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# *ANTICOSTIODUS*, A NEW MULTIELEMENT CONODONT GENUS FROM THE LOWER SILURIAN, ANTICOSTI ISLAND, QUEBEC

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ABSTRACT—The multielement conodont genus, *Anticostiodus* new genus, is described based on discrete elements from the Lower Silurian (early Aeronian) Gun River Formation of Anticosti Island, Quebec. The apparatus includes pectiniform Pa, Pb, Pc and Pd elements and ramiform M, Sa, Sb and Sc elements. Two new species are included under the new genus, *Anticostiodus fahraeusi* (type species) and *Anticostiodus boltoni*. Both species occur near the base of *Distomodus staurognathoides* Zone and in an open subtidal environment.

## INTRODUCTION

ANTICOSTI ISLAND, located in the Gulf of St. Lawrence, Quebec, is underlain by limestone and minor shale in an apparently continuous succession extending from Richmondian (Late Ordovician) to the latest Llandovery (Early Silurian), which includes the Vaurèal, Ellis Bay, Becscie, Merrimack, Gun River, Jupiter, and Chicotte formations (Fig. 1). Detailed studies on conodonts from the lower part of the sequence (Vaurèal and Ellis Bay formations) and from the upper part (Jupiter and Chicotte formations) have been undertaken by Nowlan and Barnes (1981), McCracken and Barnes (1981) and Uyeno and Barnes (1983). No previous investigation has been made of conodonts from Becscie and Gun River formations, except for a brief summary by Fåhraeus and Barnes (1981). We have completed detailed studies on the conodonts from the Becscie, Merrimack and Gun River formations and have prepared two separate papers, in which simple-cone, ramiform and pectiniform-ramiform conodont apparatuses are described. The purpose of this paper is to document the discovery of a new early Llandovery (Aeronian) multielement conodont genus with two new species from the Gun River Formation.

## BIOSTRATIGRAPHIC OCCURRENCE OF *ANTICOSTIODUS*

The Gun River Formation (early Aeronian; Early Llandovery) contains an unusually abundant and diverse Lower Llandovery conodont fauna (over 19,500 specimens from 87 samples; 25 species representing 13 multielement genera). Only two samples, A79-C99 and A79-C100, which were collected from middle part of the Gun River Formation at the La Loutre section (Section A-4 in Fig. 1) yield specimens of the new genus. In relation to the entire Gun River sequence, sample A79-C96a contains the first appearance of *Distomodus staurognathoides* (Walliser, 1964) at the La Loutre section, with sample A79-C99 occurring just 13 m above A79-C96a. If the first appearance of *D. staurognathoides* is taken as the base of the *D. staurognathoides* Zone, then the new genus first appears 13 m above the base of the zone.

## ASSOCIATED CONODONT FAUNA

Sample A79-C99 yielded the most abundant conodonts among all samples from the Gun River Formation and had a high species diversity. Over 4,600 conodonts together with numerous unidentifiable fragments were recovered. Twelve multielement species belonging to seven genera were recognized: *Icriodella deflecta* Aldridge, 1972, *Oulodus expansus* (Armstrong, 1990), *Oulodus* n. sp., *Ozarkodina clavula* Uyeno, 1983, *O. oldhamensis* (Rexroad, 1967), *O. pirata* Uyeno, 1983, *Panderodus recurvatus* (Rhodes, 1953), *P. unicostatus* (Branson and Mehl, 1933), *Pseudooneotodus beckmanni* (Bischoff and Sannemann, 1958), *Walliserodus curvatus* (Branson and Branson, 1947) as well as the two new species of the new genus, *Anticostiodus fahraeusi* and *A. boltoni* (Table 1). The fauna is dominated by *Panderodus unicostatus* (61 percent) and *Ozarkodina pirata* (29 percent); *Pseudooneotodus beckmanni* (4 percent) and *Ozarkodina oldhamensis* (2.6 percent) are less common. The remaining taxa occur in low numbers, including the two new species of the new genus (0.6 percent). Sample A79-C100 contains a less diverse fauna than sample A79-C99, with only seven multielement species belonging to five genera identified. Besides *Ozarkodina pirata, Panderodus recurvatus, P. unicostatus,* and *A. fahraeusi,* which occur in sample A79 -C99, it yields *Distomodus staurognathoides, Oulodus jeannae* Schönlaub, 1975 and *O. panuarensis* Bischoff, 1986, which do not appear in sample A79-C99. The fauna from sample A79-C100 is also dominated by *P. unicostatus* (53 percent) and *O. pirata* (40 percent). The new genus still remains the lowest percentage (0.7 percent) (Table 1).

