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FORWARD

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

During the 2017 field season, research scientists from the GEM program successfully carried out 27 research activities, 26 of which will produce an activity report and 12 of which included fieldwork (Fig. 1). Most activities included geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, Northerners and their institutions, academia and the private sector. GEM will continue to work with these key partners as the program advances.

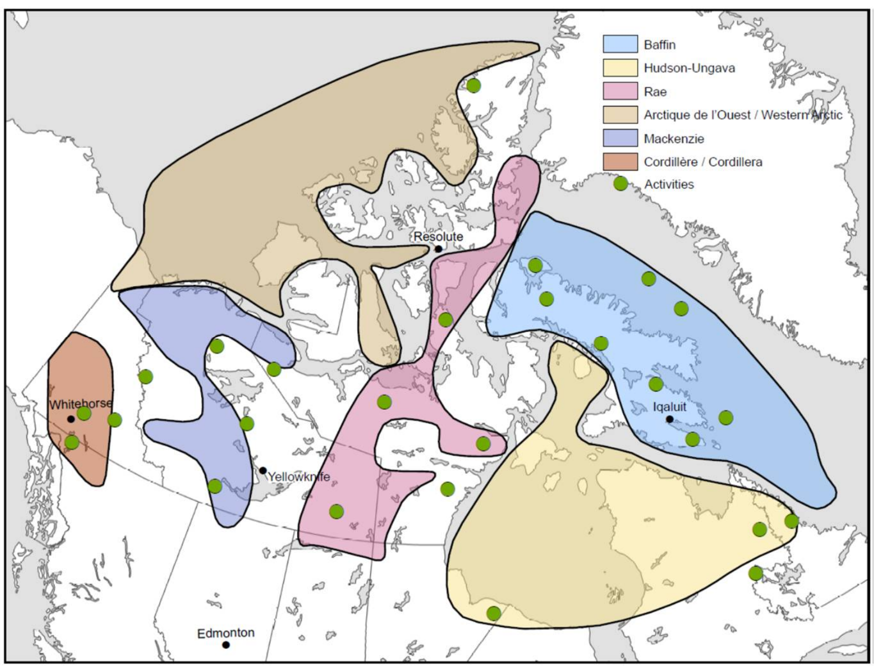

Figure 1. Location of GEM 2 projects with main research activities. The details for Hudson Bay – Ungava is on Figure 2

PROJECT SUMMARY

The Arctic is the last area with significant conventional hydrocarbon potential to be explored. A report by the United States Geological Survey indicates reserves of over 90 billion barrels of oil, 44 billion barrels of natural gas liquids and 1670 trillion cubic feet of natural gas (Bird et al., 2008), with a significant portion of these reserves located in the Canadian Arctic.

The Hudson Bay Basin is one of these under explored sedimentary basins in the Canadian Arctic. This basin is the largest intracratonic basin in North America and, unlike other similar basins in North America (Michigan, Illinois, Williston basins) which are world-class hydrocarbon producers, only ten exploration wells have been drilled in the Hudson Bay Basin (5 onshore and 5 offshore) between 1960s to early 1980s, with no commercial discovery. As part of the initial phase of the Geoscience for Energy and Minerals (GEM) program, a re-evaluation of historical exploration data and strategic acquisition of new hydrocarbon system data led to the conclusion that most of the key elements for a petroleum system are present in the Hudson Bay Basin, suggesting that its hydrocarbon potential has been under evaluated (Lavoie et al., 2013, 2015).

The Hudson Bay – Ungava project of the second phase of the GEM program aims to provide new information and models for the evolution of the Hudson Bay Basin which will serve as the cornerstone for a modern appraisal of the hydrocarbon prospectivity of the largest sedimentary basin in Canada (Fig. 1 and 2).

This report presents a summary of all laboratory works carried out in 4 activities currently in progress or phasing out for the energy component of the GEM-2 Hudson-Ungava project; stratigraphy, source and reservoir rocks, hydrographic survey and RADARSAT-2 research.

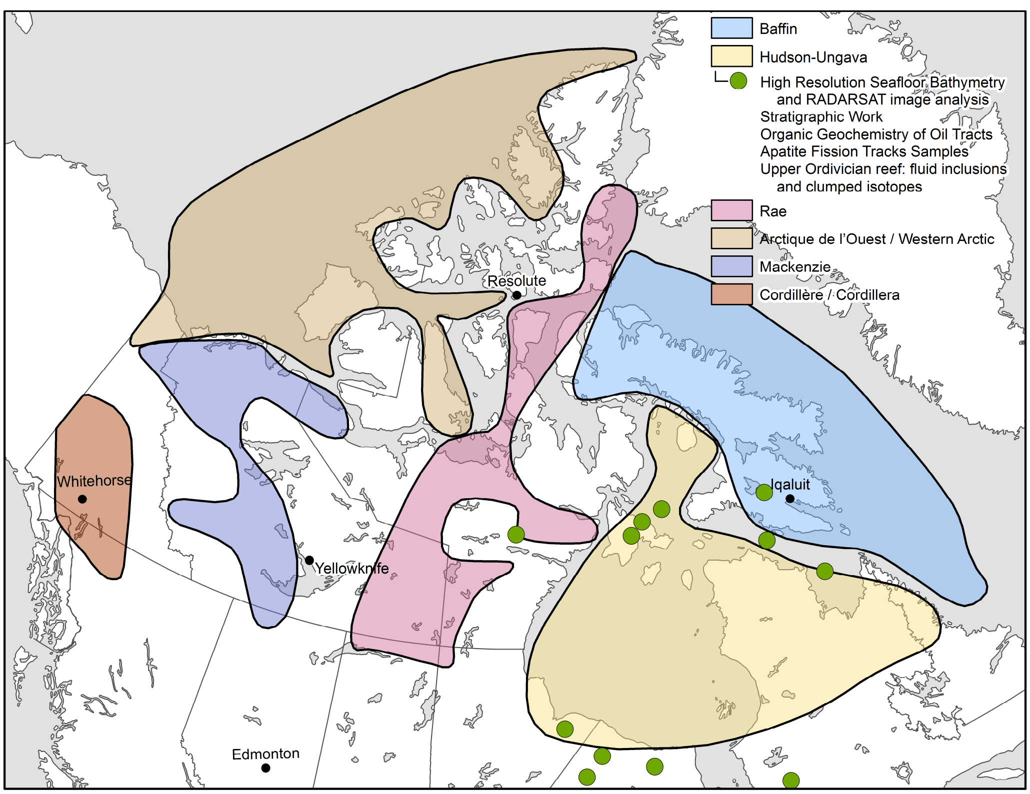

Figure 2. Location map of the Hudson Bay, Hudson Strait and Foxe Basin, together with areas of planned marine high-resolution bathymetry data acquisition and/or studied samples for research activities discussed in the report

INTRODUCTION TO HUDSON-UNGAVA 2017 ACTIVITIES

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

Building an integrated regional stratigraphic framework is the natural continuation of the work completed as part of the first phase of GEM where specific local sedimentary successions were documented (Lavoie et al., 2013). The fine-scale correlations of these successions (Ontario, Manitoba, Nunavut, 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 addresses two fundamental scientific questions:

1. How have geodynamic factors, such 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 2017 report, biostratigraphic and chemostratigraphic integrated results and transprovincial correlation from Ontario and Manitoba are presented and preliminary interpretation discussed. For this activity, the 2017-2018 period is devoted to scientific integration and diffusion of data.

