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Complete List of Authors:	Bancroft, Alyssa M.; The University of Iowa, Department of Earth and Environmental Sciences Brunton, Frank R.; Ministry of Northern Development Kleffner, Mark A.; School of Earth Sciences
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Corresponding Author:

Alyssa M. Bancroft, Department of Earth and Environmental Sciences, University of Iowa,
115 Trowbridge Hall, Iowa City, Iowa, USA 52242
[alyssa-bancroft@uiowa.edu]
+1(231)881-0533

Frank R. Brunton, Earth Resources and Geoscience Mapping Section, Ontario Geological Survey,
Willet Green Miller Center, 933 Ramsey Lake Road, Sudbury, Ontario, Canada
P3E6B5
[frank.brunton@ontario.ca]

Mark A. Kleffner, School of Earth Sciences, The Ohio State University Lima, 4240 Campus Drive,
Lima, Ohio, USA 45804
[kleffner.1@osu.edu]

Abstract

The Moose River Basin in Ontario, Canada contains nearly one kilometer of Silurian marine strata, and although it has been studied for more than a century, its precise correlation globally has not been constrained. Herein, a core from the Victor Mine in the Moose River Basin was examined for conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy to provide a detailed chronostratigraphic framework for the Silurian strata (Severn River, Ekwan River, and Attawapiskat formations) in the Moose River Basin. The recovery of *Aspelundia expansa*, *Aspelundia fluegeli fluegeli*, *Distomodus staurognathoides*, *Ozarkodina polinclinata estonica*, *Pterospirifer eopennatus*, and *Aulacognathus bullatus*, as well as the lower Aeronian, upper Aeronian, lower Telychian (Valgu), and ascending limb of the Sheinwoodian (Ireviken) positive carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions provide significantly improved chronostratigraphic correlation of Llandovery strata in the Moose River Basin.

Keywords: Silurian, conodonts, carbon isotopes, Llandovery, Moose River Basin

Introduction

The Hudson Platform (central Canadian Shield, Fig. 1) was located in the tropical climate belt during the Silurian Period at low latitudes (between 0°S and 10°S) just south of the equator on the northeastern margin of the paleocontinent Laurentia. Sediment deposition and faunal distribution during this time were controlled by a northeast-trending Precambrian basement high, the Cape Henrietta Maria Arch (Patricia Arch of Nelson and Johnson 1966), which

separated two cratonic sedimentary basins: the Hudson Bay Basin (to the north) and the Moose River Basin (to the south).

Silurian stratigraphy of the Hudson Platform has been summarized by Norris (1993a, 1993b), Sanford et al. (1993), and Norford (1997). Detailed stratigraphic studies of the Silurian succession in the Hudson Platform include conodont biostratigraphy, brachiopod biostratigraphy, and sequence stratigraphy (Le Fèvre et al. 1976; Suchy 1992; Suchy and Stearn 1992; Jin et al. 1993; Zhang and Barnes 2007). However, the relative age and regional lithostratigraphic relationships of these Silurian units have not been constrained precisely. The Moose River Basin provides the unique opportunity to examine the Llandovery Series in carbonate strata, but precise chronostratigraphic control for the nearly one-kilometer-thick succession is not available which has limited the utility of the Moose River Basin to studies of Silurian global change events.

The Silurian stratigraphic succession of the Hudson Platform (units named by Savage and Van Tuyl 1919) consists of the Severn River, Ekwan River, and Attawapiskat formations, in ascending order (Fig. 2). The Severn River Formation, comprised of shallow marine carbonates (Savage and Van Tuyl 1919), disconformably overlies the Red Head Rapids Formation, and this disconformity has been interpreted to represent either an interval containing the missing Ordovician-Silurian boundary (Sanford et al. 1968; Norris and Sanford 1969; Norford 1970, 1988; Suchy and Stearn 1992; Jin et al. 1993) or an interval of missing lower Llandovery strata (Le Fèvre et al. 1976; Norris 1993b; Jin et al. 1993). The Severn River Formation is variously interpreted to be overlain either conformably (Norris 1993b; Jin et al. 1993) or disconformably (Suchy 1992; Suchy and Stearn 1992; Armstrong 2011; Lavoie et al. 2013; Armstrong et al. 2013)

by the Ekwan River Formation, however the extent of the missing stratigraphic interval has not been constrained (Suchy and Stearn 1992; Armstrong 2011; Lavoie et al. 2013; Armstrong et al. 2013). The Ekwan River Formation is characterized by fossiliferous limestones and fine-grained dolostones, and the upper portion of this unit is interpreted to be coeval with the overlying reefal carbonates of the Attawapiskat Formation (Norris 1993b).

Le Fèvre et al. (1976) proposed four provisional conodont assemblage zones and one formal conodont zone for the Silurian succession of the Hudson Bay Basin. Zhang and Barnes (2007) provided the most recent conodont biostratigraphic data for the Hudson Bay Basin and erected three interval zones and one assemblage zone. During the last two decades there have been significant revisions to the taxonomy and ranges of conodonts used for biostratigraphic zonation of the lower Silurian (Fig. 3), and these zonations will be used throughout this manuscript (Männik 1998, 2007a, 2007b).

Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy has become a robust method for high-resolution global correlation of Silurian strata (Cramer et al. 2011; Melchin et al. 2012). Three positive carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions have been documented from Llandovery strata and one from Sheinwoodian (Wenlock) strata that are useful for global correlation (Fig. 3): lower Aeronian, upper Aeronian, lower Telychian (Valgu), and Sheinwoodian (Ireviken) excursions. Each of these excursions has been documented from multiple paleobasins (Kaljo and Martma 2000; Kaljo et al. 2003; Põldvere 2003; Melchin and Holmden 2006; Munnecke and Männik 2009). Previously, no chemostratigraphic data were available from the Hudson Platform. Here we provide integrated biochemostratigraphic data from the Victor Mine (V-03-270-AH) core in the Moose River Basin.

