Introduction and summary

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Abstract: The Geo-mapping for Energy and Minerals (GEM) program (2008–2020) of the Geological Survey of Canada made important contributions to the understanding of northern sedimentary basins in the Canadian Arctic Islands, Hudson Bay, and the mainland Northwest Territories. The goal of the program was to advance the geological understanding of the Canadian north, which the exploration industry and northern communities could then use for decision-making related to exploration and development. The most important advances are outlined in the papers in this volume and summarized in this introductory paper. In each area, improvements in the stratigraphic understanding gained through fieldwork help researchers decipher paleoenvironments, thickness variations, timing of nondeposition, and timing of erosion. These in turn allow for improved understanding of the tectonic history of each area. GEM projects produced a vast array of products, from geological and geophysical maps and geochemical data to peer-reviewed scientific papers. Reference to the most important of these products is made in the individual papers.

Résumé : Le programme Géocartographie de l'énergie et des minéraux (GEM) de la Commission géologique du Canada, en activité de 2008 à 2020, a grandement contribué à la connaissance des bassins sédimentaires du Nord dans l'archipel Arctique canadien, la baie d'Hudson et la partie continentale des Territoires du Nord-Ouest. L'objectif du programme était d'approfondir les connaissances de la géologie du Nord canadien, afin que l'industrie de l'exploration et les communautés du Nord puissent s'en servir pour prendre des décisions en matière d'exploration et de développement. Les progrès les plus importants sont présentés dans les articles de ce volume, et résumés dans le présent article d'introduction. Dans chaque région, les connaissances approfondies de la stratigraphie, acquises grâce au travail sur le terrain, aident les chercheurs à comprendre les paléoenvironnements, les variations d'épaisseur, les périodes d'interruption de la sédimentation et les périodes d'érosion. À leur tour, ces nouvelles connaissances permettent d'approfondir la compréhension de l'histoire tectonique de chaque région. Les projets du programme GEM ont mené à la création d'une vaste gamme de produits, comprenant des cartes géologiques et géophysiques, des données géochimiques et des articles scientifiques révisés par des pairs. Les produits les plus importants sont mentionnés dans les articles qui suivent.

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INTRODUCTION

The Geo-mapping for Energy and Minerals (GEM) program of the Geological Survey of Canada (GSC) was launched in 2008 following consultations with provincial and territorial geoscience partners. The goal of the program was to provide a modern geological understanding of the entire Canadian north, which the exploration industry and northern communities could use for their decision-making processes related to exploration and development. In 2020, after 12 years of northern research, the second phase of the GEM program ended. Through its two phases (GEM-1, GEM-2), with an intervening consolidation and reflection exercise, the GEM program generated a wealth of fundamental and applied geoscience contributions to the understanding of sedimentary basins in northern Canada.

During the first phase of the GEM program (2008–2013), five research projects were carried out in sedimentary basins of northern Canada (Fig. 1): Eastern Arctic, Western Arctic, Yukon, Mackenzie Delta and Corridor, and Hudson Bay–Foxe basins. Apart from the Yukon project, all included both onshore and offshore components. New geoscience research resulted in a significant number of geological and geophysical maps, technical reports, resource evaluations, peer-reviewed journal papers, and chapters in synthesis volumes.

In 2012, near the end of the first phase of GEM, new research activities were proposed to address the lack of critical geoscience in the least understood parts of Canada's north. The project known as 'Operation GEM' aimed to 1) consolidate and improve existing information; 2) acquire new geophysical and geochemical data; 3) test new GEM-derived models through targeted field activities in 2012; and 4) advance planning with respect to future works. Two desktop seismic-based activities were defined for the program's energy component in the north: subsurface mapping (eight maps released in 2013 in the GSC

