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Permanent link: https://doi.org/10.4095/311324

This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

**Recommended citation**

Bingham-Koslowski, N., Dafoe, L.T., St-Onge, M.R., Haggart, J.W., and Campbell, C., 2018. Report of activities for the Baffin geological synthesis (2018), GEM-2 Baffin Project; Geological Survey of Canada, Open File 8483, 10 p. https://doi.org/10.4095/311324

Publications in this series have not been edited; they are released as submitted by the author.

**Forward**

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 responsible land-use and 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 2018 field season, research scientists from the GEM program successfully carried out 18 research activities, 17 of which will produce an activity report and 14 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.

**Project Summary**

The Baffin Geological Synthesis is an ongoing activity under the GEM-2 Baffin Project that initiated in 2016. The activity aims to summarize existing and new geological data resulting from previous and current GEM Baffin studies and related research (Fig. 1). The Synthesis combines current and previous onshore and offshore studies in order to produce a comprehensive synopsis of the geology and tectonic history of both Baffin Island and the Labrador-Baffin Seaway. The Baffin Geological Synthesis will be published as a Geological Survey of Canada Bulletin – Compendium (titled Baffin Island and Labrador-Baffin Seaway Geological Synthesis), and will be publically available online. The compilation is subdivided into chapters that provide geological summaries, as well as high resolution reference maps and figures. Corresponding GIS datasets will also be available for download by the users.

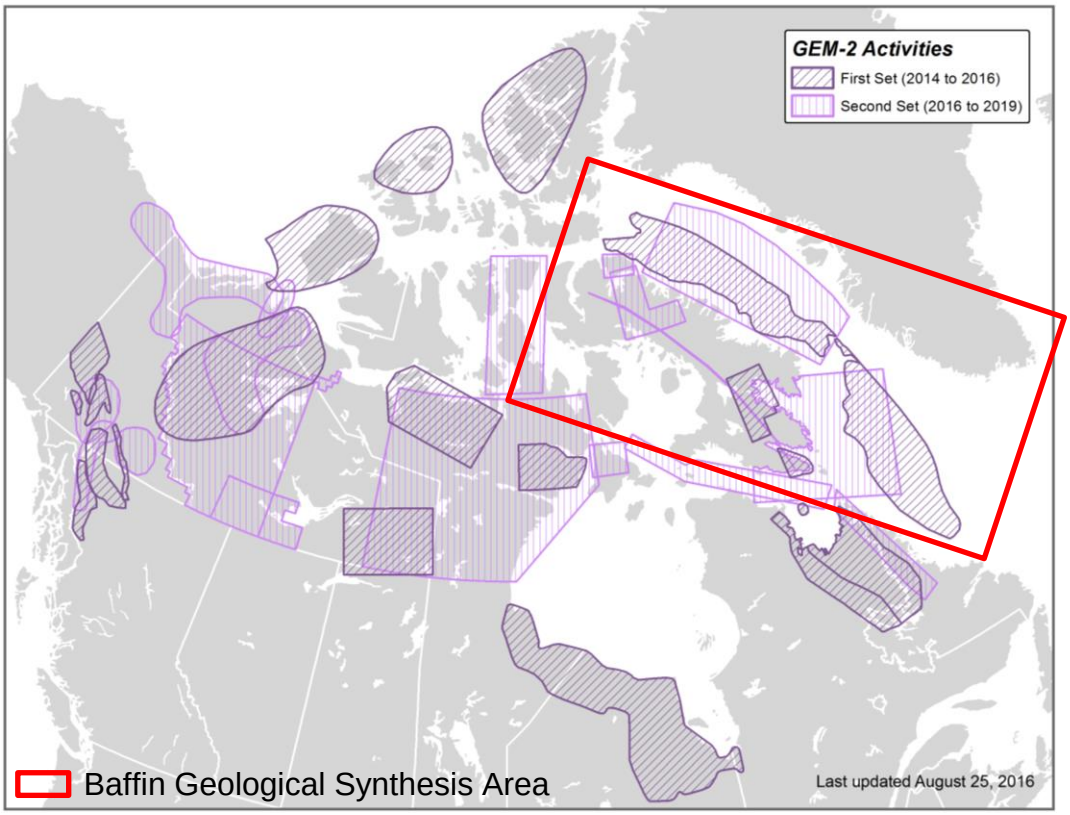


*Figure 1: A map of past and current GEM-2 activities with the Baffin Geological Synthesis area highlighted in red.*

