THE TAXONOMIC, BIOGEOGRAPHICAL, PALAEOGEOGRAPHICAL AND PALAEOECOLOGICAL SIGNIFICANCE OF THE LATE ORDOVICIAN OSTRACOD FAUNA OF THE ELLIS BAY FORMATION, ANTICOSTI ISLAND, EASTERN CANADA

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Zardasht A. Taha

Abstract

Ostracods form a significant component of the Late Ordovician fossil fauna of the Ellis Bay Formation, Anticosti Island, Canada. Sixty-two ostracod species are identified, belonging to 36 genera. These include 14 species described as new, and 13 species described in open nomenclature. The ostracod fauna reveals new and important data bearing on the biostratigraphical, palaeogeographical and palaeoecological significance of the Ellis Bay Formation. The stratigraphic distribution of the ostracods permits the recognition of four successive intervals: (A) the *Longiscula subcylindrica* Biozone, (B) *the Eurychilina erugoface* Biozone, (C) the *Tetradella anticostiensis* Biozone and (D) an Interregnum. Stratigraphical intervals A, B and D can be related to Copeland's (1973) ostracod biozonation for the Ellis Bay Formation. Biozone C is equivalent to three of Copeland's (1973) ostracod sub-zones. Presence/absence analysis of the ostracod distribution patterns in the Ellis Bay Formation identifies two palaeoecologically discrete assemblages: an open marine assemblage characterises most of the formation (lithostratigraphical members 1 to 6); whilst a lower diversity assemblage typifies the uppermost Member 7. Biogeographically, the Ellis Bay Formation ostracod fauna is typically North American (Laurentian), but also shares affinities with the Late Ordovician ostracod assemblages of palaeocontinental Baltica and Avalonia.

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Chapter 1

Introduction

Chapter 1: Introduction

1.1 Introduction

Ostracods are tiny crustaceans, typically about one to two millimetres in length, with a well-documented fossil record beginning in the early Ordovician (e.g. Tinn and Meidla 2004; Salas *et al*. 2007; Williams *et al*. 2003, 2008; Ghobadi Pour 2011). They have survived all of the five mass extinction events of the past 488 million years, adopting a range of anatomical, reproductive and environmental strategies that have facilitated this (see for example Williams *et al*. 2011). They have successfully colonised the marine benthic zone during the Ordovician (e.g. Williams *et al*. 2008), the plankton during the Silurian (Siveter *et al*. 1991), freshwater aquatic settings during the Carboniferous (Bennett *et al*. 2011) and the deep marine psychrosphere during the Cenozoic (e.g. Benson 1975). During the Ordovician ostracods already possessed a global biogeographical distribution from high southern latitudes to the palaeo-tropics (Williams *et al*. 2003; Mohibullah *et al*. 2012).

This study focuses on the Late Ordovician ostracod fauna of the Ellis Bay Formation on Anticosti Island, eastern Canada. The Ellis Bay Formation varies in thickness between 80 to 90 metres and contains a well-preserved ostracod fauna both in its mudstone and limestone deposits (see Figs 1.1, 1.2). The ostracod assemblages documented here are from the Ellis Bay Formation cropping out along the eponymous bay at the western end of the island. Previous studies (e.g. Copeland 1973) have described the taxonomy of the ostracods from the Ellis Bay Formation in its western outcrop through lithological members 1 to 6 (*sensu* Petryk 1981), but the uppermost Laframboise Member of the formation has not previously been studied for ostracods (Fig. 1.3).

The Ellis Bay Formation is the youngest Ordovician ostracod-bearing formation in the Laurentian rock succession and thus is an important repository of ostracod assemblage data from which to gauge the local diversity and environmental strategies of these arthropods during an interval of major climate change and mass extinction. This study focuses on assessing and updating the taxonomy of the ostracods, before evaluating their biostratigraphical, palaeoecological and palaeobiogeographical significance.

1.2 Material

The ostracod materials studied are sourced from 24 stratigraphically discrete samples which are divided into two different size fractions 0.20 (a) to 0.25 (b) mm for each sample. Samples are numbered with the prefix 'EB' to designate Ellis Bay. Samples EB21 a, b to EB24 a, b are from the uppermost Ellis Bay Formation Laframboise Member, the other samples are EB1a, b, EB2a, b, EB3a, b, EB4a, b, EB5 a, b, EB6 a, b, EB7a, b, , EB8 a, b, EB 9a, b, EB10 A, B, EB11 , b, EB12 , b, EB13 a, b, EB14 a, b, EB15 a, b, EB16 a, b, EB17 a, b, EB18 a, b , EB19 a, b, EB20 a, b, representing members 1-6 (*sensu* Petryk 1981) of the Ellis Bay Formation (see Figs 1.2 and 1.3 for stratigraphic distribution of the samples). Fossil materials have been made available through Professor Tõnu Meidla, Department of Geology, Institute of Ecology and Earth Sciences, University of Tartu, Estonia. The materials were collected during a field trip to Anticosti Island in August 2010, in Cooperation with Dr. André Desrochers (University of Ottawa, Canada), Dr. Leho Ainsaar and Dr. Oive Tinn (both University of Tartu) and Vincent Perrier (Lyon 1 University, France).

1.3 Taphonomy

The moderately high number of carapaces in the samples from the Ellis Bay Formation suggests a fauna that was *in situ* or with only limited transport (Whatley, 1983, 1988). The relatively small numbers of juveniles relative to adults suggests local winnowing of the ostracod assemblages by low- to high-energy currents (see chapter four). The scatter plot of length versus height for most species show appreciable gaps between the data points. The scatter of sizes in Figures (see Chapter 2) may also indicate that this is a time-averaged assemblage of valves, representing animals living at different times. Similar patterns have been identified elsewhere in the Ordovician (Tinn and Meidla 2003; Lajblova *et al*. 2014).

1.4 Geological setting

Outcrops on Anticosti Island (Gulf of Saint Lawrence, eastern Canada; Figs 1.1, 1.2) comprise a succession of Upper Ordovician and Lower Silurian strata (Fig. 1.1; see also Desrochers *et al*. 2010). The succession is subdivided into seven formations (Figs 1.1): the Upper Ordovician strata studied here, of the Ellis Bay Formation, are determined to be of late Katian to Hirnantian age.

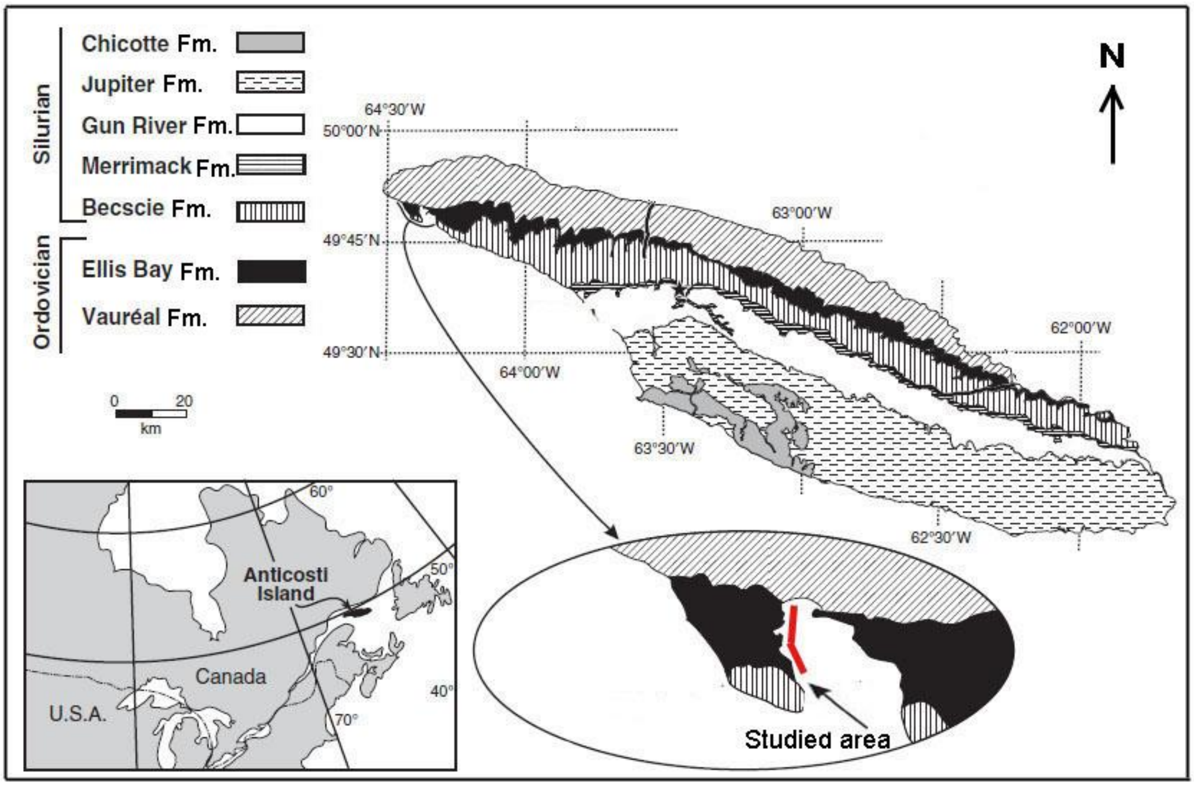

Figure 1.1. Geological map of Anticosti Island (after Achab *et al*. 2011), with main section through the Ellis Bay Formation studied for ostracods (at the western end of the island in the eponymous bay). Anticosti Island is the onshore segment of the offshore Anticosti Basin in the Gulf of Saint Lawrence in eastern Canada (see inset map, bottom left).

1.5 Methodology for the analysis of the ostracods

Samples were processed for ostracods as detailed following.

1. Preparation techniques: the main method used to prepare Upper Ordovician ostracods of the Ellis Bay Formation is chemical preparation, allowing ostracods to be released during sample break-down. This method is the best for argillaceous limestones. The main advantage of chemical preparation is that it is possible to obtain large numbers of well-preserved specimens.
2. The laboratory treatment of samples of 300-500 g with sodium hyposulphite produced hundreds of ostracod specimens per sample, but typically fewer specimens from samples near the Ellis Bay-Becscie formational contact.
3. Samples were disaggregated by means of sodium hyposulphite (Meidla 1996), with repeated heating and cooling. All 24 samples examined contain rich and diverse ostracod faunas.

4. Samples were wet-sieved and separated into different size fractions. Fractions 2.0 (a) mm and 0.25 (b) mm were picked for microfossils.
5. Ostracod species were removed from the disaggregated samples with a fine wet brush under the binocular microscope (LEICA M80).
6. Ostracod valves were cleaned by needles and by gently brushing with dilute (10%) acetic acid to remove extraneous sediment.
7. All specimens were coated with gold aluminium alloy Emitech K500X and imaged with the Scanning electron microscope Hitachi S-3600N at Leicester University.
8. Ostracod species have been identified under the binocular microscope and by using SEM images.
9. Measurements were taken using an optical lens micrometre in the objective lens of the LEICA M80 binocular microscope. Measurements taken (see Chapter 2) include L, length of valve and H, height of valve. All measurements are given in millimetres.
10. Scatter plots of length versus height have been constructed for most species to discriminate between adults and instars, or between species (see Chapter 2).
11. Selected ostracods are figured as stereo-pairs based on a tilting angle of 10° for lateral views and 6° for dorsal and ventral views. This is the methodology documented by Sylvester-Bradley (1971).

1.6 Ellis Bay Formation

The Upper Ordovician Ellis Bay Formation is of significant interest because it forms a fossiliferous succession of shallow marine to open marine deposits of late Katian to Hirnantian age. It extends over some 200 km with excellent coastal exposures at both ends of Anticosti Island (Fig. 1.1). The Ellis Bay Formation consists of argillaceous and calcareous shales, and limestone. The lower contact of the formation conformably overlies the Vauréal Formation whilst the overlying Becscie Formation has a disconformable contact with the Ellis Bay Formation (Bolton 1961; Copeland 1973; Desrochers *et al*. 2010). Deposition of the Ellis Bay Formation signals a pattern of stable, carbonate platform sedimentation in the Anticosti Basin (Petryk 1981; Barnes 1988). Petryk (1981) divided the Ellis Bay Formation into seven numbered members, where members 1, 3 and 5 defined more argillaceous and recessive units, and members 2, 4 and 6 more weathering-resistant shale units; member 7 is limestone. The formation has also been subdivided using named members: for how these schemes relate see Figures 1.2 and 1.3 below. In this thesis I use both the number scheme, and the member names *sensu* Copper *et al*. (2013). Ostracods are noticeably more species diverse and much more numerically common in the Ellis Bay Formation than in the underlying Vauréal Formation (see Chapter 3). In the Ellis Bay Formation, faunal abundances and diversities are higher in the argillaceous limestones that comprise Members 1 to 6 (*sensu* Petryk 1981), than in the oncolitic limestone that forms the topmost Laframboise Member (equivalent to Member 7 of Petryk *op. cit.*) of the Ellis Bay Formation.

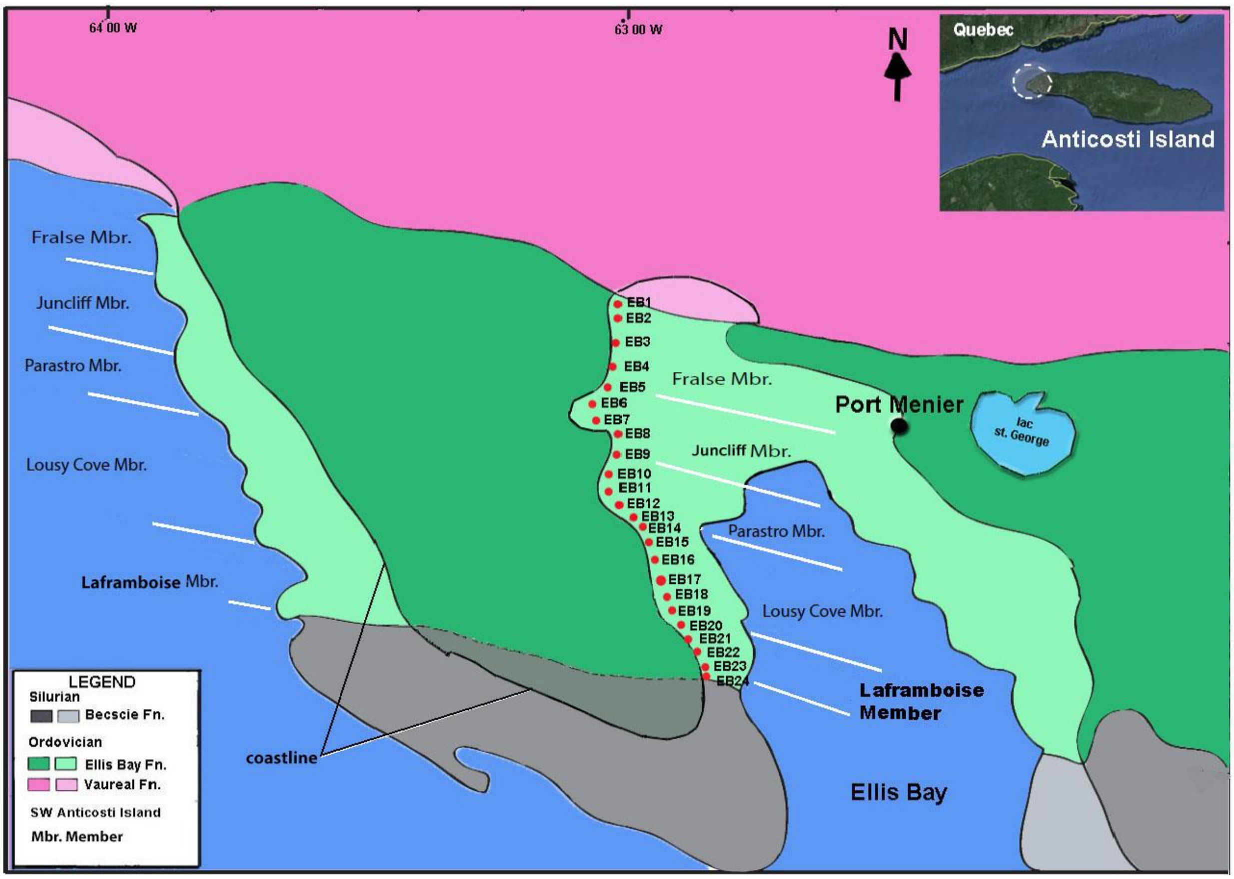

Figure 1.2. Geological map showing the location of samples studied here from the Ellis Bay Formation, western end of Anticosti Island (map after Copper *et al.* 2013). The rock succession is younging from North to South. Darker shading indicates areas of rock outcrop; lighter shading indicates the wave-cut platform exposure. Blue area is sea. Inset map (top right) shows the location of the studied section at the western end of Anticosti Island, eastern Canada.

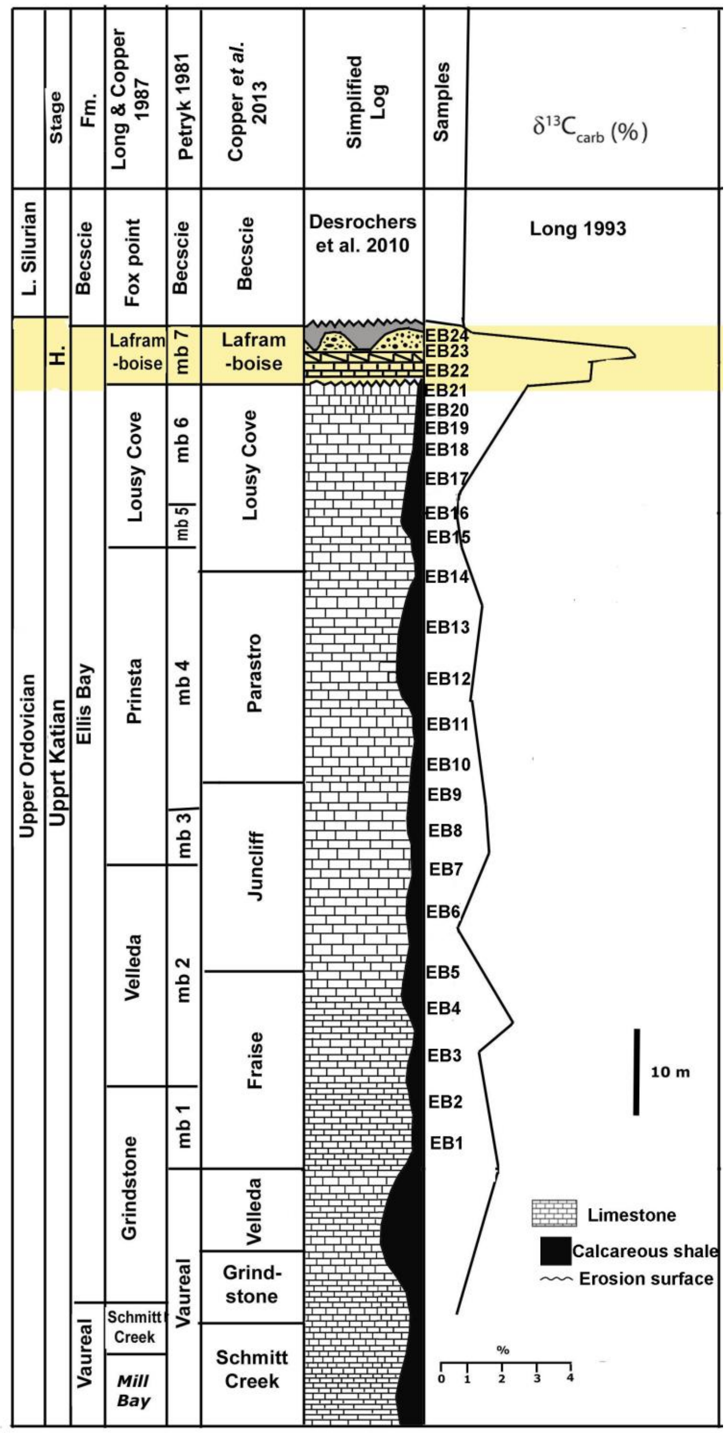

Figure 1.3. Lithostratigraphy of the Ellis Bay Formation western section on Anticosti Island, eastern Canada. Lithostratigraphical schemes of Petryk (1981), Long and Copper (1987), and Copper *et al*. (2013) are plotted for comparison. Right hand column shows the position of sample horizons collected for ostracods. Also plotted is the carbon isotope curve of Long (1983). Abbreviation: H., Hirnantian. The yellow-shaded area for the upper part of the Ellis Bay Formation (Laframboise Member) represents an interregnum for ostracod biostratigraphical patterns.

1.7 Stratigraphical age of the Ellis Bay Formation

There are two prevailing hypotheses for the stratigraphical age of the Ellis Bay Formation. First, the entire Ellis Bay Formation is of latest Ordovician Hirnantian age (Long and Copper 1987; Soufiane and Achab 2000; Copper 2001; Melchin *et al*. 2003, 2008; Melchin and Holmden 2006; Jin and Copper 2008; Desrochers *et al*. 2010; Delabroye and Vecoli 2010; Achab *et al*. 2011 and Copper *et al*. 2013). Or second, the Hirnantian is restricted to the uppermost part of the Ellis Bay Formation, being the interval represented by the Laframboise Member (Melchin *et al*. 1991; Underwood *et al* 1997; Brenchley *et al*. 2003; Bergström *et al*. 2006; Kaljo *et al*. 2008; Finnegan *et al*. 2010; Jones *et al*. 2011; Meidla *et al*. 2015). These different interpretations are summarised in Figures 1.3 and 1.4. Notably, the marked positive carbon isotope excursion of the Laframboise Member (Member 7) of the Ellis Bay Formation (Long 1993, Kaljo *et al*. 2008, Delabroye *et al*. 2011) has suggested to several authors that this represents the glacial eustatic low-stand succession of the Hirnantian.

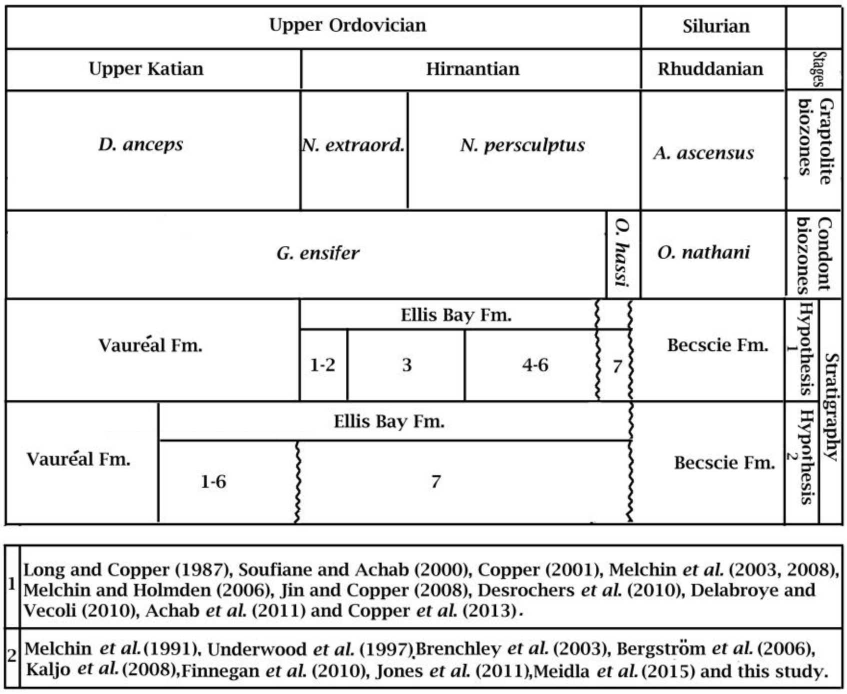

Figure 1.4. Chronostratigraphical age assignments for the Ellis Bay Formation on Anticosti Island, eastern Canada based on different biostratigraphical and geological data. Numbers 1-7 are the members of the Ellis Bay Formation *sensu* Petryk (1981). Hypothesis 1 (bottom panels) is that the whole of the Ellis Bay Formation is Hirnantian; hypothesis 2 is that only the uppermost Member 7 is Hirnantian. Ostracod biostratigraphical data presented here (Chapter 3) do not resolve this problem.

1.8 Previous work on the Upper Ordovician ostracods of North America

Ostracod faunas from the Upper Ordovician (Sandbian, Katian and Hirnantian stages) of North America have previously been studied by Kay (1934); Keenan (1951); Swain *et al*. (1961); Swain (1957, 1962, 1996); Kraft (1962); Guber (1962); Copeland (1965, 1977, 1981, 1982, 1989, 2000); Warshauer (1981); Warshauer and Berdan (1982); Williams and Siveter (1996); and Williams *et al*. (2001b). Copeland (1970, 1973, 1974, 1981) specifically described the ostracod faunas in the Ellis Bay Formation on Anticosti Island. Analysis of the inter-regional distribution patterns of North American Late Ordovician ostracods has identified two sub-biogeographical provinces that may relate to geographical barriers (Mohibullah *et al*. 2012). More broadly, the global patterns of Late Ordovician ostracod assemblages have been used to map out different palaeogeographical regions of the Ordovician world (e.g. Schallreuter and Siveter 1985). Ordovician podocope ostracods probably had limited intercontinental dispersal capability and they have been widely used for palaeogeographical analysis (Schallreuter and Siveter 1985; Vannier *et al*. 1989; Williams *et al*. 2003; Mohibullah *et al*. 2012; Meidla *et al*. 2013). Models of ostracod distribution in the Ordovician suggest that carbonate lithofacies are palaeocope-dominated, whilst mudstone lithofacies are binodicope-dominated Vannier *et al*. (1989). Late Ordovician benthic ostracods have been used to determine palaeoecological controls influencing distribution patterns (e.g. Schallreuter & Siveter 1985; Vannier *et al*. 1989; Copeland 1982; Williams *et al*. 2001; Williams *et al*. 2003; Mohibullah *et al*. 2010; Meidla *et al*. 2013).

1.9 Aims of this project

The key aims of this project are:

1) Documentation of the systematic palaeontology of Upper Ordovician ostracods from the Ellis Bay Formation of Anticosti Island, eastern Canada (62 species have been recognised);
2) Identification of the local biostratigraphical significance of the ostracods of the Ellis Bay Formation;
3) Determination of the palaeoecological significance of the ostracods;
4) Establishment of the palaeobiogeographical significance of the ostracod fauna relative to Laurentia, and to other palaeocontinental areas bordering the early Palaeozoic Iapetus Ocean such as Baltica and Avalonia.

1.10 Chapter Summary

Chapter 1 presents an introduction to this thesis.

Chapter 2 describes the systematic palaeontology of the Upper Ordovician ostracods from the Ellis Bay Formation. More than 7600 ostracod specimens have been recovered from the formation, most of them complete valves, and these provide a basis for establishing the taxonomy of 62 species belonging to 36 genera, described 47 species belonging to 31 genera with 14 species recognized as new species and one new genus. The new assemblages are better preserved and many are taxonomically different from those described by Copeland (1973): thus the work extends the faunal inventory from the Ellis Bay Formation. The main taxonomic suborders of ostracods identified and described from the Ellis Bay Formation are: Palaeocopina, Binodicopina, Paraparchitocopina, Leiocopina, Eridostraca, Metacopina, Cypridocopina, Cytherelliformes and Kloedenellocopina. The major taxonomic groups of Ordovician ostracods are distinguished on the basis of morphological features of the carapace such as sulci (depressions), lobes (elevations), overlap, dimorphic characters and surface ornament of the valves. All photomicrographs (Plates 1-22) are based on specimens recovered from new collections studied here.

Chapter 3 describes the biostratigraphical significance of the ostracod fauna from the Ellis Bay Formation, Anticosti Island, eastern Canada. Four biostratigraphical intervals are identified in ascending stratigraphical order, the first three being partial range zones: (A) the *Longiscula subcylindrica* Biozone, (B) the *Eurychilina erugoface* Biozone, (C) the *Tetradella anticostiensis* Biozone, and (D) in the upper part of the formation an interregnum. Biozones A, B and D can be related to Copeland's (1973) ostracod biozonation. Biozone C is equivalent to three of Copeland's (1973) sub-zones.

Chapter 4 examines the palaeoecology and palaeobiogeography of the ostracods of the Ellis Bay Formation. Two different ostracod assemblages are distinguished on presence-absence data that characterise more open marine and shallower shelf environments respectively. The palaeobiogeographical significance of the Ellis Bay Formation ostracod fauna is evaluated, showing links with those of other contemporaneous Laurentian faunas, and with those of palaeocontinental Baltica and Avalonia.

Chapter 5 summarizes the main conclusions of the thesis.

Chapter 2

Systematic Palaeontology of the Upper Ordovician ostracods from the Ellis Bay Formation, Anticosti Island, eastern Canada

Chapter 2: Systematic Palaeontology of the Upper Ordovician ostracods of the Ellis Bay Formation from Anticosti Island, eastern Canada

2.1 Preface

According to one view of classification two major subclasses of ostracods are discriminated based on their soft anatomy - particularly the morphology of the appendages, and these are the Myodocopa and the Podocopa (see Cohen 2013 for characteristic morphology). These two subclasses can be distinguished by their carapace morphology in the fossil record, with some caution (see Siveter *et al*. 2007), and on this basis all of the taxa described here belong within the Subclass Podocopa. Sixty-two ostracod species are identified, belonging to 36 genera. Some 14 new species and one new genus are established. The new assemblages are better preserved and many are taxonomically different from those described by Copeland (1973): thus the present work extends the faunal diversity from the Ellis Bay Formation. Higher-level taxonomic classification for Ordovician ostracods follows Meidla (1993, 1996), Schallreuter *et al*. (2006, 2011), and Mohibullah *et al*. (2014). Key references used for description and nomenclature are: Ulrich (1879, 1894); Ulrich and Bassler (1906); Swartz (1936); Teichert (1937); Öpik (1937); Spivey (1939); Kay (1940); Hessland (1949); Keenan (1951); Henningsmoen (1954); Morris and Hill (1952); Harris (1957); Neckaja (1958, 1966); Kesling (1960); Swain *et al*. (1961); Adamczak (1961); Berdan (1961, 1988); Kraft (1962); Swain (1962); Sarv (1963); Burr and Swain (1965); Guber and Jaanusson (1964); Copeland (1965, 1970, 1973, 1974, 1977a, 1977b, 1982, 1989); Warshauer (1981); Warshauer and Berdan (1982); Schallreuter (1968, 1971, 1975, 1982); Tinn and Meidla (1999, 2003, 2004); Lundin *et al*. (1995); Williams *et al*. (2001a, b, 2003); Melnikova (2010); and Lajblová and Meidla (2014).

The terminology of morphology used herein for the Ordovician ostracod carapaces is based principally on Whatley *et al*. (1993), Williams *et al*. (2001b), Mohibullah *et al*. (2014) and Vannier *et al*. (1989). The major taxonomic groups of Ordovician ostracods are distinguished on the basis of morphological features of the carapace such as sulci (depressions), lobes (elevations), valve overlap, velar morphology, dimorphic characters, and surface ornament of the valves (see Figs 2.1, 2.

Table 2.1. General taxonomic structure of the late Ordovician ostracod fauna of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Order	Suborder	Superfamily	Family	Genus
Beyrichiocopida Pokorný, 1954	Palaeocopina Henningsmoen, 1953	Hollinoidea Swartz, 1936	Hollinidae Swartz, 1936	*Anticostiella* Copeland, 1973
			Tetradellidae Swartz, 1936	*Foramenella* Stumbur, 1956
				Tetradella Ulrich, 1890
			Oepikellidae Jaanusson, 1957	*Platybolbina* Henningsmoen, 1953
				Eographiodactylus Kraft, 1962
			Tvaerenellidae Jaanusson, 1957	*Tvaerenella* Jaanusson, 1957
		Eurychilinoidea Ulrich and Bassler, 1923	Eurychilinidae Ulrich and Bassler, 1923	*Eurychilina* Ulrich, 1889
	Binodicopina Schallreuter, 1972	Binodicopina Schallreuter, 1972	Bolliidae Bouček, 1936	*Jonesites* Coryell, 1930
				Dicranella Ulrich, 1894
			Circulinidae Neckaja, 1966	*Byrsolopsina* Swain and Cornell, 1961
				Easchmidtella Schallreuter, 1967
			Aechminidae Swartz, 1936	*Aechmina* Jones and Holl, 1869
			Spinigeritidae Schallreuter, 1980	*Pseudohippula* Schallreuter, 1975
				Faurella Copeland, 1973
				Spinigerites Schallreuter, 1980
			Schmidtellidae Neckaja, 1966	*Schmidtella* Ulrich, 1892
	Paraparchitocopa Gramm, 1975		Jaanussoniidae Schallreuter, 1971	*Hemiaechminoides* Morris and Hill, 1952
				Hemeaschmidtella Schallreuter, 1971
	Leiocopina Schallreuter, 1973b	Aparchitoidea Jones (*in* Chapman), 1901	Aparchitidae Jones (*in* Chapman), 1901	*Baltonotella* Sarv, 1959
	Eridostraca Adamczak, 1961		Eridoconchidae Henningsmoen, 1953	*Cryptophyllus* Levinson, 1951
Podocopida Sars, 1866	Metacopina Sylvester-Bradley, 1961		Steusloffinidae Schallreuter, 1984	*Medianella* Neckaja, 1966
			Longisculidae Neckaja, 1966	*Longiscula* Neckaja, 1958
				Aviacypris Schallreuter, 1977
		Bairdiocypridoidea Shaver, 1961	Krausellidae Berdan, 1961	*Krausella* Ulrich, 1894
			Rectellidae Neckaja, 1966	*Rectella* Neckaja, 1958
			Bairdiocyprididae Shaver, 1981	*Elliptocyprites* Swain, 1962
			Pachydomellidae Berdan and Sohn, 1961	*Microcheilinella* Geis, 1933
		Thlipsuroidea Ulrich, 1894	Thlipsuriidae Ulrich, 1894	*Anticostus* n. gen
	Cypridocopina Jones, 1901	Bairdioidea Sars, 1865	Macrocyprididae Muller, 1912	*Macrocyproides* Spivey, 1939
Platycopida Sars, 1866	Cytherelliformes Skogsberg, 1920	Leperditelloidea Ulrich and Bassler, 1906	Leperditellidae Ulrich and Bassler, 1906	*Leperditella* Ulrich, 1894
	Kloedenellocopina Scott, 1961	Kloedenelloidea Ulrich and Bassler, 1908	Kloedenellidae Ulrich and Bassler, 1908	*Eokloedenella* Kraft, 1962

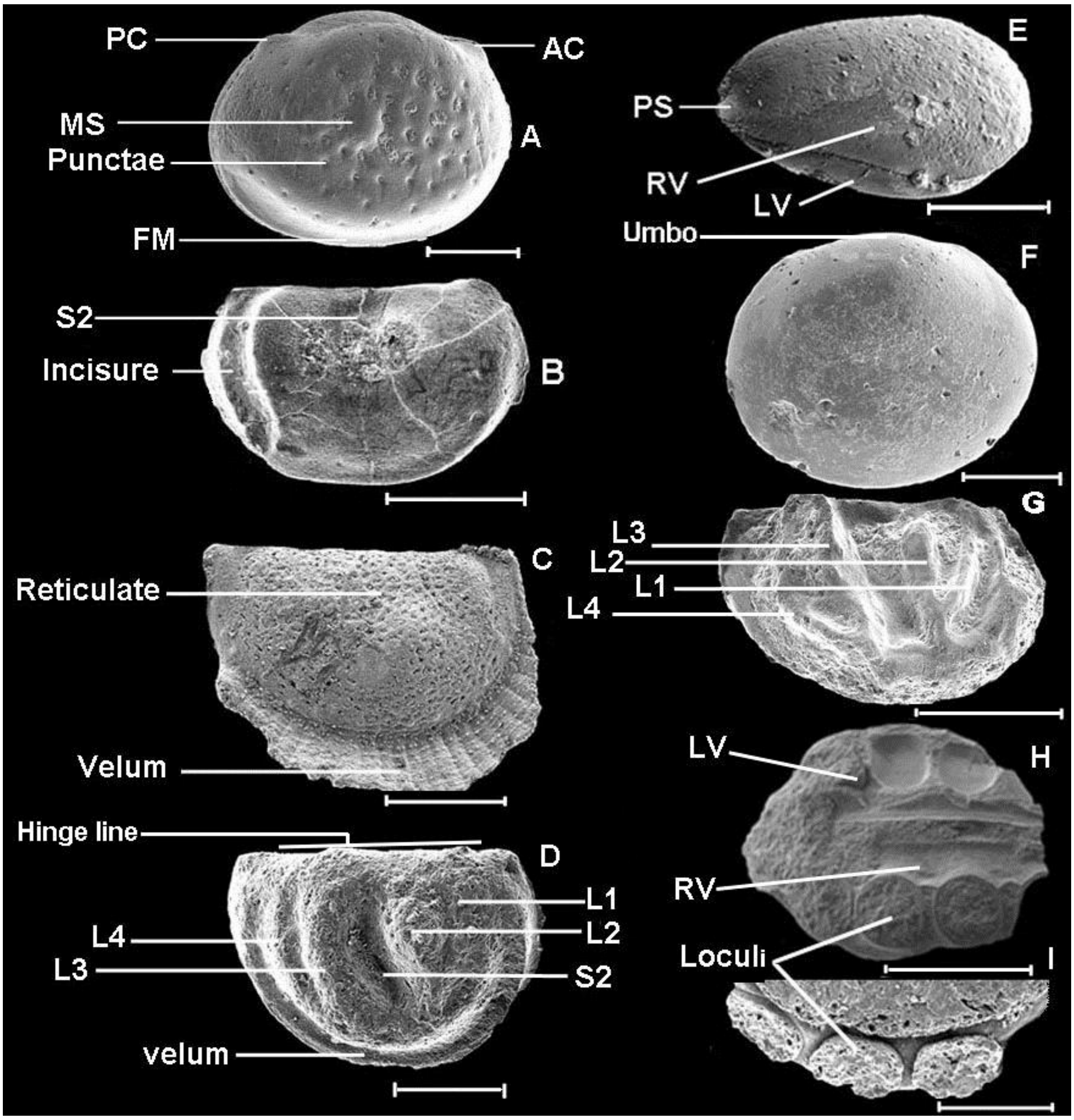

Figure 2.1. Morphological terminology for the ostracod carapace as applied in this thesis. (A, F) Binodicopina, (B) Kloedenellocopina, (C, D, H, I, G) Palaeocopina, (E) Metacopina (taxonomic groups following definitions of Whatley *et al*. 1993). Symbol: MS, muscle spot; PS, posteroventral spine; RV, right valve; LV, left valve; S2, adductorial sulcus; PC, posterior cardinal angle; AC, anterior cardinal angle; L1, anterior lobe; L2, preadductorial lobe; L3, postadductorial lobe; L4, posterior lobe; FM, flattened margin. (A, F) left valve, (B, C, D, G) right valve lateral view; (E) oblique ventral view, (H) ventral view. Scale bars represent: (C) 500µm; (B, D, G, H, I) 300µm; (A, E, F) 200µm.