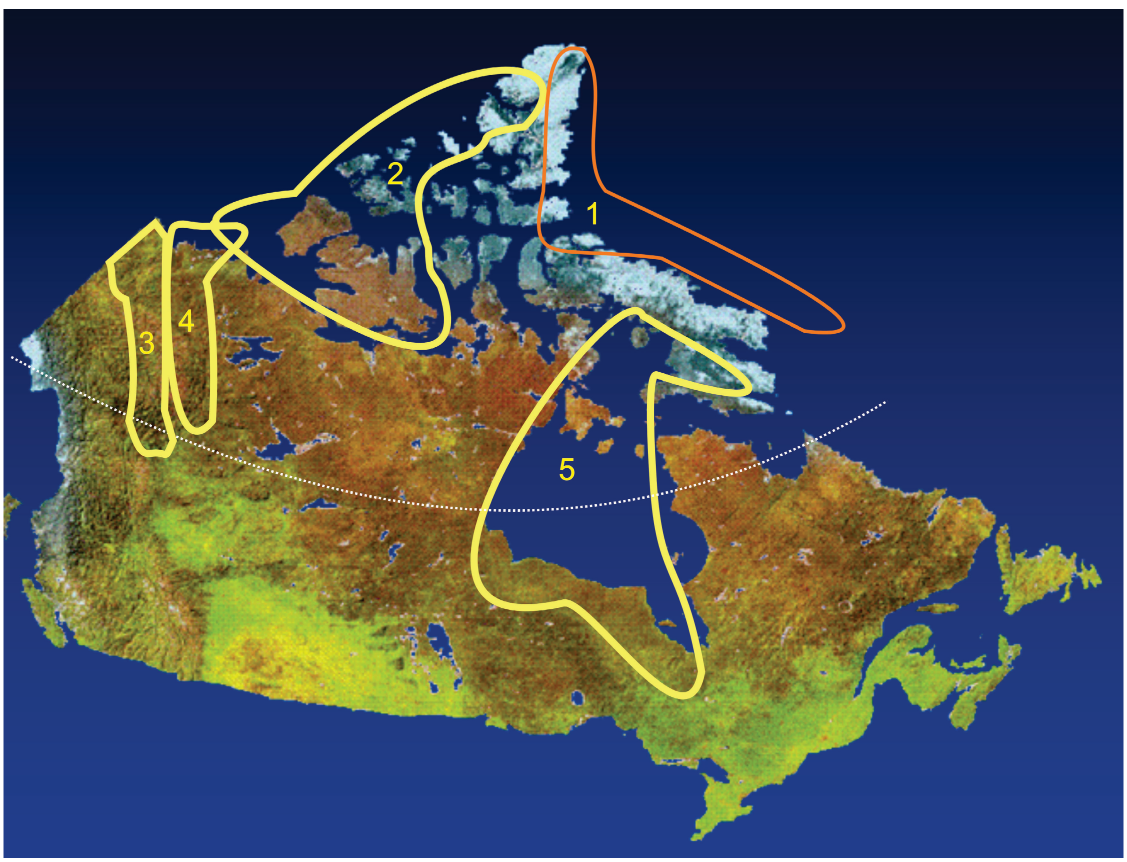

Figure 1. Schematic outline of sedimentary basins studied during phase 1 of the GEM program. 1 = Eastern Arctic; 2 = Western Arctic; 3 = Yukon; 4 = Mackenzie Delta and Corridor; 5 = Hudson Bay–Foxe Basin. Background image *modified from* Geomatics Canada (2006).

Canadian Geoscience Map series, one report, and one peer-reviewed paper); and hydrocarbon indicators (two peer-reviewed papers on methodology). Both activities relied on extensive Arctic onshore and offshore seismic and well databases.

Based on GEM-1 and Operation GEM results, GSC scientists were mobilized to provide regional fundamental scientific hypotheses, with economic implications that could be tested during a second phase of the GEM program. Research activities for the GEM-2 program (2013–2020) were carried out in six geological domains, and four projects were designed to test scientific hypotheses in sedimentary basins (Fig. 2): Baffin, Western Arctic, Mackenzie, and Hudson–Ungava. In a complementary effort to generate overarching trans-Arctic correlations between sedimentary basins, two research projects were defined: event–stratigraphic correlations and regional burial–exhumation history of Canada's north.

The scientific achievements for the GEM eastern Arctic–Baffin Bay projects are presented in a stand-alone contribution. This bulletin offers syntheses of GEM activities for sedimentary basins in the western Arctic (including the Sverdrup Basin), the Yukon, Mackenzie, and Hudson Bay areas, and two trans-Arctic research projects. Moreover, contributions for three Devonian thematic activities (Devonian tectonostratigraphy and Devonian conodont biostratigraphy of the Mackenzie project area; and Devonian stratigraphic synthesis of Hudson Bay and Moose River basins) are presented. The highlights of these research projects are presented below; details are in the individual contributions of this bulletin with, in most cases, references to peer-reviewed papers presenting the major scientific knowledge advances for these sedimentary basins.

