of Bylot Island (Jackson, 2000; Fig. 7). Jackson et al. (1975) mapped a fault on the south coast of Bylot Island that may be a southern continuation of the Cape Hay fault zone. Samples were collected in 2017 to test the hypothesis that this fault continues at least as far south as southern Bylot Island.

Analysis of a 1970s vintage marine seismic section, multichannel seafloor bathymetry, and 3.5 kHz sub-bottom profiles (Campbell et al., 2015) suggests that a fault (herein referred to as the Bylot fault; Bf, Fig. 7) may exist beneath Eclipse Sound. Samples were collected from either side of the proposed onshore trace of the Bylot fault to determine whether it has experienced sufficient displacement to be detected by low temperature thermochronology methods.

The timing of motion on northeast-striking faults in the Bylot Island - northeast Baffin Island area can be limited to Mesoproterozoic or younger where they juxtapose Archean to Paleoproterozoic gneisses against Mesoproterozoic strata (Fig. 7). Low temperature thermal modelling for samples from opposite sides of these faults may provide insight into the age of movement on some of these faults and possibly the magnitude of their displacements.

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