Canadian Journal of Earth Sciences
Revue canadienne des sciences de la Terre

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Journal:	<i>Canadian Journal of Earth Sciences</i>
Manuscript ID	cjes-2017-0023.R1
Manuscript Type:	Article
Date Submitted by the Author:	12-Jun-2017
Complete List of Authors:	Zhang, Shunxin; Canada-Nunavut Geoscience Office, Jowett, David; 215 Somerglen Place SW Barnes, Chris; School for Earth and Ocean Sciences
Is the invited manuscript for consideration in a Special Issue? :	N/A
Keyword:	latest Ordovician-Early Silurian, conodont biostratigraphy, bioevents, Cape Phillips Formation slope facies, Cornwallis Island

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**Hirnantian (Ordovician) through Wenlock (Silurian) conodont
biostratigraphy, bioevents, and integration with graptolite biozones, Cape
Phillips Formation slope facies, Cornwallis Island, Canadian Arctic Islands**

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ESS contribution number: 20160329

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26 **Abstract:** Cornwallis Island in the Canadian Arctic Archipelago provides one of the world's best areas
27 for establishing an integrated graptolite-conodont biozonation for the Late Ordovician-Silurian given the
28 well-exposed interfingering relationship of the basinal shale and carbonate platform facies. Building on
29 earlier graptolite work, 180 samples were collected from nine sections of the Cape Phillips Formation,
30 of which 118 yielded approximately 7600 conodont elements representing 54 species in 25 genera,
31 including one new genus and species, *Mayrodus melchini*; the conodonts are well preserved with
32 minimal thermal alteration (CAI 1). Nine conodont zones are recognized and defined for this region,
33 namely the *Amorphognathus ordovicicus*, *Distomodus kentuckyensis*, *Aspelundia expansa*, *As. fluegeli*
34 and *Pterospathodus celloni* Interval zones, *Pt. a. amorphognathoides* Taxon-range Zone, *Pt. pennatus*
35 *procerus* and *Kockelella ranuliformis* Highest-occurrence zones, and *K. ortus absidata* Taxon-range
36 Zone. An integration of graptolite and conodont zones is documented. Earlier paleontological and
37 isotope geochemical studies have demonstrated the dynamic nature of the Silurian ocean-climate system
38 and identified major faunal turnovers or events. Five of these are recognized in the Cornwallis fauna and
39 related to oceanographic and climate changes, in part referring to recent oxygen isotope data from
40 conodonts from the Cornwallis collections: Hirnantian extinction event, Sandvika Event (late Aeronian,
41 Llandovery), Snipklint Primo Episode (early Telychian, Llandovery), Ireviken Event (late Telychian,
42 Llandovery-Sheinwoodian, Wenlock) and Mulde Event (early Homerian, Wenlock).

43

44 **Résumé:**

45

46 Introduction

47 The global and regional biostratigraphic correlation of Upper Ordovician and Silurian strata is
48 achieved primarily using graptolites and conodonts. The former are preserved best in basinal shale facies
49 and the latter in platform and slope carbonate facies. One of the most exceptional regions in the world
50 where both facies interfinger and hence allow an integrated biozonation is Cornwallis Island. It is
51 located centrally in the Canadian Arctic Archipelago at approximately 75°N, 95°W and tectonically in
52 the central northern Boothia Uplift (Fig. 1). Ordovician and Silurian strata outcrop extensively on the
53 island and form, in part, the Cape Phillips Formation, which comprises 2.5 km of strata from the upper
54 Katian (Upper Ordovician) to Pridoli (upper Silurian) or lowest Devonian. The Cape Phillips Formation
55 is the graptolitic slope/basinal equivalent of the carbonate shelf facies represented by the Allen Bay
56 Formation, and preserves the Ordovician-Silurian boundary interval as well as the shelf step-back event
57 that followed Late Ordovician glaciation. On Cornwallis Island, an east-west trending facies front
58 separates the shelf and basinal facies, so that the southern half of the island is composed of Allen Bay
59 Formation shelf strata while the Cape Phillips Formation basinal/slope strata outcrop in the north (Fig.
60 1).

61 The Cape Phillips strata are remarkable in preserving a spectacular and diverse fauna of
62 graptolites and conodonts, which is rare when studying the correlation between graptolite and conodont
63 biostratigraphy of the Upper Ordovician and Silurian interval worldwide. A number of biostratigraphic
64 studies have focused on the formation's graptolite zonation (Melchin 1987, 1989; Melchin et al., 1991;
65 Lukasik and Melchin 1997; Lenz and Melchin 1990, 1991; Melchin and Lenz 1986; Lenz, 1993a,
66 1993b, 1995; Lenz et al. 2012; Loydell 2012) as well as initial studies on radiolarians, chitinozoans and
67 microflora (Soufiane and Achab 2000; Noble et al. 2012; Tetard et al. 2015). More recently, some

68 geochemical studies have concentrated on $\delta^{13}\text{C}$ profiles and extinction events in the Cape Phillips
69 Formation (Lenz et al. 2006; Melchin and Holmden 2006a, 2006b; Noble et al. 2005; Noble et al. 2012).

70 In an interdisciplinary team approach, the Cape Phillips was sampled at 1 to 5 m intervals in
71 July 1998, with simultaneous collection of graptolites, chitinozoans, and radiolarians, so that the
72 conodont, chitinozoan, and radiolarian data could be integrated into the existing graptolite
73 biostratigraphic framework. This team effort resulted in studies of lower Silurian radiolaria and
74 radiolarian biostratigraphy (MacDonald 1998, 1999, 2004, 2006a, 2006b), and Upper Ordovician and
75 lower Silurian chitinozoans and chitinozoan biostratigraphy (Soufiane and Achab 2000), as well as a
76 study of Upper Ordovician and lower Silurian conodonts and conodont biostratigraphy (unpublished M.
77 Sc. thesis by Jowett 2000). In this present paper, the authors have substantially updated the taxonomy,
78 biostratigraphy and correlations of Jowett (2000), and added integrations with graptolite biostratigraphy
79 and isotopic geochemical studies and a discussion on the major conodont bioevents.

80

81 **Stratigraphy and Sections**

82 The Cape Phillips Formation, the type section of which is the Cape Phillips North (CPN) section
83 sampled here, was informally divided into members by several authors (Thorsteinsson 1958; Melchin
84 1989; de Freitas and Mayr 1998). Melchin (1989) considered the formation to consist of three members,
85 A, B, and C, which range in age from Late Ordovician to middle Llandovery, early to early-latest
86 Telychian, and latest Telychian to Ludlow, respectively. On Cornwallis Island, the formation consists
87 primarily of calcareous shale and argillaceous limestone, with lesser proportions of calcareous siltstone.
88 Most of the stratigraphic details have already been discussed in the various graptolite publications from
89 the area, but lithologies and locations of conodont samples for the studied sections (Tables S1–S9),

90 adapted from Melchin and Noble (provided to Jowett in 1999), are included in the conodont range
91 diagrams (Figs. 2–5; Tables S10–S18) herein.

92 The sections studied (Figs. 1–5; Tables S1–S9) are situated north of the Allen Bay Formation
93 shelf edge within the slope/basin graptolitic shale facies of the Cape Phillips Formation. Based on
94 graptolitic data from these sections, Cape Phillips South (CPS; Fig. 2) spans the upper Katian-lower
95 Rhuddanian, Cape Phillips North (CPN; Fig. 3) the Telychian-Sheinwoodian, Cape Manning (CM1,
96 CM2, CM3; Figs. 4A–4C) the upper Katian-lower Telychian, Abbott River West (ABW1, ARW2,
97 ARW3; Figs. 5B–5D) the Sheinwoodian-lowermost Gorstian, and Abbott River East (ABE; Fig. 5A) the
98 upper Telychian-lower Sheinwoodian. These sections thus represent a composite uninterrupted interval
99 from the uppermost Ordovician to the base of the upper Silurian.

100
101
102 **Conodont fauna of the Cape Phillips Formation**

103 Previous conodont studies that include Cape Phillips Formation strata were reconnaissance-
104 oriented, focused on a preliminary analysis of the Ordovician-Silurian boundary, and biostratigraphic in
105 nature (Uyeno 1990; Melchin et al. 1991; Märss et al. 1998). A detailed conodont study (Zhang et al.
106 2016) of the Allen Bay Formation carbonate facies and a thin interfingering unit of Cape Phillips
107 Formation on Ellesmere and Devon islands documented the biostratigraphy, sea level events, and
108 regional thermal history applying conodont Colour Alteration Index (CAI) values. This present
109 complementary study presents a comprehensive analysis of conodont biostratigraphy and conodont
110 bioevents from the uppermost Ordovician and lower Silurian portion of the Cape Phillips Formation,
111 and provides integration with the graptolite biozonation.

112 Conodonts from the Cape Phillips Formation on Cornwallis Island are moderately abundant and
113 diverse and exceptionally well preserved with a CAI value of 1, indicating burial temperatures of less

than 80 degrees Celsius. Of 180 samples that were collected from the Cape Phillips Formation, yielded approximately 7600 conodont elements representing 54 species in 25 genera, including one new genus and species, *Mayrodus melchini*, plus an additional six indeterminate genera and species, as well as a subrectiform element (Figs. 6–10; Tables S10–S18). The relatively modest abundance of specimens is mostly a function of the impure carbonates that commonly were only partially dissolved during digestion in 10% acetic acid (documented in Tables S10–S18).

This fauna represents a record of the basin to slope environments and events along the northeastern margin of Laurentia during the latest Ordovician and early Silurian. The conodont biozonation allows correlations to those in other equivalent intervals worldwide in the different facies, including those from slope facies in Greenland (Armstrong 1990), platform and slope facies in the Canadian Cordillera (McCracken 1991; Pyle and Barnes 2000, 2003a, 2003b; Zhang et al. 2005) and Northwest Territories (Nowlan et al. 1988; Over and Chatterton 1987), and the platform facies in the Canadian Arctic (Zhang et al. 2016), Anticosti Island (McCracken and Barnes 1981; Uyeno and Barnes 1983; Zhang and Barnes 2002a, 2002b, 2004), China (Wang and Aldridge 2010), Sweden (Bergström et al. 2014), and Australia (Bischoff 1986).

Conodont biozones and their integration with the graptolite biozones of the Cape Phillips Formation

With aid of the graptolite zonation for the studied sections, the Cape Phillips conodont species distributions are compiled as a composite range chart (Fig. 11; conodont ranges and element counts at each measured section are shown in Figs. 2–5 and Tables S10–S18). This distribution provides a framework to construct a conodont biozonation for the slope and basinal facies of the Canadian Arctic.

136 Following the International Stratigraphic Guide (Salvador 2001), nine conodont zones are
137 recognized and defined within this Arctic region, namely the *Amorphognathus ordovicicus*, *Distomodus*
138 *kentuckyensis*, *Aspelundia expansa*, *A. fluegeli*, and *Pterospathodus celloni* Interval zones, *Pt. a.*
139 *amorphognathoides* Taxon-range Zone, *Pt. pennatus procerus* and *Kockelella ranuliformis* Highest-
140 occurrence zones, and *K. ortus absidata* Taxon-range Zone. An “Unzoned Interval” lies between the last
141 two zones. Graptolite integration refers to the graptolite zones of Cape Phillips Formation (see Fig. 11
142 for correlation of graptolite zones between Cape Phillips Formation and Geologic Time Scale (GTS)
143 2012 (Melchin et al. 2012)), and associated conodonts are listed alphabetically in the zones, in the
144 discussion below.

145

146 ***Amorphognathus ordovicicus* Interval Zone**

147 Definition: The lower boundary of this zone is marked by the first appearance of
148 *Amorphognathus ordovicicus* Branson and Mehl (Figs. 6.1–6.8).

149 Reference section: Cape Phillips South (Fig. 2), 19.7–29 m above the base of the measured
150 section.

151 Graptolite integration: *fastigatus* through *persculptus* zones (but species persists into the
152 lowermost *acuminatus* Zone (Melchin et al. 1991)).

153 Other conodonts: *Belodina confluens* Sweet (Figs. 6.9–6.10), *Besselodus borealis* Nowlan and
154 McCracken (Figs. 6.11–6.14), *Coelocerodontus trigonius* Ethington (Figs. 6.19–6.21), *Decoriconus*
155 *fragilis* (Branson and Mehl) (Figs. 7.39–7.42), *Drepanoistodus suberectus* (Branson and Mehl) (Figs.
156 6.22–6.23), *Eocarniodus gracilis* (Rhodes) (Figs. 6.25–6.26), *Panderodus unicostatus* (Branson and
157 Mehl) (Figs. 6.30–6.36), *Paroistodus? nowlani* Zhen, Webby and Barnes (Figs. 6.15–6.17),
158 *Protopanderodus insculptus* (Branson and Mehl) (no images for this well-known species),

159 *Pseudobelodina? dispansa* (Glenister) (Figs. 6.27–6.29), *Pseudobelodina torta* Sweet (Fig. 6.18),
160 *Pseudooneotodus beckmanni* (Bischoff and Sannemann) (Fig. 6.37), *Pseudooneotodus mitratus*
161 (Moskalenko) (Fig. 6.24), and *Walliserodus curvatus* (Branson and Branson) (Figs. 6.38–6.43).

162 Remarks: *Amorphognathus ordovicicus* is diagnostic of faunas 11–13 (Sweet et al. 1971) (middle
163 Katian to Hirnantian) of both the Midcontinent Province and the North Atlantic Province (Bergström
164 1971; Bergström et al. 2011). It was recovered from the lowest strata sampled in this study, near the top
165 of the *fastigatus*, the middle of the *pacificus* and the *persculptus* (?) graptolite zones at Cape Phillips
166 South section (Fig. 2). Melchin et al. (1991) recovered *Am. ordovicicus* from the *persculptus* Zone with
167 a transitional fauna containing typical Late Ordovician conodonts and early Silurian conodonts
168 belonging to the *nathani* Zone. Additionally, they recovered the transitional fauna containing *Am.*
169 *ordovicicus* within the lower *acuminatus* graptolite Zone.

171 ***Distomodus kentuckyensis* Interval Zone**

172 Definition: The lower boundary of this zone is marked by the first appearance of *Distomodus*
173 *kentuckyensis* Branson and Branson (Figs. 10.1–10.5).

174 Reference section: lower boundary at base of the *madernii-lubricus* Subzone of the *acuminatus*
175 graptolite Zone, 29.0 m above the base of Cape Phillips South section (Fig. 2).

176 Graptolite integration: *madernii-lubricus* Subzone through mid-*atavus* Zone.

177 Other conodonts: *Dapsilodus obliquicostatus* (Branson and Mehl) (Figs. 7.37–7.38), *Ozarkodina*
178 *hassi* (Pollock, Rexroad and Nicoll) (Figs. 8.17–8.22), *Oz. oldhamensis* (Rexroad) (Figs. 8.23–8.25),
179 *Pseudooneotodus tricornis* Drygant (Figs. 7.34–7.35), *Rexroadus kentuckyensis* (Branson and Branson)
180 (Figs. 8.27–8.31), *R. nathani* (McCracken and Barnes) (Figs. 8.32–8.36), and simple cone elements
181 extended from the *Am. ordovicicus* Interval Zone.

Discussion: Zhang and Barnes (2002a) suggested that the *Ozarkodina hassi* Zone on Anticosti Island should replace the *Oulodus*? (*Rexroadus* herein) *nathani* Zone that was proposed for a pre-*Distomodus kentuckyensis* interval by McCracken and Barnes (1981), because *R. nathani* was considered as an endemic taxon with a limited ecological distribution. The *Oz. hassi* Zone was employed by Bergström et al. (2011) to cover the Ordovician-Silurian boundary interval.

Part of the preliminary data provided by Melchin et al. (1991) is from two Ordovician-Silurian boundary sections of the Cape Phillips Formation at Cape Manning on Cornwallis Island. Although the nominate species of the *Rexroadus nathani* Zone was not recognized at Cape Manning, the zone was employed to cover a pre-*Distomodus kentuckyensis* Zone spanning an interval of the uppermost Ordovician–lowest Silurian, for the following reasons:

- at Cape Manning Section A (Melchin et al. 1991), two transitional faunas occur: a) *Amorphognathus ordovicicus* together with *Rexroadus kentuckyensis*, and b) those, together with *Ozarkodina* cf. *Oz. hassi*, were found 1.1 m below and 30 cm above the base of the *acuminatus* graptolite Zone, respectively;
- the first sample yielding *D. kentuckyensis* was recovered from 55 cm above the transitional fauna at Cape Manning section B (Melchin et al. 1991).

However, among the sections studied herein, only the Cape Phillips South section contains the Ordovician-Silurian boundary interval; the samples from the *persculptus* graptolite Zone yielded only *Decoriconus fragilis*, without transitional fauna (Fig. 2). Although Melchin et al. (1991) did not recognize the nominate species of the *Rexroadus nathani* Zone at Cape Manning, the species does occur in two samples at the sections studied herein. The first (CPS7), at Cape Phillips South section (Fig. 2), was recorded precisely at the base of the *acuminatus* graptolite Zone in association with *D. kentuckyensis*, *Oz. hassi*, *R. kentuckyensis*, and other simple cone conodonts. The second (CM2-3), at

205 Cape Manning Section 2 (Fig. 4A), includes a single Pa element of *R. nathani* that was identified in
206 association with *Oz. hassi* and other simple cone elements from the top of the *madernii-lubricus*
207 Subzone of the *acuminatus* graptolite Zone. At this section, the lowest occurrence of *D. kentuckyensis* in
208 sample CM2-2 is 2 m below that of *R. nathani* in sample CM2-3, and 1.4 m above the base of *madernii-*
209 *lubricus* Zone.

210 Sample CPS7 at the Cape Phillips South section (Fig. 2) was collected precisely at the base of
211 the *madernii-lubricus* graptolite Subzone, in which *D. kentuckyensis*, *Oz. hassi*, and *R. kentuckyensis*
212 and *R. nathani* were recovered together, without *Am. ordovicicus* and its associated latest Ordovician
213 conodonts. This makes it difficult to explain the transitional faunas below and above the base of the
214 *acuminatus* Zone at Cape Manning (Melchin et al. 1991). One could argue that the transitional fauna
215 could be within the *persculptus* Zone, but it would be difficult to prove because all the samples collected
216 from this zone at Cape Phillips South section and Cape Manning Section 1 are either barren of
217 conodonts or contain only simple cone elements (Figs. 2 and 4B; Tables S10 and S12). Although the
218 probability for the transitional faunas to exist at these two sections cannot be eliminated, no unequivocal
219 conodont data support the conclusion of Melchin et al. (1991) in this present study. Therefore, no pre-*D.*
220 *kentuckyensis* Zone (*nathani* or *hassi* Zone) is recognized between *Am. ordovicicus* and *D.*
221 *kentuckyensis* Interval zones herein.

222 The occurrence of *D. kentuckyensis* in sample CPS7 at the base of the *madernii-lubricus*
223 graptolite Subzone is represented by one M element and two Sa elements, but without a Pa element.
224 However, this does not preclude the ability to test whether *D. kentuckyensis* is present in boundary
225 strata, because the M element of *D. kentuckyensis* (Fig. 10.5) has a characteristic long anticusp, which is
226 different from that of *D. staurognathoides* (Walliser) (Fig. 10.6).

