Update on the GEM-2 Hudson-Ungava Project: Hudson Bay Lowland lineament mapping and geochemical profiling of core, northeastern Manitoba

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Introduction

The work described herein is part of the Manitoba Geological Survey's contribution to the second phase of the Geological Survey of Canada's Geo-mapping for Energy and Minerals program (Hudson-Ungava Project; GEM-2). This programs runs from 2013-2020.

This year's activities in Manitoba included lineament mapping of the Hudson Bay Lowland (HBL) using remote sensing, and beginning to receive and interpret the $\delta^{13}C$ and $\delta^{18}O$ stable isotope results collected from core in 2014.

Lineament mapping

Quaternary sedimentary cover obscures the Paleozoic bedrock throughout most of the HBL. Although many surficial linear features in the HBL are related to glacial and postglacial landforms (moraines, eskers, beach ridges), modern hydrographic and erosional patterns are also influenced by fractures that occur regionally in the bedrock (e.g., McRitchie and Weber, 1970; McRitchie, 1997; Nicolas, 2012). These fractures can control the courses of streams and rivers, and documenting these deviations can provide insight into possible patterns of fractures (i.e., joints or faults) in bedrock.

Identifying fracture patterns by compiling lineament data has been done in Manitoba in the past using various methods and different types of information, such as mapped bedrock faults and fractures, structure and isopach maps, and erosional trends (e.g., McRitchie, 1997; Nicolas, 2012). Fracture patterns inferred from lineament data can help constrain the potential orientations of paleostresses that acted upon the bedrock through geological history, and can provide evidence for buried faults and other structural features.

The purposes of this study are to 1) survey the HBL in northeastern Manitoba, using remote-sensing methods, to establish the locations and trends of lineaments likely controlled by basement structure (**Figure 1**); and 2) compile the resulting trend data to gain insight into possible regional fracture patterns in bedrock and identify any other buried structural features.

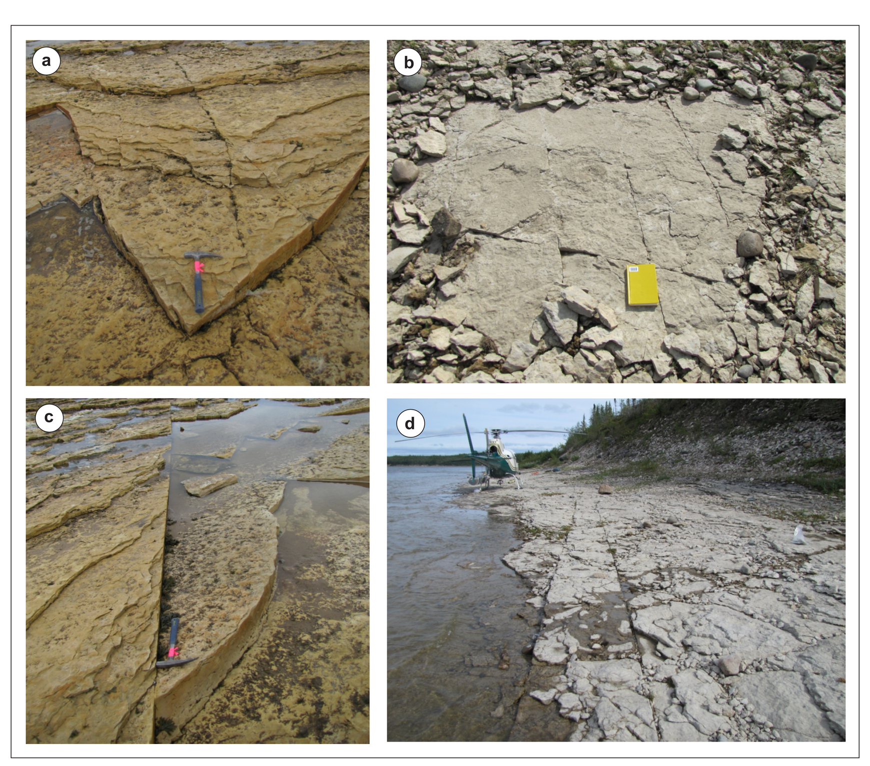

Figure 3: Well-developed joints in outcrop, northeastern Manitoba: near-orthogonal joint sets in the Churchill River Group, near Churchill (a) and the Chasm Creek Formation along the Churchill River (b), prominent north-trending joints in the Churchill River Group near Churchill (c), and parallel joints in the Chasm Creek Formation along the Churchill River (d). (From Nicolas and Clayton, 2015)