Understanding of hydrocarbon systems – source and reservoir rocks

The regional understanding of hydrocarbon systems (source and reservoir rocks, thermal maturation, hydrocarbon generation and expulsion, traps and seals) was initially addressed as part of the first phase of GEM with preliminary positive conclusions on the presence of all the above elements and events (Lavoie et al., 2013, 2015). A better knowledge of hydrocarbon systems for the entire Hudson Bay and Strait area is a critical element of the second phase of the GEM program. This will be accomplished through detailed field work combined with laboratory analyses (organic and inorganic geochemistry, thermal indicators, marine geophysical works and remote sensing).

Like the integrated stratigraphy activity, this activity addresses the same fundamental scientific questions:

1. How have geodynamic factors, such 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 2017 report, laboratory works will be discussed and include, i) organic geochemical characterization of oil extracted from the artificial maturation of immature source through hydrous pyrolysis (Reyes et al., 2016) and ii) status of the thermal modeling based on apatite fission track data.

Hydrographic survey and linked geoscience

This activity was initiated in 2016-2017 with the planning of a high-resolution seafloor bathymetry (hydrographic survey) in collaboration with the Canadian Hydrographic Service. The survey aimed at imaging possible seafloor hydrocarbon-seeping pockmarks north of Southampton island where abundant potential oil slicks were identified from analyses of RADARSAT images during GEM 1 (Decker et al., 2013). However, mechanical issues onboard the dedicated acquisition vessel prevented the study to be carried out.

A joint hydrographic survey with GEM 2 Baffin project and offshore Baffin project in the Public Safety Program was discussed, developed and funded for September 2017. The goal for the Hudson Bay – Ungava project was as in 2016, to search for seafloor pockmarks in the Hudson Strait and Foxe Channel where potential oil slicks have been imaged through GEM-1 and initial GEM-2 RADARSAT image analysis (see further in this report). In April / May 2017, a community tour included presentations to communities (Iqaluit, Kimmirut, Cape Dorset, Coral Harbour), to Hunter and Trappers Organizations (Kimmirut, Cape Dorset, Coral Harbour), to Inuit Associations (KIA in Rankin Inlet, QIA in Iqaluit) as well as presentation and discussion of the project at the Kuujjuak Mining Symposium. However, in June 2017, the Canadian Coast Gard informed us that the dedicated vessel for the survey (CCGS Hudson) would not be available because of on-going extensive repairs and that no other Coast Gard vessel was available. In July 2017, a public call of interest for technically compliant hydrographic vessel was sent out. The three shows of interest did not satisfy either the technical aspect or the strict time schedule imposed by water conditions in the Arctic. The planned hydrographic survey was cancelled for 2017-2018 with the plan to reschedule it next year.

This activity addresses the following fundamental scientific question:

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

Nonetheless, linked laboratory geoscience research is in progress. These research activities include i) detailed fluid inclusion thermometry from Upper Ordovician reef on Southampton Island and ii) development of in-house clumped isotopes facility with initial research on the same Upper Ordovician reef unit. Both activities aim at defining the complex burial history of the Upper Ordovician potential hydrocarbon reservoirs in the immediate area to be surveyed for seafloor pockmarks.

RADARSAT-2 image acquisition, interpretation, and methods development for identification of potential oil slicks

This activity involves a multi-year acquisition plan and interpretation of RADARSAT images over Hudson Strait in order to record occurrences of potential oil slicks in the area. The GEM-1 supported activity over Hudson Bay and Foxe Basin provided critical initial results and established a collection of historic data that is ultimately required as a basis for any further investigation or monitoring in the region (Decker et al., 2013). This GEM-2 activity will build upon these results by strengthening the baseline data to support further targeted investigations and will aid in improving knowledge of the subsurface geology and hydrocarbon potential in the Hudson Bay / Strait and Foxe Channel. Additional observations of spatially and temporally coincident dark features using satellite imagery raises the probability that natural seep occurrences exist and will provide valuable geoscience information about hydrocarbon resources.

This activity addresses the following fundamental scientific question:

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

In this report, images acquisition program for 2016 in the Hudson Strait and their preliminary interpretations are discussed.

METHODOLOGY and RESULTS

Chemostratigraphically supported correlations of Silurian and Lower Devonian on the southern on-shore flank of the Hudson Bay Basin

Introduction

Manitoba Geological Survey (MGS) and the Ontario Geological Survey (OGS) are partners in the Geological Survey of Canada (GSC) Geo-mapping for Energy and Minerals 2 (GEM-2) program. The MGS and OGS are participating in the Hudson–Ungava project that includes multi-jurisdictional and academic partners, including the Geological Survey of Canada, Canada-Nunavut Geoscience Office, Laurentian University and University of Manitoba.

In Manitoba and Ontario, the purpose of the project has been to enhance our understanding of the stratigraphic and sedimentological framework and structural complexities of the onshore component of the Hudson Bay Basin (HBB) in the Hudson Bay Lowland (HBL) in northeastern Manitoba and northern Ontario, correlate them between jurisdictions, and build a seamless stratigraphic framework for the southern part of the HBB. This information can then be integrated with offshore and northern models for the basin to create a basin-wide stratigraphic framework that can form the basis to better assess the petroleum potential of the basin and inform future exploration and land-use planning.

This section is a summary of a more detailed report highlighting recent successes in correlating the Silurian and part of the lower Devonian succession between northern Ontario and Manitoba (Nicolas and Armstrong 2017). The correlations are based on new lithologic logs and available geophysical logs of wells drilled onshore in northeastern Manitoba, and northern Ontario (Fig. 3), in addition to new biostratigraphic data, and new stable carbon and oxygen isotope data for carbonates that have been used to create chemostratigraphic profiles. In addition, data from outcrops examined in both Manitoba and Ontario have been incorporated in these interpretations.