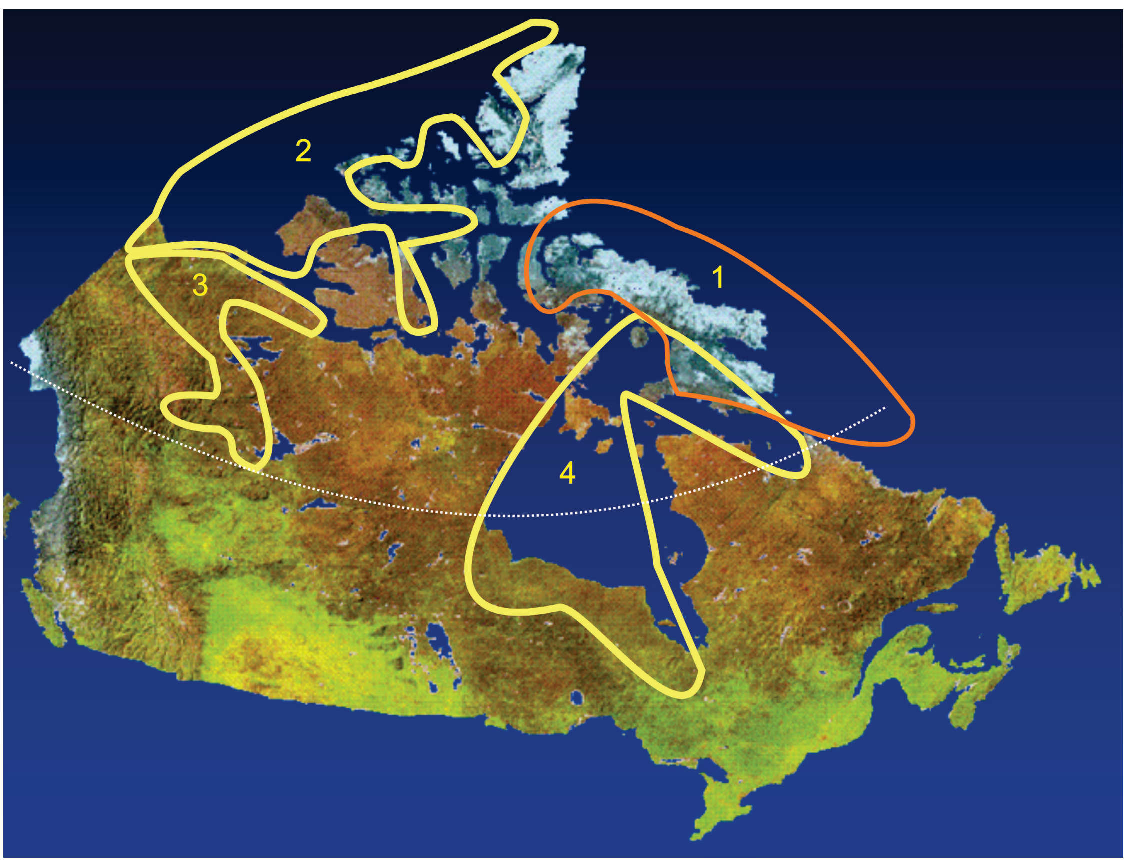

Figure 2. Schematic outline of sedimentary basins studied during phase 2 of the GEM program. 1 = Baffin Bay; 2 = Western Arctic; 3 = Mackenzie; 4 = Hudson–Ungava. Background image *modified from* Geomatics Canada (2006).

HIGHLIGHTS

Geo-mapping for Energy and Minerals program activities in the lower Paleozoic Franklinian succession in the Canadian Arctic Islands (by Dewing and Hadlari)

Lower Paleozoic-dominated strata of the Franklinian margin were deposited between Neoproterozoic and Late Devonian time and record a full Wilson cycle, from rifting of Rodinia and establishment of a passive margin (Neoproterozoic to Ordovician), through the development of an unstable margin (Ordovician to Middle Devonian), to the development of a foreland basin and subsequent deformation (Middle Devonian to Late Devonian). Lower Paleozoic strata at Bent Horn constitute the source of the only oil produced from the Canadian High Arctic, and the lower Paleozoic interval is also host to the large Polaris lead-zinc mine.

The GEM Western Arctic project identified several issues and gaps in geoscience knowledge: 1) the difficulty in accessing geochemical and geological data digitally; 2) the lack of data on some petroleum-system elements; 3) large gaps in geological mapping on Victoria Island; and 4) gaps in understanding the timing of tectonic events and provenance of the Pearya Terrane. These deficiencies were addressed initially through numerous GSC open file reports, all using a common title starting with "Geological and geochemical data from the Canadian Arctic Islands", and a series of digital geological maps of the Arctic Islands having a unified legend compiled by Harrison and co-authors. Secondly, field and laboratory studies were performed in areas of resource potential, resulting in papers on the origin of the Polaris lead-zinc deposit, the characterization of the Bent Horn oil field, and the assessment of thermal-maturity levels. Thirdly, the first geological map of northwestern Victoria Island was produced based on fieldwork in 2009–2011. Finally, studies of sandstone ages and provenance were undertaken on rocks from Pearya terrane and adjacent areas to test when Pearya became a source of sediment onto the northern Laurentian margin.

In addition to research addressing the economic potential of the Arctic Islands, the lower Paleozoic component of the GEM Western Arctic project supported graduate student projects on Cambrian tidal deposits and the provenance of Devonian strata, as well as other projects with academic collaborators on Neoproterozoic to Devonian sediment provenance and the tectonic history of the Laurentian margin. The project also supported a large body of work in upper Paleozoic and Mesozoic strata in the Arctic Islands, described elsewhere in this volume.

