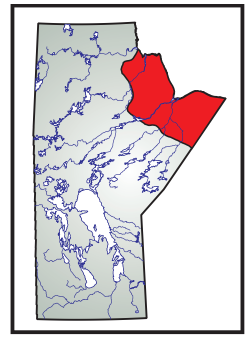
GS-17

Hudson Bay and Foxe Basins Project: update on a Geo-mapping for Energy and Minerals program (GEM) initiative, northeastern Manitoba (part of NTS 54)

by M.P.B. Nicolas and D. Lavoie[1]



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Summary

The Hudson Bay and Foxe Basins Project is in its second year. It is part of the Geological Survey of Canada Geo-mapping for Energy and Minerals (GEM) program, whose energy side aims to study the hydrocarbon potential of these Phanerozoic sedimentary basins. In Manitoba, the Hudson Bay Basin is represented by the Paleozoic carbonate succession of the Hudson Bay Lowland (HBL) in the northeastern corner of the province. Project activities this year included core logging, a core workshop and a field trip, together with various laboratory analyses. The purpose of examining core from the HBL is to better understand the stratigraphy of the basin, and search for potential source rocks and evidence of a hydrocarbon system. The field trip was essential to examine, first-hand, cross-basin correlations and stratigraphic relationships.

Preliminary results from the core logging indicate a more complex stratigraphy than expected. Stratigraphic correlations are difficult because there is evidence of complex relationships, including facies changes and missing formations, and questions arise when outcrop descriptions (particularly type sections) do not match core descriptions for the same unit. Biostratigraphy is used to help decipher some stratigraphic issues.

Evidence for a hydrocarbon system, such as bituminous residues preserved along open fractures, was found in several of the Manitoba Hydro Conawapa cores. The presence of the residues indicates that hydrocarbons have passed through this part of the sedimentary succession, but it is uncertain if the hydrocarbon system is local or basin wide. Rock Eval™ analysis of dark shaly material, which represents potential hydrocarbon source rock, is being conducted on these samples to help address these questions.

Introduction

The Hudson Bay and Foxe Basins Project of the GEM program was introduced in Nicolas and Lavoie (2009), and the Manitoba component of the project is located in the Hudson Bay Lowland of northeastern Manitoba (Figure GS-17-1). Project activities during the current, second year included core logging, a core workshop and a field trip.

Core logging

Conawapa cores

Bezys (1990) reported on logging core from 68 drillholes from Manitoba Hydro's core repository in Gillam; the core suites came from three sites on the Nelson River, the Conawapa Axis B, Conawapa Axis DX and Gillam Island sites (Figure GS-17-2). This extensive suite of cores was drilled by Manitoba Hydro to investigate potential sites for hydroelectric generation stations along the Nelson River. Bezys (1990) also discussed the stratigraphic correlations of the cores with outcrops along the Nelson River.

This summer, the Manitoba Geological Survey (MGS) and the Geological Survey of Canada (GSC) re-examined 14 of the previously logged cores from the Conawapa and Gillam Island sites, and logged three new cores from the Conawapa sites (Figure GS-17-2) stored in Gillam. Re-examination of previously documented cores was necessary to gain a better understanding of the local stratigraphy, and to search for evidence of hydrocarbon migration and rocks with high organic content, potentially correlative with oil shale identified in the northern parts of the Hudson Bay Basin, on Southampton Island in Nunavut (Zhang and Barnes, 2007; Zhang, 2008) and in northern Ontario (Armstrong and Lavoie, 2010). Due to sampling limitations on the Manitoba Hydro cores, small samples were collected only if the core was already broken.

Stratigraphic, petroleum- and mineral-exploration cores

Last year, selected cores from the HBL were examined by the GSC "with particular emphasis on features that would have been overlooked or not been given much attention during the last rounds of core logging" (Nicolas and Lavoie, 2009), including petrographic characteristics that were often overlooked in the past, such as saddle dolomite. This year, the MGS studied the HBL cores from a stratigraphic perspective, in order to build a stratigraphic database for the HBL in Manitoba that includes formation-top picks. Table GS-17-1 is a complete list of all available Paleozoic core for the HBL in Manitoba.

Some sampling was conducted on the various cores examined for organic geochemistry and biostratigraphy.