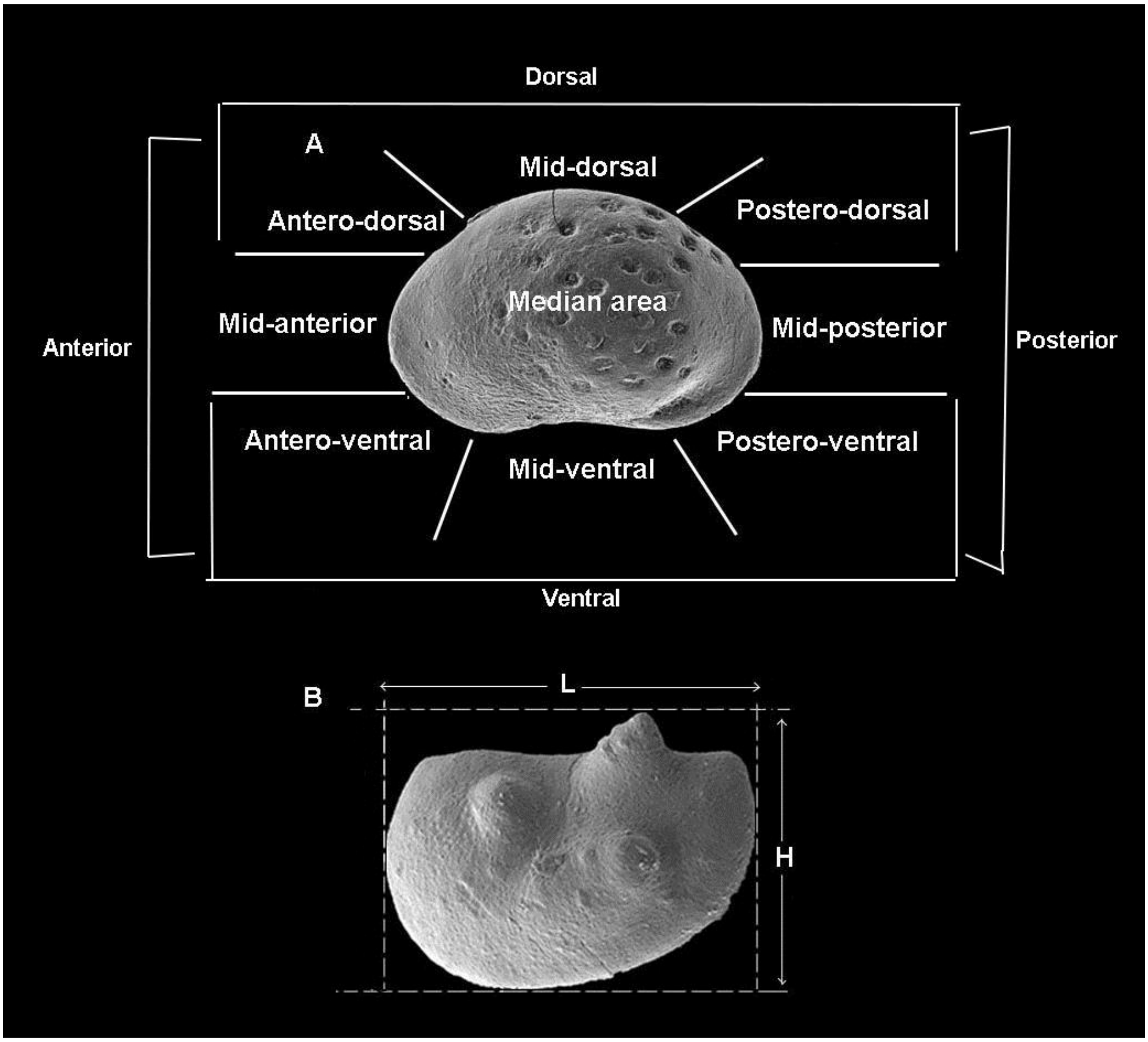

Figure 2.2. Positional (A) and morphometric (B) terminology for the ostracod valve as applied in this thesis. H, maximum valve height; L, maximum valve length.

Systematic Palaeontology

Phylum **Arthropoda** Siebold and Stannius, 1845

Subphylum **Crustacea** Pennant, 1777

Class **Ostracoda** Latreille, 1802

Subclass **Podocopa** Sars, 1866

Order **Beyrichiocopida** Pokorný, 1954

Suborder **Palaeocopina** Henningsmoen, 1953

Superfamily **Hollinoidea** Swartz, 1936

Family **Hollinidae** Swartz, 1936

Genus ***Anticostiella*** Copeland, 1973

Type species. *Anticostiella ellisensis* Copeland, 1973, by original designation. From the Upper Ordovician Ellis Bay Formation, Anticosti Island, eastern Canada.

Diagnosis. (Revised from Copeland 1973) Trilobate, lobes distinct in size and shape. Adductorial sulcus is well developed and long; anterior sulcus is poorly developed and short, and connects with the adductorial sulcus ventrally. Velar ridge narrow and complete in tecnomorphs. Heteromorphs have three large loculi. Valve surface with punctate ornament.

Discussion. *Anticostiella* is widespread in the Upper Ordovician of Anticosti Island (Copeland 1973, 1974, 1989). Tecnomorphs of *Anticostiella* resemble *Eohollina* Harris, 1957, but heteromorphs differ by possession of a loculate dolonal antrum.

Occurrence. *Anticostiella* is recorded from the Upper Ordovician Ellis Bay Formation (Copeland 1973), from the Lower Silurian Becscie and Jupiter formations, Anticosti Island (Copeland 1974), and from the Avalanche Lake area of Canada (Copeland 1989).

Anticostiella ellisensis Copeland, 1973   Pl. 12, figs 7, 9

1973 *Anticostiella ellisensis* sp. nov. Copeland, p. 9, pl. 3, figs 12-17, 24, pl. 6, fig. 5, pl. 7, figs 4-7.

1977 *Anticostiella ellisensis* Copeland; Copeland, pl. 1, fig. 25.

Holotype. Designated Copeland (1973, p. 9, pl. 3, fig. 24), a right valve, Geological Survey of Canada No. 31445, from the Ellis Bay Formation, Anticosti Island, eastern Canada.

Material. Eighty specimens from twelve samples EB2, EB7, EB8, EB9, EB10, EB11, EB14, EB16, EB17, EB18, EB19 and EB20.

Measurements. Tecnomorphs are between 0.4 to 0.6 mm in length, height ranges from 0.25 to 0.45 mm. Heteromorphs are 0.6 to 0.8 mm in length, height ranges from 0.45 to 0.6 mm; heteromorphs are generally larger than tecnomorphs (Fig. 2.3).

Diagnosis. (Revised from Copeland 1973) Trilobate, posterior lobe well developed, anterior and ventral lobes are subdued, adductorial sulcus is moderately developed. Tecnomorphs are smaller than heteromorphs. Dorsal margin concave from a lateral aspect, cardinal angles obtuse or rounded.

Description. Valves sub-elliptical, dorsal margin concave. Anterior margin is more rounded than posterior margin, ventral outline convex. Trilobate, lobes are separated by furrows. Anterior sulcus poorly developed, adductorial sulcus well-developed and elongate; shape of posterior, anterior and ventral lobes are dome-like. Heteromorphs have three anteroventral loculi.

Discussion. There are only slight intraspecific differences between Copeland's (1973) specimens from the Ellis Bay Formation and those studied here.

Occurrence. Anticostiella ellisensis is recorded from the Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation.

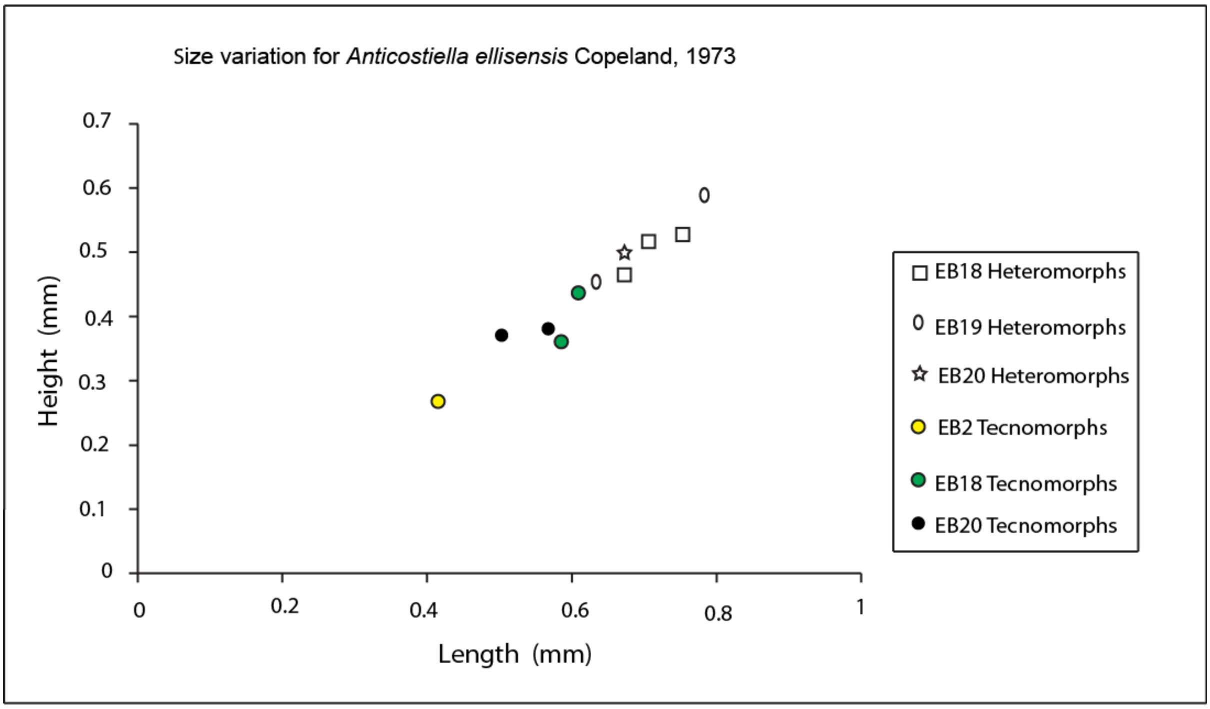

Figure 2.3. Size variation for *Anticostiella ellisensis* Copeland, 1973, right and left valves, from samples EB2, EB18, EB19 and EB20 from the Ellis Bay Formation.

Anticostiella sp. A Pl. 12, figs 6, 8

Material. Four specimens from two samples EB9 and EB10.

Measurement. Maximum length 0.45 mm, maximum height 0.25 mm.

Description. Trilobate, adductorial sulcus is small. Anterior lobe is smaller than posterior and ventral lobes: the lengths being 0.05, 0.065, and 0.06 mm respectively. Posterior lobe well-developed and subdivided by a wide furrow into ventral and anterior portions, posterior lobe height about 0.11 mm, is higher than ventral and anterior lobes, which roughly are 0.06 and 0.05 mm in height, respectively. Outline straight dorsally and all other sides weakly rounded. Velum weak. Cardinal angles obtuse. Fine punctae ornament on the surface of valves.

Discussion. *Anticostiella* sp. A differs from *A. ellisensis* in the shape and size of its lobes, especially the posterior lobe. Moreover, *A. ellisensis* is dorsally truncated, but *Anticostiella* sp. A is straight dorsally from a lateral aspect. *Anticostiella* sp. resembles *A. reticulata* Copeland, 1989 from the Upper Ordovician Whittaker Formation, but *Anticostiella* sp. A can be distinguished by the shape and the size of the anterior lobe.

Occurrence. *Anticostiella* sp. A is present in the Upper Ordovician Ellis Bay Formation (Lousy Cove Member), Anticosti Island, eastern Canada.

Family **Tetradellidae** Swartz, 1936

Genus ***Foramenella*** Stumbur, 1956

Type species. *Euprimitia parkis* Neckaja, 1952; designated Stumbur (1956, p. 187), from the Upper Ordovician Nabala, Vormsi and Pirgu regional stages of Lithuania.

Diagnosis. (Adapted from Meidla 1996) Adults unisulcate, or the adductorial sulcus developed as the most conspicuous sulcus and both S1 and S3 as poorly defined sulcal depressions; velum ridge-like or absent, heteromorphs with 4-5 loculi anteroventrally and ventrally.

Discussion. *Foramenella* is distinguished from *Ctenobolbina* Ulrich, 1890, by possessing five prominent anteroventral and ventral loculi on the surface of heteromorphic valves (see Copeland 1973, p. 17; Meidla 1996, p. 52).

Occurrence. Foramenella is recorded from the Upper Ordovician of Estonia (Sarv 1959, 1962; Meidla 1996), Latvia (Gaīlite 1972; Ulst *et al*. 1982), Lithuania (Neckaja 1952), and Gotland (Schallreuter 1980a), and from the Upper Ordovician of Canada (Copeland 1973).

Foramenella phippsi Copeland, 1973

Pl. 1, figs 1-9, Pl. 11, fig. 4, Pl. 20, figs 1-3, Pl. 22, fig. 8

1973 *Foramenella phippsi* sp. nov. Copeland, p. 14, pl. 1, figs 14-15, pl. 2, figs 20-36, pl. 4, figs 10-13, pl. 6, figs 6, 19, pl. 7, figs 2-3.

1977 *Foramenella phippsi* Copeland; Copeland, p. 17, pl. 1, figs 22-26.

1981 *Foramenella phippsi* Copeland; Copeland in Lesperance, p. 188, text-figs 3.2 a-f.

Holotype. Designated Copeland (1973, p. 15, pl. 2, fig. 29), a heteromorphic left valve, Geological Survey of Canada No. 31417, from the Ellis Bay Formation, Anticosti Island, eastern Canada.

Material. Approximately 115 specimens from samples EB1, EB2, EB3, EB4, EB5, EB6, EB7, EB8, EB9, EB10, EB11, EB12, EB13, EB14, EB15, EB16, EB17, EB18, EB19, EB20, EB22 and EB24.

Measurements. Length of valves between 0.32 to 0.75 mm, height of valves between 0.20 to 0.55 mm (Fig. 2.4).

Diagnosis. (Revised from Copeland 1973) Lateral shape sub-elliptical. Adults with well-developed adductorial sulcus. Heteromorphs with five isolated adventral loculi.

Description. Valves weakly preplete, lateral shape sub-elliptical. Unisulcate or trilobate, adductorial sulcus well-developed just in front of mid-length; S1 and S3 poorly developed. Preadductorial node is a dome-shaped. Lobes (L1, L2, and L3) are developed on the surface of juvenile valves, but they are more strongly developed on the surface of heteromorphic and tecnomorphic adult valves. L1 and L3 are long and thin; L2 short with preadductorial node. Nearly symmetrical valves, dorsal margin straight and free margin evenly rounded. Posterior and anterior cardinal angles obtuse: approximately 105°. Surface smooth. Five prominent anteroventral and ventral loculi appear in the lateral and ventral views of heteromorphic specimens.

Discussion. *Foramenella phippsi* superficially resembles *Ctenobolbina maclearni* Copeland, 1973, from the Ellis Bay Formation of Anticosti Island (see Copeland 1973, pp. 10-38) but differs by the possession of anteroventral loculi in heteromorphs.

Foramenella phippsi is more strongly lobate than other species of *Foramenella.* It differs from *Foramenella porkuniensis* Sarv, 1959, by its well-developed preadductorial node and lack of a distinct velum.

Three growth stages can be recognized in the Anticosti materials (A, A-1, A-2). A gives a mean adult average of length 0.7 to 0.75 mm and height 0.4 to 0.55 mm. A-1 gives an average of 0.5 to 0.7 mm length and height 0.32 to 0.45 mm. A-2 gives an average of 0.3 to 0.5 mm length and height 0.20 to 0.35 mm (Fig. 2.5).

Occurrence. *Foramenella phippsi* occurs in the Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

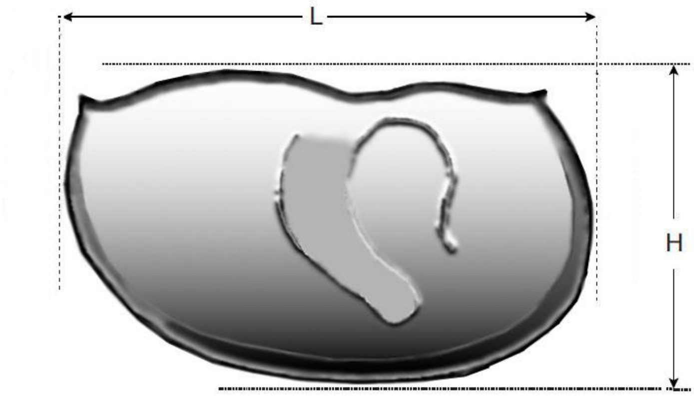

Figure 2.4. Measurements of *Foramenella phippsi* Copeland, 1973. H, maximum valve height; L, maximum valve length.

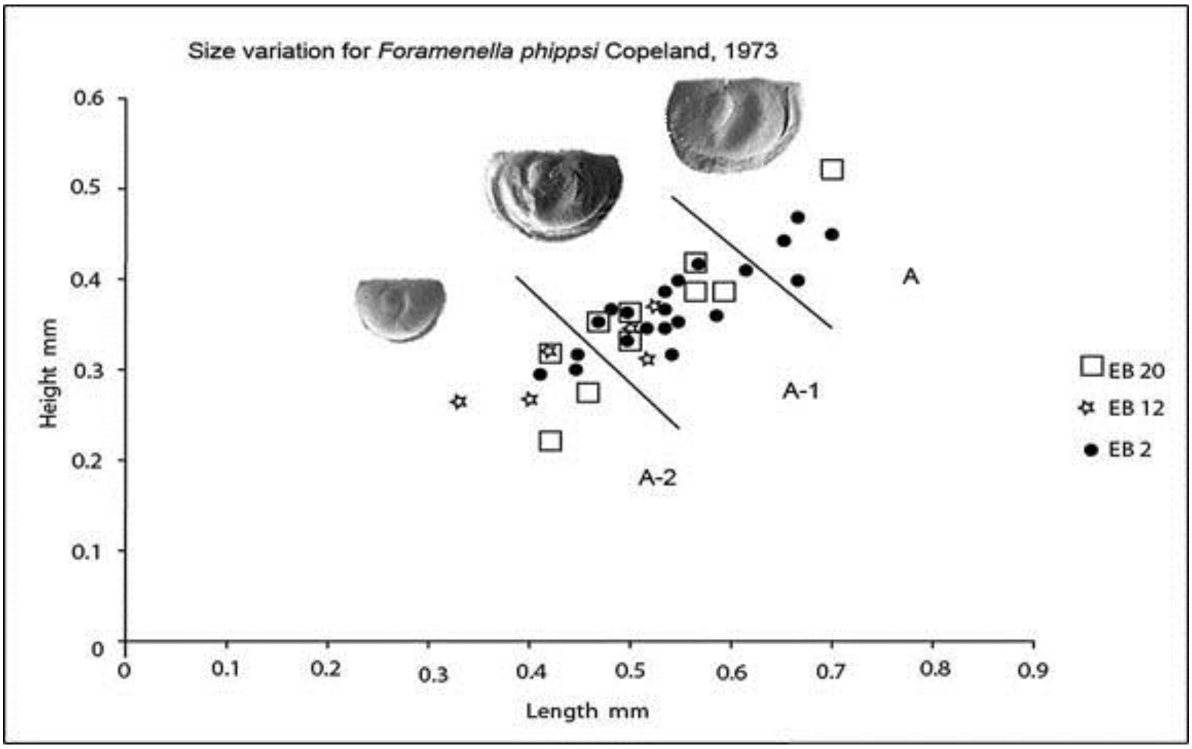

Figure 2.5. Size variation for *Foramenella phippsi* Copeland, 1973 right and left valves, for samples EB2, EB12 and EB20 from the Ellis Bay Formation. Recognition of instars A-1 and A-2 is based on morphological changes and not simply on an assessment of size variation.

Genus ***Tetradella*** Ulrich, 1890

Type species. By original designation, *Beyrichia quadrilirata* Hall and Whitfield, 1875. From the Waynesville Formation, Upper Ordovician of Ohio, USA.

Diagnosis. (Revised from Guber 1971) Valves sub-ovate. Dorsal margin straight and ventral margin evenly convex. Quadrilobate, lobes simple or divided. L1 and L4 combine ventrally to form a connecting lobe sub-parallel to the free margin. L2 and L3 merge ventrally. Heteromorphs possess locular dimorphism anteroventrally (Figs 2.6, 2.7).

Discussion. According to Meidla (1996, p. 52) *Pleurodella* Copeland, 1965 is a junior synonym of *Tetradella*. Guber (1971) discussed the history, taxonomy and dimorphism of *Tetradella* and considered that adult heteromorphs possessed four loculi (quadriloculate form), though Schallreuter (1978a, b) described a new species of *Tetradella* with five loculi, *Tetradella pentaloculata* Schallreuter, 1978a, from an Upper Ordovician Öjlemyrflint erratic boulder.

Schallreuter (1978b) mentioned the presence of four loculi in the species *Tetradella egorowi*, Neckaja, 1952 from Porchov region, Pskov District, Russia, and *T. separata* Sidaraviciene, 1971 from the Porkuni Stage, Estonia. The differentiation of taxa based on the number of loculi appears in several genera not only *Tetradella* (e.g *Semibolbina* Jordan, 1964; *Tetrasacculus* Stewart, 1936).

Occurrence. Tetradella is recorded from the Ordovician of Minnesota and Northern lowa (Swain 1965), Virginia (Rader 1965), Missouri (Keenan 1951), Ohio (Hall and Whitfield 1875; Ulrich 1890), Baltoscandia (Sarv 1959; Schallreuter 1978a, b, c, 1981; Meidla 1996, 2007; Tinn and Meidla 2004; Tinn *et al*. 2010), Russia (Neckaja 1952, 1953); Latvia (Ulst et al., 1982); Lithuiania (Sidaravičiene 1971, 1992), Norway (Öpik 1939), Podolia (Abushik and Sarv 1983), Ontario (Copeland 1965), Anticosti Island Copeland (1973), the District of Mackenzie Copeland (1978) and Manitoba, Canada (Ulrich 1889).

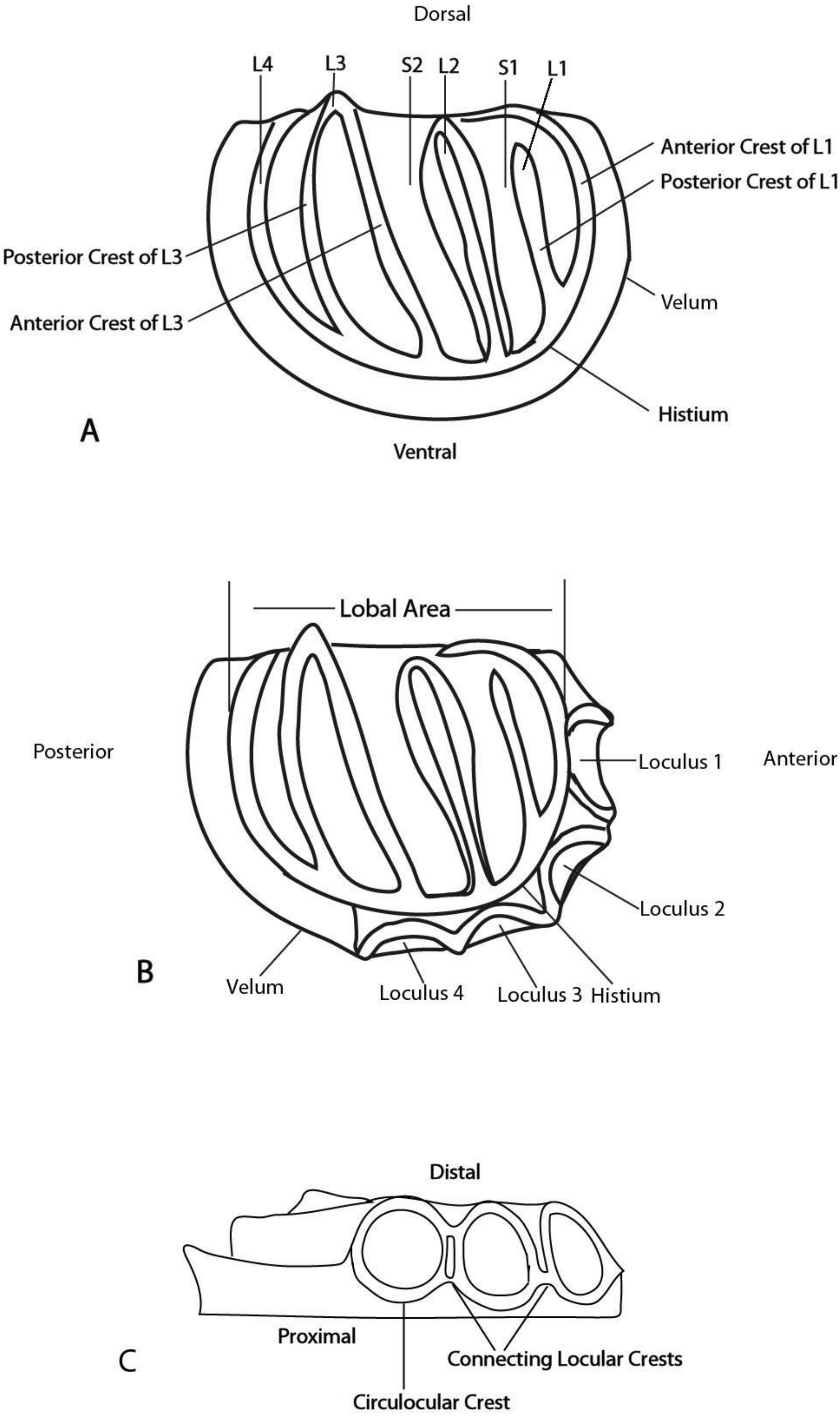
Dorsal
L4
L3
S2
L2
S1
L1
Anterior Crest of L1
Posterior Crest of L1
Posterior Crest of L3
Anterior Crest of L3
Velum
Histium
A
Ventral
Lobal Area
Posterior
Anterior
Loculus 1
Loculus 2
B
Velum
Loculus 4
Loculus 3
Histium
Distal
Proximal
C
Connecting Locular Crests
Circulocular Crest

Figure 2.6. Descriptive terminology of *Tetradella*. A. Adult tecnomorph right lateral view. B. Adult heteromorph right valve lateral view. C, Adult heteromorph right valve in ventral view. Figures after Guber (1971).

Tetradella anticostiensis Copeland, 1973 Pl. 11, figs 2-3, 5

1928 *Tetradella simplex* (Ulrich), Bassler in Twenhofel, p. 343, (not figured).

1970 *Tetradella* sp. cf. *Tetradella lunarifera* (Ulrich); Copeland, p.28, pl. 5, fig. 29.

1973 *Tetradella anticostiensis* sp. nov. Copeland, pl. 7, figs 6-15; text-fig. 9, 1a-c.

1977a *Tetradella anticostiensis* Copeland; Copeland, pl. 1, fig. 23.

1981 *Tetradella anticostiensis* Copeland; Copeland in Leserance, p. 188, text- figs 3, 1a-c.

Holotype. Designated Copeland (1973, pl. 8, fig. 15), a tecnomorphic right valve, Geological Survey of Canada No. 31554, from the Ellis Bay Formation, Anticosti Island, eastern Canada.

Material. Forty specimens from sample EB7, EB8, EB9, EB10, EB11, EB14, EB16, EB17, EB18 and EB20.

Measurements. Length of valves between 0.5 to 0.75 mm, height of valves between 0.35 to 0.5 mm (Figs 2.7, 2.8).

Diagnosis. (Revised from Copeland 1973) Sub-elliptical shape, L2 very short and S1 narrow. Heteromorph characterized by three loculi. Valve surface smooth without tubercles.

Description. Valves sub-elliptical in lateral shape. Shape high (L:H ratio between 1.4 to 1.5). Lateral surface with four lobes (L1, L2, L3 and L4) and three sulci (S1, S2 and S3), S1 and S2 connected dorsally, triangular area (S3) closed by L3, L2 shorter. From a lateral perspective the dorsal margin is long and sinuous, posterior and anterior margins evenly rounded, ventral margin convex. Cardinal angles obtuse (about 140°). Surface smooth. Locular dimorphism developed in heteromorphs, with three loculi; velar ridge present between loculum joining locular crests, histial ridge present. Tecnomorphs without a ridge (velar and histial). Preservation of pre-adults rare.

Discussion. For distinction of *T. anticostiensis* from other species of *Tetradella* see Table 2.2.

Occurrence. *T. anticostiensis* occurs in the Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Table 2.2. Comparison of Upper Ordovician species of *Tetradella* with the species *Tetradella anticostiensis* from the Ellis Bay Formation.

Species name	**Length and height of valve (mm)**	**Number of loculi**	**Type of ornament**	**Important features**	**References**
Tetradella anticostiensis Copeland, 1973	0.75-0.5	Three	Smooth	L2 very short about 0.027 mm and S1 narrow. Tecnomorphs without a ridge	This study
Tetradella buckensis Guber, 1971	1.01-0.59	Four	Smooth	The shape of L1 is different particularly the flexure in the posterior crest. The narrow triangular shape of L3 and the low crest of L4 are key features.	Guber (1971)
Tetradella ellipsilira Kay, 1934	0.83-0.55	Four	Smooth	The variable crest on L3. The posterior and anterior crests are confluent over the dorsal half of the valve.	Kay (1934)
Tetradella egorowi Neckaja, 1952	0.9-1.03	Four	Smooth or finely granulose	Spine-like nodes outline remnants of quadrilobation, and cristae developed only as rows of tubercles.	Schallreuter (1978b)
Tetradella luntifera (Ulrich, 1889)	1.15-0.66	Four	Smooth	Possesses a very sharp and high crest on L4.	Guber (1971)
Tetradella pentaloculata Schallreuter, 1978	1.10-1.15	Five	Smooth	Dorsal plica represented by two cusp-like cristae.	Schallreuter (1978a)
Tetradella plicatula (Krause, 1892)	1.08-0.54	Five	Smooth	Cristae not parallel to each other and lack of plical cusps.	Meidla (1996)
Tetradella pulchra Neckaja, 1952	0.66-0.43	Three	Smooth	Cristae developed on lobes.	Meidla (1996)
Tetradella quadrilirata (Hall and Whitfield, 1875)	0.95-1.0	Four	Smooth	The velum is entire and separated by a ridge-like structure.	Guber (1971)
Tetradella scotti Guber, 1971	1.0-0.62	Four	Smooth except for scattered granules on L3.	The velum is entire and uninterrupted.	Guber (1971)
Tetradella separata Sidaraviciene, 1971	1.0-1.13	Four	Smooth	Histium undeveloped adjacent to loculi. Two cristae in front of the adductorial sulcus (S2), three behind.	Schallreuter (1978c)
Tetradella? *triloculata* Schallreuter, 1978	1.05-1.11	Three	Surface with scattered tubercles and partly very faint reticulation.	Three posterior cristae sub-parallel to posterior valve margin.	Schallreuter (1978)
Tetradella ulrichi Kay, 1934	0.84-0.52	Four	Smooth	The posterior crest of L1 and the crest of L2 join and continue ventrally as a single crest.	Kay (1934)

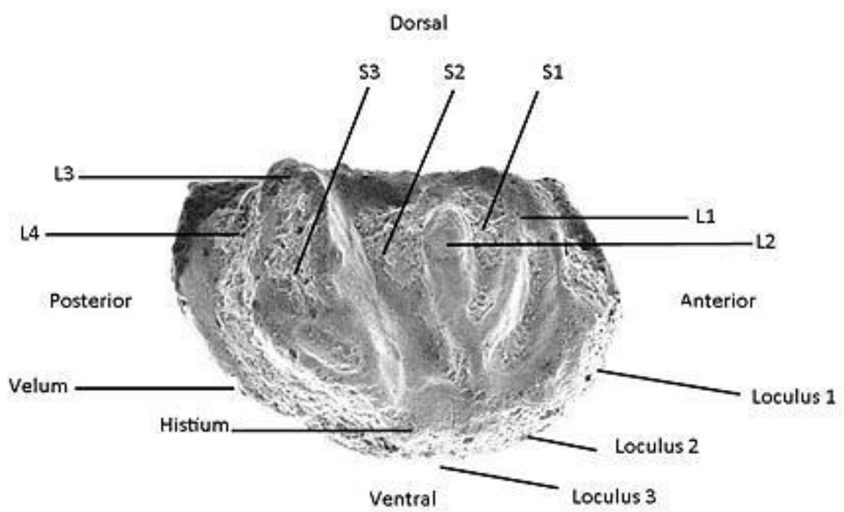

Figure 2.7. Terminology for the valve of *Tetradella anticostiensis* Copeland, 1973. Figured specimen is a lateral view of a heteromorphic right valve.

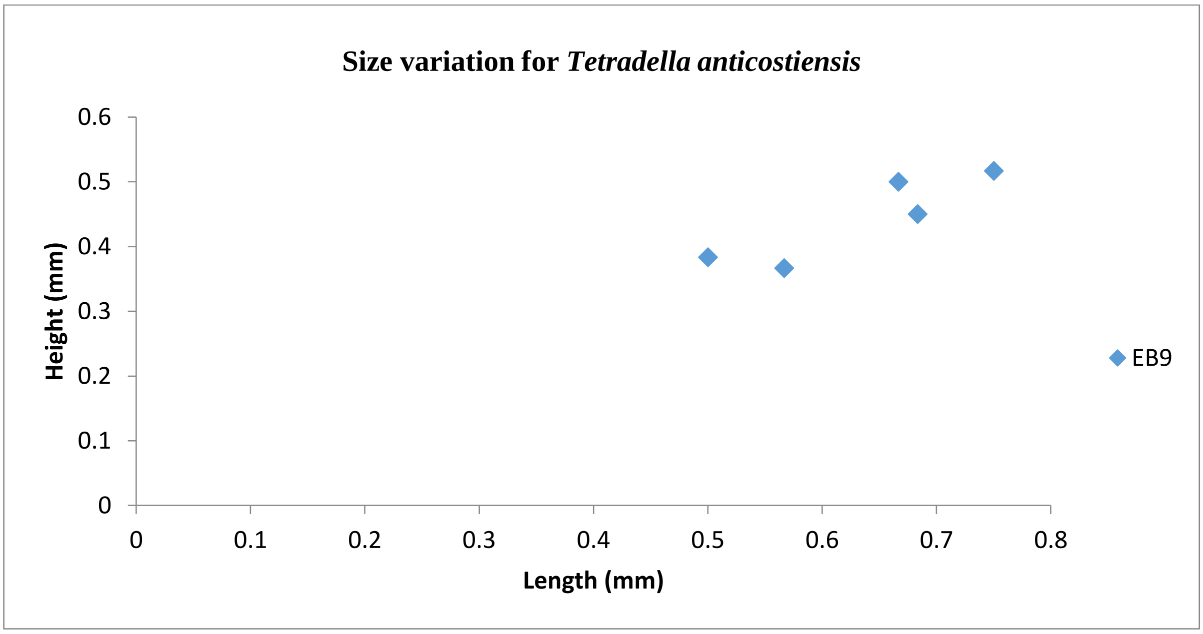

Figure 2.8. Size variation for *Tetradella anticostiensis* Copeland, 1973, right and left valves, for sample EB9 from the Ellis Bay Formation.

Family **Oepikellidae** Jaanusson, 1957

Genus ***Platybolbina*** Henningsmoen, 1953

Type species. Primitia distans Krause, 1889; by original designation. From a glacial drift boulder (Upper Ordovician), Germany.

Diagnosis. (Adapted from Mohibullah *et al.* 2014) Valves preplete, lateral outline sub-ovate to sub-quadrate. Dimorphism obvious, tecnomorphic velum developed along the entire free margin and may be shortened in some species, heteromorphs with a convex dolon anteroventrally. Non-sulcate or adductorial sulcus developed as a weak sulcal depression, or with indistinct knob-like weakly elevated L2. Surface reticulate or smooth. Muscle spot present, its shape and size varies between different species.

Discussion. Based on the velum shape and sulci, Schallreuter (1969) recognized five subgenera of *Platybolbina*: *P*. (*Platybolbina*), *P*. (*Rimabolbina*), *P*. (*Reticulobolbina*), *p*. (*Abruptobolbina*) and *P*. (*Ventriculobolbina*). But Meidla (1996) considered these subdivisions in need of revision, because several recently recognized species (*P. reducta, P. runica, P. shaleri* and *P. tiara*) cannot be accommodated into these taxa without adapting the subgeneric diagnoses. Similarly, Mohibullah *et al*. (2014) did not use these subdivisions.

Occurrence. *Platybolbina* has been recorded from the Ordovician of Scotland (Williams and Floyd 2000; Williams *et al*. 2001a; Mohibullah *et al*. 2010; Mohibullah *et al*. 2014), Virginia (Kraft 1962), Michigan (Kesling 1960a), Baltoscandia (Henningsmoen 1954; Jannusson 1957; Meidla 1996), Britain (Vannier *et al*. 1989), the Czech Republic, and Siberia (Meidla 1996).

Platybolbina shaleri Copeland, 1973 Pl. 2, figs 6-8, Pl. 20, fig. 4, Pl. 22, fig. 9

1973 *Platybolbina shaleri* sp. nov., Copeland, p. 11, pl. 1, fig. 30, pl. 3, figs 32-34, pl. 6, figs 16-18, pl. 7, figs 11-15.

1975 *Platybolbina (Reticulobolbina) kapteyni* (Bonnema); Schallreuter, p. 147, pl. l, figs 4-5.

1977a *Platybolbina shaleri* Copeland; Copeland, pl. 1, fig. 24.

l977b *Platybolbina (Reticulobolbina) lenzi* Copeland; Copeland, pp. 29-30, pl. 5, figs 12-20.

1978 *Platybolbina (Reticulobolbina) lenzi* Copeland; Copeland, p. 97, pl. 1, fig. 3.

1989 *Platybolbina (Reticulobolbina) lenzi* Copeland; Copeland, p. 13, pl. l, figs 1-3.

Holotype. Designated Copeland (1973, p. 11, pl. 6, fig. 18), a right valve, Geological Survey of Canada No. 31512, from the Ellis Bay Formation, Anticosti Island, eastern Canada.

Material. Thirteen specimens, some have broken velar frills, from samples EB1, EB9, EB10, EB12, EB15, EB16, EB17, EB18, EB20 and EB23.

Measurements. Length of valves varies between 0.55 to 0.75 mm, height of valves between 0.35 to 0.55 mm (Fig. 2.9).

Diagnosis. Valves with a weak sulcal depression, muscle spot nearly semi-circular below mid-valve. Velum along entire free margin, wide anteriorly, velum tubulous with concentric crests on the radial component. Lateral surface with fine reticulation, bordering on punctate.

