Bedrock mapping and stratigraphic studies in the Mackenzie Mountains, Franklin Mountains, Colville Hills, and adjacent areas of the Northwest Territories, Geo-mapping for Energy and Minerals program 2009–2019

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Abstract: The Geo-mapping for Energy and Minerals (GEM) program provided an opportunity to update bedrock geological maps for nearly 92 000 km^2 of the northwestern portion of the mainland area of the Northwest Territories. Twenty-four new maps (at the scale of 1:100 000 or 1:250 000) cover a region from the Colville Hills southwestward into the Mackenzie Mountains, including areas of significant mineral and energy resource potential. New mapping was informed by archived Geological Survey of Canada data, notably from Operation Norman (1968–1970), as well as by public-domain industry data. Maps incorporate numerous stratigraphic revisions that postdate Operation Norman, including GEM program innovations affecting Neoproterozoic (specifically Tonian and Ediacaran), Cambrian, and Ordovician units. In this paper, the mapping effort and stratigraphic revisions are documented, a preliminary treatment of structural geology is provided, and related subsurface studies are summarized. Following GEM, GIS-enabled bedrock maps will be available for a swath of territory stretching from the edge of the Selwyn Basin, near the Yukon border, to the Brock Inlier in the northeastern portion of the mainland area of the Northwest Territories.

Résumé : Le programme Géocartographie de l'énergie et des minéraux (GEM) a permis la mise à jour des cartes de la géologie du substratum rocheux sur une superficie de près de 92 000 km^2 dans le secteur nord-ouest de la partie continentale des Territoires du Nord-Ouest. Les 24 nouvelles cartes (à l'échelle de 1/100 000 ou 1/250 000) couvrent une région s'étendant vers le sud-ouest depuis les collines Colville jusqu'aux monts Mackenzie, où certains secteurs présentent un important potentiel en ressources minérales et énergétiques. La nouvelle cartographie a su tirer profit des données d'archives de la Commission géologique du Canada, principalement issues de l'opération Norman (1968-1970), ainsi que de données de l'industrie versées dans le domaine public. Les cartes intègrent de nombreuses révisions stratigraphiques postérieures à l'opération Norman, ainsi que des découvertes du programme GEM concernant les unités du Néoprotérozoïque (en particulier du Tonien et de l'Édiacarien), du Cambrien et de l'Ordovicien. Ce rapport documente les travaux de cartographie ainsi que les révisions stratigraphiques, offre un traitement préliminaire de la géologie structurale, et résume les études du sous-sol connexes. Grâce au programme GEM, de nouvelles cartes SIG de la géologie du substratum rocheux seront disponibles pour un vaste territoire s'étendant de la bordure du bassin de Selwyn, près de la limite territoriale du Yukon, jusqu'à la boutonnière de Brock, dans le secteur nord-ouest de la partie continentale des Territoires du Nord-Ouest.

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INTRODUCTION

In this paper, a summary is provided of bedrock mapping efforts and related stratigraphic studies undertaken under the Geo-mapping for Energy and Minerals (GEM) program that were focused on the northwestern portion of the Northwest Territories between latitudes 65°N and 68°N and longitudes 124°W and 132°W (Fig. 1). Sedimentary rocks underlie the largest part of the mainland Northwest Territories north of latitude 64°N and the region is rich in potential geological resources (Fig. 2). In the Mackenzie River valley, the region around Norman Wells has been a site of active petroleum exploration and production for a century, and petroleum exploration since the 1970s has identified oil and gas resources in the Colville Hills and easternmost Mackenzie Mountains (*see* Hannigan et al., 2011). To the west, in the Mackenzie and Selwyn mountains, there are more than 300 documented mineral deposits and prospects (Ootes et al., 2011). Nonetheless, in the early 2000s, the state of published bedrock-geology maps for the region was highly uneven. Although some areas were represented by professionally drafted, colour maps published as part of the former 'A' Series of the Geological Survey of Canada (GSC), effectively all published maps for the region were based upon GSC reconnaissance operations carried out in the 1960s and early 1970s. Notably, GSC maps for the economically important region around Norman Wells were available only as hand-lettered manuscript maps, published as Open File reports, and GSC maps for the Colville Hills exploration region were black-and-white preliminary maps. Equally notable was the lack of a publicly available, quantitative, probabilistic oil and gas resource assessment for the region (indeed, for the entire mainland area of the Northwest Territories).

In 2008, the federal government announced funding for the GEM program. Following renewal in 2013, the program ended in 2020. The northern portion of the mainland area of the Northwest Territories was a focus of GSC studies during both phases of GEM, with an emphasis on filling knowledge gaps. During the first phase (2008–2013), work in this region was focused on energy resources. The work was highly interdisciplinary, with research efforts grouped into three major activities. First, studies carried out in the Mackenzie Delta–Beaufort Sea region (Dixon et al., 2008) ended a long-standing GSC–industry research consortium for that region, which dealt with biostratigraphy, geochemistry, and quantitative basin analysis including thermal history (e.g. Issler et al., 2009, 2011, 2012); this work is not covered in this paper. Second, a quantitative, probabilistic oil and gas resource assessment was completed for the mainland Northwest Territories; this work was presented in Hannigan et al. (2011; *see also* Hannigan, 2012, 2013). Third, a major field component focused on preparing new bedrock-geology maps of the area covered at the 1:250 000 scale by the four NTS map sheets around the Norman Wells oilfield, including supporting stratigraphic work (Fig. 3); results of this work are summarized below.

During the second phase of GEM (2013–2020), the focus of bedrock mapping shifted (Fig. 3), first to the Colville Hills (2015 field season; Fallas et al., 2015c) and then to the northern Mackenzie Mountains (2016, 2017, and 2018 field seasons; Fallas et al., 2016; MacNaughton et al., 2017, 2018). As in the first phase, supporting stratigraphic studies were conducted, commonly in tandem with the bedrock mapping. Many of these studies dealt with Neoproterozoic–Silurian stratigraphic evolution and, together with the bedrock mapping, sought to update the structural geology and the pre-Devonian stratigraphic framework across the mainland Northwest Territories. These studies are summarized below. This work also tied into GEM program bedrock mapping and stratigraphic studies around the Brock Inlier (Fig. 3), to the northeast (Rainbird et al., 2015a, b; Greenman and Rainbird, 2018). During the second phase of GEM, Devonian stratigraphic studies also were carried out in tandem with the bedrock mapping and studies on pre-Devonian stratigraphic units. Reports on the Devonian studies will be published separately, dealing with sedimentology and stratigraphy (Kabanov, this volume) and conodont biostratigraphy (Gouwy, this volume).

Both phases of GEM in the Mackenzie region involved collaborative studies using detrital zircon geochronology to elucidate sediment provenance of Proterozoic to Cretaceous strata (Lemieux et al., 2011; Hadlari et al., 2012, 2014, 2015; Rainbird et al., 2017). Also, during both phases of GEM, aspects of the work were done in partnership with the Northwest Territories Geological Survey (NTGS; formerly Northwest Territories Geoscience Office). This collaboration included reciprocal advice, in-kind support for studies of hydrocarbon systems (e.g. Pyle and Gal, 2011, 2012a, b; Pyle et al., 2011), and joint participation in fieldwork (e.g. Gal et al., 2010; MacNaughton et al., 2017). These aspects of the projects are mentioned for completeness, but are not discussed in detail in this paper.

The balance of the paper is divided into six sections. In the first one, a summary of previous bedrock mapping efforts in the region is presented. In the second, the approach adopted for bedrock mapping in the region during the two phases of the GEM program is summarized. In the third section, revisions to the region's stratigraphy in the past four decades are discussed, with a particular focus on GEM program studies and recognition of revised units during bedrock mapping. In the fourth part of the paper, subsurface stratigraphic studies in the Mackenzie Plain and Great Bear Plain are briefly summarized. The structural geology of the study area, including key revisions arising from GEM bedrock mapping, are summarized in the fifth section of the paper. Finally, a summary of research highlights is provided in the sixth section. Because key aspects of these studies are ongoing as of the time of writing (mid-2019), this paper is a summary of work to date rather than a detailed synthesis of scientific observations.

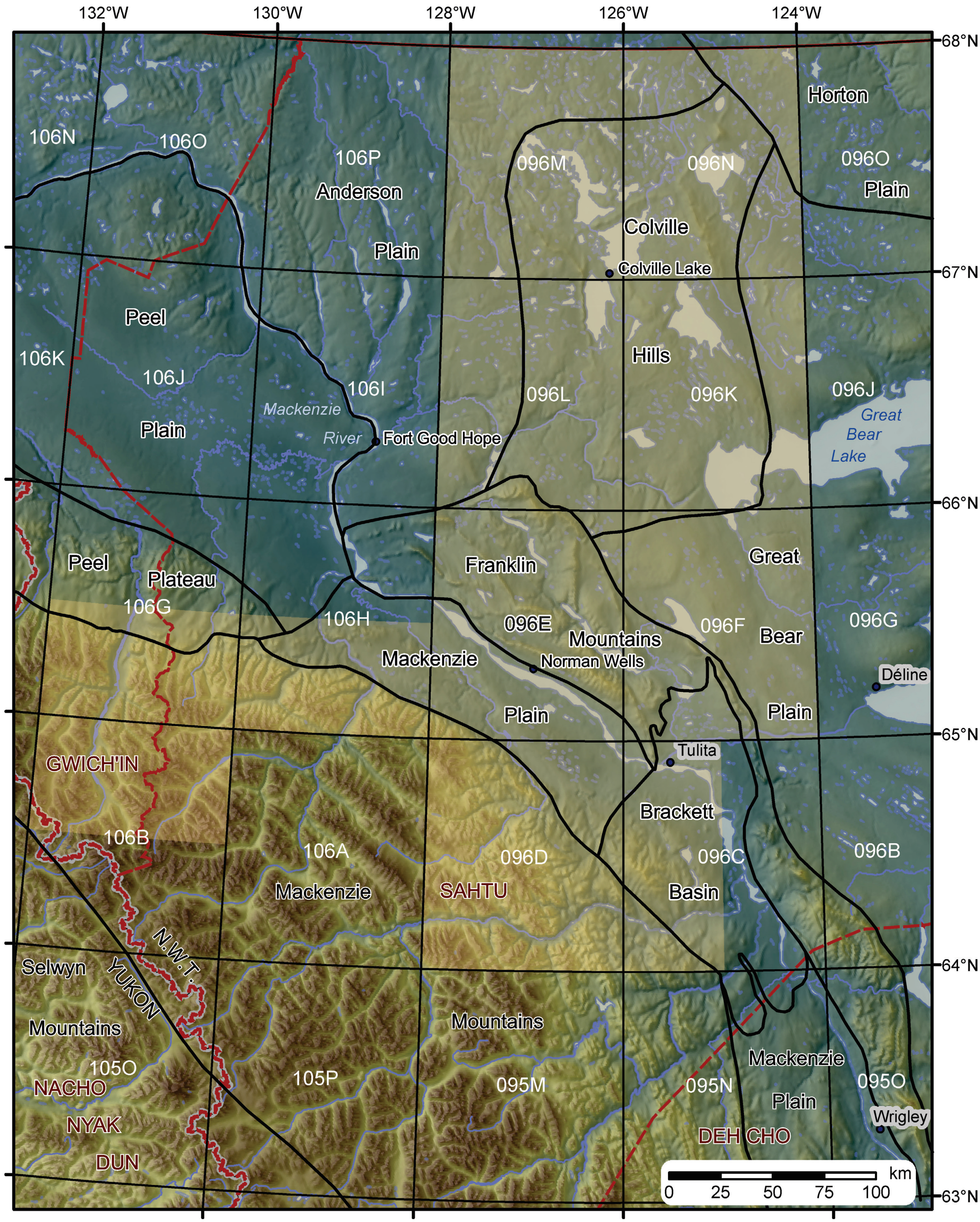

Figure 1. Geo-mapping for Energy and Minerals program Mackenzie study area (yellow tint), showing the boundaries of the physiographic regions (in black) and indigenous land-claim settlement areas (in red). Topography from Canadian Digital Elevation Model (Natural Resources Canada, 2015) Communities are labelled.

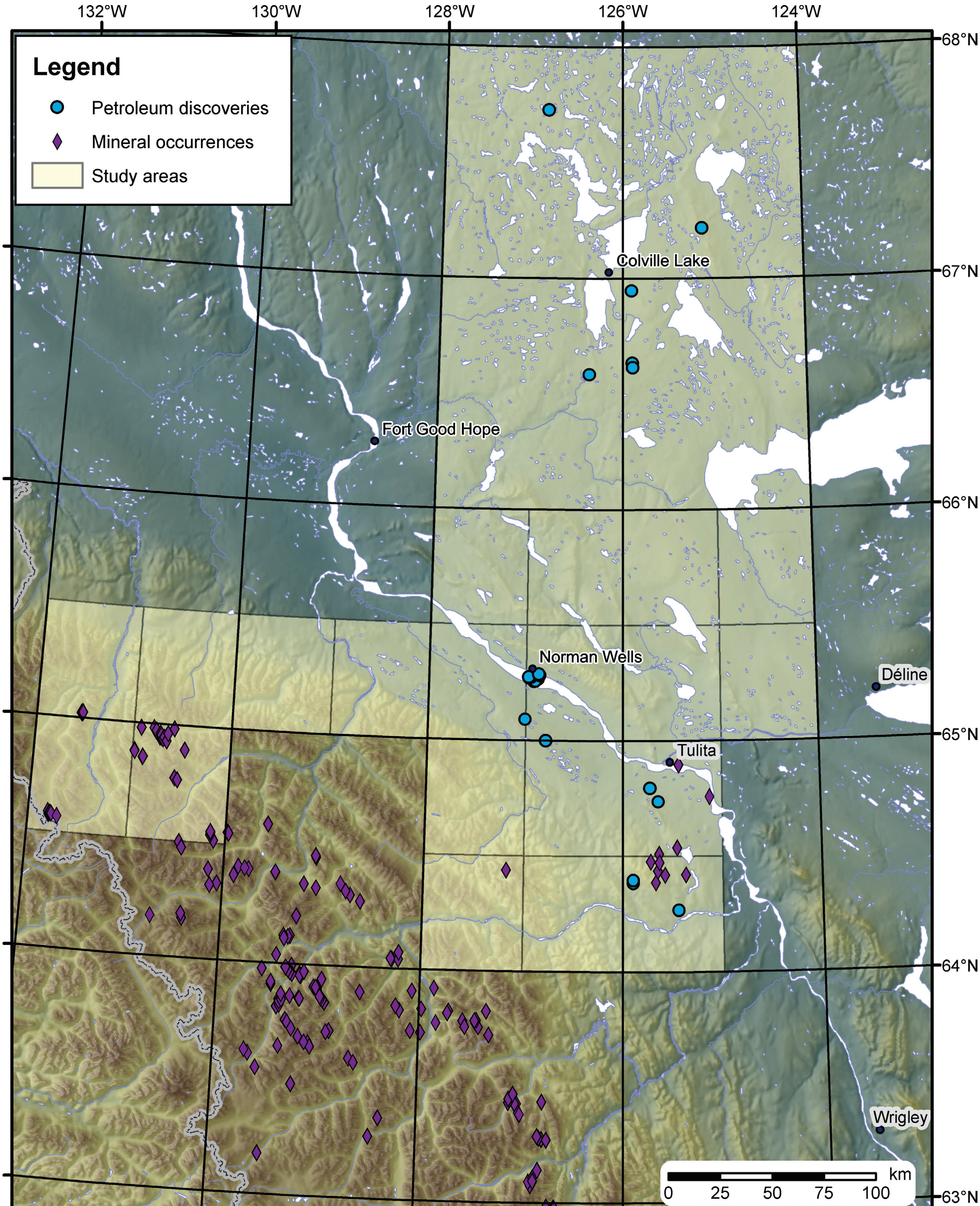

Figure 2. Mineral and petroleum resources in study area and adjacent regions. Petroleum production is limited to the oilfield at Norman Wells and none of the mineral occurrences shown are currently under production. Topography from Canadian Digital Elevation Model (Natural Resources Canada, 2015).

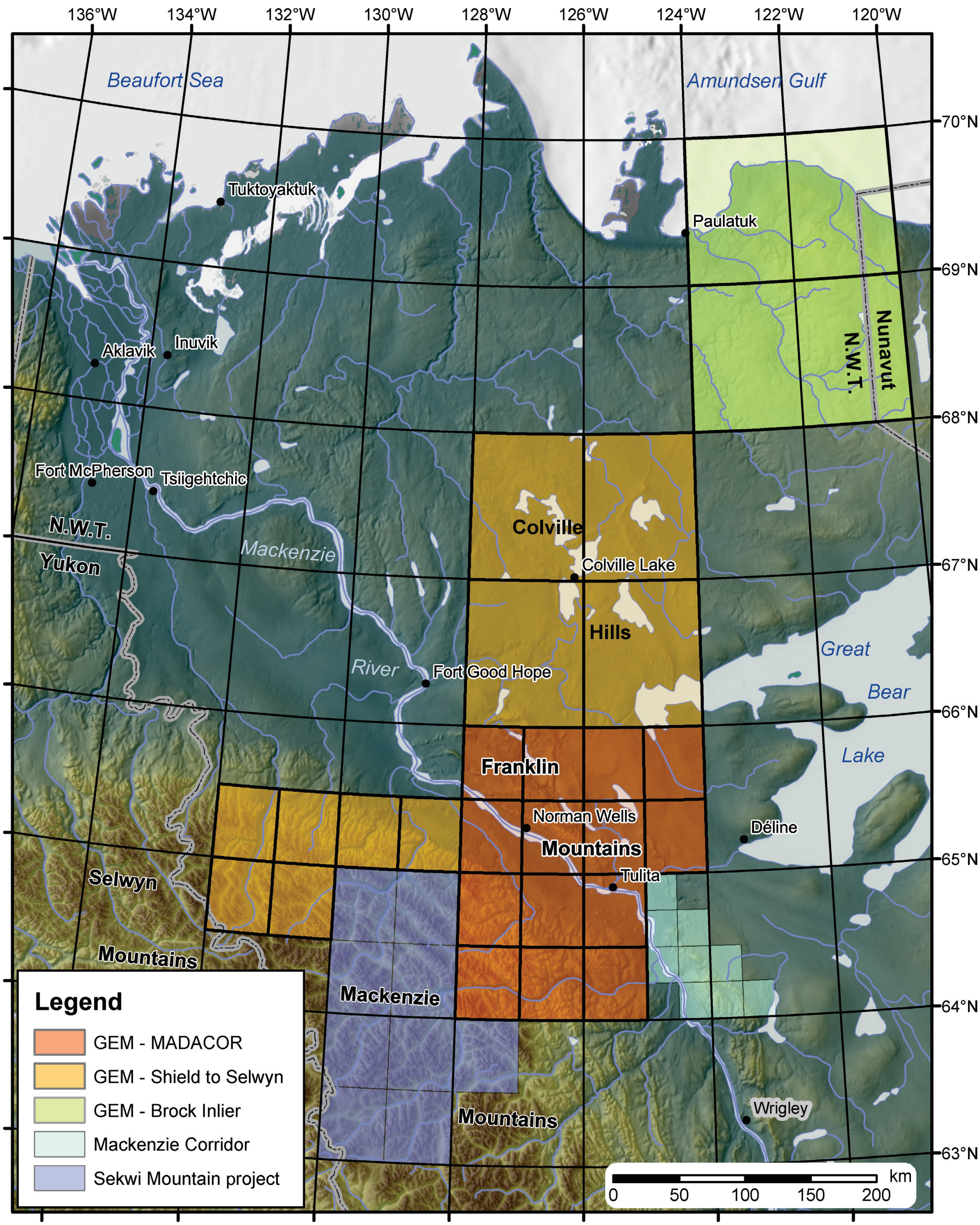

Figure 3. Geological Survey of Canada mapping activity in the sedimentary basins of the mainland area of the Northwest Territories (excluding the Richardson Mountains) since 2000. Mapping during the first phase of the Geo-mapping for Energy and Minerals program was focused on the Norman Wells region (2009–2012; this paper). During the second phase of the program, mapping took place in the Colville Hills (2015; this paper), the northern Mackenzie Mountains (2016–2018; this paper), and the Brock Inlier region (2015–2016; e.g. Rainbird et al., 2015a). Earlier mapping was conducted under the Mackenzie Corridor Project in 2003 and 2004, and Sekwi Mountain project (in conjunction with the Northwest Territories Geological Survey) from 2006 to 2008. Topography from Canadian Digital Elevation Model (Natural Resources Canada, 2015).

This paper is intended to be a source for those seeking recent information on the geology and earth resources of the study region. Such parties also can consult several other publications prepared during GEM. An overview of Cambrian to Devonian geology east of the Mackenzie Mountains can be found in Fallas et al. (in press a) and a similar overview of Cretaceous and younger strata is presented in Fallas et al. (in press b). These both include summaries of stratigraphy, structure, tectonics, and petroleum geology. A detailed treatment of petroleum potential in the mainland area of the Northwest Territories can be found in Hannigan et al. (2011). Morrow (2012; *see also* 2018) reviews the Devonian of the same region. The most thorough pre-GEM geological overview for the Mackenzie Mountains is found in Martel et al. (2011).

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BACKGROUND TO GEM PROGRAM MAPPING EFFORTS

Early geographical and geological investigations in the project area have been summarized by Hume (1954) and by Aitken et al. (1973). The successful drilling of the Norman Wells oilfield in 1920 was the stimulus for an early phase of GSC field studies in the Mackenzie River valley, which established key elements of the region's lower Paleozoic stratigraphy (e.g. Williams, 1922, 1923). The Second World War, during which the Norman Wells oilfield assumed strategic importance, corresponded with a further period of intense geological study as part of the Canol Project (1942–1945), a co-operative effort of Canada and the United States. The results of the Canol Project contributed importantly to a general understanding of the Mackenzie region's upper Paleozoic and younger stratigraphic framework (Hume and Link, 1945; Hume, 1954), but left numerous unanswered questions regarding relationships between Proterozoic and lower Paleozoic formations (Aitken et al., 1973).

At the beginning of GEM, most of the published bedrock geology maps for the Mackenzie Plain, the northern Interior Plains, the Franklin Mountains, and the Mackenzie Mountains (Fig. 4a) were based on helicopter-supported, reconnaissance-scale mapping programs undertaken by the Geological Survey of Canada in the 1960s and early 1970s. Much of this area had been mapped between 1968–1970 during Operation Norman, which extended from a southern limit at latitude 64°N, northward to the shore of the Arctic Ocean, and from a western limit at longitude 132°W, eastward to the contact between Paleozoic strata and underlying Precambrian rocks of the Canadian Shield (Cook and Aitken, 1971; Aitken et al., 1973). It encompassed parts of the Interior Plains, Franklin Mountains, Mackenzie Plain (including the oilfield at Norman Wells), and the northern and eastern Mackenzie Mountains. Parts of the Mackenzie Mountains to the west and south were mapped mainly during the 1960s as part of three other GSC projects: Operation Selwyn (Blusson, 1967, 1968, 1972; Gabrielse, 1968); Operation Stewart (Blusson and Tempelman-Kluit, 1970; Blusson, 1971, 1974); and Operation Nahanni (Gabrielse et al., 1973a). Operation Nahanni was of particular importance, inasmuch as it established much of the lithostratigraphy currently applied in the Mackenzie Mountains (Gabrielse et al., 1973a, b). Operation Norman also refined Proterozoic and lower Paleozoic lithostratigraphy in the Mackenzie Mountains and points to the east (e.g. Aitken et al., 1973; Norford and Macqueen, 1975), and laid the groundwork for the study by Yorath and Cook (1981) that established much of the Mesozoic stratigraphy for the region.

Collectively, these mapping programs produced a set of nondigital, reconnaissance-scale, printed geology maps for the eastern Cordillera and Interior Plains of the Mackenzie region of the Northwest Territories north of latitude 63°N. Maps were published as uncoloured preliminary maps and open files (the latter generally being hand-drafted and hand-lettered), or coloured GSC 'A' Series maps (Fig. 4a). Covering the largest part of the area were maps produced as part of Operation Norman.