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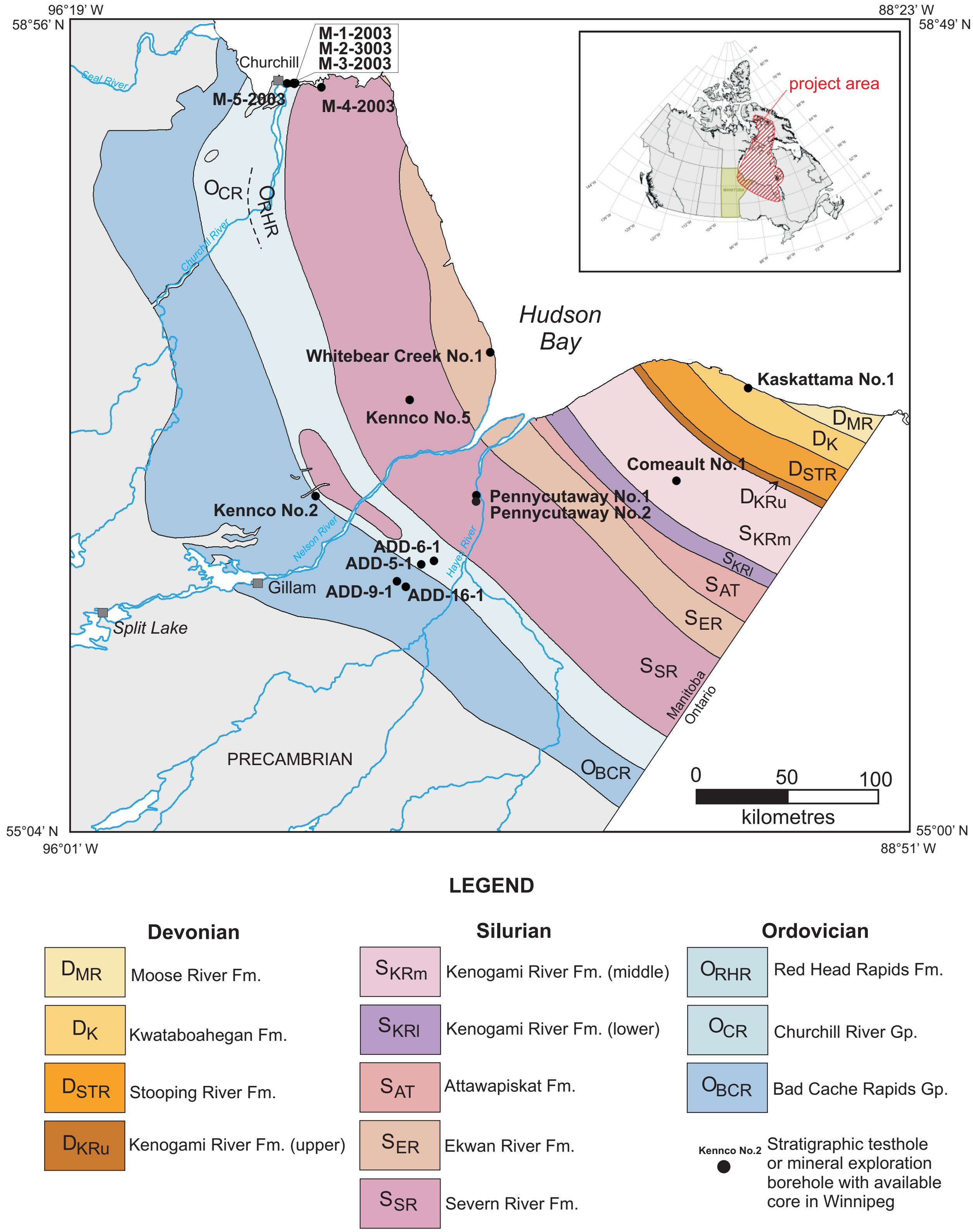

Figure GS-17-1: *Hudson Bay Lowland in northeastern Manitoba, showing the location of the cores available; inset is the project area for the GEM Hudson Bay and Foxe Basins Project.*