Biochemostratigraphic Samples from the Victor Mine (V-03-270-AH) Core

The Victor Mine is located in the north-central portion of the Moose River Basin, and two hundred and fifty meters of one core (V-03-270-AH) from the mine were sampled for conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy (Table 1). The stratigraphic units sampled include (in ascending order) the Red Head Rapids, Severn River, Ekwan River, and Attawapiskat formations. Seventeen conodont samples (between five hundred grams and two kilograms) were processed from the Silurian carbonate succession of the Victor Mine core (three from the Severn River Formation, six from the Ekwan River Formation, and eight from the Attawapiskat Formation) utilizing standard techniques (Jeppsson et al. 1985; Jeppsson and Anehus 1995, 1999). Two-hundred and thirty-four carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope samples were processed from the Victor Mine core (twenty-five from the Red Head Rapids Formation, eighteen from the Severn River Formation, sixty-five from the Ekwan River Formation, and one hundred and twenty-six from the Attawapiskat Formation). All carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope samples collected from the core were micro-drilled from micritic matrix and sent to the University of Kansas W.M. Keck Paleoenvironmental and Environmental Stable Isotope Laboratory (KPESIL) for analysis.

Results

Biostratigraphically significant species recovered from the Victor Mine core include: *Aspelundia expansa* Armstrong (taxonomic note: *Aspelundia* is a junior synonym of *Pseudolonchodina*, see Savage 1985; Wang and Aldridge 2010) from the Ekwan River Formation (Fig. 4, Fig. 5); and *Aspelundia fluegeli fluegeli* (Walliser) (taxonomic note: *Aspelundia* is a junior

synonym of *Pseudolonchodina*, see Savage 1985; Wang and Aldridge 2010), *Distomodus*
staurognathoides (Walliser), *Ozarkodina polinclinata estonica* Männik, *Pterospathodus*
eopennatus Männik, and *Aulacognathus bullatus* (Nicoll and Rexroad) from the Attawapiskat
Formation (Fig. 4, Fig. 5). The sampling interval, limited sample size, and low yields only permit
global conodont biostratigraphic correlation at the superzone level. Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$)
isotope values within the core varied from -4.7‰ to +3.0‰ with a baseline near -1.0‰ (Fig. 4).
The data record three carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions within the Ekwan River
Formation at approximately 170 m, 150 m, and 135 m, with total magnitude changes of +4.0‰,
+5.0‰, and +3.5‰, respectively. In the upper portion of the Attawapiskat Formation
carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values steadily increase to +3.0‰ and represent the
ascending limb of a fourth carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion within the core.

Discussion

Silurian strata of the Hudson Platform were previously assigned to the Llandovery
Series, but stage designations remained tentative (Le Fèvre et al. 1976; Norris 1993b; Norford
1997; Zhang and Barnes 2007). The biochemostratigraphic framework generated by this study
provides a refined chronostratigraphic correlation for this succession of Silurian strata in the
Moose River Basin (Fig. 4).

Severn River Formation

The Severn River Formation was previously interpreted to disconformably overlie the
Red Head Rapids Formation (Sanford et al. 1968; Norris and Sanford 1969; Norford 1970, 1988;

133 Le Fèvre et al. 1976; Suchy and Stearn 1993; Jin et al. 1993; Norris et al. 1993b; Zhang and
 134 Barnes 2007). This disconformity was interpreted to represent the Ordovician-Silurian
 135 boundary interval, which was a global sea-level low (e.g. Munnecke et al. 2010). Norford (1997)
 136 assigned the Severn River to the Rhuddanian through lower Telychian stages based on the
 137 nautiloid cephalopod *Dicosorus-Huronia* fauna (Flower and Teichert 1957; Flower 1968). The
 138 Severn River Formation was assigned to the Rhuddanian through lower Telychian stages by
 139 Zhang and Barnes (2007) based on the presence of the conodonts *Ozarkodina elibata* Pollock,
 140 Rexroad, and Nicoll, *Kockelella? trifurcata* Zhang and Barnes, *Aspelundia expansa*, *Aspelundia*
 141 *fluegeli fluegeli*, *Distomodus staurognathoides*, *Pterospathodus eopennatus*, *Pterospathodus*
 142 *celloni* (Walliser), *Pterospathodus amorphognathoides angulatus* (Walliser), and *Aulacognathus*
 143 *bullatus*. Based on these occurrences the Severn River Formation was assigned to the
 144 *Ozarkodina elibata* Interval Zone, *Kockelella? trifurcata* Interval Zone, *Distomodus*
 145 *staurognathoides* Interval Zone, and the *Pterospathodus celloni—eopennatus* Assemblage Zone.
 146 The *Ozarkodina elibata* fauna is provincial and has not been recognized outside North America
 147 (Pollock et al. 1970; Le Fèvre et al. 1976; Zhang and Barnes 2007). Similarly the zone based on
 148 the eponymous species has never been used globally. *Kockelella? trifurcata* has only been
 149 recovered from strata in the Hudson Platform, and its use as a zonal indicator has not been
 150 applied outside the region. Zhang and Barnes (2007) placed the base of the *Distomodus*
 151 *staurognathoides* Interval Zone at the first appearance of the nominative species, which is
 152 consistent with Männik (1998, 2007a, 2007b). The base of the overlying *Pterospathodus*
 153 *celloni—eopennatus* Assemblage Zone of Zhang and Barnes (2007) was defined by the first
 154 appearance of any of the key species within the assemblage: *Pterospathodus eopennatus*,

Pterospathodus celloni, *Pterospathodus amorphognathoides angulatus*, and *Aulacognathus bullatus*. Männik (1998, 2007a, 2007b) divided this interval into three discrete zones: *Pterospathodus eopennatus* ssp. n. 1, *Pterospathodus eopennatus* ssp. n. 2, and *Pterospathodus amorphognathoides angulatus*, the bases of which are defined by the first occurrence of their nominative species (Fig. 3). Zhang and Barnes (2007) suggested that the zones of *Pterospathodus eopennatus* ssp. n. 1, *Pterospathodus eopennatus* ssp. n. 2, and *Pterospathodus amorphognathoides angulatus* could not be identified in the Hudson Platform due to the inability to separate the *Pterospathodus eopennatus* Superzone from the *Pterospathodus celloni* Superzone. This conclusion was not based on direct co-occurrences of the nominative species but, rather, due to the presence of *Pterospathodus eopennatus* in a cutting sample from a depth of 777.20 meters to 792.50 meters and of *Apsidognathus tuberculatus* Walliser in core sample from 777.20 meters from the same well, indicating that these two species occur in close proximity. They argued that the first appearance of *Apsidognathus tuberculatus* is the same as *Pterospathodus celloni* globally (Zhang and Barnes 2007), however, the range of *Apsidognathus tuberculatus* has been significantly lowered by Männik (1998, 2007a, 2007b) to the base of *Pterospathodus eopennatus* ssp. n. 1 Zone.