Lineament mapping methods and results

Lineament mapping (**Figure 2**) of the Hudson Bay Lowland was done by remote-sensing methods, using multiple GIS information layers that include digital elevation models, geophysical data, surficial-geology maps, and Precambrian and Phanerozoic bedrock-geology maps (**Figure 1**), and outcrop data (**Figure 3**). Information layers were viewed at different scales, and lineaments not obviously related to glacial or postglacial landforms were digitized.

Lineament-trend data plotted on bidirectional rose diagrams reveal that the dominant trends are roughly north (005–010°) and east (095–100°), with less dominant trends in the southeast and northeast directions (**Figure 4**). The trend data are interpreted to reflect two sets of orthogonal fractures in bedrock (**Figure 3**). The dominant set is suggested to result from burial and exhumation events in the Hudson Bay Basin, whereas the secondary set is suggested to reflect Precambrian basement structure. Less abundant trend data in the east-southeast and east-northeast directions may result from the effects of glacial loading and isostatic rebound on recent sediments and sedimentary rocks.

Establishing potential fracture trends in the Phanerozoic bedrock and combining this with basin evolutionary history is a first step toward understanding basin dynamics over time. A compilation and statistical analysis of lineament-trend data, inferred to reflect fracture sets in bedrock, may also provide some indication of paleostress directions. Hence, lineament-trend data may provide some insight into potential fluid-flow directions, or migration paths, for groundwater, hydrothermal fluids and hydrocarbons.

For more details and discussion, refer to Nicolas and Clayton (2015).