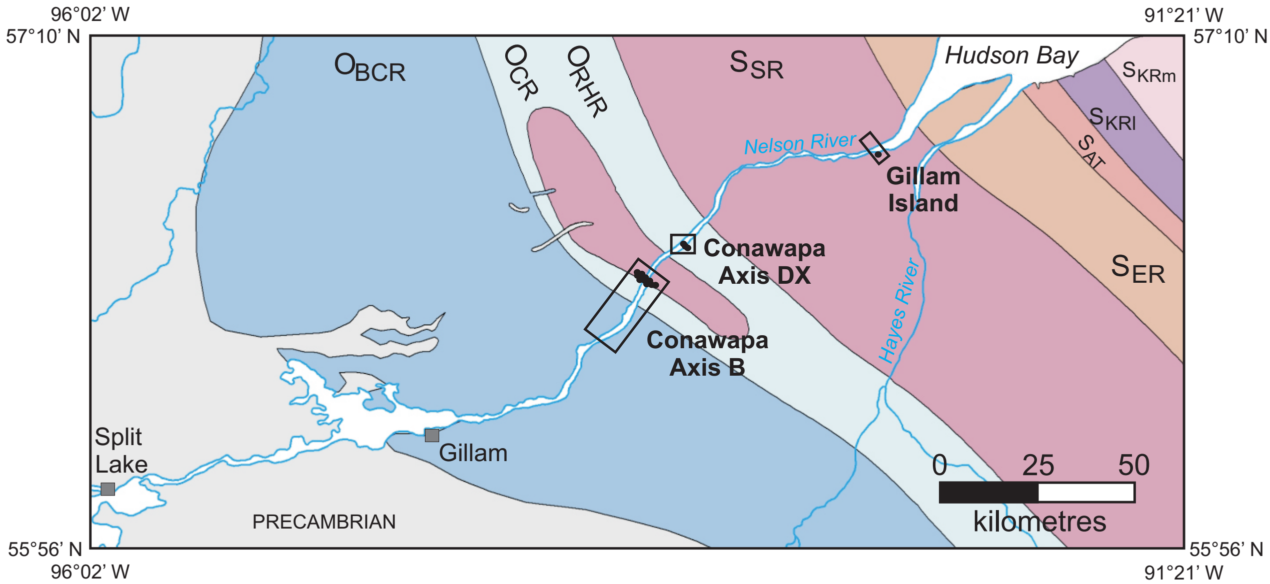

***Figure GS-17-2:** Locations of the Manitoba Hydro Conawapa Axis B, Conawapa Axis DX and Gillam Island sites (rectangular boxes), and the cores examined this year (black circles); see Figure GS-17-1 for geological legend.*

The Ordovician section of the Merland et al. Whitebear Creek Prov. core had been previously sampled in detail for biostratigraphic analysis (Le Fèvre et al., 1976), but the Silurian section had not been sampled and analyzed. Eleven samples were collected from the Silurian section of the Whitebear core and sent to the Paleontology Services laboratory at the GSC in Calgary; results are pending. Eight samples of argillaceous or shaly sections were collected from six cores for organic geochemistry using Rock Eval™–total organic carbon (TOC) analysis to measure organic content and thermal maturity. Cores with samples chosen for organic geochemistry include Houston Oils et al. Comeault Prov. No. 1, Merland et al. Whitebear Creek Prov., Manitoba Geological Survey STH M-1-03, and mineral-exploration borehole Kennco No. 5. Logging of the lowermost Silurian to Ordovician formations of the Sogepet Aquit Kaskattama Prov. No. 1 cores, the Selco Pennycutaway No. 2 and all the Arctic Star cores is planned for next year.

Stratigraphic correlations

Geological investigations of the Hudson Bay Basin were first reported by Bell (1879), but most of the work occurred in the 1960s and early 1970s, including that of Nelson (1964), Sanford et al. (1968), Cumming (1971, 1975) and Norford (1971). The stratigraphy of the Hudson Bay Basin is based on early outcrop descriptions, mostly along major river systems in the lowlands. Petroleum wells drilled within Hudson Bay and on the nearshore in Manitoba and Ontario provided some cores and drill cuttings to help correlate the stratigraphy throughout the basin. Biostratigraphy was used to facilitate the correlation of the formations from outcrop to the subsurface, and establish timelines and environments of deposition. Figure GS-17-3 shows the stratigraphy of the HBL in Manitoba, as used for this project.

In most cases, formation assignments for petroleum cores are based on detailed biostratigraphy, using fossil assemblages (e.g., Nelson, 1964) that include conodonts (e.g., Le Fèvre et al., 1976; Zhang and Barnes, 2007) and brachiopods (e.g., Jin et al., 1993, 1997). However, formation picks based on biostratigraphy may differ from true contact depths because paleontological data usually provide a bracketed depth range rather than a specific depth. Reliable stratigraphic picks depend on combining biostratigraphy with lithological and textural variations (e.g., true lithostratigraphy), in order to determine a formational pick with confidence.