If the occurrences presented by Zhang and Barnes (2007) do not represent down-hole caving contamination, then the Severn River Formation extends from the *Distomodus kentuckyensis* Zone through the *Pterospathodus amorphognathoides angulatus* Zone, which would represent all of the Rhuddanian Stage, all of the Aeronian Stage, and the lower third of the Telychian Stage. Undoubtedly, at least some part of the Severn River Formation is within the *Distomodus kentuckyensis* Zone (Zhang and Barnes (2007) recovered the nominative

species). The presence of *Pterospathodus eopennatus* in a core sample from the Severn River Formation in the Narwhal O-58 core (Zhang and Barnes 2007) demonstrates that what has been called Severn River in the Narwhal O-58 core extends at least as high as the lower part of the Telychian Stage. However, the top of the Severn River Formation in the present study is no higher than the middle Aeronian Stage. Therefore, this suggests that either the Severn River Formation is time transgressive across the Hudson Platform or the Severn River Formation is misidentified across the Hudson Platform. Data from the Severn River in this core cannot constrain the age of the Severn River on their own (Fig. 4), however, data from higher in the core limit the top of the Severn River to a position no higher than the Rhuddanian Stage (see below).

Ekwan River Formation

The Ekwan River Formation disconformably overlies the Severn River Formation (Suchy 1992; Suchy and Stearn 1992; Armstrong 2011; Lavoie et al. 2013; Armstrong et al. 2013) and was assigned to the Telychian Stage by Norford (1997) based on the presence (Larsson and Stearn 1986) of the stromatoporoid *Pseudolabechia*, which also occurs in the Upper Visby Formation of Gotland, Sweden (Sheinwoodian Stage, Wenlock Series). The Ekwan River Formation was assigned to the Telychian Stage by Zhang and Barnes (2007) based on the presence of *Pterospathodus eopennatus*, *Pterospathodus celloni*, *Pterospathodus amorphognathoides angulatus*, and *Aulacognathus bullatus*. The middle and upper portions of the Ekwan River Formation contain three positive carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions at approximately 170 m, 150 m, and 135 m (total magnitude changes of +4.0‰,

+5.0‰, and +3.5‰, respectively). *Aspelundia expansa* was recovered from strata just below the third excursion and *Ozarkodina polinclinata estonica* was recovered from strata just above the third excursion (Fig. 4). Therefore, these three excursions likely represent the lower Aeronian, upper Aeronian, and lower Telychian (Valgu) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions, respectively. As a result, the Ekwon River Formation in this core does not extend into the Wenlock Series as suggested by Larsson and Stearn (1986) and Norford (1997) and is limited to an interval from within the Rhuddanian Stage to the lower part of the Telychian Stage (Fig. 4).

Attawapiskat Formation

The Attawapiskat Formation was previously interpreted to span the upper Telychian (Llandovery) to lower Sheinwoodian (Wenlock) stages based upon nautiloid cephalopod and trilobite faunas (Norford 1997). Zhang and Barnes (2007) assigned the Attawapiskat Formation to the Telychian Stage based on the recovery of *Pterospirifer celloni* from cuttings only, and as a result placed this unit within their *Pterospirifer celloni*–*eopennatus* Assemblage Zone. *Ozarkodina polinclinata estonica* was recovered from the base of the Attawapiskat Formation in the present study (Fig. 4). This demonstrates that the base of the Attawapiskat Formation in the core correlates to a position no lower than the *Pterospirifer eopennatus* Superzone (Fig. 3) of the Telychian Stage (Männik 1992, 2002, 2007a, 2007b). Seventy meters above the base of the Attawapiskat Formation in the core (Fig. 4), the presence of *Aspelundia fluegeli fluegeli*, *Distomodus staurognathoides*, *Pterospirifer eopennatus*, and *Aulacognathus bullatus*, limit this position to no higher than the top of the *Pterospirifer eopennatus* Superzone (Fig. 3) of

Männik (1998, 2007a, 2007b), still within the lower part of Telychian Stage. *Pseudooneotodus tricornis* Drygant was recovered from a sample 28.02 to 27.55 meters from the top of the core. The occurrence of *Pseudooneotodus tricornis* on its own does not demonstrate a lower Sheinwoodian correlation (Fig. 3), but it does limit this interval of the core to a position no higher than the lower Sheinwoodian. However, the carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values steadily increase up-section within the Attawapiskat Formation until values reach nearly +3.0‰ at the top of the core (Fig. 4). A comparison of chemostratigraphic data within the core to the global ($\delta^{13}\text{C}_{\text{carb}}$) isotopic signature (Cramer et al. 2010; Cramer et al. 2011; Melchin et al. 2012) indicates that the upper portion of the Attawapiskat Formation likely records the ascending limb of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion. Based on the presence of *Pseudooneotodus tricornis* combined with the ascending limb of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion, the upper portion of the Attawapiskat Formation in this core is likely no higher than a position within the Upper *Pterospathodus procerus* Zone of the lowest part of the Sheinwoodian Stage (Wenlock Series).

Conclusions

The biochemostratigraphic data recovered from the Victor Mine (V-03-270-AH) core provide improved chronostratigraphic control for the Silurian carbonate succession in the Moose River Basin in Ontario, Canada. The Severn River Formation is limited to a position no higher than the base of the Aeronian Stage based upon the conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy of the overlying Ekwon River Formation. The Ekwon River Formation contains the lower Aeronian, upper Aeronian, and lower Telychian

(Valgu) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions, as well as *Aspeludia expansa*, limiting this unit to the middle Aeronian Stage to the lower Telychian Stage. The recovery of *Ozarkodina polinclinata estonica* from the base of the Attawapiskat Formation limit this position within the core to the *Pterospathodus eopennatus* Superzone of the Telychian Stage. The overlying seventy meters of the Attawapiskat Formation in the core are also within the *Pterospathodus eopennatus* Superzone, constrained by the recovery of *Aspelundia fluegeli fluegeli*, *Distomodus staurognathoides*, *Pterospathodus eopennatus*, and *Aulacognathus bullatus*. The presence of *Pseudooneotodus tricornis* from 28.02 to 27.55 meters within the core combined with the ascending limb of the lower Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion limits the upper portion of the Attawapiskat Formation within the core to a position no higher than the Upper *Pterospathodus procerus* Zone (lower Sheinwoodian Stage, Wenlock Series).

Comparison of the Victor Mine (V-03-270-AH) core of the Moose River Basin with the cores analyzed by Zhang and Barnes (2007) suggests that the Severn River and Ekwan River formations may be significantly diachronous across the Hudson Platform or that the lithostratigraphic nomenclature is inconsistent between the Hudson Bay Basin and Moose River Basin. Without significant new biostratigraphic and chemostratigraphic data the regional and global correlation of the Silurian succession of the Hudson Platform cannot be further refined.