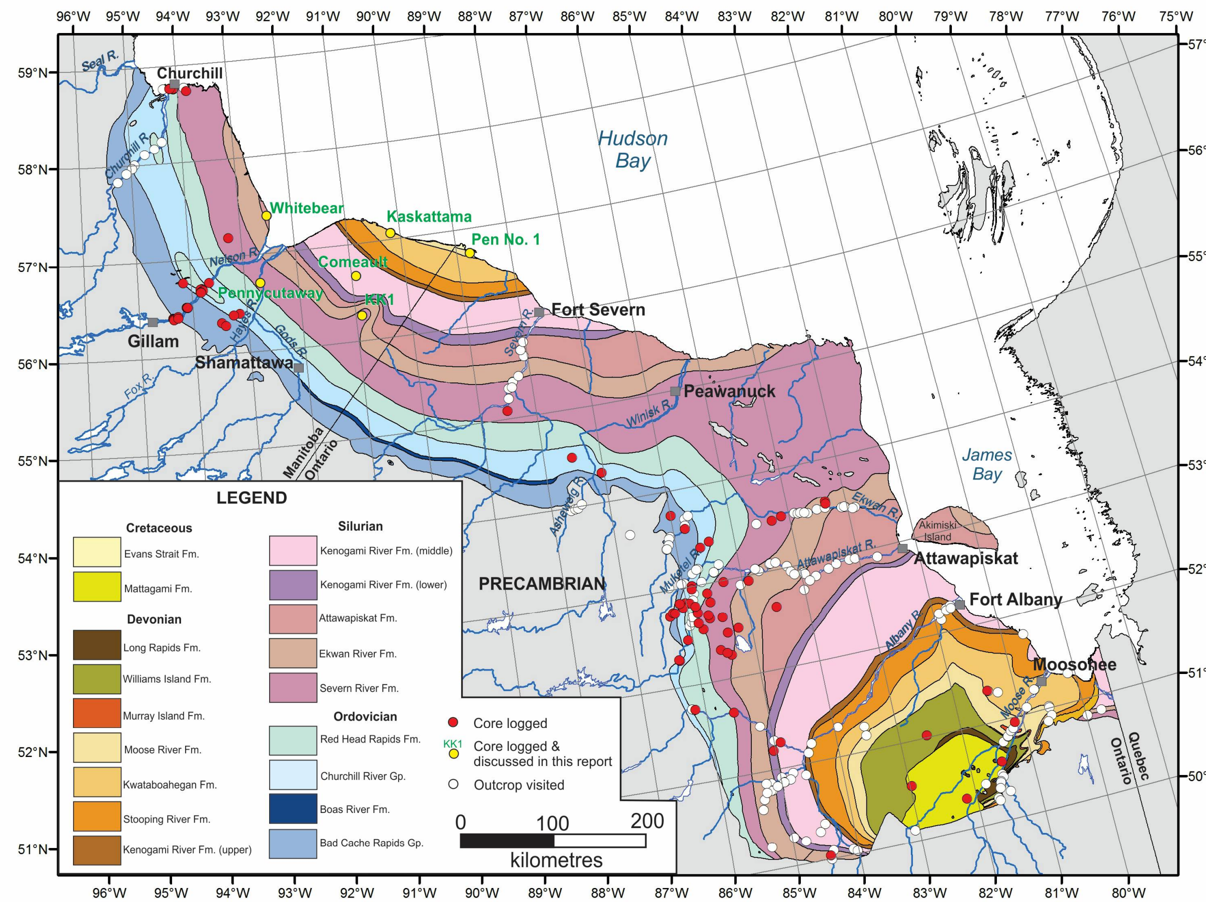

Figure 3: Regional Phanerozoic geological map showing locations of wells and outcrops studied for this project. Manitoba geology is modified from Nicolas et al. (2014); Ontario geology is modified from Ontario Geological Survey (2011) and Sanford and Grant (1998). Modified from Nicolas and Armstrong (2017).

Overview of On-shore Cores

Cores studied from northeastern Manitoba include Aquitaine Kaskattama Prov. No. 1, Houston Oils et al. Comeault Prov. No.1, Merland et al. Whitebear Creek Prov., Foran Mining Kaskattama Kimberlite No. 1, and Pennycutaway No. 1, herein referred to as Kaskattama, Comeault, Whitebear, KK1 and Pennycutaway, respectively (Fig. 3). Previous GEM-2 supported reports on these wells include Nicolas (2016a, b), Nicolas et al. (2014) and Nicolas and Lavoie (2012). These wells were correlated with the deepest well in northern Ontario, the Aquitaine Sogepet et al. Pen No. 1 well, or Pen No. 1, which has been previously reported on by Armstrong et al. (2013). Available geophysical logs, core recovery and the stratigraphic section intersected all varied among these wells. Nicolas and

Armstrong (2017) selected Pen No. 1 as a reference well for this region because it was the deepest, had the most continuous core recovery and included a limited suite of geophysical logs including with natural gamma (GR). The near continuous core recovery of this well, allowed more detailed sampling and analysis, enabling creation of a more detailed isotopic chemostratigraphic profile.

Stratigraphic Correlations

The Hudson Bay Basin Silurian and Devonian sections (Fig. 4) in the Hudson Bay Lowland region in northeastern Manitoba and into northern Ontario have been a challenge to correlate confidently. This is due in part to the widely spaced nature of the wells, their variable core recoveries and available downhole geophysical logs. For this study cores, core photographs, biostratigraphic data and geophysical logs were re-examined, in light of comparative analysis of the various $\delta^{13}C$ isotopic profiles. In some cases, formational contacts were lithologically obvious, with some coinciding with geophysical responses (especially Gamma Ray) and with features in the isotopic profile such as inflections or excursions. Where geophysical log suites differed between wells or core recovery was poor, isotopic profiles were used to extend correlations. In some cases this process resulted in changes to previous formation top picks. New, more confidently picked, stratigraphic tops for 4 of the wells re-examined for this project are presented in Table 1. Analysis of the Pennycutaway core results were still under evaluation at the time of this writing.