Conawapa stratigraphy

Manitoba Hydro has developed an internal stratigraphic nomenclature to describe the sedimentary units observed in the vicinity of their sites (Figure GS-17-3). These units are not based on formational or member breaks, but rather on lithological and textural changes, since Manitoba Hydro's cores were drilled for geotechnical purposes. Bezys (1990) reported correlations between the units seen in the Conawapa cores and those in outcrops. In Table GS-30-3 of Bezys (1990), the Manitoba Hydro units are correlated with the stratigraphic succession observed in outcrops along the Nelson River. In the area of the Conawapa sites, the Portage Chute Formation of the Bad Cache Rapids Group provided the best correlation between outcrop and core, whereas formational assignments above this basal unit have been based mainly on probable correlation due to stratigraphic positioning,

Table GS-17-1: HBL cores available at the Manitoba Geological Survey Rock Preparation and Core Storage Facility in Winnipeg.

Drillhole name	Company	Year	NTS sheet	Total depth (m)	Core interval (m)	Formation cored	UTM Zone 15, NAD 83	
							Easting	Northing
Sogepet Aquit Kaskattama Prov. No. 1*	Aquitaine Company of Canada	1967	54G	896.11	20.42–896.42	Stooping River Fm. to Precambrian	671277	6328360
Houston Oils et al. Comeault Prov. No. 1	Houston Oils Ltd.	1968	54B	647.70	60.96–647.7	Lower Kenogami to Precambrian	627674	6282230
Merland et al. Whitebear Creek Prov.	Merland Explorations Ltd.	1970	54F	427.02	30.48–306.02	Kenogami Fm. (?) to Churchill River Gp.	532063	6360180
Selco Pennycutaway No. 1	Selco Exploration Company Ltd.	1961	54C	~ 446	44.2–179.22	Churchill River Gp. (?) to Bad Cache Rapids Gp.	517758	6284030
Selco Pennycutaway No. 2	Selco Exploration Company Ltd.	1961	54C	183.18	NA	NA	517758	6284030
Kennco No. 2	Kennco Explorations Canada Ltd.	1961	54F	274.90	118.9–125.0	Bad Cache Rapids Gp.	429693	6291260
Kennco No. 5	Kennco Explorations Canada Ltd.	1961	54C	290.78	256.1–260.6	Bad Cache Rapids Gp. to Precambrian	485898	6338560
M-1-03 Churchill Airport Cove	Manitoba Geological Survey	2003	54L	41.45	0–41.45	Severn River to Precambrian	437922	6513918
M-2-03 Churchill Airport Cove East	Manitoba Geological Survey	2003	54L	102.70	0–102.70	Severn River to Precambrian	438338	6514122
M-3-03 Churchill Airport Cove West	Manitoba Geological Survey	2003	54L	93.55	0–93.55	Severn River to Precambrian	437586	6514208
M-4-03 Churchill Northern Studies Centre Quarry	Manitoba Geological Survey	2003	54K	102.80	0–102.80	Severn River to Precambrian	452492	6510505
M-5-03 Churchill Boreal Gardens	Manitoba Geological Survey	2003	54L	24.30	0–26.55	Severn River to Precambrian	433794	6514432
ADD-6-1*	Arctic Star Diamond Corp.	2005	54C	134.11	NA	NA	491537	6250769
ADD-5-1*	Arctic Star Diamond Corp.	2005	54C	155.40	48.77–88.39	NA	484460	6249626
ADD-9-1*	Arctic Star Diamond Corp.	2005	54C	136.20	39.60–115.30	NA	470286	6241708
ADD-16-1*	Arctic Star Diamond Corp.	2005	54C	118.87	NA	NA	474938	6238335

* indicates cores that are planned for future analysis
NA' indicates information that has not yet been confirmed by the authors

as indicated in Bezys (1990). This uncertainty attests of the difficulty in correlating outcrops and cores based on lithological information only, and demonstrates the need to apply biostratigraphic principles to detailed correlative work on all HBL cores.

Relogging of some Conawapa and Gillam Island cores resolved some of the stratigraphic uncertainties found in Bezys (1990). Comparison of Conawapa cores to the MGS Churchill stratigraphic testholes and Comeault core, extensive biostratigraphic study of the latter having led to accurate formational assignments, revealed anomalous stratigraphic relationships.