Description. Valve preplete, lateral outline sub-ovate, and dorsum straight. Adductorial sulcus weak, appears on the mid-ventral surface. Muscle spot semi-circular. Anterior cardinal angle obtuse and posterior cardinal angle sharp. Velum wide anteriorly, becoming narrower posteroventrally. Surface of velum radially striate with concentric crests. Tecnomorphs have velum developed along the entire free margin; heteromorphs also have velum with a convex dolon anteroventrally.

Discussion. *Platybolbina shaleri* resembles *Platybolbina tiara* Henningsmoen, 1954, but can be distinguished by its semi-circular muscle spot and weak sulcus see Table 2.2.

Copeland figured *Platybolbina shaleri* from the Ellis Bay Formation, but he found it difficult to distinguish tecnomorphs and heteromorphs.

Occurrence. *Platybolbina shaleri* occurs in the Frais, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

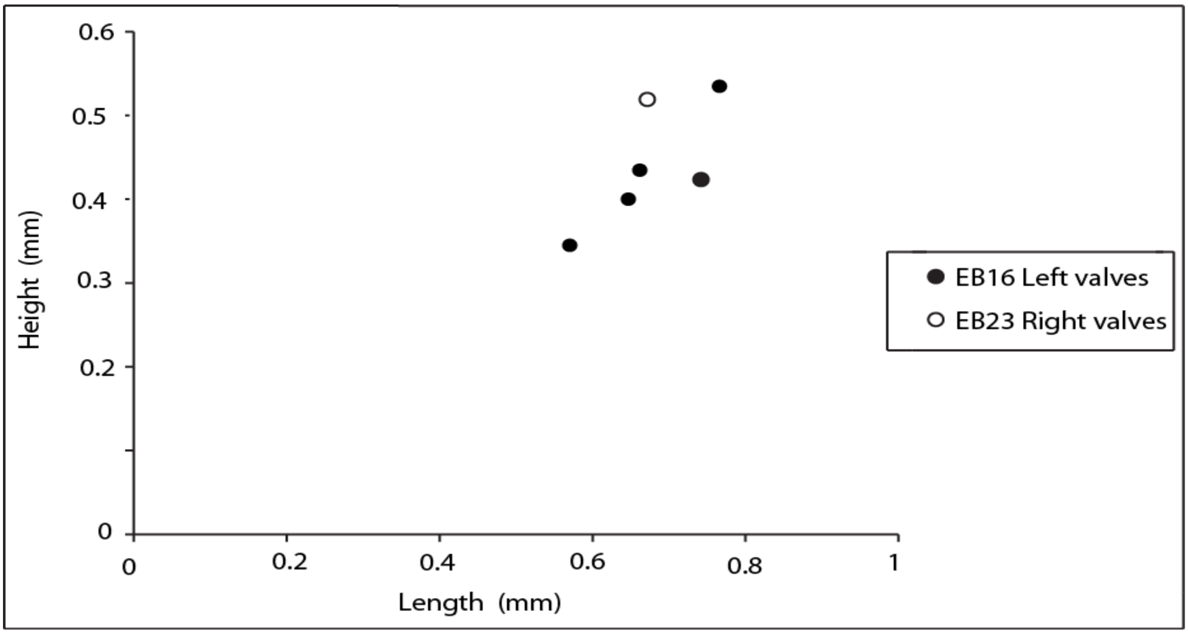

Figure 2.9. Size distribution for *Platybolbina shaleri* Copeland, 1973, right and left valves, for samples EB16 and EB23 from the Ellis Bay Formation. The absence of small instars may reflect an energetic marine environment subject to winnowing.

Platybolbina sp. A. Pl. 2, fig. 9

Material. Seven specimens from samples, EB8, EB10, EB16, EB17 and EB18.

Measurements. Base on sample EB16, length 0.70mm, height 0.52mm.

Description. Valves preplete. Very weak sulcal depression appears on the mid-ventral surface. Muscle spot semi-circular, L2 well definied. Posterior cardinal angle nearly 90°, anterior cardinal angle obtuse. Velum along the entire ventral and anterior margins but brusquely terminated at posterior margin. Small spines on the ventral area of the marginal surface from the anteroventral region towards the posteroventral region and parallel to the ventral margin, but these spines are not present on the velum. Lateral surface smooth.

Discussion. Platybolbina sp. A. resembles *Platybolbina shaleri* in the shape of its velum and in possessing a muscle spot, but is distinguished by possessing small spines on the ventral surface. *Platybolbina* sp. A differs from Meidla's species of *Platybolbina* from Baltica (see Meidla 1996, pp. 22-24), for which distinction see Table 2.2.

Occurrence. Upper Ordovician of the Parastro and Lousy Cover members of the Ellis Bay Formation, Anticosti Island.

Platybolbina sp. B. Pl. 20, figs 7-11

Material. Ten specimens from samples EB 7, EB8, EB9 and EB10.

*Measurements***.** Length of valves up to 1.30 mm and height of valves up to 0.82 mm.

Description. Carapace sub-elliptical in lateral view. Unisulcate (S2 deep, its length 0.2 mm to height 0.4 mm), L2 well defined and sub-circular in shape. Hinge line straight. Symmetrical valve, maximum high at mid, anterior and posterior cardinal angle obtuse. The free margin is obscured in the external lateral view by a velate frill. Surface reticulate.

Discussion. *Platybolbina* sp. B. resembles *Platybolbina shaleri* in the shape of its velum and in possessing a muscle spot, but is distinguished by lacking small spines on the ventral surface. *Platybolbina* sp. B differs morphologically from Meidla's specimens of *Platybolbina* species from Baltica (see Meidla 1996, pp. 22-24), for distinction of which see Table 2.3.

Occurrence. Upper Ordovician of the Parastro and Lousy Cover members of the Ellis Bay Formation, Anticosti Island.

Table 2.3. Comparison of Upper Ordovician species of *Platybolbina* from other localities with the species *Platybolbina shaleri*, *Platybolbina* sp. A. and *Platybolbina* sp. B. from the Ellis Bay Formation.

Species name	**Length and height of valves (mm)**	**Shape (in lateral view)**	**Ornament**	**Important features**	**Key reference**
Platybolbina maslovi **Sarv, 1959**	1.9-1.4 (LV)	Sub-ovate	Reticulate	One long spine well developed posteroventally.	Meidla 1996
Platybolbina orbiculata **Sarv, 1959**	1.4-0.9 (RV)	Sub-ovate	Smooth	Valves non-sulcate and velum along the entire free margin.	Meidla 1996
Platybolbina temperata **Sarv, 1959**	1.32-1.09 (LV)	Sub-ovate	Smooth	Valves non-sulcate and velum along the ventral part of the free margin.	Meidla 1996
Platybolbina tiara **Henningsmoen, 1954**	1.3-0.83 (RV)	Sub-ovate	Reticulate	Adductor muscle scar vertically elongated and depressed.	Meidla 1996
Platybolbina shaleri Copeland, 1973	0.75-0.55 (LV)	Sub-ovate	Reticulate	Valves with a weak sulcal depression, muscle spot nearly semi-circular below mid-valve.	This study
Platybolbina sp. A.	0.70-0.52 (RV)	Sub-ovate	Smooth	Very weak sulcal depression appears on the mid-ventral surface, L2 well defined.	This study
Platybolbina sp. B.	1.30-0.82 (LV)	Sub-elliptical	Reticulate	Unisulcate (S2 deep, length 0.2 mm to height 0.4 mm), L2 well defined and sub-circular in shape.	This study

Genus ***Eographiodactylus*** Kraft, 1962

Type species. *Eographiodactylus eos* Kraft, 1962; by original designation. From the Upper Ordovician Edinburg Formation of the Shenandoah Valley, Virginia, USA.

Diagnosis. (Revised from Kraft 1962). Carapace sub-quadrate in lateral view. Dorsal and ventral margin nearly straight, anterior and posterior margin rounded and posteroventral areas of the right valve often bear a posteroventral spine. Cardinal angles dissimilar and may form a blunt small spine. Inequivalved, right valve may extend beyond left valve along ventral margin, or left valve may extend beyond right valve along dorsum. Surface of valves convex with weak dorsomedian depression (S2). Surface of valves may be smooth or reticulate.

Discussion. Eographiodactylus resembles *Ectoprimitoides* Berdan, 1988. They possess identical sulcation and a velar flange extending from the margin posteriorly. *Ectoprimitoides* differs by lacking a posterior spine, the anterior widening of the velum, and in having the posterior part of the lateral area flattened.

Kraft (1962) considered *Eographiodactylus* to most closely resemble *Graphiadactyllis* Roth, 1929, but it differs from this genus in possessing a posterior spine and having a weak S2.

Occurrence. *Eographiodactylus* is recorded from the Upper Ordovician Vauréal and Ellis Bay formations of Anticosti Island, eastern Canada (Copeland 1970, 1973), Öjlemyrflint boulders of Gotland, (Schallreuter 1975b, 1980b), and from the Upper Ordovician Edinburg Formation of Virginia, USA (Kraft 1962).

Eographiodactylus hyatti Copeland, 1973 Pl. 15, figs 7-8

1973 *Eographiodactylus hyatti* sp. nov. Copeland, pl. 4, figs 18-21.

1974 *Primitiopsid* indet; Copeland, pl. 15, figs 8, 19.

1974 *Kirkbyella*? sp.; Copeland, pl. 8, fig. 8.

Holotype. Designated Copeland (1973, pl. 4, fig. 19), a left valve, Geological Survey of Canada No. 31481, from White Cliff, Port Menier quarry, east side of the Ellis Bay Formation (GSC locality 84469), Anticosti Island, eastern Canada.

Material. Nine specimens from samples EB1, EB3, EB6, EB9, EB17 and EB18.

Measurements. Length of valves up to 0.65 mm, height of valves up to 0.38 mm.

Diagnosis. (Revised from Copeland 1973) Unisulcate species having velar structure broadest anteriorly on both valves, approximately fourteen tiny spines on the posterior and anterior regions. Valve surface reticulate.

*Description***.** Carapace elongate in lateral view, nearly preplete. Weak sulcus (S2). Dorsal margin straight, ventral margin convex, posterior and anterior margin nearly rounded and posteroventral areas of the right valve bears single spine. Very obtuse cardinal corners are formed into a blunt spine, anterior cardinal angle about 135° and posterior cardinal angle about 100°. Hinge long. Velar structure on both valves, broadest anteriorly. Thin marginal ridge. More than 16 tiny spines randomly spread on the margin of the anterior and posterior areas. Asymmetrical valves, right valve larger than left valve. Surface reticulate.

Discussion. For differences between *E. hyatti* and other species in the genus *Eographiodactylus* see Table 2.4.

Occurrence. *E. hyatti* are recorded from the Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation.

Table 2.4. Species of *Eographiodactylus* from other localities compared with *E. hyatti* from the Ellis Bay Formation.

Species name	**Maximum length and height of the valve (mm)**	**Shape (in ventral view)**	**Ornament**	**Important features**	**Key reference**
Eographiodactylus eos Kraft, 1962	0.63-0.34	Sub-quadrate	Smooth	Velaum only developed in the anteroventral area and seems spine-like.	Kraft 1962
Eographiodactylus billingsi Copeland, 1970	/	Sub-quadrate	Smooth	Marginal ridge on both valves, that of the right larger.	Copeland 1970
Eographiodactylus sulcatus Schallreuter, 1975	/	Sub-quadrate	Reticulate	Velum extends from anerodorsal to ventral margin.	Schallreuter 1975b Schallreuter 1980b
Eographiodactylus hyatti Copeland, 1973	0.65-0.38	Sub-quadrate	Reticulate	More than 10 tiny spines randomly spread along the margin of anterior and posterior area.	This study

Family **Tvaerenellidae** Jaanusson, 1957

*Genus **Tvaerenella*** Jaanusson, 1957

Type species. *Primitiella carinata* Thorslund, 1940; by original designation. From the Upper Ordovician of the 'Chasmops Series' of Jämtland and Södermanland, Tvären, Sweden.

Diagnosis. (Modified from Sidaravičiene 1992). Valves sub-elliptical; lateral surfaces evenly convex. Velum a low, short ridge near the ventral margin. Marginal ridge on both valves. Weakly sulcate or non-sulcate. Symmetrical valves. Valves smooth.

Discussion. *Tvaerenella* resembles *Eoaquapulex* Levinson, 1968 most notably in having a velum in both dimorphs. *Eoaquapulex* can be distinguished from *Tvaerenella* by the relative length of the hinge, which is much longer in *Tvaerenella*, and by lacking admarginal tubercles on both valves.

Occurrence. Upper Ordovician of Baltoscandia (Meidla 1996, Hints *et al*. 2001, Sidaravičiene 1992, Truuver and Meidla 2015), glacial erratic boulders, Germany (Schallreuter 1987; Schallreuter and Hinz-Schallreuter 2011).

Tvaerenella calvatus sp. nov. Pl. 3, 1-6

1965 *Conchoprimitia* sp.; Copeland, pl. 2, fig.7.

1989 *Conchoprimitia*? sp.; Copeland, pl. 1.2, figs 7-8.

1973 *Diplopsis* sp. cf. *D. frequens* Steusloff; Copeland. pl. 6, fig. 30, pl. 8, fig. 3.

2000 *Ningulella*? sp.; Copeland, pl. 6, fig. 10.

Derivation of name. Latin '*calvatus*' bald; with reference to its lack of ornament; gender masculine.

Holotype. A carapace, Geological Museum of the University of Tartu, Estonia No. TUG 1741-1, from sample EB1 (Pl. 3, fig. 2), Fraise Member, Ellis Bay Formation.

Topotype material. 39 specimens from samples EB1, EB6, EB7, EB 9, EB 10, EB 16, EB 17 and EB24.

Measurements. Length of valves between 0.55 to 1.55 mm, height of valves between 0.3 to 1.0 mm (Fig. 2.10).

Diagnosis. Posterior and anterior outlines rounded. Cardinal angles obtuse and nearly equal. Admarginal spines absent on both valves.

Description. Sub-amplete and sub-ovate lateral shape. Shape moderately high to moderately long (L: H ratio between 1.55 to 1.83). Valves evenly convex, non-sulcate and non-lobate. Hinge line long and straight. Posterior and anterior outlines rounded. Symmetrical valves. Valve surface smooth. No admarginal spines.

Discussion. For differences between *Tvaerenella calvatus* sp. nov. and other species in the genus see Table 2.5.

Occurrence. *T. calvatus* is recorded from the Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation.

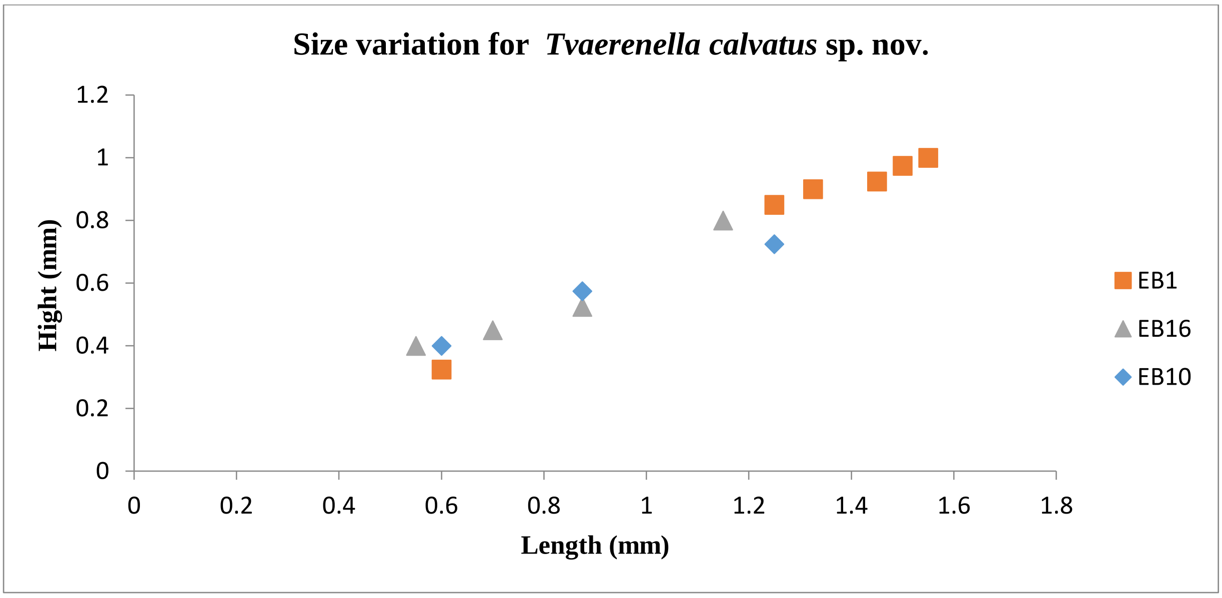

Figure 2.10. Size variation for *Tvaerenella calvatus* sp. nov., right and left valves, for samples EB1, EB10 and EB16 from the Ellis Bay Formation.

Table 2.5. Species of *Tvaerenella* from other localities compared with *Tvaerenella calvatus* sp. nov. from the Ellis Bay Formation.

Species name	Length and height of valve (mm)	Shape (in ventral view)	Ornament	Important features	Key reference
Tvaerenella tuberculata (Krause, 1892)	1.23-0.75 (RV)	Sub-elliptical	Smooth or reticulate.	Muscle spot within a weak sulcus. Velum developed as a keel.	Schallreuter and Hinz-Schallreuter 2011
Tvaerenella plana (Krause, 1889)	1.51-0.98 (LV)	Sub-elliptical	Smooth	Anterior and posterior cardinal angles are equal. Muscle spot absent.	Schallreuter and Hinz-Schallreuter 2011
Tvaerenella expedita Sarv, 1959	1.52-0.9 (RV)	Sub-elliptical	Smooth	Centrodorsal muscle spot.	Meidla 1996
Tvaerenella longa longa (Sarv, 1956)	0.66-0.41 (RV)	Sub-elliptical	Smooth	Velum poorly developed or absent, and marginal ridge absent. Muscle spot absent.	Meidla 1996
Tvaerenella longa pretiosa Sarv, 1959	1.4-0.84 (LV)	Sub-elliptical	Smooth	Velum poorly developed. Muscle spot absent.	Meidla 1996
Tvaerenella stossmeisteri Schallreuter, 1985	1.85- 1.1 (LV)	Sub-elliptical	Smooth	Cardinal angles obtuse, ventral margin convex. Muscle spot absent.	Schallreuter 1985
Tvaerenella modesta Sarv, 1959	0.65-0.34 (LV)	Sub-elliptical	Smooth	Cardinal angles equal and obtuse. Marginal ridge along the ventral margin, not developed in juveniles.	Schallreuter 1985
Tvaerenella ? sp. A	1.0-0.55	Sub-elliptical	Smooth	Cardinal angles obtuse. Marginal ridge from posteroventral to anteroventral region.	Sidaravičhiene 1992
Tvaerenella ? sp. B	2.02-1.25	Sub-elliptical	Smooth	Dorsal and ventral margin parallel. Velum developed in the ventral margin. Muscle spot absent.	Sidaravičhiene 1992
Tvaerenella ? sp. C	1.85-1.15	Sub-elliptical	Smooth	Cardinal angles acute. Weak marginal ridge from anterior to posterior ends. Muscle spot absent.	Sidaravičhiene 1992
Tvaerenella postpleta Schallreuter, 1981	1.25-0.85	Sub-elliptical	Reticulate	Postplete outline. Velum occupies the anteroventral and centroventral region of the valve and terminates abruptly at both ends.	Schallreuter 1981
Tvaerenella calvatus sp. nov.	1.55-1.0 (LV)	Sub-elliptical	Smooth	Cardinal angles obtuse and nearly equal. Marginal structure very weak. Muscle spot absent. Hinge line long.	This study

Superfamily **Eurychilinoidea** Ulrich and Bassler, 1923

Family **Eurychilinidae** Ulrich and Bassler, 1923

Genus ***Eurychilina*** Ulrich, 1889

Type species. *Eurychilina reticulata*, Ulrich, 1889, by original designation. From the Upper Ordovician of the Guttenberg Member, Decorah Formation, Fountain, Minnesota, USA.

Diagnosis. (Adapted from Williams 1990 unpublished) Eurychilininae with heteromorphic dolonal antrum not occupying the entire width of the velar frill, and unisulcate.

Discussion. Some species of *Eurychilina* are dimorphic, the heteromorphs having a sausage-shaped inflation formed along the ventral margin of the domicilium. Jaanusson (1957, pp. 230-233, text-fig. 11a) discusses the nature of the eurychilinid frill in some detail. The numerous species of *Eurychilina* were documented on the basis of ornamental variation (e.g. see Table 1.1).

Eurychilina differs from *Actinochilina* Jaanusson, 1957 by its different velar and dolonal morphology, and from *Norochilina* Copeland, 1965 by the lack of a distinctive dorsal plica, and by differing velar morphology.

Eurychilina resembles *Laccochilina* Hessland, 1949 in its velar morphology, and in possessing a depressed area mid-dorsal of S2. It differs by lacking a dolonal antrum that occupies the full width of the velum.

Occurrence. Species of *Eurychilina* have been recorded from the Upper Ordovician of the USA, Oklahoma (Harris 1957, Levinson 1961, Williams and Siveter 1996), Virginia (Kraft 1962), Iowa (Kay 1940), Minnesota (Ulrich 1889, Kay 1934, Swain *et al*. 1961, Swain 1987), Pennsylvania (Swain 1962), Kentucky (Warshauer and Berdan 1982), Michigan (Kesling 1960b), New York (Swain 1962), District of Mackenzie (Copeland 1974, 1982), Ontario (Copeland 1965) and Baffin Island, Canada (Copeland 2000), Balclatchie Formation at Penwhapple Burn, Girvan district, southwest Scotland (Williams *et al*. 2001a, Mohibullah *et al*. 2014). Also from the Late Ordovician of the Altai (Melnikova 2010), Malodiring-Ayan Formation of Kotel’nyi Island, New Siberian Island (Melnikova and Danukalova 2014) and Himachal Pradesh, northern India (Schallreuter *et al*. 2008).

Eurychilina erugoface sp. nov. Pl. 14, figs 6-10

Derivation of name. From Latin '*erugo*' meaning smooth and Latin '*face*' meaning surface, alluding to the valve smooth surface of the carapace. Gender feminine.

Holotype. A carapace, Geological museum of the University of Tartu, Estonia No. TUG 1741-3, from sample EB3 (Pl. 14, fig. 8), Juncliff Formation, Ellis Bay Formation.

Topotype material. Sixteen specimens from samples EB3 and EB15.

Measurements. Length of valves between 0.3 to 0.8 mm and height of valves between 0.2 to 0.5 mm (see Fig. 2.11).

Diagnosis. Well-developed S2 positioned centrodorsally, velum entire along the free margin. Surface of valves smooth.

Description. Carapace elongate, valves amplete, shape high (L:H ratio 1.4-1.5). Hinge line straight (length about 0.2 mm). S2 deep, open towards the dorsal margin, length 0.3 mm and height 0.5 mm), and weak S1, length 0.04 mm and height 0.08 mm. L2 sub-circular in shape (length 0.05 mm and height 0.1 mm). The anterior and posterior valve margins are rounded. Heteromorphic dolon is unclear around the ventral margin. Adult tecnomorphs with velar ridge which is constant in width along its entire length, begins at the posteriodorsal margin and ends at the anterodorsal margin. Valve surface smooth.

Discussion. For differences between *Eurychilina erugoface* sp. nov. and other species of *Eurychilina* see Table 2.6.

Occurrence. Fraise and Lousy Cove members of the Ellis Bay Formation, Anticosti Island.

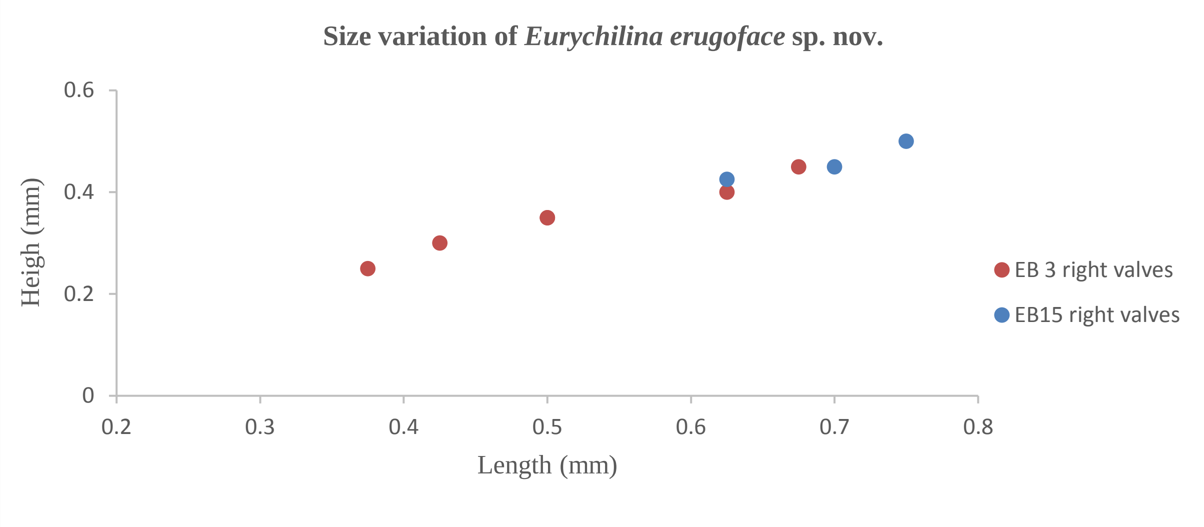

Figure 2.11. Size variation for *Eurychilina erugoface* sp. nov., right valves, for samples EB3 and EB15 from the Ellis Bay Formation.

Table 2.6. Species of *Eurychilina* from other localities compared with *Eurychilina erugoface* sp. nov. and *Eurychilina* sp. A from the Ellis Bay Formation.

Species name	Length and height of valve (mm)	Type of sulcation	Type of ornament	Important features	References
Eurychilina mattea Kraft, 1962	1.80-1.17 (R)	Unisulcate	Tuberculate	Well developed papillae and a more evenly elliptical outline.	Kraft 1962
Eurychilina strasburgensis Kraft, 1962	1.97-1.10 (L)	Unisulcate	Punctate	Characterized by a faint node anterior to the sulcus, and by its arched velum.	Kraft 1962
Eurychilina nodosa Kraft, 1962	1.93-1.10 (L)	Unisulcate	Tuberculate	A sausage-shaped dolon within the velum, developed ventrally and anteroventrally.	Kraft 1962
Eurychilina dorsovelata Kraft, 1962	1.32-0.82 (L)	Unisulcate	Tuberculate	Possesses a prominent ridge along the dorsum.	Kraft 1962
Eurychilina bulbinoda Kraft, 1962	0.97-0.57 (R)	Unisulcate	Tuberculate	Has a bulb-like preadductorial node. Velate structure initiates at the anterocardinal corner.	Kraft 1962
Eurychilina sunbloodensis Copeland, 1974	/	Unisulcate	Smoot to tuberculate	Has a row of tiny marginal denticles paralleling the contact margin.	Copeland 1982
Eurychilina subradiata Ulrich, 1890	/	Unisulcate	Punctate	Characterized by an angulated velum and cristate dorsum.	Warshauer and Berdan 1982
Eurychilina reticulata Ulrich, 1889	/	Unisulcate	Reticulate	Dolonal antrum occupying the full width of the velar field.	Williams 1990 (unpublished)
Eurychilina indivisa Levinson, 1961	2.50-1.44 (R)	Unisulcate to very weak bisulcate	Tuberculate to granulate	Velum becoming convex towards cardinal corner. Also velum broader posteriorly and narrower anteriorly.	Williams 1990 (unpublished)
Eurychilina cf. E. *ventrose* Ulrich, 18894	1.68-0.96 (R)	Unisulcate to very weak bisulcate	Weakly punctate	Velum entire and tubulose, narrows towards anterior cardinal corner.	Williams 1990 (unpublished)

Eurychilina? *simplex* Harris, 1957	1.46-0.93(R)	Unisulcate	Smoot to tuberculate	Velum incurving towards the contact margin below the dolonal antrum.	Williams 1990 (unpublished)
Eurychilina sennikovi Melnikova, 2010	1.55-0.80 (R)	Unisulcate	Smooth	The velate structure begins at the anterior margin and ends at the posteroventral margin.	Melnikova 2010
Eurychilina sunbloodensis Copeland, 1974	1.90-1.33 (R)	Unisulcate	Tuberculate	Has a well-defined preadductorial node, deep adductorial sulcus (S2) and L2 well defined and sub-circular in shape. Heteromorphic brood pouch is narrow.	Mohibullah *et al.* 2014
Eurychilina sp. A	0.75-0.60 (R)	Unisulcate	Smooth	Maximum height at mid-length, anterior and posterior cardinal angles obtuse. Dolon elongate.	This study
Eurychilina erugoface sp. nov.	0.70-0.50 (R)	Unisulcate to weak bisulcate	Smooth	S2 is bean shaped and centrodorsal, velum entire along the free margin.	This study

Eurychilina sp. A   Pl. 12, figs 2-3

*Material***.** Three specimens from sample EB10.

*Measurements***.** Length of valves up to 0.75 mm and height of valves up to 0.60 mm.

Description. Carapace sub-ovate to sub-elliptical in lateral view. Unisulcate. Hinge line straight. Symmetrical valves, maximum height at mid-length, anterior and posterior cardinal angles obtuse. Surface smooth. Brood pouch elongate anteroventrally.

Discussion. For differences between *Eurychilina* sp. A, and other species of *Eurychilina*, see Table 2.6.

Occurrence. Lousy Cove Member of the Ellis Bay Formation, Anticosti Island.

Suborder **Binodicopina** Schallreuter, 1972

Superfamily **Drepanelloidea** Ulrich and Bassler 1923

Family **Bolliidae** Bouček, 1936

Genus ***Jonesites*** Coryell, 1930

Type species. *Primitia excavata* Jones and Holl 1869; by original designation. The type species is from the Woolhope Limestone Formation, Lower Silurian of England.

Diagnosis. (Adapted from Scott and Wainwright *in* Moore (1961 p. Q l29); and Siveter 1978) Subovate and postplete, cardinal angle obtuse, dorsal margin may be straight or convex. Lateral surface of valves close to the area of the marginal ridge is depressed, and may be reticulate.

Discussion. Jonesites has been recorded in upper Wenlock strata fairly commonly (Siveter 1978). It resembles *Gravensia* Schallreuter, 2000 by possessing a lateral surface that is depressed and reticulate close to the marginal ridge, but the elongate shape and longitudinal rim of *Gravensia* distinguishes the two taxa.

Occurrence. Species of *Jonesites* are recorded from Kentucky, Cincinnati and Ohio (Ulrich 1890; Bassler and Kellett 1934), Upper Ordovician of the USA, and from the Vauréal (Copeland 1970), and Ellis Bay formations, Anticosti Island (Copeland 1973), Upper Ordovician of Canada. Also recorded from the Wenlock Limestone Formation, Gloucestershire (Siveter 1978), Silurian of England.

Jonesites semilunatus (Jones, 1890) Pl. 15, 1-2

1890 *Bollia semilunatus* sp. nov. Jones, p. 548, pl. 21, figs. 9a, b.

1928 *Bollia semilunatus* Jones; Bassler, *in* Twenhofel, p. 346.

1961 *Jonesites primitia* excavata (Jones and Holl); Scott and Wainwright *in* Moore, p. Q129, fig. 16, 14.

1970 *Jonesites semilunatus* (Jones); Copeland, pp. 19-20, fig. 10; pl. 5, fig. 14.

1973 *Jonesites semilunatus* (Jones); Copeland, pl. 1, figs 16-19; pl. 8, figs 1-2; pl. 9, fig. 14.

1977 *Jonesites semilunatus* (Jones); Copeland, p. 11, pl. 1, fig. 20.

Holotype. Designated Jones (1890, pl. 21, figs 91a, b), a left valve, the United States National Museum No. 82417, from the Vauréal Formation, Anticosti Island, eastern Canada.

Material. Fifty five specimens from samples EB1, EB3, EB5, EB6, EB7, EB8, EB10, EB13, EB16, EB17, EB18 and EB20.

Measurements. Length of valves between 0.45 to 0.75 mm, height of valves between 0.35 to 0.6 mm (Figs 2.12, 2.13).

Diagnosis. (Revised from Copeland 1970) carapace sub-ovate, adductorial sulcus well developed and surface within the marginal ridge deeply depressed: surface of the depressed area smooth.

Description. Ovate and slightly postplete, shape high (L: H ratio is 1.25 to 1.28). Adductorial sulcus well defined. Cardinal angles about 145°. Dorsal and ventral valve margins weakly convex, posterior and anterior margins rounded. Hinge line straight and substantially shorter than valve length. Lateral surface within the marginal ridge is depressed.

Discussion. Jonesites semilunatus differs from the type species *Jonesites excavata* (Jones and Holl, 1869) figured by Siveter (1978, pl. 6, figs 7-8), by having the surface adjacent to the marginal ridge deeply depressed and the surface of the marginal rim smooth. Copeland (1973) referred to a *J. semilunatus* zone for the entire Ellis Bay Formation because this species occurs throughout the formation.

Occurrence. *Jonesites semilunatus* is recorded from the Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation.

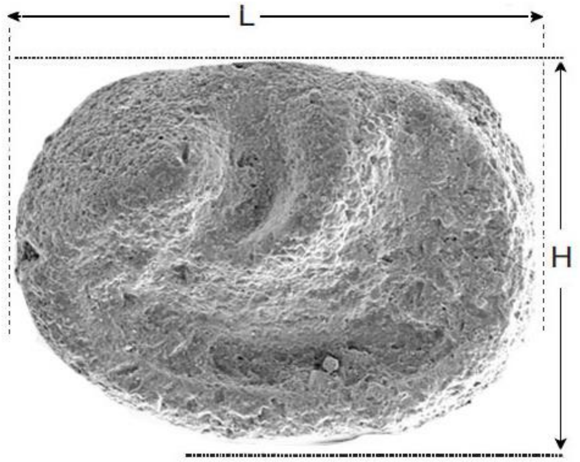

Figure 2.12. Parameters used for measurements of valves of *Jonesites semilunatus* (Jones, 1890). H, maximum valve height; L, maximum valve length.

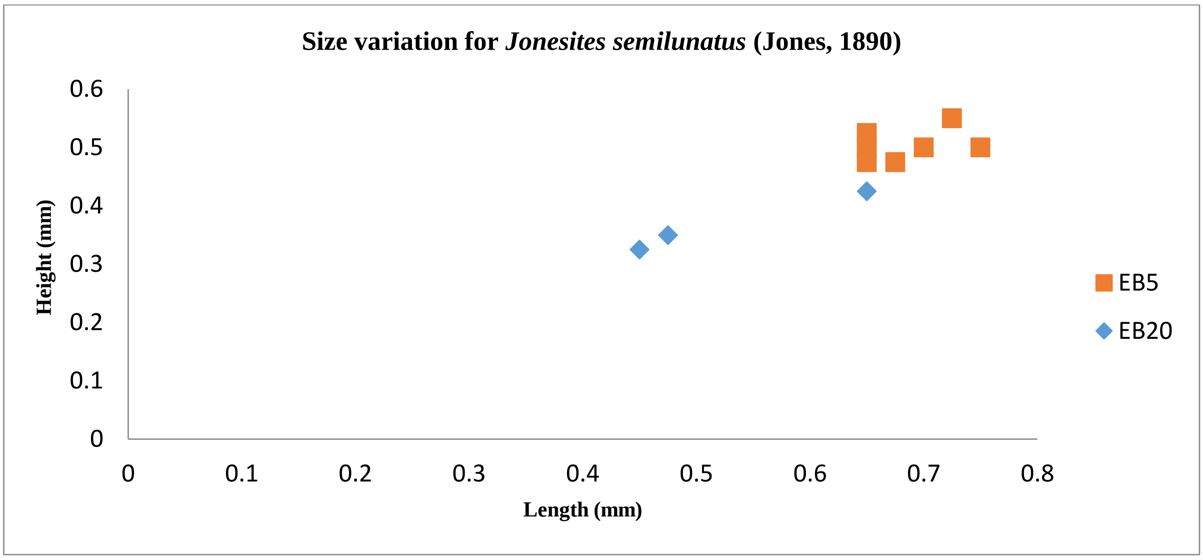

Figure 2.13. Size variation for *Jonesites semilunatus* (Jones, 1890) right and left valves, for samples EB5 and EB20 from the Ellis Bay Formation. The small dataset precludes recognition of discrete instars.

Genus ***Dicranella*** Ulrich, 1894

Type species. *Dicranella bicornis* Ulrich, 1894; by original designation, Ulrich 1894, p. 664.

Diagnosis. (Adapted from Williams 1990 unpublished). Strongly bilobate with L2 and L3 often extended dorsally as prominent spines. L3 always over-reaching dorsum higher than L2, L1 often thickened ventrally. Velum can be more convex and widened in heteromorph, particularly anteroventrally and ventrally.

*Occurrence***.** From Oklahoma (Harris 1931, 1957), Iowa and Minnesota (Ulrich 1894, Kay 1940, Swain 1987), Upper Ordovician of the USA. Also from the District of Mackenzie (Copeland 1982), Baffin Island (Copeland 1977a), Upper Ordovician of Canada.

Dicranella sp. A.   Pl. 15, fig. 3

Material. Only one carapace from sample EB18.

Measurements. Length of carapace 0.62 mm, height of carapace 0.44 mm.

Description. Valve sub-ovate and preplete. Bilobate, L3 large distinctive post-sulcal, sub-spherical L2 large and swollen. Narrow, slit-like, anteromedian S2 in lateral surface. Dorsal margin straight, ventral margin rounded with a distinctive anterior swing. Anterior margin rounded, posterior margin bluntly sub-truncate. Anterior cardinal angle about 100°. Posterior cardinal angle about 95°. Surface of valves reticulate. Velum absent.

Discussion. For differences between *Dicranella* sp. A and other species of *Dicranella* see Table 2.7.

Occurrence. *Dicranella* sp. A is recorded from the Lousy Cove Member of the Ellis Bay Formation.

Table 2.7. Species of *Dicranella* from other localities compared with *Dicranella* sp. A from the Ellis Bay Formation.