The two dominant species of the fauna, *Panderodus unicostatus* and *Ozarkodina pirata,* have relatively long biostratigraphic ranges, and they are found in most samples from the Becscie, Merrimack, and Gun River formations. The specimens of these two species are quite different from sample to sample within a section (some are small, thin, almost translucent and very fragile, whereas others are large, robust, and not translucent), possibly reflecting the changing nature of the depositional environment of the Gun River Formation, which oscillated between an open and a more restricted marine environment (Fåhraeus and Barnes, 1981; Copper and Long, 1998; Jin and Copper, 1999). All of the conodonts from sample A79-C99 fit the former case: quite small, very fragile, and almost translucent. However, those from sample A79-C100 fit in the latter category: large, robust, and almost opaque. Such individuality and richness of the fauna suggest that the new genus and its associated fauna may be related to oscillating restricted to open marine environment. However, more material of the new genus is needed to determine its ecological preference and full stratigraphic range.

## RECONSTRUCTION OF THE APPARATUS OF *ANTICOSTIODUS*

Although the elements of the two new species of *Anticostiodus* are quite rare, the apparatuses of both species can be reconstructed, but may be modified by future studies based on more material.

Thirty specimens representing 16 ($2 \times 8$ morphotypes) different elements have been found in sample A79-C99 (Table 1; Fig. 2). Although the apparatuses cannot be reconstructed using numerical ratios of the different elements, all tend to be the same

TABLE 1—Number of conodont elements recovered from the samples A79–C99 and A79–C100.

| Species and element | Number C99 | Number C100 |
|---|---|---|
| *Anticostiodus fahraeusi* n. gen and sp. | | |
| Pa | 1 | |
| Pb | 6 | 1 |
| Pc | 1 | 1 |
| Pd | 1 | |
| M | 1 | |
| Sa | 2 | |
| Sb | 1 | |
| Sc | 1 | |
| *Anticostiodus boltoni* n. gen. and sp. | | |
| Pa | 1 | |
| Pb | 2 | |
| Pc | 1 | |
| Pd | 3 | |
| M | 4 | |
| Sa | 1 | |
| Sb | 1 | |
| Sc | 1 | |
| *Distomodus staurognathoides* | | |
| Pa | | 0 |
| Pb | | 0 |
| M | | 1 |
| Sa | | 0 |
| Sb | | 1 |
| Sc | | 0 |
| *Icriodella deflecta* | | |
| Pa | 1 | |
| Pb | 2 | |
| M | 1 | |
| Sa | 1 | |
| Sb-Sc | 3 | |
| *Oulodus* n. sp. | | |
| Pa | 1 | |
| Pb | 3 | |
| M | 0 | |
| Sa | 1 | |
| Sb | 1 | |
| Sc | 1 | |
| *Ozarkodina clavula* Pa | 14 | |
| *Ozarkodina oldhamensis* | | |
| Pa | 14 | |
| Pb | 18 | |
| M | 7 | |
| Sa | 14 | |
| Sb | 66 | |
| Sc | ? | |
| *Ozarkodina pirata* | | |
| Pa | 287 | 28 |
| Pb | 257 | 21 |
| M | 249 | 20 |
| Sa | 93 | 5 |
| Sb | 166 | 18 |
| Sc | 273 | 24 |
| *Panderodus recurvatus* | | |
| aequaliform | 1 | 0 |
| truncatiform | 1 | 1 |
| symmetric acostatiform | 0 | 2 |
| asymmetric acostatiform | 0 | 6 |
| sub-symmetric graciliform | 2 | 8 |
| asymmetric graciliform | 7 | 18 |
| arcuatiform | 0 | 4 |
| compressiform | 1 | 9 |
| *Oulodus expansus* | | |
| Pa | 3 | |
| Pb | 7 | |
| M | 5 | |
| Sa | 4 | |
| Sb | 4 | |
| Sc | 8 | |
| *Oulodus jeannae* | | |
| Pa | | 1 |
| Pb | | 4 |
| M | | 0 |
| Sa | | 2 |
| Sb | | 2 |
| Sc | | 8 |
| *Oulodus panuarensis* | | |
| Pa | | 2 |
| Pb | | 1 |
| M | | 3 |
| Sa | | 1 |
| Sb | | 0 |
| Sc | | 5 |
| *Panderodus unicostatus* | | |
| aequaliform | 14 | 1 |
| truncatiform | 28 | 6 |
| sub-symmetric graciliform | 279 | 17 |
| asymmetric graciliform | 1,066 | 42 |
| arcuatiform | 729 | 53 |
| compressiform | 662 | 25 |
| tortiform | 35 | 10 |
| *Pseudooneotodus beckmanni* | 178 | |
| *Walliserodus curvatus* | | |
| unicostatiform | 29 | |
| dyscritiform | 12 | |
| deboltiform | 20 | |
| curvatiform | 5 | |
| multicostatiform | 1 | |
| Total | 4,603 | 351 |

size, color, and luster and to have a similar pattern of denticulation; most are totally different from any other known conodont elements. Among the 16 different element types, eight kinds of pectiniform elements are recognized. All of the pectiniform elements are stelliscaphate and pastiniscaphate, which are similar in having a wide and capacious basal cavity, sharp ridges on the upper surface and sharp edges on the cusp, and in closely resembling to prioniodontid conodonts. By comparison with other prioniodontid conodont apparatuses, the maximum number of pectiniform elements in one apparatus is four, suggested to occupy the Pa, Pb, Pc and Pd positions. This pattern was known previously only from the apparatus architecture of *Promissum*