227 The *Distomodus kentuckyensis* Zone was proposed by Cooper (1975) to replace the *Icriodina*
228 *irregularis* Zone of Nicoll and Rexroad (1969), which is roughly correlated to the upper Rhuddanian
229 through Telychian. Most recent studies have correlated this zone to a lower stratigraphic interval than
230 that of Cooper (1975), such as lower Rhuddanian (not lowest) through lower Aeronian (Bergström et al.
231 2011), and lowest Rhuddanian through upper Rhuddanian (not uppermost) (Cramer et al. 2011; Melchin
232 et al. 2012). The *D. kentuckyensis* Interval Zone recognized by this study is correlated to an interval
233 from the base of *acuminatus* graptolite Zone (earliest Rhuddanian) to the middle *atavus* graptolite Zone
234 (middle Rhuddanian) (Fig. 11).

235

236 ***Aspelundia expansa* Interval Zone**

237 Definition: The lower boundary of this zone is defined by the first appearance of the nominate
238 species (Figs. 7.18–7.25).

239 Reference section: Cape Manning Section 2, 16.1 m above the base of the measured section (Fig.
240 4A).

241 Graptolite integration: *atavus* Zone to middle *crispus* Zone.

242 Other conodonts: the lowest occurrence of the nominate species is found together with
243 *Distomodus kentuckyensis*, *Rexroadus kentuckyensis*, *Ozarkodina hassi*, *Oz. oldhamensis* and other
244 simple cone conodonts (Fig. 4A).

245 Remarks: At Cape Manning Section 2 (Fig. 4A; Table S13), the lowest occurrence of *As.*
246 *expansa* is represented by seven small specimens of the diagnostic M element (Fig. 7.25) in sample
247 CM2B-1 in the mid-*atavus* Zone. Except for their small size, these are almost exactly the same as full
248 size specimens (Fig. 7.21). The first sample yielding the full apparatus of *As. expansa* was recovered
249 from sample CM2C-5 in the mid-*cyphus* graptolite Zone. Samples between the mid-*atavus* Zone and

250 mid-*cyphus* Zone did not yield *As. expansa*, but did contain *D. kentuckyensis*, a few Silurian simple cone
251 conodonts, such as *Dapsilodus obliquicostatus*, *Decoriconus fragilis* and some long ranging simple cone
252 conodonts.

253 The evolution of the *Aspelundia* lineage is unclear. In other studies, the earliest occurrence of *As.*
254 *expansa* in shelf facies is from the upper *vesiculosus* graptolite Zone in New South Wales, Australia
255 (Bischoff 1986), the lowermost Aeronian at the base of the Gun River Formation on Anticosti Island,
256 Canada (Zhang and Barnes 2002a), the upper *Pterospathodus amorphognathoides* conodont Zone in the
257 Mackenzie Mountains, Canada (Over and Chatterton 1987), and from the *Pt. amorphognathoides* Zone
258 in Norway (Aldridge 1974; Aldridge and Mohamed 1982). The lowest occurrence of *As. expansa* in
259 slope facies is probably lower Aeronian, and perhaps as low as uppermost Rhuddanian in North
260 Greenland (Armstrong 1990), which was adopted by GTS 2012. The lowest occurrence of *As. expansa*
261 in sample CM2B-1 in the mid *atavus* Zone at Cape Manning Section 2 is the lowest occurrence of the
262 species worldwide so far. This may suggest that the origination of *As. expansa* was in the basinal facies.

263 This lower boundary of the *As. expansa* Zone in the mid *atavus* graptolite Zone is lower than that
264 in GTS 2012 (Melchin et al. 2012), which is in the mid *cyphus* graptolite Zone (Fig. 11). Except for the
265 lowest and uppermost intervals of the total range of *As. expansa*, almost no other age-diagnostic species
266 were found in the interval from the upper *D. kentuckyensis* through lower *Pt. eopennatus* Superzone in
267 GTS 2012. Therefore, the *As. expansa* Interval Zone in this study is correlated to the upper *D.*
268 *kentuckyensis*, *As. expansa*, *Pt. tenuis*, *D. staurognathoides* and lower *Pt. eopennatus* zones in GTS
269 2012 (Melchin et al. 2012) (Fig. 11), but can be expected to become more restricted with the discovery
270 of more diagnostic faunas.

271

272 *Aspelundia fluegeli* Interval Zone

273 Definition: The lower boundary of this zone is defined by the first appearance of the nominate
274 species (Figs. 7.9–7.17).

275 Reference section: Cape Phillips North section, at the base of measured section (0 m) (Fig. 3).

276 Graptolite integration: lower “*griestoniensis-crenulata*” Zone (pers. comm. Melchin 2017).

277 Other conodonts: *Apsidognathus*? sp. (Figs. 7.5–7.6), *Aspelundia* cf. *As. borenorensis* Bischoff
278 (Figs. 7.26–7.33), *Belodella* sp. A Miller (Figs. 8.40–8.41), *Distomodus staurognathoides* (Walliser)
279 (Figs. 10.6–10.10), *Walliserodus* cf. *W. sancticlairei* Cooper (Figs. 8.42–8.45) and other simple cone
280 conodonts.

281 Remarks: At the Cape Manning Section 2 (Fig. 4A), *As. fluegeli* was not found, but *As. expansa*
282 ranges at least up into the *turriculatus* Zone. The last sample yielding *As. expansa* is 7 m above the base
283 of the *turriculatus* Zone, however, the final 14 m of strata yielded no conodonts.

284 Between Cape Manning 2 and 3 (Figs. 4A and 4C) there is a covered interval of at most a few
285 tens of meters. This represents the remainder of the *turriculatus* Zone and possibly the lowermost
286 portion of the *crispus* Zone; the latter is represented at least by 2 m of strata above the base of Cape
287 Manning 3 (Fig. 4C). The highest sample (CM3-3) yielding unquestionable elements of *As. expansa*
288 occurs at 10 m, close to the top of the *crispus* Zone, at Cape Manning 3. A few isolated elements
289 assigned to *As. expansa* from 40 m (CM3-7) (“*griestoniensis-crenulata*” Zone) at the section may
290 include elements of *As. fluegeli*. At 79 m (CM3-10), *As. fluegeli* is definitely present (Fig. 4C). Samples
291 at Cape Manning 3 were low-yielding and dissolved poorly, and because a short covered interval occurs
292 between Cape Manning 2 and 3 representing the uppermost *turriculatus* Zone and possibly the lower
293 parts of the *crispus* Zone, the lower limit of *As. fluegeli* may be near the *turriculatus-crispus* zonal

boundary. This is in agreement with a probable *turriculatus* Zone assignment in the northern Yukon (McCracken 1991).

However, the lowest occurrence of the confirmed *As. fluegeli* is at the base of Cape Phillips North Section (Fig. 3), where the “*griestoniensis-crenulata*” Zone (pers. comm. Melchin 2017) occurs. Therefore, the *As. fluegeli* Zone is correlated to “*griestoniensis-crenulata*” graptolite Zone in this study.

The *As. fluegeli* Zone was established in North Greenland (Armstrong 1990), where the zonal species appears within the *argenteus* graptolite Zone, which is equivalent to the upper part of the *curtus* graptolite Zone in the Canadian Arctic. The *As. fluegeli* Zone was recognized between the *As. expansa* and *D. staurognathoides* zones in Estonia, although the range of *As. fluegeli* extends well into the Telychian (Männik 2007a). This zone was replaced by the *Pt. tenuis* Zone in GTS 2012 (Melchin et al. 2012) and correlated to the upper *pectinatus-triangularis* and lower *leptotheca-argenteus* graptolite zones in the middle Aeronian (Melchin et al. 2012) (Fig. 11). However, the *As. fluegeli* Interval Zone recognized in the Cape Phillips Formation occurs in the lower Telychian, significantly above that interval shown in GTS 2012 (Melchin et al. 2012, fig. 21.1). Therefore, the *As. fluegeli* Zone of Armstrong (1990) and Männik (2007a), or *Pt. tenuis* Zone of GTS 2012 (Melchin et al. 2012), and the *As. fluegeli* Interval Zone of this study are not comparable.

***Pterospathodus celloni* Interval Zone**

Definition: The lower boundary of the *Pt. celloni* Zone is defined by the first appearance of the nominate species (Figs. 9.15–9.25) with confirmed Pa element.

Reference section: Cape Phillips North Section, 8.0 m above the base of the section (Fig. 3).

Graptolite integration: upper “*greistoniensis-crenulata*” Zone to the lower *spiralis* Zone (pers. comm. Melchin 2017).

Other conodonts: *Aulacognathus bullatus* (Nicoll and Rexroad) (Figs. 10.11–10.12) and *Pt. eopennatus* spp. 2 Männik (Fig. 9.1), as well as those extended from the underlying *As. fluegeli* Interval Zone, and simple cone conodonts.

Remarks: The lowest occurrence of the diagnostic element (Pa) of the zonal species recovered was from 8.0 m above the base of the Cape Phillips North section (Fig. 3). However, S elements of *Pterospathodus* that probably belong to *Pt. celloni* (Walliser) were found below this, at 0 and 5.0 m above the base of the section (Table S11), which are possibly assigned to the “*greistoniensis-crenulata*” Zone (pers. comm. Melchin 2017). McCracken (1991) noted that in northern Yukon *As. fluegeli* appears in high-yielding samples below the occurrence of *Pt. celloni*. Because of the low yields in the few samples from the uppermost *turriculatus* Zone through *crispus* Zone interval, it is proposed that, as in the Road River Formation, Yukon (McCracken 1991), *As. fluegeli* probably also appears below *Pt. celloni* in the Cape Phillips Formation, making the *As. fluegeli* Zone of very short duration.

In Estonia, the *Pt. celloni* Superzone is characterized by the sequence of *Pt. amorphognathoides angulatus* (Walliser), *Pt. a. lennarti* Männik, and *Pt. a. lithuanicus* Brazauskas (Männik 1998), with the three species formally used as nominate species of these three zones within the *Pt. celloni* Superzone (Männik 2007a). Loydell et al. (2003) correlated the base of *Pt. a. angulatus* Zone (and also the base of *Pt. celloni* Superzone) to within the *crenulata* graptolite Zone, which has been adopted by GTS 2012 (Melchin et al. 2012). Therefore, the base of the *Pt. celloni* Zone herein occurring within the “*greistoniensis-crenulata*” graptolite Zone is close to that of GTS 2012 (Melchin et al. 2012).

***Pterospathodus a. amorphognathoides* Taxon-range Zone**

Definition: The lower and upper boundaries are defined by the first and last occurrence of *Pterospathodus a. amorphognathoides* (Walliser) (Figs. 9.2–9.14).

Reference section: The lower boundary is at 59.7 m above the base of Cape Phillips North Section (Fig. 3), and the upper boundary is at 13.6 m above the base of Abbott River East Section (Fig. 5A).

Graptolite integration: lower *spiralis* Zone to middle *sakmaricus* Zone.

Other conodonts: *Apsidognathus tuberculatus* Walliser (Figs. 7.1–7.4), *Ap. n. sp. 3* McCracken (Fig. 7.7), *Ap. cf. Ap. walmsleyi* Aldridge (Fig. 7.8), *Aulacognathus chapini* (Savage) (Figs. 10.23–10.24), *Ozarkodina hadra* (Nicoll and Rexroad) (Figs. 8.12–8.16), *Pterospathodus amorphognathoides angulatus* (no images), *Pt. pennatus procerus* (Walliser) (Figs. 9.28–9.41), and *Pt. rhodesi* (Savage) (Figs. 9.26–9.27), besides those extending from the underlying *Pt. celloni* Zone and simple cone conodonts.

Remarks: In Estonia, the base of the *Pt. a. amorphognathoides* Zone occurs close to the base of the *lapworthi* graptolite Zone (Loydell et al. 1998), which has been adopted by GTS 2012 (Melchin et al. 2012). Männik (1998) noted that *Pt. a. amorphognathoides* is common in nearshore environments; in deeper, graptolite-bearing environments it becomes rare and is replaced by *Pt. pennatus procerus* (Walliser). However, these two zones have been recognized from graptolite-bearing cores in Latvia (Loydell et al. 2003; Loydell et al. 2010) and Estonia (Loydell et al. 1998). At the Cape Phillips North section, there is an alternating replacement between *Pt. a. amorphognathoides* and *Pt. p. procerus* in samples CP22, CP24 and CP25 (Fig. 12; Table S11) in the upper *Pt. a. amorphognathoides* Taxon-range Zone, but this does not correlate to any obvious facies change.

The base of the *Pt. a. amorphognathoides* Zone was placed within the upper *griestoniensis-crenulata* graptolite Zone by the Subcommission on Silurian Stratigraphy (1995). However, in the cores in both Estonia and Latvia (Loydell et al. 1998; Loydell et al. 2003; Loydell et al. 2010), the base of *Pt. a. amorphognathoides* Zone occurs close to the base of the *lapworthi* graptolite Zone, which was

accepted by GTS 2012 (Melchin et al. 2012). The base of *Pt. a. amorphognathoides* Taxon-range Zone on Cornwallis Island is within the *spiralis* graptolite Zone, higher than that defined by Subcommittee on Silurian Stratigraphy (1995) and lower than that adopted by GTS 2012 (Melchin et al. 2012). This is another situation where the lower boundary of conodont zone on Cornwallis Island is lower than that adopted by GTS 2012 (Melchin et al. 2012).

368

***Pterospathodus pennatus procerus* Highest-occurrence Zone**

Definition: The base and the top of the *Pterospathodus pennatus procerus* Highest-occurrence Zone is defined by the highest occurrence of *Pt. a. amorphognathoides* and *Pt. p. procerus* (Walliser) (Figs. 9.28–9.41), respectively.

Reference section: Abbott River East Section, 13.6 m above the base of the measured section (Fig. 5A); Cape Phillips North Section, 182 m above the base of the measured section (Fig. 3).

Graptolite integration: upper *sakmaricus* Zone to lowermost *instrenuus-kolobus* Zone.

Other conodonts: *Distomodus staurognathoides*, *Ozarkodina e. excavata* (Branson and Mehl) (Figs. 8.6–8.11), and some simple cone conodonts that only occur in the lower part of the zone.

Remarks: Jeppsson (1997a) defined the extinction of *Pt. a. amorphognathoides* as the lower boundary of *Pt. pennatus procerus* Superzone, and correlated the Superzone to the upper *insectus* and *centrifugus* graptolite zones. However, the base of the *Pt. p. procerus* Superzone has been placed within the *murchisoni* graptolite Zone and the conodont zone has been correlated to an interval from the upper *murchisoni* to the lowermost *riccartonensis* graptolite zones in a number of studies (Männik et al. 2002; Männik 2007b; Loydell et al. 2003; Loydell et al. 2010), which has been adopted by GTS 2012 (Melchin et al. 2012).

It is unclear whether the last occurrence of *P. a. amorphognathoides* on Cornwallis Island, 13.6 m above the base of the measured Abbott River East Section, represents the last appearance of the species, but it disappears along with many other conodont species (Figs. 5A and 11). This level, within the *sakmaricus* graptolite Zone, is lower than that in the lower *murchisoni* graptolite Zone adopted by GTS 2012, although distinguishing between *P. a. amorphognathoides* and *P. pennatus procerus* can be difficult if only juvenile Pa elements are present or if Pa elements are absent.

The samples from the *insectus* graptolite Zone in the Cape Phillips Formation are generally resistant to acid digestion. However, one at Abbott River East (sample ARE6) contains *Pt. p. procerus* but not *Pt. a. amorphognathoides*, although the latter subspecies is present in the preceding sample (Fig. 5A). Hence, the extinction or last appearance datum of *Pt. a. amorphognathoides* may lie low in the *insectus* Zone in the Cape Phillips Formation. The upper range of *Pt. p. procerus* in the formation is within the lower part of the *instrenuus-kolobus* graptolite Zone, only slightly higher than that defined by GTS 2012 (Melchin et al. 2012). This adds more data in support of the extinction of *Pterospathodus*, Datum 6 of the Ireviken Event, being broadly synchronous globally.

***Kockelella ranuliformis* Highest-occurrence Zone**

Definition: The last appearances of *Pterospathodus pennatus procerus* (and hence the genus *Pterospathodus*) and *Kockelella ranuliformis* (Walliser) (Figs. 10.17–10.22) mark the base and top of the *K. ranuliformis* Highest-occurrence Zone, respectively.

Reference section: Cape Phillips North Section (Fig. 3), between 182 m and 256.5 m above the base of the measured section.

Graptolite integration: lower *instrenuus-kolobus* to lower *perneri-opimus* graptolite zones.

407 Other conodonts: *Mayrodus melchini* n. gen. et n. sp. (Figs. 10.31–10.35), *Pseudooneotodus*
408 *bicornis* Drygant (Fig. 7.36), *Ozarkodina e. excavata*, and other simple cone conodonts extending from
409 below.

410 Remarks: The *K. ranuliformis* Zone was established in Oklahoma by Barrick and Klapper
411 (1976); its base was defined by the first appearance of *Pseudooneotodus bicornis*, which coincides with
412 the last occurrence of *Pt. a. amorphognathoides*. Jeppsson (1997a) used the extinction of genus
413 *Pterospathodus* and the first appearance of *Ozarkodina sagitta rhenana* as the lower and upper
414 boundaries of the *K. ranuliformis* Zone, respectively, and correlated the zone to an interval from the
415 middle *centrifugus* to upper *riccartonensis* graptolite zones. In studying the Ohesaare core in Estonia,
416 Loydell et al. (1998) restricted the *K. ranuliformis* Superzone to include the lower and upper *K.*
417 *ranuliformis* zones that were correlated to the *firmus* and *riccartonensis* graptolite zones, respectively,
418 which has been adopted by GTS 2012 (Melchin et al. 2012). However, the base of the *K. ranuliformis*
419 Superzone lies one graptolite zone higher (near the base of the *riccartonensis* graptolite Zone) in the
420 Aizpute-41 core in Latvia (Loydell et al. 2003).

421 The upper boundary of the *K. ranuliformis* Superzone was defined by the first appearance of *Oz.*
422 *sagitta rhenana* (Jeppsson 1997a) and the boundary between the Lower and Upper *ranuliformis* zones
423 by the extinction of *Distomodus staurognathoides*, close to the boundary between the *firmus* and
424 *riccartonensis* graptolite zones (Jeppsson 1997a; Loydell et al. 1998). These two boundaries are not
425 recognized in the Cape Phillips Formation because *Oz. sagitta rhenana* is absent and the last occurrence
426 of *D. staurognathoides* is in the lower *insectus* graptolite Zone (Figs. 5A and 11), well below that
427 recognized by Jeppsson (1997a) and Loydell et al. (1998). Therefore, the *K. ranuliformis* Highest-
428 occurrence Zone is recognized at the Cape Phillips North section (Fig. 3); this interval is roughly
429 equivalent to the *K. ranuliformis* Superzone of GTS 2012 (Melchin et al. 2012) (Fig. 11).