Among the most important conclusions of these studies are that at least parts of the Pearya composite terrane on northern Ellesmere Island have always been close to their current position and are not far-travelled blocks. Clarifying tectonic relationships in this area helps with reconstruction of the opening of the Arctic Ocean, and ultimately with Canada's claims in the Arctic Ocean. The hydrocarbon prospectivity of much of the lower Paleozoic succession is hampered by both the old age of hydrocarbon generation and the fact that, in many areas, hydrocarbons migrated before traps formed. The areas of highest prospectivity are probably close to the southern margin of the Sverdrup Basin.

Hudson Bay, Hudson Strait, Moose River, and Foxe basins: synthesis of Geo-mapping for Energy and Minerals (GEM) program activities from 2008 to 2018 (by Lavoie, Pinet et al.)

The Hudson Bay Basin and its satellite Moose River, Foxe, and Hudson Strait basins form the Hudson Platform. This succession consists predominantly of Paleozoic carbonate units. Prior to the GEM program, this largely marine domain was, in geological terms, the least known sedimentary domain in Canada. From 2008 to 2018, scientists from the GSC and Canada-Nunavut Geoscience Office, in collaboration with geological surveys and universities in Ontario and Manitoba, carried out numerous research activities that were centred on three major themes: stratigraphic architecture, tectonic framework, and hydrocarbon systems.

The Ordovician to Silurian stratigraphy is synthesized in a single regional framework that correlates units over all the study area, including the offshore. The stratigraphic architecture of the Devonian succession is presented in one of the contributions to this bulletin. These significant new syntheses result from extensive onshore fieldwork, as well as work on onshore and offshore exploration wells with geophysical and stratigraphic re-logging, and new biostratigraphic and chemostratigraphic data.

A new tectonic framework is based on the re-evaluation and integration of available marine seismic data with new biostratigraphic data. The model identifies major unconformities and leads to a new time-frame for basin tectonic evolution. From the inception of the Hudson Bay Basin in the Late Ordovician to a major break in the late Silurian–Early Devonian, the basin was tectonically active, with significant faulting largely controlled by a major deformation event (Salinic Orogeny) that occurred along the ancient southern continental margin of Laurentia. The Hudson Bay Basin later evolved during the Middle to Late Devonian as a tectonically quiescent sag basin as the tectonic regime along the Laurentian margin switched from late Silurian–Early Devonian northwest-oriented accretion to the oblique southwest-oriented collision of the Devonian Acadian Orogeny.

A first round of hydrocarbon exploration in the Hudson Bay Basin from 1970 to 1985 led to the drilling of five offshore wells, with no discovery. In the mid-1980s, industry left the area, citing a lack of regional source rocks and insufficient burial. New research on source rocks clarified the potential of the Upper Ordovician shales, from which hydrocarbons can be generated at low burial temperatures. Various techniques were used to address the thermal/burial history of that large basin; organic-matter and mineral-based approaches were tested, with diverging results ranging from immature to oil-window conditions. Multiple Ordovician to Devonian porous reservoir candidates exist, and five major exploration plays were proposed during the course of the GEM program. The presence of active hydrocarbon systems is supported by 1) the occurrence of dead and live oil in several onshore porous rock units; 2) the re-evaluation of offshore well logs, indicating several bypassed pay zones; and 3) the identification of potential natural oil slicks on the surface water from multiyear satellite and airborne-radar images.

Overview of the age, evolution, and petroleum potential of the Eagle Plain Basin, Yukon (by Lane et al.)

The GEM activities produced new framework geoscience maps, synthesis publications, and energy resource assessments of Yukon's sedimentary basins. Much of the study was focused in Eagle Plain and adjacent basins and in their deformed margins in northern Yukon. New surface and subsurface mapping, biostratigraphy, geochemistry, organic petrology, and thermal history data have produced new insights into the region's structural evolution, depositional history, and resource potential.

Multikinetic apatite fission-track (AFT) thermochronology resolved new details of the thermal history of Yukon's northern basins. New modelling methods were refined and tested during the GEM program and applied to constrain the thermal history of the region. Preliminary interpretations show that at least two distinct heating–cooling cycles can be distinguished using the AFT data. These results also suggest that sediment deposited into Eagle Plain Basin was sourced from the east, as well as from the south, and that the basin hinge line lay approximately along the eastern limit of preserved Cretaceous strata.

New results support and expand on previous interpretations of the Eagle Plain Group as having been deposited principally in a marine-shelf setting, with new evidence of a marine-slope setting in the west of the basin. This represents a new potential petroleum play.