Species name	**Maximum length and height of valve (mm)**	**Shape (in ventral view)**	**Ornament**	**Diagnostic characters**	**Key reference**
Dicranella bicornis Ulrich, 1894	1.09-0.67	Sub-elongate	Tuberculate	Possesses a narrow very elongate L2 and L3. Velum separated from lateral surface of valve by a sharp 90° bend.	Williams 1990 (unpublished)
Dicranella macrocarinata Harris, 1931	1.22-0.78	Sub-ovate	Tuberculate	L2 and L3 broad and elongate. Velum narrow and wider ventrally in heteromorph.	Williams 1990 (unpublished)
Dicranella fimbriata Copeland, 1982	*1.0-* 0.75	Sub-elongate	Granular	L2 and L3 elongate and rounded. Velum narrow and sub-velar field with complete row of spines along posterior to anterior margin.	Copeland 1982
Dicranella fragilis Harris, 1957	1.07-0.75	Sub-elongate	Tuberculate	L2 and L3 rounded. Lacking a prominent basal swelling on the anterior lobe (L2).	Harris 1957
Dicranella spinosa Ulrich 1894	/	Sub-ovate	Granular	L2 and L3 rounded and short. sub-velar field with complete row of spines along posterior to ventral margin.	Copeland 1982
Dicranella sp. A	0.62-0.44	Sub-ovate	Reticulate	L2 and L3 broad and sub-elongate. Velum absent.	This study

Family **Circulinidae** Neckaja, 1966

Genus ***Byrsolopsina*** Swain and Cornell, 1961

Type species. *Paraschmidtella planilateralis* Kay, 1940; designated Swain and Cornell (1961, p. 363), from the Ordovician Decorah Shale Formation of Minnesota, USA.

Diagnosis. (Revised from Swain and Cornell 1961; Swain 1962; and Schallreuter 1982) Carapace sub-elliptical to sub-quadrate, lateral surface of valves markedly flattened. Valves are weakly asymmetrical. Both valves with a strongly flattened margin ventrally. Hinge line short, hinge margin of the left valve more thickened than in right valve, cardinal angles obtuse. Valve surface ornament of fine to coarse punctae.

Occurrence. *Byrsolopsina* is recorded from the Upper Ordovician (Sandbian) Decorah Shale Formation of Minnesota, USA (Swain and Cornell 1961), the Upper Ordovician of the Isle of Gotland (Schallreuter 1982), and Middle Ordovician strata of the eastern United States (Swain 1962).

Byrsolopsina irregularis (Keenan, 1951) Pl. 5, figs 1-6

1951 *Paraschmidtella irregularis* sp. nov. Keenan, p. 562, pl. 78, figs 32-34.

1970 *Paraschmidtella irregularis* Keenan; Copeland, p. 18.

1973 *Paraschmidtella irregularis* Keenan; Copeland, pp. 30-46, pl. 1, figs 1-2, pl. 3, fig. 11, pl. 9, figs 12-13.

1974 *Paraschmidtella irregularis* Keenan; Copeland, p. 46.

1982 *Byrsolopsina irregularis* (Keenan, 1951); Schallreuter, pp. 2-4.

Holotype. Designated Keenan (1951, pl. 78, fig. 34), a right valve, the United States National Museum No. 0-984-3, from the Ordovician Maquoketa Shale Formation, Missouri, USA.

Material. More than two thousand specimens from six samples, EB6, EB7, EB8, EB9, EB10, EB 11, EB 12, EB14, EB15, EB16, EB17, EB18, EB19, EB20, EB22 and EB23, making this the most common ostracod species in the Ellis Bay Formation.

Measurements. Length of valves range between 0.25 to 0.6 mm (right valves) and 0.3 to 0.65 mm (left valves), height of valves range from 0.15 to 0.45 mm (right valves) and 0.2 to 0.5 mm (left valves) (Figs 2.14, 2.15, 2.16).

Diagnosis. (Revised from Keenan 1951) Surface ornament consists of small (20 to 30 microns diameter), circular punctae numbering more than 35, which are irregularly distributed across the lateral surface of the valves, but define the circular outline of a smooth central muscle spot (typically 80 microns diameter). Margin of valves flattened ventrally.

Description. Carapace subovate in lateral view. Muscle spot about 80 microns in diameter on the external surface: its shape varies from sub-ovate to sub-elliptical. Hinge straight and epicline concealed in lateral view by convex dorsal umbo: length of hinge about two-thirds the length of the valve. Posterior cardinal angle smaller than anterior. Flattened margin along the ventral portion of the valves. Valves are weakly asymmetrical, umbo of the left valve is larger than right one, hinge ridge of the right valve thinner than that of the left valve, valve surface relatively flat. Surface with punctae, as described in the diagnosis. No dimorphism.

Discussion. *Byrsolopsina irregularis* (Keenan, 1951) was previously recorded by Copeland (1970, 1973) as *Paraschmidtella irregularis* Keenan, 1951 from the Upper Ordovician and Lower Silurian strata of Anticosti Island, eastern Canada. Copeland (1970, 1973) and Keenan (1951) did not recognise the well-developed external muscle spot: this suggests a preservation difference between specimens recovered from the Maquoketa Shale Formation of Missouri and the Ellis Bay Formation. The muscle spot is located centrally on both valves, and is outlined by circular punctae: it represents about 16% of the total valve length and its dimensions are length 0.08 mm and height 0.07 mm. The surface of *B. irregularis* (Keenan, 1951) shows wide variation in the number of punctae between specimens, ranging from less than 20 to well over 40 on a single valve. The number of punctae seems to be the same between individual valves of the same specimen. *Byrsolopsina irregularis* differs from the type species *Byrsolopsina planilateralis* (Kay, 1940), which has a consistently well-developed muscle spot.

Byrsolopsina irregularis (Keenan, 1951) resembles *Byrsolopsina centipunctata* (Kay, 1940) in the form of its posterior cardinal angle being less obtuse than the anterior one, but *B. irregularis* (Keenan, 1951) differs from *B. centipunctata* (Kay, 1940) by having circular punctae and by the number of punctae exceeding 50.

Occurrence. Byrsolopsina irregularis (Keenan, 1951) has been recorded from the Upper Ordovician Vauréal and Ellis Bay formations, the Lower Silurian Becscie and Jupiter formations, Anticosti Island, eastern Canada (Copeland 1974), and from the Upper Ordovician (Katian) Maquoketa Shale of Missouri north central USA (Keenan 1951).

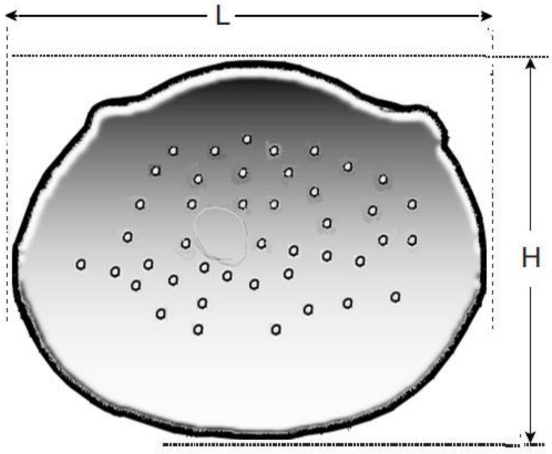

Figure 2.14. Parameters used for measurements of valves of *Byrsolopsina irregularis* (Keenan, 1951). H, maximum valve height; L, maximum valve length.

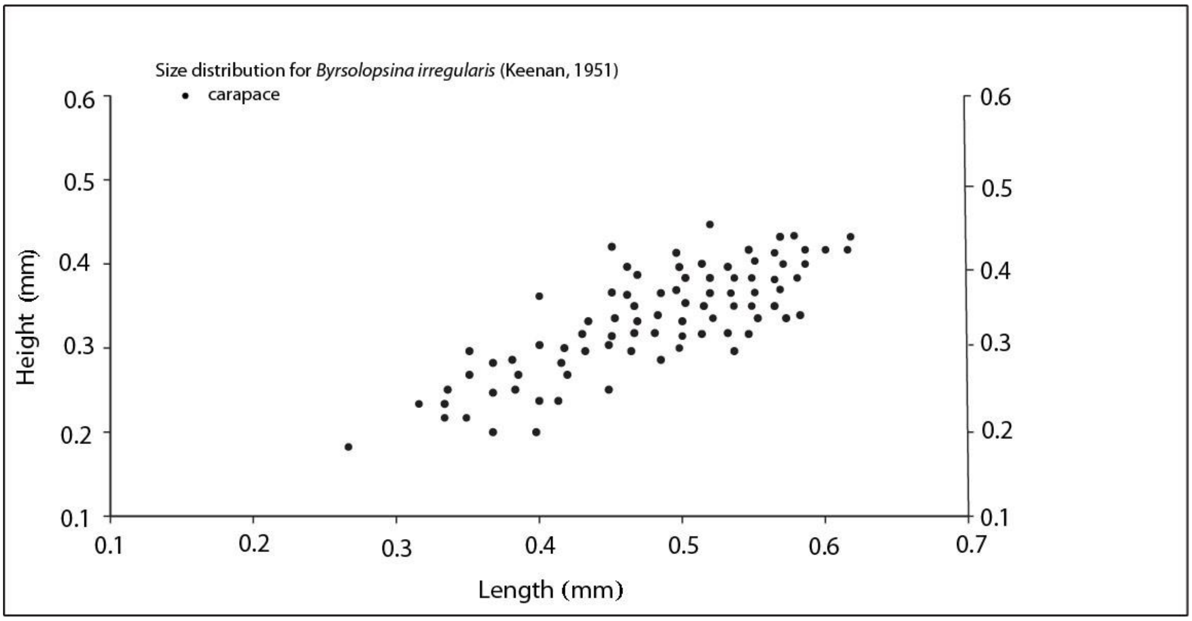

Figure 2.15. Size distribution for *Byrsolopsina irregularis* (Keenan, 1951) carapaces, for samples EB11, EB12, EB16, EB18, EB19 and EB20 from the Ellis Bay Formation.

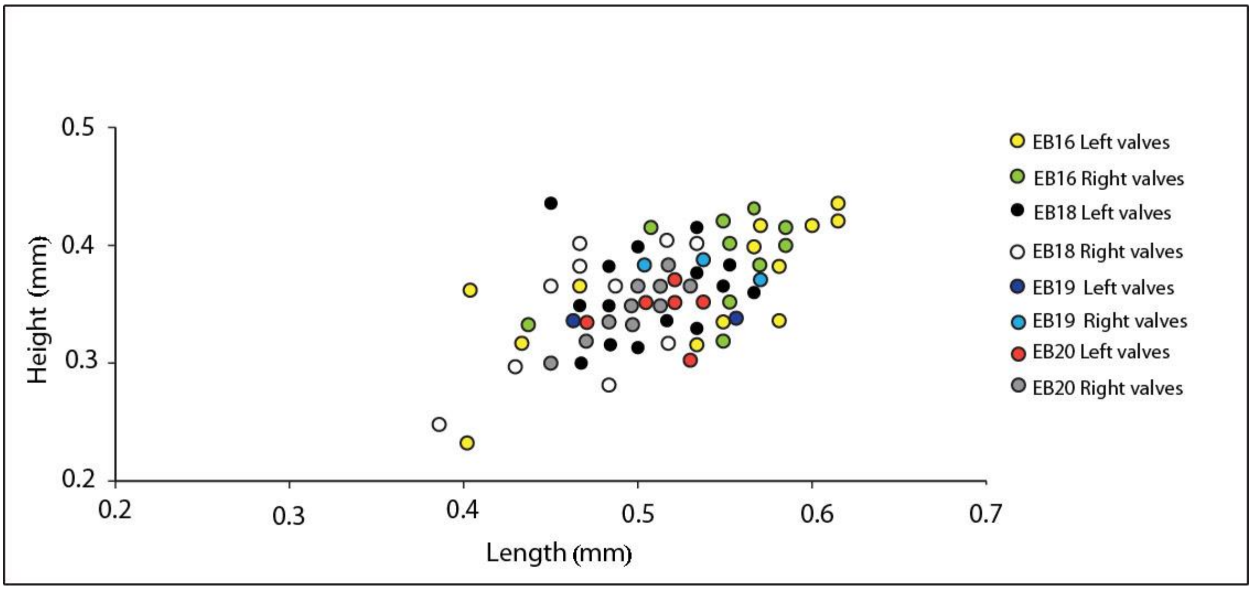

Figure 2.16. Size distribution for *Byrsolopsina irregularis* (Keenan, 1951) right and left valves, for samples EB16, EB18, EB19 and EB20 from the Ellis Bay Formation. The specimens of *B. irregularis* demonstrate continuous size variation within a relatively narrow range.

Genus ***Easchmidtella*** Schallreuter, 1967

Type species. *Easchmidtella crassiumbonata* Schallreuter, 1967; by original designation. The type species is recorded from a Rollsteinkalk (Macrouruskalk) boulder near Greifswald, Upper Ordovician of Baltoscandia.

Diagnosis. (After Schallreuter, 1967) Carapace sub-elliptical, has a weakly triangular outline in lateral view, an epicline dorsum, asymmetrical and umbonate valves, and the larger left valve overlapping the smaller right valve. Valves smooth and non-sulcate.

Discussion. Easchmidtella can be distinguished from *Schmidtella* Ulrich, 1892, on the basis of the admarginal groove, which is present in *Schmidtella crassimarginata* Ulrich, 1892, but lacking in *Easchmidtella* (see Schallreuter 1967, p. 627).

Occurrence. *Easchmidtella* has been recorded from Estonia (Meidla 1996), Lithuania (Sidaravičiene 1992), Rollsteinkalk (Macrouruskalk) boulder near Greifswald of Baltoscandia (Schallreuter, 1967), Edenian Strodes Creek and Millersburg Members of the Lexington Limestone, Kentucky (Warshauer and Berdan 1982).

Easchmidtella*? *gyroslatus sp. nov. Pl. 5, figs 8-9

Derivation of name. From Greek '*gyros*' meaning round and Latin '*latus*' meaning sides, alluding to the overall appearance of the posterior and anterior sides. Gender feminine.

Holotype. A carapace, Geological museum of the University of Tartu, Estonia No. TUG 1741-7, from sample EB7 (Pl. 5, fig. 8), Juncliff Member, Ellis Bay Formation.

Topotype material. More than 40 specimens from samples EB6, EB7, EB8, EB9, EB11, EB14, EB17, EB18 and EB24.

Measurements. Length of valves up to 0.85 mm and height of valves up to 0.55 mm.

Diagnosis. Dorsal margin straight, ventral margin weakly convex, posterior and anterior margins rounded. Umbonate valves. Muscle spot absent, valves non-sulcate.

Description. Sub-elliptical in lateral view, shape high (L: H ratio 1.55). Lateral surface of the valves smoothly convex. Umbonate valves, the umbo being 0.15 mm long with a height of 0.05 mm. Asymmetrical, left valve larger and overlaps the right. Cardinal angles obtuse and virtually equal. Dorsal margin straight and ventral margin weakly convex, posterior and anterior margin rounded. Hinge line straight. Surface of valves smooth.

Discussion. The questionable assignment of *E.*? *gyroslatus* to *Easchmidtella* is based on its similar shape to the type species *E. crassiumbonatus* Schallreuter, 1967 (see Schallreuter 1967a, p. 626). It is distinguished from other *Easchmidtella* species in Table 2.8.

Table 2.8. Species of *Easchmidtella* from other localities compared with *Easchmidtella*? *gyroslatus* sp. nov. from the Ellis Bay Formation.

Species name	**Length and height of the valve (mm).**	**Shape**	**Type of ornament**	**Important features**	**References**
***Easchmidtella crassiumbonata* Schallreuter, 1967**	0.60-0.45	Sub-elliptical	Smooth	Strongly umbonate.	Schallreuter 1967
***Easchmidtella sinuidorsata* Warshauer and Berdan, 1982**	0.73-0.58	Sub-elliptical	Smooth	Outline of dorsal margin sinuous in lateral view, umbo high.	Warshauer and Berdan 1982
***Easchmidtella fragosa* (Neckaja, 1960)**	0.91-0.65	Elliptical	Smooth	One valve is bi- and another trilamellar.	Meidla 1996
***Easchmidtella angulata* Sidaravičiene, 1975**	0.71-0.52	Elliptical	Smooth	It has an umbo.	Meidla 1996
***Easchmidtella orbicularis* Meidla, 1996**	1.33-1.03	Elliptical	Smooth	Anterior cardinal angle very blunt and posterior	Meidla 1996

				cardinal angle is more distict.	
Easchmidtella? gyroslatus sp. nov.	0.85-.055	Sub-elliptical	Smooth	Posterior and anterior margins rounded. Umbonate valves.	This study

Occurrence. Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, Anticosti Island.

Family **Aechminidae** Swartz, 1936

Genus ***Aechmina*** Jones and Holl, 1869

Type species. *Aechmina cuspidata* Jones and Holl, 1869, by original designation. From the Much Wenlock Limestone Formation (Silurian), England.

Diagnosis. (Diagnosis based on Keenan 1951; Levinson *in* Moore 1961; and Siveter 1978) Valves distinctly preplete and tapering posteriorly, with distinct, stout and often elongate dorso-median spine. Hinge line of valves is straight, ventral edge is convex. Ventral margin may have small spines present in some species. Valve surface smooth or punctate.

Discussion. *Aechmina* Jones and Holl, 1869, has a conspicuous dorso-median spine (see Williams *et al*. 2001b). *Antiaechmina* Schallreuter, 1968 could be a junior synonym of *Aechmina* (see Meidla 1996, p. 84).

Occurrence. Widely recorded from the Ordovician, including northern England (Williams *et al*. 2001b), Anticosti Island, eastern Canada (Copeland 1965, 1970, 1973), Missouri (Keenan 1951), Minnesota and northern Iowa (Burr and Swain 1965), northern Kentucky (Berdan and Balanc 1985), Michigan (Kesling 1952; Kesling and Weiss 1953), and Oklahoma, USA (Coryell and Cuskley 1934) and from the Ordovician of the Baltic region (Lindström 1953; Meidla 1996, 2007). *Aechmina* is also recorded from the Silurian of the Lower Elton Formation of the Welsh Borderland and West Midlands (Siveter 2009), from the Lower Devonian of Western Tennessee (Lundin 1992), Bolivia (Pŕibyl 1984) and from the Carboniferous of eastern Canada (Dewey 1988).

Aechmina maccormicki Copeland, 1973 Pl. 6, fig. 3, Pl. 7, fig. 3

?1951 *Aechmina maquoketensis* Keenan, p. 573, pl. 79, figs 19-20.

?1966 *Aechmina* aff. *bovina* Jones; Neckaja, p. 26, pl. 4, fig. 4.

1973 *Aechmina maccormicki*; Copeland, pp. 19-20, pl. 1, fig. 8, pl. 3, figs 5-7.

2001b *Aechmina maccormicki* Copeland; Williams *et al*., fig. 3a, fig. 2d-f.

Holotype. Designated Copeland (1973, pl. 3, fig. 6), a right valve, Geological Survey of Canada No. 31430, from the Juncliff Mmber of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Material. Twenty nine specimens from samples, EB2, EB7, EB9, EB10, EB13, EB14, EB16, EB19 and EB20.

Measurements. Length of valves ranges between 0.5 to 0.7 mm, height of valves ranges between 0.25 to 0.45 mm (Fig. 2.17).

Diagnosis. (Revised from Copeland 1973) Carapace sub-ovate and lateral outline of valves is preplete. Stout, posteriorly deflected spine rises from the anterodorsal surface of the valves and is smoothly confluent with lateral surface. Surface smooth and non-sulcate. No spines along the free margin of the valves.

Description. Valves preplete in lateral view. Dorsal margin straight, free margins evenly rounded. Large prominent anterodorsal spine that merges with the lateral surface proximally and is posterolaterally curved. Valves swollen anteroventrally. Surface smooth. No spines along the free margin of the valves.

Discussion. Aechmina maccormicki is closely allied to *Aechmina wolfensis* Copeland, 1977, from the Upper Ordovician Whittaker Formation of the Mackenzie Distict, Canada, and *Aechmina groenwalli* Troedsson, 1918 from the Upper Ordovician of the Kuldiga and Lindegard formations of Estonia. All of these species possess an anterodorsal horn-shaped spine (see Williams *et al*. 2001b; Meidla 1996). *Aechmina maccormicki* also resembles *Faurella cartieri* Copeland, 1973 from the Upper Ordovician of the Ellis Bay Formation, but is distinguished by lacking any depression on the surface of the valves (see Table 2.9).

Occurrence. The Upper Ordovician Ellis Bay Formation, Anticosti Island, eastern Canada, the Upper Ordovician Cautley Mudstone Formation, Cautley district, northern England (Williams *et al.* 2001b), and from strata of Ordovician age in the northwest part of the Russian platform (Neckaja 1966).

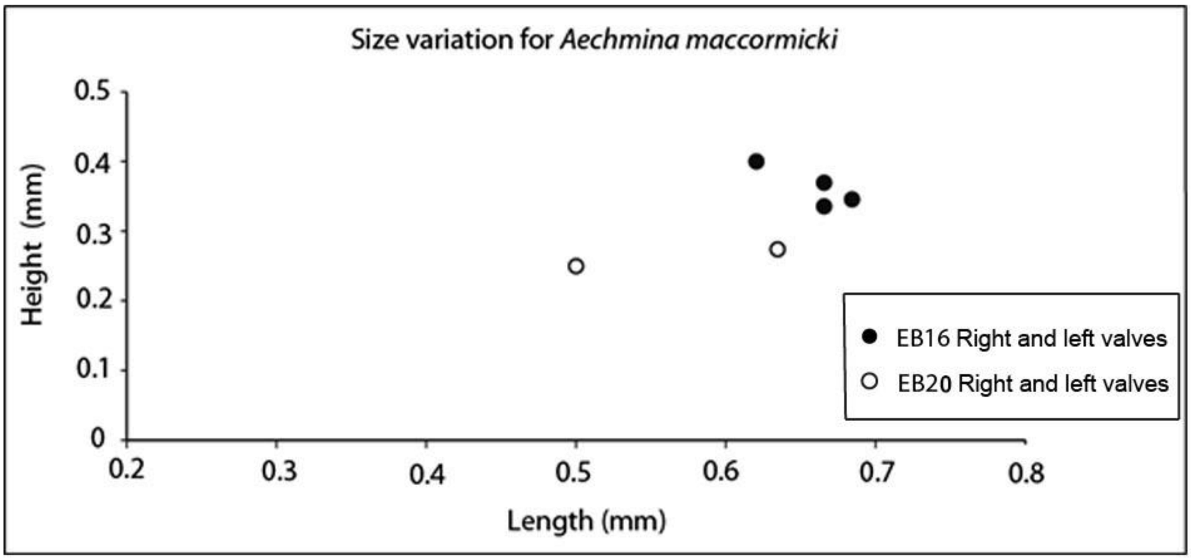

Figure 2.17. Size variation for *Aechmina maccormicki* Copeland, 1973, right and left valves, for samples EB16 and EB20 from the Ellis Bay Formation.

Aechmina richmondensis Ulrich and Bassler, 1923 Pl. 6, 4-7

1923 *Aechmina richmondensis* sp. nov. Ulrich and Bassler, p. 299, fig. 15, figs 19-21.

Holotype. Designated Ulrich and Bassler (1923, pl. 6, figs 19-21), a right valve, the United States National Museum No. 82410, from the Elkhorn Formation, Indiana, USA.

Material. Thirty seven, mostly incomplete valves from samples EB1, EB3, EB4, EB7, EB8, EB10, EB13, EB14, EB15, EB16, EB18 and EB20.

Measurements. One complete specimen possesses a valve length of 0.75 mm, and a height of 0.55 mm.

Diagnosis. (Revised from Copeland 1970) Surface punctae covering valves. Centro-dorsally situated spine is dome shaped and blunt.

Description. Lateral outline sub-ovate, dorsal margin straight. Dorsal spine as described in diagnosis. Free margins of valves do not bear spines. Equivalved, the greatest height and thickness of the valves is in the posterior part of the carapace. Surface punctate.

Discussion. *A. richmondensis* differs from *A. maquoketensis* Keenan, 1951 in the shape of its dorsal spine and its punctate ornament. *A. maquoketensis* also possesses a sulcal depression immediately posterior of the spine (see Table 2.9).

Occurrence. The Upper Ordovician Ellis Bay and Vauréal formations, Anticosti Island, eastern Canada (Copeland 1970).

Aechmina sp. A Pl. 6, figs 1-2, pl. 6, figs 8-11, Pl. 7, fig. 4

Material. About forty specimens from samples EB1, EB2, EB3, EB6, EB7, EB8, EB9, EB13, EB14, EB15, EB16, EB17 and EB18.

Measurements. Length of valves ranges between 0.3 to 0.75 mm, height of valves ranges between 0.15 to 0.45 mm (Fig. 2.18).

Description. Carapace sub-elliptical in lateral view: valves asymmetrical. Dorsal lateral outline nearly straight, anterior margin evenly convex, posterior margin gently convex. Centro-dorsally situated anterodorsal spine that is weakly extended above the hinge margin and long: length of spine is about 1.5 mm. Ventral margin has small spines, numbering 10-15. Surface of valves is smooth.

Discussion. Aechmina sp. A is distinguished from *Aechmina maccormicki* Copeland, 1973 by its marginal spines. It differs from *Aechmina maquoketensis* Keenan, 1951, by having more marginal spines (approximately 25) and smooth valve surfaces. For distinction of *Aechmina* sp. A from other species of *Aechmina* see Table 2.9.

Occurrence. From the Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Aechmina sp. B Pl. 7, figs 1-2

Material. Three specimens from samples EB16, EB17 and EB18.

Measurements. Length of valves up to 0.73 mm, height of valves up to 0.46 mm.

Description. Carapace sub-elliptical in lateral view: valves asymmetrical. Dorsal lateral outline nearly straight, anterior and posterior margin evenly convex, ventral margin gently convex. Centro-dorsally situated spine dome shaped, length of spine is about 1.3 mm. Surface of valves is punctate, numbering about 300-400.

Discussion. For distinction of *Aechmina* sp. B from other species of *Aechmina* see Table 2.9.

Occurrence. From the Lousy Cove Member of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Table 2.9. Comparison of Upper Ordovician species of *Aechmina* with the species *Aechmina richmondensis, Aechmina maccormicki, Aechmina* sp. A and *Aechmina* sp. B from the Ellis Bay Formation.

Species name	Length and height of valve (mm)	Shape of spines	Type of ornament	Important features	References
Aechmina? *bispinata* Kraft, 1962	0.91-0.50	Curved	Smooth	One tiny spine on the ventrolateral surface.	Kraft (1962)
Aechmina keitumensis (Schallreuter, 1984)	/	Curved	Smooth	Numerous long spines spread along the free margin.	Schallreuter (2000)
Aechmina groenwalli (Troedsson, 1918)	0.98-048	Curved	Smooth	Posterolaterally curved spine is located in front of mid-length of each valve.	Meidla (1996)
Aechmina maccormicki Copeland, 1973	0.7-0.45	Curved	Smooth	Posteriorly deflected spine rises from the anterodorsal surface of the valves and is smoothly confluent with lateral surface	This study
Aechmina maquoketensis Keenan, 1951	1.2-0.65	Curved	Punctae	About 80 to 100 punctae on the surface of valves.	Keenan (1951)
Aechmina overi Copeland, 1989	0.70-0.40	Dom	Punctae	Numerous short spines along entire free margin.	Copeland (1989)
Aechmina richmondensis Ulrich and Bassler, 1923	0.90-0.47	Dom (long)	Punctae	Centro-dorsally situated spine is dome-shaped and blunt.	This Study
Aechmina ssp. Copeland, 1989	/	Curved (long)	Smooth	Dorsal spine is relatively fragile.	Copeland (1989)
Aechmina sp. Copeland, 1970	/	Dom (short)	Smooth	Few spines distributed along the free margin.	Copeland (1970)
Aechmina sp. A	0.75-0.45	Triangular	Smooth	Very tiny spines distributed along the free margin, about 20-25.	This study
Aechmina sp. B	0.73-0.46	Dom (Short)	Punctae	Whole surface of valves punctate and centro-dorsally situated spine that is dome-shaped.	This study
Aechmina taurea Keenan, 1951	1.2-0.55	Curved (short)	Smooth	Numerous long spines spread along the free margin.	Keenan (1951)
Aechmina wolfensis Copeland, 1977	/	Curved (long)	Smooth	Some spines distributed along the free margin.	Copeland (1979, 1989)
Aechmina cuspidata Keenan, 1951	/	Curved (long)	Smooth	A row of small marginal spines.	Keenan (1951)

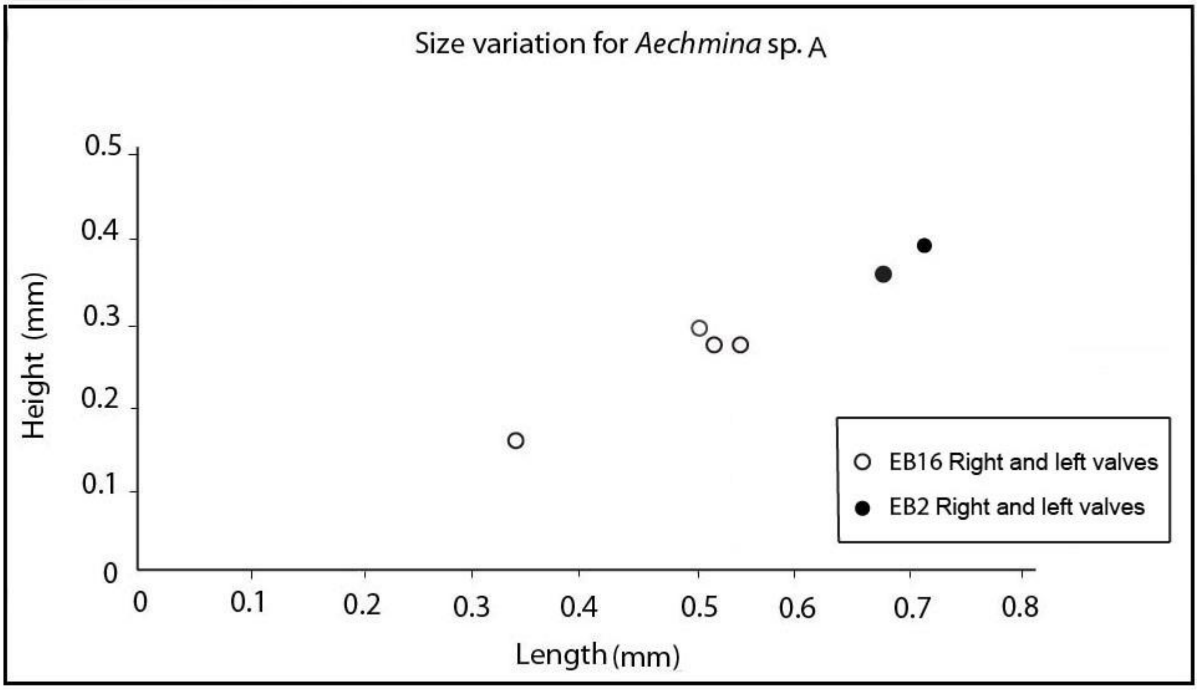

Figure 2.18. Size variation for *Aechmina* sp. A. right and left valves, for samples EB2 and EB16 from the Ellis Bay Formation.

Family **Spinigeritidae** Schallreuter, 1980

Genus ***Pseudohippula*** Schallreuter, 1975

Type species. *Pseudohippula pseudopokornina* Schallreuter, 1975; by original designation. From the Upper Ordovician Öjlemyrflint Formation, Gotland.

Diagnosis. (Diagnosis based on Schallreuter 1975a) Valves preplete, adductorial sulcus weak. Anterodorsal spine well developed; lateral spine on valve surface in a ventral position. Dimunitive spines are developed along the ventral margin towards the anterior.

Discussion. *Pseudohippula* differs from *Monoceratella* Teichert, 1937, by the shape and size of its anterodorsal and ventrolateral spines. Furthermore, *Monoceratella* lacks small spines along the ventral margin (see Teichert 1937, p. 54; Kraft 1962, p. 59). *Pseudohippula* differs markedly from *Hippula* Tromelin and Lebesconte, 1876, in its lobation (lacking S2, L1, L2, and L3; see Meidla 1996, p. 66; Mohibullah *et al*. 2014, p. 12) and absence of diagnostic toral structures at the valve margin.

Occurrence. *Pseudohippula* has previously been recorded from the Upper Ordovician Vauéal Formation (Copeland 1970) and Ellis Bay Formation of Anticosti Island (Copeland 1973), and from Baltoscandia (Schallreuter 1975a).

Pseudohippula castorensis (Copeland, 1970) Pl. 9, figs 9-11

1970 *Monoceratella castorensis* sp. nov. Copeland, p. 21, pl. 4, figs 20-22.

1973 *Monoceratella castorensis* Copeland; Copeland, p. 34, pl. 3, fig. 22.

1975 *Pseudohippula castorensis* Copeland; Schallreuter, p. 272, pl. 1, figs 4-6.

Holotype. Designated Copeland (1970, pl. 4, fig. 22), a left valve, Geological Survey of Canada No. 24001, from the Ordovician Vauréal Formation, Anticosti Island, eastern Canada.

Material and Measurement. Four incomplete valves from samples EB1, EB7, EB16 and EB19.

Diagnosis. Anterodorsal spine is thin and longer than the ventrolateral spine. Anterior and ventral valve margins have small spines, numbering approximately 30-50.

Description. Valves preplete. Adductorial sulcus poorly developed. Anterodorsal spine is thin and longer than the ventrolateral spine. Anterior and ventral valve margins have small spines, numbering approximately 30-50. Dorsal margin straight, ventral margin concave, anterior margin rounded and posterior margin weakly rounded; anterior cardinal angle obtuse and greater than posterior cardinal angle. Valve surface smooth.

Discussion. *Pseudohippula castorensis* was originally described from the Vauréal Formation (Upper Ordovician) of Anticosti Island by Copeland (1970). *P. castorensis* is morphologically close to *Pseudohippula pseudopokornina* Schallreuter, 1975, from the Upper Ordovician of Baltoscandia, but can be distinguished by the overall shape of the anterodorsal and ventral spines.

Occurrence. Upper Ordovician of the Fraise, Juncliff, Parastro and Lousy Cove members of the the Ellis Bay Formation of Anticosti Island, eastern Canada.

Genus ***Faurella*** Copeland, 1973

Type species. *Faurella cartieri*, Copeland, 1973, by original designation. From the Upper Ordovician of the Ellis Bay Formation on Anticosti Island, eastern Canada.

Diagnosis. (After Copeland 1973). Prominent horn-shaped spine anterior of mid length of valve, extending well above dorsum, curved posteriorly and slightly laterally. Spine joined ventrally to broad complete marginal ridge. Anterodorsal area between marginal ridge and spine a slit-like depression; depressed area in same position posterior of spine, broad and rounded-triangular.

Discussion. *Faurella* is most similar to *Aechmina* Jones and Holl, 1869, differing only in possessing a depression on the surface of valves. For comparison of size variation between *Faurella* and *Aechmina* (see Fig. 2.21).

Occurrence. *Faurella* is recorded from the Upper Ordovician Ellis Bay Formation, Anticosti Island.

Faurella cartieri Copeland, 1973 Pl. 7, figs 5-7

1973 *Faurella cartieri* sp. nov. Copeland, p. 20, pl. 10, figs 8, 10, 18.

Holotype. Designated Copeland (1973, p. 20, pl. 3, fig. 8), a left valve, Geological Survey of Canada No. 31432, length 0.68 mm, height 0.55 mm, from the Ellis Bay Formation, Anticosti Island, eastern Canada.

Material. Twenty nine specimens from samples EB7, EB9 and EB10.

Measurements. Length of valves between 0.5 to 0.7 mm, height of valves between 0.35 to 0.45 mm (Figs 2.19, 2.20, 2.21).

Diagnosis. As for the genus, which is monotypic.

Description. Carapace sub-ovate. Dorsal margin straight, free margins rounded. Large prominent anterodorsal horn-shaped spine that merges with the depression on the surface of the valves and is posterolaterally curved. Horn-shaped spine, length 0.15 mm and height 0.35 mm. Depression is broad and rounded-triangular posteriorly, but anterodorsally it is narrow and elongate. Valves swollen anteroventrally. No spines along the free margin of the valves. Valve surface smooth.

Discussion. *Faurella cartieri* resembles *Aechmina maccormicki* Copeland, 1973 from the Upper Ordovician of the Ellis Bay Formation by having a large prominent anterodorsal spine, but is distinguished by possessing depressions on the surface of the valves (see Figs 2.20, 2.21).

Occurrence. *F. cartieri* is recorded from the Juncliff and Parastro members of the Ellis Bay Formation.

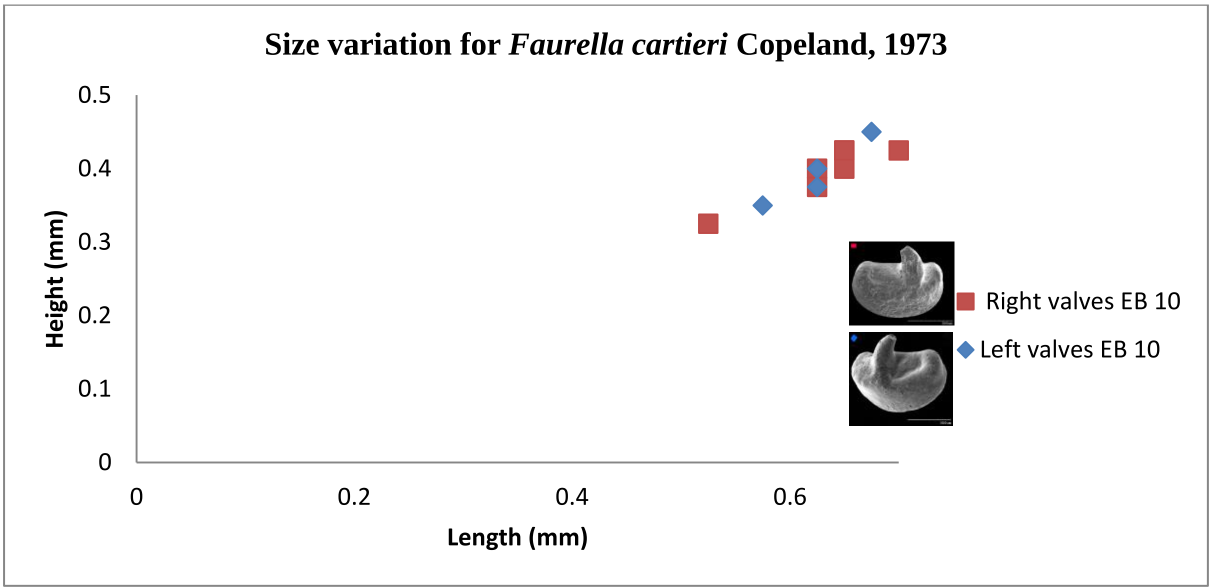

Figure 2.19. Size variation for *Faurella cartieri* Copeland, 1973 right and left valves, for sample EB10 from the Ellis Bay Formation.