Manitoba Hydro (MH) units 1A and 1B (Figure GS-17-3) refer to the Precambrian basement, unweathered and weathered, respectively; this correlation is straightforward and unquestionable. MH unit 2 refers to the basal sandstone that lies unconformably on the Precambrian surface. MH unit 3 refers to the burrow-mottled, bioclastic dolomitic limestone. MH unit 4 is a dolomitic limestone with chert nodules throughout; it can be further subdivided into a lower interval with characteristic *Chondrites* burrows and scattered bioclastic beds (informally referred to by the authors as MH unit 4a), and an upper, more massive interval (informally referred to as MH unit 4b). MH unit 5A is a nodular dolomitic limestone with occasional thin bioclastic beds; a characteristic feature of this unit is the presence of varicoloured, burrow-mottled chert nodules. MH unit 5B is an argillaceous dolomitic limestone with occasional chert nodules and bioclastic beds. MH unit 5C-6 consists of a porous mottled dolomitic limestone. MH unit 7 is a massive to faintly bedded dolomitic limestone. MH unit 8 is an olive green, argillaceous dolomitic limestone that is massive to laminated and has occasional porous beds, green shale partings and intraformational breccias. MH units 9 to 12 were not observed by the authors in the cores.

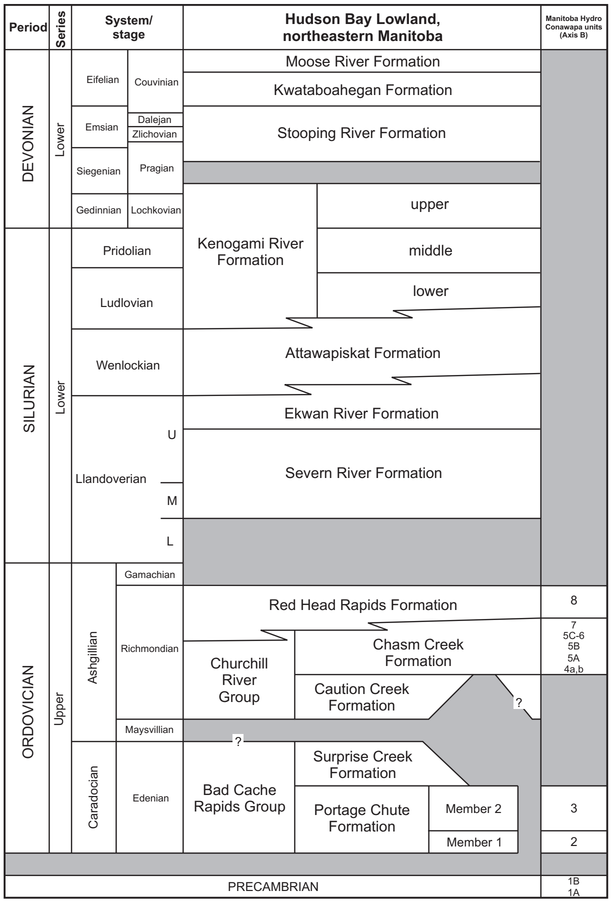

Figure GS-17-3: *Stratigraphy of the Hudson Bay Lowland, with correlations to the Manitoba Hydro units; Ordovician System/Stages from Zhang and Barnes (2007) and Silurian System/Stages from Norris (1993).*

As outlined in Figure GS-17-3, MH unit 2 correlates with Member 1 (Nelson, 1964) of the Portage Chute Formation of the Bad Cache Rapids Group. MH unit 3 correlates with Member 2 (Nelson, 1964) of the Portage Chute Formation, MH units 2 and 3 are confidently correlated from Nelson River outcrops with the Conawapa cores.

The correlations of MH units 4 to 7 are less straightforward. Their stratigraphic positioning in the Conawapa cores suggests that these units represent individual members of the Surprise Creek Formation of the Bad Cache Rapids Group. Nelson (1964) mentioned up to seven members in the Surprise Creek Formation, but his descriptions do not fit those of the MH units. Such discrepancy, as well as correlations with cores in other parts of the HBL, suggest a more complex relationship. When comparing MH units 1 to 7 to the Comeault core, MH units 1, 2 and 3 correlate well with the Precambrian rocks and the basal sandstone and burrow mottled limestone of the Portage Chute Formation. MH units 4 to 7, due to their characteristic and unique textures, are easily identifiable in the Comeault and Churchill cores, and correlate with the Chasm Creek Formation of the Churchill River Group in the Comeault core, instead of the expected Surprise Creek Formation of the Bad Cache Rapids Group, as suggested by Bezys (1990). If this stratigraphic positioning is correct, then the Surprise Creek and Caution Creek formations are absent in the Conawapa cores. Due to sampling restrictions, no samples were collected for biostratigraphy.