Advances in understanding the age and depositional history of the Eagle Plain Group are derived from numerous new fossil localities, a new U-Pb zircon radiometric age from a bentonite layer, and additional detrital zircon ages from the sandstone units. The Parkin Formation, the lowest unit in the group, is dated as Cenomanian, although it may include late Albian strata in the western (deeper) parts of the basin. The overlying Fishing Branch Formation is poorly dated, but locally is Cenomanian in age. The Burnthill Creek and Cody Creek formations are demonstrated to be time transgressive across the basin. New sampling constrains their ages as Santonian to Maastrichtian in the northeast. The eastern margin of the basin contains the thinnest preserved section, reflecting its position close to the basin hinge line, to the east of which little or no Late Cretaceous subsidence occurred.

A new petroleum resource appraisal utilizing GEM data and publications includes petroleum exploration-play concepts not previously defined, as well as a qualitative assessment of the unconventional oil and gas potential. A separate scoping study utilizing GEM publications reported on unconventional oil and gas potential in Yukon and concluded that tight-reservoir petroleum systems underlie the basin. Also, the project likely influenced private sector economic activity of $120 million, leading to employment opportunities for northerners.

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 (by McNaughton and Fallas)

During the GEM program, projects in the Mackenzie area of the Northwest Territories were strongly multidisciplinary and collaborative. Work in the region during the first phase of the program focused on energy-related studies, including completion of the first probabilistic petroleum resource assessment for the mainland Northwest Territories, new bedrock mapping and stratigraphic work in the region around the long-producing oil field at Norman Wells (including reflection-seismic work), and studies related to oil and gas systems in the Beaufort Sea–Mackenzie Delta. During the second phase of GEM, bedrock mapping and related stratigraphic work extended across a broader region of the Northwest Territories. This contribution documents the progress in mapping and stratigraphy during both phases, while also providing brief summaries of other aspects of the work.

At the beginning of the GEM program, the published bedrock geology of large parts of the mainland Northwest Territories was represented by hard-copy maps of varying detail, published in a variety of formats, based on reconnaissance work carried out in the late 1960s. During both phases of GEM, a key aim for the Mackenzie region was to update and improve the regional-scale bedrock map coverage of key areas and produce GIS-enabled map products. Mapping during GEM-1 focused on the region around Norman Wells and encompassed the eastern Mackenzie Mountains, Mackenzie Plain, the Franklin Mountains, and adjacent parts of Great Bear Plain. For GEM-2, efforts initially shifted north to the Colville Hills, a region of known oil and gas potential, and then west to the mineral-bearing northern Mackenzie Mountains. Both phases of mapping made extensive use of well curated archival data from the earlier reconnaissance work. As of this writing, 14 new maps have been published at 1:100 000 scale (Mackenzie Plain and adjacent mountains) and four at 1:250 000 scale (Colville Hills). An additional six maps from the northern Mackenzie Mountains are in press or in preparation at 1:100 000 scale. In total, the maps will cover nearly 92 000 km^2 of territory. The new mapping confirms that both pre-Laramide and Laramide structures played a role in the evolution of the region.

Geological evolution of the mapped regions is recorded by strata ranging in age from Tonian (early Neoproterozoic) to Paleocene–Eocene. Since the 1960s' generation of bedrock maps, numerous clarifications and revisions to lithostratigraphic nomenclature have been proposed, affecting virtually the entire stratigraphic record of the region. The GEM program mapping applied the updated terminology in a consistent way across the region. Additionally, it proved desirable to revise the formal lithostratigraphy of several Tonian, Ediacaran, and Cambrian units in the Mackenzie Mountains. Because reports on the crucial Ediacaran–Cambrian interval are still in preparation, the contribution in this volume presents a summary of stratigraphic usage, rather than a synthesis of stratigraphic evolution. Also included are citations to externally published GEM synthesis reports dealing with the Phanerozoic evolution of regions east of the Mackenzie Mountains.

Devonian of the Mackenzie (by Kabanov)

This contribution reviews the Devonian–Mississippian strata lying within the GEM Mackenzie project bedrock mapping areas (NTS 96 and 106) and their vicinity. Updates received from the Devonian Stratigraphic Framework activity of the GEM Mackenzie project are highlighted. The reviewed strata occur in the northern continuation of the Western Canada Sedimentary Basin (WCSB), which is outlined in some works under the name 'Canadian Mainland Sedimentary Basin'. Similarly to the WCSB, the reviewed strata host a major total petroleum system with thick, high-quality Middle to Upper Devonian source rocks bundled in the Horn River Group (HRG). Additional oil prospectivity is indicated in the latest Devonian–Early Mississippian shales in the northwestern corner of the studied area.