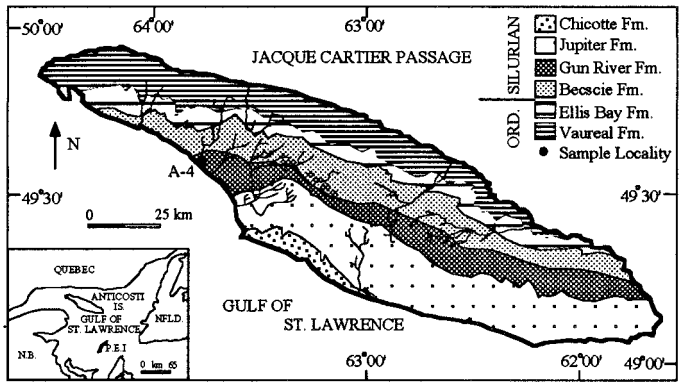


FIGURE 1—Map of Anticosti Island, Québec, showing stratigraphic units, Gun River Formation outcrop belt, and Locality A-4 from which the new taxa were recovered. The Merrimack Formation is a thin unit, not shown on the map, lying between the Becscie and Gun River formations.

*pulchrum* Kovács-Endrödy, 1986 established by Aldridge et al. (1995) based on over 100 complete bedding-plane assemblages from the Upper Ordovician Soom Shale Member, Cedarberg Formation of South Africa. There is no basis for assigning all these pectiniform elements to a single apparatus.

In our apparatus reconstructions two different element groups are evident, especially considering the denticulation of both pectiniform and ramiform elements. One ramiform group includes flakelike elements with weak denticulation (Fig. 2.14–2.19), and another ramiform group contains bladelike elements with strong denticulation (Fig. 2.26–2.28, 2.32, 2.34, 2.35). One pectiniform group contains one stelliscaphate-like pastiniscaphate element with three primary processes and three pastiniscaphate elements whose cusp is prominent, higher than or the same height as the other denticles, and in which the denticulation is relatively weak. These should logically be associated with the ramiform elements with weak denticulation. The other pectiniform group is characterized by one stelliscaphate element and three pastiniscaphate elements (or pastiniscaphate-like tertiopedate) whose cusp is extremely prominent, high, and robust, which have been assembled together with the ramiform elements with strong denticulation. Based on these relationships, two new species can be recognized among the thirty specimens.

In this reconstruction of *Anticostiodus* new genus, the apparatus has similarities to prioniodontid conodonts that have stelliscaphate and pastiniscaphate P elements, such as *Amorphognathus*, *Sagittodontina*, and *Promissum*, most of which come from the Upper Ordovician. However, such genera have a pectiniform complex that is represented by elements with well-developed processes and a ramiform complex that also has elements with well-developed processes and denticulation. They form a striking contrast with that of the new genus with its small, undeveloped processes and denticles. The ramiform complex of the new genus is most similar to the ramiform elements representing the whole apparatus of *Istorinus erectus* Knüpfer, 1967 reconstructed from the Upper Ordovician of Libya by Bergström and Massa (1992) and of Germany by Ferretti and Barnes (1997). The apparatus of *Istorinus erectus* is composed of small, laterally compressed elements with sharp anterior and posterior margins, and its position in the classification framework is unknown. Although it shows great similarity morphologically to the ramiform elements of the new genus, no pectiniform elements have yet been recognized. Morphological similarities between the new genus and any of the post-Llandoverian conodonts are not apparent. Thus, the evolutionary relationship of *Anticostiodus* remains obscure.

## SYSTEMATIC PALEONTOLOGY

Type and figured specimens illustrated in Figure 2 are deposited in the National Paleontological Type Repository, Geological Survey of Canada (GSC), Ottawa, Ontario.

Phylum CONODONTA Eichenberg, 1930
Class, Order, and Family unknown
Genus ANTICOSTIODUS new genus

*Type species.*—*Anticostiodus fahraeusi* new species

*Diagnosis.*—Apparatus of *Anticostiodus* n. gen. is octomembrate, with four morphologically different pectiniform elements in P positions. Pa element is stelliscaphate or stelliscaphate-like pastiniscaphate, and is greatly expanded laterally and antero-posteriorly. Pb, Pc and Pd elements are all pastiniscaphate, Pb element has two antero-lateral and posterior processes roughly equal in length; Pc elements and Pd elements are asymmetrical and laterally symmetrical pastiniscaphate, respectively. Cusp of P elements has three sharp edges which develop into sharp ridges on upper surface of processes. Ramiform complex contains asymmetrical to subsymmetrical elements with short processes. M element has three denticulate processes. Sa element is subsymmetrical with a central cusp. Sb element is asymmetrical with one process and a lateral cusp. Sc element is a longer and lower version of Sb element. Lower surface of all elements is wide, with capacious basal cavity expanded under each process. All elements are tiny and delicate with thin walls.