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Draft

Figure 1. Present-day map of the Hudson Platform illustrating the location of Paleozoic structural basins and arches in the region. The locality of the Victor Mine (V-03-270-AH) core in the Moose River Basin, Ontario, Canada (sampled for both conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope stratigraphy) is shown with a red circle. The Narwhal O-58 core from Zhang and Barnes (2007) is also illustrated with a white circle. Map was modified from Norris (1993b).

Draft

Figure 2. Lower Paleozoic lithostratigraphy of the Hudson Platform. Correlation on the left-side of the diagram is from Norris (1993b), while the correlation on the right-side of the diagram is from Zhang and Barnes (2007) and Zhang (2008). Chronostratigraphic units for both sides of the diagram are updated for the Ordovician from Bergström et al. (2009) and for the Silurian from Cramer et al. (2011).

Draft

Figure 3. Chronostratigraphy for the Rhuddanian, Aeronian, Telychian, and Sheinwoodian stages of the Silurian System. Chronostratigraphy, carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions, and global conodont zonation from Cramer et al. (2011); Estonian conodont zonation from Männik (2007a, 2007b); selected conodont ranges from Jeppsson (1997), Männik (2007a, 2007b), and Cramer et al. (2010). Horizontal bars at the bottom or top of a species range indicate the first appearance (FAD) and the last appearance (LAD) of that species, respectively. Dashed lines in the range of a species indicate the scattered presence of that species. Ranges of species that extend beyond what is represented in the figure are indicated with an arrow. Stage dates are from Gradstein et al. (2012). Abbreviations: *As.** – *Aspelundia* (junior synonym of *Pseudolonchodina*); *Pt.* – *Pterospathodus*; *Pt. am.* – *Pterospathodus amorphognathoides*; *Pt. p.* – *Pterospathodus pennatus*; *Oz. p.* – *Ozarkodina polinclinata*; *Ps.* – *Pseudooneotodus*; *Oz. s.* – *Ozarkodina sagitta*; *K.* – *Kockelella*; *K. o.* – *Kockelella ortus*.

Figure 4. Lithostratigraphy, conodont biostratigraphy, and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy (VPDB – Vienna Pee Dee belemnite) from the Victor Mine (V-03-270-AH) core, in the Moose River Basin, Ontario, Canada. (*Aspelundia** – junior synonym of *Pseudolonchodina*)

Draft

Figure 5. Silurian conodonts from the Victor Mine (V-03-270-AH) core, located in the Moose River Basin, Ontario, Canada. All specimens were imaged by taking a series of stacked photographs with a Cannon EOS 60D at 75x magnification and the photographs were stacked using Zerene Stacker.

A: *Ozarkodina polinclinata estonica* Männik Pa element from 133.05 meters to 132.85 meters. B: gen. et. sp. indet. from 65.00 meters to 64.66 meters. C: *Icriodella* sp. Pa element from 211.00 meters to 210.80 meters. D: *Distomodus staurognathoides* (Walliser) ? fragment of Pa element from 66.84 meters to 66.50 meters. E: gen. et. sp. indet. and F: gen. et. sp. indet. from 133.05 meters to 132.85 meters. G: *Aulacognathus* sp. Pa element from 65.00 meters to 64.44 meters. H: *Aulacognathus bullatus* (Nicoll and Rexroad) Pa element from 65.00 meters to 64.66 meters. I and J: *Aulacognathus* sp. Pa elements from 65.00 meters to 64.66 meters. K and L: *Aulacognathus bullatus* (Nicoll and Rexroad) Pb element from 65.00 meters to 64.66 meters. M and N: *Aspelundia expansa* Armstrong from 133.05 meters 132.85 meters (taxonomic note: *Aspelundia* is a junior synonym of *Pseudolonchodina*, see Savage 1985; Wang and Aldridge 2010). O: *Aspelundia fluegeli fluegeli* (Walliser) from 65.00 meters to 64.66 meters (taxonomic note: *Aspelundia* is a junior synonym of *Pseudolonchodina*, see Savage 1985; Wang and Aldridge 2010). P: P1 oral view and P2 lateral view *Pterospathodus eopennatus* (? morph 1a) Männik Pa element from 65.00 meters to 64.66 meters. Q: *Pseudooneotodus tricornis* Drygant from 28.02 meters to 27.55 meters. R, S, T and U: *Pterospathodus eopennatus* Männik Pb elements from 65.00 meters to 64.66 meters.

Table 1. Victor Mine (V-03-270-AH) core carbonate carbon (δ^{13}_{carb}) isotope data with conodont
superzones based on recovered conodont biostratigraphic data.

Draft

Figure 1

Figure 1. Present-day map of the Hudson Platform illustrating the location of Paleozoic structural basins and arches in the region. The locality of the Victor Mine (V-03-270-AH) core in the Moose River Basin, Ontario, Canada (sampled for both conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope stratigraphy) is shown with a red circle. The Narwhal O-58 core from Zhang and Barnes (2007) is also illustrated with a white circle. Map was modified from Norris (1993b).
230x341mm (300 x 300 DPI)

Figure 2

Figure 2. Lower Paleozoic lithostratigraphy of the Hudson Platform. Correlation on the left-side of the diagram is from Norris (1993b), while the correlation on the right-side of the diagram is from Zhang and Barnes (2007) and Zhang (2008). Chronostratigraphic units for both sides of the diagram are updated for the Ordovician from Bergström et al. (2009) and for the Silurian from Cramer et al. (2011).
153x106mm (300 x 300 DPI)

Figure 3

Figure 3. Chronostratigraphy for the Rhuddanian, Aeronian, Telychian, and Sheinwoodian stages of the Silurian System. Chronostratigraphy, carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions, and global conodont zonation from Cramer et al. (2011); Estonian conodont zonation from Männik (2007a, 2007b); selected conodont ranges from Jeppsson (1997), Männik (2007a, 2007b), and Cramer et al. (2010). Horizontal bars at the bottom or top of a species range indicate the first appearance (FAD) and the last appearance (LAD) of that species, respectively. Dashed lines in the range of a species indicate the scattered presence of that species. Ranges of species that extend beyond what is represented in the figure are indicated with an arrow. Stage dates are from Gradstein et al. (2012). Abbreviations: As.* – *Aspelundia* (junior synonym of *Pseudolonchodina*); Pt. – *Pterospathodus*; Pt. am. – *Pterospathodus amorphognathoides*; Pt. p. – *Pterospathodus pennatus*; Oz. p. – *Ozarkodina polinclinata*; Ps. – *Pseudooneotodus*; Oz. s. – *Ozarkodina sagitta*; K. – *Kockelella*; K. o. – *Kockelella ortus*.