Although the years following Operation Norman saw more limited bedrock mapping efforts by GSC in the Mackenzie and Selwyn Mountains (e.g. Gordey and Anderson, 1993; Cecile, 2000), most GSC work in the Mackenzie Mountains during the post-Operation Norman era dealt with stratigraphic problems. Notable progress included studies on the Proterozoic (e.g. Aitken et al., 1978; Eisbacher, 1978, 1981; Aitken, 1981, 1989, 1991; Jefferson and Parrish, 1989; Narbonne and Aitken, 1990, 1995), Cambrian (e.g. Fritz, 1972, 1976, 1978, 1979, 1982; Fritz et al., 1983), and the platformal Devonian succession (Morrow, 1991). To the west, Cecile (1982) clarified the lower Paleozoic lithostratigraphy of the more distal Selwyn Basin succession. In the Mackenzie Plain and adjacent areas, surface and subsurface studies led to the refinement of parts of the Paleozoic stratigraphy (e.g. Tassonyi, 1969; Pugh, 1983; Hamblin, 1990; Meijer-Drees, 1993; Dixon and Stasiuk, 1998). Relevant chapters in the Decade of North American Geology volume on the Canadian Cordillera (Gabrielse and Yorath, 1991) provide an important summary of the state of knowledge for the region as of the late 1980s to early 1990s.

In 2005, the NTGS began a major bedrock-mapping initiative in the Mackenzie Mountains, in partnership with the GSC. Under the Sekwi Mountain project (Martel et al., 2011), field seasons were conducted in 2005, 2006, 2007, and 2008, to update the bedrock geology of NTS 105-P, 106-A, and the northwestern part of 95-M. Resulting maps (Fig. 3, 4b) were published in 2012, with an accompanying GIS-data release (Gordey et al., 2012). These marked the first efforts undertaken in the Mackenzie Mountains to produce digital bedrock maps with GIS data that are more easily integrated with other research. At roughly the same time,

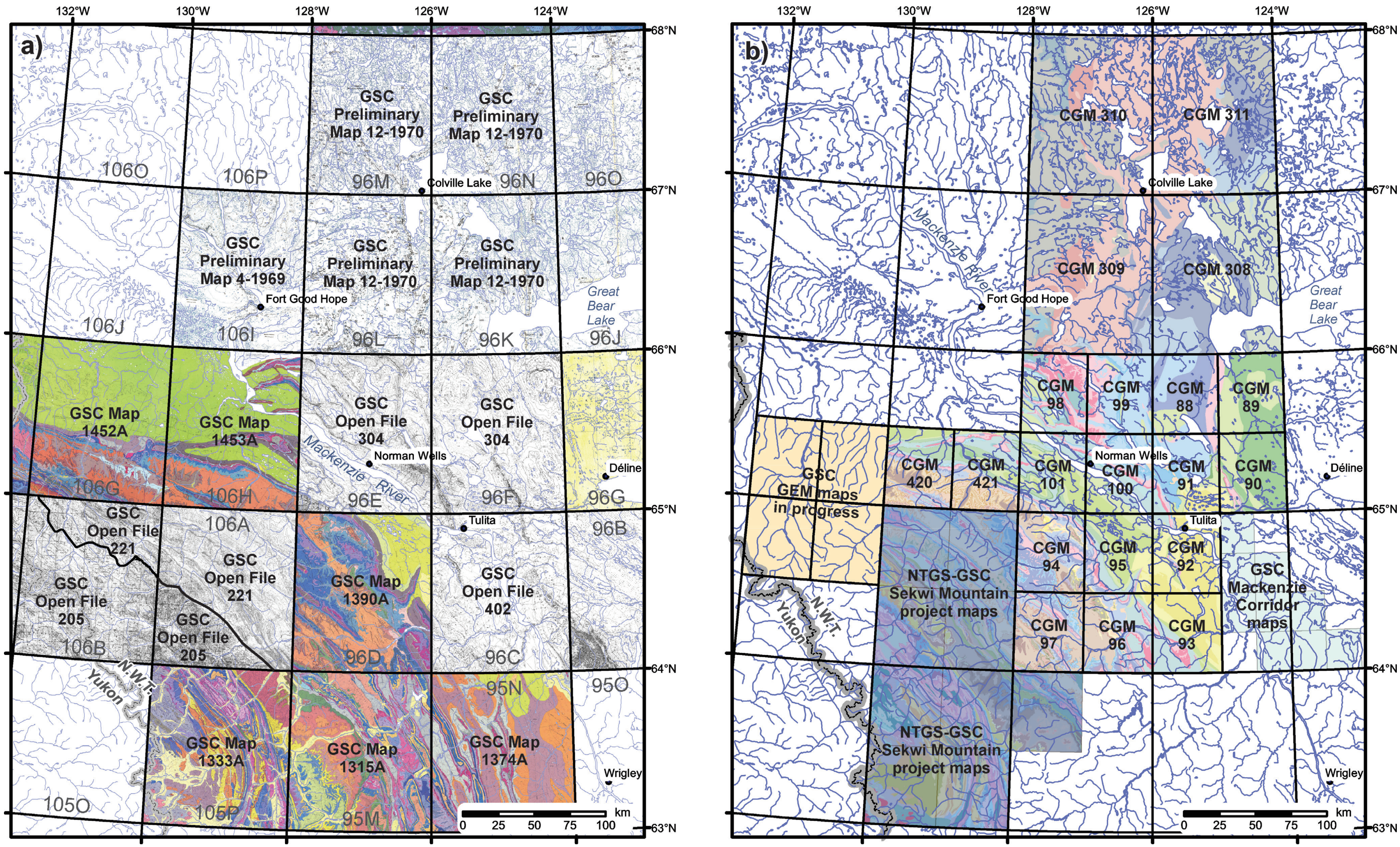


Figure 4. Comparison of the state of bedrock mapping in the Mackenzie region, before and after 2008. **a)** Hardcopy maps available in the Mackenzie region prior to 2008 (NTS map numbers shown in dark grey): Preliminary Map 4-1969, Cook and Aitken (1969); Preliminary Map 12-1970, Aitken and Cook (1970); Open File 205, Blusson (1974); Open File 221, Aitken and Cook (1974b); Open File 304, Aitken and Cook (1976); Open File 402, Cook and Aitken (1977); Map 1315A, Gabrielse et al. (1973c); Map 1333A, Blusson (1972); Map 1374A, Douglas (1974); Map 1390A, Aitken et al. (1974); Map 1452A, Aitken and Cook (1979a); Map 1453A, Aitken and Cook (1979b). **b)** GIS-enabled maps published since 2008: Sekwi Mountain project (2005–2008) maps (Northwest Territories Geological Survey [NTGS] partnering with the Geological Survey of Canada [GSC]) shown in dark blue (Gordey et al., 2012), and Mackenzie Corridor Project (2005–2008) maps shown in light blue (Cook et al., 2010). Geo-mapping for Energy and Minerals program maps: CGM 88, Fallas (2013a); CGM 89, Fallas and MacLean (2013a); CGM 90, Fallas (2013b); CGM 91, Fallas et al. (2013a); CGM 92, Fallas et al. (2013b); CGM 93, Fallas and MacLean (2013b); CGM 94, Fallas and MacNaughton (2014a); CGM 95, Fallas et al. (2013c); CGM 96, Fallas and MacNaughton (2014b); CGM 97, Fallas and MacNaughton (2014c); CGM 98, Fallas (2013c); CGM 99, Fallas (2013d); CGM 100, Fallas and MacNaughton (2013); CGM 101, Fallas et al. (2013d); CGM 308, Fallas (2017a); CGM 309, Fallas (2017b); CGM 310, Fallas (2017c); CGM 311, Fallas (2017d); CGM 420, Fallas and MacNaughton (2020a); CGM 421, Fallas and MacNaughton (2020b).

Cook et al. (2010) produced GIS-enabled maps that updated Operation Norman maps for the McConnell Range (Franklin Mountains) in the eastern half of NTS 96-C (Fig. 4b); this effort was part of the GSC's 'Mackenzie Corridor project' (part of the Secure Canadian Energy Supply program). Concurrently, the NTGS undertook a major study of stratigraphy and petroleum potential in the Peel Plateau and Peel Plain region (Pyle and Jones, 2009). A subsequent bedrock mapping effort by the NTGS updated the bedrock geology of parts of NTS 106-B (Fischer, 2016) and demonstrated the potential value of further work in the northern Mackenzie Mountains.

Following the Sekwi Mountain project, the GEM program targeted adjacent map areas (NTS 96-C, D, E, and F) for updated mapping, stratigraphic work, and GIS-enabled map production (Fig. 3, 4b); these areas straddle the petroleum-exploration region of the central Mackenzie Valley. Reconnaissance fieldwork in 2009 was followed by month-long field seasons in 2010 and 2011, and by a short wrap-up season in 2012. Fieldwork was conducted in the eastern Mackenzie Mountains, Mackenzie Plain, Franklin Mountains, and adjacent Great Bear Plain (Fallas et al., 2012). During the second phase of GEM, the work was expanded into adjacent geographic regions (Fig. 3, 4b), and an annual report of activities was published following each field season. During the summer of 2015, one month was spent in the Colville Hills (NTS map areas 96-K, L, M, N; Fallas et al., 2015c). Three weeks were spent mapping in the northern Mackenzie Mountains during the summer of 2016 (southern halves of NTS map areas 106-G and H; Fallas et al., 2016), and logistical support was provided for studies on Devonian stratigraphy (Kabanov et al., 2016). In 2017, one month was spent around the headwaters of the Arctic Red and Orthogonal rivers (northern half of NTS map area 106-B; MacNaughton et al., 2017), with logistical support also being provided for work on Devonian biostratigraphy (Gouwy et al., 2017b). This area saw a second one-month field season during July 2018, followed by a week of reconnaissance in NTS 95-M and 105-P (MacNaughton et al., 2018).

As of mid-2019, GIS-enabled bedrock-geology maps have been published for the Mackenzie Plain and adjacent mountain belts, and for the Colville Hills; maps for the northern Mackenzie Mountains are in press or in preparation (Fallas and MacNaughton, 2020 a, b; Fig. 4b). The aim is to make available modern, GIS-enabled bedrock maps for the region from the edge of the Selwyn Basin, near the Yukon border, to the Brock Inlier, in the northeast. A continuous swath of updated digital maps facilitates revising stratigraphic nomenclature, stratigraphic relationships and structural relationships, and makes it easier to assess the context of energy and mineral resources within the sedimentary basin (Fig. 2).

MAPPING APPROACH

To improve efficiency in covering the nearly 92 000 km^2 of the Mackenzie region mapping area of the GEM program, extensive use was made of historical data sets. Geological observations from Operation Norman (985 mapping stations; 147 measured sections), subsequent published stratigraphic measured-section data (416), and archived observations from the petroleum and mineral industries (1677 stations) have been digitized where possible, and integrated with observations made during the GEM program (2751 mapping stations, 84 measured sections) to inform new map interpretations (Fig. 5). The techniques used for this data-capture effort were described in Fallas et al. (2015a), with particular reference to Operation Norman mapping data and archival stratigraphic sections. Examples of public-domain industry data being used during the program were presented in Finley et al. (2017) and MacNaughton and Fallas (2019). A major release of unpublished GSC archival data from measured stratigraphic sections is available in Aitken et al. (2011), and a bibliography of published measured stratigraphic sections in the project region and adjacent map areas, including some sections from the first phase of the GEM program, can be found in Fallas et al. (2015b). Once assembled in a geodatabase, the historical data could be crossreferenced and analyzed for gaps, inconsistencies, anomalies, or problem areas where additional field observations would be helpful (Fallas et al., 2015a). These steps helped prioritize locations for field visits.

As with a majority of projects in the GEM program, GIS techniques extended to digital data collection in the field, leading to locations that are more accurately identified, faster integration with historical data, and the ability to check observations against georeferenced satellite imagery or geophysical data sets while in the field. Gravity- and aeromagnetic-anomaly data acquired in the Mackenzie region during the GEM program (Dumont, 2009; Kiss, 2018) were incorporated as they became available. With the availability in the field of new observations from each contributing scientist, map interpretation and analysis could take place concurrently and inform ongoing fieldwork. New map interpretations that consider all available evidence were facilitated by combining all these data in GIS software.

STRATIGRAPHIC REVISIONS

Maps of the Mackenzie region generated during the GEM program reflect numerous post-Operation Norman revisions to stratigraphic nomenclature, and in some areas have added stratigraphic detail in comparison to the pre-GEM maps. Changes to Operation Norman–era nomenclature affect Neoproterozoic to Cretaceous strata, with implications throughout the study area, and are summarized in two figures: Figure 6 covers Neoproterozoic units across the study area, as well as Ediacaran to Lower Cambrian units in the central

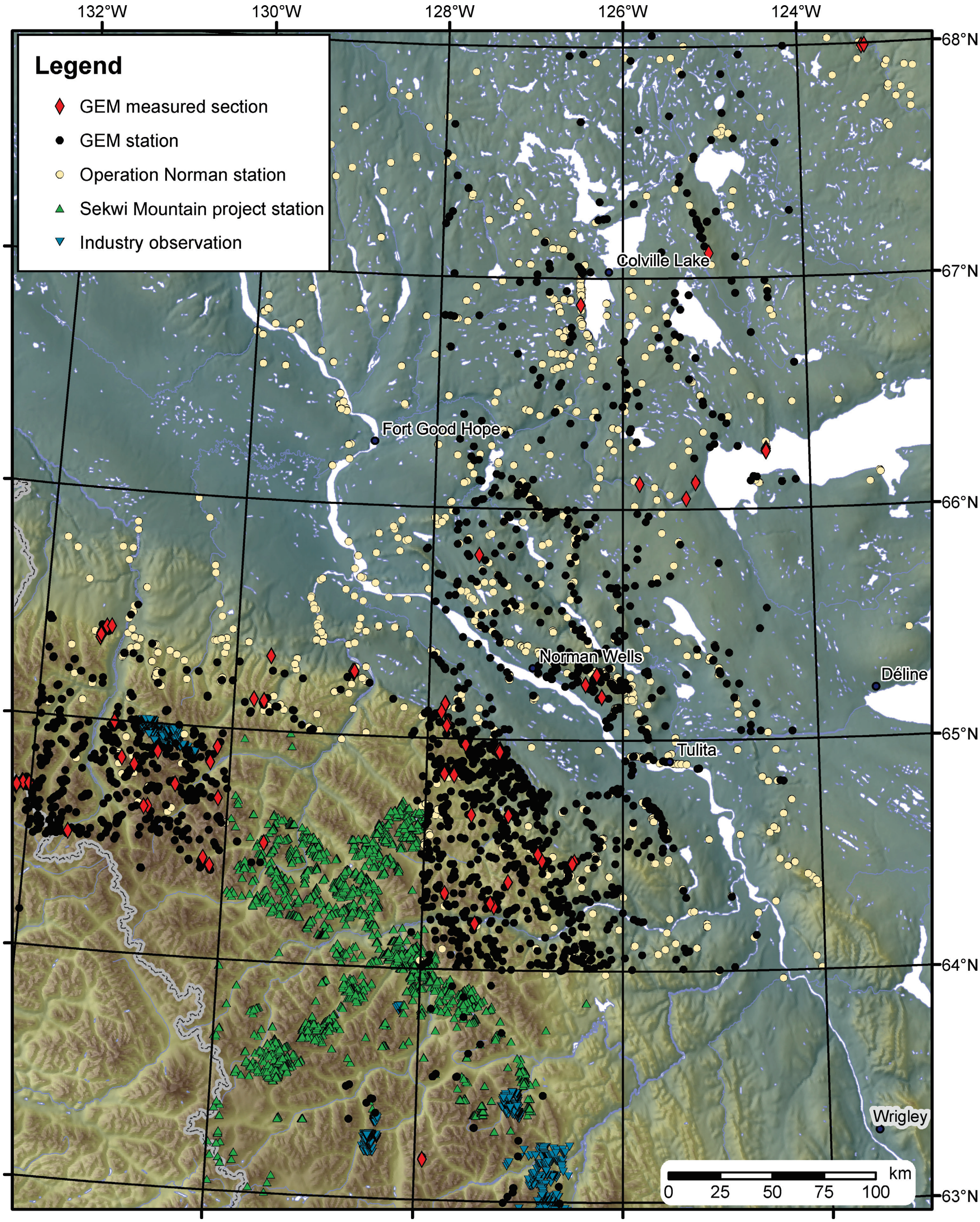


Figure 5. Distribution of bedrock-geology observations from the Geo-mapping for Energy and Minerals (GEM) program and other sources. Operation Norman observations were digitized during the GEM program from original field notes (1968–1970); Sekwi Mountain project observations were released as GIS data by Gordey et al. (2012); industry observations were digitized during the GEM program from archived reports. Topography from Canadian Digital Elevation Model (Natural Resources Canada, 2015).

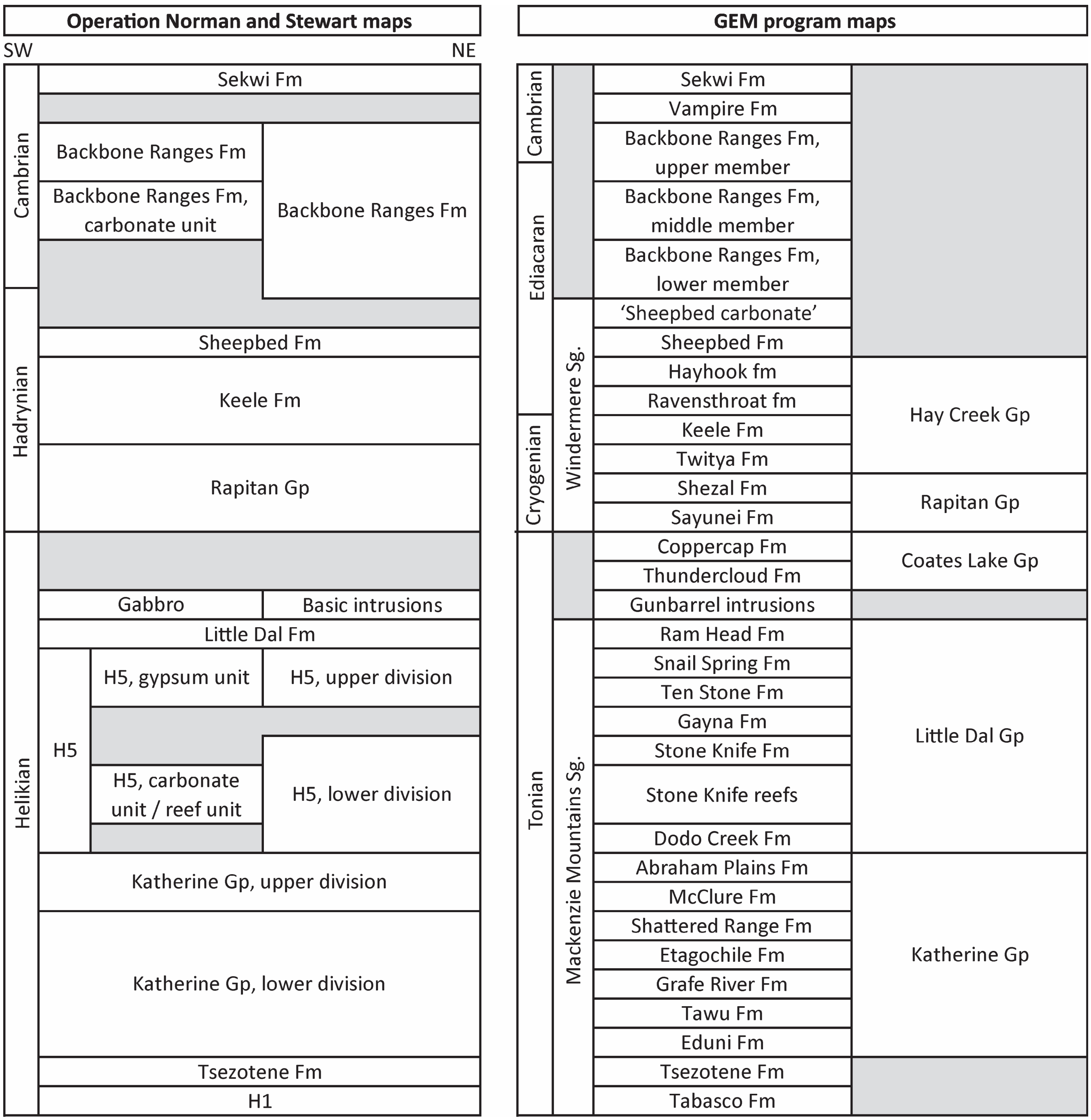


Figure 6. Comparison of map unit terminology used on Operation Norman (Aitken and Cook, 1970; 1974b; 1976; 1979a, 1979b; Aitken et al., 1974; Cook and Aitken, 1977) and Operation Stewart (Blusson, 1974) maps with the revised terminology used for the Geo-mapping for Energy and Minerals (GEM) program. Diagram covers Neoproterozoic to Lower Cambrian units encountered in the Mackenzie Mountains. Units postdating Gunbarrel intrusions are only found west of the Mackenzie Arch.

and western Mackenzie Mountains, and Figure 7 deals with Cambrian to Paleocene–Eocene stratigraphy across the study region. In the following paragraphs, changes in stratigraphic nomenclature are summarized, as well as key stratigraphic work carried out in the project areas as part of GEM. For reference, Figure 8 illustrates changes in stratigraphy from region to region across the study area, including their relationship to major tectonic elements.

The oldest map units in the study area belong to the Neoproterozoic (Tonian) Mackenzie Mountains Supergroup, which was named by Young et al. (1979) and widely used by other authors (*see* Long et al., 2008), but was not formalized until the GEM program (Long and Turner, 2012; Turner and Long, 2012). Formalization was supported by the publication of a large number of archival measured stratigraphic sections from the Mackenzie Mountains Supergroup during the first phase of GEM (Aitken et al., 2011). The Tonian age of the Supergroup is bracketed by detrital zircon found in the Katherine Group, which yielded a radiometric age of 1005 Ma (Leslie, 2009), and the crosscutting Gunbarrel intrusions dated at 779 Ma (Fig. 8; Harlan et al., 2003). Detrital muscovite dating of the Tsezotene Formation, Katherine Group, and Little Dal Group, undertaken as part of a student project supported by GEM, recorded youngest grain ages between 818 Ma and 1005 Ma (Powell and Schneider, 2013), which corroborates results from previous work.

At the deepest level of exposure of the Mackenzie Mountains Supergroup, a dolostone unit, formerly identified as 'map-unit H1' (Aitken et al., 1973), is now referred to as the 'Tabasco Formation' (Turner and Long, 2012). The overlying shale-dominated Tsezotene Formation is unchanged from its original definition (Gabrielse et al., 1973a, b), though Long and Turner (2012) informally subdivided the unit into a lower 'grey' member and an upper 'red' member. These members are identifiable within the Mackenzie Mountains, at localities where the Tsezotene Formation is well exposed. In the southwestern part of the Carcajou Canyon map area (NTS 96-D), a locally mappable carbonate interval forms a resistant cliff in the upper third of the formation (Fallas and MacNaughton, 2014c).

Above the Tsezotene Formation, the sandstone-dominated Katherine Group (Fig. 6, 8) forms the core of many of the large anticlines found in the northeastern Mackenzie Mountains. On Operation Norman maps, this group was subdivided into a lower part consisting of sandstone with minor shale-dominated intervals, and an upper part of shale and dolostone overlain by another sandstone interval. Subsequent stratigraphic work by Aitken et al. (1978) documented that the Katherine Group could be subdivided into seven units based on alternating sandstone-dominated and shale-dominated intervals. During the GEM program, Long and Turner (2012) formalized these seven units into formations (Fig. 6), which are recognized in the GEM map areas. Significant frost shattering of the sandstone units tends to create very rubbly slopes where underlain by Katherine Group strata, which covers some of the recessive shale-dominated formations. Despite this, efforts made during the GEM program to map out these seven formations (Fallas and MacNaughton, 2014a, b, c; Fallas, 2019) have helped delineate previously undocumented faults (*see* 'Laramide structures' and 'Highlights' sections).

The uppermost succession of the Mackenzie Mountains Supergroup is dominated by carbonate rocks, shale, and evaporite, formerly assigned to map-unit H5 or the Little Dal Formation on Operation Norman maps. The relationships between units within this interval are complicated by faulting and erosion beneath the sub-Cambrian unconformity, and the full succession of units was only clarified after Operation Norman (Aitken et al., 1978; Aitken, 1981). This succession is now known as the 'Little Dal Group' and formal formation-level terminology was introduced during the GEM program by Turner and Long (2012), replacing the previous informal subdivisions of Aitken (1981). Maps produced during the GEM program use the new formation names. From GEM mapping activities, it is apparent that the former map-unit H5 was equivalent to the Dodo Creek Formation, recessive shale intervals of the Stone Knife Formation, the Ten Stone Formation, and the Snail Spring Formation (Fig. 6), whereas the former Little Dal Formation was locally applied to carbonate intervals of the Stone Knife Formation, the Gayna Formation, and the Ram Head Formation.