*Etymology.*—The prefix is derived from the Anticosti Island, in reference to the locality of the genus.

ANTICOSTIODUS FAHRAEUSI new species
Figure 2.1–2.19, 2.22, 2.23

Pb element
*Ambalodus* spp., REXROAD, 1967, p. 27, pl. 3, fig. 4.

*Diagnosis.*—Apparatus of the type species of *Anticostiodus* n. gen. is characterized by eight morphotypes that probably occupy Pa, Pb, Pc, Pd, M, Sa, Sb, and Sc positions. Pa element is stelliscaphate-like pastiniscaphate, and Pb, Pc, and Pd elements are pastiniscaphate, each with a prominent cusp with three sharp edges which turn into the sharp ridges on the upper surface of the processes, the ridges may be weakly denticulated. Pa element has three primary processes and one secondary process, greatly expanded laterally and antero-posteriorly, upper view rectangular and with four-rayed ridges. Pb, Pc and Pd elements have three primary processes. Anterior, posterior and lateral processes of Pb element are roughly equal in length with sharply pointed ends; upper view provides nearly equilateral triangle, with three-rayed ridges. Anterior, posterior and antero-lateral processes of Pc element are unequal in length; the former two are longer, with rounded ends; the latter is shorter, with sharply pointed end; upper view irregular in shape and in ridge ornamentation. In Pd element, two antero-lateral processes are nearly symmetrical, and posterior process has rounded end; upper view of both element and ridge ornamentation display a ''Y'' shape. M and S elements are thin and flakelike; cusp and denticles are strongly laterally compressed, with sharp edges, and separated by wide interdenticular spaces. M element has three denticulate processes. Sa element is subsymmetrical with a central cusp. Sb element

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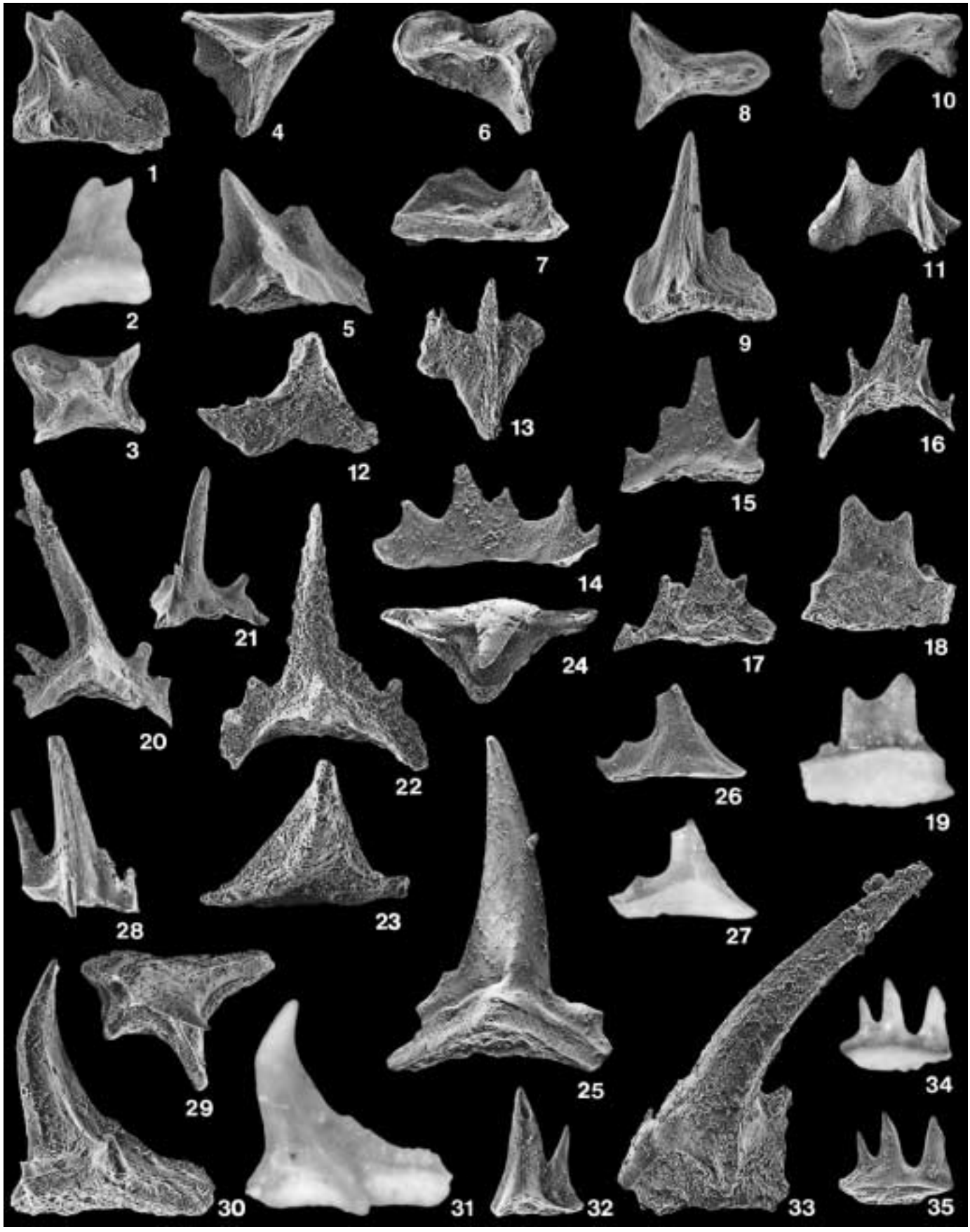
FIGURE 2—All figures are ×105; figures are SEM images, except *2, 19, 27, 31* and *34* which are optical images. *1–19, 22, 23, Anticostiodus fahraeusi* n. gen and sp.; *1–3,* outer lateral view, inner lateral and upper view of Pa element, GSC 117932 (holotype); *4, 5,* upper view and outer lateral view of Pb element, GSC 117933; *6, 7,* upper and lateral view of Pc element, GSC 117934; *8, 9*; upper view and anterio-lateral view of Pd element, GSC117935; *10, 11,* upper view and lateral view of Pc element, GSC 117936; *12, 13,* upper lateral and anterior view of Pb element, GSC 117937; *14,* inner lateral view of Sc element, GSC 117938; *15, 17,* posterior view of Sa element, GSC 117939, 117940; *16,* posterior view of M element, GSC 117941; posterior view; *18, 19,* lateral view of Sb element, GSC 117942; *22–23,* posterior view and upper view of Pb element, GSC 117943. *20, 21, 24–35, Anticostiodus boltoni* n. gen. and sp.; *20, 21,* posterior and lateral view of Pd element, GSC 117944, 117945; *24, 25,* upper and posterior view of Pb element, GSC117946; *26, 27,* lateral view of Sb element, GSC 117947; *28,* posterior view of M element, GSC117948; *29–31,* upper and inner lateral view of Pa element, GSC, 117949 (holotype); *32,* lateral view of Sb element, GSC 117950; *33,* lateral view of Pc element, GSC 117951; *34, 35,* posterior view of Sa element, GSC 117952.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is asymmetrical with a lateral cusp. Sc element lacks a prominent cusp; anterior process curves inwards. Lower surface of all elements has wide and capacious basal cavity expanded under each process.