199x186mm (300 x 300 DPI)

Figure 4

Figure 4. Lithostratigraphy, conodont biostratigraphy, and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy (VPDB – Vienna Pee Dee belemnite) from the Victor Mine (V-03-270-AH) core, in the Moose River Basin, Ontario, Canada. (*Aspelundia** – junior synonym of *Pseudolonchodina*)
275x396mm (300 x 300 DPI)

Figure 5

Figure 5. Silurian conodonts from the Victor Mine (V-03-270-AH) core, located in the Moose River Basin, Ontario, Canada. All specimens were imaged by taking a series of stacked photographs with a Cannon EOS 60D at 75x magnification and the photographs were stacked using Zerene Stacker.

A: *Ozarkodina polinclinata estonica* Männik Pa element from 133.05 meters to 132.85 meters. B: gen. et. sp. indet. from 65.00 meters to 64.66 meters. C: *Icriodella* sp. Pa element from 211.00 meters to 210.80 meters. D: *Distomodus staurognathoides* (Walliser) ? fragment of Pa element from 66.84 meters to 66.50 meters. E: gen. et. sp. indet. and F: gen. et. sp. indet. from 133.05 meters to 132.85 meters. G: *Aulacognathus* sp. Pa element from 65.00 meters to 64.44 meters. H: *Aulacognathus bullatus* (Nicoll and Rexroad) Pa element from 65.00 meters to 64.66 meters. I and J: *Aulacognathus* sp. Pa elements from 65.00 meters to 64.66 meters. K and L: *Aulacognathus bullatus* (Nicoll and Rexroad) Pb element from 65.00 meters to 64.66 meters. M and N: *Aspelundia expansa* Armstrong from 133.05 meters to 132.85 meters (taxonomic note: *Aspelundia* is a junior synonym of *Pseudolonchodina*, see Savage 1985; Wang and Aldridge 2010). O: *Aspelundia fluegeli fluegeli* (Walliser) from 65.00 meters to 64.66 meters

(taxonomic note: *Aspelundia* is a junior synonym of *Pseudolonchodina*, see Savage 1985; Wang and Aldridge 2010). P: P1 oral view and P2 lateral view *Pterospathodus eopennatus* (? morph 1a) Männik Pa element from 65.00 meters to 64.66 meters. Q: *Pseudooneotodus tricornis* Drygant from 28.02 meters to 27.55 meters. R, S, T and U: *Pterospathodus eopennatus* Männik Pb elements from 65.00 meters to 64.66 meters.

241x342mm (300 x 300 DPI)

Draft

Table 1

Victor Mine (V-03-270-AH) Core Biochemostratigraphic Data				
Meters Down Core	Conodont Superzone	$\delta^{13}\text{C}$ (VPDB)	$\delta^{18}\text{O}$ (VPDB)	Formation
7.00 - 7.08	???	2.85	-5.61	Attawapiskat
8.00 - 8.04	???	2.90	-5.31	Attawapiskat
8.75 - 9.00	0.867 kg processed -Barren			Attawapiskat
9.00 - 9.02	???	2.87	-5.04	Attawapiskat
10.00 - 10.04	???	2.68	-5.05	Attawapiskat
11.00 - 11.03	???	3.02	-4.82	Attawapiskat
12.00 - 12.03	???	2.49	-5.22	Attawapiskat
13.00 - 13.04	???	2.48	-5.64	Attawapiskat
13.95 - 14.00	???	2.46	-6.52	Attawapiskat
15.00 - 15.06	???	2.70	-5.18	Attawapiskat
16.00	???	2.73	-5.14	Attawapiskat
17.00 - 17.03	???	2.25	-5.50	Attawapiskat
18.00 - 18.04	???	2.27	-5.30	Attawapiskat
19.00 - 19.03	???	2.33	-5.87	Attawapiskat
20.05 - 20.10	???	2.25	-5.72	Attawapiskat
20.00 - 20.04	???	2.94	-4.76	Attawapiskat
21.00 - 21.06	???	2.66	-5.12	Attawapiskat
22.00 - 22.04	???	2.79	-5.00	Attawapiskat
23.00 - 23.05	???	1.94	-5.83	Attawapiskat
24.00 - 24.05	???	2.90	-4.99	Attawapiskat
25.00 - 25.04	???	2.63	-8.33	Attawapiskat
26.00 - 26.06	???	2.35	-5.08	Attawapiskat
27.00 - 27.03	???	2.85	-4.92	Attawapiskat
27.55 - 28.02	1.835 kg processed - 5 elements			Attawapiskat
28.00 - 28.06	???	2.75	-5.26	Attawapiskat
29.00 - 29.02	???	2.89	-4.73	Attawapiskat
30.00 - 30.05	???	2.78	-5.27	Attawapiskat
31.00 - 31.03	???	2.82	-5.29	Attawapiskat
32.00 - 32.04	???	2.71	-5.32	Attawapiskat
33.00 - 33.02	???	2.72	-6.40	Attawapiskat
34.00 - 34.04	???	2.79	-5.24	Attawapiskat
35.00 - 35.03	???	2.97	-4.97	Attawapiskat
36.00 - 36.03	???	2.73	-5.24	Attawapiskat
37.00 - 37.03	???	2.83	-5.23	Attawapiskat
39.00 - 39.03	???	2.71	-5.20	Attawapiskat
40.00 - 40.02	???	2.21	-6.98	Attawapiskat
41.00 - 41.02	???	2.10	-6.98	Attawapiskat