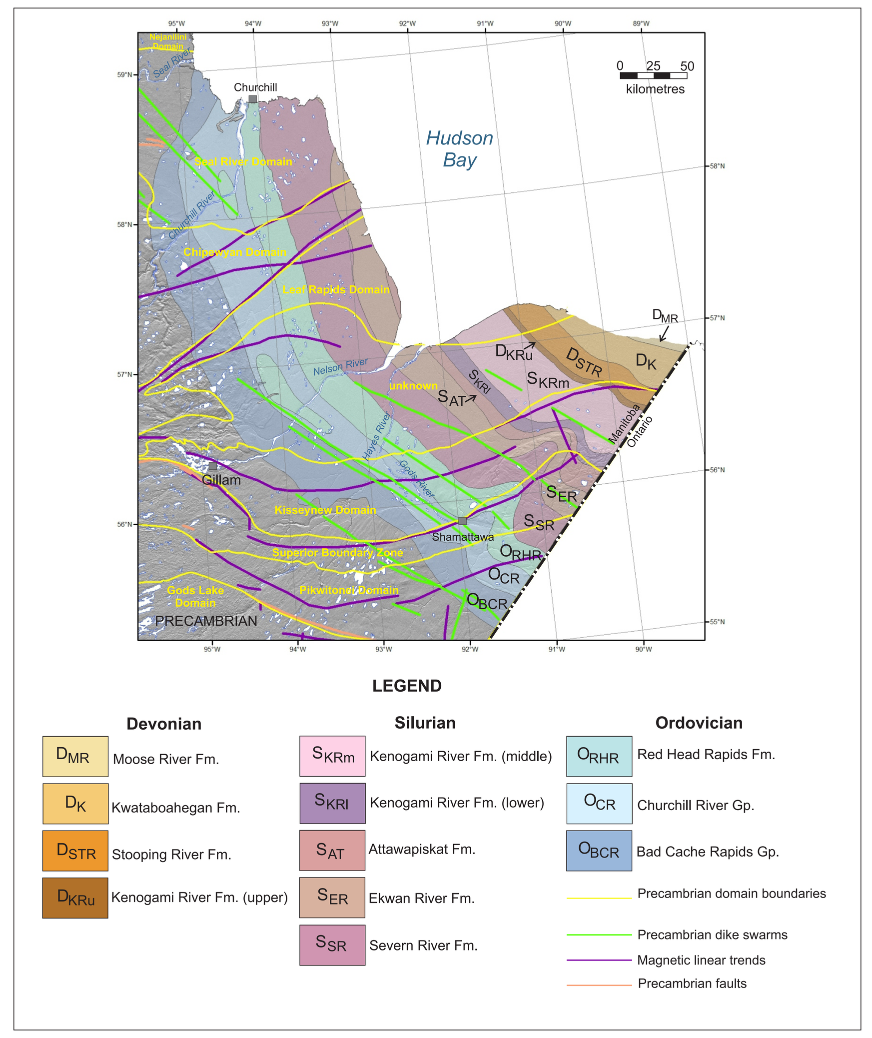

Figure 1: Paleozoic geology of the Hudson Bay Lowlands, northeastern Manitoba (modified from Nicolas et al., 2014) superimposed on a 90 m pixel-spacing digital elevation model (United States Geological Survey, 2002), and overlain with the Precambrian domain boundaries, magnetic linear trends, faults and dike swarms (from McGregor, 2013). (From Nicolas and Clayton, 2015)