430

431 **Unzoned Interval**

432 The lowest occurrence of *Kokelella ortus absidata* Barrick and Klapper (Figs. 10.13–10.15) is at
433 the base of the measured Abbott River West Section 2, within the *lundgreni* graptolite Zone (Fig. 5C);
434 although no full apparatus of the species was recovered from sample 2ARW1, two specimens of the Pa
435 element were found. This level is lower than the *Oz. bohémica longa* Zone of GTS 2012 (Fig. 11).

436 In the Clarita Formation, Arbuckle Mountains, Oklahoma, the lowest occurrence of *K. ortus*
437 *absidata* is only slightly higher than that of *Ozarkodina sagitta rhenana* (Barrick and Klapper 1976), but
438 a discussion with Barrick (Calner and Jeppsson 2003) reached an agreement that the specimens older
439 than the *Oz. bohémica longa* Zone are referred to *K. o. ortus*, although in some aspects these are
440 intermediate. Therefore, it is uncertain whether the specimens identified as *K. o. absidata* in sample
441 2ARW1 at Abbott River West Section 2 (Fig. 5C) can be referred to *K. o. ortus* as adopted by Calner
442 and Jeppsson (2003).

443 Most strata between the last occurrence of *K. ranuliformis* and the first occurrence of confirmed
444 *K. o. absidata* are best developed at the Abbott River West Section 1, Section 2 and the lower part of
445 Section 3 within an interval from the *perneri-opimus* to lower *praedeubeli-deubeli* graptolite zones
446 (Figs. 5B, 5C and 5D). Within this interval, besides some simple cone conodonts and the long-ranging
447 *Oz. e. excavata*, *Oz. confluens* (Branson and Mehl) (Figs. 8.2–8.5), the short-ranging *K. patula* Walliser
448 (Fig. 10.16) and the questionable *K. ortus absidata* are only found in sample 2ARW1 at Abbott River
449 West Section 2 (Fig. 5C). Therefore, no conodont zone is recognized between the last occurrence of *K.*
450 *ranuliformis* and the first occurrence of confirmed *K. ortus absidata* (Figs. 5B, 5C, 5D and 11) and this
451 is termed the “Unzoned Interval”.

452 The occurrence of *K. patula* and the first occurrence of *Oz. confluens* in sample 2ARW1 at
 453 Abbott River West Section 2 merit discussion. *K. patula* was used as the nominate species of the *K.*
 454 *patula* Zone by Walliser (1964) at the Cellon section, Austria, where the *K. patula* Zone directly
 455 succeeds the *Pt. amorphognathoides* Zone. Jeppsson (1997a) identified the *K. ranuliformis*, *Oz. sagitta*
 456 *rhenana*, and *K. walliseri* zones between the *Pt. pennatus procerus* and *K. patula* zones, and correlated
 457 the *K. patula* Zone to the *rigidus* graptolite Zone. Zhang et al. (2016) found that the last occurrence of
 458 *Pt. pennatus procerus* and the first occurrence of *K. patula* occurred in the same sample in the Cape
 459 Phillips Formation on Sheills Peninsula, Devon Island. They correlated the *K. patula* Local-Range Zone
 460 to the *Kockelella ranuliformis*, *Oz. sagitta rhenana*, and *K. walliseri* zones. Thus, the occurrence of *K.*
 461 *patula* in the “Unzoned Interval” in this study probably represents the last occurrence of this species in
 462 the Cape Phillips Formation. *Oz. confluens* co-occurs with *K. v. variabilis* Walliser in the *Kockelella v.*
 463 *variabilis*-*Ozarkodina confluens* Concurrent-range Zone in the Upper Member, Allen Bay Formation on
 464 Ellesmere Island, which is correlated to the *K. crassa* and *K. v. variabilis* conodont zones of Gorstian
 465 (Upper Silurian) (Zhang et al. 2016). However, the lowest occurrence of *Oz. confluens* in the Cape
 466 Phillips Formation is within the *lundgreni* graptolite Zone (Fig. 5C), lower Homerian, at the Abbott
 467 River West Section 2. The last occurrence of this species in the Abbott River West Section 3 is in the
 468 lower Gorstian (Fig. 5D), which is about the same level as its lowest occurrence on Ellesmere Island
 469 (Zhang et al. 2016). Therefore, the “Unzoned Interval” of this study and the *K. v. variabilis*-*Oz.*
 470 *confluens* Concurrent-range Zone of Zhang et al. (2016) are not equivalent; the “Unzoned Interval”
 471 correlates approximately to the *perneri-opimus* to lower *praedeubeli-deubeli* graptolite zones.

472

473 ***Kockelella ortus absidata* Taxon-range Zone**

474 Definition: The lowest and highest occurrences of the confirmed *Kockelella ortus absidata* (Figs.
475 10.13–10.15) mark the base and top of the *K. o. absidata* Taxon-range Zone, respectively.

476 Reference section: Abbott River West Section 3, between 24 m and 37 m above the base of the
477 measured section (Fig. 5D).

478 Graptolite integration: upper *praedeubeli-deubeli* and *ludensis* zones, possibly extending to
479 lower *progenitor* Zone.

480 Other conodonts: *Oulodus equirectus* Kleffner (Fig. 8.26), with *Ozarkodina e. excavata*, *Oz.*
481 *confluens* and simple cone conodonts extending from below.

482 Remarks: Calner and Jeppsson (2003) established a subspecies *Kockelella ortus absidata* taking
483 *K. absidata* Barrick and Klapper as a synonym. They also erected three new conodont zones: the
484 *Ozarkodina bohémica longa*, *K. ortus absidata* and *Ctenognathus murchisoni* zones, to replace the *Oz.*
485 *bohémica* Zone adopted by the Subcommittee on Silurian Stratigraphy (1995). The *K. o. absidata* Zone
486 represents a narrow interval that was correlated to the lower *praedeudeli* graptolite Zone (Calner and
487 Jeppsson 2003). Recently, the *K. o. absidata* and *C. murchisoni* zones have been merged into the *K. o.*
488 *absidata* Zone and correlated to the *praedeubeli*, *deubeli* and *ludensis* graptolite zones, upper Homerican,
489 by GTS 2012 (Melchin et al. 2012).

490 The first confirmed *K. ortus absidata* occurs in sample 3ARW12, 24 m above the base of
491 measured Abbott River Section 3, where the *praedeubeli-deubeli* graptolite Zone begins at 14.5 m (Fig.
492 5D). This level is higher than the base of *K. o. absidata* Zone that is correlated to the base of
493 *praedeudeli* graptolite Zone by GTS 2012 with significant uncertainty (Melchin et al. 2012). The last
494 occurrence of *K. o. absidata* at Abbott River Section 3 is in sample 3ARW37, 37 m above the base of

495 the section, and this level is probably lies within the *progenitor* graptolite Zone of the basal Gorstian
496 (upper Silurian) (Figs. 5D and 11).

497

498 **Conodont bioevents**

499 Recent paleontological and isotope geochemical studies have demonstrated the dynamic nature
500 of the Silurian ocean-climate system, with major changes in the global carbon cycle, paleoseawater
501 temperatures, and marine communities (Noble et al. 2005; Lehnert et al. 2010; Cooper et al. 2013;
502 Trotter et al. 2016). Major bioevents have been correlated with climate changes, especially in the
503 Hirnantian and early Silurian (Zhang and Barnes 2002b; Loydell 2007; Trotter et al. 2008, 2016;
504 Munnecke et al. 2010; Harper et al. 2013; Melchin et al. 2013; Baarli 2014; Ghienne et al. 2014; Sheets
505 et al. 2016). Following the terminal Ordovician glaciation, there was a progressive recovery and
506 resetting of community structures (Zhang and Barnes 2002a, 2002b; Melchin et al. 2013). Several earlier
507 benchmark studies described specific patterns in species occurrence and relative abundance of Silurian
508 conodonts from the Baltic and Avalon palaeoplates (Jeppsson 1990, 1993, 1998; Aldridge et al. 1993;
509 Jeppsson et al. 1995; Jeppsson and Aldridge 2000). These proposed a conceptual model of Silurian
510 oceans that alternated between two stable states, primo (P) and secundo (S) ‘episodes’, typically
511 separated by prominent bioevents. These earlier studies and those of Johnson (1987, 1996, 2006)
512 observed a correlation between primo episodes and eustatic lowstands, but only rarely between secundo
513 episodes and highstand events.

514 Three such events, characterized by major perturbations in biotic turnovers and isotope records
515 ($\delta^{13}\text{C}$ and/or $\delta^{18}\text{O}$), occur in the latest Llandovery-early Wenlock (Ireviken Event), late Wenlock (Mulde
516 Event), and mid Ludlow (Lau Event; not considered herein) (references above and Aldridge and
517 Jeppsson 1984; Jeppsson and Calner 2003; Cramer and Saltzman 2007; Calner 2008). Stratigraphic

evidence for Silurian glacial deposits in Gondwana is not well constrained and is limited to the Llandovery and early Wenlock (Grahns and Caputo 1992; Caputo 1998; Díaz-Martínez and Grahns 2007). Some of the Silurian sea-level and oceanographic fluctuations (Johnson 1987, 1996, 2006, 2010; Loydell 1998; Servais et al. 2014) have been correlated with these brief glacial phases (Díaz-Martínez and Grahns 2007; Lehnert et al. 2010).

Historically, most emphasis has been placed on sea level changes that can be interpreted from the stratigraphic record to partially explain bioevents. More recently, isotopic data have provided proxies for interpreting the paleoclimate records, particularly the oxygen isotope ($\delta^{18}\text{O}$) paleoseawater temperature proxy using marine biogenic archives (brachiopods, conodonts, fish remains). Initial Silurian $\delta^{18}\text{O}$ records from conodont apatite ($\delta^{18}\text{O}_{\text{phos}}$) covered particular European stratigraphic intervals between the upper Llandovery and Pridoli (Wenzel et al. 2000; Lehnert et al. 2007, 2010; Žigaitė et al. 2010), but were recently expanded by Trotter et al. (2016) who interpreted new data through the Silurian from four paleoplates based on over 2500 SHRIMP ion microprobe conodont analyses. Some of the latter analyses were on conodonts from 45 of the same Cornwallis Island samples reported in this present paper. Trotter et al. (2016, p. 38) noted that “In our prime record from Cornwallis Island, the range in $\delta^{18}\text{O}_{\text{phos}}$ throughout the Llandovery is between $\sim 19.4\text{‰}$ (late Rhuddanian) and $\sim 17.5\text{‰}$ (early Telychian), reflecting an overall maximum temperature range of $\sim 9\text{ °C}$ through this $\sim 10.5\text{ Myr}$ period” and “Thus the $\sim 2\text{‰}$ range of both cooling cycles in the early and late Wenlock represents potential temperature drops of up to $\sim 9\text{ °C}$ (depending on ice volume)”. Overall, they summarized (2016, p. 38) the main changes in the Silurian climate as: “The $\delta^{18}\text{O}_{\text{phos}}$ record shows that the Silurian was a period of significant climatic variability with warm periods having equatorial temperatures higher than today. The main trends show that an overall gradual warming phase dominated the Llandovery, two major cooling

540 peaks characterised the early and late Wenlock, and warmer conditions returned during the rest of the
541 period with extreme short-lived and rapid warming-cooling events in the mid Ludlow”.

542 Several conodont bioevents and episodes are recognized herein from collections of the Cape
543 Phillips Formation. They are identified and discussed below within specific chronostratigraphic intervals
544 and related to the integrated conodont-graptolite biozonations established above and to carbon and
545 oxygen isotopic data published by Trotter et al. (2016) and others.

546

547 **Terminal Ordovician Extinction Event (Hirnantian)**

548 From the data presented here and by Melchin et al. (1991, 2013), the *Am. ordovicicus* Zone
549 persists into the lower *persculptus* graptolite Zone, with the major conodont extinction occurring in the
550 mid-late *persculptus* Zone in the Cape Phillips Formation. At the Cape Manning section, in the lower
551 *persculptus* Zone, both $\delta^{13}\text{C}_{\text{carb}}$ and $\delta^{15}\text{N}$ have a negative shift, respectively (Melchin and Holmden
552 2006b; Melchin et al. 2013). The Cape Phillips South section (Fig. 2; Table S1) exhibits an erosional
553 surface with about 30 centimeters of relief with evidence of shallow karstic dissolution and infilling in
554 the carbonate immediately underlying the black shale strata containing *persculptus* Zone graptolites,
555 indicating the presence of a significant hiatus marking an episode of subaerial erosion. This was also
556 noted by Melchin et al. (1991).

557 Below and above this erosional surface, the conodont faunal analysis showed a change from an
558 *Amorphognathus ordovicicus* community to a *Decoriconus fragilis* community (Zhang et al. 2006). *D.*
559 *fragilis* is common in more offshore shelf areas (Aldridge and Jeppsson 1984). The *D. fragilis*
560 community recognized at the Cape Phillips South section has a very low diversity and abundance
561 (samples CPS4–CPS6 in Table S10; Zhang et al. 2006, fig. 8) and represents a survival conodont fauna
562 after the end-Ordovician extinction (Barnes and Bergström 1988). This survival coincides with a

conodont faunal turnover represented by a “transitional fauna” at Cape Manning section (=Cape Manning section 1 herein) reported by Melchin et al. (1991). However, this turnover is not recognized by this present study. The lithofacies changes from dolostone with a paleokarst surface and hosting the *Am. ordovicicus* community in an interval from upper *fastigatus* Zone through lowest *persculptus* Zone to the black fissile calcareous shales hosting the *D. fragilis* community through most of the *persculptus* Zone. These changes in both conodont communities and lithofacies coincide with both $\delta^{13}\text{C}_{\text{carb}}$ and $\delta^{15}\text{N}$ shifting back to normal values (Melchin and Holmden 2006b; Melchin et al. 2013). More especially, the $\delta^{18}\text{O}$ values (Trotter et al. 2008, 2016) from conodonts through this interval show the extent of the glacially-induced paleoequatorial ocean cooling. These data are compatible with the model proposed by Branchley et al. (2001) and Branchley (2004), in which the survival fauna in the *persculptus* Zone responded to a global warming, change in carbon cycling, sea level rise, and widespread anoxia immediately after the Hirnantian glaciation. Ghienne et al. (2014) provided a revised and more detailed interpretation, but involved older Hirnantian events are not covered by the Cornwallis sampling.

Spirodden Secundo Episode (late Rhuddanian)

In the Cape Phillips Formation, the *Distomodus kentuckyensis* Interval Zone species such as *Ozarkodina hassi*, *Oz. oldhamensis*, and *Rexroadus kentuckyensis*, which are common in the Rhuddanian and lower Aeronian elsewhere, disappear relatively early in the *atavus* or *cyphus* graptolite zones, and are replaced by the fauna that is dominated by *Aspelundia expansa*, *Walliserodus curvatus* and *Dapsilodus obliquicostatus*. This is the main fauna occurring throughout the remainder of the Rhuddanian, Aeronian and lower Telychian. The significance of this mid to late Rhuddanian replacement is uncertain, but it coincides with the progressive warming (~2‰ decrease in $\delta^{18}\text{O}$ values) from Rhuddanian to early Telychian (Trotter et al. 2016) and weak $\delta^{13}\text{C}_{\text{org}}$ positive shifts (up to +1.5‰)

on Cornwallis Island, higher than in the other regions (less than 1‰) (Melchin and Holmden 2006a). However, a $\delta^{13}\text{C}_{\text{carb}}$ negative shift (– 0.5 to – 1.5‰) in the *cyphus* graptolite Zone was recorded in Estonia (Kaljo and Martma 2000), which was adapted as part of the generalized Silurian $\delta^{13}\text{C}_{\text{carb}}$ curve by Cramer et al. (2011). The interval falls within the Spirodden Secundo Episode (Aldridge et al. 1993; Johnson 2006), and occurs prior to the onset of global early Aeronian $\delta^{13}\text{C}$ positive excursions (Melchin et al. 2012) and the postulated early Aeronian glacial phase (Page et al. 2007; Munnecke et al. 2010). Because the *Distomodus kentuckyensis* Zone species are common in the Aeronian in the Oslo Region (Aldridge and Mohamed 1982; Idris 1984) and on Anticosti Island (Zhang and Barnes, 2002a, 2002b), their early disappearance in the Cape Phillips Formation may be attributed primarily to the regional transgressive event in the late Rhuddanian. Hence, by the end of the Rhuddanian, the slope biofacies appears to have stabilized and remained constant until the early Telychian except for a short interval during the *sedgwickii* graptolite Zone as suggested by the conodont community analysis (Zhang et al. 2006).

600 Sandvika Event (late Aeronian)

The late Aeronian bioevent was named the Sandvika Event and occurred within the *sedgwickii* graptolite Zone (Aldridge et al. 1993); its effects are less significant than for the younger Ireviken and Mulde events. It has been well-documented that graptolite diversity decreased from 33 taxa in the *convolutus* graptolite Zone to 17 taxa in the upper part of the *sedgwickii* graptolite Zone (Cooper et al. 2013) and the increased rate of graptolite extinction in this interval coincided with both subtle changes in black shale lithologies, a brief slight cooling phase (Trotter et al. 2016), and a positive $\delta^{13}\text{C}$ excursion (Melchin and Holmden 2006a). The positive $\delta^{13}\text{C}$ excursion and graptolite extinction in the upper Aeronian *sedgwickii* graptolite Zone was interpreted as caused by lowered sea-levels (Loydell 2007), but

609 with probably multi-phase stress conditions that affected the pelagic realm inhabited by graptolites
610 (Štorch and Frýda 2012; Cooper et al. 2013). However, a negative $\delta^{13}\text{C}$ excursion (-1.3 to -1.4‰) was
611 recorded in the *sedgwickii* Zone of the Rumba Formation in Estonia, which was interpreted as a humid
612 climatic episode with rising sea levels (Kaljo and Martma 2000). Jeppsson (1998) noted that the
613 conodont extinction associated with this event was “relatively severe”, but it is premature to conclude
614 whether the conodont extinctions of the late Aeronian Sandvika Event and graptolite extinctions of the
615 *sedgwickii* graptolite Zone were synchronous (Loydell 2007; Loydell et al. 2003).

616 On Cornwallis Island, only the Cape Manning Section 2 (Fig. 4A) contains strata of the
617 *sedgwickii* graptolite Zone. The last occurrence of *convolutus* Zone graptolites is from the same
618 stratigraphic position as sample CM2C-13. Succeeding conodont samples CM2C-14 and CM2C-15 are
619 probably either from the uppermost *convolutus* Zone or from the lowest *sedgwickii* Zone, which is
620 represented by interbedded dolomitic mudstone and shale with the samples collected from dolomitic
621 mudstone. Sample CM2C-14 contains a few specimens of *Aspelundia expansa*, *Dapsilodus*
622 *obliquicostatus*, *Panderodus unicostatus*, and *Walliserodus curvatus*, representing the *Walliserodus*
623 *curvatus*-*Aspelundia petila* (= *expansa* herein) (*W.c.-A.p.*) community (Zhang et al. 2006); CM2C-15 is
624 barren of conodonts. Above this interval, there is a 4.5 m thick dolostone unit lacking conodont samples,
625 which is probably correlated to the *sedgwickii* graptolite Zone (Fig. 4A), and in which a strong positive
626 $\delta^{13}\text{C}$ excursion was recorded (Melchin and Holmden 2006a). This was interpreted to represent an
627 episode of sea-level fall, supported by evidence of subaerial exposure (Melchin and Holmden 2006a).
628 The *W.c.-A.p.* conodont community survived this late Aeronian sea-level fall and remained stable until
629 the early Telychian (Zhang et al. 2006).