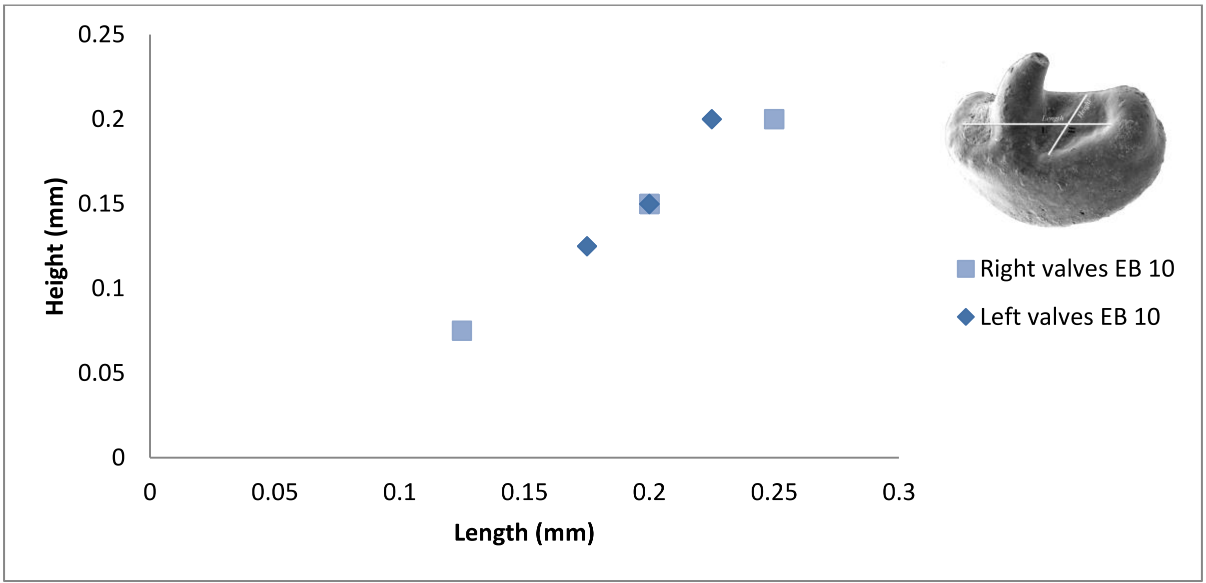

Figure 2.20. Size variation of the depression (see orientation top right) for *Faurella cartieri* Copeland, 1973 right and left valves, for sample EB10 from the Ellis Bay Formation.

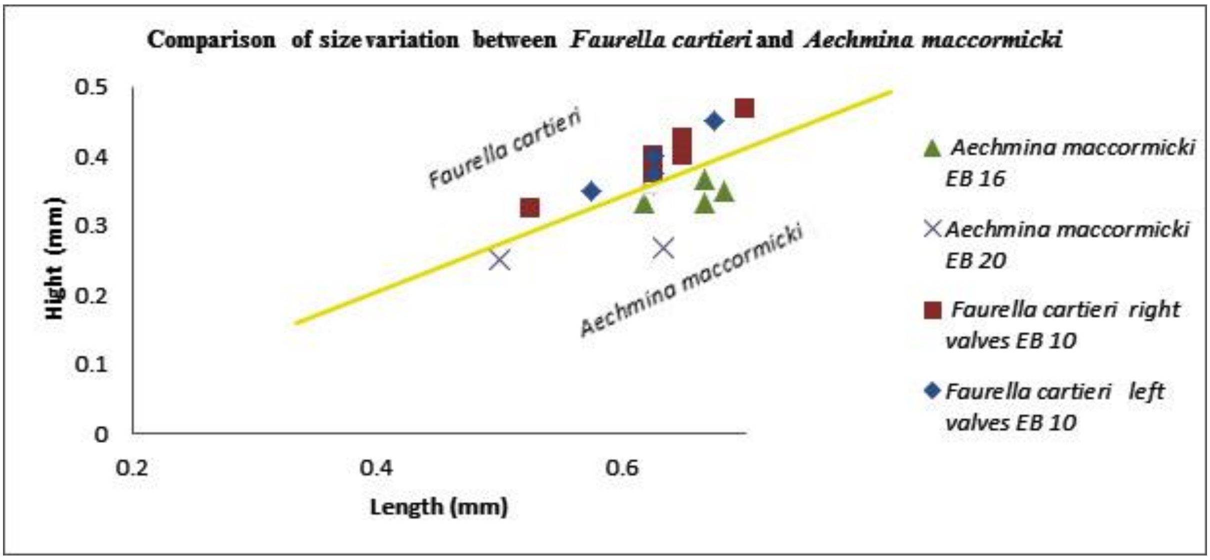

Figure 2.21. Comparison of size variation between *Faurella cartieri* Copeland, 1973 right and left valves, for sample EB10 and *Aechmina maccormicki* Copeland, 1973 right and left valves, for samples EB16 and EB20 from the Ellis Bay Formation. Yellow line is the separation between two different taxa (*Faurella cartieri* and *Aechmina maccormicki*).

Genus ***Spinigerites*** Schallreuter, 1980

Type species. *Primitiella*? *spiniger* Lindström, 1953; designated Schallreuter (1980c, p. 18), from Upper Ordovician mudstones of the Kope Formation, vicinity of Covington, Kentucky, USA.

Diagnosis. (Revised from Schallreuter, 1980) Carapace sub-rectangular, the two valves of the carapace are symmetrical. Dorsal margin straight from a lateral aspect, ventral margins weakly convex, anterior and posterior margins weakly flattened. Both valves have a small spine on the posteroventral area. Surface smooth or punctae.

Discussion. *Spinigerites* is clearly distinguished from *Primitiella* Ulrich, 1894, by its lack of domiciliar dimorphism, and by its possession of a posteroventral spine (see Schallreuter, 1980; Warshauer 1981, p. 889; Copeland 1970, p. 22; Lundin *et al*. 1995, p. 890).

Spinigerites differs from *Spinopleura* Schallreuter, 1968, by its lack of domiciliar dimorphism (see Schallreuter 1968, p. 133). *Pseudoprimitiella* Warshauer, 1981 may be a synonym of *Spinigerites*.

Occurrence. *Spinigerites* is recorded from the Upper Ordovician of the Point Pleasant Formation of Cincinnati (Bassler and Kellett 1934), the Maquoketa Shale of Missouri (Keenan 1951), the Kope Formation of south-western Ohio and northern Kentucky, USA, and from the

Upper Ordovician Ellis Bay Formation, Member 2, Anticosti Island, eastern Canada (Copeland 1973), Cautley district, northern England, UK (Williams *et al*. 2001b), and Viruan and Harjuan of Baltoscandia (Lindström 1953, Meidla 1996).

Spinigerites unicornis (Ulrich, 1879) Pl. 13, figs 5-8

1879 *Leperditia unicornis* sp. nov. Ulrich, p. 10, pl. 7, figs 4-4b.

1889 *Aprchites unicornis* (Ulrich); Ulrich, p. 50, pl. 9, figs 8-13.

1890 *Primitia unicornis* (Ulrich); Jones, p. 7, pl. 4, figs 8-13.

1890 *Primitia unicornis* (Ulrich); Ulrich, p. 649, pl. 43, figs 75-77.

1911 *Primitia unicornis* (Ulrich); Wade, p. 452, pl. 36, figs 4-5.

1926 *Primitia unicornis* (Ulrich); Ruedemann, p. 137, pl. 23, fig. 6.

1951 *Primitia unicornis* (Ulrich); Keenan, p. 568, Pl. 78, fig. 5, Pl. 79, figs 38-39.

1965 *Primitia unicornis* (Ulrich); Burr and Swain, p. 22, pl. 2, figs 21-25, Pl. 6, figs 1-10.

1970 *Primitia? huilensis* sp. nov.; Copeland, p. 22, pl. 4, figs 24-27.

1973 *Primitia unicornis* (Ulrich, 1879); Copeland, p. 23, pl. 9, figs 17-18.

1980 *Spinigerites unicornis* (Lindström); Schallreuter, p. 19-21, pl. 5, fig. 3, pl. 9, figs 1-4.

1982 *Pseudoprimitella*? sp. Warshauer and Berdan, p. H64, pl. 15, figs 19-20.

Holotype. Designated Copeland (1970, p. 22, pl. 4, figs 24, 27), a left valve, Geological Survey of Canada No. 24005, from the Vauréal Formation, Anticosti Island, eastern Canada.

Material. Approximately 128 specimens from samples EB3, EB4, EB5, EB6, EB7, EB8, EB9, EB10, EB14, EB16, EB17, EB18, EB19, EB20 and EB24.

Measurements. Length of valves between 0.55 to 0.75 mm, height of valves between 0.25 to 0.45 mm (Fig. 2.22).

Diagnosis. (Revised from Copeland 1973) Small posteroventral spine, its length being 0.04 mm and height 0.05 mm. Anterior area of valve more flattened than posterior area.

Description. Valves rectangular to sub-rectangular and non-sulcate, dorsal lateral outline straight, ventral outline gently convex. Anterior and posterior margin convex. Posteroventral spine near (but not at) the valve margin, its length being 0.04 mm and diameter 0.03 mm. Anterior area of valve more flattened than posterior area. Surface of valves smooth.

Discussion. *Spinigerites unicornis* from the Ellis Bay Formation is conspecific with those figured by Ulrich (1879) from Cincinnati and Ohio (see Copeland 1973, p. 23).

The scatter plot of length versus height for *S. unicornis* (Fig. 2.22) shows appreciable gaps between the data points. The absence of A-2 and smaller instars may indicate the presence of post-mortem winnowing of carapaces, as documented for other Ordovician ostracods (see Tinn and Meidla 2003).

Occurrence. Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members, Ellis Bay Formation, Anticosti Island, eastern Canada.

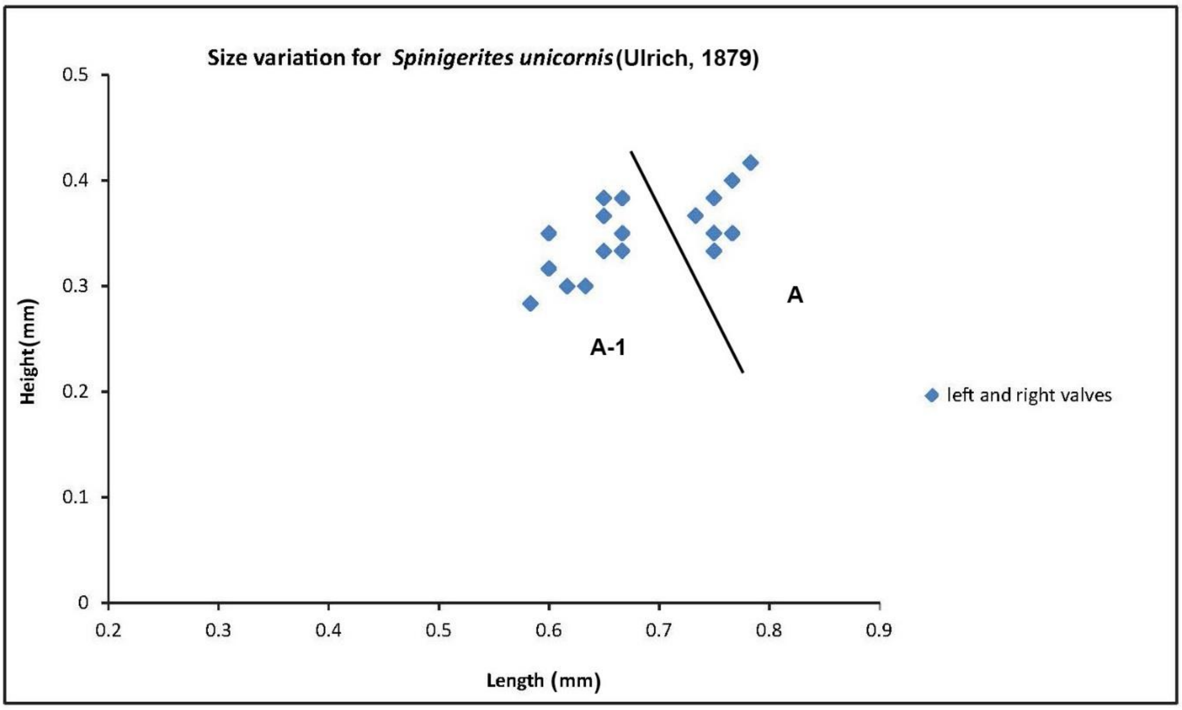

Fig 2.22. Size variation for *Spinigerites unicornis* (Ulrich, 1879), right and left valves, for samples EB4, EB16, EB19, EB20 and EB24 from the Ellis Bay Formation. Recognition of instars A-1 and adults A is based on morphological changes and not simply on an assessment of size variation.

Spinigerites sp. A Pl. 15, fig. 9

Material. Three specimens from sample, EB18.

Measurements. Length up to 0.7 mm and height up to 0.45 mm.

Description. Valves sub-rectangular. Adductorial sulcus is a weak depression in the mid-dorsal region and approximates in position to the mid-length of the valve: length 0.08 mm and height 0.13mm. Dorsal lateral outline straight, ventral outline convex from a lateral view: anterior and posterior lateral outlines are also convex. Posteroventral spine near (but not at) the valve margin. Length of spine about 0.1 mm and height about 0.06 mm. Surface of valves with small punctae. Dimorphism absent.

Discussion. Spinigerites sp. A differs from the type species *Spinigerites unicornis* (Ulrich, 1879) by its weak adductorial sulcus and punctate valves. The material from the Ellis Bay Formation may represent a new species, but there are insufficient specimens to allow a thorough diagnosis.

Occurrence. Lousy Cove Member, Ellis Bay Formation, Anticosti Island, eastern Canada.

Family **Schmidtellidae** Neckaja, 1966

Genus ***Schmidtella*** Ulrich, 1892

Type species. By original designation *Schmidtella crassimarginata* Ulrich 1892.

Other species. Schmidtella umbonata Ulrich, 1894, *Schmidtella transversa* Harris, 1957, *Schmidtella affinis* Ulrich, 1894, *Schmidtella subrotunda* Ulrich, 1894, *Schmidtella incompta* Ulrich, 1894, *Schmidtella latimarginata* Keenan, 1951.

Diagnosis. (Revised from Harris 1957; Levinson and Moore *in* Moore 1961; Burr and Swain 1965; and Warshauer and Berdan 1982). Lateral shape subovate, outline amplete and equilateral. Dorsal lateral outline strongly convex such that valves are umbonate. Valves non-sulcate or with a weak centrally positioned adductorial pit slightly anterior of mid-length. Valves possess a line marking the trace of the penultimate valve of the A-1 instar: the region from this line to the valve margin may be flattened. Valves smooth. Left valve overlapping the right valve ventrally.

Discussion. Warshauer and Berdan (1982, pl. 12, figs 19, 20) refigured the holotype (and a paratype) of the type species *Schmidtella crassimarginata. S. crassimarginata* possesses subovate valves, an amplete outline and is weakly umbonate dorsally. It has non-sulcate valves, but these are strongly flattened ventrally. There is no evidence for a limen or loculate dimorphism as in the superficially similar genus *Loculocavata* (cf. Lundin *et al*. 1996), and the dorsal hinge is simple. Warshauer and Berdan (1982) also discussed in detail the nomenclatorial history of the Schmidtellidae and noted that moult retention, used by some authors to suggest an affinity between schmidtellids and eridostracans (see for example, Henningsmoen 1953, Adamczak 1961), is rare and not diagnostic. Nevertheless, the presence of a line paralleling the valve margin and associated lateral flattening on the surface of the valves is a characteristic of *Schmidtella* and appears to represent the trace of the previous valve.

Schmidtella asymmetrica Harris, 1957, *Schmidtella excavata* Harris, 1957, and *Schmidtella brevis* Ulrich, 1894 do not belong in *Schmidtella* because they have loculate dimorphism (see Lundin *et al*. 1996, p.890).

Occurrence. Schmidtella is recorded from the Middle and Upper Ordovician of central Kentucky (Warshauer and Berdan 1982), Oklahoma (Harris1957), Anticosti Island (Copeland 1970, 1973), Iowa (Kay 1940), Missouri (Keenan 1951), Minnesota and Northern Iowa (Burr and Swain 1965).

Schmidtella sublenticularis (Jones, 1890)   Pl. 4, 5-7

1890 *Polycope sublenticularis* sp. nov. Jones, p. 550, pl. 21, figs 6a-b.

1928 *Schmidtella sublenticularis* (Jones); Bassler in Twenhofel. p. 342, (not figured).

1970 *Schmidtella sublenticularis* (Jones); Copeland, p. 22, pl. 4, fig. 23.

1973 *Schmidtella sublenticularis* (Jones); Copeland, pl. 1, figs 5-6; pl. 6, figs 21-22, 26-29.

1991 *Schmidtella sublenticularis* (Jones); Pitman, p. 250, pl. 14, fig. 2.

Holotype. Designated Jones (1890, p. 550, pl. 21, figs 6a-b), a left valve, the United States National Museum (USNM) No. 41299, from the Vauréal Formation, Anticosti Island, eastern Canada.

Diagnosis. (Revised from Copeland 1970) Lateral shape subovate, dorsum weakly umbonate, such that the dorsal extension of the valve above the hinge-line represents about 5% of the total valve height. Valves non-sulcate: no adductorial pit. Well-defined line on lateral surface of valves paralleling the valve margin at about ¾ distances from the dorsum and representing the trace of the valve of the A-1 instar. Valves unornamented.

Type-locality. Junction Cliff, GSC locality 76177 and Loon Lake-Bear Lake, GSC locality 76286. Paratypes GSC Nos. 31361, 31362. (GSC: Geological Society of Canada)

Material. 283 specimens from samples EB1, EB2, EB3, EB4, EB5, EB7, EB8, EB9, EB10, EB 11, EB 12, EB13, EB14, EB15, EB16, EB17, EB18, EB19, EB23 and EB24.

Measurements. Individual valves (both right and left) give a length range of 0.41-0.75 mm and a height range from 0.29 to 0.58 mm. (Figs 2.23, 2.24).

Description. Carapace subovate in lateral view, amplete, strongly umbonate. Dorsal margin weakly arched, free margin rounded ventrally. Equivalved, greatest length of the valve at mid-height. Cardinal angles obtuse, posterior angle smaller than anterior. Hinge straight and about one half the length of the valve. Surface of valves smooth. No dimorphism observed. No adventral or admarginal structure.

Discussion. This species was described from the Vauréal and the Ellis Bay formations by Copeland (1970, 1973). *S. sublenticularis* resembles *S. incompta* Ulrich, 1894 in having a slight curvature of the dorsal margin.

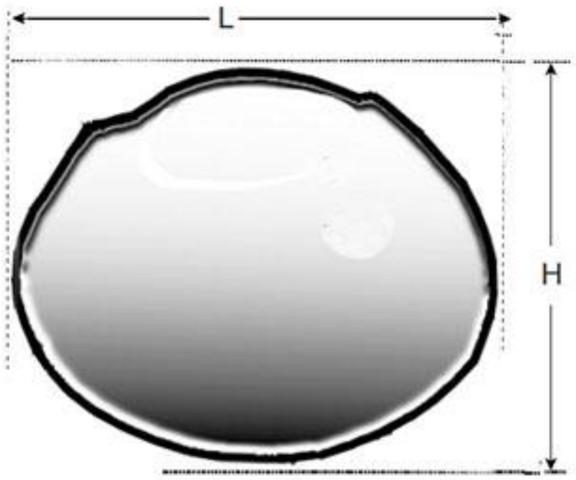

Figure 2.23. Parameters used for measurements of valves of *Schmidtella sublenticularis*. H, maximum valve height; L, maximum valve length.

Occurrence. Upper Ordovician Ellis Bay Formation, Fraise, Juncliff, Parastro and Lousy Cove members, Anticosti Island, eastern Canada.

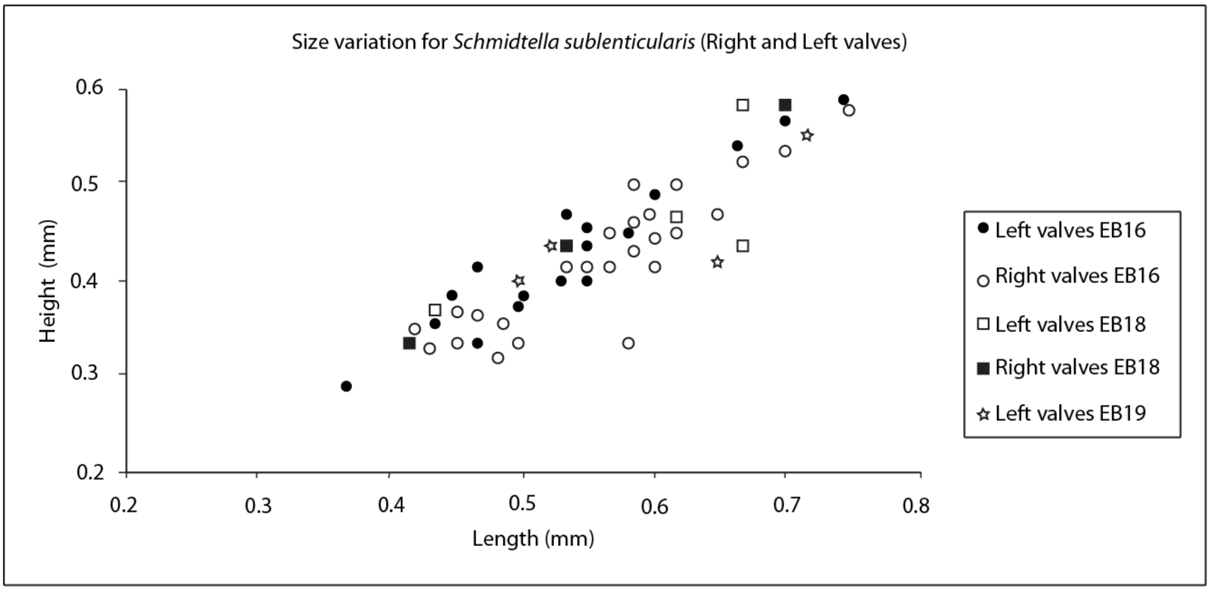

Figure 2.24. Size distribution for *Schmidtella sublenticularis* right and left valves, for samples EB16, EB18 and EB19 from the Ellis Bay Formation.

Schmidtella robervali Copeland, 1973 Pl. 4, figs 1-4

1973 *Schmidtella robervali* sp. nov. Copeland, pp. 30-39, pl. 1, figs 9-10, pl. 2, fig. 18, pl. 3, fig. 23, pl. 5, figs 1-2.

Holotype. Designated Copeland (1973, pl. 1, fig. 9), a left valve, Geological Survey of Canada No. 31365, from the Ellis Bay Formation, Anticosti Island, eastern Canada.

Diagnosis. (Revised from Copeland 1973) Lateral shape subovate, dorsum weakly umbonate, such that the dorsal extension of the valve above the hinge-line represents about 6% of the total valve height. Surface smooth, adductoral scar situated slightly above mid-point of valve, and either a smooth depression or circular pit appears above the scar, linked via small groove.

Material. More than two hundred specimens from samples EB1, EB3, EB5, EB5, EB8, EB9, EB10, EB11, EB13, EB14, EB15, EB16, EB17, EB18, EB20 and EB23.

Measurements. Individual valves (both right and left) give a length range of 0.5-0.83 mm and a height range from 0.43 to 0.70 mm (Fig. 2.25).

Description. Carapace subovate, weakly umbonate dorsally. An adductorial scar at the mid-point of the valve is joined to a circular pit in the mid-dorsal region via a narrow groove. Dorsal lateral outline convex. Equivalved. Cardinal angle at antero-dorsal greater than that at postero-dorsal. Hinge straight, sunken between dorsal elevations of both valves. Surface smooth.

Discussion. Schmidtella robervali is morphologically similar to *S. sublenticularis*, but differs by its distinct adductoral scar and circular pit.

In the present material, *Schmidtella sublenticularis* also differs from *S. robervali* in dimensions; *S. sublenticularis* is between 0.7 mm and 0.4 mm in length, 0.6mm and 0.3mm in height. *S. robervali is* between 0.8 mm and 0.5 mm in length, 0.7 mm and 0.4 mm in height. In addition, *Schmidtella sublenticularis* has a well-developed line on valves paralleling the valve margin at about ¾ distances from the dorsum and representing the trace of the A-1 valve, while this feature is absent or very weakly developed in *Schmidtella robervali.*

Occurrence. Upper Ordovician Ellis Bay Formation, Fraise, Juncliff, Parastro and Lousy Cove members, Anticosti Island, eastern Canada.

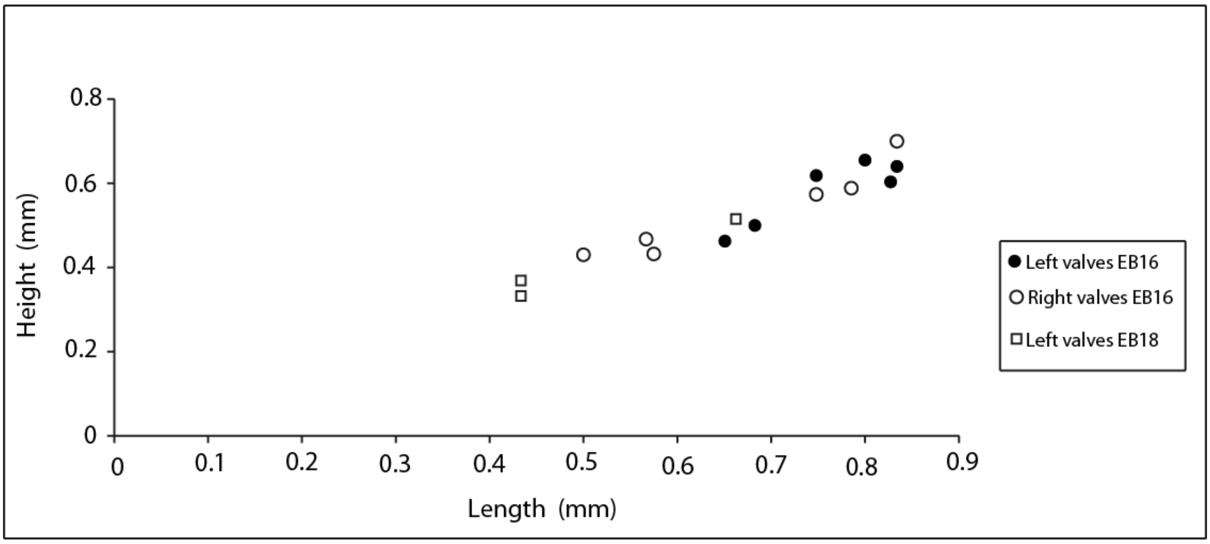

Figure 2.25. Size distribution for *Schmidtella robervali* right and left valves, for samples EB16 and EB18 from the Ellis Bay Formation.

Suborder **Paraparchitocopina** Gramm, 1975

Family **Jaanussoniidae** Schallreuter, 1971

Genus ***Hemiaechminoides*** Morris and Hill, 1952

Type species. By original designation; *Hemiaechminoides monospinus* Morris and Hill, 1952, from the Silurian of Tennessee, USA.

Diagnosis. (Adapted from Meidla 1996) Valves amplete, lateral shape oval or elongate oval. Dorsal margin short. Right valve overlaps the left along the free margin. Left valve is characterized by a prominent spine or boss centro- to postero-dorsally.

Discussion. The distinguishing feature of *Hemiaechminoides* is the shape and position of the dorsal boss or spine and the character of valve asymmetry. *Jaanussonia* Schallreuter, 1971 has been considered as a possible synonym of *Hemiaechminoides* (see. Meidla 1996, p. 99).

Occurrence. *Hemiaechminoides* has previously been recorded from the Upper Ordovician of Scotland (Mohibullah *et al*. 2010), Baltoscandia (Meidla 1996; Schallreuter 1971), the Silurian of North America (Morris and Hill 1952) and Bohemia (Přibyl 1988).

Hemiaechminoides sp. A   Pl. 7, figs 8-11

Material. Two carapaces from sample EB18.

Measurements. Length 0.31 mm, height 0.22 mm.

Description. Carapace oval in lateral shape and small (0.31 mm long). Asymmetrical valves, right valve weakly overlaps the left valve along the free margin. Dorsomedian boss. Hinge line straight. Smooth surface and non-sulcate.

Discussion. Hemiaechminoides sp. A differs from the type species *Hemiaechminoides monospinus* Morris and Hill, 1952 by having a boss, rather than a spine at the dorsal margin. *Hemiaechminoides* sp. A differs from *Hemiaechminoides* sp. of Mohibullah *et al*. 2014 by the position of the boss. This is the only record of *Hemiaechminoides* from the Ordovician of Anticosti Island.

Occurrence. Lousy Cove Member, Ellis Bay Formation, Anticosti Island, eastern Canada.

Genus ***Hemeaschmidtella*** Schallreuter, 1971

Type species. *Hemeaschmidtella exula* Schallreuter, 1971

Diagnosis. (Adapted from Schallreuter 1971) Valves are asymmetric, ventral outline convex and evenly rounded. Hinge line long and straight. The free margin of the right valve overreaches the left. The left valve is umbonate centro- and posterodorsally. The surface of the valves is smooth and non-sulcate.

Occurrence. *Hemeaschmidtella* is recorded from the Ordovician Viruan and Harjuan stages of Baltoscandia (Schallreuter 1971), and from the Pirgu to Porkuni stages of Estonia (Meidla 1996).

Hemeaschmidtella prinstaulus sp. nov. Pl. 15, figs 4-5

Derivation of name. From the Prinsta Member of the Ellis Bay Formation, Anticosti Island. Suffix 'ulus' means little.

Holotype. A carapace, Geological Museum of the University of Tartu, Estonia No. TUG 1741-5, from sample EB5 (Pl. 15, fig. 4), Juncliff Member, Ellis Bay Formation.

Topotype material. Four carapaces and three valves of *Hemeaschmidtella prinstaulus* specimens from sample EB1 and EB5.

Measurements. Length of valves ranges between 0.3 to 0.45 mm, height of valves ranges between 0.25 to 0.3 mm (Fig. 2.26).

Diagnosis. Hemeaschmidtella with a dorsal umbo on the left valve that is very high anteriorly. Asymmetrical carapace, the larger right valve overlaps the left valve along the free margin ventrally.

Description. Carapace ovate, dorsal umbo dome shaped, which has a length of 0.08 mm and a height of 0.06 mm. Hinge line straight. Valves asymmetrical: the larger right valve overlaps the left valve along the free margin ventrally. Anterior margin of valves more rounded than posterior margin. Valve surface smooth.

Discussion. *Hemeaschmidtella prinstaulus* can be distinguished from *Hemeaschmidtella exula* Schallreuter, 1971 from the Ordovician of Sweden by the shape and size of its umbo: *H. prinstaulus* has a high and tumid umbo. *H. prinstaulus* is similar to *Hemeaschmidtella* sp. 2 Meidla, 1996 from the Ordovician Rakvere Stage of Estonia in its overall carapace morphology, but *H. prinstaus* differs by its sturdy umbo on the left valve.

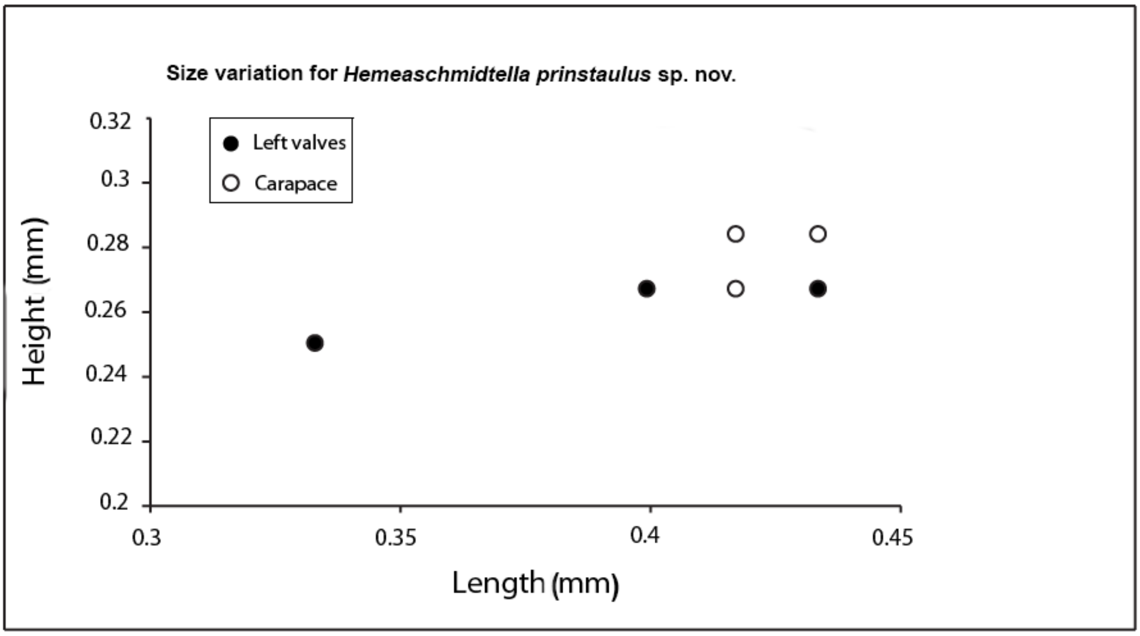

Figure 2.26. Size variation for topotype specimens of *Hemeaschmidtella prinstaulus* sp. nov. left valves and carapaces, for sample EB 16 from the Ellis Bay Formation.

Suborder **Leiocopina** Schallreuter, 1973b

Superfamily **Aparchitoidea** Jones (in Chapman), 1901

Family **Aparchitidae** Jones (in Chapman), 1901

Genus ***Baltonotella*** Sarv, 1959

Type species. By original designation (Sarv, 1959, p. 161) *Macronotella kuckersiana* Bonnema, 1909.

Diagnosis. (Adapted from Meidla 1996) Carapace sub-circular in lateral view with markedly asymmetrical valves, the larger right valve overlaps the smaller left valve along the entire free margin. The left valve may have admarginal structures consisting of spines or a row of denticles. Hinge line short and straight. Surface of valves may be reticulate, punctate or smooth.

Discussion. Sarv (1959) considered that the type species of *Baltonotella*, *B. kuckersiana* has 'pillar' structures (denticles) on the margin of its left valve, but not on the larger right valve. The right valve overlaps the left valve ventrally with straight contact, but the left valve overreaches the right valve dorsally. Meidla (1996) considered *Brevidorsa* a synonym of *Baltonontella*.

Occurrence. *Baltonotella* is very widespread, occurring in the Upper Ordovician of southwest Scotland (Williams *et al*. 2001a; Mohibullah *et al*. 2011), Oklahoma (Williams and Siveter 1996; Williams and Vannier 1995), Virginia (Kraft 1962), New York (Swain 1962), Pennsylvania (Swain 1962) and Kentucky (Warshauer and Berdan 1982), Ontario (Copeland 1965) and Baffin Island (Copeland 1977a, 2000) Canada, Baltocsandia (Sarv 1959; Meidla 1996, 2007) and from glacial erratic boulders of Late Ordovician age from the Isle of Sylt, Germany (Schallreuter 1989).

Baltonotella rotundus sp. nov.   Pl. 3, figs 7-8

Derivation of name. Latin '*rotundus*', spherical shape; with reference to the circular shape in lateral-view; gender masculine.

Holotype. A carapace, Geological Museum of the University of Tartu, Estonia No. TUG 1741-17, from sample EB17 (Pl. 3, fig. 7), Lousy Cove Member, Ellis Bay Formation.

Material. 69 specimens from samples EB7, EB9, EB10, EB14, EB15, EB17 and EB24.

Measurements. Length of valves ranges between 1.0 to 1.30 mm, height of valves between 0.8 to 1.0 mm (Fig. 2.27).

Diagnosis. Valves convex, hinge line straight and 0.55 mm long. Cardinal corners of left valve overlapping the right valve. Admarginal structures consist of a row of denticles on the left valve (see Table 2.9).

Description. Amplete and sub-circular lateral shape, shape high (L: H ratio 1.25-1.30). Hinge-line straight and length of hinge 0.55mm. Valves markedly convex. Asymmetrical, right valve larger and overlapping the left valve ventrally, left valve overreaching the right valve dorsally. Marginal ridge of the left valve. Valve surface smooth.

Discussion. For distinction of *B. rotundus* from other species of *Baltonotella* see Table 2.10.

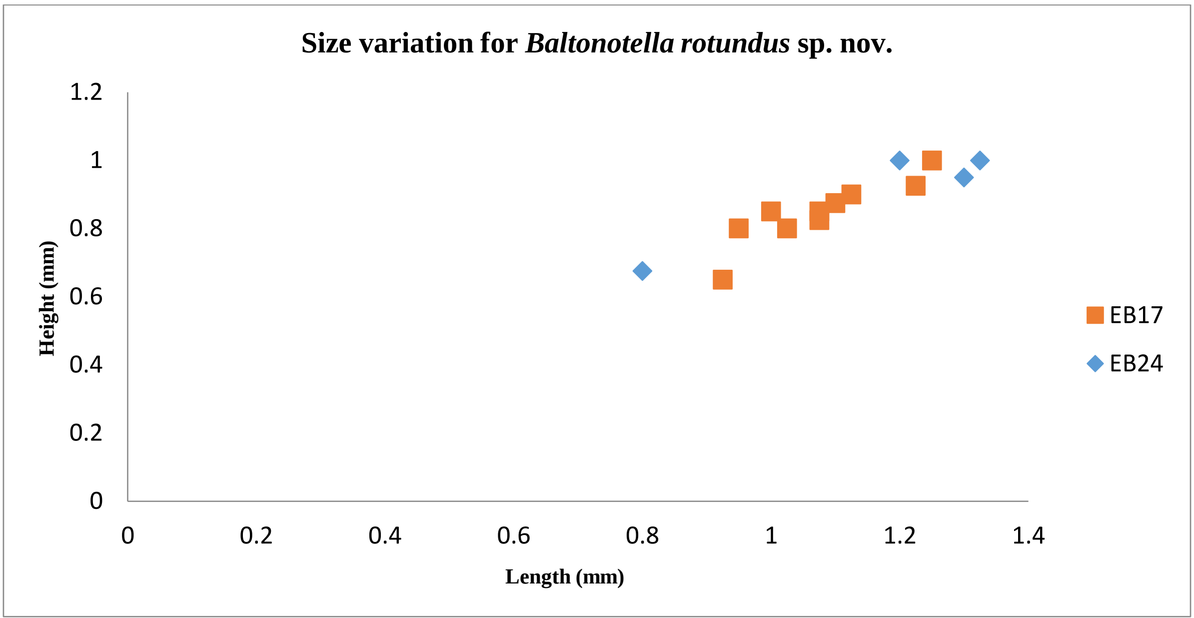

Figure 2.27. Size variation for *Baltonotella rotundus* sp. nov., right and left valves, for samples EB17 and EB24 from the Ellis Bay Formation.

Table 2.10. Species of *Baltonotella* from other localities compared with *Baltonotella rotundus* sp. nov. , *Baltonotella parsispinosa* and *Baltonotella* sp. A are from the Ellis Bay Formation.