The hypothesis of missing formations in the HBL is not new. Nelson (1964) indicated missing formations and uncertain formational boundaries along the Nelson River outcrops, including a gradational and arbitrary contact between the Portage Chute and Surprise Creek formations that reflects a depositional change from turbulent water to quiet water, an uncertainty in the temporal duration of the Surprise Creek Formation, and a complete absence of the Caution Creek Formation. Farther north of the Nelson River, the Churchill cores are completely lacking the Bad Cache Rapids Group, with the Churchill River Group rocks lying directly on the Precambrian surface, as indicated by their paleontological assemblage (G. Young, pers. comm.).

Bezys (1990) indicated that MH unit 8 is located at the base of the Caution Creek Formation. However, if the underlying units are in the Chasm Creek Formation, then the correlation for MH unit 8 would need to be moved upsection into the Red Head Rapids Formation, as suggested by Nelson (1964). The Red Head Rapids Formation in other parts of the basin has the same lithological and textural beds as those described for MH unit 8, so the correlation seems appropriate.

Hydrocarbon systems evidence

In some of the Conawapa cores, bituminous residues are present along open fractures, as shown in Figure GS-17-4. These bituminous residues likely indicate that the hydrocarbon system was active at a poorly constrained stage of basin evolution; however, whether hydrocarbons were locally produced or have undergone long-range migration from the centre of the basin is uncertain. Bituminous residues were identified in Silurian rocks from the Gillam Island core, as well as in Ordovician rocks in MH units 2, 3, 4, and 5A from the Conawapa Axis B cores, but seem most common in MH unit 3 (Member 2 of the Portage Chute Formation). Together with bituminous residue/oil stain collected from the Comeault core, the bituminous residue samples of the Conawapa cores will be analyzed by Rock Eval™.

Other activities

In addition to core relogging in Gillam, a core workshop on the comparison of the Ordovician and Silurian successions in the Comeault core and Churchill cores was held in Winnipeg in summer 2010.

A field trip with representatives of the energy industry and the research team participants from the GEM Hudson Bay and Foxe Basin Project was conducted on Southampton Island (Nunavut) in July 2010. The field

Figure GS-17-4: *Bituminous residue along open fractures in MH unit 3 in core B292 from the Manitoba Hydro Conawapa Axis B site.*

trip focused on the Ordovician stratigraphy and oil shales on the northern shore of the Hudson Bay Basin (Zhang, 2010). Although not a focus of the trip, a few Silurian section stops were included.

In 2009, core work resulted in the recognition of macroscopic features indicative of hydrothermal dolomitization in the Ordovician section of cores drilled in the Churchill area. Dolomite was sampled for stable-isotope analyses and results are pending.

As part of the GSC evaluation of the hydrocarbon system of the Hudson Bay and Foxe basins, apatite fission tracks (AFT) and helium gas in apatite ([U-Th]/He) are being analyzed in order to reconstruct the thermal history of the basin (burial or heating versus exhumation or cooling histories). These two thermochronology tools can provide precise thermal-age constraints for the succession, in particular with low-temperature imprints (Kohn et al., 2005). The precision of the AFT and (U-Th)/He analyses is increased if the data are interpreted in light of conventional organic-matter thermal analyses (reflectance). This scientific approach has been successfully applied to southern Manitoba (Osadetz et al., 2002; Feinstein et al., 2009) and is now being undertaken for the Hudson Bay Basin. Nine core samples (three Ordovician sandstone and six Precambrian gneiss) and four Precambrian outcrop samples were submitted for mineral separation in 2009 and 2010, respectively. Of these, one Precambrian sample yielded enough apatite for fission-track analysis. Better yields were obtained from wells in the central part of the bay and from northern Ontario and Southampton Island samples. Results are expected in 2011–2012.

Economic considerations

A good comprehension of the stratigraphy of the HBL and how it correlates and changes across the basin is critical in understanding the geological evolution and, in turn, the economic potential of the Hudson Bay Basin. New biostratigraphic data are being acquired and will help resolve stratigraphic correlations, whereas organic geochemistry will help characterize potential hydrocarbon source rocks.

A modern synthesis and solid understanding of the architecture and nature of potential hydrocarbon systems of the Hudson Bay and Foxe basins aims to promote hydrocarbon exploration in this region. Manitoba's primary advantage is that it manages the only deepwater port in northern waters at Churchill. Exploration activities resulting in hydrocarbon production, development and related infrastructure would therefore provide a source for significant economic growth and stimulus in northern Manitoba.

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