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Report of activities for the Hudson Platform: stratigraphic and source rock research, Ontario, Manitoba and Nunavut

D. Lavoie[1], D. Armstrong[2], M. Nicolas[3] and S. Zhang[4]

[1] Geological Survey of Canada, Québec, Quebec
[2] Ontario Geological Survey, Sudbury, Ontario
[3] Manitoba Geological Survey, Winnipeg, Manitoba
[4] Canada-Nunavut Geoscience Office, Iqaluit, Nunavut

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FOREWORD / CONTEXT

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the summer 2014, GEM's new research program has been launched with 14 field activities that include geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, northerners and their institutions, academia and the private sector. GEM will continue to work with these key collaborators as the program advances.

INTRODUCTION

Integrated regional stratigraphy of petroleum basins of the Hudson-Ungava Project

The integrated regional stratigraphic framework is the natural continuation of the work completed as part of GEM-1 where specific local frameworks were constructed (Lavoie et al., 2013). The fine-scale correlations of these frameworks (Ontario, Manitoba, offshore Hudson Bay, onshore Foxe basin, offshore Hudson Strait) is only possible through the use of a multidisciplinary approach that will combine detailed biostratigraphy, chemostratigraphy, sedimentology, petrophysics and geophysics.

This activity aims at addressing these two fundamental scientific questions:

1. How have geodynamic factors recorded as faulting and/or variable burial and exhumation influenced the architecture and petroleum prospectivity of the Hudson Bay basin?

2. Can sub-basins with distinct hydrocarbon prospectivity be identified in the Hudson Bay basin?

In this report, 2014 field work and core description from Northern Ontario, Northeastern Manitoba and Akpatok Island (Ungava Bay) will be discussed (Figure 1).

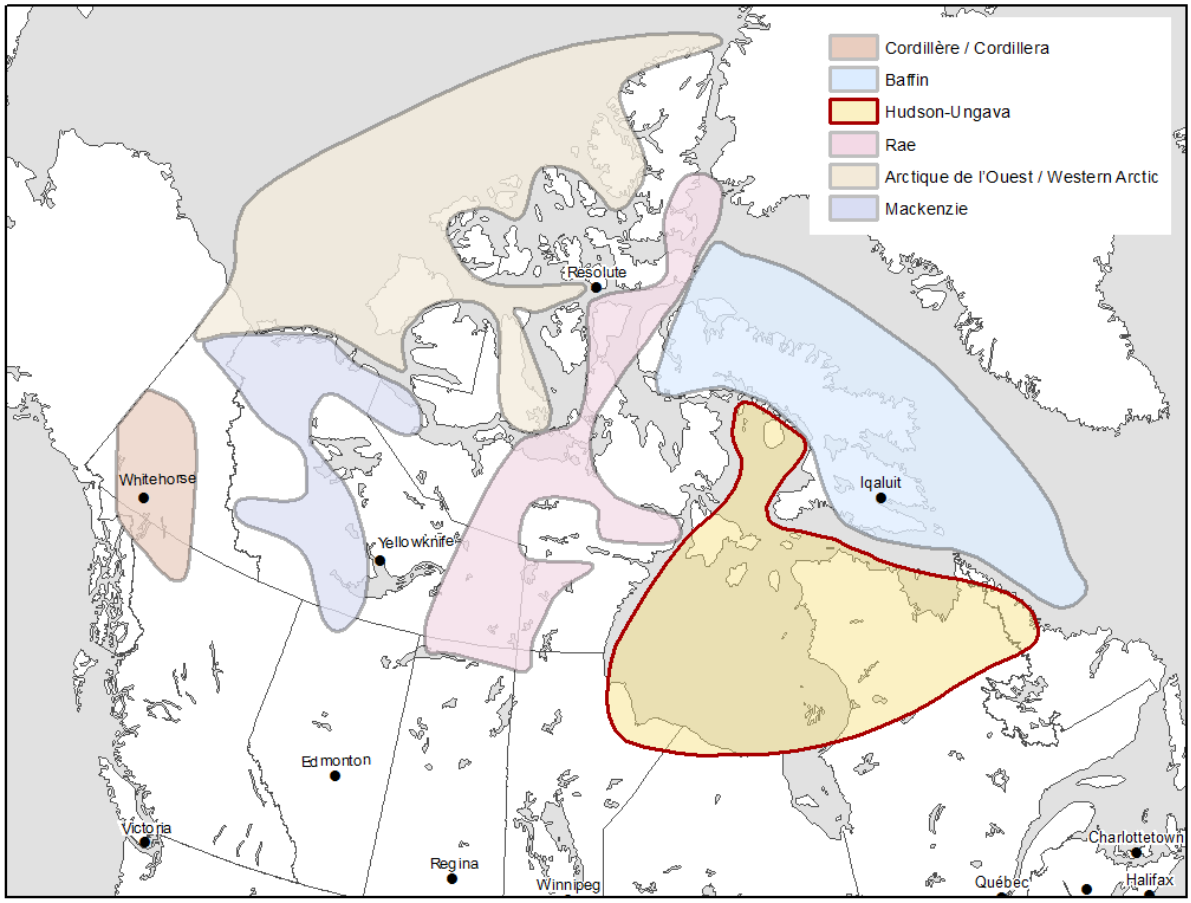

Fig. 1. Location of the Hudson Bay – Ungava GEM-2 project. Activities described in this report are located in northern Manitoba and Ontario, as well as on Akpatok Island (Ungava Bay).

Identification and characterization of hydrocarbon source rocks in Hudson Bay and Strait

An understanding of the source rock component of the hydrocarbon systems of the Hudson Bay / Strait and Foxe Basin will be addressed through various activities. The burial and thermal

evolution of the source rocks to evaluate their oil generation capacity will be refined through geothermochronology, Rock Eval analyses and source rock kinetic studies.