42.00 - 42.03	???	2.58	-5.41	Attawapiskat
43.00 - 43.02	???	2.64	-5.25	Attawapiskat
44.00 - 44.03	???	2.55	-5.19	Attawapiskat
45.00 - 45.04	???	2.21	-6.23	Attawapiskat
45.00 - 45.04	???	2.76	-5.15	Attawapiskat
46.00 - 46.03	???	2.95	-5.41	Attawapiskat
47.00 - 47.04	???	2.69	-5.42	Attawapiskat
47.59 - 47.89	1.108 kg processed - Barren			Attawapiskat
48.00 - 48.02	???	1.39	-6.36	Attawapiskat
48.95 - 49.01	???	1.17	-5.69	Attawapiskat
50.00 - 50.02	???	1.46	-5.19	Attawapiskat
51.00 - 51.02	???	1.60	-5.33	Attawapiskat
52.02	???	1.26	-6.07	Attawapiskat
52.07	???	1.49	-5.54	Attawapiskat
53.40 - 53.82	1.467 kg processed - Barren			Attawapiskat
54.00 - 54.02	???	1.53	-6.14	Attawapiskat
55.00 - 55.04	???	0.27	-7.15	Attawapiskat
56.00 - 56.03	???	1.51	-6.38	Attawapiskat
57.00 - 57.03	???	1.43	-5.62	Attawapiskat
58.00 - 58.02	???	2.27	-4.78	Attawapiskat
59.00 - 59.05	???	1.65	-5.73	Attawapiskat
60.00 - 60.02	<i>Pterospathodus eopennatus</i>	1.39	-5.99	Attawapiskat
61.00 - 61.02	<i>Pterospathodus eopennatus</i>	1.25	-5.85	Attawapiskat
62.00 - 62.03	<i>Pterospathodus eopennatus</i>	1.20	-6.08	Attawapiskat
62.84 - 63.00	0.539 kg processed - Barren			Attawapiskat
63.03 - 63.05	<i>Pterospathodus eopennatus</i>	0.75	-7.08	Attawapiskat
64.01 - 64.03	<i>Pterospathodus eopennatus</i>	-0.19	-6.18	Attawapiskat
64.66 - 65.00	1.246 kg processed - 41 elements			Attawapiskat
65.00 - 65.03	<i>Pterospathodus eopennatus</i>	-0.56	-6.11	Attawapiskat
66.00 - 66.04	<i>Pterospathodus eopennatus</i>	-0.66	-6.24	Attawapiskat
66.50 - 66.84	1.120 kg processed - 33 elements			Attawapiskat
67.00 - 67.04	<i>Pterospathodus eopennatus</i>	-0.72	-6.11	Attawapiskat
68.02 - 68.04	<i>Pterospathodus eopennatus</i>	-1.29	-5.92	Attawapiskat
69.00 - 69.03	<i>Pterospathodus eopennatus</i>	-0.80	-6.30	Attawapiskat
70.00 - 70.02	<i>Pterospathodus eopennatus</i>	-0.26	-5.71	Attawapiskat
71.00 - 71.03	<i>Pterospathodus eopennatus</i>	-0.06	-5.75	Attawapiskat
72.00 - 72.03	<i>Pterospathodus eopennatus</i>	0.21	-6.50	Attawapiskat
73.00 - 73.02	<i>Pterospathodus eopennatus</i>	0.45	-5.62	Attawapiskat
74.00 - 74.02	<i>Pterospathodus eopennatus</i>	-0.08	-5.81	Attawapiskat
75.00 - 75.03	<i>Pterospathodus eopennatus</i>	-0.23	-5.77	Attawapiskat
76.00 - 76.03	<i>Pterospathodus eopennatus</i>	0.05	-5.73	Attawapiskat
77.00 - 77.02	<i>Pterospathodus eopennatus</i>	-0.60	-5.86	Attawapiskat

78.00 - 78.02	<i>Pterospathodus eopennatus</i>	-1.77	-6.35	Attawapiskat
79.00 - 79.02	<i>Pterospathodus eopennatus</i>	-0.83	-5.64	Attawapiskat
80.00 - 80.03	<i>Pterospathodus eopennatus</i>	-0.95	-5.82	Attawapiskat
81.00 - 81.02	<i>Pterospathodus eopennatus</i>	-1.56	-6.05	Attawapiskat
82.00 - 82.02	<i>Pterospathodus eopennatus</i>	-0.38	-5.14	Attawapiskat
83.06 - 83.08	<i>Pterospathodus eopennatus</i>	-0.06	-4.33	Attawapiskat
84.00 - 84.02	<i>Pterospathodus eopennatus</i>	-0.98	-6.40	Attawapiskat
85.00 - 85.02	<i>Pterospathodus eopennatus</i>	0.30	-5.72	Attawapiskat
86.00 - 86.02	<i>Pterospathodus eopennatus</i>	0.34	-6.13	Attawapiskat
87.00 - 87.02	<i>Pterospathodus eopennatus</i>	-0.69	-5.67	Attawapiskat
88.00 - 88.02	<i>Pterospathodus eopennatus</i>	-0.10	-5.84	Attawapiskat
89.00 - 89.03	<i>Pterospathodus eopennatus</i>	-0.74	-6.29	Attawapiskat
90.00 - 90.02	<i>Pterospathodus eopennatus</i>	-1.08	-5.95	Attawapiskat
91.00 - 91.04	<i>Pterospathodus eopennatus</i>	-0.30	-6.23	Attawapiskat
92.00 - 92.02	<i>Pterospathodus eopennatus</i>	-0.29	-5.53	Attawapiskat
93.00 - 93.07	<i>Pterospathodus eopennatus</i>	-0.36	-6.16	Attawapiskat
94.00 - 94.02	<i>Pterospathodus eopennatus</i>	0.12	-5.57	Attawapiskat
95.00 - 95.03	<i>Pterospathodus eopennatus</i>	0.38	-5.17	Attawapiskat
96.00 - 96.03	<i>Pterospathodus eopennatus</i>	-0.67	-6.07	Attawapiskat
97.00 - 97.03	<i>Pterospathodus eopennatus</i>	0.10	-5.52	Attawapiskat
98.00 - 98.02	<i>Pterospathodus eopennatus</i>	-0.46	-6.00	Attawapiskat
98.96 - 99.00	<i>Pterospathodus eopennatus</i>	-0.67	-5.86	Attawapiskat
100.00 - 100.03	<i>Pterospathodus eopennatus</i>	-1.07	-6.47	Attawapiskat
101.00 - 101.04	<i>Pterospathodus eopennatus</i>	-0.57	-5.03	Attawapiskat
101.10 - 101.43	1.307 kg processed - 49 elements			Attawapiskat
102.00 - 102.02	<i>Pterospathodus eopennatus</i>	-0.66	-5.78	Attawapiskat
104.00 - 104.01	<i>Pterospathodus eopennatus</i>	-0.86	-6.19	Attawapiskat
105.00 - 105.02	<i>Pterospathodus eopennatus</i>	-0.73	-5.76	Attawapiskat
105.95 - 106.00	<i>Pterospathodus eopennatus</i>	-1.00	-6.20	Attawapiskat
107.00 - 107.02	<i>Pterospathodus eopennatus</i>	-1.34	-6.29	Attawapiskat
108.00 - 108.01	<i>Pterospathodus eopennatus</i>	-1.69	-6.23	Attawapiskat
109.00 - 109.03	<i>Pterospathodus eopennatus</i>	-1.37	-6.08	Attawapiskat
110.00 - 110.02	<i>Pterospathodus eopennatus</i>	-1.63	-5.83	Attawapiskat
111.00 - 111.04	<i>Pterospathodus eopennatus</i>	-1.32	-5.88	Attawapiskat
112.00 - 112.02	<i>Pterospathodus eopennatus</i>	-0.60	-5.33	Attawapiskat
113.00 - 113.02	<i>Pterospathodus eopennatus</i>	-1.14	-6.07	Attawapiskat
114.00 - 114.03	<i>Pterospathodus eopennatus</i>	-1.43	-6.01	Attawapiskat
115.02 - 115.05	<i>Pterospathodus eopennatus</i>	-1.62	-5.00	Attawapiskat
116.00 - 116.03	<i>Pterospathodus eopennatus</i>	-0.63	-5.52	Attawapiskat
117.00 - 117.03	<i>Pterospathodus eopennatus</i>	-0.23	-5.17	Attawapiskat
117.95 - 118.00	<i>Pterospathodus eopennatus</i>	-0.94	-5.69	Attawapiskat
119.00 - 119.03	<i>Pterospathodus eopennatus</i>	-0.34	-5.19	Attawapiskat