*Description.*—Pa element is characterized by a rectangular-shaped platform, which has two short antero-lateral processes and one bifurcated posterior process. Posterior process only possesses one laterally compressed denticle which is mostly fused with cusp, and from this denticle two postero-lateral processes are developed. The two antero-lateral processes curve downwards slightly, with the two postero-lateral processes being straight. Each of the four processes is greatly expanded from center to basal margin of element, so that basal margin of any two adjacent processes is on same straight line. Upper view of element shows a rectangular shape, with lateral margins longer than anterior and posterior margins. Cusp is situated at center of element, and slightly reclined posteriorly. Two sharp edges are developed on antero-lateral sides of cusp, which continue into ridges on upper surface of two antero-lateral processes. Another two sharp edges are developed on postero-lateral sides of single denticle of posterior process, which is also developed transitionally into ridges on upper surface of two postero-lateral processes. Thus, the four ridges on upper surface of element are distributed in a shape of diagonal lines of a rectangle. At the end of postero-lateral processes there can be a tiny single lateral compressed denticle. Lower margin of basal cavity is rectangular-shaped, and top is vaulted and usually filled by a basal plate.

Pb element is typically an equilateral triangular-shaped platform in upper view, and a low three-sided pyramid in lateral view. Element has anterior, posterior and lateral processes which are almost equal in length and width. As with Pa element, each of three processes is greatly expanded from centre to basal margin, so that basal margin of any two adjacent processes forms a straight line. Cusp is prominent, located at centre of element, and inclined posteriorly. Three sharp edges are developed on anterior and two postero-lateral sides of cusp, and they extend gradually at base of cusp into three longitudinal ridges on upper surface of the three processes. These are arranged in the form of three bisectors of an equilateral triangle forming angles of about 120 degrees. Each ridge may bear a very tiny and strongly compressed denticle. Basal cavity is wide and with equilateral triangular-shaped basal margin. Top of basal cavity is vaulted, usually filled by basal plate.