This activity aims at addressing these two fundamental questions:

1. Can sub-basins with distinct hydrocarbon prospectivity be identified in the Hudson Bay basin?

2. What mechanisms have influenced the formation, evolution and hydrocarbon potential of Hudson Strait and Foxe Basin, including opening of the Labrador Sea?

In this report, a summary of material collected specifically for this purpose during the 2014 field season will be discussed. Areas of sampling are the same as those presented in the above activity. Rock Eval results are available for Manitoba and Akpatok and reported in Nicolas et al. (in press) and Zhang and Mate (in press), respectively.

METHODOLOGY

Northern Ontario field work

Altogether, 34 outcrops and 1 diamond drill-core were examined and sampled. The sampled outcrops are located on the Albany, Kenogami, Kabinakagami, Cheepay, Stooping, Attawapiskat, Ekwan, Moose, Kwetabohigan, Abitibi, Mattagami and Coal rivers, and on the James Bay coast (see Figure 2). A water-filled abandoned quarry, just south of Moosonee was also examined and sampled. The diamond drill core was logged and sampled on site, at an inactive mineral exploration camp located approximately 7 km north of the Ekwan River. The core was drilled in 2012 by Fancamp Exploration Ltd. as part of their “Desolation Lake” project. Fancamp Exploration has provided copies of both core logs and photographs for this core and for other cores drilled as part of that project.

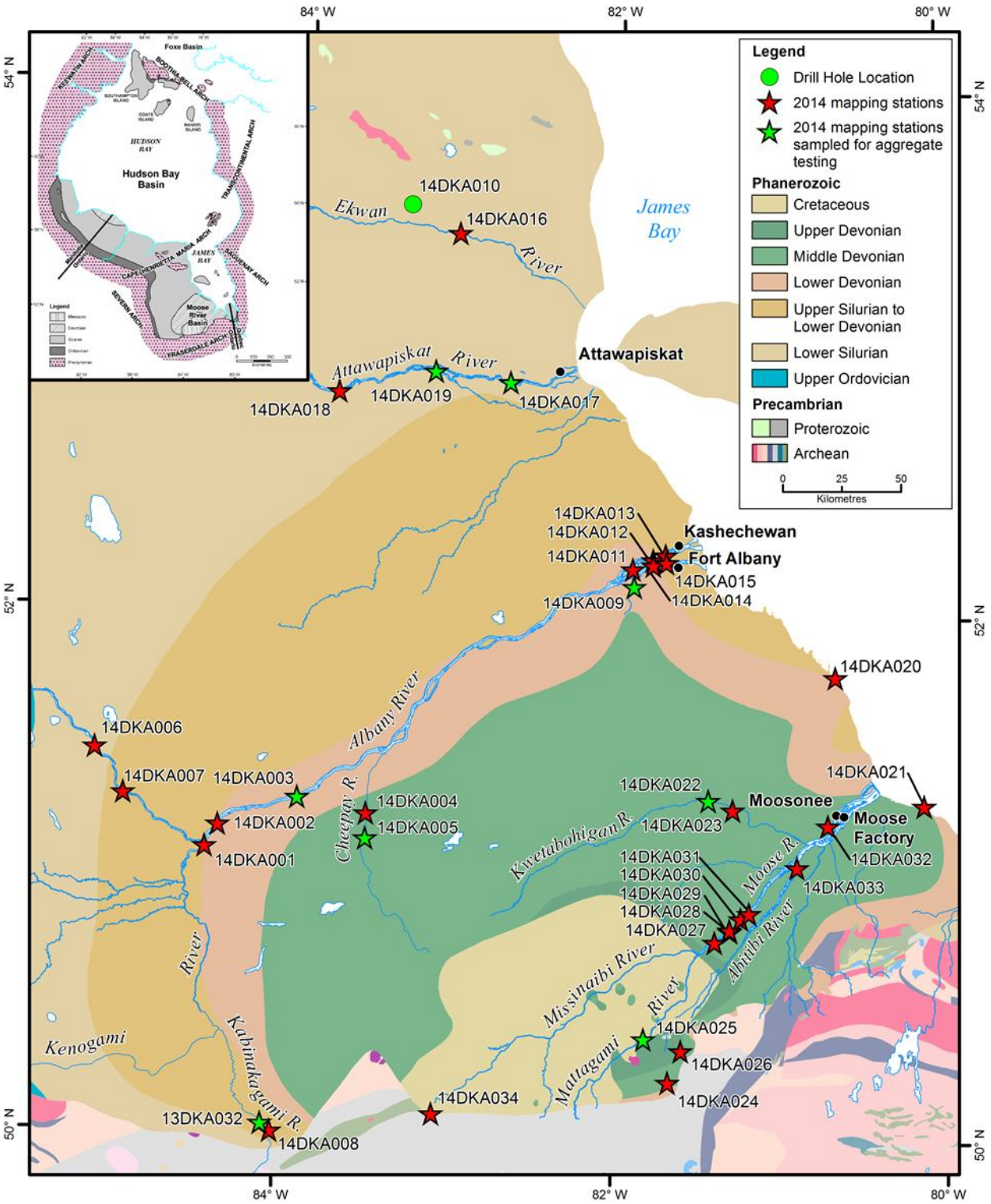

Fig. 2. Locations of field mapping stations (outcrops and core) examined in 2014, plotted on the bedrock geology of the James Bay Lowlands (Ontario Geological Survey 2011). Inset map shows the Hudson Platform with its tectonic elements (from Zhang 2010).