120.00 - 120.04	<i>Pterospathodus eopennatus</i>	-0.94	-5.74	Attawapiskat
121.00 - 121.02	<i>Pterospathodus eopennatus</i>	-0.52	-5.77	Attawapiskat
122.00 - 122.04	<i>Pterospathodus eopennatus</i>	-0.37	-6.02	Attawapiskat
123.00 - 123.03	<i>Pterospathodus eopennatus</i>	-0.42	-6.21	Attawapiskat
124.00 - 124.03	<i>Pterospathodus eopennatus</i>	-0.03	-5.80	Attawapiskat
125.00 - 125.05	<i>Pterospathodus eopennatus</i>	-0.97	-6.38	Attawapiskat
126.00 - 126.02	<i>Pterospathodus eopennatus</i>	-0.50	-6.09	Attawapiskat
126.95 - 127.02	<i>Pterospathodus eopennatus</i>	-1.08	-5.69	Attawapiskat
128.00 - 128.03	<i>Pterospathodus eopennatus</i>	-1.25	-6.48	Attawapiskat
129.00 - 129.03	<i>Pterospathodus eopennatus</i>	-1.36	-6.18	Attawapiskat
130.03 - 130.06	<i>Pterospathodus eopennatus</i>	-0.45	-5.97	Attawapiskat
131.00 - 131.03	<i>Pterospathodus eopennatus</i>	-1.15	-5.64	Attawapiskat
131.95 - 132.00	<i>Pterospathodus eopennatus</i>	-1.55	-6.21	Attawapiskat
132.85 - 133.05	0.697 kg processed - 27 elements			Ekwan River
133.00 - 133.03	<i>Pterospathodus eopennatus</i>	-1.03	-5.95	Ekwan River
133.95 - 134.00	<i>Pterospathodus eopennatus</i>	0.14	-5.07	Ekwan River
135.00 - 135.05	<i>Pterospathodus eopennatus</i>	0.88	-5.65	Ekwan River
136.00 - 136.03	<i>Pterospathodus eopennatus</i>	0.89	-6.56	Ekwan River
136.92 - 136.96	<i>Pterospathodus eopennatus</i>	0.41	-5.96	Ekwan River
138.00 - 138.03	<i>Pterospathodus eopennatus</i>	0.41	-5.12	Ekwan River
139.00 - 139.02	<i>Pterospathodus eopennatus</i>	0.23	-5.61	Ekwan River
140.05 - 140.10	<i>Aspelundia</i>	-0.77	-10.14	Ekwan River
140.95 - 141.00	<i>Aspelundia</i>	-1.92	-6.04	Ekwan River
142.00 - 142.05	<i>Aspelundia</i>	-2.17	-6.31	Ekwan River
142.26 - 142.40	0.564 kg processed - 9 elements			Ekwan River
143.00 - 143.03	<i>Aspelundia</i>	-2.08	-4.93	Ekwan River
144.00 - 144.04	<i>Aspelundia</i>	-2.74	-5.35	Ekwan River
145.00 - 145.07	<i>Aspelundia</i>	-0.93	-4.59	Ekwan River
146.00 - 146.02	<i>Aspelundia</i>	-0.47	-3.61	Ekwan River
147.00 - 147.04	<i>Aspelundia</i>	0.04	-4.26	Ekwan River
148.00 - 148.03	<i>Aspelundia</i>	0.25	-5.93	Ekwan River
148.80 - 148.86	<i>Aspelundia</i>	-0.83	-7.10	Ekwan River
150.00 - 150.01	<i>Aspelundia</i>	-0.22	-6.06	Ekwan River
151.00 - 151.03	<i>Aspelundia</i>	1.37	-6.30	Ekwan River
151.95 - 152.00	<i>Aspelundia</i>	1.59	-5.38	Ekwan River
153.00 - 153.10	<i>Aspelundia</i>	0.97	-5.04	Ekwan River
154.00 - 154.02	<i>Aspelundia</i>	-0.85	-5.61	Ekwan River
155.00 - 155.04	<i>Aspelundia</i>	-2.46	-6.49	Ekwan River
156.00 - 156.03	<i>Aspelundia</i>	-2.53	-5.04	Ekwan River
157.03 - 157.06	<i>Aspelundia</i>	-3.39	-5.52	Ekwan River
158.00 - 158.03	<i>Aspelundia</i>	-3.12	-5.58	Ekwan River
159.00 - 159.04	<i>Aspelundia</i>	-1.35	-4.92	Ekwan River