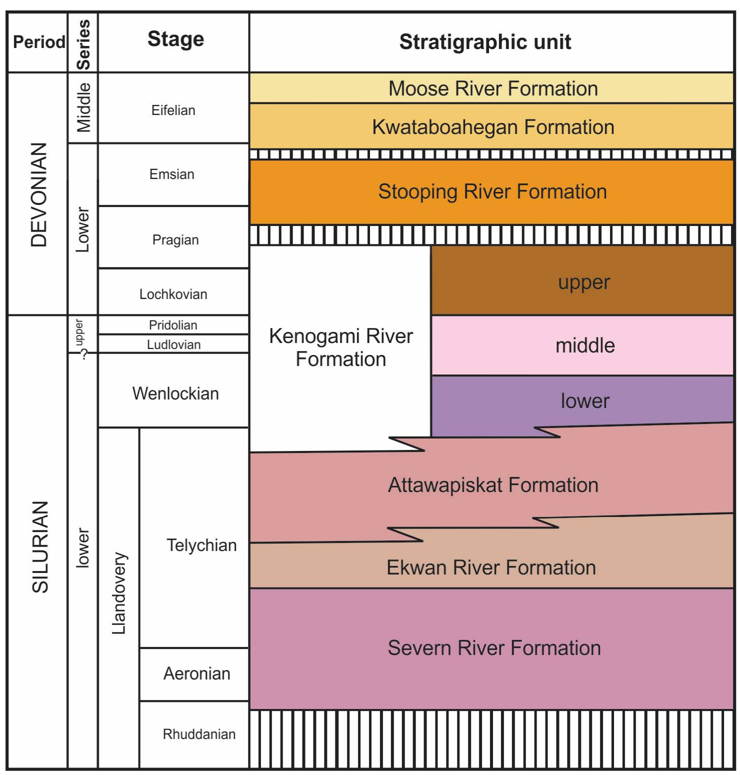

Fig. 4: Time-stratigraphic framework for the Silurian and Devonian succession in the Hudson Bay Basin in northeastern Manitoba and northern Ontario (excludes northeastern Ontario). System and stages are from the International Commission on Stratigraphy (2014), but their relationships to the formations are based on Norford (1997) and Zhang and Barnes (2007) for the Silurian, and Sanford and Norris (1975) for the Devonian. From Nicolas and Armstrong (2017).

		KK1		Whitebear		Comeault		Kaskattama		Pen No.1	
Era/Epoch	**Formation/Member**	Depth (m)	Depth (ft)	Depth (m)	Depth (ft)	Depth (m)	Depth (ft)	Depth (m)	Depth (ft)	Depth (m)	Depth (ft)
Quaternary	Glacial Drift (till and gravel)	16.80	55.12	NA	NA	NA	NA	0	0	3.00	10.00
	Base of Glacial Drift	223.40	732.94	NA	NA	NA	NA	7.01	23.00	41.80	137.00
Tertiary or Cretaceous	unnamed	223.40	732.94	-	-	-	-	-	-	-	-
Devonian	Moose River Formation	-	-	-	-	-	-	-	-	41.80	137.00
	Kwataboahegan Formation	-	-	-	-	-	-	7.01	23.00	95.10	312.00
	Stooping River Formation	-	-	-	-	-	-	46.02	151.00	133.50	438.00
	Kenogami River Formation	-	-	-	-	-	-	103.33	339.00	216.41	710.00
	upper member	-	-	-	-	-	-	103.33	339.00	216.41	710.00
Silurian	middle member	-	-	-	-	-	-	128.93	423.00	240.80	790.00
	lower member	-	-	-	-	< 60.96	< 200	283.52	930.20	382.40	1254.60
	Attawapiskat Formation	-	-	-	-	122.25	401.00	329.79	1082.00	425.50	1396.00
	Ekwan River Formation	-	-	-	-	158.59	520.30	393.50	1291.00	506.36	1661.30
	Severn River Formation	257.10	843.50	< 30.48	< 100.00	200.10	656.30	433.43	1422.00	551.66	1809.90
	upper member	-	-	< 30.48	< 100.00	200.10	656.50	433.43	1422.00	551.66	1809.90
	middle member	-	-	130.15	427.00	323.09	1060.00	555.35	1822.00	669.65	2197.00
	lower member	257.10	843.50	194.77	639.00	382.52	1255.00	634.90	2083.00	750.42	2462.00
Ordovician	Red Head Rapids Formation	330.70	1084.97	220.68	724.00	411.60	1350.40	667.97	2191.50	787.45	2583.50
	Churchill River Group			269.44	884.00	466.88	1531.75	731.89	2401.20	861.91	2827.80
	Chasm Creek Formation			269.44	884.00	466.88	1531.75	731.89	2401.20	861.91	2827.80
	Caution Creek Formation			299.92	984.00	492.80	1616.80	758.95	2490.00	886.05	2907.00
	Bad Cache Rapids Group			328.57	1078.00	529.47	1737.10	793.70	2604.00	924.15	3032.00
	Surprise Creek Formation			328.57	1078.00	529.47	1737.10	793.70	2604.00	948.38	3032.00
	Portage Chute Formation			359.66	1180.00	564.22	1851.12	818.39	2685.00	948.38	3111.50
	Member 2			359.66	1180.00	564.22	1851.12	818.39	2685.00	1018.95	3111.50
	Member 1			391.97	1286.00	614.32	2015.50	884.83	2903.00	1018.95	3343.00
Precambrian	Precambrian (weathered)			396.54	1301.00	616.00	2021.00	887.67	2912.30	1021.38	3351.00
	Precambrian (fresh)					617.22	2025.00	889.41	2918.00		

Table 1: Stratigraphic tops for select wells in the Hudson Bay Lowland in northeastern Manitoba and northern Ontario. Dashes indicate that stratigraphic unit is not present in the core. Abbreviation: NA, information not available. From Nicolas and Armstrong (2017)

Results and Concluding Remarks

Results of this project include the recognition of commonalities among $\delta^{13}C$ profiles for the wells studied and application of these to support (and in some cases modify) regional lithostratigraphic correlations. These common chemostratigraphic features or patterns were also recognized in data from the outcrop belt and cores in the Moose River Basin. For more detailed presentation and discussion of the results of this study the reader is referred to Nicolas and Armstrong (2017).

The combined efforts of the MGS and OGS, supported by the GSC, has resulted in a more robust stratigraphic framework for the Silurian of the southern HBB, supported by the development of a $\delta^{13}C$ chemostratigraphic profile for the Silurian section here.

Geochemistry of source rock extracts

Upper Ordovician limy shales to shaly limestones of the Boas River, Red Head Rapids, Amadjuak and Akpatok formations have been documented to be very rich hydrocarbon source rocks (Lavoie et al., 2013) (Fig. 1), but marginally mature to immature in outcrops at the margin of the Hudson Bay Basin. In 2016-2017, these 4 rock units were artificially matured to higher temperatures through closed-system hydrous pyrolysis (Reyes et al., 2016). The pyrolysis experiences generated various quantities of oil; the organic geochemistry of the produced oil is currently characterized.