Northeastern Manitoba field work

During spring and summer of 2014 the primary focus of the project in Manitoba was to log select cores in great detail, collect samples for various analyses, and conduct field work along the Churchill River and Churchill coastal area (Figure 3). The two cores logged were the Houston Oils et al. Comeault Prov. No.1 and the Foran Mining Kaskattama Kimberlite No. 1 (KK1). The cores were selected because they had never been logged in extensive detail. Detailed sampling programs were developed and executed for these two cores, as well as cores from the Sogepet Aquitaine Kaskattama Prov. No. 1, Merland et al. Whitebear Creek Prov. and Selco Pennycutaway No. 1 (see Nicolas et al, in press, for core location). Sampling for Rock Eval analysis, conodont biostratigraphy, and micropalynology biostratigraphy was done on these cores (Table 1). During the summer months, J. Harrison (University of Manitoba) was hired as a summer assistant to carry out part of the sampling program on select core from the Hudson Bay Lowland in Manitoba. She collected and catalogued samples for δ13C and δ18O stable-isotope geochemistry, chitinozoan biostratigraphy, clumped isotope geochemistry (from fracture fills), fluid inclusion analysis, and basin exhumation studies (e.g. apatite-fission track analysis). In addition to the scheduled samples, additional samples for sediment provenance and hydrothermal dolomite determination (isotope analysis) were collected. Results of samples studied for source rock potential (Rock Eval) are presented in Nicolas et al. (in press).

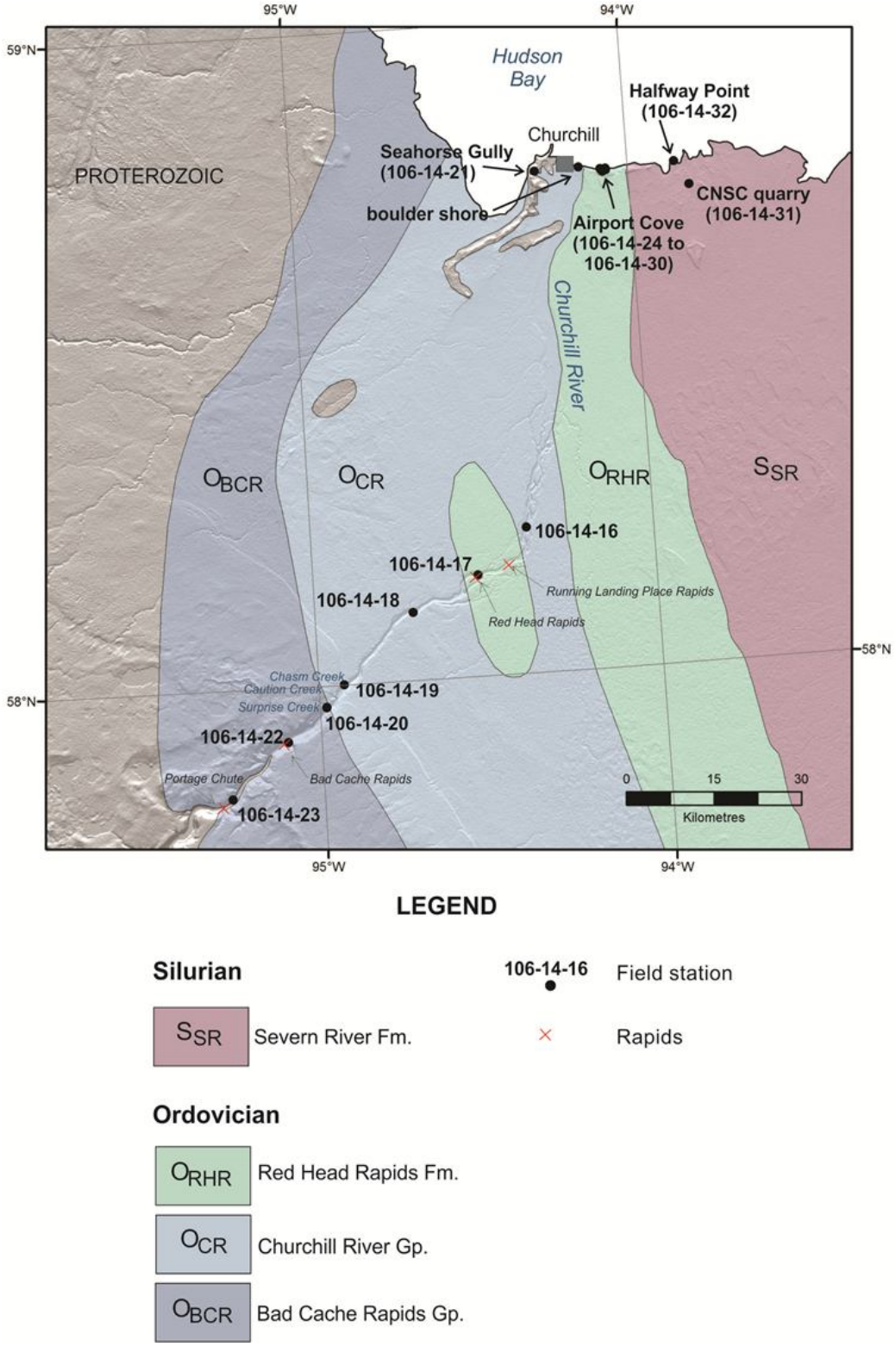

Fig. 3. Paleozoic geology map, with digital elevation model hill shaded relief underlay of the Churchill River and Churchill coastal area, northeastern Manitoba, showing the locations and names of field stations (Nicolas and Young, in press).