Species name	Valve shape	Valve size L-H (mm)	Type of ornament	Type of marginal structures of the left valve	Important features	References
Baltonotella rotundus sp. nov.	Sub-circular	1.30-1.0	Smooth	Marginal ridge	Cardinal corners of left valve overlapping the right valve.	This study
Baltonotella circulantis (Harris, 1957)	Sub-circular	1.16-0.88	Smooth or punctate	Hollow structures	Marginal hollows surmounted by tubercles.	Williams and Vannier 1995
Baltonotella elegans (Harris, 1957)	Sub-circular	1.30-0.97	Punctate	Admarginal row of minute tubercles	Central smooth muscle spot.	Williams and Vannier 1995
Baltonotella ovalis (Harris, 1957)	Egg-shaped	1.13-0.90	Smooth	Marginal ridge	Marginal tubercles on the left valve absent.	Williams and Vannier 1995
Baltonotella parsispinosa (Kraft, 1962)	Sub-circular	1.19-0.81	Smooth	Low marginal ridge	Cardinal corners of the left valve with a spine.	This study
Baltonotella sarvi Berdan, 1988	Ovate	1.04-0.76	Punctate	No marginal structures	Hinge long about two-thirds of maximum length.	Berdan 1988
Baltonotella semenformis Sidaravichiene, 1992	Egg-shaped	1.05-0.8	Punctate	Marginal ridge	Very fine punctae on both valve surfaces. Smooth muscle spot.	Sidaravičiene 1992
Baltonotella mistica Sidaravichiene, 1992	Sub-circular	1.75-1.35	Smooth or punctate	Marginal ridge	Hinge line long.	Sidaravičiene 1992

Baltonotella kuckersiana (Bonnema, 1909)	Sub-circular	1.39-1.07	Punctate	Marginal ridge	Left valve with row of spines in the anteroventral part of the valve admargin. Smooth muscle spot.	
Baltonotella sp. A	Sub-circular	1.0-0.8	Smooth	Low marginal ridge	Valves strikingly convex and with admarginal structure.	This study

Baltonotella parsispinosa (Kraft, 1962) Pl. 2, figs 1-5

1957 *Aparchites fimbriatus* (Ulrich); Swain, p. 560-561, pl. 61, figs 13a-c.

1961 *Aparchites fimbriatus* (Ulrich); Swain *et al*., p. 351-353, text-fig. 2, pl. 46, figs 1a,b.

1962 *Aparchites parsispinosus* Kraft, sp. nov., p. 30, pl. 2, figs 12-13, pl. 5, figs 1, 2, text-figs 7g-h.

1962 *Aparchites fimbriatus* (Ulrich); Kraft p. 28-29, pl. 2, figs 1-11, pl. 3, fig. 3, text-figs 1g-e.

1962 *Aparchites fimbriatus* (Ulrich); Swain.

1965 *Aparchites fimbriatus*? (Ulrich); Copeland, p. 29, pl. 2, figs 5, 13.

1973 *Leperditella*? sp.; Copeland, pl. 2, fig. 19, pl. 6, fig. 20, pl. 9, fig. 15.

1977a *Leperditella*? sp.; Copeland, pl. 2, fig. 10.

1982 *Aparchites fimbriatus* (Ulrich); Copeland, pl. 9, fig. 1.

1995 *Baltonotella parsispinosa* (Kraft, 1962); Williams and Vannier, p. 12, figs 4.1- 4.7, pl. 1, figs 9, 11, 14.

1996 *Baltonotella parsispinosa* (Kraft, 1962); Williams and Siveter, pl. 2, fig. 10.

2011 *Baltonotella parsispinosa* (Kraft, 1962); Mohibullah *et al*., figs 4e, h.

2014 *Baltonotella parsispinosa* (Kraft, 1962); Mohibullah *et al*., pl. 3, figs 2, 3.

Holotype. Designated Kraft (1962, pl. 2, figs 12a-c), left valve, the United States National Museum in Washington D.C. No. 136581, from the Ordovician Edinburg Formation, Virginia, USA.

Material. More than 40 specimens from sample EB 14.

*Measurements***.** Length of valves ranges between 0.4 to 2.0 mm and height of valves ranges between 0.20 to 1.30 mm (Fig. 2.28).

Diagnosis. (Adapted from Mohibullah *et al*. 2014). *Baltonotella* with well-developed posterior and anterior cardinal spines, robust, spaced, marginal denticles on the left valve.

Description. Carapace smooth and non-lobate, sub-circular from a lateral aspect: shape high (L: H ratio 2.0-1.5). Valves amplete and lateral surfaces evenly convex. Hinge line straight and typically both valves meet dorsally at the same height; length of hinge about half the total length of the valves. Asymmetrical, the larger right valve overlapping the smaller left valve along the ventral, posterior and anterior margins. Left valve has stout, evenly spaced marginal denticles.

Discussion. For differences between *B. parspinosa* and other *Baltonotella* species see Table 2.9. As a result of differential preservation, the number of spaced marginal denticles on the left valve often differs and in some cases they can be completely eroded (Williams and Vannier 1995) (see Table 2.10).

Occurrence. *B. parsispinosa* are recorded from the Upper Ordovician of the lower part of the 'Ardwell Farm Formation', Girvan district, southwest Scotland (Williams *et al*. 2001a; Mohibullah *et al*. 2011, 2014), Bromide Formation of Oklahoma (Williams and Siveter 1996), Lincolnshire and Edinburg formations of Virginia (Kraft 1962), Hatter and Benner formations of Pennsylvania (Swain 1957, 1962), Day Point, Crown Point and Valcour formations of New York (Swain 1957, 1962), Decorah Formation of Minnesota (Swain *et al*. 1961), Silliman's Fossil Mount, Franklin district, Canada (Copeland 2000), Lower Esbataottine Formation, the Mackenzie district, Canada (Copeland 1982) and from the Liskeard Formation of Ontario, Canada (Copeland 1965).

Discussion. For distinction of *B. parsispinosa* from other species of *Baltonotella* see Table 2.9.

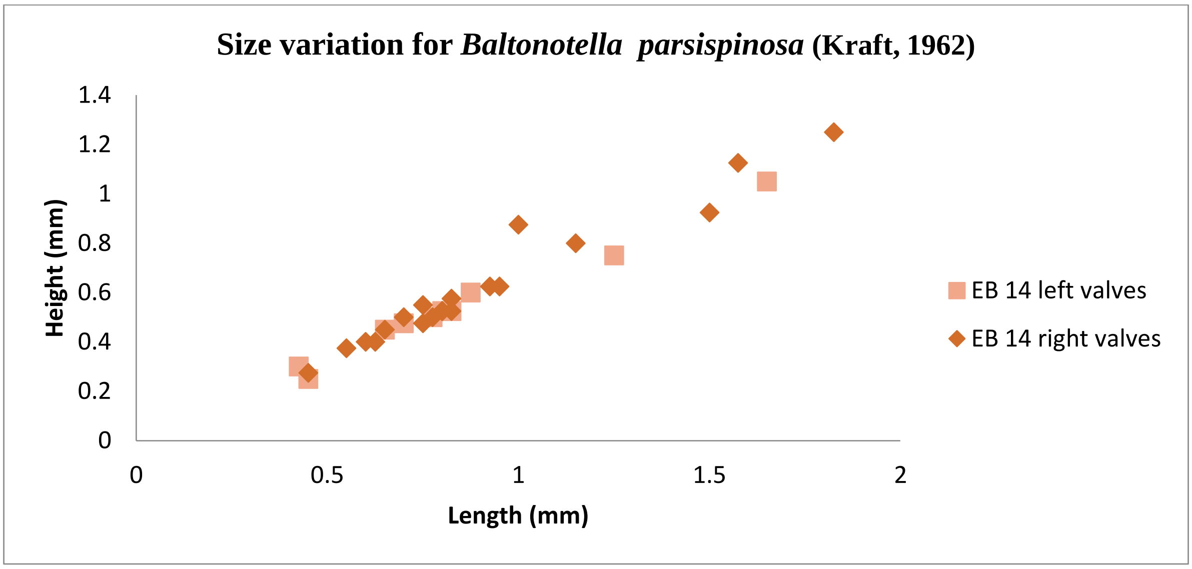

Figure 2.28. Size variation for *Baltonotella parsispinosa* (Kraft, 1962), right and left valves, for sample EB14 from the Parastro Member of the Ellis Bay Formation.

Baltonotella sp. A   Pl. 3, fig. 9, Pl. 22, fig. 7

Material. 5 specimens from samples EB10, EB17 and EB22.

Measurements. Length of valves between 0.65 to 0.8 mm, height of valves between 0.45 to 0.65 mm (Fig. 2.29).

Description. Sub-amplete and sub-circular, shape high to very high (L: H ratio between 1.23 to 1.45). No sulcation or lobation on the surface of valves. Asymmetrical valves, right valve larger and overlapping the left valve ventrally. Valves strongly convex. Hinge line straight and short, about 0.20 mm long. Valve surface smooth.

Discussion. *Baltonotella* sp. A differs from *Baltonotella rotundus* by its valves being strongly convex and by the morphology of its admarginal structure (see Table 2.10).

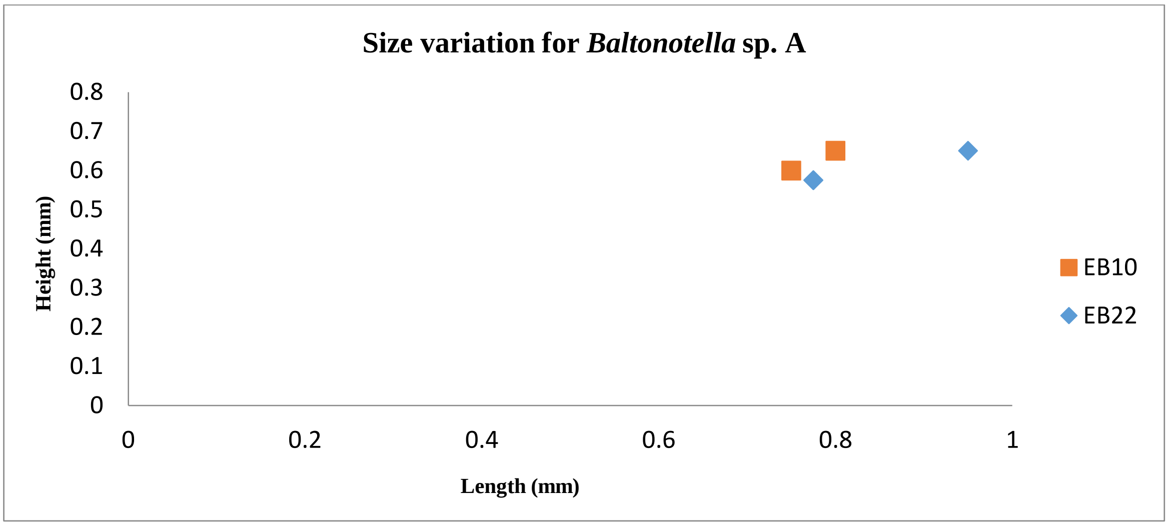

Figure 2.29. Size variation for *Baltonotella* sp. A, right and left valves, for samples EB10 and EB22 from the Ellis Bay Formation.

Suborder **Eridostracina** Adamczak, 1961

Family **Eridoconchidae** Henningsmoen, 1953

Genus ***Cryptophyllus*** Levinson, 1951

Type species. *Eridoconcha oboloides* Ulrich and Bassler, 1923; by original designation. From the Upper Ordovician Decorah shale of Minnesota, USA.

Diagnosis. (Adapted from Williams 1990 unpublished) Adults retaining several valve lamellae. Each lamella is demarcated by a narrow median groove, sometimes V-shaped. No admarginal ridges.

Discussion. *Cryptophyllus* is morphologically very similar to *Eridoconcha* Ulrich and Bassler, 1923 by retaining several lamellae, but *Eridoconcha* differs from *Cryptophyllus* by having a strong marginal ridge, and by having deep 'U' shaped grooves between the lamellae.

Occurrence. *Cryptophyllus* is recorded from Oklahoma (Harris 1957), Pennsylvania (Swain 1962), and Minnesota (Ulrich and Bassler 1923), Upper Ordovician of the USA. From West Newfoundland (Copeland 1977b), the District of Mackenzie (Copeland 1974) and Baffin Island (Copeland 1977a), Upper Ordovician of Canada. Possibly from the Upper Ordovician of Britain (Siveter 1978) and from the Upper Ordovician of Baltoscandia (Schallreuter 1977a, 1986; Sidaravičiene 1992).

Cryptophyllus punctoligos sp. nov.   Pl. 10, figs 1-3

Derivation of name. From the punctae of the surface of valves and 'oligos' (Greek) meaning few, gender feminine.

Holotype. A carapace, Geological Museum of the University of Tartu, Estonia No. TUG 1741-16, from sample EB16 (Pl. 10, fig. 2), Lousy Cove Member, Ellis Bay Formation.

Topotype material. One hundred and ninety four valves and carapaces from samples EB1, EB3, EB6, EB7, EB8, EB9, EB10, EB13, EB16, EB 17 and EB18.

Measurements. Length of valves between 0.3 to 0.6 mm, height of valves between 0.25 to 0.4 mm (Fig. 2.30).

Diagnosis. Two lamellae on the surface of each valve with surface punctae. Naupliconch with sub-central shallow sulcus.

Description. Amplete, with two retained lamellae. Shape high (L: H ratio 1.20 to 1.5). Dorsally umbonate, weak adductorial sulcus, ventrally the valves are weakly convex. No muscle scar. Hinge line short. Valves symmetrical. Surface punctae randomly distributed on both valves. Lacking any adventral structures.

Discussion. Cryptophyllus punctoligos can be distinguished from other Upper Ordovician *Cryptophyllus* species as indicated in Table 2.11.

Occurrence. Upper Ordovician Ellis Bay Formation, Fraise, Juncliff, Parastro and Lousy Cove members, Anticosti Island, eastern Canada.

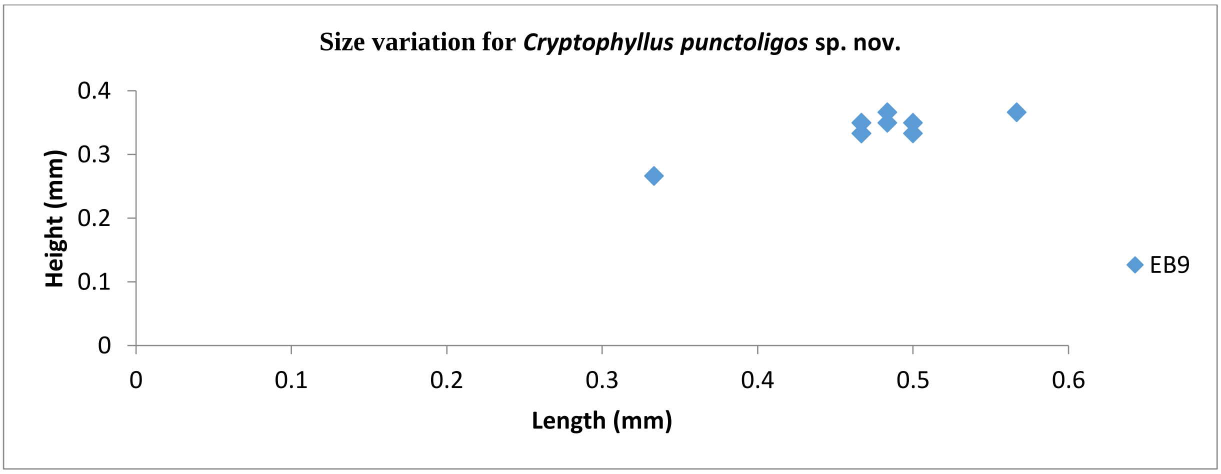

Figure 2.30. Size variation for *Cryptophyllus punctoligos* sp. nov., right and left valves, for sample EB9 from the Ellis Bay Formation.

Table 2.11. Comparison of Upper Ordovician species of *Cryptophyllus* with *C. bilamella* sp. nov. and *C. punctoligos* sp. nov. from the Ellis Bay Formation.

Species name	Lateral outline of carapace	Valve size L-H (mm)	Type of ornament	No. of lamellae on the surface of valve	Important features	References
Cryptophyllus punctoligos sp. nov.	Amplete	0.60-0.40	punctae	Two	Naupliconch with sub-central shallow sulcus and surface punctae.	This study
Cryptophyllus bilamella sp. nov.	Amplete	0.55-.35	Smooth	Two	Naupliconch without sulcus and surface smooth.	This study
Cryptophyllus gibbosum Harris, 1957	Amplete	0.98-0.79	Smooth	Three to five	Naupliconch with a low sub-central knob-like spine or a shallow sulcus.	Williams (unpublished 1990)
Cryptophyllus magnus (Harris, 1957)	Amplete	1.91-1.33	Smooth	Up to eleven	Internally there is a sulcament just below the midpoint of the umbonate area.	Williams (unpublished 1990)
Cryptophyllus? sp. nov.	Amplete	1.10-0.73	Smooth	Three	Last lamellae with imprint of previous lamellae superimposed on it.	Williams (unpublished 1990)
Cryptophyllus nuculopsis Harris, 1957	Amplete	0.70-0.52	Smooth	Up to eight	Lateral outline strongly asymmetric.	Williams (unpublished 1990)
Cryptophyllus gutta Schallreuter, 1968	Amplete	0.75-0.62	Smooth	Three to four	Lamellae flattened and slightly concave.	Sidaravichiene (1992)

Cryptophyllus bilamella sp. nov. Pl. 10, figs 4-5

Derivation of name. From the retention of two lamella on the surface of the valve.

Holotype. A carapace, Geological Museum of the University of Tartu, Estonia No. TUG 1741-7, from sample EB7 (Pl. 10, fig. 5), Juncliff Member, Ellis Bay Formation.

Topotype material. Seventy specimens from sample EB1, EB3, EB6, EB7, EB8, EB9, EB10, EB11, EB13, EB15, EB16, EB17 and EB18.

Measurements. Length of valves up to 0.55 mm, height of valves up to 0.35 mm.

Diagnosis. Retention of two lamellae and smooth surface. Naupliconch without sulcus.

Description. Amplete and sub-ovate lateral shape, two retained lamellae. Shape high (L: H ratio 1.57). Equivalved, naupliconch without sulcus. Ventral outline convex, and posterior and anterior margins arched.

Discussion. Cryptophyllus bilamella differs from *C. punctoligos* by the absence of surface punctae and by possessing a naupliconch without a sulcus. For specific differences from other *Cryptophyllus* species see Table 2.11.

Occurrence. Upper Ordovician Ellis Bay Formation, Fraise, Juncliff, Parastro and Lousy Cove members, Anticosti Island, eastern Canada.

Order **Podocopida** Sars, 1866

Suborder **Metacopina** Sylvester-Bradley, 1961

Family **Steusloffinidae** Schallreuter, 1984

Genus ***Medianella*** Neckaja, 1966

Type species. *Bythocypris aequa* Stumbur, 1956; by original designation. From the Upper Ordovician of Estonia.

Diagnosis. (Modified from Neckaja, 1966). Elongate to sub-elliptical valves from a lateral view. Asymmetrical: larger left valve overlaps the right valve along the ventral margin. Non-sulcate or very weakly sulcate. Valve surface smooth.

Discussion. I follow Meidla (1996, p.124) and Mohibullah *et al*. (2014, p. 24) in assigning *Medianella* to the Steusloffinidae. According to Schallreuter and Hinz-Schallreuter (1998, 2011) *Medianella* differs from typical steusloffinids by lacking spines or ridges on its valve surface, by having a shorter hinge line, and a smooth surface.

Longiscula Neckaja, 1958, resembles *Medianella* in possessing a short hinge line, but it is distinguished by its sub-ovate to sub-triangular shape in lateral view, weak asymmetrical carapace and different overlap.

Occurrence. Upper Ordovician and Lower Silurian strata of Baltoscandia (Meidla 1996), Öjlemyrflint boulders, Germany (Schallreuter and Hinz - Schallreuter 2011), questionably from the Ordovician of Czech Republic (Schallreuter and Kruta 2001), questionably from the Ordovician of Argentina (Salas, 2002), the British Isles (Vannier *et al*. 1989), Upper Ordovician strata of Scotland (Mohibullah *et al*. 2010, 2014) and Upper Ordovician of Poland (Olempska 1994).

Medianella meidlai sp. nov. Pl. 14, figs 1-5

Derivation of name. After Professor Tõnu Meidla of the University of Tartu, Estonia, for his significant contribution to the study of lower Palaeozoic ostracods.

Holotype. A carapace, Geological Museum of the University of Tartu, Estonia No. TUG 1741-8, from sample EB8 (Pl. 14, fig. 1), Juncliff Member, Ellis Bay Formation.

Topotype material. More than 50 specimens from samples EB1, EB3, EB7, EB8, EB9, EB10, EB11, EB13, EB18 and EB24.

Measurements. Length of valves up to 0.65 mm and height of valves up to 0.40 mm.

Diagnosis. Outlines of anterior and posterior margins triangular, dorsal and ventral margins straight and parallel. Left over right valve overlap is limited to the ventral margin. Non-sulcate.

Description. Valves amplete, elongate and elliptical in lateral view. Shape high (L: H ratio 1.6). Non-sulcate and non-lobate. Dorsal and ventral margins straight and parallel to each other; lateral outlines of anterior and posterior margins triangular. Greatest length recorded at a level slightly below mid-height. Asymmetrical valves, larger left valve overlaps the right valve along the ventral margin only. Valve surface smooth.

Discussion. For specific differences from other described species see Table 2.12.

Occurrence. Upper Ordovician Ellis Bay Formation, Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members, Anticosti Island, eastern Canada.

Table 2.12. Species of *Medianella* compared with *Medianella meidlai* sp. nov. from the Ellis Bay Formation.

Species name	Length and height of the valve (mm)	Shape (in ventral view)	Ornament	Important features	Key reference
Medianella aequa (Stumbur, 1956)	1.0-0.53 (RV)	Elongate	Smooth	Larger left valve overlaps the right valve. Anterior rounded and ventrally slightly curved. Interior stop ridges not seen.	Meidla 1996
Medianella longa (Stumbur, 1956)	1.6-0.76 (RV)	Elongate	Smooth	Larger left valve overlapping the smaller right valve along the anterior and ventral margins. Interior stop ridges not seen.	Meidla 1996
Medianella longa (Stumbur, 1956)	1.30-0.67	Elongate	Smooth	Larger left valve overlaps the right valve along the posterior, anterior and ventral margins. Interior stop ridges absent.	Mohibullah *et al*. 2010
Medianella intecta (Stumbur, 1956)	1.5-0.8 (RV)	Sub-circular	Smooth	Larger left valve overlaps the right valve only along the ventral margin. Interior stop ridges not seen.	Meidla 1996
Medianella blidenensis (Gailite, 1975)	1.2-0.62 (RV)	Sub-circular	Smooth	Two interior stop-ridges present.	Meidla 1996
Medianella ? sp. nov.?	1.56-0.80	Elongate	Smooth	Distinct sulcament and unequally sized stop-pegs.	Schallreuter and Hinz-Schallreuter 2011
Medianella meidlai sp. nov.	0.65-0.40	Sub-circular	Smooth	Lateral outlines of anterior and posterior margins triangular, dorsal and ventral margins parallel and straight.	This study
Medianella ? sp.	1.32-0.63	Sub-circular	Smooth	Elongate carapace (L/H ratio is more than 2) with weak sulcament. Stop pegs absent.	Schallreuter and Kruta (2001, 1996)
Medianella ? *pudica* sp. nov.	1.10-0.60	Elongate	Smooth	Greatest width and height in posterior part. Two stop pegs present.	Olempska 1994
Medianella? sp. 1	0.63-0.41	Sub-elongate	Smooth	Sub-elongate carapace (L/H ratio is less than 2), stop pegs absent.	Olempska 1994
Medianella? sp. 2	1.13-0.45	Elongate	Smooth	Elongate carapace (L/H ratio is more than 2.5). And parallel dorsal and ventral margins.	Olempska 1994

Family **Longisculidae** Neckaja, 1966

Genus ***Longiscula*** Neckaja, 1958

Type species. *Longiscula arcuaris* Neckaja, 1958; by original designation. From the Middle Ordovician *Echinosphaerites* beds, north-western Russia.

Diagnosis. (Adapted from Meidla 1993) Carapace sub-elliptical to sub-triangular in lateral view, elongate to oval with pointed ends in dorsal view. Asymmetrical valves, the larger left valve overlaps the smaller right valve along the ventral and anterodorsal margins. The surface of the valves is smooth or granulated. Non-sulcate.

Discussion. Longiscula is widespread in the Baltic region, but this is the first record from Anticosti Island.

Pullvillites Öpik, 1937, resembles *Longiscula*, but can be distinguished by its relatively high valve shape, elongate-triangular right valve, and the right valve overlap of the left valve along the ventral margin.

Occurrence. Longiscula has previously been recorded from the Upper Ordovician of Scotland (Mohibullah *et al*. 2010), Baltoscandia (Meidla 1993, 1996; Nõlvak *et al.* 1995; Tinn and Meidla 1999), Podolia, China, Uzbekistan, Altai (Melnikova and Michailova 1999; Melnikova 2010; Meidla 1993), east central Iran (Ghobadi Pour *et al*. 2006), Argentina (Salas 2002); Early Silurian strata of Baltoscandia, Uzbekistan, Eastern Siberia, Tian-Shan, Urals and Altai (Meidla 1986, 1993; Melnikova and Michailova 1999; Melnikova 1986; Neckaja 1966).

Longiscula subcylindrica (Ulrich, 1889) Pl. 18, figs 1-7

1889 *Leperditia subcylindrica* Ulrich, p. 49, pl. 9, figs 4a-b.

1970 “*Bythocypris” subcylindrica* (Ulrich, 1889); Copeland, p. 23, pl. 4, fig. 26.

1973 “*Bythocypris” subcylindrica* (Ulrich, 1889); Copeland, p. 32, pl. 2, fig. 1, p. 36, pl. 4.

1974 “*Bythocypris”* sp. cf. *“B.” cylindrica* (Hall, 1871); Copeland, p. 90, pl. 8, figs 1-3.

1989 *Phelobythocypris* sp.; Copeland, p. 64, pl. 3, fig. 7.

Holotype. Designated Ulrich (1889, pl. 9, figs 4a-b), a left valve, the United States National Museum No. 82375, from Story Mountain, Manitoba, eastern Canada.

Material. 443 specimens from samples EB1, EB 2, EB 3, EB6, EB7, EB8, EB9, EB10, EB 11, EB 12, EB13, EB14, EB15, EB16, EB17, EB18, EB 19 and EB24.

Measurements. Length of valves between 0.45 to 0.95 mm, height of valves between 0.25 to 0.45 mm (Fig. 2.31).

Diagnosis. Dorsal margin is convex**,** with shorter and steeper anterior slope. Ventral outline weakly concave in the adult but nearly straight in juveniles. Posterior and anterior outline rounded, posterior end more obtrusively.

Description. Carapace is sub-elliptical, non-sulcate and non-lobate. Dorsal outline is convex, posterior and anterior outline rounded, posterior end more obtrusively, and in lateral outline the ventral margin is weakly concave**.** Asymmetrical valves; the larger left valve overlaps the smaller right valve along the ventral and anterodorsal margins, but only weakly overlaps along the anterior and posterior margins. Surface may be smooth or granulated.

Discussion. For distinction of *Longiscula subcylindrica* from other species of *Longiscula* see Table 2.13.

Table 2.13. Comparison of Upper Ordovician species of *Longiscula* with *Longiscula subcylindrica* sp. nov. from the Ellis Bay Formation.

Species name	**Length and height of valve (mm) L.**	**Shape**	**Type of ornament**	**Important features**	**References**
Longiscula obliqua Abushik and Sarv, 1993	0.74-0.35	Elongate-triangular	Smooth	The dorsal margin is convex and the ventral margin straight.	Meidla 1996
Longiscula perfecta Meidla, 1993	1.60-0.79	Sub-ovate	Smooth	The dorsal margin is irregularly curved, with shorter and steeper anterior slope.	Meidla 1996
Longiscula tersa (Neckaja, 1966)	1.2-0.60	Elongate	Smooth	The posterior valve margin is less rounded than the anterior.	Meidla 1996
Longiscula porrecta Stumbur in Meidla, 1993	2.45-1.14	Trapezoidal	Smooth	The dorsal margin is almost straight. Shape is trapezoidal.	Meidla 1996
Longiscula impercepta Meidla, 1996	1.25-0.71	Elongate	Smooth	The anterior and posterior margins are rounded.	Meidla 1996
Longiscula ovata Neckaja, 1966	1.0-0.57	Sub-ovate	Smooth	The dorsal margin is curved and the ventral margin concave. Both the anterior and posterior margin are more broadly rounded.	Meidla 1996
Longiscula sp. Mohibullah *et al*. 2010	0.63-0.28	Sub-ovate	Smooth	Asymmetrical valves, but only weakly overlaps along the anterior and posterior margins.	Mohibullah et al. 2014
Longiscula subcylindrica sp. nov.	0.95-0.45	Elongate-subcylindrical	Smooth	Dorsal margin is intermittently convex, with shorter and steeper anterior slope. Posterior and anterior outline rounded	This study

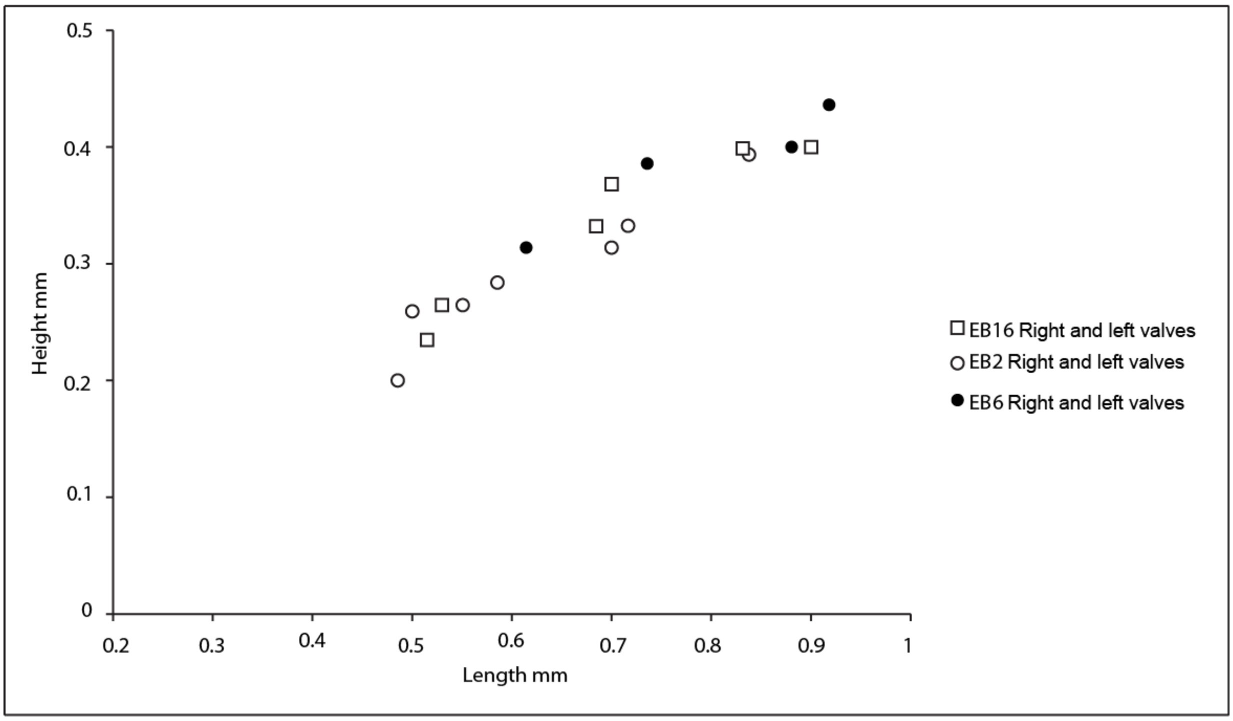

Figure 2.31. Size variation for *Longiscula subcylindrica*, right and left valves, for samples EB2, EB6 and EB16 from the Ellis Bay Formation. The absence of small instars may reflect an energetic marine environment subject to winnowing.

Occurrence. From the Upper Ordovician of the Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Genus ***Aviacypris*** Schallreuter, 1977

Type species. *Aviacypris avia* Schallreuter, 1977; by original designation. From an Upper Ordovician Öjlemyrflint boulder, NW-Germany.

Diagnosis. (Revised from Schallreuter 1977) Valve elongate-elliptical, small to medium-sized and narrowing in height at mid-length. Shape varies between moderately high to very long (L: H ratio between 1.65 to >2.05). Hinge line straight and long, but not corresponding to the greatest length of the valve. Posterior end of valve higher than that of anterior. Anterior end symmetrically rounded and flattened anterocentrally. Ventrally gently concave. Left valve with duplicature and lacking stop-pegs. Valve surface smooth.

Discussion. *Aviacypris* resembles *Bulbosclerites* Meidla, 1996 (pl. 23, figs 7-8) from the Upper Ordovician of Estonia, but can be distinguished by possessing a duplicature and by lacking stop-pegs in the left valve.

Schallreuter and Hinz-Schallreuter (2011) described three new species belonging to *Aviacypris* from Öjlemyrflint erratic boulders of Late Ordovician age from Gotland (*A. planta, A. coartata and A. truncate*).

Ocurrence. *Aviacypris* has been recorded from Upper Ordovician Öjlemyrflint boulders, Germany (Schallreuter 1977; Schallreuter and Hinz-Schallreuter 2011).

Aviacypris ichnos sp. nov.   Pl. 17, fig. 7

Derivation of name. From Greek '*ichnos*' meaning footstep; alluding to the shape of the valve, gender masculine.

Holotype. A carapace, Geological Museum of the University of Tartu, Estonia No. TUG 1741-9, from sample EB9 (Pl. 17, fig. 7), Juncliff Member, Ellis Bay Formation.

Topotype material. Eighty four valves and fifteen carapaces from samples EB1, EB6, EB7, EB8, EB9, EB10, EB13, EB14, EB16, EB17 and EB24.

Measurements. Length of valves between 0.6 to 0.8 mm, height of valves between 0.35 to 0.45 mm (Figs 2.32, 2.34).

Diagnosis. Posterior and anterior margin rounded. Shape moderately high (L: H ratio between 1.7 to 2). Hinge line long and straight.

Description. Sub-elongate valves. Hinge line long and straight and length about 0.32 mm. Dorsal margin straight, ventral margin weakly concave. Posterior margin rounded and anterior gently rounded. Marginal surface posteroventrally and anteroventrally evenly flattened. Ventral outline concave. Valve surface smooth.

Discussion. *Aviacypris ichnos* differs from the type species *A. avia* Schallreuter, 1977 form the Upper Ordovician of Germany by its sub-elongate shape and posterior and anterior margin being rounded. Also, the hinge line of *A. ichnos* is shorter than other species of *Aviacypris see* Table 2.14.

A. coartata Schallreuter and Hinz-Schallreuter, 2011 and *A. truncata* Schallreuter and Hinz-Schallreuter, 2011, from the Upper Ordovician of Gotland are very similar to *A. ichnos*, which can be distinguished from both of them by the valves being highest anteriorly and having a longer hinge line (about 0.32 mm).

Occurrence. From the Upper Ordovician of the Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Aviacypris tarsos sp. nov. Pl. 17, figs 1-6

1973 "*Bathocypris" lindstroemii* ? Jones; Copeland, pl. 1, fig. 3; pl. 6, fig. 7.

Derivation of name. From Greek '*tarsos*' meaning edge of the eyelid; alluding to the valve shape, gender feminine.

Holotype. A carapace, Geological Museum of the University of Tartu, Estonia No. TUG 1741-17, from sample EB17 (Pl. 17, fig. 5), Lousy Cove Member, Ellis Bay Formation.

Topotype material. More than one hundred and seventy valves and carapaces, from samples EB3, EB6, EB7, EB8, EB9, EB10, EB13, EB14, EB15, EB17, EB18, EB23 and EB24.

Measurements. Length of valves range between 0.6 to 0.8 mm, height of valves between 0.2 to 0.4 mm (Fig. 2.33, 2.34).

Diagnosis. Shape very long (L: H ratio 2 to 2.30). Posterior margin unequally rounded, anterodorsal flattened and anteroventral rounded. Length of hinge line about 0.75 mm. Duplicaticure distinct.

Description. Elongate shape. Hinge line long and straight. Dorsal margin straight, ventral margin weakly concave and posterior and anterior gently rounded. Marginal surface posterventrally and anteroventrally flattened. 'Vecon' very distinct. Valve surface smooth.

Discussion. For distinction of *A. tarsos* from other species of *Aviacypris* see Table 2.14.

Occurrence. From the Upper Ordovician of the Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Table 2.14. Comparison of Upper Ordovician species of *Aviacypris* with *Aviacypris ichnos* sp. nov., *Aviacypris tarsos* sp. nov., and *Aviacypris* sp. A from the Ellis Bay Formation.

Species name	**Lateral outline of carapace**	**Valve size L:H (mm)**	**Type of ornament**	**Important features**	**References**
Aviacypris ichnos sp. nov.	Sub-elongate	1.7-2.0	Smooth	Hinge line long and straight.	This study
Aviacypris tarsos sp. nov.	Elongate	2-30	Smooth	Anterodorsal margin flattened and anteroventral rounded.	This study
Aviacypris sp. A	Elongate	2	Smooth	Posterior rounded	This study
Aviacypris avia Schallreuter, 1977	Elongate-elliptical	> 2.05	Smooth	Weakly epicline dorsum.	Schallreuter (1977b)
Aviacypris coartata Schallreuter and Hinz-Schallreuter, 2011	Elongate	2.41-2.44	Smooth	Ventral margin concave.	Schallreuter and Hinz- Schallreuter (2011)
Aviacypris planta Schallreuter and Hinz- Schallreuter, 2011	Elongate	2.66-2.74	Smooth	Posterior end of valves located close to dorsal margin.	Schallreuter and Hinz- Schallreuter (2011)
Aviacypris truncata Schallreuter and Hinz-Schallreuter, 2011	Elongate	2.5-2.6	Smooth	Anterodorsally truncated.	Schallreuter and Hinz- Schallreuter (2011)

Aviacypris sp. A   Pl. 17, fig. 8

1974 *Bairdiacypris* sp. Copeland, p. 91, pl. 8, fig. 13.

Material. About 36 valves and one carapace from samples EB3, EB7, EB9, EB10, EB14, EB16, EB17, EB18.

Measurements. Length 0.6 mm, height 0.3 mm.

Description. Elongate valve. Dorsum straight and gently concave ventrally. Hinge line straight. Posterior and anterior margins evenly rounded. Lateral valve outline weakly concave midway along the anteroventral margin. Valve surface smooth.