GC and GC-MS analysis has been completed on the solvent extracts of the pyrolyzed shale samples at 310 to 350°C for 3 days, and at 350°C for 7 and 9 days. Full interpretation of the analytical results aims to evaluate the thermal evolution character of the biomarkers of these Upper Ordovician limey shales, and this may assist us with oil-oil and oil-source correlation if any hydrocarbon fluids are available in the future.

However, a partial interpretation of the results has been done to demonstrate the variation of the depositional environment and maturation related parameters Pr/Ph, Pr/nC17 and Ph/nC18 with increasing thermal maturation (Fig. 5). The information obtained is being used for investigating whether the xenolith shale from Hall Peninsula (samples submitted by Shunxin Zhang) is related to the Upper Ordovician shale. The following attached figure seems to indicate that the xenolith is of similar origin to the Upper Ordovician outcrop shales from Southern Baffin, with the exception that the xenolith is thermally more mature. Results from bulk carbon isotope analysis of the saturate and aromatic fractions also suggest the xenolith can be a result of the thermal maturation of Upper Ordovician shale.

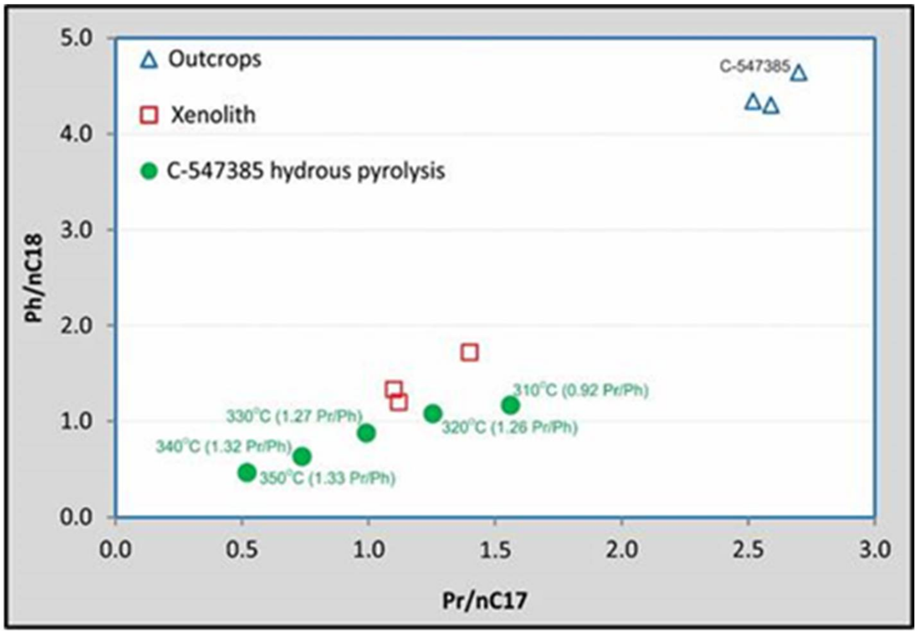

Figure 5. Cross-plot of ratios pristane over C17 n-alkane (Pr/nC17) and phytane over C18 n-alkane (Ph/nC18) for the xenolith samples from Hall Peninsula, the Upper Ordovician outcrop samples from southern Baffin Island, and the extracts from sample C-547385 after hydrous pyrolyzed at 310 to 350C for three days. Pr/Ph ratios are shown for the pyrolyzed samples in bracket for each temperature point. Pr/Ph of 1.42-1.46 for xenolith samples (red squares); and 0.66-0.67 for the Upper Ordovician outcrop samples (blue triangles).

Apatite fission track study

The analyses and inverse modeling of apatite fission track (AFT) allows better constraining the burial and exhumation history of sedimentary basins as well as providing critical information about the maximum burial temperature reach by the succession. As part of GEM-1, a first suite of samples has been analyzed (Lavoie et al., 2013) and those results were re-evaluated as the initial phase of AFT research for GEM-2 (Pinet et al., 2016).

In 2017-2018, the AFT activity consists in the analysis of eight new samples from material collected in a 3.6 km deep profile (LaRonde Mine). More samples from the Musselwhite, Meadowbank and Roberto mines will be integrated in the existing dataset to better constrain the spatial variability of AFT data for the regional burial history of the Hudson Bay Basin (Fig. 1).

The samples consist of Precambrian basement lithologies known to carry various amounts of apatite. The selected localities are located around the Hudson Bay Basin and may have recorded burial/exhumation events linked to the Phanerozoic history of the craton. The material submitted at the thermochronology laboratory at Dalhousie University were analyzed and the lengthy process of data modelling and interpretation is in progress.

Upper Ordovician reef fluid inclusion study

The study reef is located 34 km SW of Coral Harbour on Southampton Island where a large massive and very porous reef mound of the Red Head Rapids Formation is exposed (Heywood and Sanford, 1976; Zhang, 2010) (Fig 1). The mound core facies is well visible, but flanking and inter-reef facies were eroded. Castagner (2016) and Castagner et al (2016) presented a detailed analyses of the facies architecture and initiated the study of the diagenetic evolution of the reef in order to understand the porosity origin with respect to the burial history of the unit. The work consisted of petrography and analyses of conventional oxygen and carbon isotopes of the various carbonate phases.

Eighteen (18) double-polished thin sections for fluid inclusions microthermometry were prepared from the samples that were selected for the diagenetic analyses. Data is currently available for 7 samples. Fluid inclusions microthermometry documents the presence of two distinct populations of homogenization temperatures (T_h), one present in secondary pore-filling burial calcite cement (T_h between 70 and 135°C) and a second one in neomorphosed early marine cements (T_h between 94 and 177°C). (Fig. 6). The combined $\delta^{18}O_{VPDB}$ and T_h data from individual samples suggest late burial cements precipitated from a fluid having $\delta^{18}O_{SMOW}$ values between 1 and -2‰, whereas the marine cements data indicate resetting of the fluid inclusions in the presence of a high temperature, $\delta^{18}O_{SMOW}$ heavy brine (+3 to +12‰) (Fig. 7). The lower temperature fluid inclusions of the late pore-filling calcite cement is in good agreement with recent Apatite Fission Track data suggesting early oil window temperature (*circa* 72°C). The higher temperature T_h values recorded in the neomorphosed marine cement are interpreted to represent fluid inclusions resetting or entrapment of new fluid inclusions from fracture-controlled circulation of basement-derived hotter fluids. The circulation of the hot brines that had affected the marine cement occurred sometime after start of burial, a scenario also supported by the presence of hydrothermal carbonate breccia in other Upper Ordovician facies in the succession. The petrographic and geochemical data suggest that after marine cementation, inception of burial and early aragonite to calcite neomorphism, fault and fracture-controlled high temperature brines circulation resulted in generation of significant secondary porosity later filled by lower temperature burial cements and hydrocarbons.