## Introduction

Knowledge of the bedrock geology and tectonic history of Canada's North, specifically modern map coverage of onshore Baffin Island and offshore stratigraphy and structure of the Labrador-Baffin Seaway, has significantly improved since the commencement of the Geo-mapping for Energy and Minerals (GEM) Program in 2008. The goal of the Baffin Geological Synthesis Activity is to produce a digital, publically available, comprehensive document that summarizes the new geological and tectonic understanding of Baffin Island and the Labrador-Baffin Seaway that has been developed through GEM and its collaborators over the last decade. The Baffin Island and Labrador-Baffin Seaway Geological Synthesis is divided into three parts: Part 1 – Precambrian and Paleozoic, Part 2 – Mesozoic to Present, and Part 3 – Land Use. Part 2 is further subdivided into subregions that include the Labrador Margin, western Davis Strait, Baffin Island margin, Baffin Island, Bylot Island, and the West Greenland Margin (Fig. 2). Parts 1 and 2 aim to resolve and summarize the geological and tectonic history of the region, and Part 3 is intended to provide information on known resources in the area which may be of interest to northern communities, academia, provincial/territorial governments, and industry. Due to the scope of the project, the Synthesis involves collaboration with university partners and the Geological Survey of Denmark and Greenland (GEUS).

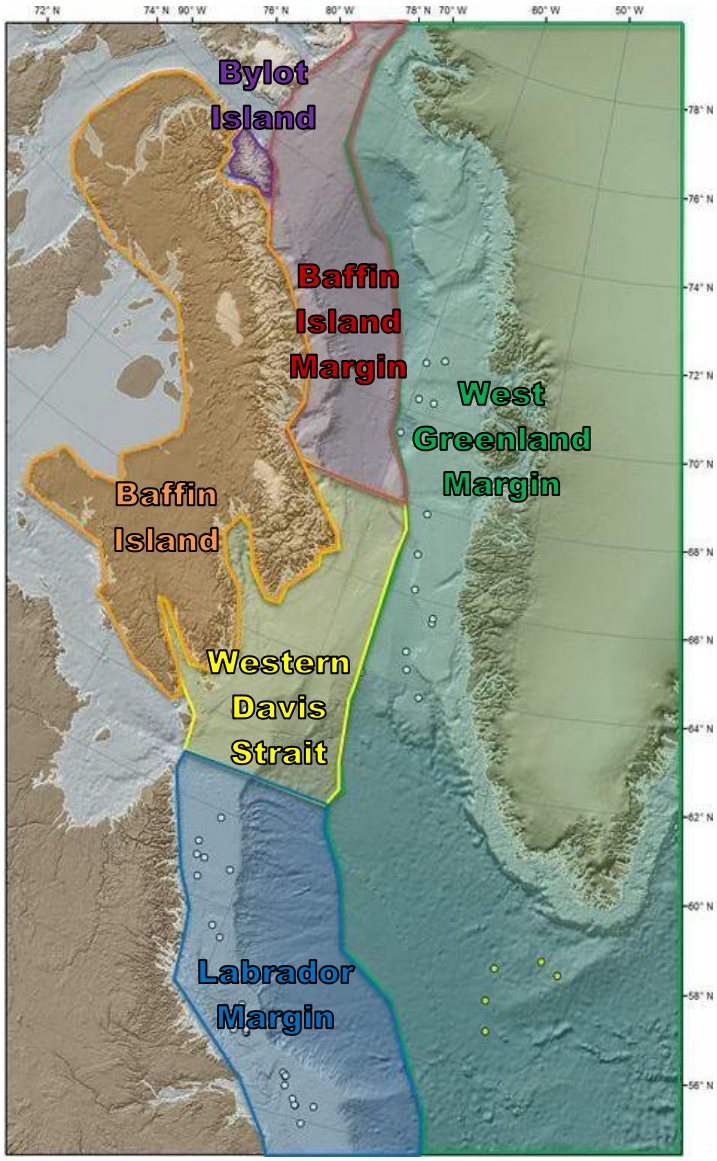


*Figure 2: The Baffin Geological Synthesis is subdivided into 6 geological regions, the locations of which are highlighted on the map: Bylot Island (purple), Baffin Island (orange), Baffin Island margin (red), Western Davis Strait (yellow), Labrador Margin (blue), and West Greenland Margin (green).*

## Methodology

The Baffin Geological Synthesis is a desktop study that integrates and summarizes previous knowledge and new results from geological research conducted in the Baffin region during the GEM program. A general overview of the methodology employed to construct the Synthesis and associated activities can be found in Bingham and Dafoe (2017).