Mafic igneous rocks, identified as 'basic intrusions' on Operation Norman maps, intrude strata of the Mackenzie Mountains Supergroup within the GEM program map areas of the Mackenzie Mountains. These rocks occur as discontinuous sills at various levels within the Tsezotene Formation and as dykes cutting through strata from the Tabasco Formation to the upper Little Dal Group. Geochemical and geochronological studies (Harlan et al., 2003; Sandeman et al., 2014; K. Fallas and S. Kamo, unpub. data, 2018) indicated a single suite of intrusions ranging in age from 770 Ma to 782 Ma, assignable to the Gunbarrel mafic magmatic event (Harlan et al., 2003).

Units of the Coates Lake Group, a Neoproterozoic (Tonian) succession that unconformably overlies the Mackenzie Mountains Supergroup, are exposed on either side of the Plateau Fault in a narrow belt known as the 'Redstone copper belt' (Jefferson and Ruelle, 1986). These units had not been identified in the study area prior to the GEM program. During the 2017 and 2018 field seasons, two units of the Coates Lake Group, the heterolithic (dolostone, shale, sandstone, conglomerate) Thundercloud and limestone-dominated Coppercap formations, were traced across parts of the Bonnet Plume Lake and Ramparts River map areas (NTS 106-B and G), extending the known range of these units by approximately 85 km (Fig. 9). Some workers have assigned the Coates Lake Group to the overlying Windermere Supergroup (e.g. Aitken, 1991; Narbonne and Aitken, 1995), but the decision was taken to follow Jefferson and Parrish (1989) in excluding it from either of the adjacent supergroups.

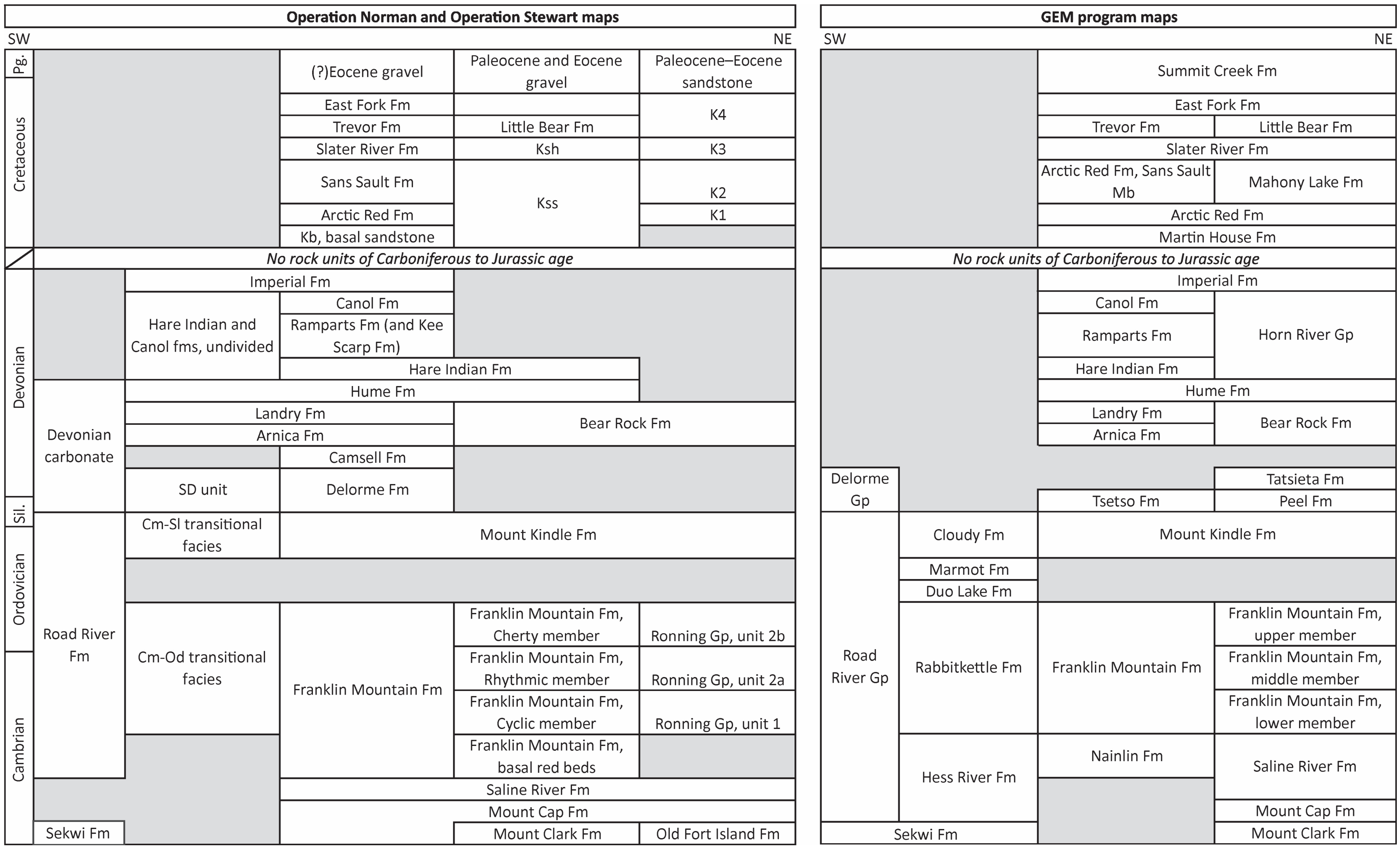


Figure 7. Comparison of map unit terminology used on Operation Norman (Aitken and Cook, 1970; 1974b; 1976; 1979a, 1979b; Aitken et al., 1974; Cook and Aitken, 1977) and Operation Stewart (Blusson, 1974) maps with the revised terminology used for the Geo-mapping for Energy and Minerals (GEM) program. Diagram covers Cambrian and younger units across the study region. Abbreviations: Sil. = Silurian; Pg. = Paleogene.

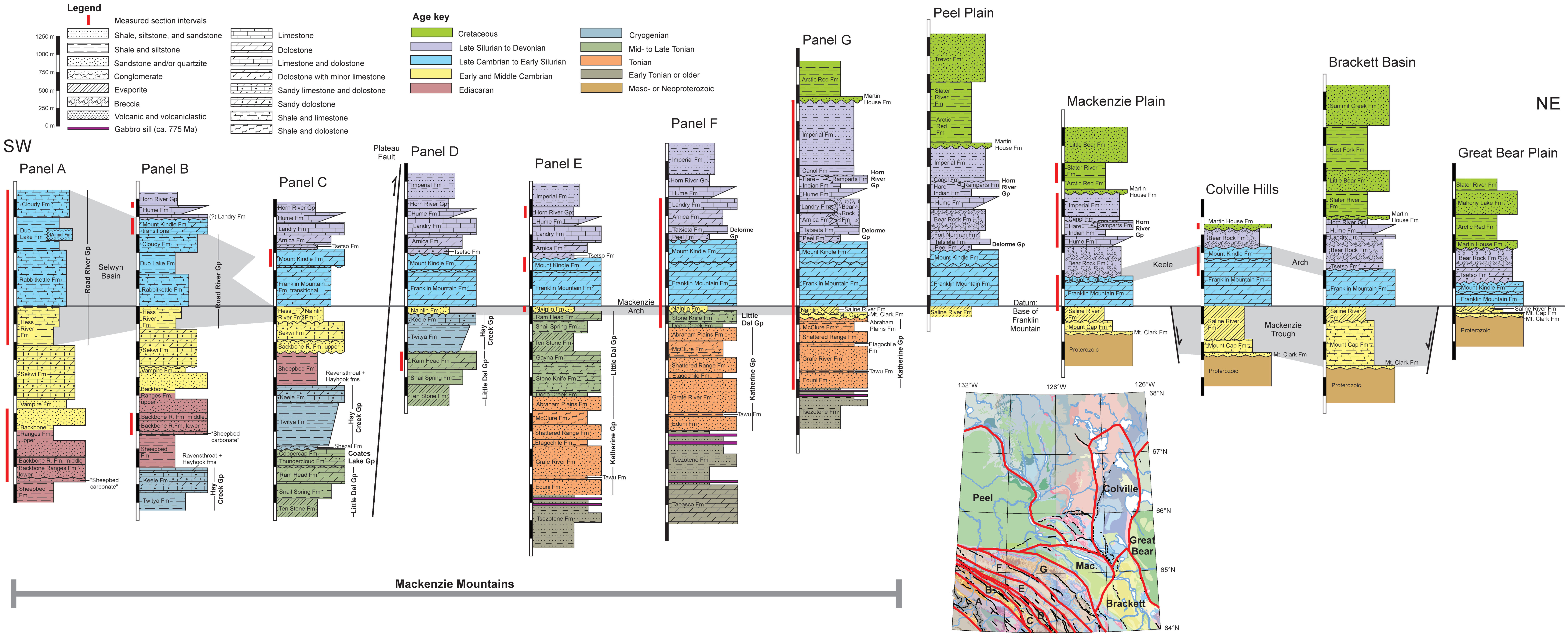


Figure 8. Chart of regional variations in stratigraphy across the Mackenzie region illustrated by a series of graphic logs, organized by structural domain (indicated on inset map). Panels A through G represent structural panels within the Mackenzie Mountains; remaining columns are identified by physiographic region. Stratigraphic intervals measured in detail during Geo-mapping for Energy and Minerals program are shown with vertical red bar beside the appropriate column; other stratigraphic thicknesses determined from historical measured sections and field relationships. Lower Paleozoic shale-dominated Selwyn Basin in the southwestern part of the study area passes northeastward into carbonate-dominated Mackenzie Platform. Thinning of Cambrian strata across the Mackenzie Arch is visible in panels D through G. Thicker Cambrian succession of the Mackenzie Trough is documented by reflection-seismic data and petroleum exploration wells across the Colville Hills and Brackett Basin (MacLean, 2011b). Keele Arch is illustrated by thinned or absent Mount Kindle Formation in the Mackenzie Plain (Mac.), Colville Hills, and Brackett Basin columns.

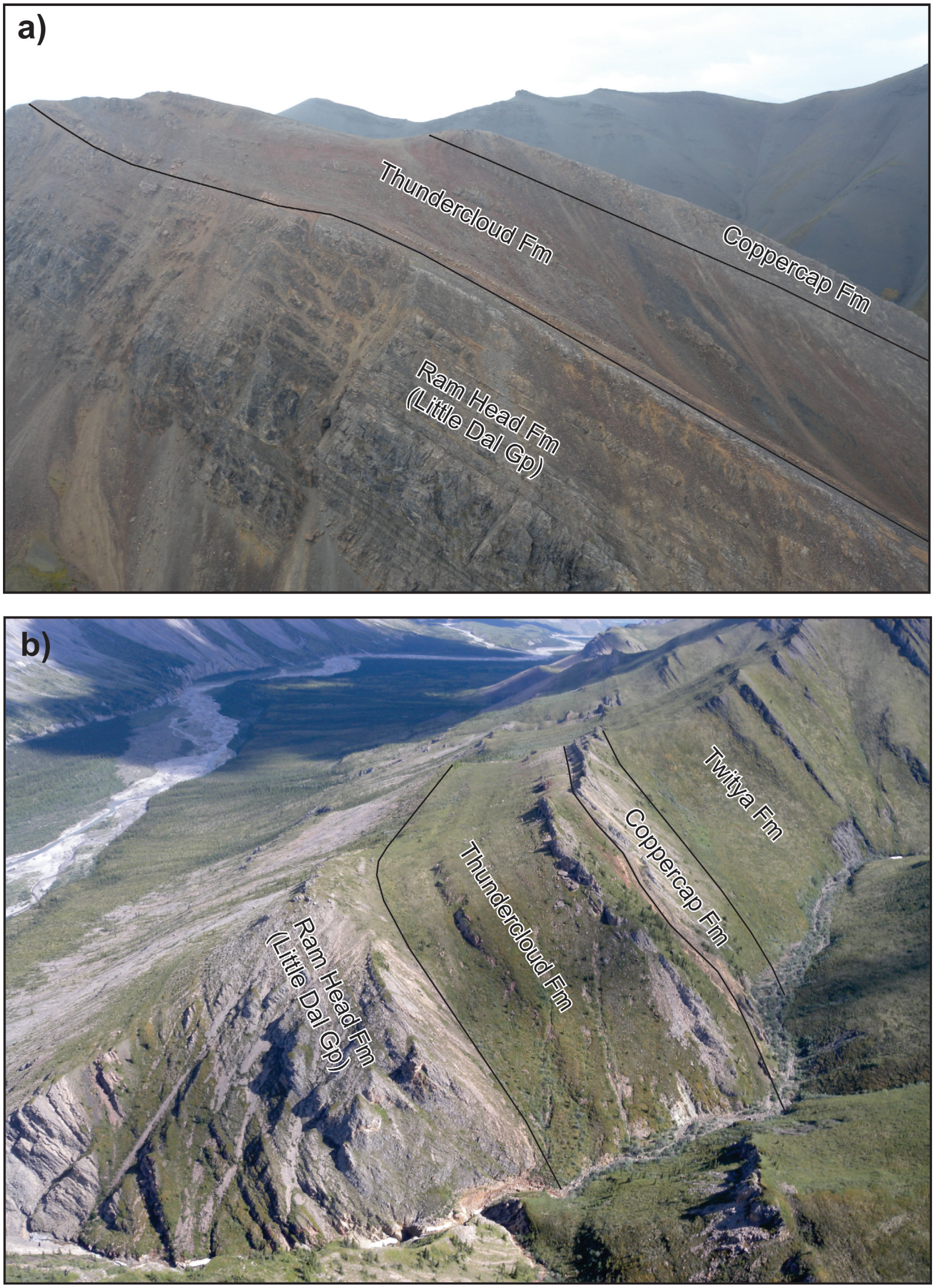


Figure 9. Newly documented exposures of the Coates Lake Group (Thundercloud and Coppercap formations) in the hanging wall of the Plateau Fault in the Bonnet Plume Lake map area (NTS 106-B). **a)** View, looking south, of the Coates Lake Group; the Thundercloud Formation is approximately 150 m thick at this location. Photograph by K. Fallas. NRCan photo 2019-274. **b)** View, looking southeast, of the Coates Lake Group; the Thundercloud Formation is approximately 160 m thick at this location. Photograph by K. Fallas. NRCan photo 2019-271. This figure originally appeared in MacNaughton et al. (2018).

At the base of the Neoproterozoic (Cryogenian to Ediacaran) Windermere Supergroup, the Rapitan Group (Cryogenian) originally was subdivided into lower, middle, and upper units (e.g. Gabrielse et al., 1973a, b), a practice followed on various historical maps. Eisbacher (1978) erected the formal names Sayunei Formation (deep-water marine shale and sandstone, commonly maroon, with minor diamictite), Shezal Formation (diamictite), and Twitya Formation (deep-water marine shale and sandstone, locally coarsening upward to sandstone and conglomerate) for the three subdivisions (in ascending order). Later workers excluded the Twitya Formation from the Rapitan Group and instead treated it as the basal unit of the overlying Hay Creek Group (Yeo, 1978; Young et al., 1979; Turner et al., 2011). Twitya Formation is recognized in the westernmost GEM map areas, Bonnet Plume Lake (NTS 106-B) and Ramparts River (NTS 106-G), and Sayunei and Shezal formation strata may be present locally in the Bonnet Plume Lake map area.

Also included in the Hay Creek Group is the Keele Formation (Gabrielse et al., 1973a, b), which may be dominated by carbonate or sandstone, depending on location, and commonly displays repetitive vertical-facies successions (Eisbacher, 1978; Day et al., 2004). Keele Formation appears on historical maps for the Bonnet Plume Lake (NTS 106-B) and Ramparts River (NTS 106-G) map areas. On these maps, the Keele Formation included a capping set of distinctively pale-weathering carbonate units, which were originally treated as an informal member of the Keele Formation (Gabrielse et al., 1973a, b). Later workers referred to them as the informal 'Tepee dolostone' (Eisbacher, 1981; Aitken, 1991), and they subsequently were divided into the informal Ravensthroat and Hayhook formations (James et al., 2001). Although individually thin (tens of metres), the Ravensthroat and Hayhook formations were recognized and mapped as a combined unit in the southwestern part of the GEM program study area. Local diamictite deposits at the top of the Keele Formation indicate that facies of the glacially influenced Ice Brook Formation (Aitken, 1991) may also be present.

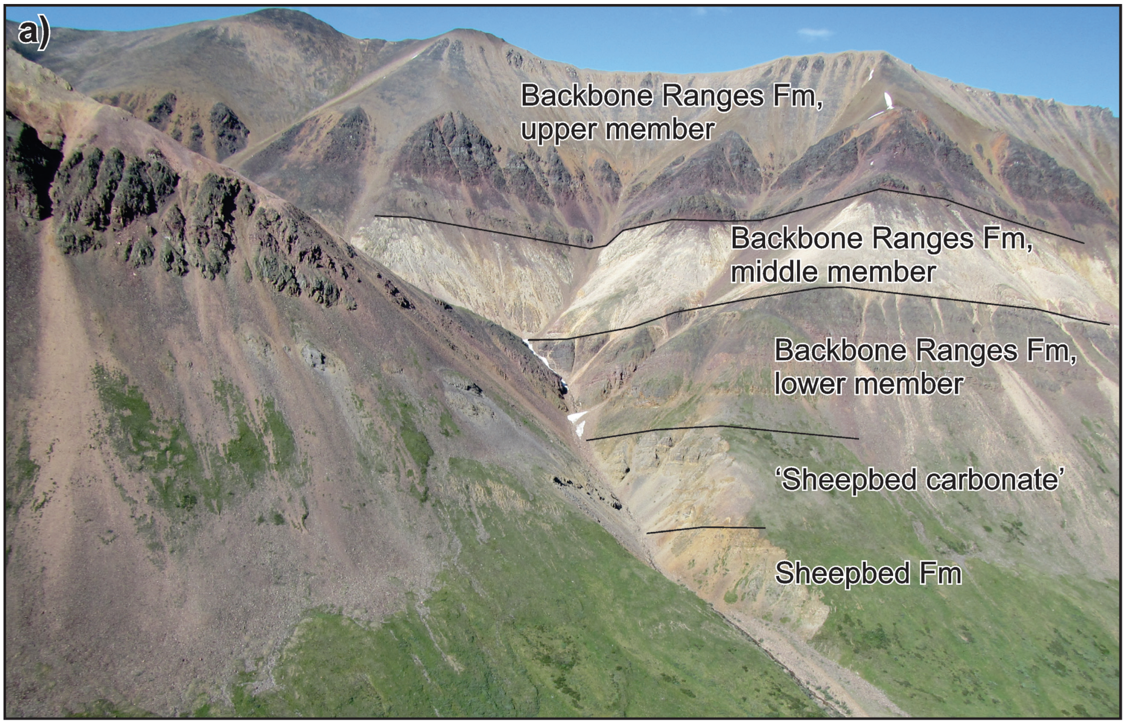
Although the shale-dominated Sheepbed Formation (Ediacaran) is unchanged from its original usage (Gabrielse et al., 1973a, b), a carbonate unit locally present at the top of the unit has required additional consideration. The carbonate unit was first documented by Eisbacher (1981) and later referred to informally as the 'Sheepbed carbonate' by Aitken (1984). Exposures of the unit along the Plateau Fault subsequently were assigned to the Gametrail Formation (Aitken, 1989) and were mapped as such during the Sekwi Mountain project (Turner et al., 2011). Macdonald et al. (2013) falsified this assignment based on evidence from stable-isotope chemostratigrapy and reverted to the earlier, informal name. During mapping and stratigraphic work of the GEM program, the Sheepbed carbonate was documented in the Bonnet Plume Lake map area (NTS 106-B), where it likely was incorrectly assigned to the overlying Backbone Ranges Formation on historical maps. Several sections were measured through the unit during GEM (e.g. Fig. 10a) and it will be formalized under a new formation name.

The Backbone Ranges Formation (Ediacaran to Cambrian) was defined based on exposures in map areas NTS 95-L and M (Gabrielse et al., 1973a, b), but is widely distributed in the Mackenzie Mountains. In its type area, the Backbone Ranges Formation is subdivided into three mappable members: a lower member dominated by quartzite or sandstone, a middle carbonate member, and an upper quartzite member that regionally is a prominent cliff-forming interval. The Backbone Ranges Formation appears on historical maps for the northwest Mackenzie Mountains either as an undivided unit of quartzite or sandstone with minor carbonate, or as a succession with the carbonate member shown as a separate unit. During GEM program mapping, the typical threefold subdivision was recognized in the Bonnet Plume Lake map area (NTS 106-B; Fig. 10a), and map publications derived from this work will reflect these subdivisions.

In the western part of the Bonnet Plume Lake map area, near the Yukon–Northwest Territories border, the upper member of the Backbone Ranges Formation shows a consistent succession of sandstone-dominated versus shale-dominated units, suggesting the upper member can be subdivided further into mappable units (Fig. 10b). MacNaughton et al. (2018, p. 11) described these units as follows:

> A basal, semi-resistant succession (Unit A: approximately 225 m thick) is dominated by maroon and grey weathering sandstone and siltstone, and contains a distinctive medial marker of grey-weathering, platy, locally fetid limestone. The basal unit is overlain in turn by a mainly recessive succession (Unit B: approximately 170 m thick) dominated by brown siltstone with lesser sandstone and dolostone. This succession is capped by a grey- to orange or brown-weathering carbonate that is generally only a few metres thick in the project area, but that thickens into a potentially mappable unit to the south and west. Above this is a second recessive succession (Unit C: approximately 50 m thick), consisting of brown siltstone and sandstone and locally containing abundant trace fossils. The uppermost part of the succession is dominated by quartzite (Unit D: approximately 220 m thick) that mimics the cliff-forming character of the upper Backbone Ranges Formation as seen in other areas.

These subdivisions of the upper member will be formalized as new units on the project maps; these units are of formation scale and mappable over a large area, emphasizing the long-standing need for review and revision of the Backbone Ranges Formation. The need for revision is further emphasized by biostratigraphic



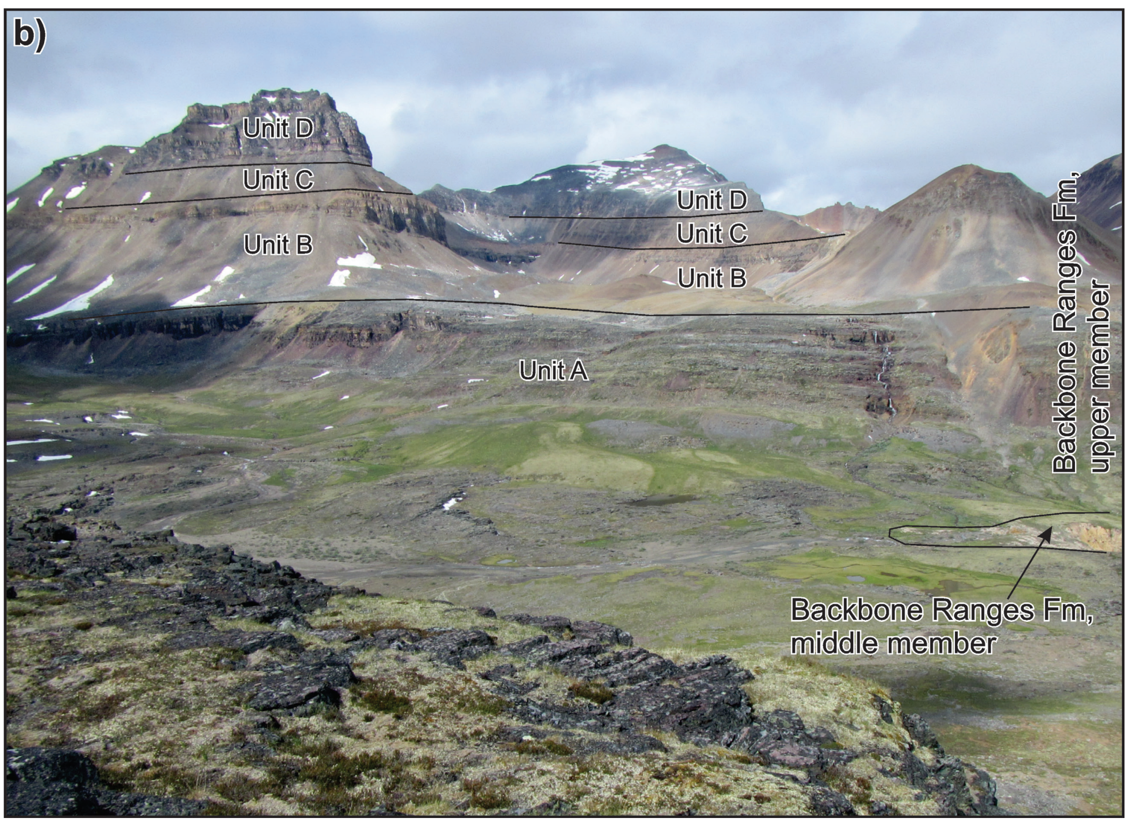


Figure 10. Ediacaran–Cambrian stratigraphy at the headwaters of Reptile Creek, immediately west of the western edge of the Bonnet Plume Lake map area (NTS 106-B). **a)** Sheepbed Formation, including 'Sheepbed carbonate', overlain by Backbone Ranges Formation showing typical tripartite arrangement of members (view is to the northeast); the middle member of the Backbone Ranges Formation is approximately 100 m thick. Photograph by R. MacNaughton. NRCan photo 2019-277. **b)** Newly recognized internal divisions of the upper member of the Backbone Ranges Formation (view to the northwest), with unit labels keyed to descriptions in the text (unit C is approximately 50 m thick). Photograph by R. MacNaughton. NRCan photo 2019-276. Figure *modified from* MacNaughton et al. (2018).