Well Name	Rock Eval geochemistry	$\delta^{13}C$ and $\delta^{18}O$ stable-isotope geochemistry	Biostratigraphy	Fracture-fills (clumped isotope geochem)	Fluid Inclusions	Apatite Fission Track	Provenance study	Hydro Thermal Dolomite analysis
Comeault	25 samples submitted[1] and results received.	428 samples submitted[2]	95 chitinozoan samples submitted[3]	13 samples submitted[6]	13 samples submitted[6]	6 samples submitted[6]	-	-
KK1	-	51 sample collected	10 conodont samples submitted[4] and results received; 9 micro-palynology samples submitted[4]	1 sample collected	-	-	5 samples submitted[5]	1 sample submitted[6]
Whitebear	1 sample submitted[1] and results received.	195 samples collected	39 chitinozoan samples submitted[3]	13 samples submitted[6]	5 samples submitted[6]	-	-	-
Kaskattama	-	360 samples collected	-	-	-	2 samples collected	-	-
Pennycutaway 1	-	64 samples collected	-	1 sample collected	-	-	-	-

Table 1. Summary of total samples collected in 2013-2014, types of analyses and status of samples.
[1] Submitted to the GSC-Calgary organic geochemistry lab
[2] Submitted to GSC-Quebec Delta Lab
[3] Submitted to E. Asselin, GSC-Quebec chitinozoan paleontology lab
[4] Submitted to A.D. McCracken, GSC-Calgary paleontology lab
[5] Submitted to J. Galloway (GSC-Calgary)
[6] Submitted to D. Lavoie, GSC-Quebec

Akpatok Island field work

A one-day reconnaissance survey on Akpatok Island (Figure 4) was carried out on the 15th of August, 2014, to collect geological, topographical and logistical information to help in decision-making for a potential field study on the island in 2015. The goal of a future Akpatok Island study would be to define the stratigraphic framework of this area and integrate it with the existing Hudson Bay - Foxe basins scenario (Lavoie et al., 2013). Moreover, the potential of known hydrocarbon source rock (Macauley, 1987) must be reevaluated in light of recent modern

data derived from the GEM-1 results.

The field crew included one research scientist and two polar bear monitors that were transported by a twin otter flight to Akpatok Island in the morning and picked up from the island in the evening.

During the one-day reconnaissance survey, a locality known for its organic-rich rocks was visited and several samples were collected for petroleum source rock evaluation. Furthermore, a search for outcrops with workable stratigraphic sections and the collection of samples for preliminary conodont biostratigraphy was also carried out.

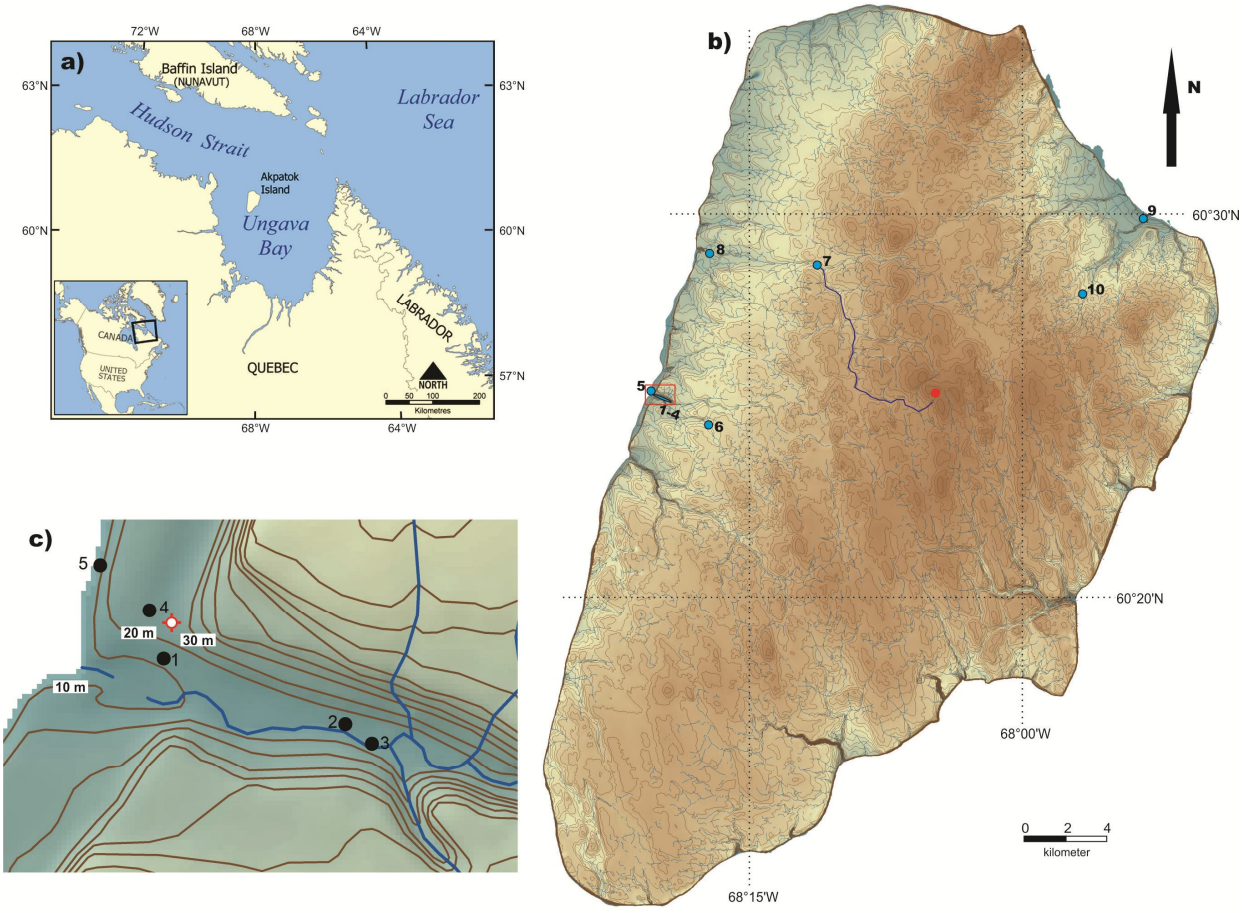

Fig. 4. a) Geographic map showing the location of Akpatok Island in Ungava Bay and Hudson Strait; b) Topographic map of Akpatok Island showing the field localities during one-day geological reconnaissance study; c) enlargement of the area marked by red rectangle in b. Modified from Zhang and Mate (in press).