## Results

The second full year of the Baffin Geological Synthesis Activity has seen progress on all of the 14 component chapters and/or related publications, with the Synthesis volume on track to be submitted for review and editing in 2019. The following presents individual chapter updates that include key references highlighting new GEM Baffin results.

*Chapter 1: Introduction*

The introduction chapter details the purpose of the Baffin Geological Synthesis, defines the study area, as well as provides a general overview of the regional geology, methodology, and organization of the Synthesis. Work

has begun on this chapter with development of an outline, but this chapter relies on input from all other chapter leads and therefore will be one of the last chapters to be completed.

*Chapter 2: Archean and Paleoproterozoic Cratonic Rocks of Baffin Island*

This chapter presents an overview of the history of geological investigations on Baffin Island (Fig. 2), from Martin Frobisher's trans-Atlantic voyages completed during the second half of the 16$^{th}$ C (Hogarth et al., 1994) through to the current GEM North Baffin Mapping activity (Skipton et al., 2017). This is followed by a detailed description and illustration of the main Archean and Paleoproterozoic lithotectonic domains of Baffin Island and a synthesis of how these were assembled into their present configuration during a period of global continental aggregation in the middle Paleoproterozoic period. From north to south, there are four crustal domains. 1) Archean basement orthogneiss, felsic plutonic rocks and supracrustal packages, comprising the eastern upper-plate Rae craton (Skipton et al., 2017), unconformably overlain along its southern margin by middle Paleoproterozoic supracrustal cover (Piling Group; Wodicka et al., 2014) and stratigraphically similar units of the Hoare Bay Group on Cumberland Peninsula (Sanborn-Barrie et al., 2017). A middle Paleoproterozoic felsic plutonic suite (Qikiqtarjuaq suite; Rayner et al., 2012) intrudes both the cratonic basement and supracrustal cover strata. 2) Archean to middle Paleoproterozoic metaplutonic gneissic units and middle Paleoproterozoic tectonostratigraphic cover units (Lake Harbour Group; Jackson and Taylor, 1972), collectively termed the 'Meta Incognita microcontinent' by St-Onge et al. (2000), which represents crust rifted from the Rae craton, the Superior craton, or an exotic craton. 3) Middle Paleoproterozoic, dominantly monzogranitic to granodioritic orthogneiss, interpreted as a deformed arc-magmatic terrane (Narsajuaq terrane; Scott, 1997; Wodicka and Scott, 1997; Thériault et al., 2001; St-Onge et al., 2009). 4) Archean tonalitic to granitic orthogneiss, interpreted as the northern continuation of the lower-plate Superior craton crystalline basement, and associated middle Paleoproterozoic continental margin supracrustal cover (Povungnituk Group; St-Onge et al., 1996). The four tectonic elements were progressively accreted from north to south across a series of north-dipping crustal sutures during long-lived deformation associated with the Himalayan-scale Trans-Hudson orogen.

*Chapter 3: Mesoproterozoic Borden Basin*

The third chapter in the Baffin Geological Synthesis focusses on the geology of the Mesoproterozoic Borden Basin located on northern Baffin Island (Fig. 2). A summary of early work and issues related to ore deposits in the Basin is followed by a synthesis of modern geological research including stratigraphy, geochronology, basin evolution, geochemistry, diagenesis, and ore geology, which has been conducted in the Borden Basin, up to 2018. The chapter also discusses outstanding issues related to the Basin, as well as its economic potential.