(MacNaughton and Fallas, 2018) and lithostratigraphic (MacNaughton and Fallas, 2019) evidence that the sub-Cambrian unconformity lies within the upper member rather than at its base, as has commonly been argued (*see* MacNaughton, 2011).

Locally, a recessive shale and sandstone interval overlies the Backbone Ranges Formation. This does not appear on historical maps for the Bonnet Plume Lake area, but was documented by Fritz (1976, 1978, 1979) in several measured sections and is treated as a tongue of the Lower Cambrian Vampire Formation (Fritz, 1982). The Vampire Formation locally separates the Backbone Ranges Formation from the overlying Sekwi Formation (Lower Cambrian), which is a heterolithic, carbonate-dominated unit (Handfield, 1968; Fritz, 1976, 1978, 1979) that contains facies recording tidal-flat to deep-water marine deposition (Krause and Oldershaw, 1979; Dilliard, 2006; Dilliard et al., 2010). The treatment of the Sekwi Formation during GEM was essentially unchanged from that associated with historical mapping, although an isopach study prepared during the program emphasized the desirability of subdividing this very thick unit into members (Chan et al., 2019; *see also* Turner et al., 2011).

Passing northeast from the Bonnet Plume Lake map area (NTS 106-B), map units from the Little Dal Group to the Sekwi Formation are truncated beneath one or more unconformities at the base of, or within, the Cambrian succession (Fig. 8). Lower Paleozoic strata (Cambrian to Devonian) are found throughout the entire study area.

Within the Mackenzie Mountains, in the extreme southwestern portion of the study area, the shale- and carbonate-dominated Road River Group (shown as undivided Road River Formation on historical maps) represents Lower Paleozoic (Cambrian to Silurian) strata. These strata constitute the relatively recessive basinal facies of Selwyn Basin. Cecile (1982) subdivided the Road River Group (in ascending order) into Hess River (dark shale, argillaceous limestone, local sandstone), Rabbitkettle (thin-bedded silty limestone), Duo Lake (dark shale, commonly graptolitic, with silty limestone), Marmot (volcanic and volcaniclastic strata), and Cloudy (limestone with shale and chert) formations (Fig. 7). Each of these units is recognizable and mappable in the Bonnet Plume Lake map area (NTS 106-B).

On the Mackenzie Arch (Fig. 8), a long-lived, elongate, northwest-trending positive tectonic feature in the northeastern Mackenzie Mountains (Aitken et al., 1973; MacNaughton et al., 2016), basal, red-weathering siliciclastic Cambrian strata were identified as ‘Franklin Mountain Formation red beds’ on Operation Norman maps. During GEM, this succession was separated from the overlying carbonate units of the Franklin Mountain Formation and defined as the Nainlin Formation (Fig. 11). This new unit has been mapped in the Carcajou Canyon (NTS 96-D), Sans Sault Rapids (NTS 106-H), and Ramparts River (NTS 106-G) map areas (Fallas and MacNaughton, 2014a, b, c; MacNaughton and Fallas, 2014; Fallas et al., 2016; MacNaughton et al., 2017).

Northeast of the Mackenzie Arch, from the northeastern margin of the Mackenzie Mountains to the edge of the Canadian Shield, the Lower and Middle Cambrian consist of three formations, which are, in ascending order, the Mount Clark (dominantly quartz sandstone), Mount Cap (shale, carbonate, and lesser sandstone), and Saline River (shale, evaporite, and lesser carbonate) formations (Williams, 1922,

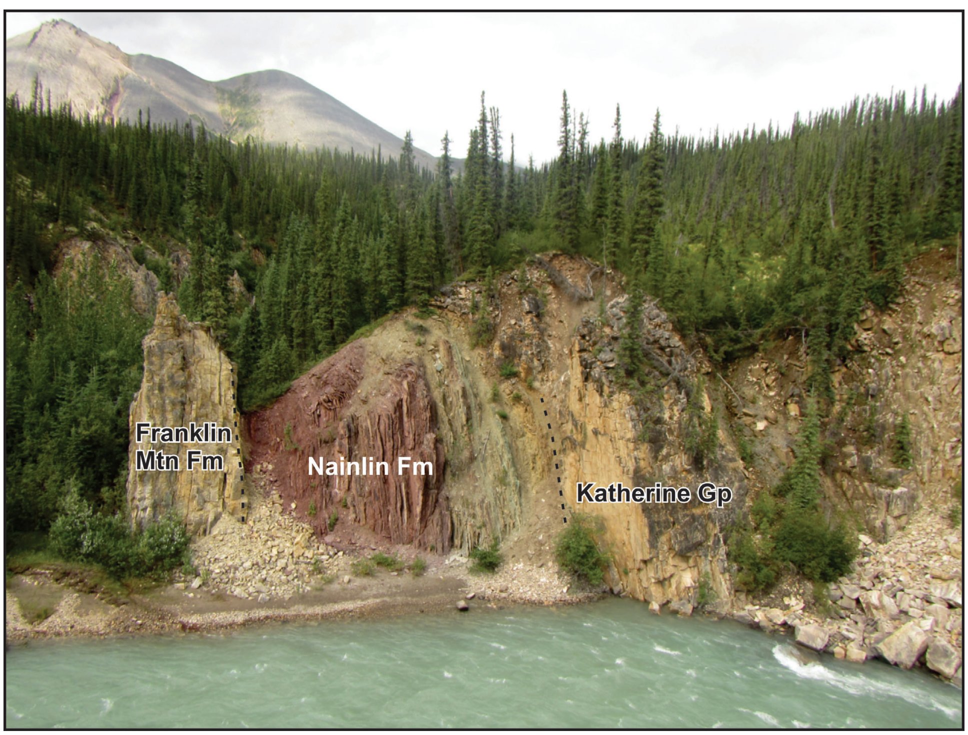


Figure 11. Near-complete exposure of Nainlin Formation along Gayna River, southwestern portion of Sans Sault Rapids map area (NTS 106-H). Nainlin Formation was defined during bedrock mapping in the first phase of the Geo-mapping for Energy and Minerals program in the Mackenzie region. Note contrast in colour and lithology between red-weathering, siliciclastic-dominated Nainlin Formation and overlying beige-weathering, carbonate-dominated Franklin Mountain Formation (at left). Measured thickness of the Nainlin Formation at this location is 22 m. Photograph by R. MacNaughton. NRCan photo 2019-278.

1923; Aitken et al., 1973; Dixon and Stasiuk, 1998). This nomenclature was in use during Operation Norman and appeared on those maps, although the name 'Old Fort Island Formation' (Balkwill, 1971; Cook and Aitken, 1971) was applied to Mount Clark equivalent strata along the edge of the Canadian Shield. Old Fort Island Formation subsequently was abandoned by Dixon and Stasiuk (1998). The presence of the Mount Clark Formation in the eastern Mackenzie Mountains was not recognized during Operation Norman, although a basal sandstone was considered to be present in the Mount Cap Formation (Aitken et al., 1973). Subsequent suggestions that Mount Clark Formation was present in the Mackenzie Mountains (Serié et al., 2013) were confirmed during GEM (Fallas and MacNaughton, 2012; Hamel and MacNaughton, 2013; MacNaughton et al., 2013). Trilobite biostratigraphy for the Mount Cap Formation, dating from Operation Norman and before (Kobayashi, 1936; Aitken et al., 1973), was augmented during GEM (MacNaughton et al., 2013; *see also* Serié et al., 2013) and currently is the subject of M.Sc. research by N. Handkamer at the University of Saskatchewan, under the supervision of B.R. Pratt.

During mapping for the GEM program, the Mount Clark, Mount Cap, and Saline River formations were recognized in the Carcajou Canyon (NTS 96-D) and eastern Sans Sault Rapids (NTS 106-H) map areas. Saline River Formation was also mapped within the Franklin Mountains of the Norman Wells (NTS 96-E), Mahony Lake (NTS 96-F), and western Fort Norman (NTS 96-C) map areas. Along the eastern flank of the Mackenzie Arch, proximal facies assigned to the Saline River Formation during Operation Norman (Aitken et al., 1973) have been reassigned to the Nainlin Formation (MacNaughton and Fallas, 2014).

Lying conformably upon the Nainlin or Saline River formations is the Franklin Mountain Formation (Williams, 1922, 1923), a dolostone unit of Late Cambrian to Ordovician age. On Operation Norman maps, this unit and the overlying Mount Kindle Formation, which is discussed below, were assigned to the Ronning Group. Additionally, during Operation Norman (Fig. 7), the Franklin Mountain Formation was identified variously as Ronning Group (units 1, 2a, and 2b), Franklin Mountain Formation (Cyclic member, Rhythmic member, and Cherty member, in ascending order), or Franklin Mountain Formation (undivided); however, it should be noted that the Ronning Group was rendered obsolete in the project area by the work of Macqueen (1970; *see also* Norford and Macqueen, 1975). Stratigraphic work by Turner (2011) during GEM reassessed the subdivisions of the Franklin Mountain Formation and recommended the use of lower, middle, and upper members in place of Cyclic, Rhythmic, and Cherty members, respectively. The lower, middle, and upper members of the Franklin Mountain Formation are recognizable in the Franklin Mountains, Colville Hills, and northeastern Mackenzie Mountains, and these three subdivisions are used on maps generated for these areas during the GEM program. Regional studies by E.C. Turner of the Franklin Mountain Formation and its correlatives are ongoing (e.g. Chevrier and Turner, 2013; Fallas et al., 2015c; Rainbird et al., 2015b; MacNaughton et al., 2016; Turner et al., 2017).

The name 'Mount Kindle Formation' (Williams, 1922, 1923) was applied during Operation Norman (Norford and Macqueen, 1975) to a distinctively fossiliferous, locally silicified dolostone unit. It is a resistant, cliff-forming unit with a distinctive dark-grey-weathering tone at a distance, and thus a useful marker during mapping. In the project area, it forms an unconformity-bounded Late Ordovician to early Silurian sequence. Mount Kindle Formation passes southward into the Whittaker Formation (Gabrielse et al., 1973a) in the Mackenzie Mountains, and westward into the Duo Lake and Cloudy formations in the region underlain by the Selwyn Basin (Cecile, 1982). Stratigraphic sections were measured through the Mount Kindle Formation in the eastern Mackenzie Mountains and Franklin Mountains (Pope and Leslie, 2013), the Colville Hills (Fallas et al., 2015c), and along the northern edge of the Mackenzie Mountains (Fallas et al., 2016). Sections also were measured in the northwestern Mackenzie Mountains, where the Mount Kindle Formation passes into Selwyn Basin equivalent units (MacNaughton et al., 2017, 2018). These observations and associated samples are the subject of an M.Sc. project being pursued by J. Martell at Texas A&M University under the supervision of M.C. Pope. Ongoing conodont biostratigraphy and stable-isotope chemostratigraphy will aid in regional correlation (e.g. Pope and Leslie, 2013).

On Operation Norman maps, the Mount Kindle Formation was shown as overlain by a discontinuous, unnamed Siluro-Devonian unit. In a few cases, this unit was identified as the Delorme Group (latest Silurian to Early Devonian). Stratigraphic work on the Delorme Group by Morrow (1991, 1999) distinguishes the Peel (mainly dolostone, locally argillaceous) and Tatsieta (limestone, shale, local dolostone) formations on the northern slope of the Mackenzie Mountains (*see* Pugh, 1983, for the definitions of these units), and Tsetso Formation (dolostone, sandstone, shale; *see* Meijer-Drees, 1993) within the Mackenzie Mountains and Franklin Mountains (Fig. 7). Maps of the GEM program follow Morrow's geographic constraints on the application of terminology for these three units.

Early and Middle Devonian units used on Operation Norman maps included (in ascending order) the Arnica (dolostone; Douglas and Norris, 1961), Landry (dominantly limestone; Douglas and Norris, 1961), Bear Rock (carbonate breccia; Hume and Link, 1945), and Hume (fossiliferous limestone and argillaceous limestone; Bassett, 1961) formations. These remain useful map units for the Devonian carbonate-platform succession and are retained on maps from the GEM program. One modification made in the Colville Hills (Fallas, 2017a, b, c, d; Gouwy et al., 2017a) was the use of the term 'Bear Rock assemblage' (*after* Morrow, 2012) for the interval including the Bear Rock, Arnica, and Landry formations, to indicate uncertainty regarding the exact distribution of each of these units in an area of generally poor exposure. It is also uncertain whether any Delorme Group strata are present in the Colville Hills, but if present, they would be included in the 'Bear Rock assemblage' unit.

The Middle Devonian succession can be mapped discontinuously along the northern Mackenzie Mountains front and within the Franklin Mountains. On Operation Norman maps, these strata were assigned, in ascending order, to the Hare Indian Formation (shale, commonly with a calcareous and bituminous basal member; Kindle and Bosworth, 1921), Ramparts Formation (limestone; Kindle and Bosworth, 1921) or Kee Scarp Formation and/or Member (bioclastic limestone; Hume and Link, 1945; Hume, 1954; C.R. Stelck, unpub. rept., 1944), and Canol Formation (dark, siliceous shale; Bassett, 1961). On maps produced during the GEM program, the Hare Indian, Ramparts, and Canol formations are represented as separate units, where all three are present. Where limestone of the Ramparts Formation is absent, and shale units of the Hare Indian and Canol formations are difficult to distinguish, these units are combined into a single unit referred to as the 'Horn River Group' (*see* Pugh, 1983), a term not used during Operation Norman (Fig. 7). Late Devonian Imperial Formation (Hume and Link, 1945; T.A. Link, unpub. rept., 1921) is treated on GEM program maps in the same manner as it is on the Operation Norman maps, and refers to a succession of sandstone and shale, with minor conglomerate and fossiliferous limestone. A review of the complicated nomenclatural history of this unit is presented in Caldwell (1964). The known distribution of the Jungle Ridge Member, a locally developed carbonate marker unit within the Imperial Formation (Hume and Link, 1945; Hume, 1954; C.R. Stelck, unpub. rept., 1944) was extended to the western flank of the Franklin Mountains (Fallas and MacNaughton, 2013; Fallas et al., 2013b, c) in the course of GEM program bedrock-mapping activities.

During the first phase of the GEM program, field support was provided for work on a graduate thesis on the sedimentology and stratigraphic packaging of the Imperial Formation, based on exposures along the eastern edge of the Mackenzie Mountains (Acker, 2013). Hadlari et al. (2009) can be consulted for a regional study of the Imperial Formation. Summaries of additional work on Devonian stratigraphy conducted during the second phase of GEM can be found in Kabanov et al. (2016) and Kabanov (this volume), while studies on conodont biostratigraphy are presented in Gouwy et al. (2017a, b) and Gouwy (this volume).

Northeast of the Mackenzie Mountains, Cretaceous and younger siliciclastic strata were identified on the Operation Norman maps using various formal and informal terms (Fig. 7). Subsequent stratigraphic work (Yorath and Cook, 1981; Dixon, 1999) established formal terminology from the Lower Cretaceous Martin House Formation to the Upper Cretaceous–Paleocene Summit Creek Formation. This formal terminology generally has been used on GEM program maps, although sparsely outcropping strata with poor biostratigraphic control east of the Colville Hills are treated as an undivided Cretaceous unit. Most units are found anywhere Cretaceous strata are preserved, although the Sans Sault Member of the Arctic Red Formation is only recognizable on the western flank of the Franklin Mountains and its stratigraphic equivalent, the Mahony Lake Formation, is restricted to the eastern side of the Franklin Mountains. The youngest units, the East Fork and Summit Creek formations, are restricted to the southeastern portion of the study area, in the Brackett Basin (Fig. 8). A recent overview of Cretaceous stratigraphy in the project area and adjacent regions can be found in Fallas et al. (in press b). During the GEM program, graduate projects were completed dealing with the sedimentology and stratigraphy of the Martin House Formation (Davison, 2011), and with aspects of the region's Cretaceous biostratigraphy (Bell, 2018). Additionally, some attention was given to the sedimentology and petroleum geochemistry of oil-stained Cretaceous outcrops in the Colville Hills (Fallas et al., 2015c; Jiang et al., 2019).

A NOTE ON SUBSURFACE STUDIES

Although this paper focuses on studies carried out in relation to bedrock mapping, both phases of the GEM program in the Mackenzie region included subsurface components. Key elements of this work are briefly summarized here. Much of the subsurface work reflected the goal of improved oil- and gas-exploration success in the Mackenzie and Great Bear plains (e.g. Hannigan et al., 2011), although efforts to unravel regional tectonostratigraphic evolution were also significant. From the former perspective, Hu and Hannigan (2009) provided an important evaluation of reservoir petrophysics for key stratigraphic intervals (Cambrian to Cretaceous) in numerous industry wells. The study by Hadlari et al. (2009) on the Upper Devonian Imperial Formation (referred to above) incorporated subsurface data consisting of wireline logs and reflection-seismic profiles. Dixon (2011) reported on core-based subsurface correlations in the Devonian to Carboniferous clastic-wedge succession (Imperial and Tuttle formations), and a graduate project by Raska (2017) sought to apply three-dimensional subsurface-modelling methods to the geological structure of the Devonian beneath the Mackenzie Plain. Additional subsurface studies on Devonian facies and stratigraphy during the second phase of GEM are summarized in a contribution by P.B. Kabanov (this volume).

Reflection-seismic studies were an important component of both phases of GEM. This included a regional overview of subsurface Phanerozoic structure (MacLean, 2012), a study of the complex structural evolution of the Keele Arch (MacLean et al., 2014, 2015) that is discussed further below, and a major restudy of the tectonic and stratigraphic evolution of the Cambrian succession in the subsurface of the project area (MacLean, 2011a, b); the last provided the impetus for additional regional studies on the Cambrian System. A preliminary core study of reservoir facies in the Mount Clark Formation beneath the Colville Hills (Herbers et al., 2016) was followed by a regional core and wireline study of the Mount Clark and Mount Cap formations, which formed the basis of a graduate project (Sommers, 2018) that currently is being prepared for external publication. This thesis project was designed to build upon outcrop-based studies of Cambrian stratigraphy from the first phase of GEM (Hamel and MacNaughton, 2013; MacNaughton et al., 2013) by erecting a sequence-stratigraphic framework for the subsurface succession. Trilobite faunas previously collected from industry cores (e.g. Macqueen and Mackenzie, 1973) have been the subject of a preliminary reassessment (C.A. Morgan, unpub. GSC Paleontological Report 1-CAM-2019, 2019), which suggests that updated Cambrian biozones can be applied to the succession for greater biostratigraphic precision. The subsurface work complements a second, outcrop-based graduate project (Bouchard, 2019) dealing with outcrop exposures around the Brock Inlier and in the eastern Mackenzie Mountains (Bouchard and Turner, 2017a, b). The goal of this combined effort is to provide an updated stratigraphic framework for the Mount Clark and Mount Cap formations, from where they onlap the eastern flank of the Mackenzie Arch to their zero edge against the Brock Inlier.

STRUCTURAL GEOLOGY IN THE MACKENZIE REGION

The Mackenzie-region study areas of the GEM program encompass a significant portion of the northern Foreland Belt of the Canadian Cordillera (Norris, 1985). Structures associated with both pre-Laramide and fold-and-thrust style deformation of the Laramide Orogeny are recognized from the Mackenzie Mountains to the Colville Hills (Fig. 1). Summary overviews of the regional structural geology have been presented by Norris (1985), Cook (*in* McMechan et al., 1991), Hyndman et al. (2005), and Martel et al. (2011).

Pre-Laramide structures

Structures formed during the Cretaceous to Eocene Laramide Orogeny dominate the Mackenzie region (Eisbacher, 1981; Cook *in* McMechan et al., 1991); however, within the GEM study area, there are also mappable structures with a demonstrable pre-Laramide history. In a regional study beneath the northern plains, Cook and MacLean (2004) used reflection-seismic data to document a series of subsurface contractional and extensional faults, with associated folding, affecting Paleo- and Mesoproterozoic sedimentary and metasedimentary successions that constitute 'basement' to the region's Neoproterozoic to Paleocene strata. These basement structures were interpreted to have varying trends, although approximately northward trends are common. Aitken and Cook (1974a) documented another set of faults, presumed by them to be normal faults, trending north-northwest (340–360°) and cutting Neoproterozoic strata in the Mackenzie Mountains. They noted that map relationships indicate these antecedent faults were active before Upper Cambrian strata were deposited and they suggested that the lack of involvement of Rapitan Group or younger strata indicates these faults may have formed before Rapitan deposition. Eisbacher (1981) documented a set of normal faults affecting strata of the Coates Lake and lower Rapitan groups in the Mackenzie Mountains. Fault trends vary with latitude, from northeastward near latitude 63°N, to northward at latitude 64°N, and northwestward at latitude 65°N. These faults were interpreted to be syndepositional to the Coates Lake and Rapitan groups. Young et al. (1979) assigned these syndepositional faults to the Hayhook Orogeny. As part of GEM program research, north to north-northeast-trending, early to mid-Cambrian normal faulting has been documented in the subsurface of the Mackenzie Plain, Franklin Mountains, and Colville Hills (MacLean, 2011b; MacLean et al., 2014, 2015). Syndepositional normal faulting in the Middle Cambrian Nainlin Formation was also documented within the Mackenzie Mountains (Fig. 12a, b; MacNaughton and Fallas, 2014; Fallas et al., 2016). The dominant north-northwest trend of these faults is coincident with the antecedent faults of Aitken and Cook (1974a), and in some cases, they are the same features.

Laramide structures

Most structures mapped within the study area formed during the development of the Canadian Cordillera. In the present context, the term Laramide Orogeny is used to indicate contractional deformation during Cretaceous to Eocene time. The timing of Laramide deformation in the study area is based on multiple lines of evidence: the presence of sediment derived from the Cordillera in Late Cretaceous strata (Hadlari et al., 2014); the presence of Cretaceous bentonites indicating volcanic activity in the region (Thomson et al., 2011); and the involvement of Cretaceous to Paleocene units in Laramide folding. This timing is further supported by a GEM program thermochronological study showing uplift on thrust faults in the Mackenzie Mountains from the mid-Cretaceous to the Eocene (Breker, 2012; Powell et al., 2016; Powell, 2017).