630

631 Snipklint Primo Episode (early Telychian)

632 The next major conodont turnover occurred within the *Aspelundia fluegeli* and *Pterospathodus*
 633 *celloni* Interval zones, and *Pt. a. amorphognathoides* Taxon-range Zone in the middle Telychian in the
 634 Cape Phillips Formation. As discussed earlier, no significant faunal change was observed over the
 635 Aeronian-Telychian boundary in the formation, largely because the fauna that disappeared during the
 636 oceanic episodes or events in the Jeppsson models (e.g. *Ozarkodina hassi*) had disappeared from the
 637 Cape Phillips Formation much earlier. In the *guerichi* graptolite Zone, *Walliserodus curvatus* and
 638 *Dapsilodus obliquicostatus* disappeared, the latter re-appearing in the early Wenlock. *As. expansa*
 639 disappeared in the middle Telychian in the Cape Phillips Formation, approximately in the
 640 “*griestoniensis-crenulata*” graptolite Zone (pers. comm. Melchin 2017) (Fig. 4C, 11), which may be
 641 slightly later than the first appearance of *Aspelundia fluegeli*, *As. cf. As. borenorensis* and *Walliserodus*
 642 *cf. W. sancticlairi* (sample CP1 in Fig. 3). Shortly after this replacement in the conodont fauna, a sharp
 643 faunal change is seen near the base of the *Pterospathodus celloni* Interval Zone (Figs. 3, 4C, and 11);
 644 many lineages (including *Aulacognathus*, *Aspidognathus*, *Pterospathodus*,) with unknown ancestors
 645 appeared at this level; and these lineages diverged later at a level in the mid-*spiralis* Zone or above the
 646 base of *Pt. a amorphognathoides* Taxon-range Zone (Figs. 3, 5A and 11). These faunal turnovers
 647 correspond to the Snipklint Primo Episode with the richest and morphologically most variable faunas in
 648 the Silurian globally.

649 The Valgu Event was recognized in the early stage of the Snipklint Primo Episode; this event
 650 caused a rapid drop in the abundance of conodonts, temporal disappearance of several species, and also
 651 extinction of some taxa, such as *Astropentognathus irregularis*, in the *Pt. eopennatus* Superzone in
 652 Estonia (Männik 2005). The conodont turnover accompanied by the disappearance of *Au. bullatus*, *Pt.*
 653 *celloni*, and *Pt. eopennatus* spp. 2 in the mid-*spiralis* Zone or above the base of *Pt. a*

654 *amorphognathoides* Taxon-range Zone in the Cape Phillips Formation (Fig. 11) is similar to the Valgu
655 event in nature, but apparently later than it.

656 Trotter et al. (2016) showed a cooling of ocean temperatures (positive shift ~2‰ of $\delta^{18}\text{O}$ values)
657 through the Snipklint Primo Episode interval. Based on the conodont community analysis, the conodont
658 faunal change in the interval spanning the *crispus* and “*griestoniensis-crenulata*” graptolite zones was
659 interpreted as caused by a sea level fall (Zhang et al. 2006). This part of the interpreted sea level curve
660 (Zhang et al. 2006) is similar to that of Johnson (2006, 2010).

661

662 **Ireviken Event (late Telychian-Sheinwoodian)**

663 The Ireviken Event starts just below the Llandovery-Wenlock boundary, corresponding to the
664 upper part of the *lapworthi* graptolite Zone (Loydell, 2012; Loydell et al. 1998, 2003). In conodont-
665 bearing sequences, the beginning of the event matches the boundary between the *Pterospathodus*
666 *amorphognathoides* and *Pseudooneotodus bicornis* zones, and the end of the event occurs between
667 Lower and Upper *Kockelella ranuliformis* zones (Jeppsson 1997a; Calner 2008; Lehnert et al. 2010). In
668 many localities globally, the Ireviken Event is marked by a significant change in the pattern of
669 sedimentation from shale-dominated units of the *Pterospathodus amorphognathoides* Zone to pure
670 carbonates of the *Kockelella ranuliformis* Zone (Saltzman 2001). This facies shift has been interpreted
671 as the largest worldwide regression of the entire Silurian (Johnson 1996; Barrick, 1997). Johnson (2006)
672 remarked that the extinction associated with the Ireviken Event seems to start somewhat after the onset
673 of global sea-level fall and terminate before reaching the lowest sea level, meaning that the event took
674 place entirely during a regression. This is supported by evidence from the East Baltic where a hiatus and
675 sequence boundary have been proposed within the earliest part of the event (Nestor et al. 2002; Loydell
676 et al. 2003).

677 The Ireviken Event is characterized by a low survival ratio among conodonts of merely twelve
678 out of about sixty globally-known species, with about 80% of conodont species becoming extinct
679 (Aldridge et al. 1993; Jeppsson 1997b). It is associated with a marked ocean cooling (positive shift $\sim 2\%$
680 $\delta^{18}\text{O}$ values; Trotter et al. 2016) and a strong positive ($+3\%$) $\delta^{13}\text{C}$ excursion in the shallow water facies
681 recorded in the Baltic region (Samtleben et al. 1996; Wenzel and Joachimski 1996; Bickert et al. 1997;
682 Kaljo et al. 1997, 1998; Munnecke et al. 2003), England (Corfield et al. 1992), Australia (Talent et al.
683 1993; Andrew et al. 1994), and the Great Basin of Nevada (Saltzman 2001), and in the deep water facies
684 recorded in the Canadian Arctic (Noble et al. 2005).

685 The conodont extinction during the Ireviken Event is also observed in the Cape Phillips
686 Formation at the Cape Phillips North Section. Within the interval from samples CP33 to CP46, which is
687 the middle to upper part of *Pterospirifer pennatus procerus* and lowest *Kockelella ranuliformis*
688 Highest-occurrence zones (Figs. 3 and 11), only a few specimens of *Pt. p. procerus* and some long-lived
689 conodont species are recovered (Fig. 3; Table S11). However, it is still questionable whether the
690 Ireviken Event and its related conodont extinction took place entirely during a regression as suggested
691 by Johnson (2006) for the following two reasons.

692 Firstly, conodont faunal replacement: the important conodont change during the Ireviken Event
693 is the replacement of *Pt. a. amorphognathoides* by *Pt. pennatus procerus*. Männik (1998) remarked that
694 *Pt. a. amorphognathoides* is abundant and dominates conodont faunas in the open shelf carbonate-
695 terrigenous facies; it becomes rare and is ecologically replaced by *Pt. p. procerus* towards the basin.
696 This suggests that the replacement of *Pt. a. amorphognathoides* by *Pt. p. procerus* in the same section
697 should represent a transgressive event. This replacement is also seen at Cape Phillips North Section (Fig.
698 3) and Figure 12 shows the number of specimens of both species from the first occurrence of *Pt. a.*
699 *amorphognathoides* to the last occurrence of *Pt. pennatus procerus*. The interesting interval is from

sample CP22 to CP26, especially among samples CP22, and CP24–CP26 where the two species show an alternating replacement pattern, and eventually *Pt. a. amorphognathoides* is completely replaced by *Pt. p. procerus* after sample CP26. Given that almost all these samples were preferentially collected from laminated lime mudstones, the relationship between facies change and fauna replacement is unclear.

Secondly, facies change on Devon Island: *Pt. a. amorphognathoides* was not found on Devon Island; only *Pt. pennatus procerus* was recovered from the thin Cape Phillips Formation unit that interfingers with the shallow water carbonate facies of the Allen Bay Formation. In places, the *Pt. p. procerus* Zone strata directly overlie the Upper Ordovician Irene Bay Formation (Zhang et al. 2016, section 14 in fig. 4) indicating an unconformable relationship with a transgression during the *Pt. p. procerus* Zone time.

After the extinction of *Pterospirifer*, the dominant fauna is the low diversity association of *Kockelella ranuliformis*, *Ozarkodina e. excavata*, and *Mayrodus melchini* in the *K. ranuliformis* Highest-occurrence Zone. However, this faunal turnover started with the reappearance of *Dapsilodus obliquicostatus* near the base of the *instrenuus-kolobus* graptolite Zone; the fauna remained stable throughout this zone until the lower *perneri-opimus* Zone (Fig. 3). If the end of the Ireviken Event was between the Lower and Upper *Kockelella ranuliformis* zones (Jeppsson 1997a; Calner 2008; Lehnert et al. 2010), this faunal change in the Cape Phillips Formation would occur in the late stage of the Ireviken Event, with the fauna remaining stable until the early part of the post-Ireviken Event in the middle Sheinwoodian.

Within the same interval of the *K. ranuliformis* Highest-occurrence Zone at the Cape Phillips North Section, in the samples at 196m, 213m, and 216m of MacDonald (2004) (= same level as samples CP47, CP49B, and CP50 in Fig. 3; Table S2), the spicular radiolarians reached their highest diversity

with 11–12 species since the early Llandovery. This interval was interpreted as representing the highest sea level since the beginning of the Silurian (Zhang et al. 2006).

It is difficult to recognize the division of the *K. ranuliformis* Superzone into Lower and Upper *K. ranuliformis* zones in this study. Among the samples CP47, CP49B, and CP50, the former contains the lowest occurrence of *K. ranuliformis* (Fig. 3; Table S11), which should correlate to the Lower *K. ranuliformis* Zone. Most recent studies reported that the onset of the well-known Ireviken positive $\delta^{13}\text{C}_{\text{carb}}$ excursion lies within the lower part of the bioevent, and its values continue to rise through the lower *K. ranuliformis* Zone (e.g. summarized by Cramer et al. 2011). If the positive $\delta^{18}\text{O}$ and $\delta^{13}\text{C}_{\text{carb}}$ excursions were related to the Sheinwoodian glaciation that caused the lowered sea level as several authors have suggested, the diversification of spicular radiolarians (MacDonald 2004) may have been more related to cooler ocean temperatures and enhanced upwelling than an interpreted sea level increase.

Mulde Event (early Homeric)

The Mulde Event refers to a faunal crisis at the end of the lower Homeric Stage, which is characterized by the extinction of some 95% of the graptolite species globally – a lower Homeric fauna of about 50 species was reduced to two or three in the basal upper Homeric (e.g. Melchin et al. 1998; Cooper et al. 2013). This event has been alternatively called “die große Krise” (Jaeger 1991), the *lundgreni* Event (Koren’ 1991) or the *lundgreni* Extinction Event (LEE; Lenz et al. 2006). Stratigraphically, the Mulde Event starts at the last appearance datum (LAD) of the graptolite *Cyrtograptus lundgreni* and ends at the first appearance datum (FAD) of the graptolite *Colonograptus praedeubeli* in shale successions, and at the LAD of the conodonts *Ozarkodina sagitta sagitta* and

744 *Ctenognathodus murchisoni* in carbonate successions, respectively (Calner 2008); the event mainly
745 occurred within the *parvus-nassa* graptolite Zone.

746 Moderate conodont extinctions were recorded during the Mulde Event by Jeppsson and Calner
747 (2003) on Gotland, and the other affected fossil groups including planktonic radiolarians, acritarchs,
748 chitinozoans and nautiloid cephalopods were summarized by Calner (2008). The extinctions among the
749 graptolites, radiolarians and palynomorphs in the Cape Phillips Formation in Arctic Canada were
750 documented by Noble et al. (2012).

751 This event is within the upper part of “Unzoned Interval” of the Cape Phillips Formation (Fig.
752 11), which is represented by the Abbott River West Section 3 (Fig. 5D). There, the *lundgreni* Zone
753 graptolites are found within a 10 m interval from the base of the section, and the *praedeubeli-deubeli*
754 graptolite Zone occurs within the interval of 14.5–17.5 m (Table S9). No graptolites were recovered in
755 the interval between 10 m and 14.5 m, which is most likely equivalent to the *parvus-nassa* graptolite
756 zone; the single conodont sample collected from this interval lacked conodonts. Although not many
757 conodont species are recovered from the “Unzoned interval”, it is noteworthy that both
758 *Pseudooneotodus beckmanni* and *P. bicornis* last appeared within the *lundgreni* graptolite Zone, and
759 *Kockelella ortus absidata* first appeared in the *praedeubeli-deubeli* graptolite Zone (Figs. 5D and 11).
760 These may have been affected by the Mulde Extinction Event that corresponds to significant
761 environmental changes indicated by the marked ocean cooling (positive shift $\sim 2\text{‰}$ $\delta^{18}\text{O}$ values; Trotter
762 et al. 2016) and by the $\delta^{13}\text{C}$ excursion at the C4 peak and the post-extinction recovery at the $\delta^{13}\text{C}$
763 excursion at the C5 peak (Noble et al. 2012), respectively.

764 Abbott River West Section 3 is the same as the Abbott River Section described by Noble et al.
765 (2012); it is situated near the basin margin, approximately 25 km from the shelf break (Noble et al.
766 2012). Over 40 m of strata are composed of shaly limestone with interbedded limestone; the limestone

contains poorly sorted, coarse-grained bioclasts (Table S9). This lithological evidence further supports a regression during the Mulde Event.

Taxonomic Notes

Aspelundia expansa Armstrong

Aspelundia expansa was established by Armstrong (1990) as a septimembrate apparatus consisting of Pa, Pb, M, Sa, Sb₁, Sb₂ and Sc elements, without including any previously published taxa in synonymy. The species is characterized by having elements with compressed denticles and with a broad, shallowly excavated basal cavity. McCracken (1991) described *As. petila* (Nicoll and Rexroad) as a multielement species with *a*, *b*, *c*, *e*, *f*, and *g* elements and listed many synonyms including *Ligonodina petila* Nicoll and Rexroad and *As. expansa* Armstrong. However, the type specimens of *Ligonodina petila* illustrated by Nicoll and Rexroad (1969, pl. 5, figs. 20–22) are robust with discrete rounded denticles with only a modestly expanded basal cavity. These types are bipennate ramiform (*a*, or *Sc*) elements that are not diagnostic elements in the apparatus of *Aspelundia* and they do not closely resemble the *Sc* elements in *As. expansa* in both Armstrong (1990) and the Cape Phillips material. The present authors favour retention of *As. expansa* over *As. petila*, pending further taxonomic studies, noting also that *As. expansa* has been widely adopted as a zonal species since 1990.

Class, Order and Family unknown

Genus *Mayrodus* new genus

Type species: *Mayrodus melchini* new species.

788 Diagnosis: Apparatus of *Mayrodus* n. gen. contains a single morphotype of excavated, erect, cone-like
789 elements with thin lateral walls, which are typically costate, and may occupy various positions in the
790 apparatus.

791 Etymology: The prefix is in honour of Ulrich Mayr, a pioneer in Paleozoic stratigraphy of the Canadian
792 Arctic.

793 Repository: Type specimens noted below have been deposited in the National Invertebrate Fossil Type
794 Collections of the Geological Survey of Canada, Ottawa.

795

796 *Mayrodus melchini* new species

797 Figs. 10.31–10.35

798 Diagnosis: *Mayrodus melchini* n. sp. consists of an apparatus comprising a single but variable element
799 morphotype consisting of small, thin, erect, excavated, and tapering, cone-like or pyramidal elements
800 with thin lateral walls. Smooth lateral surfaces bear aborally diverging costae that extend almost to base
801 of element.

802 Etymology: In honour of Michael J. Melchin, who has made substantial contributions to Silurian
803 graptolite biostratigraphy and chemostratigraphy in the Canadian Arctic and elsewhere, and was a field
804 leader for this study.

805 Description: Small, erect, entirely excavated cone or pyramidal elements. Three costae diverge aborally
806 from central upper apex, and, in some elements, continue free of the lateral wall for a distance
807 representing one third to one half of total height of specimen. Small amount of variation occurs in
808 relative prominence of costae and length of lateral surfaces. Costae may be prominent (Fig. 10.32) or
809 present as rounded corners between faces (Fig. 10.33). Lateral surfaces adjoining corners are smooth, or
810 may be slightly concave or convex. They continue to near endpoints of apices, or end approximately

811 midway between apex and tips and continue as spike-like protrusions (Fig. 10.33). In specimens where
812 the latter morphology is present, specimens tend to be wider and costae diverge at a greater angle (Fig.
813 10.33).

814 Types: Holotype GSC120604 (Fig. 10.32); paratypes GSC120603 (Fig. 10.31) and GSC120605–120607
815 (Figs. 10.33–10.35).

816 Other material examined: 31 elements.

817 Occurrence: Upper *instrenuus-kolobus* graptolite Zone. These samples are from concretions that also
818 yielded prolific radiolarians.

819 Discussion: No transitional series is identified from the collections of this species, although subtle
820 differences in symmetry exist. The species co-occurs with *Pseudooneotodus bicornis*, *Kockelella*
821 *ranuliformis*, and *Dapsilodus obliquicostatus* in a low diversity fauna. The morphology of the elements
822 is reminiscent of the Middle–Late Ordovician *Coelocerodontus*, but the latter contains a four-costae
823 element, and its three-costae element does not develop costae free of the lateral wall for one third to one
824 half of total height of element.

825

826 **Summary**

827 Cornwallis Island lies at the northern end of the Boothia Uplift, which acted as a protective
828 buttress to limit significant tectonic and thermal affects, resulting in spectacular preservation of
829 graptolites and conodont elements in the Cape Phillips Formation. The lower Paleozoic shelf break
830 passes east-west through the middle of the island, with excellent stratigraphic sections of carbonate shelf
831 facies in the south and slope to basin facies in the north. The present study focused on latest Ordovician
832 through early Silurian conodonts from the basin to slope facies of the 2.5-km-thick Cape Phillips
833 Formation on northern Cornwallis Island.

Graptolites and conodonts are the leading fossil groups in establishing biozones for Late Ordovician and Silurian chronostratigraphy. Hence, the Cornwallis sections provided the opportunity to establish the detailed conodont faunas, biostratigraphy and bioevents and link them precisely into the graptolite biostratigraphy; specific results include:

- 180 samples were collected from nine sections of the Cape Phillips Formation, of which 118 yielded approximately 7600 conodont elements representing 54 species in 25 genera, including one new genus and species, *Mayrodus melchini*, and an additional six indeterminate genera and species and a subrectiform element. A taxonomic note with regard to the apparatus structure and biozonation usage is included for *Aspelundia expansa*. The conodonts are taxonomically diverse and exceptionally well-preserved with a CAI value of 1, indicating burial temperatures of less than 80 degrees Celsius.
- The number of conodont elements and species ranges are tabulated for each stratigraphic section. Nine conodont zones are recognized and defined, and an integration of graptolite and conodont zones is achieved within this Arctic region (graptolite zones in parentheses), namely: the *Amorphognathus ordovicicus* (*fastigatus* through *persculptus* zones), *Distomodus kentuckyensis* (*madernii-lubricus* Subzone through mid-*atavus* Zone), *Aspelundia expansa* (*atavus* to middle *crispus* zones), *As. fluegeli* (lower “*griestoniensis-crenulata*” Zone), and *Pterospathodus celloni* Interval zones (upper “*greistoniensis-crenulata*” Zone to the lower *spiralis* Zone), *Pt. a. amorphognathoides* Taxon-range Zone (lower *spiralis* Zone to middle *sakmaricus* Zone), *Pt. pennatus procerus* (upper *sakmaricus* to lowermost *intrenuus-kolobus* zones) and *Kockelella ranuliformis* Highest-occurrence zones (lower *instrenuus-kolobus* to lower *perneri-opimus* zones), and *K. ortus absidata* Taxon-range Zone (upper *praeduebeli-deubeli* and *ludensis* zones). An

“Unzoned Interval” lies between the last two zones; it equates approximately to an interval of *perneri-opimus* to *praedeubeli* graptolite zones.