*Chapter 4: Lower Paleozoic Strata in the Labrador-Baffin Region*

The lower Paleozoic of the Labrador-Baffin Seaway is the focus of Chapter 4. The Paleozoic strata in the region is sparse, disconnected, and has been subjected to deformation and diagenesis (Bell and Howie, 1990). It has therefore been historically understudied resulting in a poor understanding of the paleoenvironments that existed during this time interval, the depositional history of the interval, and its economic potential. This chapter summarizes previous knowledge of this strata and the work that has been done under the GEM-2 Baffin Geological Synthesis Activity to further the knowledge of the Paleozoic in the following areas: the Labrador margin, the western Davis Strait and Baffin Island margins, as well as onshore Baffin Island (Fig. 2). Paleozoic strata is intersected in seven exploration wells along the Labrador margin; however, existing biostratigraphic ages for this strata are highly variable and sometimes inconclusive preventing correlations between wells and with adjacent regions. Lithological analysis of Paleozoic cores from the Labrador margin is currently being prepared in a Geological Survey of Canada Open File Report that will contribute to this subsection of Chapter 4. In addition, recent palynological analysis of the Paleozoic interval from the Labrador margin wells provides new biostratigraphic constraints for these strata, enabling comparisons with age-equivalent strata of neighbouring regions (Bingham-Koslowski, 2018c, d). Physical evidence of Paleozoic strata that underlies the western Davis Strait region and Baffin Island margin is limited to six drill cores. This chapter also summarizes the geological history of this offshore region based on the results of a detailed lithological analysis of these drill cores (Bingham-Koslowski, 2018a, b). A summary of the known onshore Paleozoic geology is also presented in this chapter.

*Chapter 5: Stratigraphy of Bylot Island and onshore areas of Baffin Island*

This chapter synthesizes existing published and unpublished literature dealing with two principal areas of outcropping Mesozoic and younger strata of northeast Nunavut along Baffin Bay: exposures on Bylot Island and adjacent areas of northern Baffin Island in the vicinity of Pond Inlet; and exposures on the coast of southeastern Baffin Island in the vicinity of Cape Dyer. The known geology of additional minor exposures of Mesozoic(?) and younger strata in Clyde Foreland and Rimrock Lake area of interior Baffin Island is also summarized. The scientific literature dealing with all of these areas includes both published and unpublished sources, including numerous university theses, much of it dating from several decades ago. Ongoing GEM studies are addressing some aspects of the basic stratigraphic science for these areas that are lacking, in particular the regional extent of stratigraphic units, their ages, and their correlation. As a complement to this chapter of the Synthesis, a Geological Survey of Canada Open File report is planned detailing measured stratigraphic sections of Cretaceous-Paleogene strata of Bylot Island and northern Baffin Island. The Open File report will present a preliminary lithostratigraphic framework for these strata based on geological mapping and stratigraphic studies undertaken under the current GEM program (see Haggart et al., 2018). These studies have relied heavily on biostratigraphic analysis, principally palynology, to provide correlation of lithostratigraphic units and to formulate the lithostratigraphic framework. Initial work has suggested that the age of the succession ranges from the latest Early Cretaceous (Albian) to the early Paleogene (Selandian), with most stages of the Upper Cretaceous represented as well. This work will provide new information on the sequence stratigraphic history of both the onshore and offshore successions.

*Chapter 6: Stratigraphy of the Labrador Margin*

The stratigraphy of the Labrador margin (Fig. 2) was one of the main focuses for the GEM-2 Baffin: Stratigraphic and Tectonic Framework for the Baffin Bay Petroleum Systems Activity (Dafoe et al., 2014, 2016a, b, 2017). Revision of the stratigraphy is closely linked to new biostratigraphic ages also acquired under this activity (Williams, 2017a, b). Dafoe et al. (2018) recently discussed the latest clinoform trajectory model for Late Cretaceous and Cenozoic sedimentation on the Labrador-Baffin Island margins. These new results form the basis for reinterpreting the stratigraphy of the margin. In Chapter 6 of the Synthesis, this latest work is merged with existing knowledge regarding the stratigraphy of the margin. The available datasets are discussed, which is followed by a presentation of the lithostratigraphic units within key time intervals including: Lower Cretaceous, Upper Cretaceous, Paleocene-Eocene, and Oligocene-Pleistocene. The distribution of each major time-slice is also shown, as well as seismic profiles illustrating key stratal relationships. Formations are discussed in terms of their lithology, biostratigraphy and paleoenvironmental significance, seismic character, and mapping criteria. This chapter further summarizes previously established unconformities and linkages to tectonics.