RESULTS

Northern Ontario

The Hudson Platform contains mainly shallow marine carbonate rocks, evaporites and minor siliciclastics ranging from Late Ordovician to Late Devonian in age. Tectonic elements making up the platform include, from north to south, the Foxe, Hudson Bay, and Moose River sedimentary basins and the Cape Henrietta Maria Arch, separating the latter 2 basins (see inset map, Figure 2). Mesozoic marine sediments occur in the middle of the Hudson Bay Basin and continental siliciclastic sediments of Jurassic and Cretaceous age occur in the southern Moose River Basin. A stratigraphic column for the Moose River Basin is presented in Figure 5.

Late Ordovician to Early Silurian carbonate rocks that outcrop along the margin of the platform in northern Ontario were the subject of previous work during the GEM-1 project (e.g., Armstrong, 2011; Ratcliffe and Armstrong, 2013). Field work in 2014 focused on the Devonian strata of the Moose River Basin, the southernmost tectonic element of the Hudson Platform. Overviews of the Devonian stratigraphy of this region are presented by Sanford and Norris (1975), Stoakes (1978); Telford (1988) and Norris (1993).

The summary of stratigraphic assignment based on visited outcrops is presented in Table 2. The stratigraphic succession examined covers the entire Silurian – Upper Devonian interval whereas the core intercepted Lower Silurian and Upper Ordovician rocks and ended in Precambrian basement (Table 2).

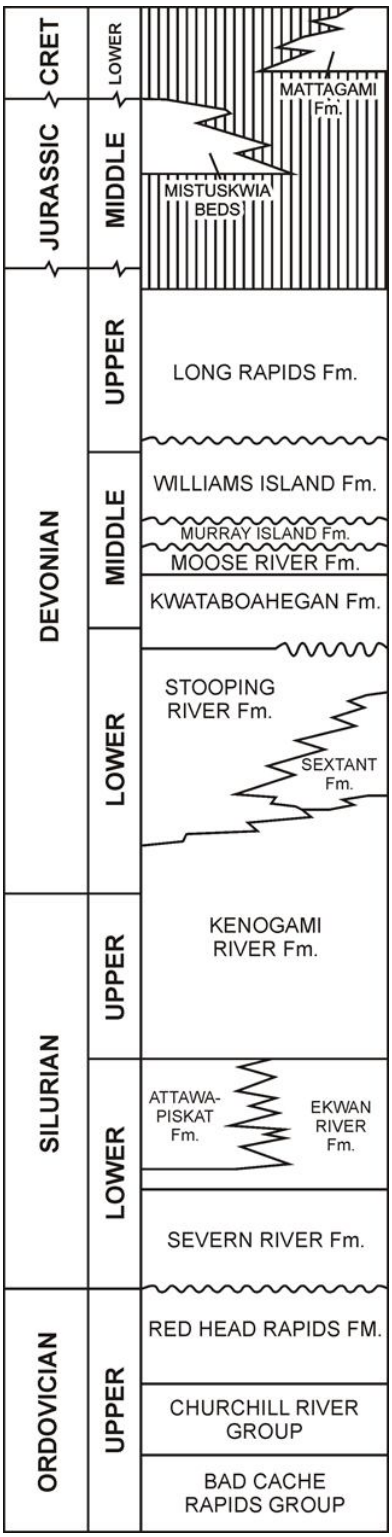

Fig. 5. Paleozoic and Mesozoic stratigraphy of the Moose River Basin (after Telford 1988 and Klapper et al. 2004).