- Detailed conodont community studies in the Baltica, Avalonia, and Laurentia paleoplates have previously defined many Primo (P) and Secundo (S) Episodes and specific brief Events marking faunal turnovers during the Hirnantian and early Silurian. The episodes and events recognized in this present study are: Terminal Ordovician Extinction Event (Hirnantian), Spirodden Secundo Episode (late Rhuddanian), Sandvika Event (late Aeronian), Snipklint Primo Episode (early Telychian), Ireviken Event (late Telychian-Sheinwoodian), and the Mulde Event (early Homerian). Several can be correlated to cooling events and some to intervals of lowered sea level, some being correlative with known brief glaciations in Gondwana.

The Cornwallis sections near the Ordovician-Silurian shelf break between the platform and basinal facies provide key data on conodont biozones and their integration with existing graptolite biozones to yield a refined biostratigraphy. Changes in the conodont faunas and communities through the Hirnantian to Ludlow are linked to many of the previously formally named episodes and events from the Baltic and Welsh Borderlands. Interpretations regarding the controlling environmental conditions on several conodont bioevents are related to eustatic and ocean paleotemperature changes, with quantification from recent oxygen isotopic analyses of these Cornwallis conodonts, which affected much of the Silurian paleoequatorial marine realm.

Acknowledgements

This study was supported by research grants to C.R. Barnes from the Natural Sciences and Engineering Council of Canada (NSERC) and Imperial Oil Limited. Field logistic support, advice, and stratigraphic data for D.M.S. Jowett’s fieldwork were kindly given by M.J. Melchin (St. Francis Xavier

University), the Polar Continental Shelf Project, with sample shipment by the Geological Survey of Canada. Information and advice were also provided by P. Noble (University of Nevada) and A. Lenz (Western University). Student grants-in-aid were awarded to D.M.S. Jowett by the Society of Economic Paleontologists and Mineralogists and the American Association of Petroleum Geologists. S. Zhang acknowledges continued financial support from the Strategic Investments in Northern Economic Development (SINED) and the Canada–Nunavut Geoscience Office (CNGO) for Arctic geoscience research. Thanks are also extended to C. Singla (University of Victoria) who helped in taking the SEM images, to A.D. McCracken, M.J. Melchin and S.M. Bergström who acted as Earth Science Sector internal and external scientific reviewers of the manuscript, and to A. Polat, M. Laflamme, B. Tryhuda, and D.L. Regier for their assistance from the journal.

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Figure captions

Figure 1. Geological map of the Canadian Arctic Archipelago showing the location of Cornwallis Island and section localities of the Cape Phillips Formation (modified from Trettin 1991). CM: Cape Manning; CPS: Cape Phillips South; CPN: Cape Phillips North; ARE: Abbott River East; ARW: Abbott River West.

Figure 2. Conodont distribution in the Cape Phillips Formation at the Cape Phillips South section. See Figure 1 for its locality, Table S1 for section description, and Table S10 for numerical distribution data. Graptolite zones in third and fourth columns are in the Cape Phillips Formation and in GTS 2012 (Melchin et al. 2012), respectively; conodont zones in fifth column are in this study.

Figure 3. Conodont distribution in the Cape Phillips Formation at the Cape Phillips North section. See Figure 1 for its locality, Table S2 for section description, and Table S11 for numerical distribution data. Graptolite zones in third and fourth columns are in the Cape Phillips Formation and in GTS 2012 (Melchin et al. 2012), respectively; conodont zones in fifth column are in this study.

Figure 4. Conodont distribution in the Cape Phillips Formation at the Cape Manning sections. A: Cape Manning section 2; B: Cape Manning section 1; C: Cape Manning section 3. See Figure 1 for their localities, Tables S3–S5 for section descriptions, and Tables S12–S14 for numerical distribution data. Graptolite zones in third and fourth columns are in the Cape Phillips Formation and in GTS 2012 (Melchin et al. 2012), respectively; conodont zones in fifth column are in this study.

Figure 5. Conodont distribution in the Cape Phillips Formation at the Abbott River East and West sections. A: Abbott River East section; B, C, and D: Abbott River West section 1, 2 and 3, respectively. See Figure 1 for their localities, Tables S6–S9 for section descriptions, and Tables S15–S18 for numerical distribution data. Graptolite zones in third and fourth columns are in the Cape Phillips

1255 Formation and in GTS 2012 (Melchin et al. 2012), respectively; conodont zones in fifth column are in
1256 this study.

1257

1258 **Figure 6.** Ordovician conodonts (1–29) and conodonts common in both Ordovician and Silurian strata
1259 (30–43).

1260 **1–8.** *Amorphognathus ordovicicus* Branson and Mehl (×65); from CPS1; 1. upper view of Pa element,
1261 GSC120403; 2–3. upper view and outer lateral of Pb element, GSC120404, GSC120405; 4. lateral view
1262 of Sb element, GSC120406; 5. lateral view of Sc element, GSC120407; 6. Sd element, lateral view,
1263 GSC120408; 7. lateral view of Sa element, GSC120409; 8. M element, inner lateral view, GSC120410.

1264 **9–10.** *Belodina confluens* Sweet (×35); from CM1; 9. lateral view of grandiform element, GSC120411.
1265 10. lateral view of compressiform element, GSC120412. **11–14.** *Besselodus borealis* Nowlan and
1266 McCracken (×80); from CPS1; 11–12. lateral view of acodiform (Sb) element, GSC120413,
1267 GSC120414; 13. lateral view of distacodiform (Pa) element, GSC120415; 14. lateral view of
1268 oistodiform (M) element, GSC120416. **15–17.** *Paroistodus? nowlani* Zhen, Webby and Barnes (×80);
1269 from CPS1; 15. lateral view of distacodiform (Sc) element, GSC120417; 16. lateral view of oistodiform
1270 (M) element, GSC120418; 17. lateral view of acodiform (Sb) element, GSC120419. **18.** *Pseudobelodina*
1271 *torta* Sweet (×45); from CPS1; lateral view of Sc⁰ element; GSC120420. **19–21.** *Coelocerodontus*
1272 *trigonus* Ethington (×70); from CPS1; 19. posterior view of symmetrical trigoniform element,
1273 GSC120421; 20–21. outer and inner lateral views of tetragoniform element, GSC120422, GSC120423.

1274 **22–23.** *Drepanoistodus suberectus* (Branson and Mehl) (×40); from CPS1; 21. inner lateral view of
1275 homocurvatiiform element, GSC120424; 22. inner lateral view of curvatiiform element, GSC120425. **24.**
1276 *Pseudooneotodus mitratus* (Moskalenko) (×35); from CPS1; upper view, GSC120426. **25–26.**
1277 *Eocarniodus gracilis* (Rhodes) (×100); from CPS1; 24. lateral view of element with broken cusp,

1278 GSC120427; lateral view of element with fractured cusp, GSC120428. **27–29.** *Pseudobelodina?*
 1279 *dispana* (Glenister) ($\times 80$); 27 and 29 from CPS1 and 28 from CM1; 27. outer lateral view of Sc¹
 1280 (unicostate) element, GSC120429; 27. outer lateral view of Sg² (bicostate) element, GSC120430; 29.
 1281 outer lateral view of Sg¹ (unicostate) element, GSC120431. **30–36.** *Panderodus unicostatus* (Branson
 1282 and Mehl) ($\times 100$); from ARE1; 30. outer lateral view of truncatiform, GSC120432; 31. inner lateral
 1283 view of arcuatiform, GSC120433; 32. lateral view of aequaliform, GSC120434; 33. inner lateral view of
 1284 sub-symmetric graciliform element, GSC120435; 34. outer lateral view of tortiform element,
 1285 GSC120436; 35. outer lateral view of asymmetric element, GSC120437; 36. outer lateral view of
 1286 compressiform element, GSC120438. **37.** *Pseudooneotodus beckmanni* (Bischoff and Sannemann)
 1287 ($\times 100$); from CM2C-11; top view, GSC120439. **38–43.** *Walliserodus curvatus* (Branson and Branson)
 1288 ($\times 85$); from CM2C-18; 38. outer lateral view of unicostatiform element, GSC120440; 39. outer lateral
 1289 view of deboltiform element, GSC120441; 40–41. outer lateral and posterior view of dyscritiform
 1290 element, GSC120442, GSC120443; 42. inner lateral view of curvatiform element, GSC120444; 43.
 1291 outer lateral view of multicostatiform element, GSC120445.

1292

1293 **Figure 7.** Silurian conodonts.

1294 **1–4.** *Apsidognathus tuberculatus* Walliser ($\times 55$); from CP17; 1. upper view of Pa element, GSC120446;
 1295 2. upper view of lyriform element, GSC120447; 3. upper view of ambalodiform element, GSC120448;
 1296 4. upper view of lenticular element, GSC120449. **5–6.** *Apsidognathus?* sp. ($\times 55$); 5 from CP17 and 6
 1297 from CP25; upper view unknown element, GSC120450; GSC120451. **7.** *Apsidognathus* n. sp. 3
 1298 McCracken ($\times 55$); from CP27; upper view of Pa element, GSC120452. **8.** *Apsidognathus* cf. *A.*
 1299 *walmsleyi* Aldridge ($\times 55$); from CP17; upper view of lyriform element, GSC120453. **9–17.** *Aspelundia*
 1300 *fluegeli* (Walliser) ($\times 65$ except 9×30); from ARE1; 9–10. upper inner-lateral and inner lateral view of Pb

1301 element, GSC120454, GSC 120455; 11. posterior view of Sa element, GSC120456; 12. inner lateral
1302 view of M₂ element, GSC 120457; 13. posterior view of Sb element, GSC120458; 14. posterior view of
1303 Pa element, GSC120459; 15. inner lateral view of M₃ element, GSC120460; 16. inner lateral view of
1304 M₁ element, GSC120461; 17. inner lateral view of Sc element, GSC120462. **18–25. *Aspelundia expansa***
1305 **Armstrong** (×75); from CM2C-7 (except 25 from CM2B-1); 18. posterior view of Sb element,
1306 GSC120463; 19–20. posterior and anterior view of Pa element, GSC120464, GSC120465; 21. inner
1307 lateral view of M element, GSC120466; 22. posterior view of Sa element, GSC120467; 23. inner lateral
1308 view of Pb element, GSC120468; 24. inner lateral view of Sc element, GSC120469; 25. inner lateral
1309 view of M element, GSC120615. **26–33. *Aspelundia* cf. *A. borenorensis* Bischoff**; (all ×75 except
1310 31×40); from ARE1; 26–27, anterior and posterior view of Pa₂ (denticulate) element, GSC120470;
1311 GSC120471; 28. anterior view of Pa₁ element, GSC120472; 29. inner lateral view of M₁ element,
1312 GSC120473; 30. upper anterior view of Sa element, GSC120474; 31. posterior view of Sb element,
1313 GSC120475; 32. inner lateral view of M₂ element, GSC120476; 33. inner lateral view of Sc element;
1314 GSC120477. **34–35. *Pseudooneotodus tricornis* Drygant** (×100); from ARE6; 34. upper view of tri-
1315 denticulate element, GSC120478; 35. lateral view of conical element, GSC120479. **36.**
1316 ***Pseudooneotodus bicornis* Drygant** (×70); from CP47; upper view of bi-denticulate element,
1317 GSC120480. **37–38. *Dapsilodus obliquicostatus* (Branson and Mehl)** (×55); from CP55; 36. lateral view
1318 of Sb element, GSC120481; 37. lateral view of M element, GSC120482. **39–42. *Decoriconus fragilis***
1319 **(Branson and Mehl)** (×110); 39 and 41 from CPS10; 40 and 42 from CM2B-1. 39. inner lateral view of
1320 Sc element without anticus, GSC120483; 40. lateral view of Sb element, GSC120484; 41. lateral view
1321 of Sa element, GSC120485; 42. lateral view of Sc element with anticus, GSC120486.

1322

1323 **Figure 8. Silurian conodonts.**

1324 **1.** *Ozarkodina clavula* (Uyeno) ($\times 65$); from CM2C-11; lateral view of Pa element, GSC120487. **2–5.**
1325 *Ozarkodina confluens* (Branson and Mehl) (2–3 $\times 35$; 4–5 $\times 45$); from ARW12; 2. lateral view of Pa
1326 element, GSC120488; 3. outer lateral view of Pb element, GSC120489; 4. posterior view of Sa element,
1327 GSC120490; 5. posterior view of Sb element, GSC120491. **6–11.** *Ozarkodina excavata excavata*
1328 (Branson and Mehl) (all $\times 55$ except 7 $\times 65$); from ARE6; 6. outer lateral view of Pa element,
1329 GSC120492; posterior view of Sb element, GSC120493; 8. inner lateral view of Pb element,
1330 GSC120494; 9. posterior view of Sa element, GSC120495; 10. inner lateral view of Sc element,
1331 GSC120496; 11. posterior view of M element, GSC120497. **12–16.** *Ozarkodina hadra* (Nicoll and
1332 Rexroad) ($\times 65$); from ARE6; 12. lateral view of Pa element, GSC120498; 13. lateral view Pb element,
1333 GSC120499; 14. posterior view of Sa element, GSC120500. 15. posterior view of M element,
1334 GSC120501; 16. posterior view of Sb element, GSC120502. **17–22.** *Ozarkodina hassi* (Pollock,
1335 Rexroad and Nicoll) ($\times 65$); from CM2B-1; 17. lateral view of Pa element, GSC120503; 18. posterior
1336 view of Sb element, GSC120504; 19. posterior view of Sa element, GSC120505; 20. inner lateral view
1337 of Sc element, GSC120506; 21. outer lateral view of Pb element, GSC120507; 22. posterior view of M
1338 element, GSC120508. **23–25.** *Ozarkodina oldhamensis* (Rexroad) ($\times 65$); from CM2B-2; 23. posterior
1339 view of M element, GSC120509; 24. lateral view of Pa element, GSC120510; 25. lateral view of Pb
1340 element, GSC120511. **26.** *Oulodus equirectus* Kleffner ($\times 60$); from ARW12; posterior view of Pa
1341 element, GSC120512. **27–31.** *Rexroadus kentuckyensis* (Branson and Branson) ($\times 50$); from CM2b-1;
1342 27. posterior view of M element, GSC120513; 28. posterior view of Pb element, GSC120514; 29. inner
1343 lateral view of Sc element, GSC120515; 30. posterior view of Sb element, GSC120516; 31. outer lateral
1344 view of Pa element, GSC120517. **32–36.** *Rexroadus nathani* (McCracken and Barnes) ($\times 50$); from CPS
1345 7; 32. inner lateral view of Sc element, GSC120518; 33. posterior view Pb element, GSC120519; 34.
1346 posterior view of M element, GSC120520; 35. posterior view of Sb element, GSC120521; 36. inner

1347 lateral view of Pa element, GSC120522. **37–39.** *Oulodus* sp. ($\times 45$); from CP17; 37. posterior view of Sb
1348 element, GSC120523; 38. posterior view of Sa element, GSC120524; 39. inner lateral view of Sc
1349 element, GSC120525. **40–41.** *Belodella* sp. A Miller ($\times 90$); from ARE1; 40. outer lateral view of Sb
1350 element, GSC120526; 41. outer lateral view of Sc element, GSC120527; **42–45.** *Walliserodus* cf. *W.*
1351 *sancticlairi* Cooper ($\times 60$); from ARE1; 42. outer lateral view of Sc element, GSC120528; 43. inner
1352 lateral view of Sb element, GSC120529; 44. posterior view of Sa element, GSC120530; 45. outer lateral
1353 view of M element, GSC120531.

1354

1355 **Figure 9.** Silurian conodonts.

1356 **1.** *Pterospathodus eopennatus* ssp. 2 Männik ($\times 55$); inner lateral view of Pa element, from CM3-4,
1357 GSC120532; **2–14.** *Pterospathodus amorphognathoides amorphognathoides* Walliser ($\times 55$ except 2, 10
1358 and 11 $\times 35$); from ARE5; 2. outer lateral view of Pb₁ element, GSC120533; 3. posterior view of Sa
1359 element, GSC120534; 4. inner lateral view of M element, GSC120535; 5. posterior view of modified
1360 carnuliform element, GSC120536; 6. lateral view of carnuliform (cf.) element, GSC120537; 7. outer
1361 lateral view of Pb₂ element, GSC120538; 8. lateral view of Pc element, GSC120539; 9. lateral view of
1362 carnuliform (cf.)? element, GSC120540; 10. upper view of Pa element without bifurcated lateral
1363 process, GSC120541; 11. upper view of Pa element with bifurcated lateral process, GSC120542; 12.
1364 outer lateral view of curved element, GSC120543; 13. outer lateral view of Sc₁ element, GSC120544;
1365 14. lateral view of Sc₂ element, GSC120545. **15–25.** *Pterospathodus celloni* (Walliser) ($\times 70$); from
1366 CP13; 15. lateral view of Pa? element, GSC120546; 16. outer lateral view of Pb₁ element, GSC120547;
1367 17–18. lateral views of Pa element, GSC120548, GSC120549; 19. lateral view of Pc element,
1368 GSC120550; 20. posterior view of M element, GSC120551; 21. posterior view of Sa element,
1369 GSC120552; 22. posterior view of carnuliform (cf.) element, GSC120553; 23. outer lateral view of Sc₂

1370 element, GSC120554; 24. postero-lateral view of Sb element, GSC120555; 25. inner lateral view of Sc₃
 1371 element, GSC120556. **26–27. *Pterospathodus rhodesi* (Savage) (×50);** from ARE1; 26. posterior view
 1372 of M element, GSC120557; 27. upper view of Pa element, GSC120558. **28–41. *Pterospathodus***
 1373 ***pennatus procerus* (Walliser) (×100);** 28, 32–35 and 41 from ARE6; rest from ARE 3; 28. outer lateral
 1374 view of Sb₂ element, GSC120559; 29. outer lateral view of Pb₂ element, GSC120560; 30. inner lateral
 1375 view of M₁ element, GSC120561; 31. outer lateral view of Sc₂ element, GSC120562; 32–35. upper view
 1376 of Pa element, GSC120563, GSC120564, GSC120565, GSC120566; 36. lateral view of Sc₃ element,
 1377 GSC120567; 37. anterior view of carnuliform element, GSC120568; 38. inner-lateral view of M₂
 1378 element, GSC120569; 39. inner lateral view of Sc₁ element, GSC120570; 40. outer lateral view of Pb₁
 1379 element, GSC120571; 41. anterior lateral view of Sb₂ element, GSC120572.