*Chapter 7: Stratigraphy of the western Davis Strait Region*

Between the Labrador and Baffin Island margins, the western Davis Strait region forms a complex transform margin where strike-slip motion resulted in compression, major fault offset, and development of complex structure, all of which is in addition to significant volcanism (Fig. 2; Oakey and Chalmers, 2012 and references therein). Only a few industry wells were drilled in this region; however, legacy GSC drill core samples collected from the seabed during past marine cruises provide further lithological and biostratigraphic control on the stratigraphy (MacLean et al., 2014). Parts of this region have also been investigated under GEM from a lithostratigraphic, structural and petroleum perspective (Jauer et al., 2014; Jauer and Oakey, 2018). This chapter focuses on the stratigraphy of the region in the context of the Cretaceous, Paleocene-Eocene and Oligocene-Pleistocene intervals. Available datasets are presented as well as existing knowledge related to the lithostratigraphic units for the northern Saglek Basin. Distribution maps of each major time-slice are linked to illustration of the stratigraphy using key seismic profiles. Formations are discussed in terms of their lithology, biostratigraphy, paleoenvironmental significance, seismic character, and mapping criteria. This chapter further summarizes major unconformities and linkages to tectonics during the late Mesozoic and Cenozoic.

*Chapter 8: Stratigraphy of the Baffin Island Margin*

The Baffin Island margin (Fig. 2) is a key area of interest due to the presence of an active oil seep in Scott Inlet (Moir et al., 2011; Oakey et al., 2012), which provides direct evidence of a viable petroleum system. One of the

challenges with this region is the lack of sample data from wells, and seismic data is typically vintage and of poor quality. This area was one of the main focuses of the GEM-2 Baffin: Stratigraphic and Tectonic Framework for the Baffin Bay Petroleum Systems activity (Dafoe et al., 2014, 2016a, b, 2017). Under this activity and GEM-1, a digital seismic dataset was compiled and available samples including the ODP 645 well and legacy GSC drill cores were reassessed (MacLean et al., 2014; Dafoe et al., 2014, 2016a, b). Chapter 8 presents a synopsis of previous work on the region and available datasets. The stratigraphic succession of the region is grouped into a section discussing three generalized intervals: Cretaceous, Paleocene-Eocene, and Oligocene-Pleistocene. The distribution of strata related to each time interval is shown and tied to key seismic profiles that demonstrate the stratigraphic relationships. Formations are not established in this region; however, some sample information provides context to seismic-stratigraphic mapping.

*Chapter 9: Stratigraphy of the West Greenland Margin*

Chapter 9 summarizes the current understanding of the offshore bedrock geology of the West Greenland Margin (Fig. 2), as well as key onshore components of the basement and volcanic rocks. This chapter is directed and written by the Geological Survey of Denmark and Greenland (GEUS). The chapter is subdivided by region first (Southern West Greenland, Central West Greenland, and Northern West Greenland) and then by age (Pre-Cretaceous, Early Cretaceous, Late Cretaceous, Early Cenozoic, and Late Cenozoic), with each subsection describing the stratigraphy of each region for the associated time interval. A tectono-stratigraphic summary is also included, which correlates the geology of each region and presents an overall geological synthesis for the West Greenland Margin.

*Chapter 10: Stratigraphic summary of the Labrador-Baffin Seaway*

Chapters 5 through 9, covering the late Mesozoic and Cenozoic stratigraphy of the region, are compared and contrasted in Chapter 10 in order to show broad, regional trends and differences. This chapter presents a palynological events chart for the Mesozoic and Cenozoic onshore and offshore rocks (Nøhr-Hansen et al., 2016). Correlations are described between neighbouring areas/basins and illustrated with seismic profiles that extend across both the Canadian and West Greenland margins. This chapter also highlights regional trends in paleoclimate and eustatic sea level fluctuations over time.

*Chapter 11: Rifting and evolution of the Labrador-Baffin Seaway*

The geological history and stratigraphy of the Labrador-Baffin Seaway is intricately tied to its tectonic history. This chapter builds on the work of Oakey and Chalmers (2012) and others to update the understanding of both margin segmentation (areas that underwent extension vs. strike-slip motion) and margin zonation (variation in crustal types). Some of the key publications that feed into this chapter relate to the margin zonation of both the central (Keen et al., 2018a) and northern (Keen et al., 2018b) portions of the Labrador margin. In addition, seismic interpretation is combined with gravity inversion to provide new constraints on the crustal structure of Baffin Bay (Welford et al., 2018). Chapter 11 summarizes the previous work in the region in relation to rift history, crustal structure, volcanism, and seismicity. Key datasets are described, as well as methodologies and results surrounding new compilations of sediment thickness, depth to basement, potential fields datasets, fault plane solutions, and seismic refraction experiments. Finally, the chapter presents an updated, regional tectonic and geological map of the Labrador-Baffin Seaway.