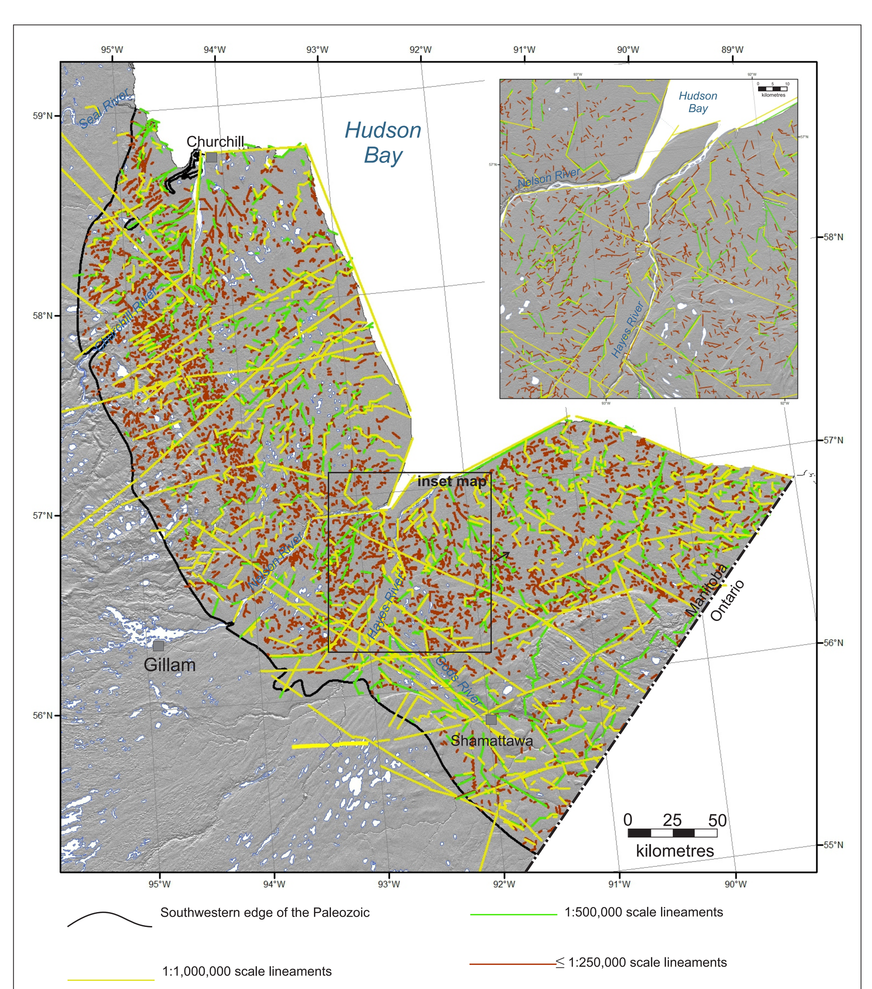

Figure 2: Hudson Bay Lowland in northeastern Manitoba, showing the lineaments mapped using remote-sensing methods. Background is a digital elevation model with 90 m pixel spacing derived from Shuttle Radar Topography Mission data (United States Geological Survey, 2002). Inset map is a close-up of part of the area to better show the difference between the different scales of linear features captured. Not all linear features were drawn in any given area. (From Nicolas and Clayton, 2015)

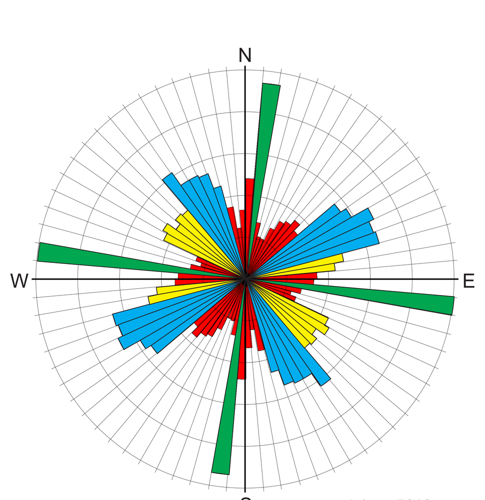

Figure 4: Bidirectional, linear-scaled rose diagram with all the lineament-trend data compiled from all map scales and field measurements. Green sections are interpreted as the dominant trend, blue sections are the secondary trend, yellow sections are the tertiary trend and red represents data scatter. (From Nicolas and Clayton, 2015)

$\delta^{13}C$ and $\delta^{18}O$ stable isotope

In the Hudson Bay Basin, geophysical logs, litho- and biostratigraphy have been used in long distance correlations of the Paleozoic sequence within the basin, as well as to other basins, with success, but not without its challenges. One of the objectives for the GEM-2 Hudson–Ungava project is to use chemostratigraphy from $\delta^{13}C$ and $\delta^{18}O$ stable isotope profiles of entire cores as a method for long-distance correlation to help supplement the correlation information gathered in other studies.

During the GEM Energy project (2008-2012), systematic and regular-interval sampling of full-length cores was carried out in Ontario (Armstrong, 2011). In Manitoba, only limited $\delta^{13}C$ and $\delta^{18}O$ stable isotope profiling was carried out through the upper portion of the Upper Ordovician and the lower portion of the Lower Silurian sections (Wheadon, 2011; Duncan, 2012; Lapenskie, 2012; Demski et al., 2015; Hanasyk, 2015). Previous stable isotope profiling in Manitoba focused on identifying the Ordovician–Silurian boundary and the Hirnantian isotopic carbon excursion (HICE), while the profiling in Ontario identified the HICE and used ^{13}C as a potential chemostratigraphic correlation tool. (Nicolas et al., 2014)

The purpose of the chemostratigraphic program in Manitoba is to expand the $\delta^{13}C$ and $\delta^{18}O$ stable isotope database beyond the Ordovician–Silurian boundary and provide a chemostratigraphic profile of the entire Paleozoic sequence preserved in Manitoba, similar to that previously done in Ontario. The hypothesis is that the isotope information may help with stratigraphic correlations throughout the basin.

The cores sampled for carbon and oxygen stable isotope analysis were Houston et al. Comeault Prov. No.1, Foran Mining Kaskattama Kimberlite No. 1, Sogepet Aquitaine Kaskattama Prov. No.1, Merland et al. Whitebear Creek Prov., and Pennycutaway No. 1 (Comeault, KK1, Kaskattama, Whitebear and Pennycutaway No. 1, respectively; **Figure 5**). Data were collected at minimum 1.5 m (5 ft) intervals, with a tighter sampling interval when needed based on lithology or stratigraphic position. For example, tighter sample spacing was done at the top of the Red Head Rapids Formation and base of Severn River Formation to help identify the HICE. While all the cores have been sampled already, results for the Comeault core are the only ones received to date.