The Devonian strata usually reach well in excess of 1 km in noneroded sections, cropping out extensively in the Cordillera and occurring in the subsurface of the adjacent Interior Plains. Major stratigraphic assemblages are 1) the latest Silurian–Eifelian shallow-water platform carbonate and evaporite units; 2) the latest Eifelian–Frasnian basinal shales, siliceous mudrocks, and isolated carbonate banks of the HRG; and 3) the thick, coarsening-upward siliciclastic succession of Frasnian–Tournaisian age deposited in the distal settings of the Ellesmerian foreland basin. Review of the lithostratigraphic nomenclature is supplemented with highlights on the depositional environments and patterns of thermal maturity in the HRG. This review also provides insights into the nature of stratigraphic surfaces bounding formations and occurring inside them, leading to reinterpretations and raising questions for future research.

The HRG is receiving particularly detailed updates owing to wide application of chemostratigraphic tools. In the central Mackenzie Valley, detailed inductively coupled plasma elemental and pyrolysis logs from cored black-shale sections add more constraints on subdivisions. Alumina-normalized U and Mo logs reveal four main horizons of enhanced anoxia that may correlate globally as ‘Devonian black-shale events’. A combination of observations, well logs, and chemostratigraphy allows six new members to enter formal usage and redefines two previous members within the Hare Indian and Canol formations and the basal part of the Imperial Formation. Gamma spectrometry surveys of reference outcrops of the HRG substantiate correlations with borehole sections. A combination of spectral gamma and conventional borehole logs is used to trace horizons of enhanced anoxia and subdivisions established in the central Mackenzie Valley over long distances and across facies zonation. In the area of particularly sparse well coverage in the western Peel Plain and Plateau, energy dispersive X-ray fluorescence surveys of cutting samples provide robust logs of major oxides, augmenting the limited resolution of legacy borehole logs. Resultant updates in formation tops of exploration wells are very significant; they are available in project publications.

Devonian conodont biostratigraphy of the Mackenzie Mountains, western part of the Northwest Territories (by Gouwy)

The Devonian of the Mackenzie Mountains has been a topic of conodont biostratigraphic research since the early 1970s. The buildup of the Lower and lower Middle Devonian shelf, its subsequent drowning with deposition of organic-rich black shales (Hare Indian and Canol shales), and the development of platform and reefal facies (Ramparts limestone) led to very diversified paleoenvironments characterized by various conodont fauna. Comparison with conodont data from the Selwyn Basin in the western part of the Mackenzie Mountains allows for correlations between shelf and off-shelf deposits.

An overview of the current understanding of Devonian conodont biostratigraphy in the Mackenzie Mountains is based on a re-evaluation of available data combined with new biostratigraphic material per stratigraphic unit. Unit distribution maps give an idea of the extent of the formations in the Mackenzie Mountains. Two chronostratigraphic charts present the northern and southern Mackenzie Mountain Devonian stratigraphy linked to the conodont biozonation, from the first deposits on top of the sub-Devonian unconformity to the lower part of the Imperial and Fort Simpson formations, and can provide a biostratigraphic framework for future Devonian studies in the area.

The update reveals that several of the assemblage and formation contacts are younger than presumed in the earlier time-stratigraphic chart.

Several formations and members are now better constrained in the chart. The update also points out intervals in the charts for which no data were available and for which more research is needed to delimit formations in the Devonian conodont biozonation.

Regional and global correlations of the Devonian stratigraphic succession in the Hudson Bay and Moose River basins from onshore Manitoba and Ontario to offshore Hudson Bay (by Larmagnat and Lavoie)

The Hudson Bay Basin is the largest intracratonic basin in North America. Geological descriptions, mostly stratigraphic and paleontological, started in the middle of the twentieth century, with descriptions of onshore and offshore rock successions resulting in local stratigraphic nomenclature and frameworks that are not easy to correlate from one area to another. At the beginning of the GEM program, a major research goal was to produce a unified, or at least a modern, understanding of the stratigraphic succession over this large geological domain. This contribution presents the stratigraphic framework proposed after nine years (2008–2017) of new work on Devonian lithostratigraphic, biostratigraphic, and chemostratigraphic onshore and offshore data over the entire basin.

The Lower to Upper Devonian onshore successions in northeastern Manitoba and northern Ontario that occur in the Hudson Bay Lowland and Moose River Basin are integrated into a single stratigraphic framework. To the north, in the offshore Hudson Bay Basin, stratigraphic nomenclature is unified in a single amended framework that is now correlated with the successions farther to the south. Biostratigraphy and chemostratigraphy were both instrumental in these correlations.

The $\delta^{13}C$ Vienna Pee Dee Belemnite (VPDB) trends for Lower and Middle Devonian carbonate units in the Moose River Basin and Hudson Bay lowland are used for regional correlations and are compared with global Devonian carbon stable-isotope excursions. Global major $\delta^{13}C_{VPDB}$ positive excursions provided clues about the potential stratigraphic position of the elusive Silurian–Devonian boundary in the Hudson Platform.