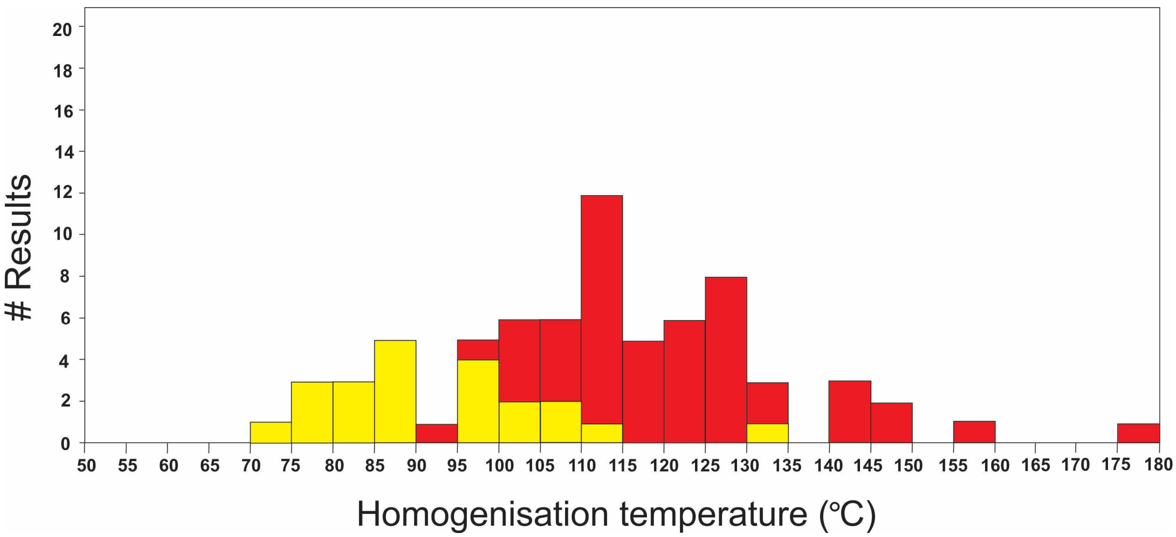

Figure 6. Histogram showing the distribution of fluid inclusions homogenization temperature (T_h). Late calcite cements are in yellow and recrystallized early marine cements are in red.

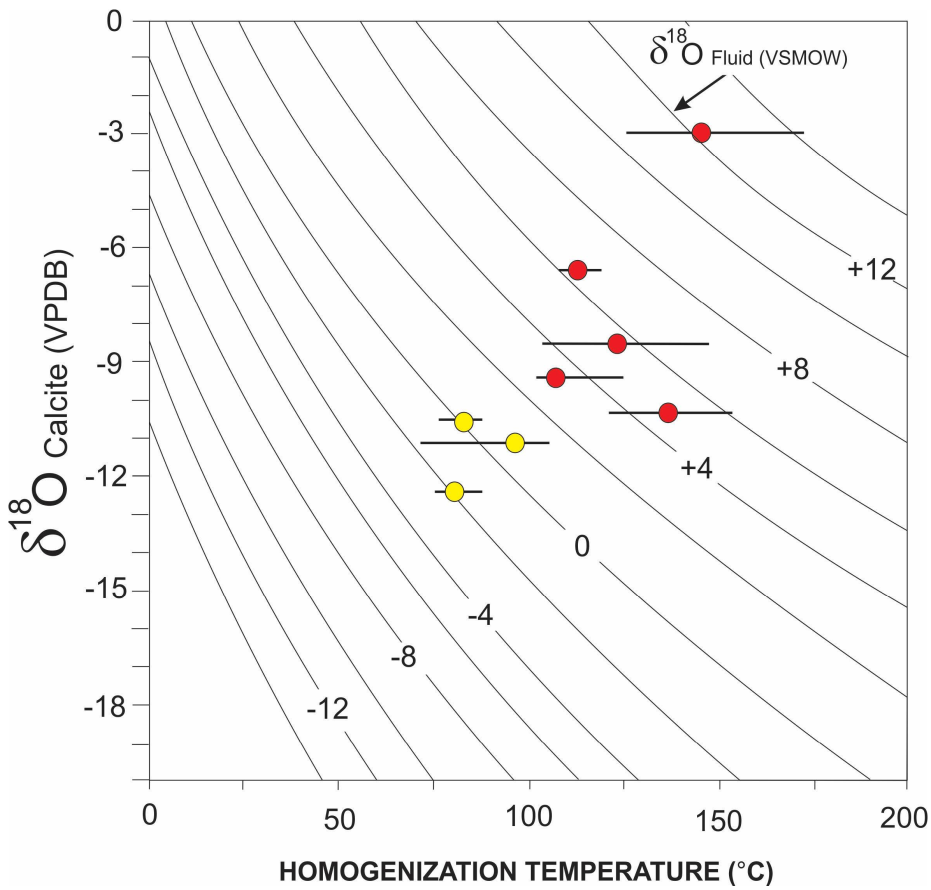

Figure 7. Cross-plot of fluid inclusions homogenization temperature (T_h in °C) versus the $\delta^{18}O_{VPDB}$ value of late calcite cements in the Red Head Rapids Formation. The $\delta^{18}O_{VSMOW}$ of the diagenetic fluid in equilibrium with the calcite is indicated by the value of the curves (Friedman and O'Neil, 1977). In red, average value for synsedimentary cements and in yellow, average value for late burial cements. The horizontal line covers the spread of T_h data for samples.

Development of clumped isotopes research

Carbonate clumped isotope thermometry is a recently developed geochemical technique that measures the abundance of the doubly-substituted isotopologue $^{13}C^{18}O^{16}O$ relative to the theoretical stochastic distribution of this isotopologue (Δ47) in a given carbonate material (Wang et al., 2004; Ghosh et al., 2006). The temperature during precipitation directly controls the Δ47 value of carbonate minerals and this proxy (commonly called "clumped isotopes") is completely independent of the parent water composition. Clumped isotopes in carbonates, therefore, provide us with valuable information about environmental temperatures when the carbonate was precipitated. For instance, this technique can be used to determine ancient seawater temperatures, or help understand burial temperatures in basin analysis studies.