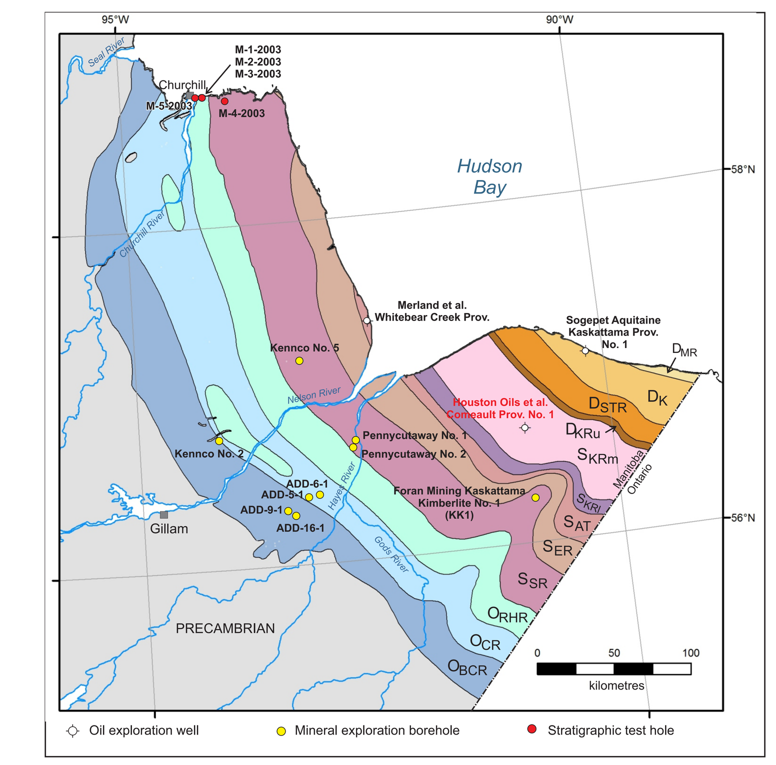

Figure 5: Stratigraphic map of the Hudson Bay Lowland, showing location of oil exploraiton wells, mineral exploration boreholes and stratigraphic test holes. See Figure 1 for legend. (From Nicolas et al., 2014)