Pc element also has three processes, but they are characterized by unequal length and different shape. Upper view of element resemble an irregular ''8'' shape. Posterior process is about twice that of anterior process in length, both processes are greatly expanded with wide and rounded end. Antero-lateral process is almost same length as anterior process, but far less expanded, and has a pointed end as well as a tiny denticle. Cusp is situated at junction of three processes and is erect and ornamented with sharp anterior, posterior and antero-lateral edges. Upper surface of anterior process is smooth, and that of antero-lateral process has longitudinal ridge which is connected with antero-lateral edge of cusp. Upper surface of posterior process has an erect denticle, which is almost same size as cusp, located near posterior end. Denticle on posterior process has two sharp edges on its anterior and posterior sides, but posterior one is located either on inner lateral or outer lateral side. Anterior edge of denticle on posterior process is linked with posterior edge of cusp through ridge on upper surface of process. Posterior edge on denticle develops into a ridge on either inner lateral or outer lateral side of upper surface of posterior process depending on location of posterior edge of cusp. Basal cavity is wide, but may be slightly narrower at front part of posterior process.

Pd element is marked by both three processes and three ridges on upper surface exhibiting a ''Y'' shape in upper view. Cusp is slightly inclined posteriorly, and is as high as length of posterior process. Cusp is high pyramid in shape, on which three sharp edges are symmetrically distributed antero-laterally and posteriorly. Three edges are well developed from top to base of cusp, then are transformed into the ridges on antero-lateral and posterior processes. Ridges produce one or two weak and compressed denticles on each process. Three processes are straight, symmetrically arranged laterally, and any two of them form an angle of about 120 degrees. Posterior process is about twice that of antero-lateral processes in length and strongly expanded evenly through whole length terminating with rounded end. Two antero-lateral processes are equal in length, expanded as strongly as posterior one near base, then less strongly expanded distally, terminating sharply. Basal cavity is ''Y'' shaped, wide and shallow, opens throughout three processes, and filled entirely by a basal plate.

M element has three delicate denticulate processes, lateral two are subequal in length and roundly arched, and inner lateral one is more delicate than outer lateral one. Each of lateral processes has two tiny, fragile and sharply pointed denticles. On average, interdenticular spaces are 4–5 times as wide as denticles. Posterior process is much shorter than lateral two and has only one denticle situated close to inner lateral process. Cusp is prominent, slightly reclined posteriorly, with wide base and sharply pointed tip. Basal cavity is open beneath cusp and three processes and narrows distally in two lateral processes.

All S elements are thin and flakelike; cusp and denticles are strongly compressed with sharp lateral edges, and with wide base and sharply pointed tips. Shape of cusp and denticles is triangular in lateral view. Basal cavity is open along entire element, occupied by the basal filling in some specimens.

Sa element is subsymmetrical laterally. Cusp is prominent and erect. Each of lateral processes usually have two denticles, separated by wide interdenticular space. Distal denticle is much shorter than that flanking cusp. One denticle flanking cusp on one lateral process is almost entirely fused to sharp edge of cusp.

Sb element has only one process. Cusp is situated terminally and is not as prominent as that of Sa element. Process only has two denticles separated by a wide interdenticular space. Denticle flanking cusp has almost same height as cusp and almost entirely fused to cusp. Distal denticle is tiny, and about one-third to one-fourth the height of the one flanking cusp.

Sc element has two processes and anterior process is about twice of posterior one in length. Cusp is not prominent and slightly reclined posteriorly. Anterior process is curved inwards distally and has three widely separated denticles, with denticle flanking cusp partially fused to cusp. Posterior process is straight with only one denticle.

*Etymology.*—In honor of the late Lars E. Fåhraeus, formerly of Memorial University of Newfoundland, a close colleague who collaborated in earlier studies of the lower Llandovery conodonts from Anticosti Island.

*Types.*—Holotype, GSC 117932; paratypes, GSC 117933–117943 (see Fig. 1 caption for locality data).

*Other material examined.*—Pa element—1; Pb element—7; Pc element—2; Pd element—1; M element—1; Sa element—2; Sb element—1; Sc element—1 (see Table 1 for distribution).

*Occurrence.*—Near the lower boundary of the *Distomodus staurognathoides* Zone in the middle part of the Gun River Formation.

*Discussion.*—Rexroad (1967) reported eighteen specimens of three-rayed or triangular platform conodonts, referred to *Ambalodus* spp., from the Brassfield Formation (Lower Silurian) of the Cincinnati Arch area. He noted that the material represents

different ontogenetic stages, is morphologically variable, and generally is fragmentary. Although he thought the material precluded species identification, he provisionally referred one specimen (Rexroad, 1967, pl. 3, fig. 4) to *Ambalodus triangularis* Branson and Mehl. There was no detailed description of this specimen, but it shows a three-rayed or triangular platform with anterior and posterior processes almost equal in length and width and an outer lateral process shorter than the others, bearing orally anterior, posterior, and outer lateral longitudinal ridges which meet at the junction of three processes, and end distal at the terminus of each of them, with the ridges forming angles of about 120 degrees. It is difficult to discern whether a cusp occurs at their point of union, but no small denticles occur on the specimen. This figured specimen shows great resemblance to the Pb element of *Anticostiodus fahraeusi* recognized here.