Station ID	General Location	Latitude	Longitude	UTM easting	UTM northing	Stratigraphy	Height (m)
14DKA001	Kenogami and Albany River	51.10180	-84.48215	676278	5664161	Kenogami River Fm	7.2
14DKA002	Albany River	51.18669	-84.40842	681106	5673778	Kenogami River Fm	4.3
14DKA003	Albany River	51.30101	-83.93237	295591	5687383	Stooping River Fm	2.9
14DKA004	Cheepay River	51.24752	-83.51288	324625	5680351	Kwataboahegan Fm	1.5
14DKA005	Cheepay River	51.15268	-83.51152	324358	5669802	Kwataboahegan Fm	5.5
14DKA006	Albany River	51.45911	-85.17733	626625	5702457	Ekwan River Fm	3.3
14DKA007	Albany River	51.29130	-84.99157	640040	5684135	Kenogami River Fm	18.0
14DKA008	Kabinakagami River	50.02663	-84.02151	713325	5545843	Ekwan River Fm & Kenogami River Fm & younger clay unit	12.0
14DKA009	Stooping River	52.13335	-81.89592	438678	5776248	Stooping River Fm	1.7
14DKA010	Fancamp Exploration core DL-12-05	53.57236	-83.34344	344831	5938498	Ekwan River Fm to Precambrian	245.0
14DKA011	Albany River	52.20066	-81.90645	438051	5783744	Stooping River Fm	3.0
14DKA012	Albany River	52.23591	-81.77970	446755	5787564	Stooping River Fm	1.2
14DKA013	Albany River	52.25498	-81.70361	451972	5789631	Kenogami River Fm	0.2
14DKA014	Albany River	52.21562	-81.78050	446677	5785307	Stooping River Fm	1.8
14DKA015	Albany River	52.22617	-81.69775	452341	5786423	Kenogami River Fm	1.2
14DKA016	Ekwan River	53.46883	-83.03077	365203	5926345	Attawapiskat Fm	10.0
14DKA017	Attawapiskat River	52.90608	-82.68932	386388	5863159	Attawapiskat Fm	1.9
14DKA018	Attawapiskat River	52.85419	-83.76632	313746	5859636	Attawapiskat Fm	8.0
14DKA019	Attawapiskat River	52.94146	-83.16231	354700	5867947	Attawapiskat Fm	8.0
14DKA020	James Bay shore	51.78569	-80.65448	523833	5737259	Stooping River Fm	0.2
14DKA021	James Bay shore	51.29297	-80.11710	561561	5682775	Kwataboahegan Fm?	0.2
14DKA022	Kwetabohigan River	51.31791	-81.43078	469980	5685267	Kwataboahegan Fm	0.2
14DKA023	Kwetabohigan River	51.28133	-81.28258	480291	5681149	Kwataboahegan Fm	0.2
14DKA024	Abitibi River	50.24241	-81.66553	452544	5565795	Kwataboahegan & Stooping River Fms & dike	10.0
14DKA025	Mattagami River	50.40677	-81.81183	442311	5584173	Kwataboahegan Fm	10.0
14DKA026	Abitibi River	50.36248	-81.58877	458123	5579099	Long Rapids Fm & dike	2.0
14DKA027	Moose River	50.77673	-81.38978	472518	5625069	Williams Island Fm	2.0
14DKA028	Moose River	50.81818	-81.29783	479020	5629648	Murray Island & Moose River Fms	7.5
14DKA029	Moose River	50.82387	-81.29852	478974	5630281	Murray Island Fm	4.9
14DKA030	Moose River	50.86660	-81.23137	483718	5635016	Murray Island Fm	1.2
14DKA031	Moose River	50.88755	-81.18165	487223	5637336	Moose River Fm	3.8
14DKA032	Moosonee quarry	51.22049	-80.70290	520749	5674387	Kwataboahegan Fm	2.0
14DKA033	Abitibi River	51.06134	-80.89154	507601	5656652	Kwataboahegan Fm	2.3
14DKA034	Coal River (tributary to Missinaibi River)	50.10926	-83.06687	352215	5552825	Kenogami River Fm	10.0

13DKA023	Kabinakagami River	50.05488	-84.07849	709122	5548822	Kenogami River Fm	1.0

Table 2. Location and basic stratigraphic information for 2014 field mapping stations (outcrop and drill-core). Height is measured from the base of the outcrop; for outcrops with significant dip, height is true stratigraphic height. Height value listed for 14DKA010 (drill-core DL12-05), refers to the total vertical thickness of Paleozoic bedrock intersected. Modified from Armstrong (in press).

Northeastern Manitoba

The Manitoba Geological Survey (MGS) 2014 field component of GEM-2 focused on outcrop exposures located along the Churchill River and the Churchill coastal area (Figure 3). Over the course of three days (helicopter support), M. P. B. Nicolas (MGS) and G. Young (The Manitoba Museum) visited key sites along the Churchill River. Lithostratigraphic type sections for the Upper Ordovician Portage Chute, Surprise Creek, Caution Creek, Chasm Creek and Red Head Rapids formations (Figure 6) are all located along the Churchill River and its tributaries. Each of the type section localities were visited, with the exception of the type locality for the Caution Creek Formation (for this formation, exposures at other sites were visited). Over four days, by truck, exposures along the Churchill coastal area were visited. These exposures provided a comparative section to those observed along the Churchill River, demonstrating the stratigraphic complexities caused by the proximity to the Proterozoic-aged Churchill quartzite, which stood out as islands during the Ordovician.

The preliminary results from this field work indicated that the Lower Paleozoic strata visited along the Churchill River correlate well with observations made in core from boreholes, and in field visits to other parts of the Hudson Bay Basin (e.g. Southampton Island). While there are broad similarities to strata of similar age in other parts of the basin, some of the sections visited in the Churchill coastal area exhibit features that are distinctly local in distribution and reflective of the diverse micro-environments characteristic of nearshore conditions.

Bulk samples were collected by the MGS at most of the field stations visited, with the expectation to conduct $\delta^{13}C$ and $\delta^{18}O$ stable-isotope geochemistry on them. Fossil specimens were

collected by G. Young at most sites to assist with the biostratigraphy of the sections and to collect representative specimens present in each formation.

A detailed evaluation of the diagenetic evolution of the Lower Silurian carbonates was carried out at the University of Manitoba (Eggie et al, in press), and will be released shortly. The Lower Silurian carbonates are considered as potential hydrocarbon reservoirs elsewhere in the Hudson Bay basin (Lavoie et al., 2013).