1380

1381 **Figure 10.** Silurian conodonts.

1382 **1–5. *Distomodus kentuckyensis* (Branson and Branson) (×40 except 1×20 and 3×30);** from CM2B-1; 1.
 1383 upper view Pa element, GSC120573; 2 and 5. inner lateral and upper anterior view of M element,
 1384 GSC120574, GSC120577; 3. posterior view of Sa element, GSC120575; 4. lateral view of Sb element,
 1385 GSC120576. **6–10. *Distomodus staurognathoides* (Walliser) (×35);** all from ARE5 except 9 from
 1386 ARE6; 6. lateral view of M element, GSC120578; 7. posterior-lateral view of Sa element, GSC120579;
 1387 8. posterior-lateral view of Sb element580, GSC120; 9. outer lateral view of Sc element, GSC120581;
 1388 10. upper view of Pa element, GSC120582; **11–12. *Aulacognathus bullatus* (Nicoll and Rexroad)**
 1389 **(11×55; 12×55);** from CP17; 11. upper view of Pa element, GSC120583; 12. Inner lateral view of Sb-c
 1390 element, GSC120584. **13–15. *Kockelella ortus absidata* Barrick and Klapper (×40 except 17×30);** from
 1391 3ARW12; 13. lateral view of M element, GSC120585; 14. posterior view of Sb element, GSC120586;
 1392 15. lateral view of Pa element, GSC120587. **16. *Kockelella patula* Walliser (×25);** from 2ARW1; upper

1393 view of Pa element, GSC120588. **17–22.** *Kockelella ranuliformis* (Walliser) ($\times 65$ except 22×60); 18, 20,
1394 22 from CP47, 19 from CP51, 17, 21 from CP49A; 17. inner lateral view of Sc element, GSC120589;
1395 18. posterior view of Sb element, GSC120590; 19. lateral view of Pb element, GSC120591; 20.
1396 posterior view of M element, GSC120592; 21. posterior view of Sa element, GSC120593; 22. lateral
1397 view of Pa element, GSC120594. **23–24.** *Aulacognathus chapini* (Savage) ($\times 30$); from ARE6; 23. upper
1398 view of Pa element, GSC120595; 24. lateral view of Pb element, GSC120596. **25–28.** *Kockelella* sp.
1399 ($\times 80$); from CP25 except 26 from CP23; 25 and 26. lateral view of Pa element, GSC120597,
1400 GSC120598; 27. posterior view of Sa element, GSC120599; 28. posterior view of Sb element,
1401 GSC120600. **29–30.** *Astropentagnathus?* sp. ($\times 55$); from CM2C-16; 29. inner lateral view of Sc
1402 element, GSC120601; 30. posterior view of Sa element, GSC120602. **31–35.** *Mayrodus melchini* n. gen.
1403 et n. sp. ($\times 115$); from CP49A; 31–33. lateral view of conical element, GSC120603, GSC120604,
1404 GSC120605; 34. upper view of conical element, GSC120606; 35. lateral view of conical element with
1405 attached radiolarian, GSC120607. **36.** gen. et sp. indet. 4 ($\times 60$); from ARE5; upper view of platform
1406 element, GSC120608. **37.** ‘subrectiform element’ ($\times 100$); from ARE1; lateral view, GSC120609. **38.**
1407 gen. et sp. indet. 5 ($\times 115$); from CP27; lateral view of coniform element, GSC120610. **39.** gen. et sp.
1408 indet. **1** ($\times 55$); from CP25; posterior view, GSC120611. **40.** gen. et sp. indet. 2 ($\times 110$); from CP27;
1409 upper view of platform element, GSC120612. **41.** gen. et sp. indet. 3 ($\times 75$); from ARE1; upper view of
1410 platform element, GSC120613. **42.** gen. et sp. indet. 6 ($\times 40$); from ARE; inner lateral view,
1411 GSC120614.
1412
1413 **Figure 11.** Conodont and graptolite zonation for the Cape Phillips Formation, Cornwallis Island, and
1414 correlation to the graptolite and conodont zonation in GTS 2012 (Melchin et al. 2012).

1415 **Figure 12.** The abundance of *Pterospathodus a. amorphognathoides* and *Pt. pennatus procerus* in the
1416 Cape Phillips North section, Cornwallis Island.

1417

Draft

Figure 1

152x146mm (300 x 300 DPI)

Figure 2

84x119mm (300 x 300 DPI)

Figure 4

174x152mm (300 x 300 DPI)

Figure 6

175x229mm (300 x 300 DPI)

Figure 7

175x229mm (300 x 300 DPI)

Figure 8

175x229mm (300 x 300 DPI)

Figure 9

175x187mm (300 x 300 DPI)

Figure 10

175x229mm (300 x 300 DPI)

<https://mc06.manuscriptcentral.com/cjes-pubs>

Figure 12

120x62mm (300 x 300 DPI)

Table S1. Caper Phillips South (CPS) Section

Section B is located near the head of Vendom Fiord at 77°32' N, 83°55' W. Cape Phillips South section is exposed as two weathered sections on the crests of two ridges approximately 120 m apart. The lower and upper parts of the sections are exposed on the north and south ridges, respectively, and overlap 0.5 m (27.5-28.0 m). The base of the section, which is within the *fastigatus* Zone, lies at the top of a thick covered interval, below which is exposed massive limestone of the basal Cape Phillips "Allen Bay tongue" and the "cliff member". Conodont collecting began near the top of the *fastigatus* Zone beds, immediately prior to the Late Ordovician conodont extinction events, and continued across the Ordovician-Silurian boundary. The section covers the first three graptolite zones of the Llandovery.

Height above base (m)	Thickness (m)	Sample number	Sample height (m)	Description
0	4.5			Calcareous shale grading upwards into lime wackestone; large orthoconic nautiloids, trilobites (<i>Pseudogygites</i>); <i>fastigatus</i> Zone graptolites.
5.5	1			Lime wackestone: medium-thick bedded, medium brown.
11.5	6			Lime wackestone: rubbly, thin-medium bedded; trilobite <i>Pseudogygites</i> .
13.7	2.2			Lime wackestone: light brown-grey, medium-bedded.
16.5	2.8			Covered interval.
20.5	4	CPS1	19.7	Dolostone: medium-bedded, light brown.
23	2.5	CPS2	22.5	Shale: calcareous, dark brown-grey; <i>pacificus</i> Zone graptolites.
24.1	1.1			Dolostone: medium-bedded, light grey-brown, medium crystalline.
24.7	0.6			Dolostone: thin-medium-bedded, light grey, trilobites.
25.2-25.5	0.5-0.8	CPS3	25.2	As above but contains large vugs infilled with reddish brown, sandy sediment (possibly paleokarst surface).
25.2-25.5 (where present)	0.3			(Where present—may be infill of eroded paleokarst surface) Mudstone: calcareous, dark brown-grey.
28.5	3	CPS4	26.25	Mudstone: calcareous, platy, laminated, black mudstones interbedded with fissile, black, calcareous shales; platy oblate concretions begin at 26.0 m; " <i>persculptus</i> " Zone graptolites.
		CPS5	27	
		CPS6	28	
38.6	10.1	CPS7	29	As above, but larger more spherical, laminated and may be massive rather than platy at 1-2m concretions, <i>acuminatus</i> Zone graptolites.
		CPS8	30	
		CPS9	31	
		CPS10	32	
		CPS11	33	
		CPS12	34	
		CPS13	35	
		CPS14	37.2	
39.5	0.9	CPS15	39.2	Dolowackestone: finely crystalline, light brown, rubbly.
40.5	1			Mudstones: calcareous, laminated, platy, rare concretions; no visible graptolites.
41	0.5	CPS16	41	Mudstone: calcareous, medium-bedded, dark brown.
41.3	0.3			Dolostone: finely crystalline, medium brown-grey.
41.5	0.2			Covered interval.
43.7	2.2	CPS17	43.7	Shale: black, rare concretions; <i>atavus</i> and possibly <i>acinaces</i> Zone graptolites.
44	0.3			Dolostone: nodular, vuggy, bituminous.
44.5	0.5			Shale: black, concretionary; graptolites of <i>atavus</i> or <i>acinaces</i> Zone.
52.4	7.9			Dolostone: medium-bedded, medium brown, nodular, vuggy, bituminous.

Table S2. Caper Phillips North (CP) Section

Cape Phillips North, the type section for the Cape Phillips Formation, outcrops near the northernmost point of the island, at 75°37'N, 94°30'W. It begins near the point where the slope hill becomes a coastal cliff and is approached from the south. The entire section outcrops along the beach of Wellington Channel, opposite Devon Island. North of the base of this section, the beds become folded and faulted and can no longer be traced laterally.

Height above base (m)	Thickness (m)	Sample number	Sample height (m)	Description
16	16	CP1	0	Interbedded calcareous shale and lime mudstone: shales are thin; lime mudstones 0.1-0.2 m thick (laminated or massive), some more nodular beds; very small concretions abundant, some chert pebbles; <i>crispus</i> and/or <i>griestoniensis</i> Zone graptolites; samples from lime mudstone.
		CP2	5	
		CP3	8	
		CP4	12	
		CP5	15.4	
35	19	CP6	19.6	Lime mudstone and shale: mudstone laminated and massive; shaly partings and thin shale interbeds; some nodular beds, lime grainstones that thicken towards top, mudchip conglomerates and cherty beds; concretions uncommon, <i>crispus</i> and/or <i>griestoniensis</i> Zone graptolites; samples from mudstone.
		CP7	25.4	
		CP8	30.1	
40	5	CP10	39.9	Interbedded lime mudstone and calcareous shale: mudstone thinner and laminated; concretions common; <i>griestoniensis</i> Zone graptolites.
59	19	CP11	45.3	Calcareous shales: small concretions and some thin limestone beds, becomes cherty towards top; samples from concretions.
		CP12	50.4	
		CP13	55.5	
65	6	CP14	59.7	Limestone: thin-medium bedded, shaly partings, some bioclastic, some mottled mudstone, some concretionary; bioclastic sample.
84	19	CP15	65	Lime mudstone and calcareous shale: mudstone laminated, platy and argillaceous, some bioclastic; CP16 pelmatozoan-rich with some coral, others from lime mudstone.
		CP16	70.6	
		CP17	78.7	
106	22	CP18	85	Interbedded calcareous shale and lime mudstone: mudstone platy to thin-bedded, cherty, some concretions becoming more common in upper 2 m; <i>sakmaricus</i> Zone graptolites begin at ~90 m; CP20 from concretion and has some pelmatozoan debris, other samples, others from laminated mudstone.
		CP19	90	
		CP20	94.3	
		CP21	100	
		CP22	105	
115.4	9.4	CP23	110	Interbedded calcareous shale and lime mudstone: shaly and massive laminated lime mudstone dominate; some nodular beds and mudchip conglomerates, chert less common; some slumping and wavy beds with uncompressed graptolites; <i>sakmaricus</i> Zone graptolites; sample from mudstone.
120	4.6	CP24	166.7	Interbedded calcareous shale and thin, laminated lime mudstone; concretions uncommon; sample from partly laminated mudstone.
122.5	2.5	CP25	120	Lime mudstone: laminated, platy to medium bedded.
124	1.5			Calcareous shale; some thin, laminated lime mudstone beds, concretions uncommon.
127	3	CP26	126.1	Lime mudstone: laminated, platy to medium-bedded.
133	6			Lime mudstone: thin-medium-bedded, shaly partings, small concretions.
138	5	CP27	137.5	Limestone: platy, small concretions.
145.5	7.5	CP28	141	Lime mudstone/grainstone: thin-medium-bedded, shaly partings, uncommon small concretions, some slumping; both samples from non-laminated mudstone.
		CP29	145.4	
162.5	17	CP30	149.5	Lime mudstone: platy to thin-bedded, laminated, shaly partings; some irregularly bedded lime grainstone with uncompressed graptolites, concretions common and abundant near top; CP31 has some rip-up clasts, other samples from mudstones.
		CP31	155.6	
		CP32	158	
		CP33	161	

163.2	0.7			Calcareous shale, abundant concretions.
166.3	3.1	CP34	163.5	Lime mudstone: (less limy than below or more indurated), platy to thin-bedded, shaly parting, no concretions; both samples laminated.
		*CP36	165.5	
171	4.7	CP35	167.5	Lime mudstone and lime siltstones: flaggy-platy laminated, abundant fish macrofossils; <i>insectus</i> Zone graptolites.
		CP37	169.5	
196	25	CP38	171.5	Interbedded lime mudstone and calcareous shale: mudstone shaly to platy, laminated, med-dark grey, some thick (0.1 m) beds; base of <i>centrifugus</i> Zone at 169.6 m; base of <i>murchisoni</i> Zone at 172.0 m; base of <i>instrenuus-kolobus</i> Zone at 175.5 m; CP41-43 from oily shale/mudstone, CP45-46 graptolite-rich shaly mudstone
		CP39	173	
		CP40	175	
		CP41	178	
		CP42	180	
		CP43	182	
		CP45	184	
		CP46	189	
199	3	CP47	196	As above, but some 0.2-0.5 m thick concretionary units; <i>instrenuus-kolobus</i> Zone; sample from concretions.
203.5	4.5	CP48	200	As above, but no concretions; <i>instrenuus-kolobus</i> Zone; sample from organic rich mudstone/shale.
220	16.5	CP49A	206.6	As above, but with concretions; <i>instrenuus-kolobus</i> Zone; CP49A, CP50-51 from concretions, CP49B from mudstone
		CP49B	213	
		CP50	216	
		CP51	219.9	
231	11	CP52	227.2	As above, but no concretions; <i>instrenuus-kolobus</i> Zone and/or <i>perneri-opimus</i> zone; sample from isolated concretions.
234	3	CP53	232.7	As above, but with concretions; <i>perneri-opimus</i> Zone?; sample from concretions.
240.5	6.5	CP54	238.5	As above, but no concretions; <i>perneri-opimus</i> Zone; sample from thinly-bedded mudstone/shale.
256.5	16	CP55	245.2	As above, but with concretions; <i>perneri-opimus</i> Zone; both samples from concretions.
		CP56	250.9	
293	36.5	CP57	256.5	As above, no concretions except for a single thick concretionary bed at 283.5 m; <i>perneri-opimus</i> Zone; CP57 from concretions, the remainder from mudstones.
		CP58	262.5	
		CP59	268.3	
		CP60	277.5	
		CP61	283.5	
		CP62	288	
		CP63	292	

*numbers out of order in the field

Table S3. Cape Manning Section 1 (CM)

The lowest section at Cape Manning is continuous and spans the Ordovician-Silurian boundary. It is located at 75°26'N, 94°20'W, and along with the lower part of Cape Manning Section 2 in a small creek that runs into a larger, unnamed river.

Height above base (m)	thickness (m)	Sample number	Sample height (m)	Description
0	6.5			Dolostone: thin-medium-bedded, medium brown, wackestone with lesser mudstone, rarely laminated; <i>fastigatus</i> Zone graptolites, trilobite, <i>Pseudogygites</i> , and gastropods in lower 2 m.
6.7	0.2			Dolomudstone: laminated, argillaceous, dark brown-grey; <i>pacificus</i> Zone graptolites.
7.1	0.4			Lime wackestone: massive, medium brown-grey.
7.3	0.2			Dolomudstone: laminated, argillaceous, dark brown-grey, platy-shaly beds.
7.4	0.1			Dolomudstone: irregular, concretionary bed.
8.4	1			Dolomudstone: argillaceous, dark, laminated; <i>pacificus</i> Zone graptolites.
8.5	0.1			Shale: dolomitic, burrowed, grades upward to massive, burrowed dolowackestone.
10.3	1.8	CM1	9.5	Dolowackestone-mudstone: medium-thick bedded, medium brown-grey.
10.5	0.2			Shale: dolomitic, silty, dark grey, shaly-platy.
11.9	1.4	CM2	11.5	Siltstone: greenish, brown, dolomitic, beds coarsen and thicken slightly upward; platy-flaggy near base to thin-bedded at top; topmost beds are medium grey.
11.92	0.02			Dolomudstone: irregular, dark shaly.
12	0.08			Shale: black, fissile, friable.
12.06	0.06			Dolomudstone: chocolate brown.
12.1	0.04			Clay-shale: friable, orange-brown.
12.4	0.3			Mudstone: calcareous, cherty, shaly; " <i>persculptus</i> " Zone graptolites.
15.3	2.9	CM3	12.8	Interbedded shale and mudstone: calcareous shales and black, platy, argillaceous lime mudstones; platy concretions at 14.5 and 15.0 m with; " <i>persculptus</i> " Zone and <i>acuminatus</i> Zone graptolites begin at 12.9 m.
		CM4	13.5	
		CM5	14.5	
		CM6	15	

Table S4. Cape Manning Section 2 (CM2)

Cape Manning Section 2 begins approximately 140 m downstream from Cape Manning Section 1. Based on the graptolite faunas, the basal 1 m overlaps with Section 1.

Height above base (m)	thickness (m)	Sample number	Sample height (m)	Description
4.6	4.6	CM2-(-1)	0.5	Interbedded black, calcareous shales and black, platy argillaceous lime mudstones; platy concretions as in Section 1 at 14.5 and 15.0 m; <i>persculptus</i> Zone graptolites up to 0.6 m, <i>acuminatus</i> Zone graptolites above.
		CM2-1	1	
		CM2-2	2	
		CM2-3	4	
15.6	11			Covered interval
16.1	0.5	CM2B-1	16.1	Dolostone: medium brown-grey, crystalline, vuggy, nautiloids and bitumen.
18.3	2.2			Shale: black, dolomitic, poorly-moderately developed concretions; <i>atavus</i> Zone and possibly <i>acinaces</i> Zone graptolites.
20	1.7	CM2B-2	19.3	Interbedded dolostone and shale: dolostone is thin-bedded, medium-brown, vuggy, nodular, bituminous interbedded with black, dolomitic shale.
29.2	9.2	CM2C-1	21.7	Dolostone: thin-medium-bedded, light-medium brown, vuggy, nodular, bituminous, thicker and lighter beds near top of unit.
		CM2C-2	24.7	
		CM2C-3	27.7	
30.5	1.3	CM2C-4	30.3	Shale: dolomitic/calcareous, some concretions and lime mudstone beds 10 cm thick; <i>cyphus</i> Zone graptolites; sample from concretion.
35.7	5.2	CM2C-5	33.2	Interbedded shale and lime mudstone: shale is black, calcareous-to-dolomitic, lime mudstone beds are laminated, tabular and concretionary; some pelmatozoan-rich turbiditic beds present; thin cherty beds and dolomitic content increase toward top of unit; <i>cyphus</i> Zone graptolites; sample mainly from concretion.
37.7	2	CM2C-6	36.2	As above, but less common concretions and completely dolomitic, grades into overlying unit; sample mainly from concretion.
39.1	1.4			Dolostone: medium-thick-bedded, fine-medium crystalline, vuggy, mottled bituminous, some pelmatozoan-rich layers near base, wavy-laminated near top.
39.2	0.1	CM2C-7	39.2	Dolomudstone: brown, pelmatozoan fragments.
39.8	0.6			Covered interval.
49.3	9.5	CM2C-8	42.1	Interbedded shale and lime mudstone: shale is black, calcareous; lime mudstone is black, argillaceous and contains abundant large (1 m) concretions; <i>curtus</i> Zone graptolites; CM2C-8 from lime mudstone; CM2C-9, 10 from concretions.
		CM2C-9	45	
		CM2C-10	49	
51.4	2.1			as above, smaller concretions (0.4 m); possibly <i>convolutus</i> Zone graptolites.
51.7	0.3	CM2C-11	51.4	Limestone: thick turbidite bed, some grading and parallel lamination in lower part, cross-lamination and white chert in middle, and laminated lime mudstone in upper part.
59.5	8.1	CM2C-12	55	Interbedded shale and lime mudstone: shale is black, calcareous; mudstone is laminated, black; abundant concretions (0.1-0.3 m), some beds, especially 54-57 m composed of laterally coalesced concretions; <i>convolutus</i> Zone graptolites; both samples from concretions.
		CM2C-13	58.7	
65	5.5	CM2C-14	62	Interbedded dolomitic mudstone and shale: mudstone is thin-bedded, medium dark brown-grey; shale interbeds are thin; some bitumen and chert; both samples from dolomitic mudstone.
		CM2C-15	65	
66	1			Dolostone: flaggy-thin-bedded, light brown, laminated, silty-sandy texture.
68	2			Dolostone: thin-medium-bedded, brown, laminated, sandy texture, grades into overlying unit.
69.5	1.5			Dolostone: flaggy-thin-bedded, medium-brown, laminated, silty-sandy texture.