Laramide deformation is recognized throughout most of the study area, but varies in the types of structures, level of detachment, strata involved, and structural trends. These variations can be characterized for each physiographic region (Fig. 1) as belonging to a particular structural domain (Fallas, 2013e). Laramide structures include thrust faults (northeast-directed faults cutting through strata at angles between 0° and 45°, regardless of present-day dip), backthrusts (southwest-directed faults with the same geometry as thrust faults), reverse faults (faults cutting through strata at >60°, typically with steep fault-plane dips), and minor strike-slip faults. Northwest-trending thrust faults are the dominant fault type in the Mackenzie Mountains (Fig. 13a), Mackenzie Plain, and Franklin Mountains, and are present to a lesser degree in the Colville Hills. Northwest- or west-trending backthrusts are present in the Mackenzie Mountains, the northwestern margin of the Mackenzie

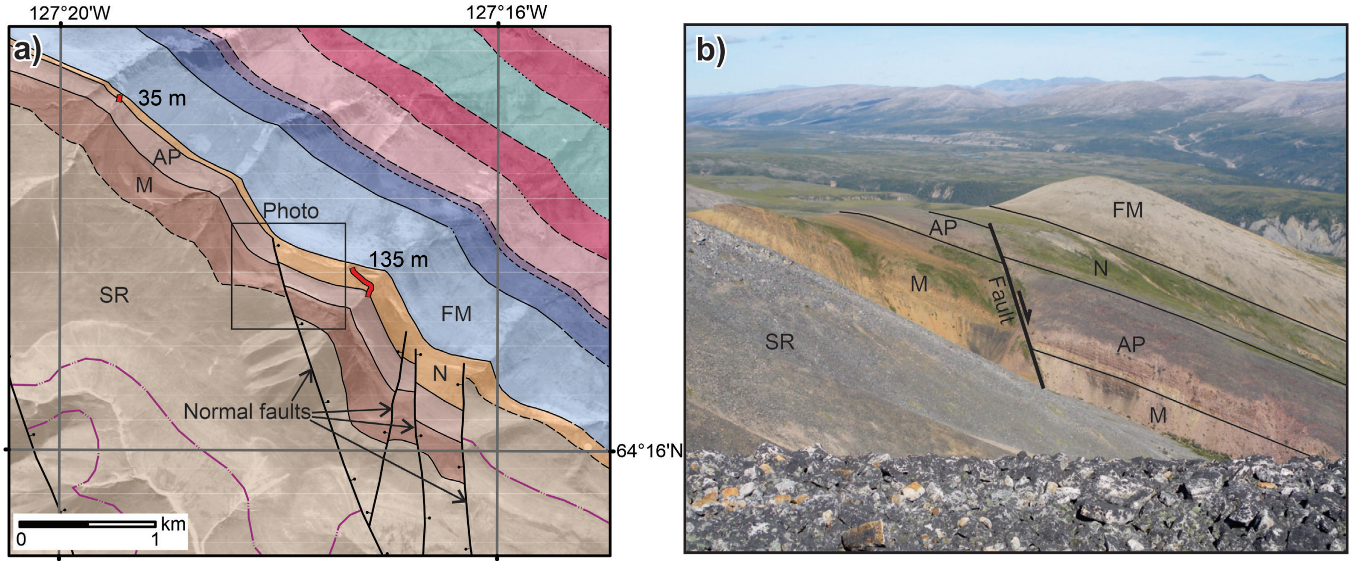


Figure 12. Evidence of Cambrian motion on pre-Laramide faults. **a)** Interpretation *modified from* Fallas and MacNaughton (2014c). Labelled units include Neoproterozoic Katherine Group: Shattered Range Formation (SR), McClure Formation (M), Abraham Plains Formation (AP), Middle Cambrian Nainlin Formation (N), and Cambro-Ordovician Franklin Mountain Formation (FM). Pre-Laramide normal faults cut the Katherine Group and Nainlin Formation, whereas the overlying Franklin Mountain Formation is not offset by the fault. Measured sections through the Nainlin Formation are shown on the map as red lines with measured thickness of unit annotated. Black box indicates the area of the annotated field photograph opposite. Satellite image from Centre national d'études spatiales (©2012 CNES), licensed by Planet Labs Geomatics Corp. **b)** Field photograph looking north-northwest along the down-to-the-east normal fault shown opposite; half arrow indicates fault motion. For scale, Nainlin Formation in b) is 135 m thick on the right-hand side of the fault. Units are labelled with the same abbreviations on both a) and b). Photograph by T. Proks. NRCan photo 2019-279

Plain, and in the Franklin Mountains (Fig. 13b). North- to north-northwest-trending reverse faults are the dominant fault type in the Colville Hills and the eastern Franklin Mountains; they are also present as a minor fault type within the Mackenzie Mountains (Fig. 13c). West-, northwest-, and north-trending folds are present throughout the deformed belt and are the dominant Laramide structures northeast of the Plateau Fault in the Mackenzie Mountains (Fig. 13d), as well as in the Mackenzie Plain, Brackett Basin, and Colville Hills. Where thick packages of resistant carbonate or quartz sandstone are involved in folding, larger folds with wavelengths of 5–25 km dominate the structural style (Fig. 13b, d). Near the Yukon–Northwest Territories border in the Mackenzie Mountains, shale-dominated Selwyn Basin strata fold at multiple scales with wavelengths of tens to hundreds of metres (Fig. 13e). North- to north-northwest-trending normal faults are common in the Mackenzie Mountains, but typically are found in Neoproterozoic and Cambrian strata and therefore generally are interpreted as pre-Laramide structures (Fig. 12a, b). Normal faults typically have smaller displacements (from a few metres up to 300 m) as compared to contractional Laramide faults (from hundreds of metres up to a few kilometres).

Laramide folds and faults in the Mackenzie Mountains are detached at multiple stratigraphic levels, with major structures exploiting weak, commonly shaly or evaporitic strata in the Neoproterozoic Tsezotene Formation, the Ten Stone or Snail Spring formations of the Little Dal Group (Fig. 13a), the Twitya Formation, and the Sheepbed Formation. An additional detachment level must be present below the Tabasco Formation, but is not exposed in the Mackenzie Mountains. Minor folds are also detached in the Devonian Landry and Hume formations. Major structures in the Mackenzie Plain, Brackett Basin, Franklin Mountains, and Colville Hills are detached within evaporitic strata of the Cambrian Saline River Formation (Fig. 13f). One such structure in the Brackett Basin, forming the MacKay Range, was studied in detail as a student project during the GEM program (Proks, 2012).

A characteristic of many reverse faults in the study area is evidence of a pre-Laramide extensional history (Fallas, 2013e). In the Mackenzie Mountains, faults with normal stratigraphic offset can be traced into faults with reverse offset (*see* Conundrum Fault in Fallas and MacNaughton, 2014c), and stratigraphic relationships show that some reverse faults have thicker successions in the hanging wall, indicating that the hanging wall was once the downdropped side of the fault. The dominant trend of reverse faults, near 340°, also matches the dominant trend of mapped normal faults of the Hayhook Orogeny and Cambrian extensional phase. In the subsurface of the Mackenzie Plain, Brackett Basin, Franklin Mountains, and Colville Hills, reflection-seismic data show a similar inversion of stratigraphy on major steeply dipping reverse faults (i.e. thicker stratigraphic successions in

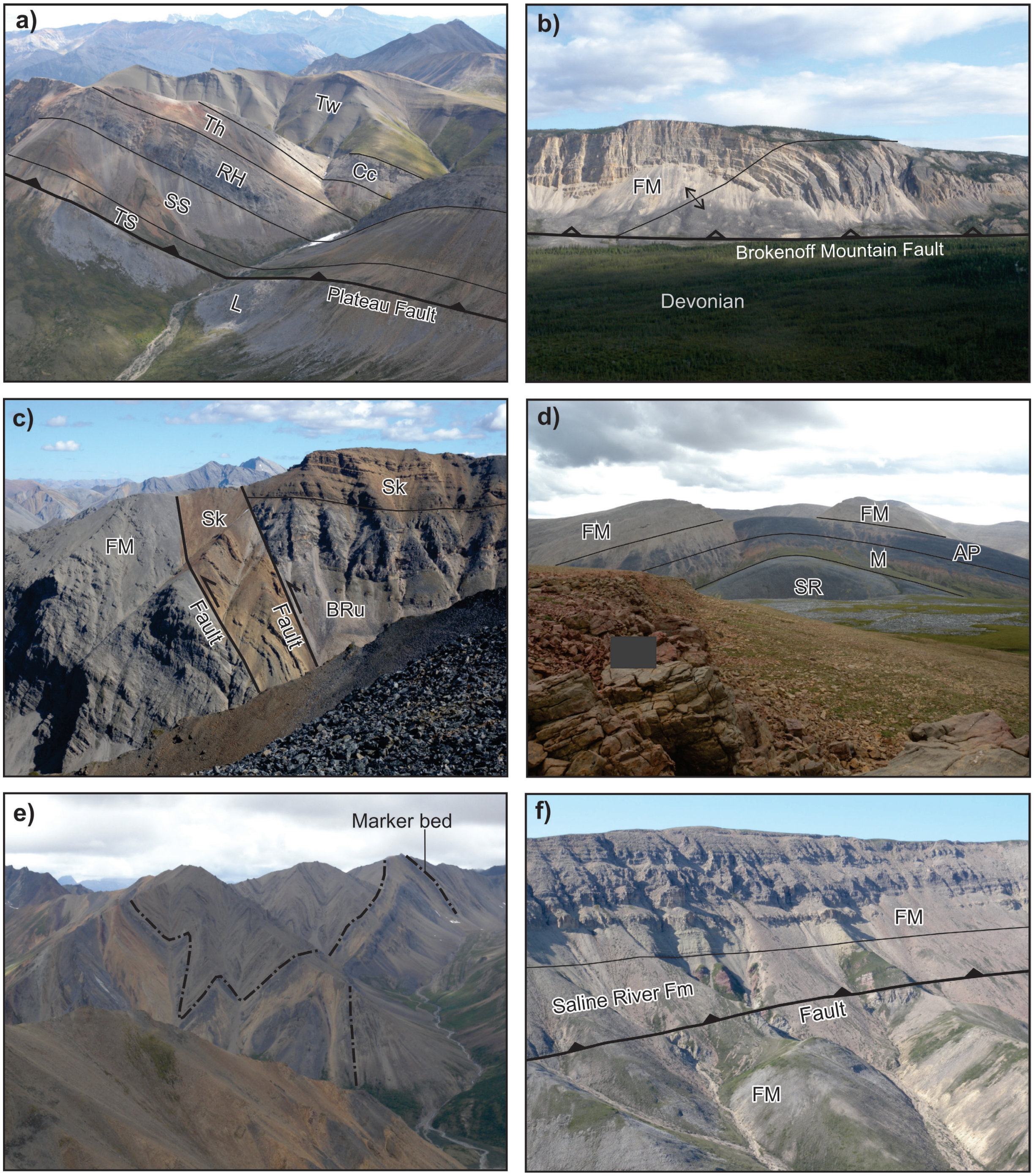


Figure 13. Structures associated with the Laramide Orogeny. **a)** Looking south at the Plateau Fault in the Bonnet Plume Lake map area (NTS 106-B), where the thrust detachment lies within evaporite of the Ten Stone Formation. Field of view at thrust fault is approximately 1.4 km, thickness of Ram Head Formation (RH) is approximately 170 m. Photograph by K. Fallas. NRCan photo 2019-270. **b)** Looking northeast at backthrust (open triangle symbol) and anticline (line with arrows) on Brokenoff Mountain in Norman Wells map area (NTS 96-E). Field of view at base of mountain is approximately 2 km, mountain rises approximately 400 m above valley. Photograph by K. Fallas. NRCan photo 2019-268. **c)** Looking southeast at reverse faults in Bonnet Plume Lake map area, with half arrows indicating fault movement. Field of view is approximately 1 km, Sekwi Formation (Sk) on right-hand side of photo is approximately 150 m thick. Photograph by K. Fallas. NRCan photo 2019-272. **d)** Looking southeast along the McDermott anticline in the Carcajou Canyon map area (NTS 96-D). Width of visible Shattered Range Formation (SR) is approximately 1.2 km, McClure Formation (M) is approximately 100 m thick. Photograph by K. Fallas. NRCan photo 2019-267. **e)** Looking northwest at tight folds in carbonate and shale of the Sekwi Formation, in the eastern part of the Nadaleen River map area (NTS 106-C). Field of view along skyline is approximately 3.5 km, vertical relief from stream on right to top of peak in middle ground is 750 m. Photograph by K. Fallas. NRCan photo 2019-275. **f)** Looking southwest at thrust splay in the Norman Range of the Franklin Mountains, Norman Wells map area, where the thrust detachment lies within evaporite of the Saline River Formation. Photograph by K. Fallas. NRCan photo 2019-266. Abbreviations: AP = Abraham Plains Formation; BRu = Backbone Ranges Formation, upper member; Cc = Coppercap Formation; FM = Franklin Mountain Formation; L = Landry Formation; M = McClure Formation; RH = Ram Head Formation; Sk = Sekwi Formation; SR = Shattered Range Formation; SS = Snail Spring Formation; Th = Thundercloud Formation; TS = Ten Stone Formation; Tw = Twitya Formation.

the hanging wall) cutting through the detachment level in the Saline River Formation, and connecting with structures in the underlying Proterozoic strata (MacLean et al., 2014, 2015). In this manner, the Mackenzie Trough (*see* Fig. 8) was inverted during the Laramide Orogeny as the second phase of the Keele Arch along the eastern Franklin Mountains and Colville Hills.

Difficulties in resolving the details of some stratigraphic intervals, notably the Katherine Group, Little Dal Group, Backbone Ranges Formation, and Road River Group, led previous mappers to leave these intervals partly or completely undivided on reconnaissance maps. Improved understanding of stratigraphic detail since the 1970s, and particularly during the GEM program, has facilitated subdividing such thick (>500 m) successions based on consistent lithological variations. In turn, these stratigraphic refinements have locally revealed new structural details, and in some cases allowed for the recognition of structures previously overlooked. One example of this is the northwestern extent of the Canyon Fault in the Carcajou Canyon map area (NTS 96-D), where an undivided 'lower division' of the Katherine Group disguised the trace of the Canyon Fault and led Aitken et al. (1974) to interpret a termination just north of the Carcajou River (Fig. 14a). Mapping of the subdivisions of the Katherine Group during the GEM program (Fig. 14b) demonstrated the continuation of the Canyon Fault to the northwestern margin of the map area (Fallas and MacNaughton, 2014a). In other instances, correcting earlier misidentifications of units led to the revision of previously mapped faults, or the new identification of faults (Fig. 15a, b). Accurate mapping of units and structures has implications for identifying prospective versus nonprospective areas for mineral exploration. For example, previous maps in some cases misidentified Ediacaran Sheepbed Formation as lower Paleozoic Road River Group (Aitken and Cook, 1974b). In the Yukon portion of the Selwyn Basin, thin-bedded silty carbonate of the Road River Group is a host for Carlin-type gold deposits (Arehart et al., 2013) and similar Road River Group lithologies are potential targets for Carlin-type gold exploration in the project area (Fischer, 2018); however, suitable lithologies for Carlin-type mineralization are not known to be present in the Sheepbed Formation. Thus, misidentification of Sheepbed Formation as Road River Group (Fig. 16) could be a significant exploration risk, with the potential to send mineral exploration companies into nonprospective areas.

HIGHLIGHTS

During the two phases of the GEM program, Geological Survey of Canada scientists and collaborators remapped nearly 92 000 km^2 of territory in the Mackenzie region. To date, eighteen new bedrock geology maps have been published at the scale of 1:100 000 or 1:250 000, and six additional maps are currently in preparation (Fallas and MacNaughton, 2020a, b; Fig. 4b). In addition to bedrock mapping, geophysical mapping covered nearly 13 000 km^2 in the Mackenzie Valley (airborne gravity survey; Dumont, 2009) and 48 300 km^2 in the Mackenzie Mountains (airborne aeromagnetic survey; Kiss, 2018). As of mid-2019, scientists affiliated with the GEM program have published at least 38 GSC reports on Mackenzie region geology, to which can be added at least 5 relevant reports published by other government agencies and 17 peer-reviewed articles in journals or books. Also of note, are the new biostratigraphic and other data contained in at least 36 internal GSC Paleontological Reports (*see* Appendix A). Important syntheses of Mackenzie

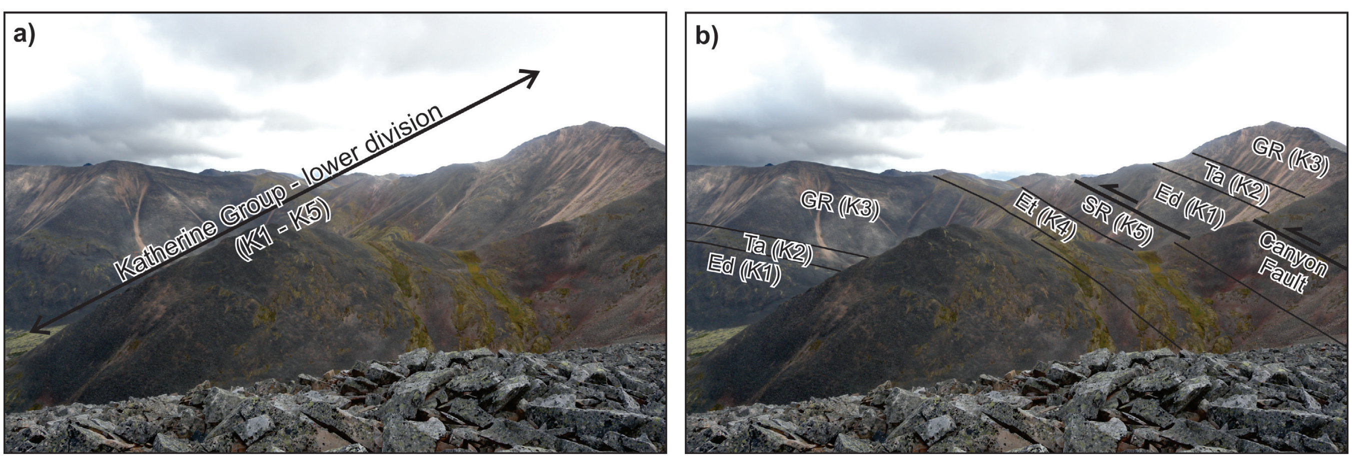


Figure 14. Revised structural interpretation resulting from subdivision of the Katherine Group. **a)** View looking southeast at undivided lower Katherine Group of Operation Norman (Aitken et al., 1974), with no interpreted fault, in northwest Carcajou Canyon map area (NTS 96-D). Field of view along skyline is approximately 2.3 km. **b)** Extension of the Canyon Fault recognized by mapping the formations of the Katherine Group (Fallas and MacNaughton, 2014a), with fault movement indicated by half arrow. Etagochile Fm (Et) is approximately 120 m thick. Abbreviations: Ed = Eduni Formation; Et = Etagochile Formation; GR = Grafe River Formation; SR = Shattered Range Formation; Ta = Tawu Formation. Informal K1 to K5 designations for the lower division of the Katherine Group of Aitken et al. (1978) also shown for reference. Photograph by K. Fallas. NRCan photo 2019-269

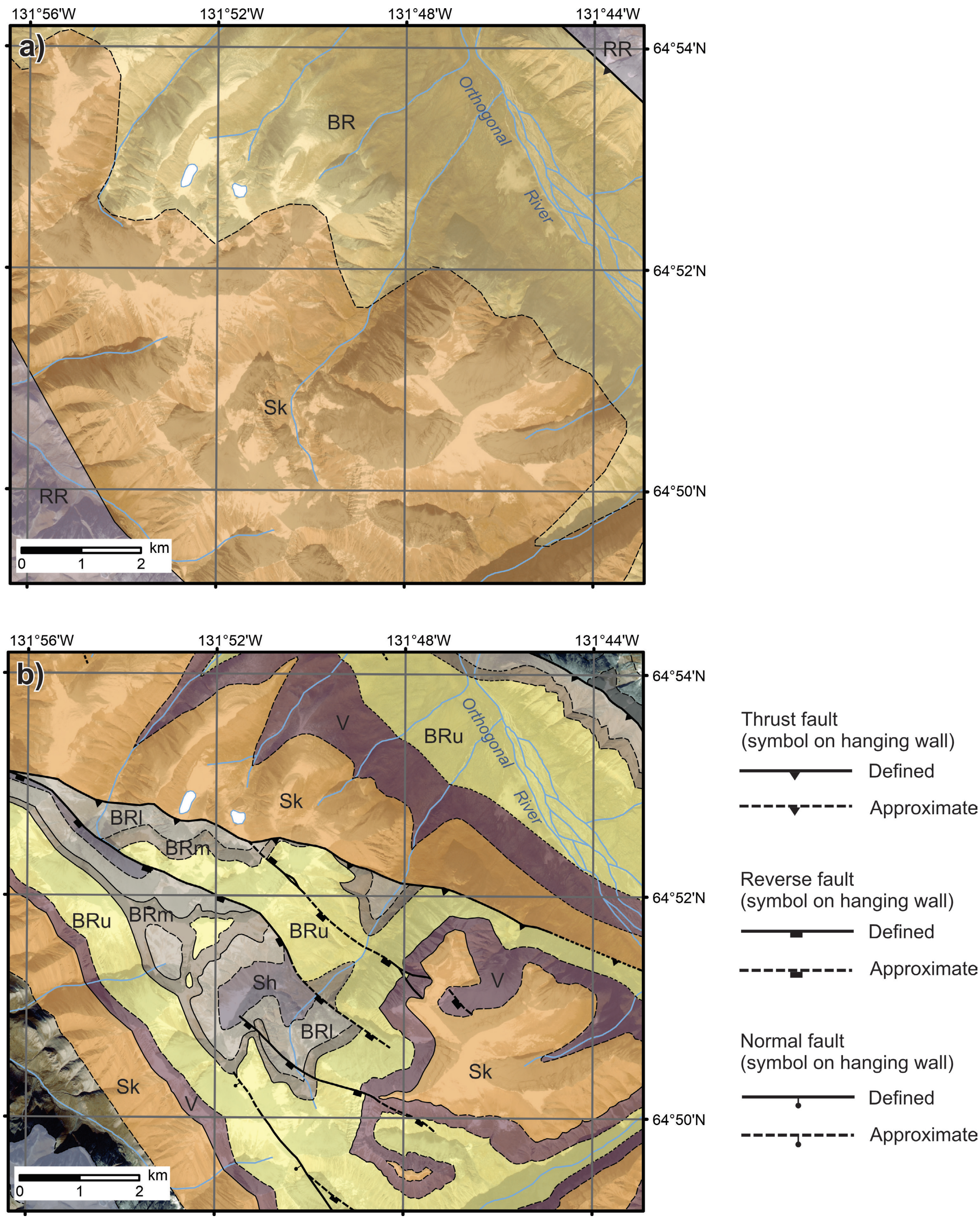


Figure 15. Geological interpretations of the northwestern Bonnet Plume Lake map area (NTS 106-B). **a)** Interpretation of Blusson (1974), showing an unfaulted succession southwest of Orthogonal River. **b)** Revised interpretation based on Geo-mapping for Energy and Minerals program mapping with thrust, reverse, and normal faults identified. Abbreviations: BR = Backbone Ranges Formation (BRl, BRm, BRu refer to lower, middle, and upper members, respectively); RR = Road River Group; Sh = Sheepbed Formation; Sk = Sekwi Formation; V = Vampire Formation. Satellite imagery from ©2015 Airbus Defence and Space, licensed by Planet Labs Geomatics Corp.