160.00 - 160.02	<i>Aspelundia</i>	-1.99	-7.00	Ekwan River
161.00 - 161.03	<i>Aspelundia</i>	-2.23	-7.51	Ekwan River
161.57 - 161.78	0.738 kg processed - 31 elements			Ekwan River
162.00 - 162.02	<i>Aspelundia</i>	-3.48	-9.84	Ekwan River
163.00 - 163.01	<i>Aspelundia</i>	-4.23	-4.25	Ekwan River
164.00 - 164.03	<i>Aspelundia</i>	-3.36	-4.29	Ekwan River
165.00 - 165.02	<i>Aspelundia</i>	-1.39	-6.05	Ekwan River
166.00 - 166.02	<i>Aspelundia</i>	0.00	-6.58	Ekwan River
167.00 - 167.02	<i>Aspelundia</i>	0.45	-4.50	Ekwan River
168.00 - 168.01	<i>Aspelundia</i>	1.00	-4.05	Ekwan River
169.00 - 169.02	<i>Aspelundia</i>	1.35	-5.40	Ekwan River
170.00 - 170.03	<i>Aspelundia</i>	1.53	-7.31	Ekwan River
171.00 - 171.04	<i>Aspelundia</i>	1.77	-4.95	Ekwan River
172.00 - 172.05	<i>Aspelundia</i>	0.43	-4.62	Ekwan River
173.00 - 173.03	<i>Aspelundia</i>	-0.44	-6.31	Ekwan River
174.00 - 174.05	<i>Aspelundia</i>	-0.93	-6.20	Ekwan River
174.44 - 174.45	0.458 kg processed - 5 elements			Ekwan River
175.00 - 175.05	<i>Aspelundia</i>	-1.95	-4.45	Ekwan River
176.00 - 176.07	<i>Aspelundia</i>	-1.09	-3.70	Ekwan River
177.00 - 177.03	<i>Aspelundia</i>	0.91	-4.43	Ekwan River
178.00 - 178.04	<i>Aspelundia</i>	0.58	-4.89	Ekwan River
178.90 - 178.95	<i>Aspelundia</i>	0.07	-6.29	Ekwan River
179.95 - 180.00	<i>Aspelundia</i>	-0.33	-5.70	Ekwan River
181.00 - 181.04	<i>Aspelundia</i>	-1.80	-8.77	Ekwan River
181.95 - 182.00	<i>Aspelundia</i>	-1.23	-7.81	Ekwan River
183.00 - 183.03	<i>Aspelundia</i>	-1.19	-7.42	Ekwan River
184.00 - 184.03	???	-1.23	-7.40	Ekwan River
185.00 - 185.04	???	0.19	-4.76	Ekwan River
186.00 - 186.05	???	0.20	-5.16	Ekwan River
187.00 - 187.04	???	-0.48	-4.48	Ekwan River
188.00 - 188.04	???	-0.99	-6.81	Ekwan River
189.00 - 189.05	???	0.43	-6.51	Ekwan River
190.00 - 190.02	???	-1.12	-8.22	Ekwan River
190.66 - 190.78	0.586 kg processed - Barren			Ekwan River
191.00 - 191.04	???	1.11	-4.80	Ekwan River
191.93 - 192.00	???	0.74	-5.00	Ekwan River
192.95 - 193.01	???	0.29	-4.42	Ekwan River
194.00 - 194.02	???	0.73	-5.55	Ekwan River
195.00 - 195.03	???	0.48	-5.93	Ekwan River
195.13 - 195.53	1.494 kg processed - 11 elements			Ekwan River
195.95 - 196.03	???	0.07	-6.59	Ekwan River
197.10 - 197.15	???	0.09	-6.29	Ekwan River

198.00 - 198.05	???	0.09	-6.02	Severn River
199.00 - 199.04	???	0.36	-6.51	Severn River
200.00 - 200.01	???	0.12	-6.31	Severn River
200.84 - 201.00	0.640 kg processed - 15 elements			Severn River
201.00 - 201.02	???	0.80	-6.51	Severn River
202.00 - 202.04	???	0.97	-6.47	Severn River
202.95 - 203.08	???	0.75	-6.13	Severn River
204.00 - 204.02	???	0.28	-6.40	Severn River
205.00 - 205.02	???	0.25	-6.33	Severn River
206.00 - 206.04	???	0.22	-6.66	Severn River
207.00 - 207.04	???	0.10	-6.50	Severn River
208.00 - 208.03	???	0.99	-6.63	Severn River
209.00 - 209.04	???	0.68	-6.63	Severn River
209.95 - 210.00	???	1.06	-6.02	Severn River
210.80 - 211.00	0.650 kg processed - 3 elements			Severn River
211.00 - 211.02	???	0.87	-6.22	Severn River
212.90 - 212.92	???	1.04	-6.02	Severn River
214.00 - 214.20	???	0.76	-5.93	Severn River
215.09 - 215.13	???	0.40	-5.64	Severn River
215.55 - 215.80	0.890 kg processed - Barren			Severn River
216.00 - 216.03	???	-0.36	-5.24	Severn River
218.00 - 218.04	???	0.00	-5.17	Red Head Rapids
219.00 - 219.04	???	0.06	-4.94	Red Head Rapids
220.00 - 220.06	???	-0.19	-4.97	Red Head Rapids
221.00 - 221.02	???	-0.64	-5.31	Red Head Rapids
222.00 - 222.02	???	-1.21	-6.75	Red Head Rapids
223.00 - 223.05	???	0.05	-5.86	Red Head Rapids
224.00 - 224.02	???	-0.35	-5.34	Red Head Rapids
225.00 - 225.04	???	-0.29	-5.65	Red Head Rapids
226.00 - 226.04	???	-0.24	-5.06	Red Head Rapids
230.96 - 231.00	???	-0.86	-5.56	Red Head Rapids
232.00 - 232.05	???	-1.75	-5.81	Red Head Rapids
232.95 - 233.00	???	0.07	-2.10	Red Head Rapids
233.94 - 234.00	???	-0.35	-4.35	Red Head Rapids
235.00 - 235.04	???	1.24	-0.31	Red Head Rapids
236.00 - 236.04	???	0.87	-1.81	Red Head Rapids
236.95 - 237.00	???	1.07	-2.07	Red Head Rapids
238.00 - 238.10	???	-0.61	-1.66	Red Head Rapids
239.00 - 239.20	???	-1.25	-1.90	Red Head Rapids
239.95 - 240.00	???	0.43	-2.42	Red Head Rapids
241.00 - 241.30	???	-2.24	-11.04	Red Head Rapids
242.00 - 242.20	???	-1.97	-9.56	Red Head Rapids

242.60 - 242.63	???	-1.47	-4.85	Red Head Rapids
243.00 - 243.20	???	-2.56	-2.82	Red Head Rapids
243.00 - 243.20	???	-4.73	-7.99	Red Head Rapids
245.00 - 245.20	???	-2.37	-4.20	Red Head Rapids

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