Houston Oils et al. Comeault Prov. No. 1

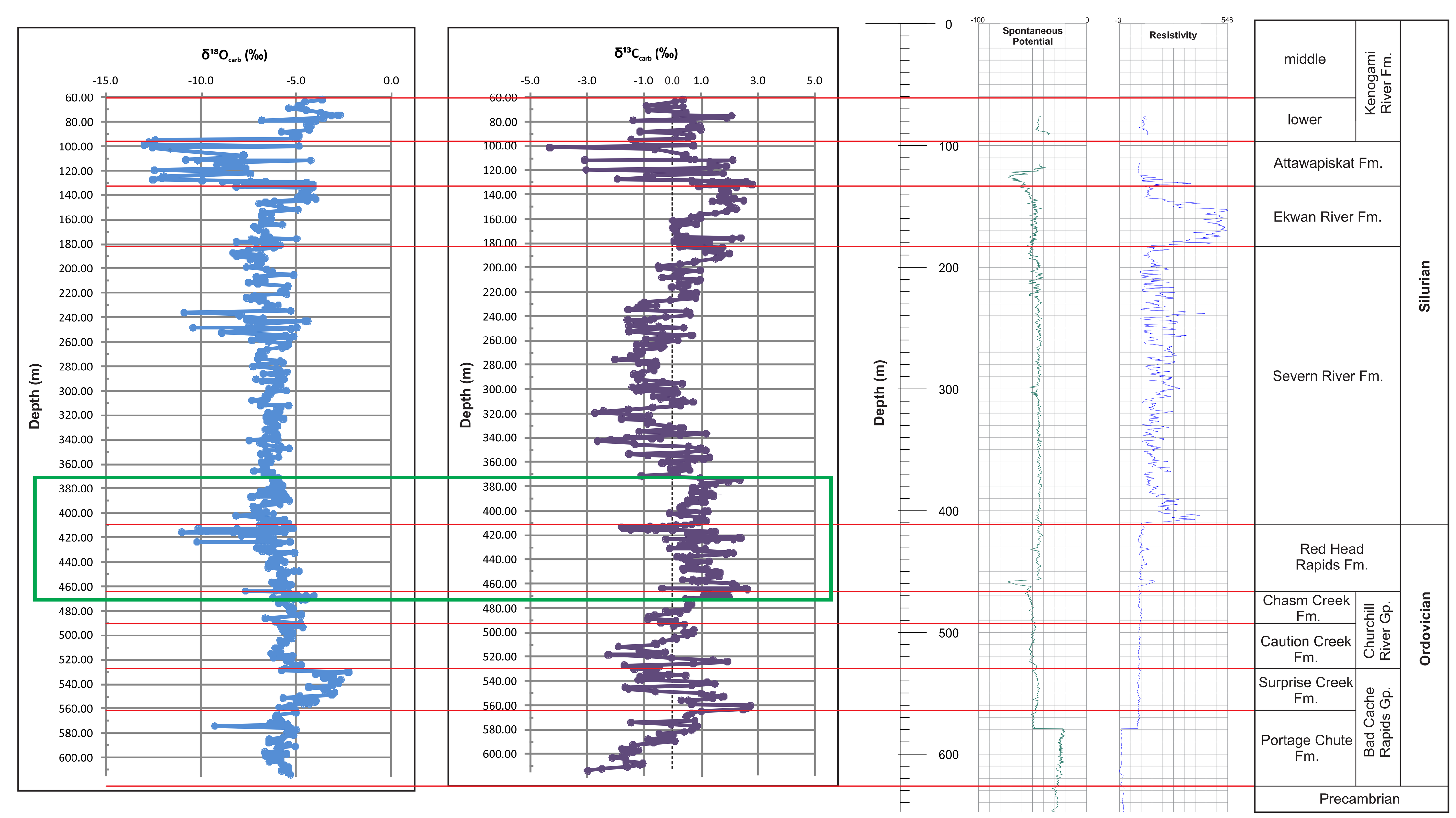

Figure 6: $\delta^{13}C$ and $\delta^{18}O$ stable isotope profile for the entire Houston et al. Comeault Prov. No. 1 core, correlated with the geophysical well log and stratigraphic column; green box is the interval reproduced in detail in Figure 7. The $\delta^{13}C$ and $\delta^{18}O$ stable isotope values shown are from carbonate samples relative to CPDB and VPDB, respectively.

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Comeault core sampling and results

A total of 428 samples were collected from the Comeault core for stable isotope analysis. A preliminary depth profile of the $\delta^{13}C$ and $\delta^{18}O$ stable isotope results for this core is shown in **Figure 6**. There is much dissection and interpretation still to be done on these results because they represent a large stratigraphic interval. However, the HICE is discernable near the top of the Red Head Rapids Formation on the $\delta^{13}C$ curve (**Figure 7**), as expected; the similarity in profile of the $\delta^{18}O$ values to the $\delta^{13}C$ profile suggests a primary isotope signal with no overlapping diagenetic effects (Brenchley et al, 2003; Demski et al, 2014).

The profile for the Comeault core in **Figure 6** represents a large stratigraphic interval, and detailed analysis of the results is still in progress. However, a preliminary examination of the profile around the Ordovician–Silurian boundary shows a signature typical for the HICE (**Figure 7**). While these results still need to be confirmed with pre-existing biostratigraphic information, the location of this carbon isotopic excursion fits well with the lithostratigraphic assignments made by the author.

Figure 8 shows the sampling method used for the stable isotope program.