The Devonian succession on the Hudson Platform belongs to the Kaskaskia sequence of North America and is compared with the stratigraphy from the Williston and Michigan intracratonic basins, with which the Hudson Platform shares a dominant carbonate–evaporite succession. In these three intracratonic basins, two episodes of roughly coeval reef development (late Emsian to early Eifelian and Givetian) are present, with corals and stromatoporoids as the main framework constituents.

Devonian reefs and dolomitized facies on the Hudson Platform exhibit significant porosity and could form sizable hydrocarbon reservoirs. Some intervals in offshore wells provide significant local direct and petrophysical evidence for hydrocarbon charge.

Geo-mapping for Energy and Minerals program: activities in the Sverdrup Basin, Canadian Arctic Islands (by Hadlari)

The Sverdrup Basin is the continental counterpart to an adjacent rift basin that ultimately opened to form the Amerasia Basin as part of the Arctic Ocean. It preserves the history of a continental setting that was responding to tectonic events at the paleo-Pacific plate margin of North America from the Carboniferous to Early Cretaceous and then to extension tectonics related to the opening of the northern Atlantic Ocean during the Late Cretaceous and Cenozoic.

The first of four main stages of the Sverdrup Basin consists of strata deposited in extensional basins from the Carboniferous to the early Permian. Significant hydrocarbon source rocks were formed during pronounced subsidence of the second stage from the mid-Permian to Late Triassic. Another rifting event (the third stage) that was under way by the Early Jurassic culminated in Early Cretaceous breakup and seafloor spreading in the Amerasia Basin, which led to the fourth stage of passive-margin subsidence, until the shift to uplift and erosion during the Eurekan Orogeny in the Cenozoic.

The GEM program led to advances in understanding the geoscientific framework of the Sverdrup Basin, especially tectonics, hydrocarbon and mineral potential, chronostratigraphy, paleoenvironment, and paleoclimate. The main results are those focusing on the stratigraphic interval spanning synrift, breakup, and postrift history related to opening of the Amerasia Basin, the study of which led to the interaction of multiple geoscience disciplines. Many rocks previously mapped as volcanic flows were discovered to be sills and, combined with ground truthing of volcanic flows higher in the section, this narrowed the correlation between volcanic rocks of the High Arctic large igneous province (HALIP) and sedimentary stratigraphy. Conversely, new ash beds were identified and dated from Lower Cretaceous strata that expanded the known range of volcanism. Integrated chemostratigraphy and biostratigraphy provided new age constraints for the postrift succession in the Isachsen Formation, which finally enabled magmatic rocks to be incorporated into the geochronological framework. Biostratigraphy, igneous petrology and geochronology, chemostratigraphy, radiometric chronostratigraphy, structure, and tectonostratigraphy were combined to significantly refine and clarify the origin of the western Arctic rifted margin, showing that the HALIP is part of the postrift succession, postdated breakup, and was therefore emplaced when the thickness of the crust of the Amerasia Basin was most likely similar to that of the present day.

The 2020 Canada datapack for TimeScale Creator: a new tool for Mesozoic–Cenozoic stratigraphy of the Canadian North (by Bringué et al.)

Biostratigraphy has been fundamental to understanding the geological history of northern Canada. Traditional biostratigraphy was based on zonation schemes that assimilated aspects of species ranges, and such schemes are still widely used, especially for macrofossils. In recent decades, some micropaleontological subdisciplines have been using selected events instead of zones. Proponents of an event approach argue that it facilitates better integration from region to region and between fossil groups. Thus, developing an event scheme for the Mesozoic and Cenozoic across the GEM regions was initiated in 2017 under the auspices of the Trans-GEM Event Stratigraphy activity.

The availability of TimeScale Creator® (TsC) early in the activity somewhat changed the focus. TimeScale Creator is a JAVA package managed by the Geologic TimeScale Foundation out of Purdue University, Indiana. This free package enables exploration and creation of charts of any portion of the geological time scale from an extensive suite of global and regional events. TimeScale Creator is designed to contain limitless amounts of data that can be selectively downloaded, and users of the TsC Pro version can add their own data. Data in TsC are combined in regional, subdiscipline, or other packages known as 'datapacks'.

Although a priority of the Trans-GEM Event Stratigraphy activity remained biostratigraphic event stratigraphy, equal emphasis was given to developing a new TsC datapack to incorporate stratigraphic data from the GEM regions, in the spirit that the accumulated content will facilitate data visualization, comparison, and correlation within and between the GEM regions. One aspect of the modified objectives of the activity was to incorporate revised and updated data from the Mesozoic–Cenozoic portion of an earlier Canada datapack that was compiled under GSC contract by the TimeScale Foundation in 2010 but never quality checked; the earlier datapack includes both litho- and biostratigraphic data. A major advantage of using TsC is that it is revised periodically with updated age calibrations of the geological timescale, which are automatically reflected in the absolute ages of events or zone boundaries and facilitate comparison of stratigraphic data.