Branson and Mehl (1933) established the conodont form genus *Ambalodus*, with *A. triangularis* as the type species from the Thebes Formation (Upper Ordovician) of Missouri. *A. triangularis* is an element with a base roughly crescent-shaped and with one process longer and more slender than the other. On the convex side of the element, there is a denticulate parapet which is composed of six to eight low, rounded, fused denticles on the long process and about four on the short process. On the convex margin of the crescentic base, at the base of the cusp there is a very small pointed erect single denticle or a platelike flange with a median crest composed on three or more fused denticles.

*Ambalodus triangularis* form species is clearly part of the apparatus of a late Ordovician species, *Amorphognathus ordovicicus* Branson and Mehl, 1933. The one specimen (Rexroad, 1967, pl. 3, fig. 4) referred to *A. triangularis* does not possess the characteristics of the type *A. triangularis*, and is referred to *Anticostiodus fahraeusi.*

ANTICOSTIODUS BOLTONI new species
Figure 2.20, 2.21, 2.24–2.35

M element
? *Neoprioniodus costatus* Walliser. REXROAD, 1967, pl. 3, fig. 13.
Sb or Sc element
? *Neoprioniodus triangularis* Walliser. REXROAD, 1967, pl. 3, fig. 12.

*Diagnosis.*—Species of *Anticostiodus* n. gen. with an apparatus consisting of eight morphotypes, namely Pa, Pb, Pc, Pd, M, Sa, Sb, and Sc. Four P elements are characterized by extremely high, prominent, robust cusp with three or four sharp edges that develop into sharp ridges on upper surface of processes. Processes are rather short compared with cusp, with tiny and compressed denticles. Pa element is stelliscaphate and expanded irregularly; upper view is an irregularly rectangular in shape; upper surface has asymmetric four-rayed ridges. Pb element is pastiniscaphate, expanded posteriorly with three processes of almost same length; upper view nearly a right isosceles triangle provided by three-rayed ridges. Pc element is similar to Pb element but its posterior process is longer than the two antero-lateral processes but is not expanded posteriorly. Pd element has three expanded processes that are almost symmetrical laterally. Ramiform M, Sa, Sb, and Sc elements have a cusp that is less prominent than those of P elements and have denticles which are much stronger than those of P elements and with oval cross section and two lateral sharp edges. M element has three denticulate processes. Sa element subsymmetrical lacks a prominent cusp. Sb element is asymmetrical with a lateral cusp. Sc element is a slightly longer and lower version of Sb element. All of elements have thin walls. Lower surface of all elements has wide and capacious basal cavity extending under each process.

*Description.*—Pa element is characterized by well-developed, high and robust cusp, having four small processes which are unequal in length, and upper view being an irregular rectangle. Cusp is proclined on the lower two-thirds of cusp; anterior margin is slightly tilted anteriorly, but posterior margin is inclined posteriorly; on upper one-third part of cusp, both anterior and posterior margins are inclined posteriorly. Cusp is ornamented by four sharp edges, two of which are located on anterior and posterior sides, with other two situated on inner antero-lateral and inner postero-lateral sides, respectively. The four sharp edges of cusp develop into sharp ridges on upper surface of anterior, posterior and two inner lateral processes. Base of cusp is expanded with sharp pointed tip. Four processes are much narrower and smaller than cusp in width and length. Anterior and posterior ones are adenticulate, almost extended in same plane, the former is about one-third the latter in length but is same as the latter in width. Two inner lateral processes are weakly denticulate, each of them has a tiny distal denticle. Two inner lateral processes form a similar angle with anterior and posterior processes, respectively, and anterior and posterior inner lateral processes are slightly smaller versions of anterior and posterior processes, respectively, but rarely have weak denticles. Each of processes is slightly bent downwards. Upper view shows an irregular rectangle in outline. Basal cavity is wide and shallow, extending throughout all processes, and filled by a basal plate that is slightly wider than basal cavity.

Pb element has well-developed, high and robust cusp, three small processes with upper view being nearly a right isosceles triangle. Cusp is slightly inclined posteriorly and inwards, and is as high as length of two lateral processes. Base of cusp is rather wide and occupies middle one-third part of two lateral processes. Cusp has three edges on lateral and posterior sides, the two on lateral sides are fairly sharp and well developed from top to base of cusp, then transformed into ridges on lateral processes that produce one or two weak and compressed denticles; one on posterior side of the cusp is wide and round, extending from top to base of cusp, and is deflected into ridge on upper surface of posterior process. Three processes are almost same in length, and symmetrically distributed laterally. Two lateral processes are straight, narrow, with sharp end, and situated in same plane. Posterior process is flat, wide, strongly expanded, with round end, and symmetrically located behind two lateral processes. Basal cavity is triangular in shape, wide and shallow, open throughout three processes, and is filled by basal plate which extends beyond the basal cavity.