*Chapter 12: Surficial geology of Baffin Island and the Labrador-Baffin Seaway*

Progress on the surficial geology chapter has focused on publication of key outputs on the marine geology of Baffin Bay (Jenner et al., 2018; Andrews et al., 2017; Jennings et al., 2018), marine geological hazards assessments (Broom et al., 2017; Campbell et al., 2017; Deering et al., 2018), new fieldwork (Normandeau, 2018), and discussions on how to integrate terrestrial and marine information. A glacial dynamics approach, rather than conventional surficial geology mapping, is applied for the Baffin Island region (Fig. 2). A depositional element approach is employed for the marine areas.

*Chapter 13: Mineral resources of Baffin Island*

Chapter 13 is one of two chapters in Part 3: Land use, and highlights the mineral resources known on Baffin Island. This chapter summarizes the history of mining on the island and provides an overview of known

occurrences of base metals, carving stones, and kimberlites/diamonds. Chapter 13 is being led by the Geological Survey of Canada with input from the Qikiqtani Inuit Association (QIA).

*Chapter 14: Petroleum occurrences in the Labrador-Baffin Seaway*
Chapter 14 presents an overview of the known petroleum occurrences in the Labrador-Baffin Seaway and onshore Baffin Island. This chapters is divided into subsections which focus on hydrocarbon systems and exploration activity in each of the major subregions (Labrador margin, western Davis Strait, Baffin Island margin, West Greenland margin, and onshore). A summary of the exploration history and current industry activity on the Labrador margin, the western Davis Strait region, and the West Greenland margin is provided. The location and geochemistry of known sea surface slicks and seafloor oil seeps (e.g. Scott Inlet) is also discussed.

**Conclusions**
The Baffin Geological Synthesis is an ongoing activity that is on track for completion at the end of GEM-2 in 2020. The advancement and finalization of the Synthesis is linked to the progression and completion of other GEM-2 Baffin activities, the majority of which have either concluded or are in their final stages. Once complete, the Synthesis will provide a regional and up-to-date understanding of the mineral-bearing bedrock geology of Baffin Island, as well as of the pre-rift, syn-rift, and post-rift stratigraphic sequences and related petroleum systems in the offshore of Labrador-Baffin Bay Seaway.

**Acknowledgements**
The Baffin Geological Synthesis is the product of a significant collaborative effort between the Geological Survey of Canada (GSC), academic institutions, and the Geological Survey of Denmark and Greenland (GEUS). Thank you to all of the collaborators, project management, and the GEM co-ordination team; this project would not be possible without your continued efforts. Thank you to: Allison Bent (GSC), Jørgen Bojesen-Koefoed (GEUS), Tom Brent (GSC), Elliott Burden (MUN), Paul Champagne (GSC), Kate Clark (GSC), Lisel Currie (GSC), Gregers Dam (GEUS), Sonya Dehler (GSC), Kevin DesRoches (GSC), Kate Dickie (GSC), Ross Elgin (QIA), Rob Fensome (GSC), Thomas Funck (GEUS), Ulrik Gergerson (GEUS), Linda Ham (GSC), Chris Harrison (GSC), John R. Hopper (GEUS), Sheila Hynes (GSC), Jon Ineson (GEUS), Evelyn Inglis (GSC), Peter Japsen (GEUS), Charlotte Keen (GSC), Rosemarie Khoun (GSC), Christian Knudsen (GEUS), Paul Knutz (GEUS), Lotte M. Larsen (GEUS), Denis Lavoie (GSC), Qingmou Li (GSC), Tannis McCartney (GSC), Merrell Miller (IRF Group), Andy Mort (GSC), Tove Nielsen (GEUS), Henrik Nøhr-Hansen (GEUS), Gordon Oakey (GSC), Eric Patton (GSC), Gunver Krarup Pedersen (GEUS), Nicole Rayner (GSC), Mary Sanborn-Barrie (GSC), Benoit Saumur (UQAM), Claudia Schroder-Adams (Carleton), Dave Scott (Polar Knowledge), Natalie Shea (GSC), Emma Sheldon (GEUS), Diane Skipton (GSC), Tommy Tremblay (GSC), Elizabeth Turner (Laurentian University), Peter Voss (GEUS), Kim Welford (Memorial University), Owen Weller (University of Cambridge), Graham Williams (GSC), Natasha Wodicka (GSC), and Shunxin Zhang (GSC). Thank you also to Dawn Kellett for her thoughtful review and comments.

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