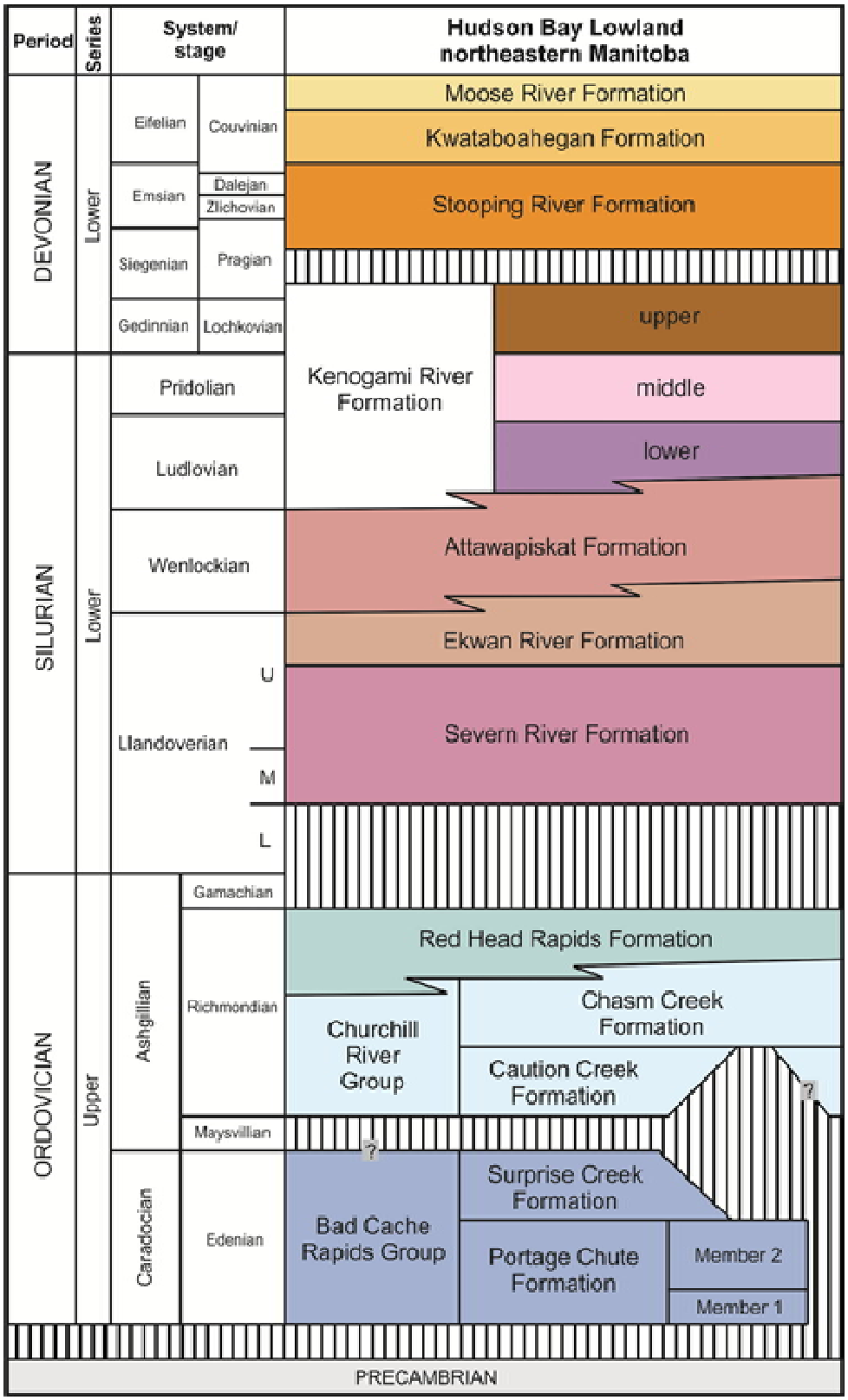

Fig. 6: Stratigraphy of the Hudson Bay platform in Manitoba. From Lavoie et al. (2013).

Akpatok Island

A total of five rubble samples (Table 3) of brown argillaceous and bituminous limestone were collected at stations 2, 3 and 4 (Figs. 4b and 4c) at an elevation of 10–30 m along a valley immediately southeast of Akpatok F-26 well for Rock Eval[6] analysis. The results are more favorable for hydrocarbon generation than suggested in previous report (Macauley, 1987) and will be released soon (Zhang and Mate, in press).

A total of 13 limestone samples were collected from outcrops at stations 5–9 along three discrete valleys (Fig. 4b) for conodont processing. The samples are being processed in the Paleo-lab at GSC-Calgary. The conodonts will provide information about the age of the exposed limestone on the island and correlation to the Ordovician strata in Foxe Basin and Hudson Bay areas, and the stratigraphic position of the organic-rich interval within the Ordovician sequence on the island.

The one-day reconnaissance survey aimed to visit several known sites. However the previously reported outcrops of brown argillaceous and bituminous limestone were not found, nor were the outcrops 130–140 m above the mean sea level.

Stations	coordinates		Samples	
			Conodonts (C)	Rock Eval (R)
1	60°25'31.1"	68°20'02.3"	no samples	
2	60°25'26.7"	68°19'38.2"	SZ14-02A-01C	
			SZ14-02A-02C	
				SZ14-02A-02R
3	60°25'25.3"	68°19'34.6"		SZ14-03A-01R
				SZ14-03A-02R

4	60°25'34.3"	68°20'04.1"		SZ14-04A-01R
5	60°25'37.3"	68°20'10.6"	SZ14-05A-01C	
			SZ14-05A-02C	
6	60°24'42.5"	68°17'07.5"	SZ14-06A-01C	
			SZ14-06A-02C	
			SZ14-06A-03C	
7	60°28'54.8"	68°11'09.8"	SZ14-07A-01C	
			SZ14-07A-02C	
8	60°29'15.0"	68°16'57.7"	SZ14-08A-01C	
			SZ14-08A-02C	
9	60°30'04.5"	67°53'31.5"	SZ14-09A-01C	
	60°29'57.2"	67°53'32.6"	SZ14-09A-02C	
10	60°28'02.7'	67°56'53.7"	no samples	

Table 3. Location and nature of samples collected on Akpatok Island

CONCLUSIONS

As planned at the start of the Hudson Bay – Ungava GEM-2 project, field work and core descriptions were carried out in northern Ontario, northeastern Manitoba and Akpatok Island. The goal of these surveys was to enhance our stratigraphic understanding of the Manitoba section and to generate a new stratigraphic description for the Devonian succession in Ontario as well as the Ordovician one on Akpatok Island (Nunavut). All these new observations, complemented by biostratigraphy and chemostratigraphy (in progress) will allow the definition of fine-scale stratigraphic correlation at the basin-scale.