70	0.5	CM2C-16	70	Mudstone: wavy-irregularly laminated to thin-bedded, dolomitic; also argillaceous dolomudstones, some grey chert; sample from concretion.
78.9	8.9	CM2C-17	73	Interbedded shale and lime mudstone: shale is black, calcareous; mudstone thin-bedded, cherty; concretions common towards top; CM2C-17 from turbidite bed; CM2C-18 from concretion; CM2C-19 from mudstone.
		CM2C-18	75.9	
		CM2C-19	78.5	
82.1	3.2			Covered interval.
87	4.9	CM2C-20	82.5	Interbedded calcareous shale and lime mudstone: mudstones thin-bedded, cherty, concretions common; both samples partly from concretions.
		CM2C-21	85.1	
88	1	CM2C-22	88	Lime mudstone: thin-medium wavy-bedded, medium grey, some cherty layers.
91.1	3.1			Covered interval
107.5	16.4	CM2C-23	92	Interbedded thin lime mudstones and calcareous shales: mudstones dark grey, laminated to wavy-bedded, argillaceous; shales black; sparse lime concretions (<0.3 m in diameter); beds tend to be thinner and shalier towards top; all samples partly from concretions.
		CM2C-24	95.2	
		CM2C-25	98	
		CM2C-26	100.8	
		CM2C-27	104.1	
		CM2C-28	107	
112	4.5	CM2C-29	112	Interbedded lime/dolomitic mudstone and shale: mudstones very thin-bedded (5-20 mm) "ribbon limestones", dark brown; shale black; sample from mudstone.
114	2	CM2C-30	114	Interbedded mudstones and calcareous shales: mudstones medium-dark grey, wavy-bedded to nodular; shales thin; sample from mudstone

Table S5. Cape Manning Section 3 (CM3)

A covered interval separates Cape Manning Section 2 from Section 3, which occur about 150 m apart on the same side of the stream (the latter being downstream from the other). This covered interval represents the upper part of the *guerichi* graptolite Zone and presumably the entire *turriculatus* graptolite Zone.

Height above base (m)	thickness (m)	Sample number	Sample height (m)	Description
3	3	CM3-1	0	Laminated brown-grey dolomudstone: thinly bedded. The lowest graptolite sample, at 2.0 m, contains <i>crispus</i> Zone graptolites.
6	3	CM3-2	4.5	Dolomudstone and interbedded limestone: brown-grey dolomudstone with cherty horizons; limestone is thin-bedded.
56.8	50.8	CM3-3	10	Dolomudstone and interbedded lime mudstone: dolomudstone is laminated; limestone is medium bedded and vaguely concretionary. The highest sample that is demonstrably <i>crispus</i> graptolite Zone was recovered from the 10.2-10.6 m interval, whereas the first <i>griestoniensis</i> graptolite Zone identification was placed at 23.5 m. The intervening strata contain undiagnostic graptolites.
		CM3-4	15.1	
		CM3-5	20	
		CM3-6	30	
		CM3-7	40	
		CM3-8	49	
		CM3-9	56.7	
75	18.2			Covered interval.
90	15	CM3-10	79	Dolomudstone interbedded with lime mudstone: dolomudstone laminated; lime mudstone interbeds are more limy than underlying strata.
102.5	12.5	CM3-11	90	Interbedded laminated dolomudstone and lime mudstone as previous; lime mudstone beds have large vague concretions. Sample CM3-11 contained vague lens-like concretions as well as bioclasts and mudchips that remained after dissolution.
		CM3-12	101.5	
130.7	28.2	CM3-13	110	Interbedded laminated dolomudstone and lime mudstone: lime mudstone interbeds are less frequent and thinner than underlying strata. Sample CM3-13 contained cherty interbeds that remained after dissolution. The base of the <i>sakmaricus</i> graptolite Zone was recorded at 116.0 m.
147	16.7			Fining upwards sequences approximately 1.5 m thick of mudstone with rip-up clasts at base followed by mudstone and laminated mudstone (first begins at 140.3 m).
169.9	22.9			Interbedded laminated mudstone and medium and thick-bedded lime mudstone. Scattered large concretions.

Table S6. Abbott River East Section (ARE)

The Abbott River East Section is exposed along the side of a small, unnamed creek that runs into the Abbott River, at 75°13'40"N, 95°32'06"W. The base of the section was placed at the top of ice and snow covered strata, but intermittent exposure was present below this (hence negative measurements).

Height above base (m)	thickness (m)	Sample number	Sample height (m)	Description
-3.5	3			Interbedded calcareous shales and lime mudstone: shales wavy-bedded, some mudchip conglomerates; massive limestone beds, some mudchip conglomerates; uncommon graptolites, probably lower <i>sakmaricus</i> Zone.
0	3.5			Covered interval
5	5	ARE1	0	Laminated, calcareous shales to platy argillaceous lime mudstone with concretionary horizons every 0.1-0.5 metres; <i>sakmaricus</i> Zone graptolites; ARE1 includes concretions and mudstone; sample ARE2 from concretions.
		ARE2	4	
5.5	0.5			Shales: calcareous, recessive; <i>sakmaricus</i> Zone graptolites common.
8	2.5	ARE3	8	Laminated, calcareous shales to platy, argillaceous lime mudstones, with concretionary horizons every 0.1-0.5 metres; <i>sakmaricus</i> Zone graptolites common; sample from concretions.
13	5	ARE4	12	As above, but uncommon concretions, large concretions horizon at 12.5 m, graptolites uncommon, <i>sakmaricus</i> Zone; sample from concretion.
14.2	1.2	ARE5	13.6	As above, but no concretions, graptolites uncommon, <i>sakmaricus</i> or <i>insectus</i> Zone; sample from lime mudstone.
15.2	1			Covered interval
19.3	4.1	ARE6	16	Interbedded lime mudstones and calcareous shales: mudstones platy to flaggy, some up to 0.1 m thick; no concretions; <i>insectus</i> Zone graptolites common; samples from lime mudstones.
		ARE7	18	
		ARE8	19.1	
19.9	0.6			Covered interval
20.2	0.3			Interbedded lime mudstones and calcareous shales: mudstones platy to flaggy, some up to 0.1 m thick; <i>centrifugus</i> Zone graptolites common.
22	1.8			Covered interval

Table S7. Abbott River West Section 1 (ARW)

Located about 8 km from Abbott River East, the Abbott River West section is exposed as three continuous sections outcropping as steep cliffs along the banks of an unnamed tributary that runs north into Abbott River. Sections 1 (the stratigraphically lowest section at 75°14'47"N, 95°43'12"W) and 3 are exposed along the west side of the tributary. Section 2 is exposed along the east side, and covers the interval intermediate in age between sections 1 and 3. The three sections span mid-Wenlock to earliest Ludlow time. Section 1, the southernmost, is within the mid-Wenlock *perneri*-*opimus* Zone. Section 2 and the basal 10 m of Section 3 are within the *testis*-*lundgreni* Zone. The Wenlock/Ludlow boundary occurs between 33.5-40.0 m. A. Lenz (pers. comm. 2000) indicates that the lower and upper Homeric graptolite extinctions occur in section 3. The lower (*lundgreni* Event) is between 14.5-17.5 m, and the upper (*ludensis* Event) is at ~37 m.

Height above base (m)	thickness (m)	Sample number	Sample height (m)	Description
8	8	ARW1	0	Calcareous shale with concretions; ARW1 from concretion contains sponge spicules, ARW2 from shale; <i>perneri</i> graptolite Zone.
		ARW2	4.6	
16	8	ARW3	8	Interbedded lime mudstone and calcareous shale: rare poorly-sorted bioclastic limestone beds with pelmatozoans, brachiopods, nautiloids, sponge spicules, concretions common; ARW3 from mudstone, ARW4 from shale.
		ARW4	12	
16.5	0.5	ARW5	16	as above, but with very large concretion horizon (0.5 m diameter concretions); sample from large concretion.
21	4.5	ARW6	20	Lime mudstone: concretion-rich, medium to thick-bedded, argillaceous; sample from concretionary lens contains fish microfossils, brachiopods and radiolarians.
35.5	14	ARW7	24	Mudstone: indurated or non-calcareous, medium bedded, laminated, concretions absent.
		ARW8	28	
		ARW9	32	
38	2.5	ARW10	35.5	Lime mudstone: bioclastic, lens-like, pinches out laterally; sample from concretion contains brachiopods, fish microfossils and radiolarians.
40	2			Lime mudstone: medium-bedded, laminated.
40.5	0.5	ARW11	40	Bioclastic mudstone; sample from concretion.
52	11.5	ARW12	44	Calcareous shale, platy, with bioclastic limestone beds intercalated more frequently, some medium-bedded indurated shaly limestone, some pyrite-rich beds; all samples from concretions ARW14 may be bioclastic bed; <i>lundgreni</i> graptolite Zone begins at 52 m.
		ARW13	48	
		ARW14	52	

Table S8. Abbott River West Section 2 (2ARW)

Abbott River West Section 2 (2ARW) is located at 75°14'N, 95°42'30"W. All strata of Section 2 are within the *lundgreni* graptolite Zone (lower Homerian).

Height above base (m)	thickness (m)	Sample number	Sample height (m)	Description
0.4	0.4	2ARW1	0	Bioclastic lime mudstone: sample contains pelmatozoans, brachiopods, ostracods, fish microfossils, sponge spicules.
7.5	7.1	2ARW2	4	Calcareous shale: platy, poorly exposed.
8	0.5	2ARW3	7.8	Bioclastic lime mudstone: sample contains brachiopods and ostracods.
18	10	2ARW4	12	Calcareous shale: platy, thin-bedded, laminated, hard concretions, pyrite; sample 2ARW4 contains prolific fish microfossils.
		2ARW5	16	
26	8	2ARW6	20	Shaly carbonate: indurated, large (>1 m diameter) vague dolomitic concretions, pyrite.
		2ARW7	24	

Table S9. Abbott River West Section 3 (3A			
Abbott River West Section 3 (3ARW) is locat			
Height above base (m)	thickness (m)	Sample number	Sample height (m)
12	12	3ARW1	0.5
		3ARW2	4.5
		3ARW3	8
		3ARW4	10
25	13	3ARW8	14
		3ARW5	15
		3ARW9	17
		3ARW10	19
		3ARW6	20
		3ARW11	21
		3ARW12	24
		3ARW7	25
42	17	3ARW34	~35.0
		3ARW37	~37.0
		3ARW13	40
		3ARW41	~41.0

.RW)

ed at 75°14'03"N, 95°42'30"W.

Description

Shaly limestone with interbedded limestone: indurated, medium grey weathered, dark grey fresh concretions (0.2-0.5 m) abundant; limestone bioclastic, slumpy medium to thick-bedded, approximately 0.1-0.5m thick beds every >1 m, poorly sorted, coarse-grained, pelmatozoan-rich, chocolate brown fresh; *lundgreni* graptolite Zone.

Shaly carbonate: shalier and fewer concretions than underlying unit, moderately indurated, medium-thin-bedded, cliff forming; graded beds with shelly turbidites with shell hash at base, each approximately 0.3 m thick; *deubeli* graptolite Zone begins between 14.5-17.5 m.

Calcareous shale interbedded with lime mudstone: shale platy, weathers yellow, dark grey/brown fresh; lime mudstone bioclastic, interbedded ~ every 4 m, medium-bedded, medium brown fresh; 'highest Wenlock fauna' at 33 m, *ludensis* Event occurs between 33.5 and 40.0 m.

Table S10. Conodont distribution data for Cape Phillips South Section

Sample Number	CPS1	CPS2	CPS3	CPS5	CPS6	CPS7	CPS10	CPS11	CPS14	CPS16	Total
Height from base (m)	19.7	22.5	25.2	27.0	28.0	29.0	32.0	33.0	37.2	41.0	
Sample Mass (g)	3.2	3.4	3.2	3.0	3.2	3.0	3.2	3.0	3.1	3.1	
% Dissolution	52	49	80	69	63	95	74	87	56	47	
Species and element											
<i>Amorphognathus ordovicianus</i>											
Pa	7	6	1								14
Pb	10										10
M	3	1									4
Sa	1										1
Sb	2										2
Sc	5	1									6
Sd	4										4
'carniodiform'	72	5									77
<i>Aspelundia</i> sp.											
M										1	1
<i>Besselodus</i>											
M	12	3									15
Sa		1									1
Sb	6	4									10
Sd/f	8										8
<i>Coelocerodontus trigonius</i>											
trigoniform	2										2
tetragoniform	3										3
basal funnel	3										3
<i>Dapsilodus obliquicostatus</i>											
Sa						1					1
Sb						5			5		10
M						3					3
<i>Decoriconus fragilis</i>											
Sa		1			1	1	2	1	4	4	14
Sb		1				3	4		5	8	21
Sc				1	1	9		1	6	4	22
<i>Distomodus kentuckyensis</i>											
Pa										1	1
Pb										1	1
M						1				1	2
Sa						2				3	5
Sb										3	3
Sc										2	2
<i>Drepanoistodus suberectus</i>											
oistodiform	1	1									2
homocurvatifform	8	3									11
suberectiform	1										1
<i>Eocarniodus gracilis</i>	16										16
<i>Rexroadus kentuckyensis</i>											
Pa							0				0
Pb						7	4		2	1	14
M						2	2	1	1		6
Sa						4	3	1	3	1	12
Sb						6	2		3	2	13
Sc						3	11	4	4		22
<i>Rexroadus nathani</i>											
Pa						7					7
Pb						7					7

M						3					3
Sb						2					2
Sc						13					13
<i>Ozarkodina hassi</i>											
Pa							2			8	10
Pb						3	5	3		8	19
M							4	2		10	16
Sa						1	5	1		6	13
Sb							2	2		7	11
Sc						4	3	10		7	24
<i>Panderodus unicostatus</i>											
aequaliform	7										7
tortiform	4	13	1							12	30
subsym. graciliform										7	7
asym. graciliform	26	28	5					1		32	92
truncatiform	5	1								4	10
arcuatiform	14	4								21	39
compressiform	14	5								14	33
<i>Panderodus</i> sp.	24	31									55
<i>Paroistodus ? nowlani</i>											
M	21	1									22
Sb	3	1									4
Sc	5	3									8
<i>Pseudobelodina ? dispansa</i>											
Sc ⁰	1										1
Sc ¹	11										11
<i>Pseudobelodina torta</i>											
Sc ⁰	1										1
<i>Pseudooneotodus mitratus</i>	5										5
<i>Pseudooneotodus tricornis</i>											
slender, conical										13	13
<i>Pseudooneotodus</i> sp.						2	1	1			4
<i>Walliserodus curvatus</i>											
M	2									1	3
Sa	1									1	2
Sc	3										3
Total Elements	311	114	7	1	2	89	50	28	33	183	818
Elements/kg	185	68	3	0	1	31	21	11	19	124	

Table S11. Conodont distribution data for Cape Phillips North Section

Sample Number	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP9	CP10	CP11	CP13	CP14	CP15	CP16	CP17	CP18	CP20	CP22
Height above base (m)	0.0	5.0	8.0	12.0	15.4	19.6	25.4	35.0	39.9	45.3	55.5	59.7	65.0	70.6	78.7	85.0	94.3	105.0
Sample Mass	2.9	3.0	3.0	3.0	3.1	3.0	3.0	3.0	3.0	3.4	3.4	2.9	3.1	3.7	3.7	3.2	4.0	3.2
% Dissolution	68.5	53.4	64.8	69.0	60.1	57.3	62.5	61.2	80.1	29.6	86.6	41.3	81.3	79.6	92.0	36.6	71.8	67.1
Species and element																		
<i>Apsidognathus tuberculatus</i>																		
Pa															2			1
lenticular															1			
lyriform															1			
stromatolitic-like															1			
<i>Apsidognathus cf. walmsleyi</i>													2		2			
<i>Apsidognathus n. sp. 3 Mc.</i>															2			
<i>Apsidognathus? sp.</i>		1													1			
<i>Decoriconus fragilis</i>							1											
<i>Aspelundia fluegeli</i>																		
Pa	1		1	4					1		1	1			9		2	2
Pb	2		1	4											8		6	
M ₁	1		7	5	3				1		2	3			36	1	4	13
M ₃				2											8		1	1
Sa			1	1		1					1		1		2			
Sb			3	3													1	5
Sc			1	14	3						3				31		4	
<i>Aspelundia cf. A. borenorensis</i>																		
sym. dentic.	1		1	1											5			1
asym. dent.				1							3				3		1	4
asym. adent.	2	1		3							1				5		1	2
dentic. Sb element			1	2							3				6			
dentic. Pa				1						1					1		1	2
M ₃ ? (post.dent.process)																		
Sc w. process					1				2						4			
<i>Aulocognathus bullatus</i>																		
Pa															5			
M															2			
Sa															10			
Sb															6			
Sc															2			
<i>Belodella sp. A</i>																		
Sa																		1
Sb	1				1								1		1			1
Sc															13			
M																		
<i>Belodella sp.</i>																		
<i>Dapsilodus obliquicostatus</i>																		
Sa																		
Sb/Sc																		
M																		
<i>Distomodus staurognathoides</i>																		
Pb																		
M				1									1					
Sa		1											1		2			
Sb													1		1			
Sc				1									1		2		1	
<i>Kockelella sp.</i>																		
Pa																		
M																		