A new clumped isotope facility has been developed in the Delta Lab at the Geological Survey of Canada-Quebec (LM Sector). The facility includes an offline, stainless steel, high vacuum, ultra-purification CO_2 extraction line (Fig. 8A), which is required for clumped isotope analysis. Purified CO_2 samples are analyzed on a Thermo Scientific MAT 253 isotope ratio mass spectrometer that is configured specifically for clumped isotope analysis (Fig. 8B). Initial calibrations of this facility are completed and a small suite of test samples and standards has already been analyzed. Significant data processing is required in clumped isotope studies (e.g., Dennis et al., 2011) and lab-specific corrections are currently being developed by Delta Lab scientists.

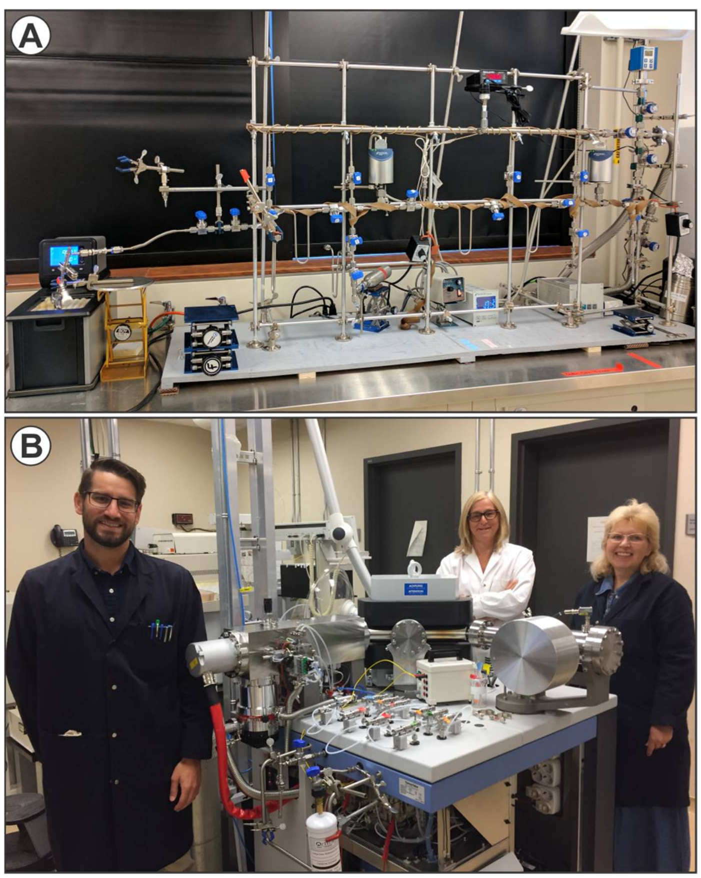

Figure 8. A: Image of the ultra-purification CO_2 extraction line in the Delta Lab. Carbonate powders are reacted with phosphoric acid in a glass vessel held at 90°C in a water bath and the resulting CO_2 gas is sent through two water traps and a U-trap packed with porapak Q and silver wool to remove any hydrocarbons or other contaminants. B: Image of the Thermo Scientific MAT 253 isotope ratio mass spectrometer used for clumped isotope analysis. Also pictured are the Delta Lab scientists working in the clumped isotope facility—from left to right: Ryan S. Dhillon, Martine M. Savard, and Anna Smirnoff.

The clumped isotope facility of the Delta-Lab is the first of its kind in Canada. It was introduced at the 6th International Clumped Isotope Conference in Paris, France, in August of 2017. The Delta Lab is now part of the international community addressing the analytical challenges in the systematics of clumped isotopes (Dhillon et al., 2017a; Savard et al., 2017). The initial application of this facility is to evaluate the thermal history of Upper Ordovician reef carbonates from the Red Head Rapids Formation, which directly overlies the potential source rock for the Hudson Bay Basin (Dhillon et al., 2017a,b). These results will be compared with fluid inclusion temperature estimates and other thermal indicators to better understand burial temperatures and the potential for hydrocarbon development in the basin. Preliminary results from this study show promising trends in the data, however, it is still too early to present absolute temperature values derived from the preliminary data set. A variety of inter-laboratory protocols were agreed upon at the Clumped Isotope Conference and these are currently being implemented in the Delta Lab. A carbonate $\Delta47$-temperature calibration specific to the laboratory is also under development and must be completed before absolute temperature values can be calculated.

RADARSAT-2 image acquisition, interpretation, and methods development for identification of potential oil slicks

Activity Description:

Visual interpretation of 109 RADARSAT-2 images for potential oil slicks detection over Hudson Strait.

RADARSAT-2 coverage

The area surveyed in 2016 is approximately the same as for 2015 (Fig.9) (see Figure 10, Lavoie et al., 2016).