Pc element is a narrower version of Pb element and is same as Pb element in number of processes, and similar to Pb element in robustness and curvature of cusp, and in ridge ornamentation of upper surface. Antero-lateral processes of Pc element are tiny, with an anticusplike outline; its length is about of one-seventh cusp's height, curves down strongly, with tiny denticle. Posterior process is narrow, straight and longer than two anterio-lateral processes based on the broken specimen, and also with tiny denticle. Basal cavity is open beneath three processes, and it is filled by basal plate restricted just to cavity area.

Pd element has high, robust cusp which is inclined posteriorly and three processes which are unequal in length. Cusp has even width, widening slightly at base. It is ornamented by three faint edges on anterior, posterior and outer-lateral sides. Cusp is situated at junction of anterior, posterior and outer-lateral processes which are roughly same in length. Three processes are all slightly arched and arranged asymmetrically, each bears one or two small denticles that are elliptical in cross section, sharp edged, and about one-fifth of the cusp in height and width. Denticles and cusp are separated by a wide interdenticular space, but edges of both cusp and denticles are linked by sharp ridge on this space which develops from edges of cusp. Basal cavity is basically triangular in shape, wide and expanded.

All M and S elements are thin and bladelike, and with typical ramiform denticulation. Cusp and denticles are elliptical in cross section, with sharp lateral edges and sharp tip.

M element has a cusp which is prominent, tilted outwards and laterally, and with three sharp edges on lateral and posterior sides. It possesses three denticulated processes, lateral two are straight and subequal in length, and outer lateral one is slightly longer and more delicate. Each of the lateral processes has one or two denticles which are all tilted outer laterally. Posterior process is much shorter than lateral two and only has one denticle, which is obviously connected with posterior edge of cusp. Basal cavity is open beneath cusp, and tends to terminate near ends of three lateral processes.

Sa element is subsymmetrical and has two straight lateral processes, each of which has one erect denticle. Cusp is not prominent, arranged almost parallel with denticles, and almost same size as largest denticle. Basal cavity is open under processes, with top of basal cavity nearly flat. Basal cavity is filled by long, narrow basal plate.

Sb element has only one lateral process with a single denticle. Cusp is prominent, and slightly curved posteriorly. Lateral margin of cusp forms an angle of about 80 degrees with aboral margin. Denticle is about one-half and one-third of cusp height and width, respectively. Basal cavity is expanded beneath cusp, more strong posterior than anterior, and closed at end of process. Basal filling is preserved.

Sc element is a longer and lower version of Sb element, base of cusp is wider than that of Sb element, so that lateral margin of cusp forms an angle of about 60 degrees with aboral margin. Lateral process has two denticles, distal one is much smaller than that flanking the cusp. Basal cavity is expanded beneath cusp, and becomes shorter and narrower under lateral process. Basal cavity is arch-like in anterior and posterior view and filled by basal filling.

*Etymology.*—In honor of the late Thomas E. Bolton, formerly of the Geological Survey of Canada, who made substantial contributions to the knowledge of the macropaleontology and stratigraphy of Anticosti Island.

*Types.*—Holotype, GSC 117949; paratypes, GSC 117944–117948, GSC 117950–117952.

*Other material examined.*—Pa element—1; Pb element—2; Pc element—1; Pd element—3; M element—4; Sa element—1; Sb element—1; Sc element—1 (see Table 1 for distribution).

*Occurrence.*—Near the lower boundary of the *Distomodus staurognathoides* Zone in the middle part of the Gun River Formation.

*Discussion.—Anticostiodus boltoni* n. gen. and sp. has a similar apparatus structure to the type species *Anticostiodus fahraeusi* n. gen. and sp. both in pectiniform and ramiform complexes. Both contain morphologically four different pectiniform elements in the P positions and four different ramiform elements in M and S positions. Both have stelliscaphate-like pastiniscaphate or steliiscaphate Pa element, pastiniscaphate Pb, Pc and Pd elements, as well as the ramiform complex containing asymmetrical to subsymmetrical tiny and delicate elements with short processes and few denticles. The lower surface of all elements in these two species have wide and capacious basal cavity expanded under each process, most of them occupied by well-preserved basal fillings.

However, they are different from each other in several aspects. The P elements of *Anticostiodus boltoni* are much more robust than those of *A. fahraeusi*; the cusp of the former is prominent, stout, with a very wide base compared to the latter. From the upper view, the Pa element of *A. boltoni* is an irregular quadrilateral in shape, but that of *A. fahraeusi* is almost regularly quadrilateral; Pb element of the former is a right isosceles triangle, but that of the latter is an equilateral triangle. Pc and Pd elements of the former are more close to ramiform elements, but those of the later are typical pectiniform elements. The elements in the transition series of *A. boltoni* are more robust than those of *A. fahraeusi*, the denticles flanking the cusp of the former are completely separated from the cusp, but one denticle flanking the cusp of the latter is almost completely fused to the cusp; the cross section of the denticles of the former is elliptical, but that of the latter is flakelike.

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