Sa																		
Sb																		
Sc																		
Kockelella ranuliformis																		
Pa																		
Pb																		
M																		
Sa																		
Sb																		
Sc																		
Mayrodus melchini																		
gen. et sp. indet. 1																		
gen. et sp. indet. 5																		
gen. et sp. indet. 2																		
Oulodus sp.																		
Sa															10			
Sc															6			
Ozarkodina e. excavata																		
Pa																		
Pb																		
M																		
Sa																		
Sb																		
Sc																		
Ozarkodina oldhamensis																		
M																		
Sb																		
Ozarkodina sp.							4					5	1					
Panderodus unicostatus																		
aequaliform				1	2										1			
tortiform					2	1												
subsymmetric graciliform			1	4		1	2	1		1		1		4			1	
asymmetric graciliform	1		1	6		4				2				7		1		
truncatiform				2	1	3												
arcuatiform	2	1	4	25	3				1			1		4		2	1	
compressiform	2	3	5	14	10	2			7					1		4	1	
Panderodus sp.	2	1	6	27	4	8	1				1	9	11	1	188		21	32
Pseudooneotodus beckmanni					1													
Pseudooneotodus bicornis																		
Pseudooneotodus tricornis						1						4		1				
Pt. a. amorphognathoides																		
Pa											1				1		1	
Pb ₁											4	1						
Pb ₂											1	1						
Pc																		
M ₁ (smooth)													1				3	
M ₁ (w. costae)																	1	
M ₂																	1	
Sc ₁											1						2	
Sc ₂											1							
Sb ₁																	1	
Sb ₂																		
cf											1							
mcf																		2
ccf											1							3
curved																	1	
Pterospathodus a. angulatus																		
Pa															18			

Pb ₁															9			
Pb ₂															7			
Pc															4			
M ₁ (smooth)															6			
M sharp costae															4			
M ₂															6			
Sa															2			
Sc ₁															9			
Sc ₂															11			
Sb ₁															5			
Sb ₂															4			
cf															13			
<i>Pterospathodus celloni</i>																		
Pa			1	1	1				1		5				13			
Pb ₁			1	2							3	2						
Pb ₂							1?					1						
Pc											5							
M ₁				3							3	1						
Sc ₁				1														
Sc ₂		1?	1	5	1						4							
Sc ₃									1		3							
Sb ₁					1						1							
Sb ₂	1?	1?		4	1	1?					2							
Sa											1							
ccf											2	1						
<i>Pt. pennatus procerus</i>																		
Pa																		4
Pb ₁																		5
Pb ₂																		
Pc																		
M ₁ (smooth)																		3
M sharp costae																		1
M ₂																		
Sc ₁																		1
Sc ₂																		3
Sc ₃																		2
Sb ₁																		2
Sb ₂																		6
cf																		
mcf?																		2
ccf																		
'suberectiform' element											1						3	6
<i>W. cf. W. sancticlairei</i>																		
M	1		2	4	6	3	1		1				2		10		2	
Sa	2			1	2			1	1				1		3			
Sb	2			3	7				3						10			
Sc	1		5	12	20	8		1	4			2	6		35		8	2
Total Elements	21	8	43	158	70	36	4	3	24	1	48	30	42	2	563	1	73	110
Elements/kg	11	5	22	76	38	21	2	2	10	1	16	25	17	1	167	1	26	51

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		8		1		3	1			1		1											
			1		1					1													
		2	1			1				1													
		1		1	1	1																	
		2	1	2		1																	
		4																					
				1																			
		4				1	1	1				1											
		1		2	1					1													
		5																					
		1	1	1		3																	
		2								1													
		7		2																			
1			2				1																
	1																						
8	8	8	2	1	2	1	3											1?					
84	181	302	156	131	13	52	36	1	4	4	6	1	4	3	11	66	11	15	21	32	29	45	39
37	98	177	76	71	10	33	28	2	4	2	5	0	2	2	5	27	4	6	10	13	12	20	16

Table S12. Conodont distribution data for Cape Manning Section 1

Sample Number	CM1	CM2	CM3	CM4	CM5	CM6	Total
Height from base (m)	9.5	###	###	###	###	###	
Sample Mass (g)	3.0	3.0	3.0	3.0	3.0	3.0	
% Dissolution	56	27	10	15	41	36	
Species							
<i>Belodina confluens</i>							
grandiform	12						12
compressiform	7						7
<i>Besselodus borealis</i> M	4						4
<i>Drepanoistodus suberectus</i>							
suberectiform							0
homocurviform	10						10
oistodiform	2						2
<i>Panderodus unicostatus</i>							
aequaliform	1						1
tortiform	2						2
subsym. graciliform	18						18
asym. graciliform							0
truncatiform	2						2
arcuatiform	5						5
compressiform	6						6
<i>Panderodus</i> sp.	13						13
<i>Paroistodus ? nowlani</i>							
M	2						2
Sa	1						1
<i>Protopanderodus insculptus</i>							
a/b	6						6
c	1						1
e	1						1
<i>Pseudobelodina dispansa</i>							
unbowed, acostate	2						2
bowed, unicastate	3						3
bowed, bicostate	2						2
<i>Walliserodus curvatus</i>							
M w/o outer costae	2						2
Sb	1						1
Sd	1						1
Total Elements	104	0	0	0	0	0	104
Elements/kg	62	0	0	0	0	0	0

Table S13. Conodont distribution data for Cape Manning Section 2

Sample Number	CM2-2	CM2-3	CM2B-1	CM2B-2	CM2C-2	CM2C-3	CM2C-5	CM2C-7	CM2C-8	CM2C-9	CM2C-10	CM2C-11	CM2C-12	CM2C-13	CM2C-14	CM2C-16	CM2C-17	CM2C-18	CM2C-19	CM2C-20	CM2C-21	CM2C-22	CM2C-23	CM2C-25	CM2C-26	CM2C-27	CM2C-28	Total
Height from base (m)	2.0	4.0	16.1	19.3	24.7	27.7	33.2	39.2	42.1	45.0	49.0	51.4	55.0	58.7	62.0	70.0	73.0	75.9	78.5	82.5	85.1	88.0	92.0	98.0	####	####	####	
Sample Mass (g)	3.0	3.0	3.8	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
% Dissolution	87	50	76	65	72	95	78	58	57	73	76	70	70	67	80	71	79	81	70	30	42	10	31	41	62	11	72	
Species																												
<i>Aspelundia expansa</i>																												
Pa							2	10	1	3	6	8	0		1		4	2	1						2		2	42
Pb							1	7		4	15	10	3	1	4	1									1		3	50
M			7				4	12		2	17	12	7	1	2	1	2	8	2	2	2				6		6	93
Sa							2	9	1	4	1	10	4		4										1		1	37
Sb							2	10	1		10	28	7	1	6			5	1						3		4	78
Sc							5	25	1	6	6	20	14		5	2	3	10	6	1					4		5	113
<i>Astropentagnathus sp.</i>																												
Sa																1												
Sc																1												
<i>Dapsilodus obliquicostatus</i>																												
Sa		0			0	2		1		1		2						2			1							9
Sb/Sc		5	12		2	18						9			2	3		2										53
M		0	6		1	8				1		3			2													21
<i>Decoriconus fragilis</i>																												
Sa		5	14					2				1																22
Sb	3	1	19					1			1																	25
Sc		2	14			2		2			1	1							1									23
<i>Distomodus kentuckyensis</i>																												
Pa			2																									2
Pb			1																									1
M			3			2																						5
Sa	1		7																									8
Sb			10			1																						11
Sc			4																									4
<i>Distomodus staurognathoides</i>																												
Pb									1																			1
M																1			1									2
Sa									2			1						1										5
Sb					1				1																			2
Sc									1							1												2
<i>Rexrodus kentuckyensis</i>																												
Pa			12																									12

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Table S14. Conodont distribution data for Cape Manning Section 3

Sample Number	CM3-3	CM3-4	CM3-7	CM3-8	CM3-10	CM3-11	CM3-12	CM3-13	Total
Height from base (m)	10.0	15.1	40.0	49.0	79.0	90.0	###	###	
Sample Mass (g)	3.0	3.1	3.0	3.1	3.0	3.0	3.0	3.1	
% Dissolution	69.9	53.4	31.4	27.1	77.7	37.2	27.5	29.8	
Species									
<i>Aspelundia fluegeli</i>						1			1
Pb									
M ₁					1				1
Sc					3				3
<i>Aspelundia expansa</i>									
Pb	2								2
M	1		2						3
Sb	3		1						4
Sc	4		1						5
<i>Pterospirifer eopennatus</i> ssp. 2 Pa		1							1
<i>Aulacognathus bullatus</i> Sb/Sc		1							1
<i>Aspelundia</i> cf. <i>A. borenorenensis</i>									
sym. denticulated						1			1
asym. denticulated					3				3
denticulated S				1		1	1		3
<i>Distomodus staurognathoides</i>									
Pa		1							1
Sa		1							1
Sc		1							1
<i>Panderodus recurvatus</i>		1							1
<i>Panderodus unicostatus</i>									
aequaliform			1			1			2
tortiform									0
subsyzmmetric graciliform	1								1
asymmetrical graciliform	1	2			3	3			9
arcuatiform		1		1	2	1			5
compressiform			2		2				4
<i>Pseudooneotodus beckmanni</i>			4						4
<i>Pterospirifer celloni</i>									
Pa			1		1	1			3
Pb ₁			2	1					3
Pc							1		1
Sc ₃					1				1
<i>Pterospirifer a. amorphognathoides</i>									
Pa						1			1
Pb ₁						2			2
Pb ₂						1			1
<i>Walliserodus</i> c.f. <i>W. sancticlairei</i>									
M					3		1		4
Sa				2			1		3
Sb					1	1	1		3
Sc				1	2	6	5	1	15
Total Elements	12	9	14	6	22	20	10	1	94
Elements/kg	6	6	15	7	9	18	12	1	

Table S15. Conodont distribution data for Abbott River East

Sample Number		ARE1	ARE2	ARE3	ARE5	ARE6	Total
Height from base (m)		0.0	4.0	8.0	###	###	
Sample Mass (g)		3.6	3.6	3.3	3.6	3.1	
% Dissolution		62.8	64.8	57.9	60.7	65.0	
Species	element						
<i>Apsidognathus tuberculatus</i>	lyriform				2		2
	clavohamulus-like				1		1
<i>Apsidognathus</i> sp.					1		1
<i>Aspelundia fluegeli</i>	Pa	24					24
	Pb	39	4	2	7		52
	M ₁	31	1	4	8		44
	M ₂	1					1
	M ₃	65		5	2		72
	Sa	39	6	5	3		53
	Sb	27	2		1		30
	Sc	66	12	11	16		105
<i>Aspelundia</i> cf. <i>A. borenorensis</i>	sym. dentic.	7		2	1		10
	asym. dentic.	52	11	13	10		86
	adentic. asym	25	8	2	3		38
	dentic. Sb	3		1	1		5
	dentic. Pa	10	1	2	3		16
	M ₂ ? (post.dent.process)	16	2	3	3		24
<i>Aulacognathus chapini</i>	Pa				2		2
	Pb				3		3
<i>Belodella</i> sp. A	Sa	3			2	1	6
	Sb	8					8
	Sc	10			2		12
	M	6					6
<i>Decoriconus fragilis</i>	Sb					1	1
<i>Distomodus staurognathoides</i>	Pa				1		1
	M				3	1	4
	Sa					1	1
	Sb				5		5
	Sc				2		2
gen. et sp. indet. 3	Pa	4					4
gen. et sp. indet. 4					1		1
<i>Ozarkodina excavata excavata</i>	Pa					2	2
	Pb					2	2
	M					3	3
	Sa					3	3
	Sb					3	3
	Sc					5	5
<i>Ozarkodina hadra</i>	Pa	2			3		5
	Pb	6			1		7
	M	1			2		3
	Sa	4			3		7
	Sb	7			2		9
	Sc	2			1		3
<i>Panderodus recurvatus</i>	aequaliform			4		1	5
	asymmetrical graciliform	3		5			8
	acruatiform	2			4	1	7
	compressiform	21			9		30
	truncatiform	3					3
<i>Panderodus unicostatus</i>	aequaliform		1	22	5		28
	tortiform	25	1	8	3	3	40

	subsymmetric graciliform	91			5	3	99
	asymmetric graciliform	114		20	14	1	149
	truncatiform	5		11	3		19
	arcuatiform	122	3	20	10	1	156
	compressiform	181	2	87	42	8	320
<i>Panderodus</i> sp.			1	12	20	1	34
<i>Pseudooneotodus beckmanni</i>	unidenticulate					1	1
<i>Pseudooneotodus tricornis</i>	slender conical				10		10
	squat tri-denticulate				2		2
<i>Pt. a. amorphognathoides</i>	Pa	1			5		6
	Pb ₁				2		2
	Pb ₂				2		2
	Pc				1		1
	M ₁				1		1
	Sc ₁				4		4
	Sc ₂				5		5
	Sa				1		1
	cf				5		5
	Sc?				4		4
	mcf				2		2
	curved				5		5
<i>Pt. pennatus procerus</i>	Pa	19		4	9	6	38
	juvenile Pa	5				5	10
	Pb ₁	5		2	7	4	18
	Pb ₂	5		2	2		9
	Pc	8			1		9
	M ₁	13		2	1	1	17
	M ₂				1		1
	Sc ₁	3		1	4		8
	Sc ₂	7		4			11
	Sc ₃			3		2	5
	Sb ₁					1	1
	Sb ₂	4		2			6
	cf.a	5		2			7
	curved	1					1
'suberectiform' element		10			5		15
<i>Pterospathodus rhodesi</i>	Pa	3					3
	M	1					1
<i>Walliserodus</i> cf. <i>W. sancticlairei</i>	M	63		1	0		64
	Sa	14	1	0	0	1	16
	Sb	31	1	0	0	4	36
	Sc	202		6	0		208
gen. et sp. indet. 6		1					1
Total Elements		1426	57	268	289	66	2106
Elements/kg		637	24	139	132	33	

Table S16. Conodont distribution data for Abbott River West Section 1

Sample Number	ARW1	ARW3	ARW5	ARW6	ARW10	ARW11	ARW12	ARW13	Total
Height from base (m)	0.0	8.0	16.0	20.0	35.5	40.0	44.0	48.0	
Mass (g)	3.0	2.9	3.1	3.0	4.0	3.1	3.0	3.1	
% Dissolution	68.6	52.8	71.2	95.8	97.0	71.6	74.4	51.1	
Species and element									
<i>Belodella</i> sp. A Miller									
Sa		2	5						7
Sb									0
Sc			4						4
M									0
<i>Dapsilodus obliquicostatus</i>									
Sa	1			1	0	0			2
Sb/Sc	10	2	1	8	14	1	6	1	43
M	2	2		3	10	0	2		19
<i>Decoriconus fragilis</i>									
Sa									0
Sb			3						3
Sc			1						1
<i>Ozarkodina excavata excavata</i>									
Pa	2			3	2	1	4	1	13
Pb			2	3	2			1	8
M				2		2		1	5
Sa				0	1				1
Sb			1	15		2	4		22
Sc			2	7	2	2			13
<i>Panderodus unicostatus</i>									
aequaliform									0
tortiform		1		1	1		1		4
subsymmetric graciliform		1					1		2
asymmetric graciliform		1		2			4		7
truncatiform							7		7
arcuatiform		4		3	2		5	2	16
compressiform		4		2	1	1	4		12
<i>Panderodus</i> sp.		2		1	1		6	1	11
<i>Pseudooneotodus beckmanni</i>							2		2
<i>Pseudooneotodus bicornis</i>				1				1	2
<i>Walliserodus</i> cf. <i>W. sancticlairei</i> ? M								2	2
Total Elements	15	20	19	52	36	9	46	10	206
Elements/kg	7	13	9	18	9	4	21	6	

Table S17. Conodont distribution data for Abbott River West Section 2

Sample Number	2ARW1	2ARW3	2ARW4	Total
Height from base (m)	0.0	8.0	###	
Mass (g)	3.0	3.0	3.0	
% Dissolution	57.3	53.8	25.6	
Species and element				
<i>Dapsilodus obliquicostatus</i>				
Sa		1		1
Sb/Sc		2	2	4
M		2		2
<i>Kockelella absidata</i>				
Pa	2			2
Pb				0
M				0
Sa	1			1
Sb				0
Sc	3			3
<i>Kockelella patula</i> Pa	1			1
<i>Ozarkodina confluens</i> Pa	1	1		2
<i>Ozarkodina e. excavata</i> Pa	3			3
<i>Panderodus unicosatus</i>				
tortiform			2	2
subsymmetric graciliform				0
asymmetric graciliform	2	2	7	11
truncatiform	1			1
arcuatiform	3		3	6
compressiform	2	1	4	7
<i>Panderodus</i> sp.	2	1	3	6
<i>Pseudooneotodus bicornis</i>				
slender conical	1		1	2
squat bi-denticulate			1	1
Total Elements	22	10	23	55
Elements/kg	13	6	30	

Table S18. Conodont distribution data for Abbott River West Section 3

Sample Number	3ARW1	3ARW2	3ARW3	3ARW4	3ARW5	3ARW9	3ARW10	3ARW12	3ARW34	3ARW37	3ARW13	Total
Height from base (m)	0.5	4.5	8.0	10.4	15.0	16.6	19.0	23.5	35.0	38.0	40.0	
Mass (g)	3.0	3.0	3.0	3.0	3.0	3.2	3.1	3.4	0.5	3.0	3.3	
% Dissolution	95.3	98.3	65.6	91.9	71.5	65.5	24.3	73.5	91.2	75.5	66.7	
Species and element												
<i>Dapsilodus obliquicostatus</i>												
Sa		5			2	1				2		10
Sb	1	52		3	3	6			1	29	3	98
M	1	28		3				1	1		1	35
<i>Kockelella absidata</i>												
Pa								6		1		7
Pb								2				2
M								3				3
Sa								3				3
Sb								2				2
Sc								4				4
<i>Kockelella</i> sp.												
Pa				3								3
Sa				3								3
Sc				5								5
<i>Oulodus equirectus</i>? Pa												
								2				2
<i>Ozarkodina confluens</i>												
Pa								10			12	22
Pb						1		1			2	4
M											3	3
Sa								1			1	2
Sb								1				1
Sc											3	3
<i>Ozarkodina e. excavata</i>												
Pa				1		4	1	14	1	5	3	29
Pb					2	2		9	2	4		19
M					3	2		6	2	3		16
Sa						0		3	5	2		10
Sb				1	2	3		7	4	5		22
Sc				3	1	3		14	5	10		36
<i>Panderodus unicastatus</i>												
aequaliform				1								1
tortiform											1	1
subsyzmmetric graciliform			1								4	5
asymmetric graciliform	10			4	1			3	4	3	5	30
truncatiform								1			2	3
arcuatiform	3		3	8				3		6	9	32
compressiform	11		3	11	1			5	1	3	9	44
<i>Panderodus</i> sp.												
	22		2	23	1				1		10	59
<i>Pseudooneotodus beckmanni</i>												
				2							1	3
<i>Pseudooneotodus bicornis</i>												
slender conical				2								2
squat bi-denticulate				1								1
<i>Walliserodus</i> sp. Sc												
					1							1
Total Elements	48	85	9	74	17	22	1	101	27	73	69	526
Elements/kg	17	28	5	26	8	10	1	40	62	33	31	