As part of the stratigraphy activity, samples for source rock evaluation were collected in all three study areas. Rock Eval results are available for Manitoba and Akpatok Island and are

reported in Nicolas et al (in press) and Zhang and Mate (in press), respectively. In Manitoba, intervals with significant source rock potential from high organic matter content have been identified with previously poorly characterized Lower Silurian intervals with source rock potential.

ACKNOWLEDGEMENTS

The first author of this report acknowledges the diligent and rapid submission of the summary of stratigraphic activities from its three co-authors. Virgina Brake is gracefully thanked for her review of this contribution. Thanks are also extended to Réjean Couture for efficient leadership of the project and comments on this contribution.

REFERENCES

Armstrong, D.K. 2011. Re-evaluating the hydrocarbon resource potential of the Hudson Platform: Interim results from northern Ontario. In: Summary of Field Work and Other Activities 2011, Ontario Geological Survey, Open File Report 6270, p.27-1 to 27-11.

Armstrong, D.K. in press. Project Unit 10-028. Hudson Platform Project: aggregate sampling and Paleozoic geology of the Moose River Basin, Northern Ontario. In: Summary of Field Work and Other Activities 2014, Ontario Geological Survey, Open File Report

Eggie, L.A., Pietrus, E., Ramdoyal, A. and Chow, N. in press. Diagenesis of the Lower Silurian Ekwan River and Attawapiskat formations, Hudson Bay Lowland, northern Manitoba (part of NTS 54B, F and G). In: Report of Activities 2014, Manitoba Mineral Resources, Manitoba Geological Survey.

Klapper, G., Uyeno, T.T., Armstrong, D.K. and Telford, P.G. 2004. Conodonts of the Williams Island and Long Rapids formations (Upper Devonian, Frasnian-Famennian) of the Onakawana B drillhole, Moose River Basin, northern Ontario, with revision of the lower Famennian species; Journal of Paleontology, v.78, p.371-387.

Lavoie, D., Pinet, N., Dietrich, J., Zhang, S., Hu, K., Asselin, E., Chen, Z., Bertrand, R., Galloway, J., Decker, V., Budkewitsch, P., Armstrong, D., Nicolas, M., Reyes, J., Kohn, B.P., Duchesne, M.J., Brake, V., Keating, P., Craven, J. and Roberts, B. 2013. Geological framework, basin evolution, hydrocarbon system data and conceptual hydrocarbon plays for the Hudson Bay and Foxe basins, Canadian Arctic; Geological Survey of Canada, Open File 7363, 210 p.

Macauley, G. 1987. Geochemistry of organic-rich Ordovician sediments on Akpatok and Baffin islands, Northwest Territories; Geological Survey of Canada, Open File 1502, 27 p.

Nicolas, M.P.B., Lavoie, D. and Harrison, J. in press. Introduction to the new GEM-2: Hudson–

Ungava Project, Hudson Bay Lowland, northeastern Manitoba. In: Report of Activities 2014, Manitoba Mineral Resources, Manitoba Geological Survey.

Nicolas, M.P.B. and Young, G.A. in press. Reconnaissance field mapping of the Paleozoic rocks along the Churchill River and Churchill coastal area, northeastern Manitoba (parts of NTS 54E, L and K). In: Report of Activities 2014, Manitoba Mineral Resources, Manitoba Geological Survey.

Norris, A.W. 1993. Hudson Platform—Geology. In: Sedimentary cover of the craton in Canada. D.F. Stott and J.D. Aitken (eds.). Geological Survey of Canada, Geology of Canada, no.5, p.653-700. (also Geological Society of America, The Geology of North America, v.D-1).

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

Ratcliffe, L.M. and Armstrong, D.K. 2013. The Hudson Platform Project: 2013 field work and drill-core correlations, western Moose River Basin. In: Summary of Field Work and Other Activities 2013, Ontario Geological Survey, Open File Report 6290, p.36-1 to 36-19.

Sanford, B.V. and Norris, A.W. 1975. Devonian stratigraphy of the Hudson Platform—Part 1: Stratigraphy and economic geology; —Part II: Outcrop and subsurface sections; Geological Survey of Canada, Memoir 379, 372p.

Stoakes, F.A. 1978. Lower and Middle Devonian strata of the Moose River Basin, Ontario; Ontario Petroleum Institute Proceedings, v.17, Paper 4.

Telford, P.G. 1988. Devonian stratigraphy of the Moose River Basin, James Bay Lowland, Ontario. In: Devonian of the World, Volume 1: Regional Syntheses, Canadian Society of Petroleum Geologists, Memoir 14, p.123-132.

Zhang, S. 2010. Upper Ordovician stratigraphy and oil shales on Southampton Island, field trip guidebook; Geological Survey of Canada, Open File 6668, 42p.

Zhang, S. and Mate, D. in press. Geological Reconnaissance, Akpatok Island, Nunavut. Canada. In: Summary of Activities 2014, Canada-Nunavut Geoscience Office.