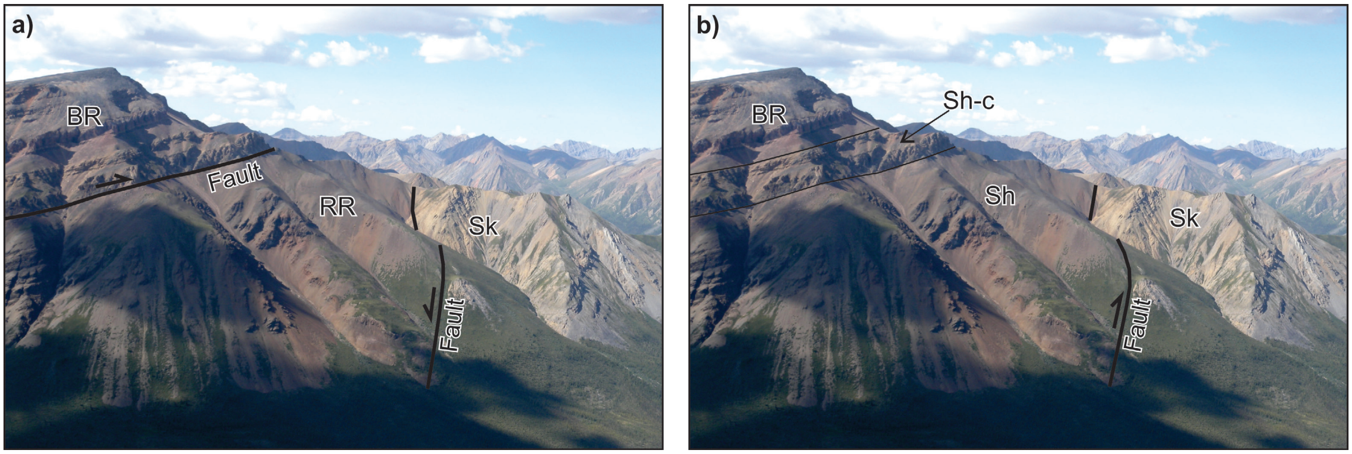


Figure 16. Reinterpreted structural relationships in the northeastern portion of the Bonnet Plume Lake map area (NTS 106-B). **a)** View looking west at Operation Norman interpretation (Aitken and Cook, 1974b) of unnamed thrust fault and normal fault (half arrows indicate fault motion). Abbreviations: BR = Backbone Ranges Formation; RR = Road River Formation; Sk = Sekwi Formation. **b)** Revised interpretation, from Geo-mapping for Energy and Minerals program work, of a single thrust fault based on the recognition of Sheepbed Formation (Sh) and the 'Sheepbed carbonate' (Sh-c) underlying the Backbone Ranges Formation. Field of view along base of mountain is approximately 2 km and vertical relief from base of mountain to peak is approximately 1000 m. Photograph by K. Fallas. NRCan photo 2019-273

region geology generated during the GEM program include: Hannigan et al. (2011) on oil and gas potential of the mainland area of the Northwest Territories, including an overview of regional geology; MacLean (2011b) on the Cambrian in the subsurface; Morrow (2012, 2018) on regional Devonian stratigraphy; Fallas et al. (in press a) on the Cambrian to Devonian Mackenzie Platform east of the Mackenzie Mountains; and Fallas et al. (in press b) on Mesozoic and Cenozoic geology east of the Mackenzie Mountains.

Prior to GEM, the state of published bedrock-geology maps across the Mackenzie Mountains and Interior Plains was uneven and largely based on reconnaissance studies conducted a half-century ago, particularly during Operation Norman. Although GEM mapping demonstrated the large-scale reliability of the earlier generation of maps, it also provided an opportunity to take advantage of scientific and technological advances. The advent of GIS technology has facilitated the incorporation of legacy data from government (Fallas et al., 2015a) and industry sources (Finley et al., 2017) into the project geodatabase, lending additional value to the work of earlier geologists. Modern methods of field-data collection permit near-instantaneous incorporation of mapping and stratigraphic data into the geodatabase. The use of the geodatabase in the field was a boon for on-the-ground planning of mapping strategies and daily work goals. Of similar importance was access to high-resolution, colour satellite imagery for much of the region, which also has been invaluable for post-field map compilation. The delivery of underlying observations with map interpretations allows the user to assess the reliability of published interpretations, reinterpret the geology, and/or reuse the observations in new research.

The most obvious visual change in the new generation of maps may be the use of updated stratigraphic nomenclature that postdates Operation Norman. As discussed above, these revisions affect essentially every geological system, from the Tonian to the Paleocene. Stratigraphic innovations published during GEM include: formalization of lithostratigraphy for the Mackenzie Mountains Supergroup (Long and Turner, 2012; Turner and Long, 2012); recognition of greater stratigraphic complexity in the Ediacaran–Cambrian transition (MacNaughton and Fallas, 2018, 2019; MacNaughton et al., 2018), studies of which are still ongoing; revisions to the Cambrian stratigraphy of the eastern Mackenzie Mountains (e.g. MacNaughton et al., 2013), including formalization of the new Nainlin Formation (MacNaughton and Fallas, 2014); clarification of the internal stratigraphy of the Cambro-Ordovician Franklin Mountain Formation (Turner, 2011); and the use of biostratigraphy to resolve issues in mapping the Bear Rock Formation and related units in the Colville Hills (Gouwy et al., 2017a).

The GEM program provided an important opportunity to update the Operation Norman generation of maps, not least because the work could be conducted in more detail than was possible during the earlier reconnaissance programs. By comparison, fieldwork for Operation Norman was limited to three summer field seasons, whereas GEM mapping on a subset of the area covered by the Operation Norman maps included six field seasons of 3–6 weeks each, plus two shorter seasons of 1–2 weeks. As a result, geological boundaries have been traced on the ground and structures mapped in greater detail than was possible for earlier workers. Such revisions have identified additional faults, with associated implications for estimates of shortening across the Mackenzie Mountains, fault-controlled mineralization, and tectonic history. Greater stratigraphic and structural detail is also aiding in ongoing revisions to understanding the tectonostratigraphic evolution of the Mackenzie region.

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REFERENCES

(Asterisks (*) indicate publications generated during the GEM program.)

*Acker, R.M., 2013. Sedimentology and stratigraphy of the Devonian Imperial Formation, Mackenzie Valley, Northwest Territories, Canada; M.Sc. thesis, University of Calgary, Calgary, Alberta, 115 p. https://doi.org/10.11575/PRISM/27732

Aitken, J.D., 1981. Stratigraphy and sedimentology of the upper Proterozoic Little Dal Group, Mackenzie Mountains, Northwest Territories; *in* Proterozoic Basins of Canada, (ed.) F.H.A. Campbell; Geological Survey of Canada, Paper 81-10, p. 47–71. https://doi.org/10.4095/109385

Aitken, J.D., 1984. Strata and trace fossils near the Precambrian–Cambrian boundary, Mackenzie, Selwyn and Wernecke mountains, Yukon and Northwest Territories: discussion; *in* Current research, Part B; Geological Survey of Canada, Paper 84-1B, p. 401–407. https://doi.org/10.4095/119557

Aitken, J.D., 1989. Uppermost Proterozoic formations in central Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Bulletin 368, 26 p. https://doi.org/10.4095/126611

Aitken, J.D., 1991. The Ice Brook Formation and post-Rapitan, Late Proterozoic glaciation, Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Bulletin 404, 43 p. https://doi.org/10.4095/132664

Aitken, J.D. and Cook, D.G., 1970. Geology, Colville Lake and Coppermine, District of Mackenzie; Geological Survey of Canada, Preliminary Map 12-1970, scale 1:500 000. https://doi.org/10.4095/220386

Aitken, J.D. and Cook, D.G., 1974a. Effect of antecedent faults on "Laramide" structure, Mackenzie Arc; *in* Report of activities, Part B; Geological Survey of Canada, Paper 74-1B, p. 259–264. https://doi.org/10.4095/104770

Aitken, J.D. and Cook, D.G., 1974b. Geological maps showing bedrock geology of the northern parts of Mount Eduni and Bonnet Plume Lake map areas, District of Mackenzie, Northwest Territories; Geological Survey of Canada, Open File 221, scale 1:125 000. https://doi.org/10.4095/129332

Aitken, J.D. and Cook, D.G., 1976. Geology, Norman Wells, Mahony Lake, District of Mackenzie; Geological Survey of Canada, Open File 304, scale 1:125 000. https://doi.org/10.4095/129433

Aitken, J.D. and Cook, D.G., 1979a. Geology, Upper Ramparts River, District of Mackenzie; Geological Survey of Canada, Map 1452A, scale 1:250 000. https://doi.org/10.4095/123318

Aitken, J.D. and Cook, D.G., 1979b. Geology, Sans Sault Rapids, District of Mackenzie; Geological Survey of Canada, Map 1453A, scale 1:250 000 scale. https://doi.org/10.4095/123316

Aitken, J.D., Macqueen, R.W., and Usher, J.L., 1973. Reconnaissance studies of Proterozoic and Cambrian stratigraphy, lower Mackenzie River area (Operation Norman), District of Mackenzie; Geological Survey of Canada, Paper 73-9, 178 p. https://doi.org/10.4095/103313

Aitken, J.D., Cook, D.G., Balkwill, H.R., and Yorath, C.J., 1974. Geology, Carcajou Canyon, District of Mackenzie; Geological Survey of Canada, Map 1390A, scale 1:250 000. https://doi.org/10.4095/109026

Aitken, J.D., Long, D.G.F., and Semikhatov, M.A., 1978. Progress in Helikian stratigraphy, Mackenzie Mountains; *in* Current research, Part A; Geological Survey of Canada, Paper 78-1A, p. 481–484. https://doi.org/10.4095/119799

*Aitken, J.D., Turner, E.C., and MacNaughton, R.B., 2011. Thirty-six archival stratigraphic sections in the Katherine, Little Dal, Coates Lake, and Rapitan groups (Neoproterozoic), Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Open File 6391, 9 p., 1 CD-ROM. https://doi.org/10.4095/288059

Arehart, G.B., Ressel, M., Carne, R., and Muntean, J., 2013. A comparison of Carlin-type deposits in Nevada and Yukon; Society of Economic Geologists, Special Publication 17, p. 389–401.

Balkwill, H.R., 1971. Norman, and Camsell River, District of Mackenzie; Geological Survey of Canada, Preliminary Map 5-1971, scale 1:500 000. https://doi.org/10.4095/107936

Bassett, H.G., 1961. Devonian stratigraphy, central Mackenzie River region, Northwest Territories, Canada; *in* Geology of the Arctic, Proceedings of the First International Symposium on Arctic Geology,Volume 1, (ed.) G.O. Raasch; Alberta Society of Petroleum Geologists and University of Toronto Press; p. 481–498. https://doi.org/10.3138/9781487584979-043

Bell, K.M., 2018. Biostratigraphy of Cretaceous and Paleogene strata from northern Yukon Territory and District of Mackenzie, Northwest Territories; Ph.D. thesis, University of Calgary, Calgary, Alberta, 350 p.

Blusson, S.L., 1967. Sekwi Mountain, Nahanni and Frances Lake map areas; *in* Report of activities, Part A; Geological Survey of Canada, Paper 67-1A, p. 44–45. https://doi.org/10.4095/106478

Blusson, S.L., 1968. Sekwi Mountain (105P) and Nahanni (105I) map areas, District of Mackenzie and Yukon Territory; *in* Report of activities, Part A; Geological Survey of Canada, Paper 68-1A, p. 14. https://doi.org/10.4095/106249

Blusson, S.L., 1971. Operation Stewart, Yukon Territory and District of Mackenzie; *in* Report of activities, Part A; Geological Survey of Canada, Paper 71-1A, p. 19. https://doi.org/10.4095/105508

Blusson, S.L., 1972. Geology, Sekwi Mountain, Northwest Territories–Yukon Territory; Geological Survey of Canada, Map 1333A, scale 1:250 000. https://doi.org/10.4095/109068

Blusson, S.L., 1974. Five geological maps of northern Selwyn Basin (Operation Stewart), Yukon Territory and District of Mackenzie, Northwest Territories; Geological Survey of Canada, Open File 205, scale 1:250 000. https://doi.org/10.4095/129320

Blusson, S.L. and Tempelman-Kluit, D.J., 1970. Operation Stewart, Yukon Territory, District of Mackenzie (105N, O, 106B, C); *in* Report of activities, Part A; Geological Survey of Canada, Paper 70-1A, p. 29–32. https://doi.org/10.4095/105700

Bouchard, M.L., 2019. Litho- and chemostratigraphy of the Lower to Middle Cambrian Mount Clark, Mount Cap, and Saline River formations in Hornaday River Canyon, Carcajou Range, and Norman Range, Northwest Territories; M.Sc. thesis, Laurentian University, Sudbury, Ontario, 415 p.

*Bouchard, M.L. and Turner, E.C., 2017a. Stratigraphy of the Mount Clark, Mount Cap and Saline River formations in the Hornaday River canyon, Northwest Territories (NTS 97A); Geological Survey of Canada, Open File 8180, 44 p. https://doi.org/10.4095/299603

*Bouchard, M.L. and Turner, E.C., 2017b. Cambrian lithostratigraphy of the Mount Clark, Mount Cap, and Saline River formations in the Carcajou Range and Norman Range, Northwest Territories (NTS 96E1, 3, and 4); Geological Survey of Canada, Open File 8246, 35 p. https://doi.org/10.4095/302730

*Breker, K., 2012. (U-Th)/He thermochronology across the Plateau Fault, Mackenzie Mountains, NWT: resolving the timing of thrusting in the Eastern Cordillera; B.Sc. thesis, University of Ottawa, Ottawa, Ontario, 26 p.

Caldwell, W.G.E., 1964. The nomenclature of the Devonian formations in the lower Mackenzie River valley; Bulletin of Canadian Petroleum Geology, v. 12, p. 611–622.

Cecile, M.P., 1982. The Lower Paleozoic Misty Creek Embayment, Selwyn Basin, Yukon and Northwest Territories; Geological Survey of Canada, Bulletin 335, 78 p. https://doi.org/10.4095/111346

Cecile, M.P., 2000. Geology of the northeastern Niddery Lake map area, east-central Yukon and adjacent Northwest Territories; Geological Survey of Canada, Bulletin 553, 119 p. https://doi.org/10.4095/211664

*Chan, W.C., MacNaughton, R.B., and Fallas, K.M., 2019. Isopach maps for the Sekwi Formation (Cambrian Series 2), Mackenzie Mountains, Northwest Territories and Yukon; Geological Survey of Canada, Open File 8371, 18 p. https://doi.org/10.4095/321055

Chevrier, T.S. and Turner, E.C., 2013. Lithostratigraphy of deep-water lower Paleozoic strata in the central Misty Creek embayment, Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Current Research 2013-14, 25 p. https://doi.org/10.4095/292568

Cook, D.G. and Aitken, J.D., 1969. Geology, Fort Good Hope, District of Mackenzie; Geological Survey of Canada, Preliminary Map 4-1969, scale 1:250 000. https://doi.org/10.4095/109213

Cook, D.G. and Aitken, J.D., 1971. Geology, Colville Lake map-area and part of Coppermine map-area, Northwest Territories; Geological Survey of Canada, Paper 70-12, 42 p. https://doi.org/10.4095/102357

Cook, D.G. and Aitken, J.D., 1977. Geological map of Blackwater Lake (96B) and Fort Norman (96C), District of Mackenzie; Geological Survey of Canada, Open File 402, scale 1:125 000. https://doi.org/10.4095/129207

Cook, D.G. and MacLean, B.C., 2004. Subsurface Proterozoic stratigraphy and tectonics of the western Plains of the Northwest Territories; Geological Survey of Canada, Bulletin 575, 92 p. https://doi.org/10.4095/215739

Cook, D.G., MacLean, B.C., and Morrow, D.W., 2010. GIS-enabled geology maps of the McConnell Range and environs, Northwest Territories; Geological Survey of Canada, Open File 6175, 1 .zip file. https://doi.org/10.4095/285368

*Davison, J.E.A., 2011. Sedimentology and stratigraphy of the Lower Cretaceous Martin House Formation, Mackenzie Corridor, Northwest Territories, Canada; M.Sc. thesis, University of Calgary, Calgary, Alberta, 146 p. https://doi.org/10.11575/PRISM/11347

Day, E.S., James, N.P., Narbonne, G.M., and Dalrymple, R.W., 2004. A sedimentary prelude to Marinoan glaciation, Cryogenian (Middle Neoproterozoic) Keele Formation, Mackenzie Mountains, northwestern Canada; Precambrian Research, v. 133, p. 223–247. https://doi.org/10.1016/j.precamres.2004.05.004

Dilliard, K.A., 2006. Sequence stratigraphy and chemostratigraphy of the Lower Cambrian Sekwi Formation, Northwest Territories, Canada; Ph.D. thesis, Washington State University, Pullman, Washington, 298 p. https://searchit.libraries.wsu.edu/permalink/f/1j6uprt/CP71149150890001451

Dilliard, K.A., Pope, M.C., Coniglio, M., Hasiotis, S.T., and Lieberman, B.S., 2010. Active synsedimentary tectonism on a mixed carbonate–siliciclastic continental margin: third-order sequence stratigraphy of a ramp to basin transition, lower Sekwi Formation, Selwyn Basin, Northwest Territories, Canada; Sedimentology, v. 57, no. 2, p. 513–542. https://doi.org/10.1111/j.1365-3091.2009.01095.x

Dixon, J., 1999. Mesozoic–Cenozoic stratigraphy of the northern Interior Plains and plateaux, Northwest Territories; Geological Survey of Canada, Bulletin 536, 56 p. https://doi.org/10.4095/210800

*Dixon, J., 2011. Subsurface correlations in the Upper Devonian to Lower Carboniferous clastic wedge (Imperial and Tuttle formations), Northwest Territories; Geological Survey of Canada, Open File 6862, 51 p. https://doi.org/10.4095/289618

Dixon, J. and Stasiuk, L.D., 1998. Stratigraphy and hydrocarbon potential of Cambrian strata, Northern Interior Plains, Northwest Territories; Bulletin of Canadian Petroleum Geology, v. 46, p. 445–470.

Dixon, J., Dietrich, J.R., Lane, L.S., and McNeil, D.H., 2008. Geology of the Late Cretaceous to Cenozoic Beaufort-Mackenzie Basin, Canada; Chapter 16 *in* The Sedimentary Basins of the United States and Canada, (ed.) A.D. Miall; Sedimentary Basins of the World, Elsevier, v. 5, p. 551–572. https://doi.org/10.1016/S1874-5997(08)00016-6

Douglas, R.J.W., 1974. Geology, Dahadinni River, District of Mackenzie; Geological Survey of Canada, Map 1374A, scale 1:250 000. https://doi.org/10.4095/109153

Douglas, R.J.W. and Norris, D.K., 1961. Camsell Bend and Root River map-areas, Northwest Territories; Geological Survey of Canada, Paper 61-13, 36 p. https://doi.org/10.4095/101102

*Dumont, R., 2009. Geophysical Series, NTS 96 E, 106 H and parts of 96 C, 96 D, 96 F, and 106 A, central Mackenzie Valley airborne gravity survey, Norman Wells, Northwest Territories; Geological Survey of Canada, Open File 6154, 2 sheets, scale 1:250 000. https://doi.org/10.4095/247764

Eisbacher, G.H., 1978. Re-definition and subdivision of the Rapitan Group, Mackenzie Mountains; Geological Survey of Canada, Paper 77-35, 21 p. https://doi.org/10.4095/103527

Eisbacher, G.H., 1981. Sedimentary tectonics and glacial record in the Windermere Supergroup, Mackenzie Mountains, northwestern Canada; Geological Survey of Canada, Paper 80-27, 40 p. https://doi.org/10.4095/119453

*Fallas, K.M., 2013a. Geology, Mahony Lake (northwest), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 88, scale 1:100 000. https://doi.org/10.4095/292211

*Fallas, K.M., 2013b. Geology, Mahony Lake (southeast), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 90, scale 1:100 000. https://doi.org/10.4095/292282

*Fallas, K.M., 2013c. Geology, Norman Wells (northwest), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 98, scale 1:100 000. https://doi.org/10.4095/292290

*Fallas, K.M., 2013d. Geology, Norman Wells (northeast), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 99, scale 1:100 000. https://doi.org/10.4095/292291

*Fallas, K.M., 2013e. Cambrian features constrain Cordilleran structures in the central Mackenzie Valley region; Canadian Society of Petroleum Geologists, GeoConvention 2013: Integration, 2013 CSPG CSEG CWLS Conference, Calgary, Alberta, May 6–10, 2013, Abstract, 4 p. https://www.geoconvention.com/conference/abstract-archives/2013-abstracts.html

*Fallas, K.M., 2017a. Bedrock geology, Lac des Bois, Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 308, scale 1:250 000. https://doi.org/10.4095/306203

*Fallas, K.M., 2017b. Bedrock geology, Lac Belot, Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 309, scale 1:250 000. https://doi.org/10.4095/306202

*Fallas, K.M., 2017c. Bedrock geology, Aubry Lake, Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 310, scale 1:250 000. https://doi.org/10.4095/306201

*Fallas, K.M., 2017d. Bedrock geology, Lac Maunoir, Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 311, scale 1:250 000. https://doi.org/10.4095/306205

*Fallas, K.M., 2019. A reconnaissance section through the Neoproterozoic Katherine Group of the northern Mackenzie Mountains, Northwest Territories, and implications for mapping its subdivisions; Geological Survey of Canada, Open File 8554, 22 p. https://doi.org/10.4095/314498

*Fallas, K.M. and MacLean, B.C., 2013a. Geology, Mahony Lake (northeast), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 89, scale 1:100 000. https://doi.org/10.4095/292174

*Fallas, K.M. and MacLean, B.C., 2013b. Geology, Fort Norman (southwest), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 93, scale 1:100 000. https://doi.org/10.4095/292285

*Fallas, K.M. and MacNaughton, R.B., 2012. Distribution of Cambrian formations in the eastern Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Current Research 2012-2, 12 p. https://doi.org/10.4095/289498

*Fallas, K.M. and MacNaughton, R.B., 2013. Geology, Norman Wells (southeast), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 100, scale 1:100 000. https://doi.org/10.4095/292292

*Fallas, K.M. and MacNaughton, R.B., 2014a. Geology, Carcajou Canyon (northwest), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 94, scale 1:100 000. https://doi.org/10.4095/292286

*Fallas, K.M. and MacNaughton, R.B., 2014b. Geology, Carcajou Canyon (southeast), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 96, scale 1:100 000. https://doi.org/10.4095/292288

*Fallas, K.M. and MacNaughton, R.B., 2014c. Geology, Carcajou Canyon (southwest), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 97, scale 1:100 000. https://doi.org/10.4095/292289

*Fallas, K.M. and MacNaughton, R.B., 2020a. Bedrock geology, southwest Sans Sault Rapids, Northwest Territories, NTS 106H southwest; Geological Survey of Canada, Canadian Geoscience Map 420, scale 1:100 000. https://doi.org/10.4095/314794

*Fallas, K.M. and MacNaughton, R.B., 2020b. Bedrock geology, southeast Sans Sault Rapids, Northwest Territories, NTS 106H southeast; Geological Survey of Canada, Canadian Geoscience Map 421, scale 1:100 000. https://doi.org/10.4095/314787

*Fallas, K.M., MacLean, B.C., MacNaughton, R.B., and Hadlari, T., 2012. New bedrock map compilations for the central Mackenzie Corridor, Northwest Territories; Geological Survey of Canada, Scientific Presentation 11, poster. https://doi.org/10.4095/289633

*Fallas, K.M., MacLean, B.C., and Hadlari, T., 2013a. Geology, Mahony Lake (southwest), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 91, scale 1:100 000. https://doi.org/10.4095/292283

*Fallas, K.M., MacLean, B.C., and Proks, T., 2013b. Geology, Fort Norman (northwest), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 92, scale 1:100 000. https://doi.org/10.4095/292284

*Fallas, K.M., Hadlari, T., and MacLean, B.C., 2013c. Geology, Carcajou Canyon (northeast), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 95, scale 1:100 000. https://doi.org/10.4095/292287

*Fallas, K.M., MacNaughton, R.B., MacLean, B.C., and Hadlari, T., 2013d. Geology, Norman Wells (southwest), Northwest Territories; Geological Survey of Canada, Canadian Geoscience Map 101, scale 1:100 000. https://doi.org/10.4095/292293

*Fallas, K.M., MacNaughton, R.B., and Sommers, M.J., 2015a. Maximizing the value of historical bedrock field observations: an example from northwest Canada; GeoResJ, v. 6, p. 30–43. https://doi.org/10.1016/j.grj.2015.01.004

*Fallas, K.M., MacNaughton, R.B., and Kung, L., 2015b. A bibliography of published sources for measured stratigraphic sections, central and northern mainland Northwest Territories, Canada; Geological Survey of Canada, Open File 7812, 49 p. https://doi.org/10.4095/296398

*Fallas, K.M., MacNaughton, R.B., Turner, E.C., and Sommers, M.J., 2015c. GEM 2 Mackenzie project: Colville Hills bedrock mapping, stratigraphy, and related studies; Geological Survey of Canada, Open File 7963, 19 p. https://doi.org/10.4095/297301

*Fallas, K.M., MacNaughton, R.B., Finley, T.D., and Gouwy, S.A., 2016. Report of activities for the GEM 2 Mackenzie project: northern Mackenzie Mountains bedrock mapping, stratigraphy, and related studies; Geological Survey of Canada, Open File 8132, 15 p. https://doi.org/10.4095/299297

*Fallas, K.M., MacNaughton, R.B., Hannigan, P.K., and MacLean, B.C., in press a. Mackenzie-Peel Platform and Ellesmerian foreland composite tectono-sedimentary element, northwestern Canada; *in* Arctic tectono-sedimentary elements and their hydrocarbon prospectivity, (ed.) S.S. Drachev and T.E. Moore; Geological Society of London, Memoirs, v. 57.