Discussion. The Ellis Bay specimens are weakly concave midway along the anterovental margin, and the duplicature is unclear, whereas in *A. avia* valves are concave ventrally and the duplicature is very distinct see Table 2.14.

Occurrence. From the Upper Ordovician of the Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

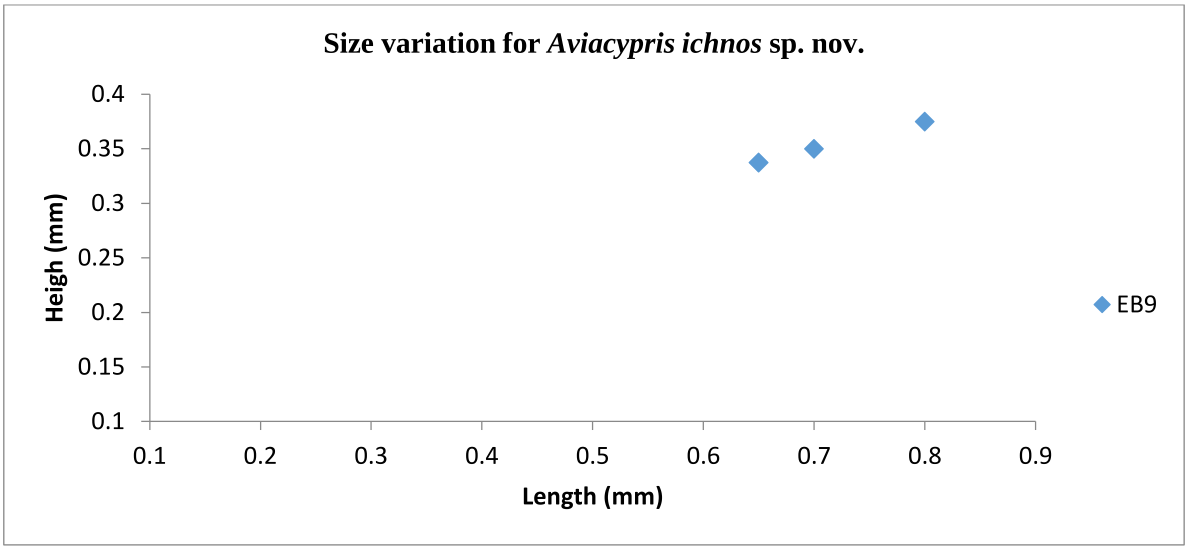

Figure 2.32. Size variation for *Aviacypris ichnos* sp. nov., right valves, for sample EB9 from the Ellis Bay Formation.

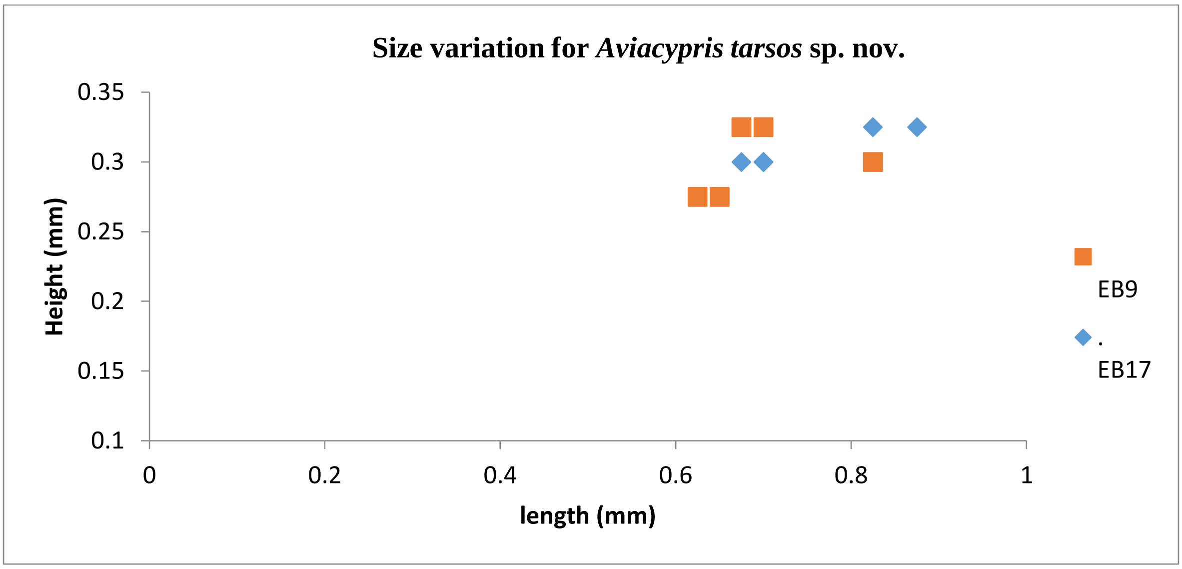

Figure 2.33. Size variation for *Aviacypris tarsos* sp. nov., right valves, for samples EB9 and EB17 from the Ellis Bay Formation.

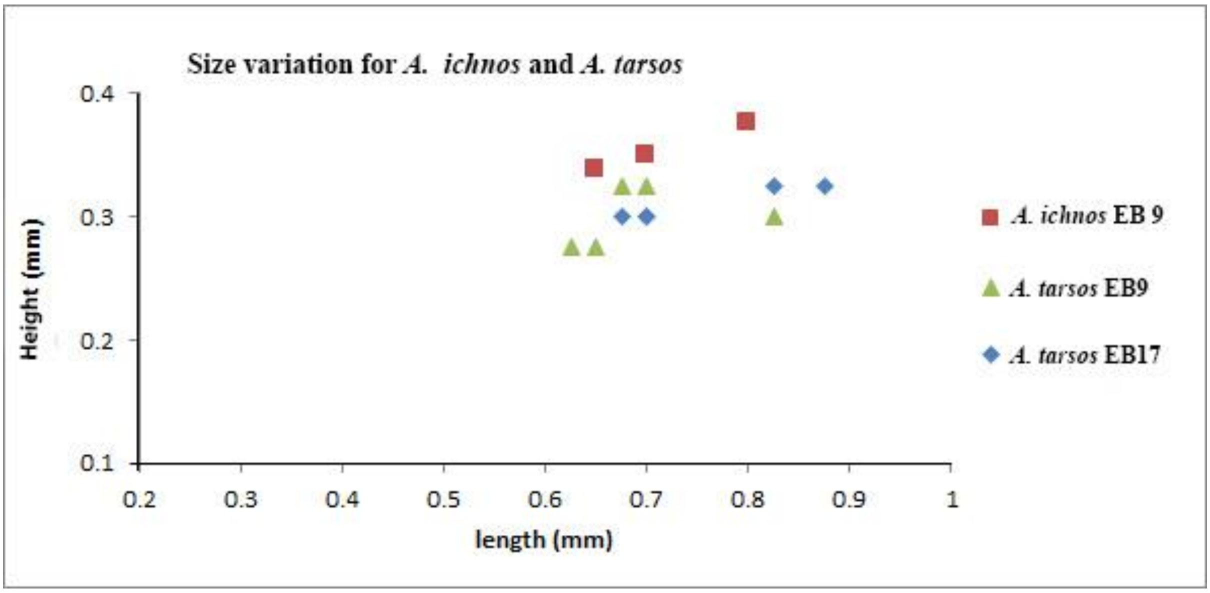

Figure 2.34. Size variation for *Aviacypris tarsos* sp. nov. and *Aviacypris ichnos* sp. nov., right valves, for samples EB9 and EB17 from the Ellis Bay Formation.

Superfamily **Bairdiocyprioidea** Shaver, 1961

Family **Krausellidae** Berdan, 1961

Genus ***Krausella*** Ulrich, 1894

Type species. Krausella inaequalis Ulrich, 1894; by original designation. From the Upper Ordovician Platteville Formation, Dixon, Illinois, North America.

Diagnosis. (After Mohibullah *et al*. 2014) Carapace elongate, dorsal lateral outline convex. Asymmetrical valves, the larger left valve overlaps the smaller right valve along the ventral margin and weakly overlaps the dorsal margin at the cardinal corners. Dorsum moderately epicline. Right valve has a short posteroventral spine; left valve lacks spine. Valves smooth and non-sulcate.

Discussion. *Krausella* is widespread in North America and Baltoscandia. *Krausella* includes species that occur in shallow shelf and deeper shelf settings (see Copeland 1982). The genus *Rayella* Teichert, 1939 resembles *Krausella* by its overlap of the right valve by the left valve dorsally towards the anterocardinal angle and its possession of the stout spine, but it differs from *Krausella* by very weak overlap of the right valve to the left valve dorsally.

Occurrence. Krausella has been recorded from the Ordovician of Scotland (Williams *et al*. 2001a; Mohibullah *et al*. 2010, 2011, 2014), Oklahoma (Harris 1957; Williams and Siveter

1996), Kentucky (Warshauer and Berdan 1982), Virginia (Kraft 1962), New York (Swain 1962), Pennsylvania (Swain 1962), Iowa, Minnesota (Kay 1940), Utah (Berdan 1988) Ontario, (Copeland 1965), district of Mackenzie (Copeland 1974, 1982), district of Franklin (Copeland 1977a), and Baffin Island Canada (Copeland 2000), the Baltic region (Meidla 1996), and the Himalaya (Schallreuter 2008).

Krausella lousyunculus sp. nov.   Pl. 13, figs 1-4, Pl. 18, fig. 11

Derivation of name. From the Lousy Cove Member of the Ellis Bay Formation, Anticosti Island and 'unculus' (Latin) meaning little, gender masculine.

Holotype. A carapace, Geological Museum of the University of Tartu, Estonia TUG 1741-16, from sample EB16 (Pl. 13, fig. 4), Lousy Cove Member, Ellis Bay Formation.

Topotype material. One hundred and four specimens from samples EB1, EB2, EB3, EB7, EB9, EB10, EB13, EB14, EB15, EB16, EB17, EB18, EB19, EB22 and EB24.

Measurements. Length of valves ranges between 0.5 to 0.75 mm, height of valves 0.25 to 0.45 mm (Fig. 2.35).

Diagnosis. Carapace sub-reniform. Right valve has a short posteroventral spine, left valve lacks spine.

Description. Lateral outline sub-reniform, dorsal margin nearly straight, anterior margin broadly arched, ventral margin weakly convex, posterior margin less broadly arched than anterior. Greatest height of the valve at anterior, greatest length at mid-height. Right valve has a short posteroventral spine, left valve without spine. The surface of the valves is smooth and non-sulcate.

Discussion. *Krausella lousyunculus* differs from the type species *Krausella inaequalis* Ulrich, 1894, by its sub-reniform shape and spine morphology. *K. lousyunculus* is characterized by its sub-elongate carapace outline; it has a short spine on the right valve and left valve overlapping right, which is typical for species of *Krausella*. *Krausella* sp. nov. Mohibullah *et al*. (2014) differs from *K. lousyunculus* by its diminutive posteroventral spine, concave ventral margin (from a lateral aspect) and less convex dorsal margin. *K. lousyunculus* differs from *Krausella*? sp. figured by Copeland (1973, pl. 2, figs 8-10) in overall shape and ventral valve overlap.

Occurrence. *Krausella lousyunculus* is from the Upper Ordovician Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

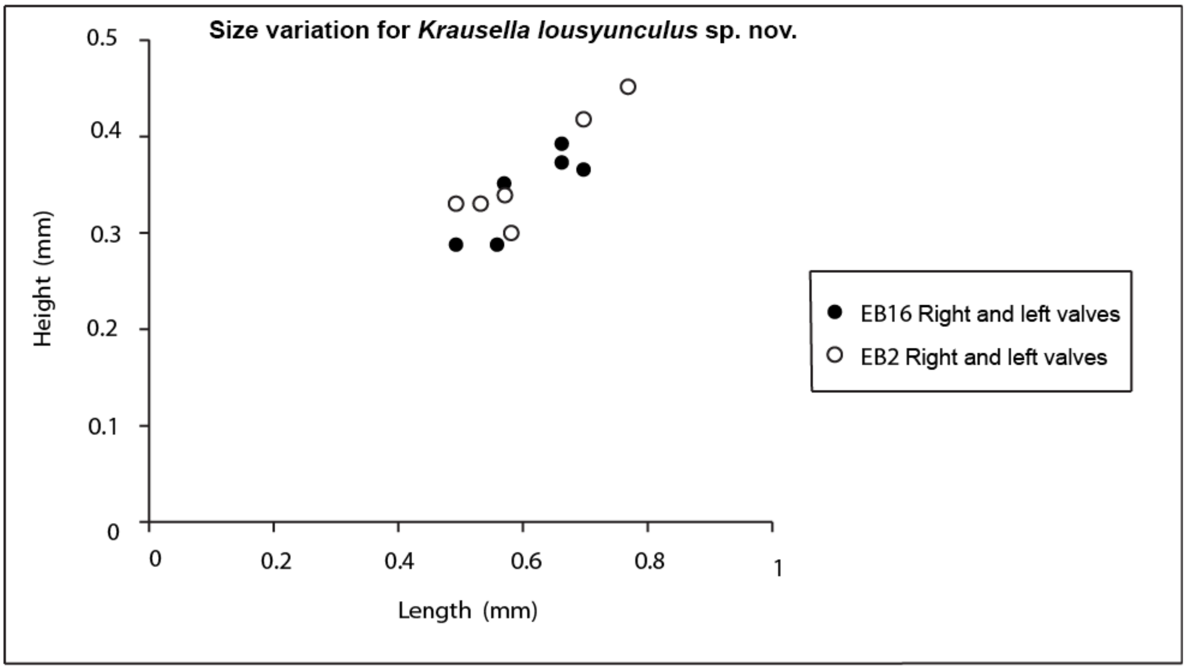

Figure 2.35. Size variation for *Krausella lousyunculus* sp. nov. right and left valves, for samples EB2 and EB16 from the Ellis Bay Formation.

Family **Rectellidae** Neckaja, 1966

Genus ***Rectella*** Neckaja, 1958

Type species. *Mica inaequalis*, Neckaja, 1952, by original designation. From the Upper Ordovician of the north-western part of the Russian Platform.

Diagnosis. (Modified from Neckaja 1952). Ventral and dorsal margins approximately parallel, posterior and anterior end rounded. The antero− and posteroventral areas of the right valve may often bear different inflations.

Discussion. The genus *Rectella* differs from *Longiscula* in its relatively longer valve shape, roughly parallel ventral and dorsal margins, the dorsal one being broadly curved. Characteristic features for *Rectella* are that the ends of the valves are broadly rounded and higher than *Longiscula*. According to the original description (Neckaja 1952, p. 228) the carapace of *Rectella* is inequivalved. Particularly the antero- and posteroventeral area of the right valve may frequently bear dissimilar structures (inflations), which serve as outer stop-ridges (Meidla 1996, p. 146).

Occurrence. *Rectella* are recorded from the Upper Ordovician strata of Baltoscandia (Neckaja, 1958, Gailíte, 1975, Abushik and Sarv, 1963, Olempska, 1994, Meidla 1996), glacial erratic boulders (Schallreuter 1986) and from Öjlemyrflint boulders (Schallreuter 1972).

Rectella derosforma sp. nov.   Pl. 19, fig. 6, Pl. 21, figs 4-7

1970 *"Bythocypris" cylindrica* (Hall); Copeland, pl. 4, fig. 25.

1973 "*Bythocypris" cylindrica* (Hall); Copeland, pl. 2, figs 5, 7.

Derivation of name. From Greek '*deros*' meaning long and Latin '*forma*' meaning shape, alluding to the overall appearance of the carapace long. Gender feminine.

Holotype. A carapace, Geological museum of the University of Tartu, Estonia No. TUG 1741-17, from sample EB17 (Pl. 21, figs 4, 5), Lousy Cove Member, Ellis Bay Formation.

Topotype material. Eleven specimens from samples EB1, EB2, EB11, EB17, EB18, EB23 and EB24.

Measurements. Length of valves between 0.75 to 1.25 mm and height of valves between 0.3 to 0.5 mm (see Fig. 2.36).

Diagnosis. Dorsal and ventral margins parallel, anterior and posterior margins rounded. Surface of valve weakly convex. Lack of spines and valve surface smooth.

Description. Carapace elongate, valves amplete, shape high (L: H ratio 2.0-2.4). Hinge line straight. Dorsal and ventral margin parallel, anterior and posterior ends rounded. Lack of inflation on the right surface. Asymmetrical valves, the larger left valve overlaps the smaller right valve along the hinge, ventral, posterior and anterior margins. Valve surface smooth.

Discussion. For differences between *Rectella derosforma* sp. nov. and other species of *Rectella* see Table 2.15.

Occurrence. Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members, Ellis Bay Formation, Anticosti Island, eastern Canada.

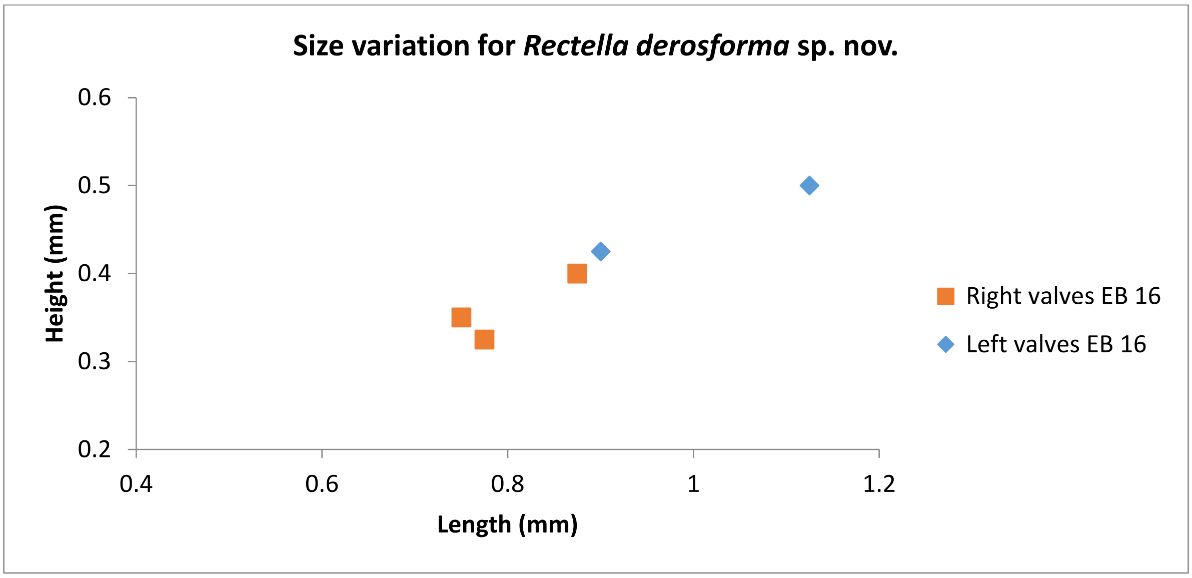

Figure 2.36. Size variation for *Rectella derosforma* sp. nov., right and left valves, for sample EB16 from the Ellis Bay Formation.

Rectella anticostensis sp. nov. Pl. 19, fig. 3, Pl. 21, figs 1-3, 13

Derivation of name. After the Island of Anticosti, eastern Canada.

Holotype. A right valve, Geological Museum of the University of Tartu, Estonia No. TUG 1741-7, from sample EB7 (Pl. 21, fig. 1), Juncliff Member, Ellis Bay Formation.

Topotype material. Twenty one specimens from samples EB1, EB3, EB7, EB8, EB11, and EB24.

Measurements. Length of valves ranges between 0.48 to 0.56 mm and height of valves between 0.25 to 0.32 mm (see Fig. 2.37).

Diagnosis. Dorsal and ventral margin weakly convex, anterior and posterior margin rounded.

Description. Carapace sub-elongate, valves amplete, shape high (L: H ratio of 1.75-1.92). Hinge line straight. Dorsal and ventral margin parallel, anterior and posterior margin rounded. Asymmetrical valves, the larger left valve overlaps the smaller right valve along the dorsal margin. Surface smooth.

Discussion. For precise differences between *Rectella anticostensis* sp. nov. and other species of *Rectella* see Table 2.15.

Occurrence. Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

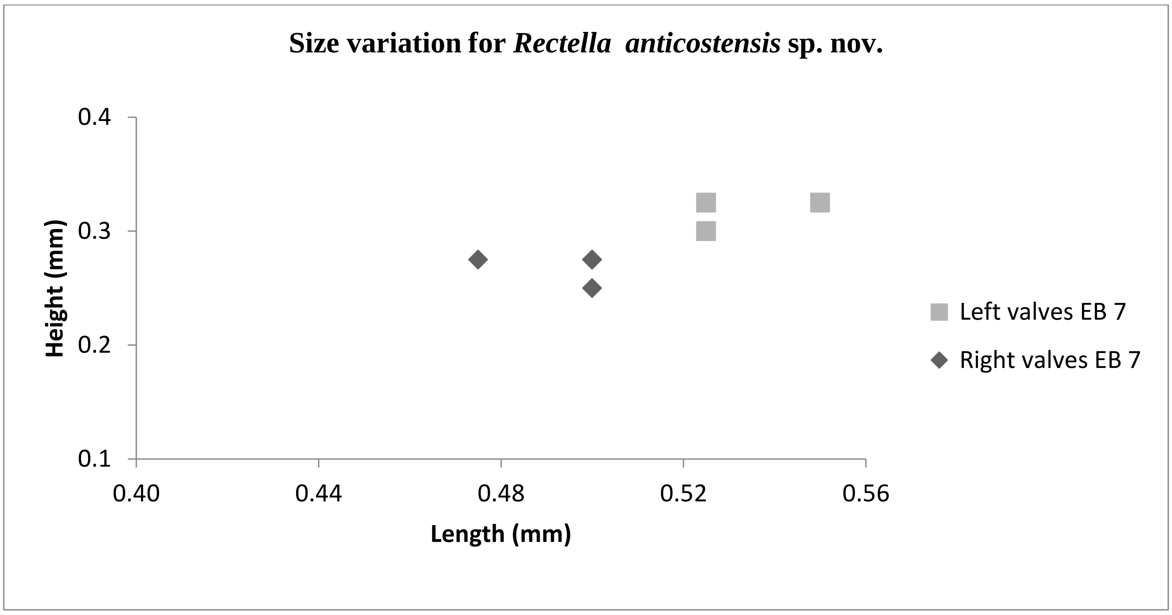

Figure 2.37. Size variation for *Rectella anticostensis* sp. nov., right and left valves, for sample EB7 from the Ellis Bay Formation.

Rectella sp. A Pl. 19, fig. 7, Pl. 21, fig. 8

Material. Fifteen specimens from samples EB1, EB18 and EB23.

Measurements. Length of valves up to 0.7 mm and height of valves up to 0.4 mm.

Description. Carapace elongate, shape high (L: H ratio 1.75). Hinge line straight. Dorsal and ventral margin parallel, anterior and posterior margin rounded. Asymmetrical valves, the larger left valve overlaps the smaller right valve. Surface of valves smooth.

Discussion. For differences between *Rectella* sp. A and other species of *Rectella* see Table 2.15.

Occurrence. Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Table 2.15. Species of the genus *Rectella* compared with the *Rectella derosforma* sp. nov., *Rectella anticostensis* sp. nov. and *Rectella* sp. A from the Ellis Bay Formation.

Species name	**Maximum length and height of the right valve (mm)**	**Shape (in ventral view)**	**Ornament**	**Diagnostic characters**	**Key reference**
Rectella romboformis Neckaja, 1966	0.80-0.46	Elongate	Smooth	Possesses outer stop-ridges well developed on the right valve.	Meidla 1996
Rectella carinaspinata Schallreuter, 1972	0.78-0.44	Elongate	Smooth	Posterior and anterior area rounded and flattened. Possesses outer stop-ridges on the right valve.	Meidla1996
Rectella sturiensis Gailíte, 1975	0.70-0.40	Elongate	Smooth	The anterior end is sharper and the posterior end is higher than in other *Rectella* species. Lacks outer stop-ridges on the right valve	Meidla 1996 Meidla 2007
Rectella explanata Meidla, 1996	0.75-041	Sub-elongate	Smooth	The lateral surface is more flattened and lacks crest-like structures in the ventral part. Lacks outer stop-ridges on the right valve	Meidla 1996
Rectella composita Meidla, 1996	0.70-038	Sub-elongate	Smooth	Posteroventral area has a tumid process comparatively far from the contact margin, and lack of a crest anteroventrally.	Meidla1996
Rectella ? *proposita* Abushik and Sarv, 1963	1.11-0.46	Elongate	Smooth	Ventral margin slightly curved. Lacks outer stop-ridges on the right valve.	Meidla 1996
Rectella nais Neckaja, 1958	0.70-0.45	Sub-elongate	Smooth	Possesses outer stop-ridges (spine-like) on the right valve.	Meidla 1996
Rectella cf. *composita* Meidla, 1996	/	Sub-elongate	Smooth	Posterior and anterior margin weakly rounded. Lacks outer stop-ridges on the right valve	Meidla 2009
Rectella cf. *sturiensis* Gailíte, 1975	/	Elongate	Smooth	The anterior end is sharper than the posterior end. No spine on the right valve.	Truuver and Meidla 2015
Rectella derosforma sp. nov.	0.87-0.42	Elongate	Smooth	Dorsal and ventral margin straight, anterior and posterior margin rounded. Surface of valve weakly convex. Lack of spine on right valve.	This study
Rectella anticostensis sp. nov.	0.55-0.35	Sub-elongate	Smooth	Dorsal and ventral margin weakly convex, anterior and posterior margin rounded. Lack of spine on right valve	This study
Rectella sp. A	0.7-0.4	Elongate	Smooth	Dorsal and ventral margin parallel, anterior and posterior margin rounded. Lack of spine on right valve	This study

Family **Bairdiocyprididae** Shaver, 1981

Genus ***Elliptocyprites*** Swain, 1962

Type species. *Elliptocyprites parallela* Swain, 1962, by original designation. From the Upper Ordovician of the Day Point and Crown Point formations, the southern end of Valcour Island, New York.

Diagnosis. (Revised from Swain 1962) Elongate sub-amplete carapace, outline of dorsal and ventral margin nearly straight. Valves well-rounded anteriorly and posteriorly, anterior end slightly broader. Valves moderately to strongly convex; surface sloping gradually to ends. Non-sulcate. Ventral overlap contact straight.

Discussion. *Elliptocyprites* has a morphologically simple carapace (see Swain, 1962, pl. 111, figures 9a-c, 10). A key feature of this genus is the incurvature of the mid-ventral part of the carapace viewed in lateral profile. *Elliptocyprites* resembles *Bythocypris* Brady, 1880, but can be distinguished by having a strong ventral lappet on the left valve. *Elliptocyprites* also resembles *Aviacypris* Schallreuter, 1977, but can be distinguished by having its anterior and posterior margins rounded in lateral view, and lacks an inner lamella.

Occurrence. *Elliptocyprites* has been recorded from the Upper Ordovician of the USA, Oklahoma, Minnesota (Swain 1987), Oklahoma (Williams *et al*. 1996), New York (Swain 1962), Virginia (Kraft 1962), and Kentucky (Warshauer and Berdan 1982). Also from Baffin Island (Copeland 1977a), Quebec (Copeland 1973), Orphan Knoll (Adamczak 1994) Canada. From the Ordovician of Australia (Schallreuter 1988a). Also from east of Anarak (Schallreuter and Hinz-Schallreuter 2006) Iran, lower Niur Formation of east central Iran (Hairapetian *et al*. 2010), and the Baltic region (Meidla 1998; Tinn and Meidla, 2001, 2004; Tinn *et al*., 2006).

Elliptocyprites mawilliamsia sp. nov. Pl. 19, figs 1, 9-12

Derivation of name. After Professor Mark Willilams, University of Leicester, for his contribution to the study of Ordovician ostracods. Gender feminine.

Holotype. A right valve, Geological Museum of the University of Tartu, Estonia No. TUG 1741-1, from sample EB1 (Pl. 19, fig. 1), Fraise Member, Ellis Bay Formation.

Material. About sixty specimens from samples EB3, EB6, EB7, EB8, EB10, EB13, EB14, EB15, EB16, EB17 and EB18.

Measurements. Length of valves ranges between 0.4 to 1.7 mm and height of valves between 0.15 to 0.75 mm (Fig. 2.38).

Diagnosis. Anterior and posterior margin rounded, the outline of the anterior part of the valve is gently convex but with remarkably strong convexity posteriorly. Ventral and dorsal margin nearly straight and parallel.

Description. Elongate carapace in lateral view. Valve surface gently convex without trace of sulcation, dorsal and ventral margin nearly straight and parallel, anterior and posterior outline well-rounded. Left valve slightly larger but the overlap is minor, occurring ventrally and posteroventrally. Valve surfaces smooth. No adventral or admarginal structures.

Discussion. For specific differences from other described species see Table 2.16.

Occurrence. Fraise, Juncliff, Parastro and Lousy Cover members of the Ellis Bay Formation, Anticosti Island.

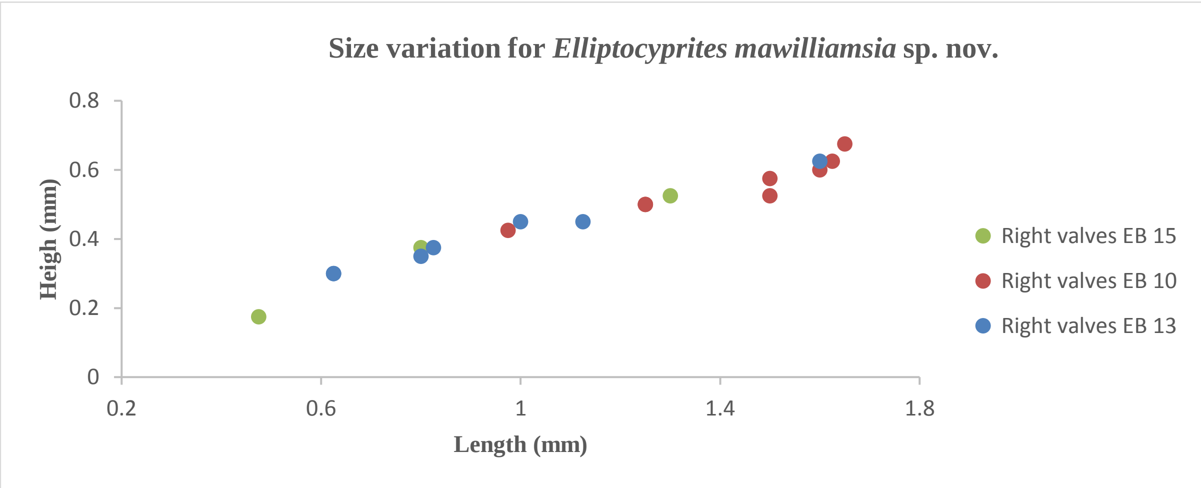

Figure 2.38. Size variation for *Elliptocyprites mawilliamsia* sp. nov., right valves, for samples EB10, EB13 and EB15 from the Ellis Bay Formation.

Table 2.16. Species *Elliptocyprites* compared with *Elliptocyprites mawilliamsia* sp. nov. from the Ellis Bay Formation.

Species name	**Length and height of the valve (mm) Left (L).**	**Shape**	**Type of ornament**	**Important features**	**References**
Elliptocyprites parallela Swain, 1962	1.50-0.76	Elongate	Smooth	Characterized by parallel dorsal and ventral margins and large size.	Swain 1962
Elliptocyprites longula Swain, 1962	0.95-0.46	Elongate	Smooth	Parallel dorsal and ventral margins.	Swain 1962
Elliptocyprites sp. cf. *E. rectangulatus* Williams, 1990	0.72-0.33	Elongate	Smooth	Ventral outline with incurvature posterior of mid-ventral position, and ventral contact of valves straight with weak or no overlap.	Williams 1990 (unpublished)
Elliptocyprites sp. Williams, 1990	0.81-0.33	Elongate	Smooth	Possesses a convex dorsal outline and a weak mid-ventral incurvature.	Williams 1990 (unpublished)
Elliptocyprites nesowa Schallreuter, 1988b	0.71-0.31	Elongate	Smooth	Ventral and centroventral margin weakly arched, dorsal margin nearly straight.	Schallreuter 1988b
Elliptocyprites sp. A Schallreuter and Hinz- Schallreuter, 2006	1.12-0.52	Elongate	Smooth	Dorsal margin broadly convex with central summit. Both anterior and posterior margins equally and broadly rounded with their points of maximum lateral extent located near mid-height.	Schallreuter and Hinz-Schallreuter 2006
Elliptocyprites sp. Hairapetian *et al.*, 2010	/	Sub-elongate	Smooth	Sub-elliptical to sub-quadrate in lateral view, straight dorsal margin with obtuse cardinal angles.	Hairapetian *et al.* 2010
Elliptocyprites mawilliamsia sp. nov.	1.8-0.75	Elongate	Smooth	Anterior and posterior margin rounded. Ventral and dorsal margin nearly straight and parallel.	This study

Family **Pachydomellidae** Berdan and Sohn, 1961

Genus ***Microcheilinella*** Geis, 1933

(Syn: ***Microcheilus*** Geis, 1932, non Kittl, 1894)

Type species. By original designation; *Microcheilus distortus* Geis, 1932, from the Ordovician of the East Baltic region.

Diagnosis. (Revised from Geis 1933) Carapace elliptical in lateral view. Asymmetrical valves, the left valve larger than the right. Dorsal margin of the left valve convex, of the right straight. Ventral margin straight. Anterior end of carapace rounded. Posterior end of the right valve rounded, of the left slightly truncate in the posteroventral part. Carapace strongly convex. A longitudinal depression occurs in the dorsomedial part of the left valve only. Surface of valves smooth.

Discussion. Sarv (1963) suggested a close relationship between *Microcheilinella* and *Trianguloschmidtella* Schallreuter, 1980, as both possess stop-ridges on the inner ventral valve surface of the right valve. *Microcheilinella* differs from *Trianguloschmidtella*, by its non-triangular carapace shape when viewed from an anterior or posterior view.

Occurrence. *Microcheilinella* is recorded from the Upper Ordovician of the Baltoscandia, Öjlemyrgeschiebe (erratic boulders) from Gotland (Schallreuter 1972), Rassnasudden, Sweden (Truuver and Meidla 2011, 2015), Estonia (Meidla 1996, Meidla 2007), Pskov district, Russia (Pranskevičius 1972) and Latvia and Lithuania (Neckaja 1966, Meidla 1996).

Microcheilinella lubrica (Stumbur, 1956) Pl. 22, figs 1-6

1956 *Bythocypris lubrica* sp. nov. Stumbur, p. 191, pl. 3, figs 1-6.

1962 *Bythocypris lubrica* Stumbur; Sarv, pp. 96-98 (*partim*).

1966 *Microcheilinella lubrica* (Stumbur); Neckaja, pp. 44-45, pl. 10, figs 4-5.

1972 *Trianguloschmidtella posterolatissima* sp. nov. Schallreuter, pp. 257-258, figs 2.1-2.5.

1972 *Microcheilinella lubrica* (Stumbur); Pranskevičius, p. 113, pl. 23, figs 4-6.

1973 *Platyrhomboides*? *dixoni* sp. nov. Copeland, p. 25, pl. 4, figs 8, 9, pl. 6, figs 23-25, pl. 8, fig. 1.

1979 *Trianguloschmidtella posterolatissima* Schallreuter; Schallreuter, p. 26, pl. 1, figs 5-6.

1983 *Microcheilinella lubrica* (Stumbur); Meidla, p. 54.

1983 *Microcheilinella lubrica* (Stumbur); Abushik and Sarv, p. 127, pl. 8, figs 1-7.

1984 *Microcheilinella lubrica* (Stumbur); Sarv and Meidla, pp. 8, 11, 13-15.

1986 *Trianguloschmidtella posterolatissima* Schallreuter; Schallreuter, pl. 7, fig. 4.

1989 *Microcheilinella lubrica* (Stumbur); Nõlvak et al., p. 90.

1990 *Microcheilinella lubrica* (Stumbur); Meidla et al., p. 135.

1996 *Microcheilinella lubrica* (Stumbur); Meidla, p. 129, pl. 27, figs 1-5.

Diagnosis. (Revised from Neckaja 1966) Carapace large-sized, elliptical outline. Dorsal margin curved and ventral margin strongly flattened. Hinge line situated in a narrow depression and half of valve length. Surface of valves smooth.

Holotype. Designated Stumbur (1956, pl. 3, figs 1-6), carapace, Institute of Geology, Tallinn No. 5010, 31542, from the Porkuni quarry, West Viru, Estonia.

Material. More than 90 specimens from samples EB4, EB5, EB11, EB14, EB16, EB17, EB18, EB22, EB23 and EB24.

Measurements. Length of right and left valves ranges between 0.4 to 1 mm, height of right and left valves ranges from 0.35 to 0.6 mm (Fig. 2.39).

Description. Carapace sub-ovate in lateral view. Hinge line half of valve length: dorsum hypocline. Dorsal outline arched, ventral outline also convex. Anterior outline more rounded than posterior. Inequivalved, left valve larger than the right, overlapping it along the free margin, but more extensively along the ventral margin. Left valve overreaching the right valve in right lateral view along the dorsal margin. Greatest height of valve near mid length. Valve surface smooth.

Discussion. Meidla (1996) mentioned *T. posterolatissima* as a junior synonym of *M. lubrica* see Table 2.17.

Occurrence. Microcheilinella lubrica is recorded from the Upper Ordovician Ellis Bay Formation, White Cliff, Port Menier quarry, from the Lower Silurian Becscie Formation, Anticosti Island, eastern Canada (Copeland 1973). Material documented here is from the Juncliff, Parastro and Lousy Cave members of the Ellis Bay Formation, Anticosti Island, eastern Canada. From Baltoscandia (Stumbur 1956, Neckaja 1966, Pranskevicius 1972, Meidla 1996, Meidla 2007, Truuver and Meidla 2015).

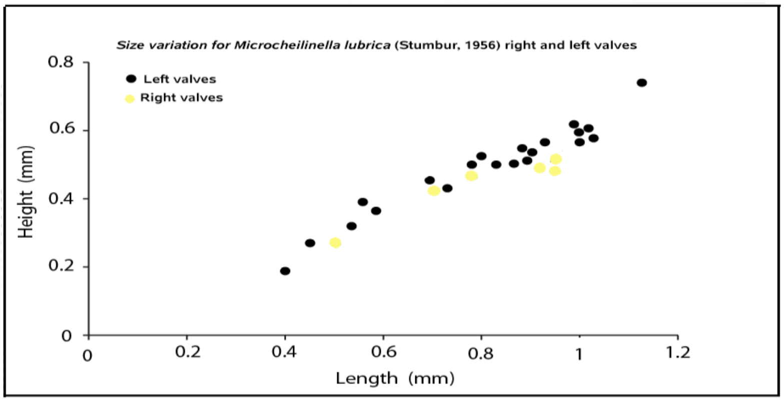

Figure 2.39. Size variation for *Microcheilinella lubrica* (Stumbur, 1956) right and left valves, for samples EB4, EB5, EB16 and EB23 from the Ellis Bay Formation. Growth stages cannot easily be distinguished.