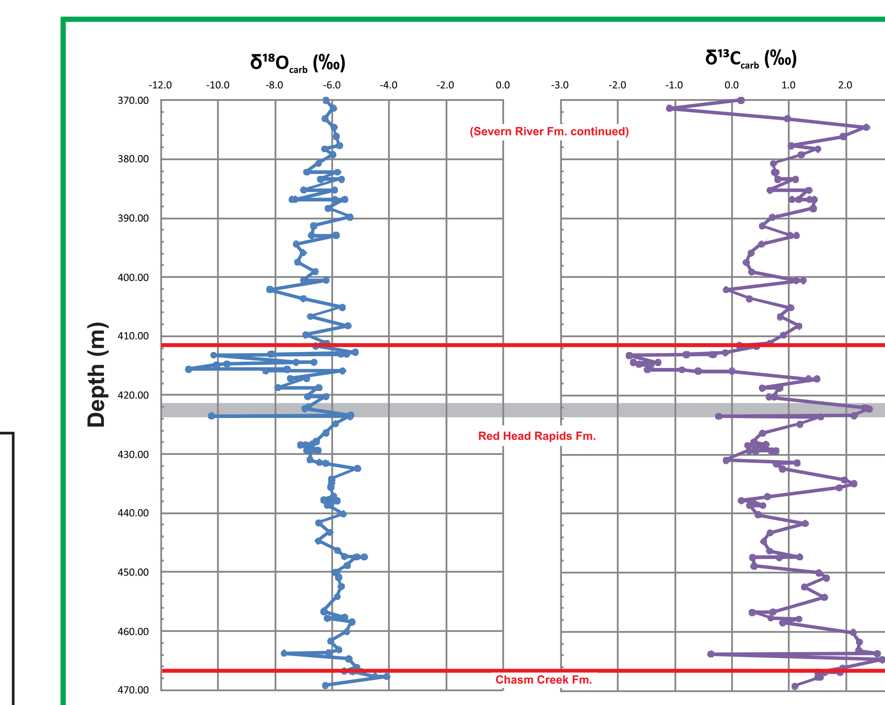

Figure 7: $\delta^{13}C$ and $\delta^{18}O$ stable isotope profile close-up of the interval straddling the Ordovician-Silurian boundary from Figure 6. Highlighted grey area indicate the HICE interval, where the boundary is expected to be located at the top of this interval where the $\delta^{13}C$ reach around zero. The $\delta^{13}C$ and $\delta^{18}O$ stable isotope values shown are from carbonate samples relative to CPDB and VPDB, respectively.

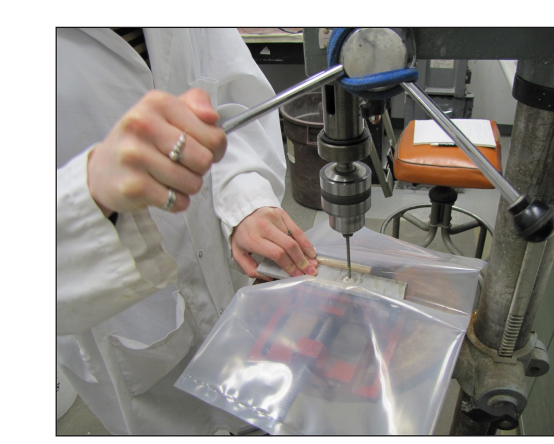

Figure 8: Sampling set up for stable isotope analysis. Powdered samples were taken using a drill press with a 4.76 mm (3/16 in.) carbide-tipped masonry drill bit. Between samples, the drill bit was cleaned with acetone. Compressed air was used to remove loose material from the surface of the core and to ensure that the core was dry. The core was first drilled shallowly to remove surface contamination and compressed air was used to remove the powdered material from the drillhole and drill bit. Next, the core was drilled to a depth of approximately 1.5 cm in the same location. A 0.5 g sample of the carbonate powder was collected from the drillhole and from the surface of the core. The samples were sent to the Delta Lab, GSC-Quebec (Ste-Foy, Quebec) for analysis. (Nicolas et al., 2014)

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Manitoba

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