*Fallas, K.M., Dixon, J., Hannigan, P.K., MacLean, B.C., and MacNaughton, R.B., in press b. Cordilleran foreland tectono-sedimentary element, Canadian northern Interior Plains; *in* Arctic tectono-sedimentary elements and their hydrocarbon prospectivity, (ed.) S.S. Drachev and T.E. Moore; Geological Society of London, Memoirs, v. 57.

*Finley, T.D., Fallas, K.M., and MacNaughton, R.B., 2017. Supplementing public geoscience knowledge with archived industry data: an example from northwest Canada; Geological Survey of Canada, Open File 8188, 18 p. https://doi.org/10.4095/299605

Fischer, B.J., 2016. Bedrock geology of part of the Misty Creek paleo-embayment, Mackenzie Mountains (NTS 106B); Northwest Territories Geological Survey, NWT Open File 2016-01, scale 1:100 000.

Fischer, B.J., 2018. Carlin-type gold and clastic-dominated zinc-lead potential of the Misty Creek Embayment region, Mackenzie Mountains, Northwest Territories; Northwest Territories Geological Survey, NWT Open File 2017-02, 90 p.

Fritz, W.H., 1972. Lower Cambrian trilobites from the Sekwi Formation type section, Mackenzie Mountains, northwestern Canada; Geological Survey of Canada, Bulletin 212, 90 p. https://doi.org/10.4095/100784

Fritz, W.H., 1976. Ten stratigraphic sections from the Lower Cambrian Sekwi Formation, Mackenzie Mountains, northwestern Canada; Geological Survey of Canada, Paper 76-22, 42 p. https://doi.org/10.4095/102628

Fritz, W.H., 1978. Fifteen stratigraphic sections from the Lower Cambrian of the Mackenzie Mountains, northwestern Canada; Geological Survey of Canada, Paper 77-33, 19 p. https://doi.org/10.4095/103391

Fritz, W.H., 1979. Eleven stratigraphic sections from the Lower Cambrian of the Mackenzie Mountains, northwestern Canada; Geological Survey of Canada, Paper 78-23, 19 p. https://doi.org/10.4095/105322

Fritz, W.H., 1982. Vampire Formation, a new Upper Precambrian(?)/Lower Cambrian formation, Mackenzie Mountains, Yukon and Northwest Territories; *in* Current research, Part B; Geological Survey of Canada, Paper 82-1B, p. 83–92. https://doi.org/10.4095/119316

Fritz, W.H., Narbonne, G.M., and Gordey, S.P., 1983. Strata and trace fossils near the Precambrian–Cambrian boundary, Mackenzie, Selwyn and Wernecke mountains, Yukon and Northwest Territories; *in* Current research, Part B; Geological Survey of Canada, Paper 83-1B, p. 365–375. https://doi.org/10.4095/109342

Gabrielse, H., 1968. Operation Selwyn, 1967, Yukon Territory, District of Mackenzie, British Columbia; *in* Report of activities, Part A; Geological Survey of Canada, Paper 68-1A, p. 24–27. https://doi.org/10.4095/106253

Gabrielse, H. and Yorath, C.J. (ed.), 1991. Geology of the Cordilleran Orogen in Canada; Geological Survey of Canada, Geology of Canada, no. 4, 844 p. (also Geological Society of America, The geology of North America, v. G-2). https://doi.org/10.4095/134069

Gabrielse, H., Blusson, S.L., and Roddick, J.A., 1973a. Geology of Flat River, Glacier Lake, and Wrigley Lake map-areas, District of Mackenzie and Yukon Territory, Part 1: general geology, structural geology, and economic geology; Geological Survey of Canada, Memoir 366, 153 p. https://doi.org/10.4095/100705

Gabrielse, H., Blusson, S.L., and Roddick, J.A., 1973b. Geology of Flat River, Glacier Lake, and Wrigley Lake map-areas, District of Mackenzie and Yukon Territory, Part 2: measured sections; Geological Survey of Canada, Memoir 366, 268 p. https://doi.org/10.4095/100706

Gabrielse, H., Roddick, J.A., and Blusson, S.L., 1973c. Geology, Wrigley Lake area, District of Mackenzie; Geological Survey of Canada, Map 1315A, scale 1:250 000. https://doi.org/10.4095/107939

*Gal, L.P., MacNaughton, R.B., and Fallas, K.M., 2010. Little Bear River measured section: Upper Cambrian to Middle Devonian stratigraphy, Little Bear River, Northwest Territories, Canada, NTS 096D/07; Northwest Territories Geoscience Office, NWT Open Report 2010-006, 20 p.

Gordey, S.P. and Anderson, R.G., 1993. Evolution of the northern Cordilleran miogeocline, Nahanni map area (105I), Yukon and Northwest Territories; Geological Survey of Canada, Memoir 428, 214 p. https://doi.org/10.4095/183983

Gordey, S.P., Pierce, K.L., Fallas, K., Martel, E., and Roots, C.F., (comp.), 2012. GIS compilation for the geology of Sekwi Mountain, Mount Eduni, and northwest Wrigley Lake areas (NTS 105P, 106A, and 95M NW), Mackenzie Mountains, Northwest Territories; Northwest Territories Geoscience Office, NWT Open Report 2012-002, 14 p.

*Gouwy, S.A., MacNaughton, R.B., and Fallas, K.M., 2017a. New conodont data constraining the age of the ‘Bear Rock assemblage’ in the Colville Hills, Northwest Territories; Geological Survey of Canada, Current Research 2017-3, 11 p. https://doi.org/10.4095/306171

*Gouwy, S.A., Tingley, L.M., Deblonde, C., and Chan, W.C., 2017b. Report of activities for the GEM-2 Mackenzie project: Devonian litho- and biostratigraphy in the northern Mackenzie Mountains, NWT; Geological Survey of Canada, Open File 8332, 11 p. https://doi.org/10.4095/306213

*Greenman, J.W. and Rainbird, R.H., 2018. Stratigraphy of the upper Nelson Head, Aok, Grassy Bay, and Boot Inlet formations in the Brock Inlier, Northwest Territories (NTS 97-A, D); Geological Survey of Canada, Open File 8394, 63 p. https://doi.org/10.4095/308268

*Hadlari, T., Tylosky, S.A., Lemieux, Y., Zantvoort, W.G., and Catuneanu, O., 2009. Slope and submarine fan turbidite facies of the Upper Devonian Imperial Formation, Northern Mackenzie Mountains, NWT; Bulletin of Canadian Petroleum Geology, v. 57, no. 2, p. 192–208. https://doi.org/10.2113/gscpgbull.57.2.192

*Hadlari, T., Davis, W.J., Dewing, K., Heaman, L.M., Lemieux, Y., Ootes, L., Pratt, B.R., and Pyle, L.J., 2012. Two detrital zircon signatures for the Cambrian passive margin of northern Laurentia highlighted by new U-Pb results from northern Canada; Geological Society of America, Bulletin, v. 124, no. 7–8, p. 1155–1168. https://doi.org/10.1130/B30530.1

*Hadlari, T., MacLean, B.C., Galloway, J.M., Sweet, A.R., White, J.M., Thomson, D., Gabites, J., and Schröder-Adams, C.J., 2014. The flexural margin, the foredeep, and the orogenic margin of a northern Cordilleran foreland basin: Cretaceous tectonostratigraphy and detrital zircon provenance, northwestern Canada; Marine and Petroleum Geology, v. 57, p. 173–186. https://doi.org/10.1016/j.marpetgeo.2014.05.019

*Hadlari, T., Swindles, G.T., Galloway, J.M., Bell, K.M., Sulphur, K.C., Heaman, L.M., Beranek, L.P., Fallas, K.M., 2015. 1.8 billion years of detrital zircon recycling calibrates a refractory part of Earth’s sedimentary cycle. PLoS ONE v. 10 (12), p. 1–10: e0144727. https://doi.org/10.1371/journal.pone.0144727

Hamblin, A.P., 1990. Petroleum potential of the Cambrian Mount Clark Formation (Tedji Lake Play), Colville Hills area, Northwest Territories; Geological Survey of Canada, Open File 2309, 36 p. https://doi.org/10.4095/131309

*Hamel, C.M. and MacNaughton, R.B., 2013. Petrographic assessment and stratigraphy of Neoproterozoic and Cambrian sandstones from measured sections, eastern Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Open File 7472, 125 p. https://doi.org/10.4095/292914

Handfield, R.C., 1968. Sekwi Formation, a new Lower Cambrian formation in the southern Mackenzie Mountains, District of Mackenzie; Geological Survey of Canada, Paper 68-47, 23 p. https://doi.org/10.4095/101427

*Hannigan, P., 2012. An assessment of conventional petroleum resource of the Mackenzie Corridor, northern mainland, Canada: a case study; Bulletin of Canadian Petroleum Geology, v. 60, no. 3, p. 97–111. https://doi.org/10.2113/gscpgbull.60.3.97

*Hannigan, P.K., 2013. A GIS petroleum prospectivity map of the northern mainland of Canada (Mackenzie Corridor); Geological Survey of Canada, Open File 7110, 11 p. https://doi.org/10.4095/292148.

*Hannigan, P.K., Morrow, D.W., and MacLean, B.C., 2011. Petroleum resource potential of the northern mainland of Canada (Mackenzie Corridor); Geological Survey of Canada, Open File 6757, 271 p. https://doi.org/10.4095/289095

Harlan, S.S., Heaman, L., LeCheminant, A.N., and Premo, W.R., 2003. Gunbarrel mafic magmatic event: a key 780 Ma time marker for Rodinia plate reconstructions; Geology, v. 31, no. 12, p. 1053–1056. https://doi.org/10.1130/G19944.1

*Herbers, D., MacNaughton, R.B., Gingras, M.K., and Timmer, E., 2016. Sedimentology and ichnology of an Early–Middle Cambrian barred storm-influenced shoreface succession, Colville Hills, Northwest Territories; Bulletin of Canadian Petroleum Geology, v. 64, p. 538–554. https://doi.org/10.2113/gscpgbull.64.4.538

*Hu, K. and Hannigan, P., 2009. Reservoir petrophysical property evaluation from well logs for the Mackenzie Corridor, northern mainland, Canada; Geological Survey of Canada, Open File 5897, 47 p. https://doi.org/10.4095/248032

Hume, G.S., 1954. Lower Mackenzie River area, Northwest Territories and Yukon; Geological Survey of Canada, Memoir 273, 118 p. https://doi.org/10.4095/101498

Hume, G.S. and Link, T.A., 1945. Canol geological investigations in the Mackenzie River area, Northwest Territories and Yukon; Geological Survey of Canada, Paper 45-16, 87 p. https://doi.org/10.4095/101370

Hyndman, R.D., Flück, P., Mazzotti, S., Lewis, T.J., Ristau, J., and Leonard, L., 2005. Current tectonics of the northern Canadian Cordillera; Canadian Journal of Earth Sciences, v. 42, p. 1117–1136. https://doi.org/10.1139/e05-023

*Issler, D.R., Chen, Z., Hu, K., and Lane, L.S., 2009. Geo-mapping for Energy and Minerals (GEM): studies of the Beaufort–Mackenzie Basin thermal regime; 37th Annual Yellowknife Geoscience Forum , Yellowknife, Northwest Territories, November 17–19, 2009; Northwest Territories Geoscience Office, Abstracts Volume, p. 27–28.

*Issler, D.R., Hu, K., Lane, L.S., Dietrich, J.R., 2011. GIS compilations of depth to overpressure, permafrost distribution, geothermal gradient, and regional geology, Beaufort-Mackenzie Basin, northern Canada; Geological Survey of Canada, Open File 5689, 1 CD-ROM, scale 1:1 000 000. https://doi.org/10.4095/289113

*Issler, D.R., Obermajer, M., Reyes, J., and Li, M., 2012. Integrated analysis of vitrinite reflectance, Rock-Eval 6, gas chromatography, and gas chromatography-mass spectrometry data for the Mallik A-06, Parsons N-10 and Kugaluk N-02 wells, Beaufort-Mackenzie Basin, northern Canada; Geological Survey of Canada, Open File 6978, 78 p. https://doi.org/10.4095/289672

James, N.P., Narbonne, G.M., and Kyser, T.K., 2001. Late Neoproterozoic cap carbonates: Mackenzie Mountains, northwestern Canada: precipitation and global glacial meltdown; Canadian Journal of Earth Sciences, v. 38, p. 1229–1262. https://doi.org/10.1139/e01-046

Jefferson, C.W. and Parrish, R., 1989. Late Proterozoic stratigraphy, U-Pb zircon ages, and rift tectonics, Mackenzie Mountains, northwestern Canada; Canadian Journal of Earth Sciences, v. 26, p. 1784–1801. https://doi.org/10.1139/e89-151

Jefferson, C.W. and Ruelle, J.C.L., 1986. The Late Proterozoic Redstone Copper Belt, Mackenzie Mountains, N.W.T.; *in* Mineral deposits of the northern Cordillera, (ed.) J.A. Morin; Canadian Institute of Mining and Metallurgy, Special Volume 37, p. 154–168.

Jiang, C., Fallas, K.M., and MacNaughton, R.B., 2019. An organic geochemical study of outcrop oil shows in the Colville Hills, Mackenzie Corridor: oil-saturated Quaternary sand and Cretaceous sandstone and oil-stained Devonian dolostone; Geological Survey of Canada, Open File 8569, 22 p. https://doi.org/10.4095/314731

*Kabanov, P., Gouwy, S.A., and Chan, W.C., 2016. Report on field activity for Devonian studies in the Mackenzie Mountains in 2016, GEM 2 Mackenzie project; Geological Survey of Canada, Open File 8131, 18 p. https://doi.org/10.4095/299288

Kindle, E.M. and Bosworth, T.O., 1921. Oil-bearing rocks of lower Mackenzie River Valley, Northwest Territories; Geological Survey of Canada, Summary Report 1920, Part B, p. 37–63. https://doi.org/10.4095/103621

*Kiss, F., 2018. Aeromagnetic survey of the Redstone River, Keele River, and Mountain River areas, Mackenzie Mountains, Northwest Territories, NTS 95-M, 105-P, 106-A, and parts of NTS 95-N, 96-D, 105-I, O, 106-B, C; Geological Survey of Canada, Open File 8456, 22 sheets, scale 1:100 000. https://doi.org/10.4095/308440

Kobayashi, T., 1936. Cambrian and Lower Ordovician trilobites from northwestern Canada; Journal of Paleontology, v. 10, p. 157–167. https://www.jstor.org/stable/1298447

Krause, F.F. and Oldershaw, A.E., 1979. Submarine carbonate breccia beds–a depositional model for two-layer, sediment gravity flows from the Sekwi Formation (Lower Cambrian), Mackenzie Mountains, Northwest Territories, Canada; Canadian Journal of Earth Sciences, v. 16, p. 189–199. https://doi.org/10.1139/e79-017

*Lemieux, Y., Hadlari, T., and Simonetti, A., 2011. Detrital zircon geochronology and provenance of Devono–Mississippian strata in the northern Canadian Cordilleran miogeocline; Canadian Journal of Earth Sciences, v. 48, p. 515–541. https://doi.org/10.1139/E10-056

Leslie, C.D., 2009. Detrital zircon geochronology and rift-related magmatism: central Mackenzie Mountains, Northwest Territories; M.Sc. thesis, University of British Columbia, Vancouver, British Columbia, 224 p. https://doi.org/10.14288/1.0052744

*Long, D.G.F., Rainbird, R.H., Turner, E.C., and MacNaughton, R.B., 2008. Early Neoproterozoic strata (Sequence B) of mainland Northern Canada and Victoria and Banks Islands: a contribution to the Geological Atlas of the Northern Canadian Mainland Sedimentary Basin; Geological Survey of Canada, Open File 5700, 27 p. https://doi.org/10.4095/226070

Long, D.G.F. and Turner, E.C., 2012. Formal definition of the Neoproterozoic Mackenzie Mountains Supergroup (Northwest Territories), and formal stratigraphic nomenclature for terrigenous clastic units of the Katherine Group; Geological Survey of Canada, Open File 7113 (revised), 118 p. https://doi.org/10.4095/293417

Macdonald, F.A., Strauss, J.V., Sperling, E.A., Halverson, G.P., Narbonne, G.M., Johnston, D.T., Kunzmann, M., Schrag, D.P., and Higgins, J.A., 2013. The stratigraphic relationship between the Shuram carbon isotope excursion, the oxygenation of Neoproterozoic oceans, and the first appearance of the Ediacara biota and bilaterian trace fossils in northwestern Canada; Chemical Geology, v. 362, p. 250–272. https://doi.org/10.1016/j.chemgeo.2013.05.032

*MacLean, B.C., 2011a. Updates to the Cambrian Basin of the northern Northwest Territories; Geological Survey of Canada, Current Research 2011-10, 12 p. https://doi.org/10.4095/288642

*MacLean, B.C., 2011b. Tectonic and stratigraphic evolution of the Cambrian basin of northern Northwest Territories; Bulletin of Canadian Petroleum Geology, v. 59, p. 172–194. https://doi.org/10.2113/gscpgbull.59.2.172

*MacLean, B.C., 2012. GIS-enabled structure maps of subsurface Phanerozoic strata, northwestern Northwest Territories; Geological Survey of Canada, Open File 7172, https://doi.org/10.4095/292152

*MacLean, B.C., Fallas, K.M., and Hadlari, T., 2014. The multi-phase Keele Arch, central Mackenzie Corridor, Northwest Territories; Bulletin of Canadian Petroleum Geology, v. 62, no. 2, p. 68–104. https://doi.org/10.2113/gscpgbull.62.2.68

*MacLean, B.C., Fallas, K.M., and Hadlari, T., 2015. The evolution of Keele Arch, a multiphase feature of the northern mainland, Northwest Territories; Geological Survey of Canada, Bulletin 606, 39 p. https://doi.org/10.4095/293877

MacNaughton, R.B., 2011. Lowest Paleozoic siliciclastic succession; Chapter 3.4.1. *in* Geology of the Central Mackenzie Mountains of the northern Canadian Cordillera, Sekwi Mountain (105P), Mount Eduni (106A), and northwestern Wrigley Lake (95M) map-areas, Northwest Territories, (ed.) E. Martel, E.C. Turner, and B.J. Fischer; Northwest Territories Geoscience Office, NWT Special Volume 1, p. 131–142.

*MacNaughton, R.B. and Fallas, K.M., 2014. Nainlin Formation, a new Middle Cambrian map unit from the Mackenzie Mountains, Northwest Territories; Bulletin of Canadian Petroleum Geology, v. 62, p. 37–67. https://doi.org/10.2113/gscpgbull.62.2.37

*MacNaughton, R.B. and Fallas, K.M., 2018. New fossil constraints on the Ediacaran–Cambrian boundary in the northwestern Mackenzie Mountains, NWT and Yukon; *in* Proceedings of the Canadian Paleontology Conference, (ed.) M. Cuggy, Volume no. 15 (not paginated).

*MacNaughton, R.B. and Fallas, K.M., 2019. The eastern extent of the Risky Formation (Ediacaran), Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Current Research 2019-2, 15 p. https://doi.org/10.4095/314518

*MacNaughton, R.B., Pratt, B.R., and Fallas, K.M., 2013. Observations on Cambrian stratigraphy in the eastern Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Current Research 2013-10, 7 p. https://doi.org/10.4095/292423

*MacNaughton, R.B., Fallas, K.M., Pratt, B.R., MacLean, B.C., and Turner, E.C., 2016. Tectonic evolution of the Mackenzie Arch, a major control on Cambrian depositional patterns in the westernmost Northwest Territories, Canada; Annual Meeting of the Geological Society of America, Phoenix, Arizona, September 22–25, 2016, Abstracts with Programs, v. 48, no. 7. https://doi.org/10.1130/abs/2016AM-281200.

*MacNaughton, R.B., Fallas, K.M., Fischer, B.J., Pope, M.C., Chan, W.C., Finley, T.D., and Martell, J., 2017. Report of activities for GEM 2 Mackenzie project: Bonnet Plume Lake map area (NTS 106B) bedrock mapping, stratigraphy, and related studies, Northwest Territories and Yukon; Geological Survey of Canada, Open File 8333, 14 p. https://doi.org/10.4095/306133

*MacNaughton, R.B., Fallas, K.M., Martell, J., and Edgeworth, I., 2018. Bedrock mapping, stratigraphy, and related studies, Bonnet Plume Lake (NTS 106-B) and Wrigley Lake (NTS 95-M) map areas, Northwest Territories and Yukon: GEM-2 Mackenzie project, report of activities 2018; Geological Survey of Canada, Open File 8471, 17 p. https://doi.org/10.4095/311294

Macqueen, R.W., 1970. Lower Paleozoic stratigraphy and sedimentology, eastern Mackenzie Mountains, northern Franklin Mountains; *in* Report of activities, Part A; Geological Survey of Canada, Paper 70-1A, p. 225–230. https://doi.org/10.4095/105809

Macqueen, R.W. and Mackenzie, W.S., 1973. Lower Paleozoic and Proterozoic stratigraphy, Mobil Colville Hills E-15 well and environs, Interior Platform, District of Mackenzie; *in* Report of activities, Part B; Geological Survey of Canada 1973, Paper 73-1, p. 183–187. https://doi.org/10.4095/104927

Martel, E., Turner, E.C., and Fischer, B.J. (ed.), 2011. Geology of the central Mackenzie Mountains of the northern Canadian Cordillera, Sekwi Mountain (105P), Mount Eduni (106A), and northwestern Wrigley Lake (95M) map-areas, Northwest Territories; Northwest Territories Geoscience Office, NWT Special Volume 1, 423 p.

McMechan, M.E., Thompson, R.I., Cook, D.G., Gabrielse, H., and Yorath, C.J., 1991. Foreland Belt; Chapter 17 *in* Geology of the Cordilleran Orogen in Canada, (ed.) H. Gabrielse and C.J. Yorath; Geological Survey of Canada, Geology of Canada, no. 4, p. 634–650 (also Geological Society of America, The geology of North America, v. G-2). https://doi.org/10.4095/134117

Meijer-Drees, N.C., 1993. The Devonian succession in the subsurface of the Great Slave and Great Bear plains, Northwest Territories; Geological Survey of Canada, Bulletin 393, 231 p. https://doi.org/10.4095/183905

Morrow, D.W., 1991. The Silurian–Devonian sequence in the northern part of the Mackenzie shelf, Northwest Territories; Geological Survey of Canada, Bulletin 413, 121 p. https://doi.org/10.4095/132170

Morrow, D.W., 1999. Lower Paleozoic stratigraphy of northern Yukon Territory and northwestern District of Mackenzie; Geological Survey of Canada, Bulletin 538, 202 p. https://doi.org/10.4095/210998

*Morrow, D.W., 2012. Devonian of the northern Canadian Mainland Sedimentary Basin (a contribution to the Geological Atlas of the northern Canadian Mainland Sedimentary Basin); Geological Survey of Canada, Open File 6997, 88 p. https://doi.org/10.4095/290970

*Morrow, D.W., 2018. Devonian of the northern Canadian Mainland Sedimentary Basin: a Review; Bulletin of Canadian Petroleum Geology, v. 66, p. 623–694.

Narbonne, G.M. and Aitken, J.D., 1990. Ediacaran fossils from the Sekwi Brook area, Mackenzie Mountains, northwest Canada; Palaeontology, v. 33, p. 945–980. https://www.palass.org/publications/palaeontology-journal/archive/33/4/article_pp945-980

Narbonne, G.M. and Aitken, J.D., 1995. Neoproterozoic of the Mackenzie Mountains, northwestern Canada; Precambrian Research, v. 73, p. 101–121. https://doi.org/10.1016/0301-9268(94)00073-Z

Natural Resources Canada, 2015. Canadian digital elevation model; Natural Resources Canada, URL <https://open.canada.ca/data/en/dataset/7f245e4d-76c2-4caa-951a-45d1d2051333> [accessed March 15, 2015]

Norford, B.S. and Macqueen, R.W., 1975. Lower Paleozoic Franklin Mountain and Mount Kindle formations, District of Mackenzie: their type sections and regional development; Geological Survey of Canada, Paper 74-34, 37 p. https://doi.org/10.4095/102525

Norris, D.K., 1985. Eastern Cordilleran foldbelt of northern Canada: its structural geometry and hydrocarbon potential; American Association of Petroleum Geologists, Bulletin, v. 69, p. 788–808.