The new 2020 Canada datapack incorporates new data, as well as some data brought forward and checked from its 2010 predecessor. The 2020 Canada datapack focuses on Mesozoic–Cenozoic litho- and biostratigraphy and, where possible, event stratigraphy. It includes revised stratigraphic data as well as new inputs, many of which were generated from GEM-funded research activities. Special attention has been given to updating the Jurassic ammonite horizons from the Sverdrup Basin and northern Yukon. Included are new lithostratigraphic and palynostratigraphic data sets for the Labrador–Baffin Seaway, filling a critical gap in the spatial and temporal coverage of Canadian strata in TsC. Another noteworthy addition to the 2020 Canada datapack is a suite of benthic foraminifer biostratigraphic data sets from Upper Jurassic to Cenozoic strata of the Beaufort–Mackenzie Basin, extracted from five charts from the *Geological Atlas of the Beaufort–Mackenzie Area* (Dixon, 1996). Owing to their relevance to (bio)stratigraphic control of age-equivalent strata in the Canadian north, several sets of data are included, even though their geographic provenance is not directly or primarily located within GEM regions of interest.

Exhuming the Canadian Shield: preliminary interpretations from low-temperature thermochronology and significance for the sedimentary succession of the Hudson Bay Basin (by McDannell et al.)

The Canadian Shield is a geomorphic feature that is characterized by mostly ancient, peneplained Archean and Paleoproterozoic crystalline and high-grade metamorphic rocks exposed at the surface. The difference in age of most Canadian Shield rocks with respect to areas with overlying Phanerozoic sediments is striking and represents a hiatus of more than 2 Ga, or more than 50% of Earth history unaccounted for in the geological record. The presence of remnant intracratonic basins of Proterozoic age, as well as fragmented Paleozoic platform sediments throughout the Canadian Arctic Archipelago and within the Hudson Bay Basin, demonstrates that this landscape was intermittently buried in the past. However, as most of the Canadian Shield remains devoid of any evidence of sedimentary burial, the timing, extent, and magnitude of erosion and sedimentary burial remain unanswered. The primary questions related to the evolution of this landscape are the following:

- Was the sedimentary burial and exhumation history of the Canadian Shield uniform and/or diachronous?
- Are preserved sedimentary basins intact, or were they more laterally or vertically extensive in the past, and if so, is there any support for basin connectivity?
- What is the hydrocarbon potential for reconstructed basins, and how does this link to producing or frontier basins with known hydrocarbon resources?

The Trans-GEM Low Temperature Histories for Resource Potential project was initiated to investigate erosion and burial history at the continental scale using apatite fission-track (AFT) low-temperature thermochronology. Determining ages using AFT is predicated on quantifying the relationship between damage trails produced in an apatite crystal during spontaneous fission events due to radioactive decay of ^{238}U. Fission-track 'apparent' ages are proportional to time, since appreciable tracks formed in a crystal relative to the parent uranium content, whereas measured track-length distributions yield information about thermal history due to the temperature dependence of track-length annealing. Tracks are long when first formed, but they progressively anneal to shorter lengths during heating. The relationship between fission-track annealing, temperature, and apatite chemistry has been calibrated in multiple laboratory experiments, and this relationship has been extrapolated to geological timescales for use in reconstructing the thermal histories of rocks. The apatite fission-track method is typically sensitive to temperatures that vary between 60°C and 120°C, but this range varies according to apatite chemistry.

As part of the project, AFT data for crystalline bedrock samples were obtained from across the Canadian Shield to reconstruct the erosion and burial history during the Phanerozoic. Preliminary results demonstrate that Southampton Island (north of Hudson Bay) and northern Ontario shield rocks experienced approximately 2 to 4 km of burial by sediments during Ordovician through Devonian times and that part of these sediments was subsequently removed by erosion. Modelled thermal histories from Ontario establish that the Hudson Bay Basin extended farther south than the present outcrop and reveal that the area was shallowly buried in the Cretaceous during high sea level. These models are supported by the local preservation of Jurassic to Lower Cretaceous rocks in the Moose River Basin and by previous studies suggesting an Albian extension of the Western Interior Seaway. Thermal history inverse modelling also lends support for minor Cretaceous burial, about 1 to less than 3 km thick, on Southampton Island that may have been structurally focused by the Hudson Strait fault system. Predicted vitrinite-reflectance values generally agree with measured data in the Hudson Bay region, and thermal-history models suggest rocks reached early oil maturity in the Paleozoic. These results, along with other published thermochronology studies, tentatively support the hypothesis that the fragmented localities with preserved Paleozoic and late Mesozoic sedimentary cover may have been nearly contiguous with sediments of varying thickness. This would also imply that erosion dominated the latest Paleozoic, early to middle Mesozoic, and Cenozoic intervals.

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