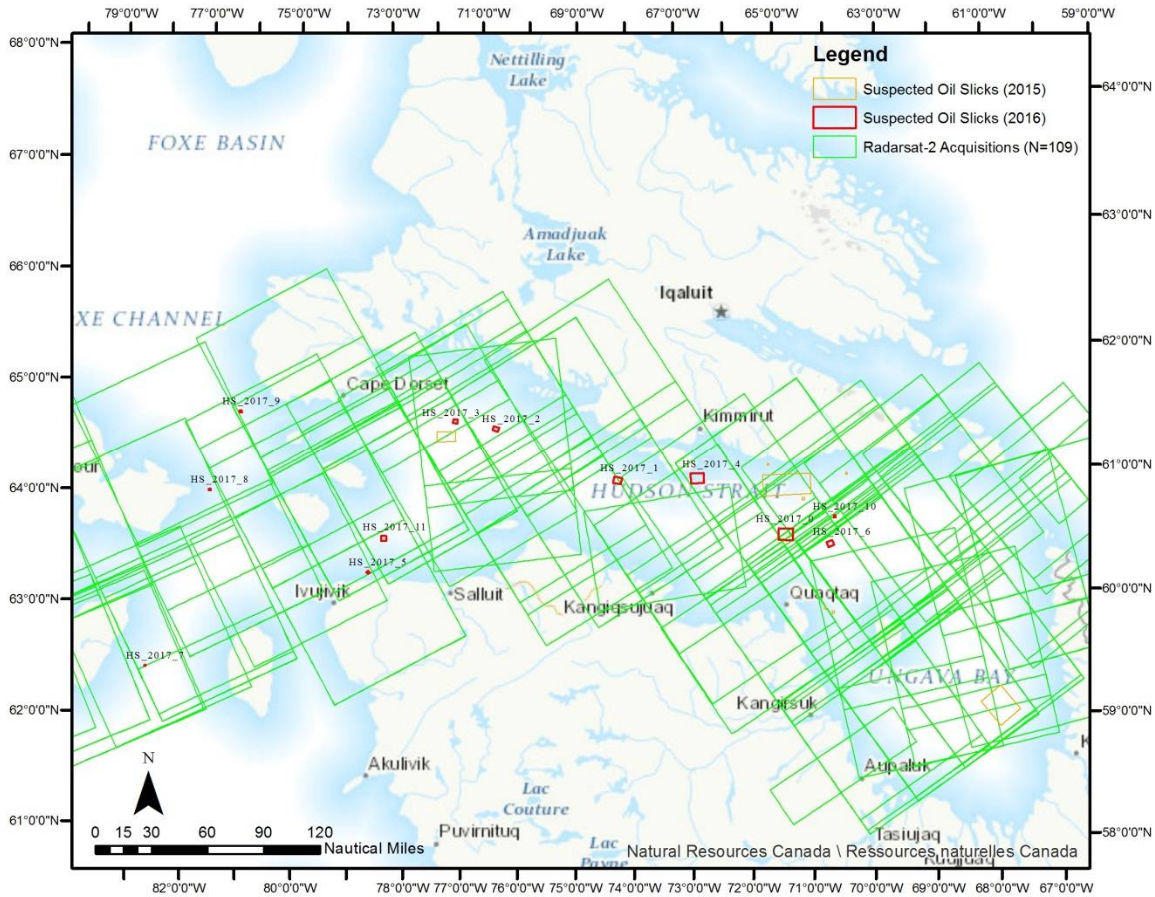

Figure 9. The green rectangles in the figure below show the distribution of the image footprints for 2016. There are 109 images in total (VV polarization, 12.5 m pixel spacing). The suspected oil slicks for 2016 are indicated with red boxes

Methodology

The entire image mosaic was inspected visually on a large monitor. This was achieved by displaying the mosaic, a small portion at a time, and using visual enhancement techniques if necessary. A specialist in interpreting images for potential oil slicks identified locations of these specific anomalies. These locations were vectorized and registered into a GIS database. The following subjective ranking system was used to assign a confidence level to each “dark target” as defined in Decker et al. (2013):

Rank = 1: Best candidate – a location either known to be related to an active seep or has characteristics such as a repeated observations.

Rank = 2: Unknown origin – a dark target that could be equally explained by the presence of a seep or other phenomena. Repeat observations are required to infer its origin.

Rank = 3: Unlikely to be of hydrocarbon origin – a dark feature that could be the result of phenomena other than a hydrocarbon seep but is included until more information (additional observations) can rule it out with greater confidence as a false positive

Results

The interpretation reveals a few dark targets with confidence levels of rank=2 and none with a rank=1 and some with a rank=3. Figure 10 below displays all dark targets found over the entire 2016 RADADSAT 2 mosaic with a ranking of 2

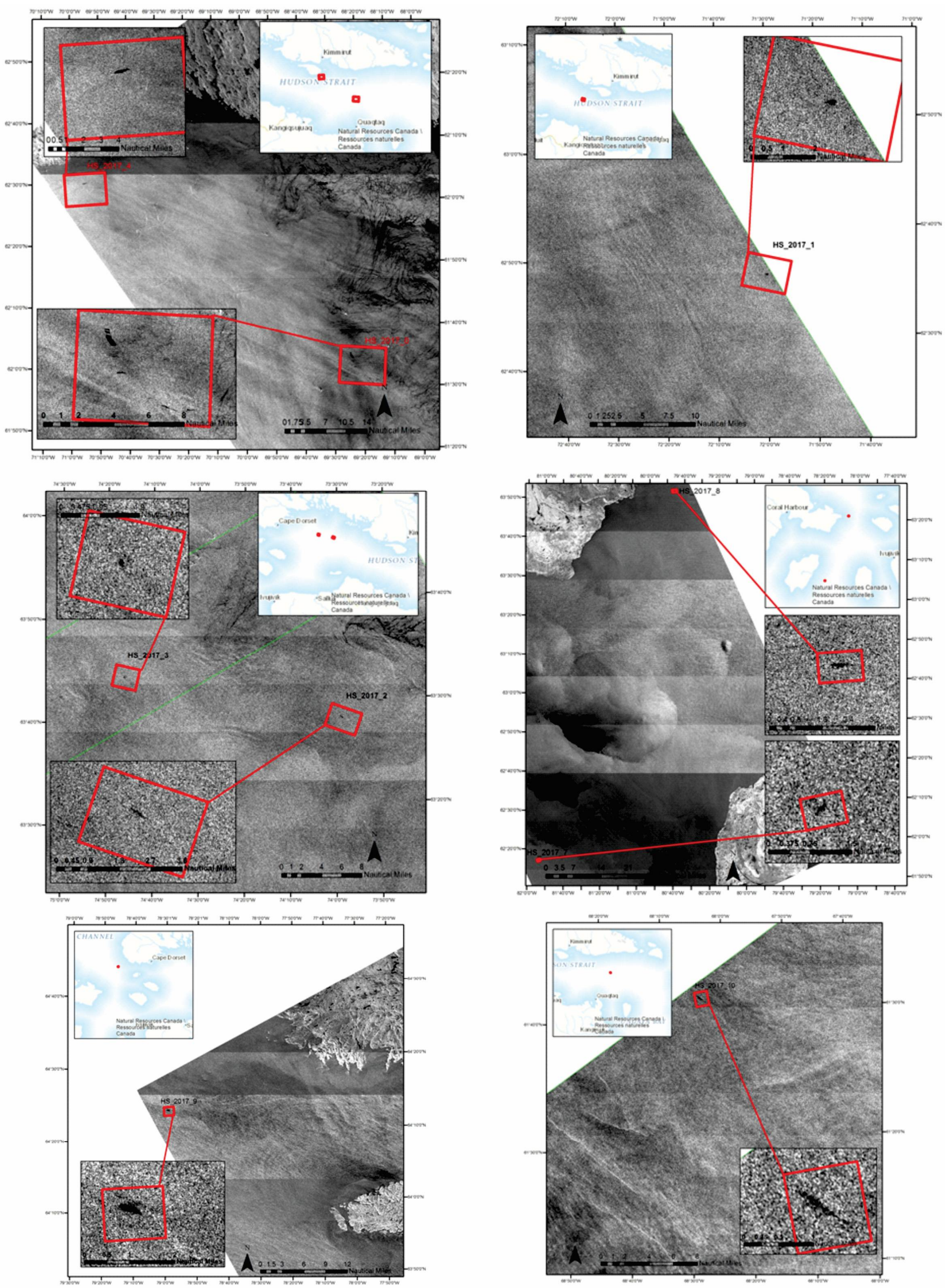

Figure 10. Radarsat-2 images showing 9 anomalies with a ranking of 2 (potential)

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