Ootes, L., Fischer, B.J., Rasmussen, K.L., Borkovic, B., Long, D.G.F., and Gordey, S.P., 2011. Mineral deposits and prospects; Chapter 7 *in* Geology of the central Mackenzie Mountains of the northern Canadian Cordillera, Sekwi Mountain (105P), Mount Eduni (106A), and northwestern Wrigley Lake (95M) map-areas, Northwest Territories, (ed.) E. Martel, E.C. Turner, and B.J. Fischer; Northwest Territories Geoscience Office, NWT Special Volume 1, p. 255–268.

*Pope, M.C. and Leslie, S.A., 2013. New data from Late Ordovician–Early Silurian Mount Kindle Formation measured sections, Franklin Mountains and eastern Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Current Research 2013-8, 11 p. https://doi.org/10.4095/292389

*Powell, J.W., 2017. Burial and exhumation history of the Mackenzie Mountains and Plain, NWT, through integration of low-temperature thermochronometers; Ph.D. thesis, University of Ottawa, Ottawa, Ontario, 354 p. https://ruor.uottawa.ca/bitstream/10393/35994/1/Powell_Jeremy_2017_thesis.pdf

*Powell, J. and Schneider, D.A., 2013. Preliminary results of detrital muscovite $^{40}Ar/^{39}Ar$ geochronology from the eastern Mackenzie Mountains and Mackenzie Plain, Northwest Territories; Geological Survey of Canada, Current Research 2013-18, 16 p. https://doi.org/10.4095/292712

*Powell, J., Schneider, D., Stockli, D., and Fallas, K., 2016. Zircon (U-Th)/He thermochronology of Neoproterozoic strata from the Mackenzie Mountains, Canada: implications for the Phanerozoic exhumation and deformation history of the northern Canadian Cordillera; Tectonics, v. 35, p. 663–689. https://doi.org/10.1002/2015TC003989

*Proks, T., 2012. A geological and structural analysis of the MacKay Range, Mackenzie Plain area, Northwest Territories; B.Sc. thesis, Brock University, St. Catharines, Ontario, 21 p.

Pugh, D.C., 1983. Pre-Mesozoic geology in the subsurface of Peel River map area, Yukon Territory and District of Mackenzie; Geological Survey of Canada, Memoir 401, 61 p. https://doi.org/10.4095/119498

*Pyle, L.J. and Gal, L.P., 2011. Petroleum potential data from Cambrian sections in the northern Mackenzie Mountains, NTS 96D and 106H, Northwest Territories; Northwest Territories Geoscience Office, NWT Open Report 2011-008, 59 p.

*Pyle, L.J. and Gal, L.P., 2012a. Measured sections and petroleum potential data (conventional and unconventional) of Horn River Group outcrops, NTS 95M, 95N, 96C, 96D, 96E, 106H, and 106I, Northwest Territories–Part II; Northwest Territories Geoscience Office, NWT Open Report 2012-008, 114 p.

*Pyle, L.J. and Gal, L.P., 2012b. Petroleum potential data (conventional and unconventional) for Horn River Group from 26 exploration wells – NTS 95N, 96C, 96D, 96E, 96F and 106H, Northwest Territories; Northwest Territories Geoscience Office, NWT Open Report 2012-009, 41 p.

Pyle, L.J. and Jones, A.L. (ed.), 2009. Regional geoscience studies and petroleum potential, Peel Plateau and Plain, Northwest Territories and Yukon: project volume; Northwest Territories Geoscience Office and Yukon Geological Survey, NWT Open File 2009-02 and YGS Open File 2009-25, 549 p.

*Pyle, L.J., Gal, L.P., and Lemiski, R.T., 2011. Measured sections and petroleum potential data (conventional and unconventional) of Horn River Group Outcrops - Part 1, NTS 96D, 96E, and 106H, Northwest Territories; Northwest Territories Geoscience Office, NWT Open File 2011-09, 116 p.

*Rainbird, R.H., Ielpi, A., Turner, E.C., and Jackson, V.A., 2015a. Reconnaissance geological mapping and thematic studies of northern Brock Inlier, Northwest Territories; Geological Survey of Canada, Open File 7695, 10 p. https://doi.org/10.4095/295697

*Rainbird, R.H., Craven, J.A., Turner, E.C., Jackson, V.A., Fischer, B.J., Bouchard, M., Greenman, J.W., and Gibson, T., 2015b. Reconnaissance geological mapping, stratigraphy and magnetotelluric survey of northern Brock Inlier, Northwest Territories; Geological Survey of Canada, Open File 7955, 16 p. https://doi.org/10.4095/297296

*Rainbird, R.H., Rayner, N.M., Hadlari, T., Heaman, L.M., Ielpi, A., Turner, E.C., and MacNaughton, R.B., 2017. Zircon provenance data record the lateral extent of pancontinental, early Neoproterozoic rivers and erosional unroofing history of the Grenville orogeny; Geological Society of America Bulletin, v. 129, no. 11/12, p. 1408–1423. https://doi.org/10.1130/B31695.1

*Raska, N., 2017. 3D geologic subsurface modeling within the Mackenzie Plain, Northwest Territories, Canada; M.Sc. thesis, Lund University, Lund, Sweden, 100 p. https://lup.lub.lu.se/student-papers/search/publication/8902243

Sandeman, H., Ootes, L., Cousens, B., and Kilian, T., 2014. Petrogenesis of Gunbarrel magmatic rocks: homogeneous continental tholeiites associated with extension and rifting of Neoproterozoic Laurentia; Precambrian Research, v. 252, p. 166–179. https://doi.org/10.1016/j.precamres.2014.07.007

*Serié, C., Bergquist, C.L., and Pyle, L.J., 2013. Seventeen measured sections of Cambrian Mount Clark and Mount Cap formations, northern Mackenzie Mountains and Franklin Mountains, Northwest Territories; Geological Survey of Canada, Open File 6148 (revised), 81 p. https://doi.org/10.4095/292553

*Sommers, M.J., 2018. Subsurface analysis and correlation of Cambrian formations beneath the Colville Hills, northern mainland, Northwest Territories; M.Sc. thesis, University of Alberta, Edmonton, Alberta, 151 p. https://doi.org/10.7939/R3RV0DG0J

Tassonyi, E.J., 1969. Subsurface geology, lower Mackenzie River and Anderson River area, District of Mackenzie; Geological Survey of Canada, Paper 68-25, 207 p. https://doi.org/10.4095/103335

*Thomson, D., Schröder-Adams, C.J., Hadlari, T., Dix, G., and Davis, W.J., 2011. Albian to Turonian stratigraphy and palaeoenvironmental history of the northern Western Interior Sea in the Peel Plateau region, Northwest Territories, Canada; Palaeogeography, Palaeoclimatology, Palaeoecology, v. 302, p. 270–300. https://doi.org/10.1016/j.palaeo.2011.01.017

*Turner, E.C., 2011. A lithostratigraphic transect through the Cambro-Ordovician Franklin Mountain Formation in NTS 96D (Carcajou Canyon) and 96E (Norman Wells), Northwest Territories; Geological Survey of Canada, Open File 6994, 28 p. https://doi.org/10.4095/289612

*Turner, E.C. and Long, D.G.F., 2012. Formal definition of the Neoproterozoic Mackenzie Mountains Supergroup (Northwest Territories), and formal stratigraphic nomenclature for its carbonate and evaporate formations; Geological Survey of Canada, Open File 7112, 57 p. https://doi.org/10.4095/292167

*Turner, E.C., Roots, C.F., MacNaughton, R.B., Long, D.G.F., Fischer, B.J., Gordey, S.P., Martel, E., and Pope, M.C., 2011. Stratigraphy; Chapter 3 *in* Geology of the central Mackenzie Mountains of the northern Canadian Cordillera, Sekwi Mountain (105P), Mount Eduni (106A), and northwestern Wrigley Lake (95M) map-areas, Northwest Territories, (ed.) E. Martel, E.C. Turner, and B.J. Fischer; Northwest Territories Geoscience Office, NWT Special Volume 1, p. 31–192.

Turner, E.C., MacNaughton, R.B., and Fallas, K., 2017. Litho- and chemostratigraphic transect of the Cambro-Ordovician Franklin Mountain Formation across the Interior plains, NWT; Geological Association of Canada–Mineralogical Association of Canada Joint Annual Meeting, Kingston, Ontario, May 14–18, Abstract v. 40, p. 389.

Williams, M.Y., 1922. Exploration east of Mackenzie River between Simpson and Wrigley, Northwest Territories; Geological Survey of Canada, Summary Report 1921, part B, p. 56–66. https://doi.org/10.4095/103141

Williams, M.Y., 1923. Reconnaissance across northeastern British Columbia and the geology of the northern extension of Franklin Mountains, Northwest Territories; Geological Survey of Canada, Summary Report 1922, part B, p. 65–87. https://doi.org/10.4095/103143

Yeo, G.M., 1978. Iron-formation in the Rapitan Group, Mackenzie Mountains, Yukon and Northwest Territories; *in* Mineral Industry Report 1975; Department of Indian and Northern Affairs, Canada, p. 170–175.

Yorath, C.J. and Cook, D.G., 1981. Cretaceous and Tertiary stratigraphy and paleogeography, northern Interior Plains, District of Mackenzie; Geological Survey of Canada, Memoir 398, 76 p. https://doi.org/10.4095/109299

Young, G.M., Jefferson, C.W., Delaney, G.D., and Yeo, G.M., 1979. Middle and late Proterozoic evolution of the northern Canadian Cordillera and Shield; Geology, v. 7, p. 125–128.https://doi.org/10.1130/0091-7613(1979)7%3c125:MALPEO%3e2.0.CO%3b2

Appendix A

Internal Geological Survey of Canada paleontological reports generated for the Mackenzie region during the GEM program. These reports are available by request from the Geological Survey of Canada, Calgary office, and represent a significant investment of time and provide key data underpinning bedrock-geology maps and stratigraphic reports.

Asselin, E., 2009. Palynological report on 15 samples from the Katherine Group and the Mount Cap Formation of the Peel Sequence, NW Territories and Yukon (NTS 96C/08, D/07, 11, 13, 14, 15, E/04 and 106H/01), as requested by L. Pyle (GSC-Pacific); Geological Survey of Canada, Paleontological Report 01-EA-2009, 23 p.

Boyce, K.J., 2010. Palynological report on 11 samples of probable Paleozoic, Cretaceous and undeterminable ages from NTS 096-E-04, 096-E-08 and 106-H-05, Northwest Territories, as requested by T. Hadlari, GSC-Calgary; Geological Survey of Canada, Paleontological Report 01-KJB-2010, 13 p.

Galloway, J.M., 2017. Palynological report on samples submitted by Robert MacNaughton and Karen Fallas, Geological Survey of Canada, Calgary, in support of the GEM Mackenzie project (various NTS map sheets); Geological Survey of Canada, Paleontological Report JMG-2017-04, 10 p.

Gouwy, S.A., 2016. Report on conodonts and tentaculites from 12 Devonian samples from the Arnica, Landry, Bear Rock and Hare Indian formations, Colville Hills, NWT, NTS 96E, 96K, 96L, 96M, 96N and 97B collected and submitted by Karen Fallas and Robert MacNaughton (GEM-2 Shield to Selwyn) Con. No. 1807; Geological Survey of Canada, Paleontological Report 2-SAG-2016, 13 p.

Gouwy, S.A., 2017. Report on 20 conodont samples from the Bear Rock, Landry, Hume and Canol formations from Powell Creek, Mackenzie Mountains (NWT), NTS 106H, collected by Pavel Kabanov and Sofie Gouwy and submitted by Pavel Kabanov (Con No. 1810-1 to 1810-8 and 1810-17) and under R.B. MacNaughton's Northern Mackenzie Mountains bedrock mapping and stratigraphic studies project (GEM-2 Shield-to-Selwyn) (Con No. 1813-1 to 1813-11); Geological Survey of Canada, Paleontological Report 3-SAG-2017, 17 p.

Gouwy, S.A., 2018. Report on nine samples from the Hume, Franklin Mountain, Mount Kindle and unknown formations, northern Mackenzie Mountains, NWT, NTS 106B collected by Karen Fallas and Robert MacNaughton and submitted under R.B. MacNaughton's Northern Mackenzie Mountains Bedrock mapping and stratigraphic studies project (GEM-2 Shield-to-Selwyn) Con. N.o 1817-1 to 1817-9; Geological Survey of Canada, Paleontological Report 1-SAG-2018, 7 p.

Gouwy, S.A., 2018. Report on seven samples from the Hume, Hare Indian and Canol formations from the Arctic Red River East and Flyaway Creek sections, Northern Mackenzie Mountains, NWT, NTS 106G, NTS 106F collected by Viktor Terlaky (NTGS) and submitted under R.B. MacNaughton's Northern Mackenzie Mountains Bedrock Mapping and Stratigraphic Studies project (GEM-2 Shield-to-Selwyn) Con. No. 1818-1 to 1818-7; Geological Survey of Canada, Paleontological Report 2-SAG-2018, 11 p.

Gouwy, S.A., 2018. Report on thirteen conodont samples from the Hume and Hare Indian formations from Powell Creek Tributary, northern Mackenzie Mountains (NWT), NTS 106H, collected by Pavel Kabanov and Sofie Gouwy and submitted by Pavel Kabanov (Con. No. 1810-19 to 1810-29) and under R.B. MacNaughton's northern Mackenzie Mountains bedrock mapping and stratigraphic studies project (GEM-2 Shield-to-Selwyn) (Con. No. 1813-12 and 1813-13); Geological Survey of Canada, Paleontological Report 3-SAG-2018, 14 p.

MacNaughton, R.B., 2013. Report on two collections of Cambrian ichnofossils from the Mount Eduni (NTS 106 A) and Carcajou Canyon (NTS 96 D) map areas, Northwest Territories, submitted by Karen Fallas (GSC-Calgary) under the Mackenzie Delta and Corridor Project (Project EGM003–GEM Program); Geological Survey of Canada, Paleontological Report 01-RBM-2013, 4 p.

McCracken, A.D., 2011. Report on 18 conodont samples from the Cambrian–Ordovician Franklin Mountain Formation, the Silurian Mount Kindle Formation (barren), the Devonian Hume, Imperial, Landry and Ramparts Formations, and the Cretaceous Slater River Formation (barren), Norman Wells area, NWT, submitted by Karen Fallas (Geological Survey of Canada-Calgary) in 2010; Con. No. 1757, NTS 096C/12, C/13, 096D/05, D/11, D/12, D/13, 096E/04, E/05, E/07, E/08, E/09, E/13, E/14; Geological Survey of Canada, Paleontological Report 3-ADM-2011, 13 p.

McCracken, A.D., 2011. Report on 20 conodont samples from the Cambrian–Ordovician Franklin Mountain Formation, the Ordovician–Silurian Mount Kindle, and the Devonian Bear Rock, Hume and Ramparts Formations, and the Bluefish Member (Hare Indian Fm.), Franklin and Mackenzie Mountains areas, NWT, submitted by Karen Fallas (Geological Survey of Canada-Calgary) in 2009. Con. No. 1747, NTS 096C/04, 096D/09, D/10, 096E/01, E/04, E/08, E/09, E/10, E/12, E/13, 096F/12, F/13, F/15, 106H/16; Geological Survey of Canada, Paleontological Report 4-ADM-2011, 15 p.

McCracken, A.D., 2012. Report on one Upper Devonian conodont sample from the Canol Formation, Dodo Canyon, NWT collected by Adrienne Jones (NTGO) and submitted under R.B. MacNaughton's Mackenzie Delta and Corridor: Mapping for Energy (MADACOR) Project in 2011; NTS 096E/03; Con. No. 1767-1; Geological Survey of Canada, Paleontological Report 1-ADM-2012, 8 p.

McCracken, A.D., 2013. Report on three Devonian conodont samples from the Bear Rock Formation and Tsetso Formation, Mackenzie Mountains, NWT collected by Karen Fallas (GSC-Calgary) and submitted in 2012 under R.B. MacNaughton's Mackenzie Delta and Corridor: Mapping for Energy (MADACOR) Project in 2012; NTS 096D/02, 96D/03, 96D/10; Con. No. 1779; Geological Survey of Canada, Paleontological Report 1-ADM-2013, 4 p.

McCracken, A.D., 2013. Report on four Devonian conodont samples from the Canol, Nahanni and Hare Indian formations, District of Mackenzie, NWT collected by Leanne Pyle and Ryan Thomas Lemiski for Adrienne Jones (NTGO) and submitted under R.B. MacNaughton's Mackenzie Delta and Corridor: Mapping for Energy (MADACOR) Project in 2010, NTS 96D/10, 95K/14, Con. No. 1759; Geological Survey of Canada, Paleontological Report 2-ADM-2013, 7 p.

McCracken, A.D., 2013. Report on one Devonian conodont sample from the Hare Indian Formation, District of Mackenzie, NWT submitted by Kathryn Fiess (NTGO) under R.B. MacNaughton's Mackenzie Delta and Corridor: Mapping for Energy (MADACOR) Project in 2012, NTS 96E/01, Con. No. 1782; Geological Survey of Canada, Paleontological Report 4-ADM-2013, 3 p.

McCracken, A.D., 2013. Report on 37 Early Ordovician through Late Devonian conodont samples from the Cloudy, Hailstone, Grizzly Bear, Arnica, Tsetso, Marmot, Duo Lake, Nahanni, Mount Kindle, Canol, and unknown formations, District of Mackenzie, NWT collected by Beth Fischer (NTGO) and submitted under R.B. MacNaughton's Mackenzie Delta and Corridor: Mapping for Energy (MADACOR) Project in 2012, NTS 105I/06, 105O/16, 106B/01, 106B/05, 106B/06, 106B/07, 106B/10, Con. No. 1780; Geological Survey of Canada, Paleontological Report 5-ADM-2013, 25 p.

McCracken, A.D., 2016. Report on thirty-two Ordovician and Silurian conodont samples from the Franklin Mountain Formation and Mount Kindle Formation, Colville Hills, Northwest Territories, collected in 2015 by Robert MacNaughton, Karen Fallas (GSC-Calgary) and Elizabeth Turner (Laurentian University) as part of GEM-2 Shield to Selwyn, NTS 096K/01, 096K/02, 096K/03, 096K/08, 096K/12, 096N/06, 096N/15, Con. No. 1807-13 to 1807-44 (LSA 16-3-006); Geological Survey of Canada, Paleontological Report 5-ADM-2016, 15 p.

McNeil, D.H., 2010. Micropaleontology report on 6 outcrop samples from Devonian strata of the Franklin and Mackenzie Mountains, Northwest Territories (NTS 96D, E); Geological Survey of Canada, Paleontology Report DHM-2010-03, 4 p.

McNeil, D.H., 2013. Micropaleontology report on two outcrop samples from the Franklin Mountain and Saline River formations in the Mackenzie Mountains, Northwest Territories (NTS 96-D-06); Geological Survey of Canada, Paleontology Report DHM-2013-2, 3 p.

Morgan, C.A., 2019. Report on a re-examination of Cambrian trilobite collections from the Mobil Colville E-15 well, NWT (NTS 96M); request for re-examination by R.B. MacNaughton (GEM-II Program, Mackenzie project); Geological Survey of Canada, Paleontological Report 1-CAM-2019, 9 p.

Norford, B.S., 2018; Report on twelve samples collected by Drs. Karen Fallas and Robert MacNaughton from the Bonnet Plume map-area, Northwest Territories (NTS 106B); Geological Survey of Canada, Paleontological Report O-1 BSN 2018, 4 p.

Nowlan, G.S., 2010. Report on four samples of Ordovician and Silurian strata from Little Bear River, Mackenzie Plain, Northwest Territories; collected by Leonard Gal (NWT Geoscience) and submitted for microfossil analysis by Thomas Hadlari (Geological Survey of Canada-Calgary); NTS 096D/07; Con. No. 1749; Geological Survey of Canada, Paleontological Report 006-GSN-2010, 6 p.

Nowlan, G.S., 2012. Report on five samples from the Franklin Mountain and Mount Kindle formations, Franklin and Mackenzie Mountains, Northwest Territories (Ordovician and Silurian) submitted for conodont analysis by Karen Fallas (Geological Survey of Canada); NTS 096D/03, 096D/04, 096D/06, 096F/06, 096F/14; Con. No. 1767; Geological Survey of Canada, Paleontological Report 001-GSN-2012, 4 p.

Poulton, T.P., 2012. Report on 2 collections of Middle Albian (Early Cretaceous) ammonites, collected in the Sans Sault Member, Arctic Red Formation along Imperial River in Norman Wells map area, NWT, by Thomas Hadlari in 2011 (NTS 96E); Geological Survey of Canada, Paleontological Report K1-2012-TPP, 4 p.

Sweet, A.R., 2010. Applied research report on 14 outcrop samples from the Bracket Basin (NTS map sheets 096D/09, 096C/16, 096E/04, 096C/05 and 106H/05); Geological Survey of Canada, Paleontological Report ARS-2010-01, 12 p.

Sweet, A.R., 2010. Applied research report on 3 Cretaceous samples from the Brackett Basin, Northwest Territories (NTS 96-D-09); report compiled for Karen Fallas (Geological Survey of Canada, Calgary); Geological Survey of Canada, Paleontological Report ARS-2010-02, 4 p.

Sweet, A.R., 2011. Applied research report on 2 outcrop samples from Mackenzie Corridor, NWT (NTS Map Sheets 096C/13 and 096E/09; NAD 83); Geological Survey of Canada, Paleontological Report ARS-2011-06, 4 p.

Sweet, A.R., 2011. Applied research report on 7 outcrop samples from the Northwest Territories, (NTS Map Sheets 096C/07, 096C/12, 096C/13, 096D/06, 096E/02, 096E/04, 096E/06, 096E/09, 096F/01, 096F/12); Geological Survey of Canada, Paleontological Report ARS-2011-11, 10 p.

Utting, J., 2009. Palynological investigation of 11 outcrop samples from the Devonian and Cretaceous of the Mackenzie Corridor, N.W.T. submitted by K. Fallas, Geological Survey of Canada (Calgary) (NTS 96D and 96E); Geological Survey of Canada, Paleontological Report JU-2009-07, 6 p.

Utting, J., 2011. Palynological investigation of 2 outcrop samples from Paleozoic rocks of Northwest Territories, NTS 96E; Geological Survey of Canada, Paleontological Report JU-2011-01, 3 p.

Utting, J., 2011. Palynological investigation of 1 outcrop sample from the Devonian, Mackenzie Mountains NWT, (NTS 96C4); Geological Survey of Canada, Paleontological Report JU-2011-02, 1 p.

White, J.M., 2009. Palynological report on 10 samples of probable Devonian and Cretaceous age, from NTS 96-C-13, 96-C-16, 96-F-03, 96-F-06, 96-E-04 and 96-E-08, Northwest Territories, as requested by J. Davison, Univ. of Calgary; Geological Survey of Canada, Paleontological Report 02-JMW-2009, 7 p.

White, J.M., 2010. Palynological report on 15 samples of probable Carboniferous and younger, and of Cretaceous age, from NTS 96-C-15, 96-C-16, 96-F-10, 96-G-12, 96-G-14, 106-H-11, 106-H-13, 106-H-14, 106-K-05, Northwest Territories, as requested by J. Davison, Univ. of Calgary; Geological Survey of Canada, Paleontological Report 01-JMW-2010, 10 p.

White, J.M., 2010. Palynological report on 1 sample of probable Turonian to Maastrichtian age, from NTS 96-E-03, Northwest Territories; as requested by K. Fallas, GSC-Calgary, Geological Survey of Canada-Calgary; Geological Survey of Canada, Paleontological Report 02-JMW-2010, 4 p.

White, J.M., 2010. Palynological report on 11 samples of probable Paleozoic, Cretaceous and undeterminable ages from NTS 096-E-04, 096-E-08 and 106-H-05, Northwest Territories; as requested by T. Hadlari, GSC Calgary; Geological Survey of Canada, Paleontological Report 03-JMW-2010, 13 p.

White, J.M., 2010. Palynological report on 5 samples of Cretaceous age from NTS 096-E-05, 096-E-06, 096-E-12, 096-F-12; as requested by K. Fallas, Geological Survey of Canada - Calgary; Geological Survey of Canada, Paleontological Report 05-JMW-2010, 10 p.