Table 2.17. Comparsion of *Microcheilinella lubrica* with some other *Microcheilinella* species.

Species name	Valve shape	Valve size L-H (mm)	Type of ornament	Overlapping (LV>RV)	Important features	References
Microcheilinella lubrica (Stumbur, 1956)	Elliptical	1.0-0.60	Smooth	Overlaps it along all margins, but more extensively along the ventral and hinge margins.	Dorsal outline arched, the ventral margin of the carapace is strongly convex. Anterior outline more rounded than posterior.	This study
Microcheilinella lubrica (Stumbur, 1956)	Elliptical	0.88-0.51	Smooth	Overlaps it along all margins, but more extensively along the ventral and hinge margins.	Anterior outline more rounded than posterior. The ventral margin of the carapace is convex.	Meidla 1996
Microcheilinella rozhdestvenskaja Nekaja, 1966	Elliptical	0.85-0.43	Smooth	Overlaps it along all margins, but very weakly at the posterior and posteroventral margins.	Dorsal margin weakly curved, posterior and anterior margins rounded and ventral margin arched.	Meidla 1996
Microcheilinella dagoensis Meidla, 1996	Sub- elliptical	1.19-0.66	Smooth	Overlaps along the ventral and posterodorsal margins.	Dorsal margin curved, ventral margin arched, anterior and posterior ends rounded, the anterior one more strongly.	Meidla 1996
Microcheilinella pirguensis Meidla, 1996	Elliptical	0.93-0.60	Smooth	Overlaps along the free margin and overreaching it weakly at the ends, but more extensively along the ventral and dorsal margins.	Dorsal margin of left valve bow-shaped, forming a high dorsal protrusion.	Meidla 1996

Superfamily **Thlipsuroidea** Ulrich, 1894

Family **Thlipsuriidae** Ulrich, 1894

Genus ***Anticostus*** n. gen.

Derivation of name. After Anticosti Island, eastern Canada.

Type species. Designated here, *Anticostus jolieti* (Copeland, 1973) from the Upper Ordovician of the Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation, Anticosti Island, eastern Canada.

Diagnosis. Lateral shape triangular, small size less than 1 mm in length as adults: valves asymmetrical with the left valve much larger and overreaching the right valve along the entire free margin, maximum height at the midpoint of the valve. Both valves with posteroventral flattened margin. Surface marked by distinct and rounded punctae.

Discussion. This genus differs from the lower Devonian genus *Tubulibairdia* Swartz, 1936, in the shape of its carapace, having a posteroventral incisure and no spines on the surface. Swartz (1936, p. 581) reported an important distinguishing character of the Devonian *Tubulibairdia* Swartz, 1936, with spine on the surface, notable in the type species *Tubulibairdia tubulifera* Swartz, 1936.

Later, Sohn (1960) recognized the presence of tubules in the carapace of *Pachydomella* Ulrich, 1891 from the Late Devonian of Ohio, *Tubulibairdia* Swartz, 1936 from the lower Devonian of Pennsylvania and *Phanassymetria* Roth, 1929 from the Devonian of Oklahoma. *Anticostus* is different from these genera because it has punctae on the valve surface, and both valves have a posteroventral flattened margin and sub-triangular shape when viewed laterally.

Occurrence. Recorded from the type locality, Ellis Bay Formation, Anticosti Island, eastern Canada.

Anticostus jolieti (Copeland, 1973) Pl. 8, figs 1-11, Pl. 9, figs 1-8

1970 *Tubulibairdia* sp. Copeland, p. 25, fig. 9.

1973 *Tubulibairdia jolieti* sp. nov. Copeland, pp. 30-38, pl. 1, fig. 4, pl. 3, figs 1-4, pl. 4, fig. 1, pl. 5, figs 9-10.

1989 *Tubulibairdia* sp. Copeland, p. 92, pl. 17, figs 5-7.

Holotype. GSC (Geological Survey of Canada) No. 31360, Ellis Bay Formation.

Material. More than 1000 specimens from the Ellis Bay Formation, the samples being prefixed with the identifiers, EB 1, EB 2, EB 4, EB 5, EB 11, EB 13, EB14, EB16, EB17, EB18, EB19 and EB20.

Measurements. Individual valves (both right and left) give maximum length range of 0.25-0.8 mm and the maximum height range of 0.16-0.45 mm. Carapaces are 0.45-0.75 mm long and the height ranges between 0.1-0.45 mm (Fig. 2.40).

Diagnosis. As for the genus, which is monotypic.

Description. Carapace approaches the form of an inequilateral triangle from a lateral view, the ventral margin forming the longest side of the triangle; dorsal lateral outline arched, ventral lateral outline concave, posterior and anterior outlines evenly convex. Greatest valve width and height is the mid-point of the valve, greatest length is in the ventral part of the valve. Hinge adont, short about 0.2 mm long-being less than half of the maximum length of the carapace, recessed between elevated dorsal portions of the right and left valves. Inequivalved, the left valve larger than the right valve, dorso-laterally the right valve slightly overreaches the left valve, whilst ventro-laterally the left valve overreaches the right valve. Surface is punctae with strong rectangular punctae that approach the morphology of reticulation; number of punctae varies between the right and left valves, being typically 30 and 20, respectively, the length and height of the punctae typically 0.04 to 0.05 mm in diameter, respectively for both valves.

Discussion. Anticostus jolieti resembles *Olbianella fabacea* (Pranskevicius, 1972) in general shape, inequilateral triangular shape, and valve overlap, but possesses rectangular punctae and a posteroventral flattened margin posteriorly.

Occurrence. From the Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation, Anticosti island, eastern Canada.

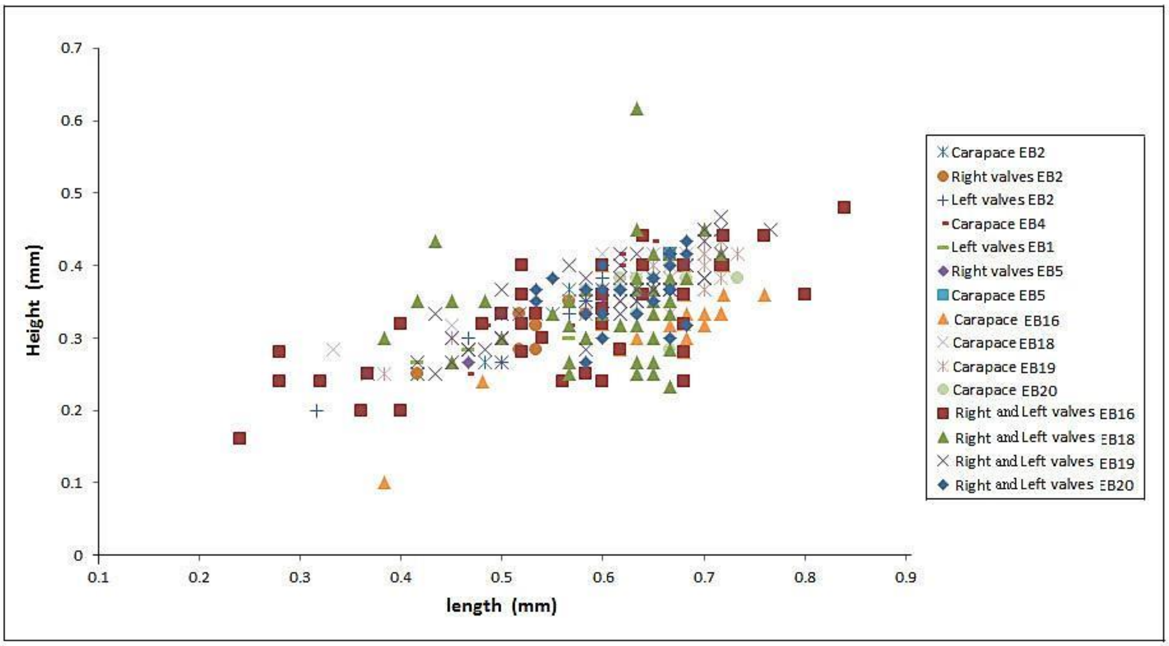

Figure 2.40. Size variation for *Anticostus jolieti* (Copeland, 1973) right and left valves, for samples EB1, EB2, EB4, EB5, EB16, EB18, EB19 and EB20 from the Ellis Bay Formation.

Suborder **Cypridocopina** Jones, 1901

Superfamily **Bairdioidea** Sars, 1865

Family **Macrocyprididae** Muller, 1912

Genus ***Macrocyproides*** Spivey, 1939

Type species. *Macrocyproides clermontensis* Spivey, 1939, by original designation. From the Middle Ordovician of Iowa and Minnesota, USA.

Diagnosis. (Revised from Burr and Swain 1965) Carapace sub-ovate to reniform, valves asymmetrical, the larger right valve overlaps the smaller left valve, but the left valve weakly overreaches the right valve posterodorsally. Hinge line short and straight. Surface of valves is smooth and non-lobate.

Discussion. *Macrocyproides* is similar to *Punctaparchites* Kay, 1934, but can be distinguished by lacking punctate ornamentation and a muscle spot. *Macrocyproides* differs from *Phelobythocypris* Warshauer and Berdan, 1982, by its short hinge line and by the left valve weakly overreaching the right valve posterodorsally. *Macrocyproides* resembles *Adamczakia* Schallreuter, 1986, by its outline and general shape.

Occurrence. Macrocyproides has been recorded from the Ordovician of Iowa and Minnesota (Spivey 1939; Kay 1940; Keenan 1951; Swain and Cornell 1961; Burr and Swain 1965), Virginia (Kraft 1962), Valcour Island, USA, (Swain 1962), and Anticosti Island, eastern Canada (Copeland 1965, 1970, 1973).

Macrocyproides trentonensis (Ulrich, 1894)   Pl. 17, figs 9-11

1894 *Aparchites minutissimus trentonensis* sp. nov. Ulrich, p. 646, pl. 43, figs 18-20.

1915 *Aparchites minutissimus trentonensis* Ulrich; Bassler, p.54.

1934 *Aparchites minutissimus trentonensis* Ulrich; Bassler and Kellett, p.159.

1939 *Aparchites minutissimus trentonensis* Ulrich; Spivey, p. 165, pl. 21, figs 26, 27.

1940 *Aparchites trentonensis* Ulrich; Kay, p. 244; pl. 29, fig. 33.

1951 *Aparchites trentonensis* Ulrich; Keenan, p. 562; pl. 78, figs 29-31.

1961 *Macrocyproides trentonensis* (Ulrich); Swain, Cornell and Hansen, p. 371, pl. 48, fig. 11, pl. 50, figs 5a-d, text-figs 1-2.

1962 *Macrocyproides trentonensis* (Ulrich); Swain, p. 740, pl. 111, figs 2a-c.

1965 *Macrocyproides trentonensis* (Ulrich); Copeland, p. 48, pl. 2, fig. 1.

1970 *Macrocyproides trentonensis* (Ulrich); Copeland, p. 24, pl. 5, figs 5, 10, 15.

1973 *Macrocyproides trentonensis* (Ulrich); Copeland, p. 33, pl. 2, figs 2, 3, 6, p. 41, pl. 6, fig. 9.

Holotype. Designated Ulrich (1894, pl. 43, figs 18-20), a right valve, the United States National Museum, No. 41303, from the Trenton Shale Formation, Minnesota, USA.

Material. Approximately 35 specimens from samples EB1, EB2, EB3, EB6, EB7, EB8, EB9, EB10, EB11, EB 12, EB13, EB14, EB15, EB16, EB17, EB19, EB22 and EB24.

Measurements. Length of valves between 0.4 to 0.7 mm, height of valves between 0.3 to 0.45 mm (Figs 2.41, 2.42).

Diagnosis. (Revised from Swain, Cornell and Hansen 1961) Anterior margin narrowly rounded, posterior margin more broadly rounded; lacking muscle spot. Hinge line short and straight.

Description. Carapace reniform. Dorsal margin strongly convex, ventral margin nearly straight; posterior and anterior margin rounded, the posterior outline is more broadly rounded than the anterior. Hinge line straight and short. Valves asymmetrical, the larger right valve overlaps the smaller left valve posteriorly and ventrally. Surface smooth.

Discussion. *M. trentonensis* resembles *M. clermontensis* Keenan, 1951 from the Maquoketa Shale of Iowa and Minnesota, but can be distinguished by its carapace shape and by the posterior and anterior margins being rounded from a lateral aspect. Individual growth stages are discernible in the Anticosti material (Fig. 2.42. A). Comparison of specimens of *M. trentonensis* different localities shows a similar size distribution (Fig. 2.42B).

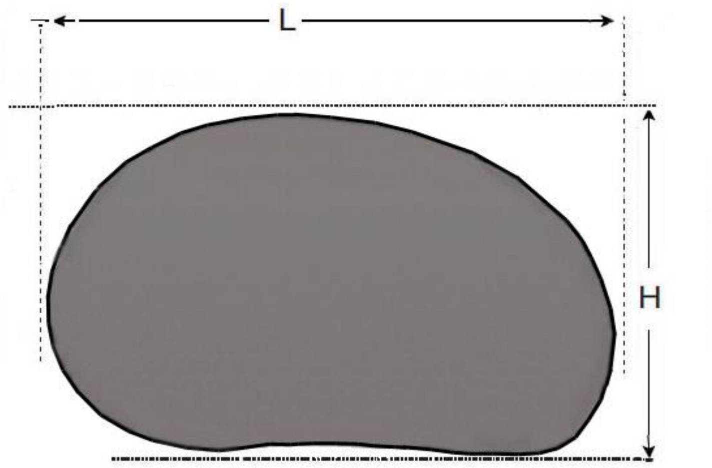

Figure 2.41. Parameters used for measurements of valves of *Macrocyproides trentonensis* (Ulrich, 1894). H, maximum valve height; L, maximum valve length.

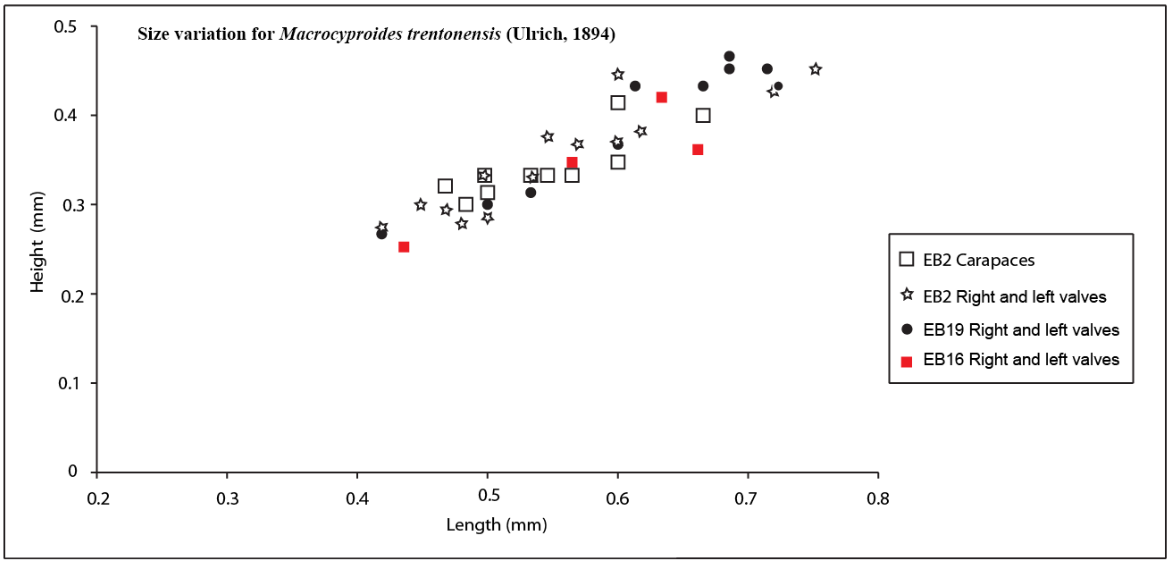

Figure 2.42A. Size variation for *Macrocyproides trentonensis* (Ulrich, 1894), right and left valves, for samples EB2, EB16 and EB19 from the Ellis Bay Formation.

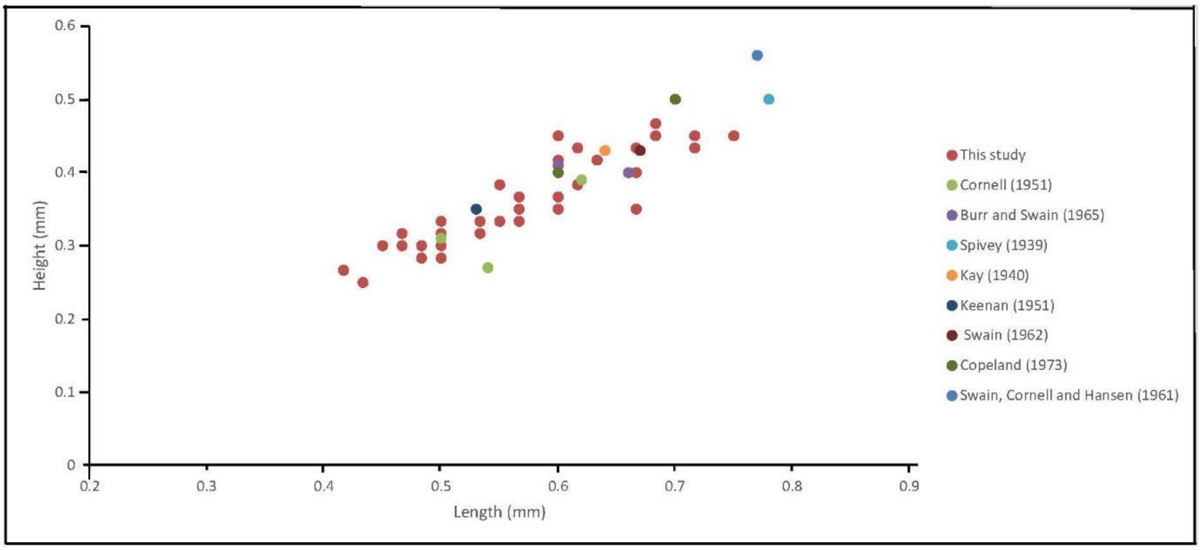

Figure 2.42B. Comparison of *M. trentonensis* (Ulrich, 1894) from the Ellis Bay Formation (this study and Copeland 1973) with other specimens of *M. trentonensis* from the Decorah Shale of Minnesota (Kay 1940, Cornell 1951, Swain, Cornell and Hansen 1961), and Maquoketa Shale of Missouri (Spivey 1939, Keenan 1951).

Order **Platycopida** Sars, 1866

Suborder **Cytherelliformes** Skogsberg, 1920

Superfamily **Leperditelloidea** Ulrich and Bassler, 1906

Family **Leperditellidae** Ulrich and Bassler, 1906

Genus ***Leperditella*** Ulrich, 1894

Type species. *Leperditella rex* (new name for *L. inflate* Ulrich, 1892). Designated by Coryell and Schenk, 1941, p. 176. From the Upper Ordovician of Stones River, Minnesota, USA.

Diagnosis. (Adapted from Mohibullah *et al*. 2014). Sub-ovate valves from a lateral view. Non-sulcate, or with a weak sulcal depression. Valve asymmetric, the left valve is larger and overlaps the smaller right valve along the ventral margin. Surface smooth or punctate.

Occurrence. *Leperditella* are recorded from the Ordovician of Scotland (Williams and Floyd 2000; Williams et al. 2001a), Oklahoma (Harris 1957; Williams and Siveter 1996), Utah (Berdan 1988), Kentucky (Warshauer and Berdan 1982), Iowa (Kay 1940), Minnesota (Ulrich 1894), Also recorded from the Late Ordovician strata of the District of Mackenzie (Copeland 1974), Ontario, Canada (Copeland 1965), and the Ordovician of the Baltic region (Sarv 1959, Meidla 1996).

Leperditella sp. A   Pl. 5, fig. 10

1965 *Leperditella* spp. Ulrich; Copeland pl. 8, figs 10, 13.

1970 *Leperditella*? *billingsi* Copeland, pl. 5, figs 6, 7, 11, 12.

1973 *Primitiella*? sp. Copeland, pl. 4, fig. 14.

Material. 13 valves from samples EB1, EB14, EB16 and EB17.

Measurements. Length of valves up to 0.93 mm, height of valves up to 0.69 mm.

Description. Carapace of medium size, strongly postplete, very high, sub-ovate in lateral view. Maximum height just posterior of mid-length, maximum length above the valve centre. The dorsal margin is long and straight, corresponding to the hinge line (no depressed dorsum). Posterior margin broadly rounded, merges with the broadly rounded ventral margin. The curvature of the ventral margin more flat anterventrally than posteroventrally. The anterior is more narrowly rounded nearer to the dorsal margin. Cardinal angles distinct, obtuse, the anterior one larger than the posterior one. The valves strongly and evenly convex, convexity regular, the maximum width of the carapace in the middle. Carapace is slightly asymmetric, the larger left valve weakly and evenly overlaps the smaller right valve along the entire free margin. Valve surface smooth.

Discussion. For precise differences between *Leperditella* sp. A and other species of *Leperditella* see Table 2.18.

Occurrence. *Leperditella* sp. A is recorded from the Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation.

Table 2.18. Some species of *Leperditella* compared with *Leperditella* sp. A from the Ellis Bay Formation.

Species name	**Maximum length and height of the right valve (mm)**	**Shape (in ventral view)**	**Ornament**	**Diagnostic characters**	**Key reference**
Leperditella girvanensis Mohibulla *et a*l., 2014	1.54-0.93	Sub-ovate	Punctate	Valve surface finely punctate. Postplete, valves thickened postero-cardinally.	Mohibulla *et a*l. 2014
Leperditella brachynotos (Schmidt, 1858)	1.9-1.33	Sub-ovate	Smooth	Amplete equilateral. Long hinge line. Dorsum epicline.	Meidla 1996
Leperditella primav Sarv, 1956	1.43-0.96	Sub-ovate	Smooth	Left valve overlaps the right valve ventrally.	Meidla 1996
Leperditella tumida (Ulrich, 1892)	2.11-1.39	Sub-ovate	Smooth	Postplete, Nodes antero and posterocardinally on both valves.	Williams 1990 (unpublished)
Leperditella valida Harris, 1957	1.79-1.29	Sub-ovate	Smooth	Amplete to weakly postplete. Left valve large with thickened ventral margin developed into laterally projecting boss at mid-ventral.	Williams 1990 (unpublished)
Leperditella bulbosa (Harris, 1931)	1.67-1.07	Sub-ovate	Smooth	Postplete. Surface of valve smoothly convex and flattened antero- and posteromarginally.	Williams 1990 (unpublished)
'Leperditella' Copperi Harris, 1931	1.63-1.09	Sub-ovate	Smooth	Postplete. Valve surface evenly convex, dorsum weakly epicline.	Williams 1990 (unpublished)
'Leperditella' brookingi Harris, 1931	1.12-0.72	Sub-ovate	Smooth	Weakly postplete. Dorsum epicline posteriorly, orthocline towards anterior cardinal corner.	Williams 1990 (unpublished)
Leperditella sp. A	0.93-0.69	Sub-ovate	Smooth	Posterior margin broadly rounded, merges with the broadly rounded ventral margin.	This study

Suborder **Kloedenellocopina** Scott, 1961

Superfamily **Kloedenelloidea** Ulrich and Bassler, 1908

Family **Kloedenellidae** Ulrich and Bassler, 1908

Genus ***Eokloedenella*** Kraft, 1962

Type species. *Eokloedenella posterodepressa* Kraft, 1962; by original designation. From the Upper Ordovician Edinburg Formation of the Shenandoah Valley, Virginia, USA.

Diagnosis. (Revised from Kraft 1962; Copeland 1970) Carapace sub-ovate, lateral valve surface with a well-developed adductorial sulcus situated anterodorsally; dorsal margin nearly straight, anterior margin weakly convex. Posterior part of the lateral valve surface with a marked incisure; greatest valve height is posterior. Surface of valves smooth.

Discussion. Although, Guber and Jaanusson (1964, p. 8) suggested that *Eokloedenella* may belong to Leperditellidae Ulrich and Bassler, 1906, ostracods assigned to that family are typified by postplete, asymmetrical valves that are non-sulcate or with a very weak sulcal depression, and the valves are often markedly inflated posteriorly. *Eokloedenella* is similar to the family Euprimitiidae Hessland, 1949, which is typified by ostracods that have a small to medium size unisulcate valve typically about 1 mm long. In euprimitiids dimorphism usually is expressed in the width of the velum, it being broader in heteromorphs (see Schallreuter 1978a).

Kraft (1962) assigned *Eokloedenella* in the family Kloedenellidae Ulrich and Bassler, 1908, and that family is characterized by a posterior brood chamber in the heteromorph that is separated by an inner portion called the limen: in addition, kloedenellid ostracods may also possess an anterior stragular process, a dorsal flap-like overlap of the left valve over the right valve (see also Adamczak 1961).

Eokloedenella resembles the euprimitiid *Hallatia* Kay, 1934, in its amplete valves with a well-developed adductorial sulcus and in possessing a velum, but it is distinguished by its posterior valve incisure.

Occurrence. *Eokloedenella* has been recorded from the Upper Ordovician Vauréal Formation of Anticosti Island, Canada (Copeland 1970), and from the Upper Ordovician Edinburg Formation of Virginia, USA (Kraft 1962).

Eokloedenella canadensis (Bassler, 1927) Pl. 11, figs 6-9

1927 *Primitiella canadensis* sp. nov. Bassler, p. 345.

1970 *Eokloedenella Canadensis*; Copeland, p. 34, pl. 4, figs 13-14, pl. 5, fig. 1.

1973 *Eokloedenella Canadensis*; Copeland, p. 34, pl. 3, figs 19-21, p. 40, pl. 4, figs 10-13.

Holotype. Designated Bassler (1927, p. 345), the United States National Museum, holotype number of species not determined, from the Vauréal Formation, Anticosti Island, eastern Canada.

Material. Fifty specimens from samples EB17, EB18 and EB19.

Measurements. Length of valves between 0.5 to 0.85 mm, height of valves between 0.35 to 0.55 mm (Figs 2.43, 2.44).

Diagnosis. (Revised from Copeland 1970) Valves amplete, lateral shape sub-rectangular. Posterior part of valve surface with a marked incisure that is parallel to the posterior margin and extends from the dorsal to ventral surface. Surface of valves smooth. Dimorphism not observed.

Description. Sub-rectangular valves in lateral view. Sub-vertically orientated-adductorial sulcus, which possesses an overall hour-glass shape, the sulcus broadening and opening towards the dorsal margin: length of sulcus 0.11 mm, width 0.15 mm. Ventral lateral outline is gently convex. Posterior and anterior margins are evenly rounded. Posterior part of lateral valve surface is strongly incised, the incisure being parallel with the posterior valve outline: this incisure extends from the dorsal to ventral margin of the lateral surface. Cardinal angles obtuse, roughly 135°. Hinge essentially straight, but with a small dorsal cusp overreaching the hinge line posteriorly. Narrow velar ridge that is apparently non-dimorphic.

Discussion. *Eokloedenella canadensis* differs from *Eokloedenella posterodepressa* Kraft, 1962 by the greater width, length and hour-glass shape of its adductorial sulcus: in *E. posterodepressa* the sulcus is narrow, shorter and crescent-shaped (see Kraft 1962, pl. 8, figs 8-12). In addition, the posterior incisure is much reduced in *E. posterodepressa.*

Eokloedenella canadensis differs from *E. svenhedini* Schallreuter, 1993 principally by the larger size of the adductorial sulcus and by the posterior incisure of the valve surface, which is longer in *E*. *canadensis*. The length of adults of *E*. *svenhedini* is more than 1 mm, larger than *E*. *canadensis*.

The scatter plot of length versus height for *E*. *canadensis* (Fig. 2.44) shows appreciable gaps between the data points, but it is not possible to clearly distinguish instar patterns based on morphometrics, probably as a result of the small dataset. The scatter of sizes in Figure 2.44 may also indicate that this is a time-averaged assemblage of valves, representing animals living at different times. Similar patterns have been identified in the Ordovician (Tinn and Meidla 2003; Lajblova *et al*. 2014). By contrast, eight moulting stages are identified for the ostracod *Brezelina palmate* from the mid-Dapingian of Estonia (Tinn and Meidla 2003). Lajblova *et al*. (2014) described the same number of instars (including adults) in *Conchoprimitia osekensis* from the Darriwilian of the Prague Basin.

Occurrence. *Eokloedenella canadensis* is recorded from the Upper Ordovician Vauréal and Ellis Bay formations, Anticosti Island, eastern Canada (Copeland 1970, 1973): the material described here is from the Lousy Cove Member of the Ellis Bay Formation.

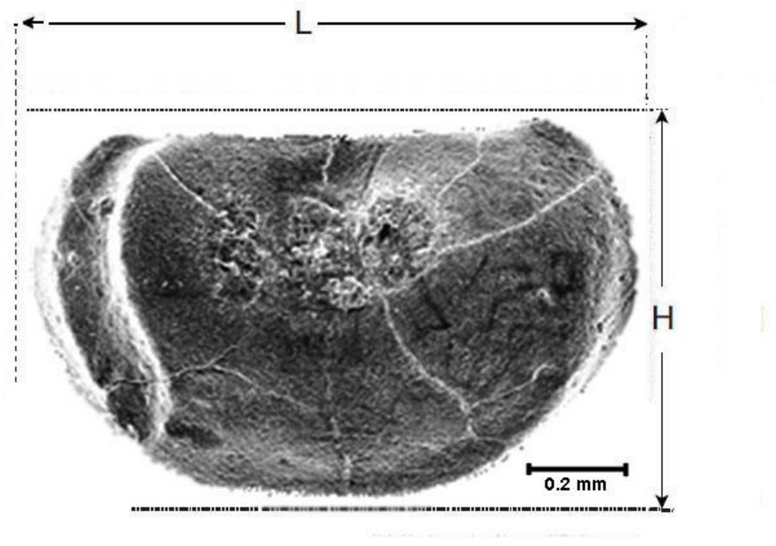

Figure 2.43. Parameters used for measurements of valves of *Eokloedenella canadensis* (Bassler, 1927). H, maximum valve height; L, maximum valve length.

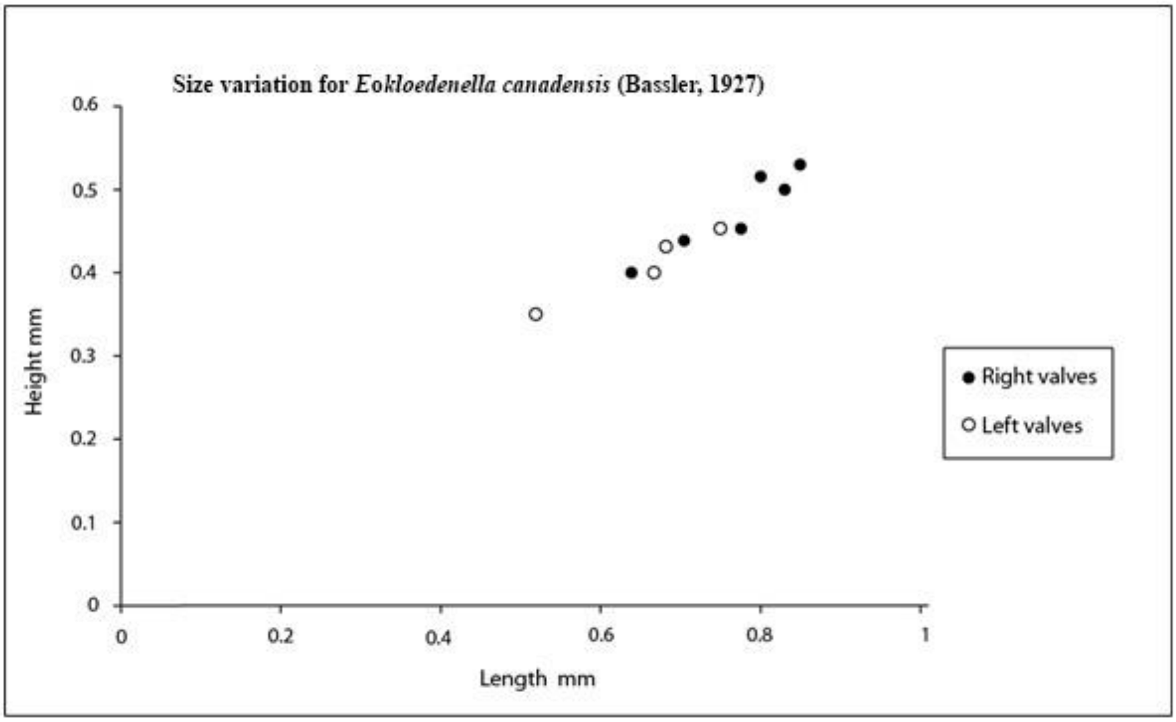

Figure 2.44. Size variation for *Eokloedenella canadensis* (Bassler, 1927) right and left valves, for sample EB19 from the Ellis Bay Formation. The small dataset precludes recognition of discrete instars.

Plates

Chapter 2: Systematic Palaeontology of the Upper Ordovician ostracods from the Ellis Bay Formation, Anticosti Island, eastern Canada.

Plate 1

Figures 1-9. ***Foramenella phippsi*** Copeland, 1973. Ellis Bay, Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, sample EB2. Scale bars: 300 µm. All stereo-pairs. 1-3, juveniles, 4-9, adults.

Fig. 1. Carapace, left valve, lateral view.

Fig. 2. Carapace, right valve, lateral view.

Fig. 3. Carapace, right valve, lateral view.

Fig. 4. Carapace, right valve, lateral view.

Fig. 5. Carapace, ventral view.

Fig. 6. Carapace, dorsal view.

Fig. 7. Carapace, heteromorphic left valve, lateral view, sample EB9. Scale bar 300 µm.

Fig. 8. Carapace, tecnomorphic right valve, lateral view, sample EB16. Scale bar 300 µm.

Fig. 9. Carapace, tecnomorphic right valve, lateral view, sample EB18. Scale bar 300 µm.

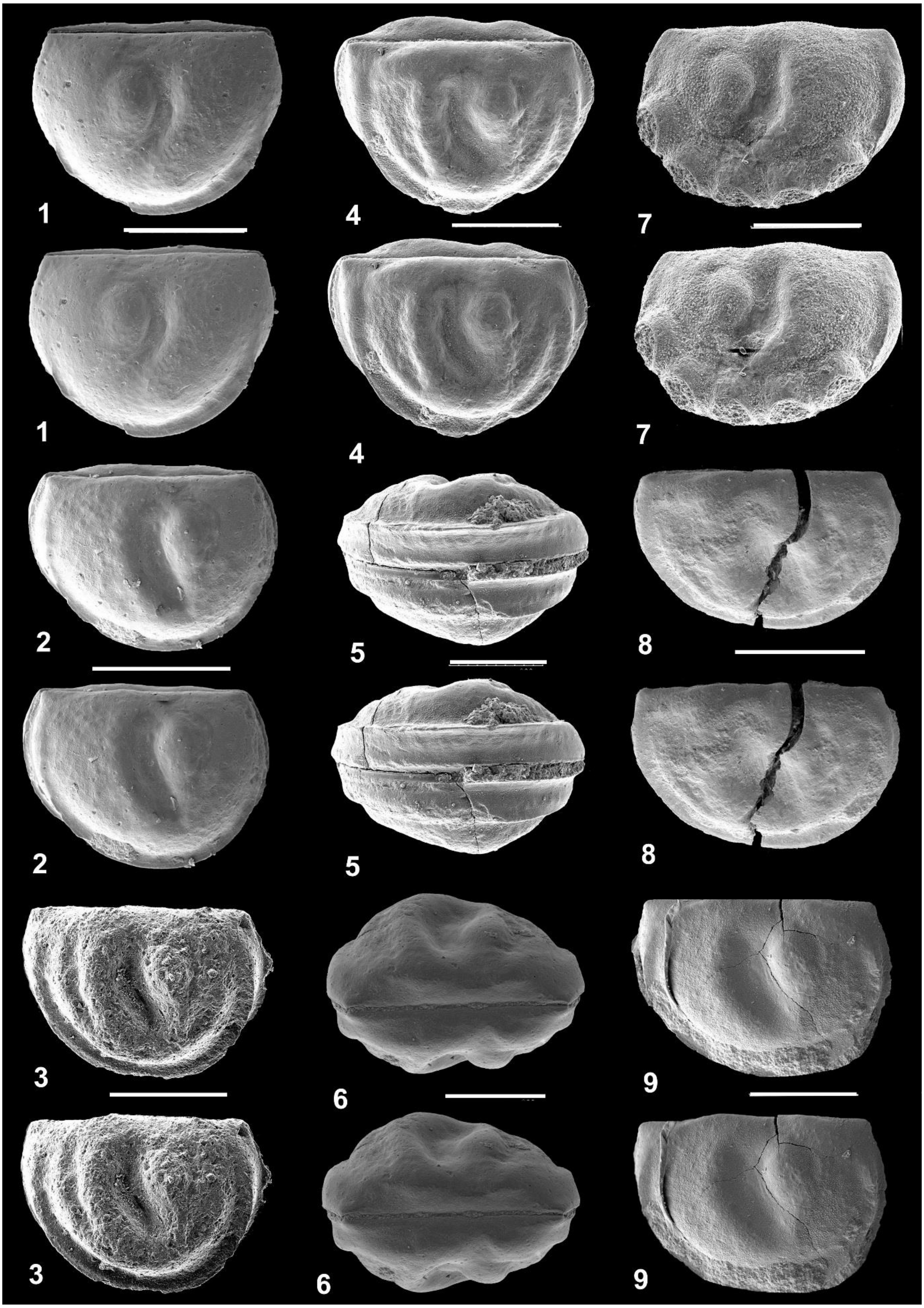
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Plate 2

Figures 1-5**. *Baltonotella parsispinosa*** (Kraft, 1962). Ellis Bay, Parastro Member of the Ellis Bay Formation, sample EB14. Scale bars 300 µm. 1-2 juveniles, 3-5 adults.

1-2. Carapace, right valve, lateral (stereo-pair) views.

3-4. Carapace, right valve, lateral (stereo-pair) views.

5. Carapace, left valve, lateral (stereo-pair) view.

Figure 6-8 ***Platybolbina shaleri*** Copeland**,** 1973. Ellis Bay, Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation. Adults.

6. Left lateral view (stereo-pair), sample EB16. Scale bar 500 µm.

7. Right lateral view (stereo-pair), sample EB16. Scale bar 500 µm.

8. Right lateral view (stereo-pair), sample EB18. Scale bar 300 µm.

Figure 9. ***Platybolbina*** sp. A. Left valve, lateral (stereo-pair) view, sample EB16. Scale bar 300 µm.

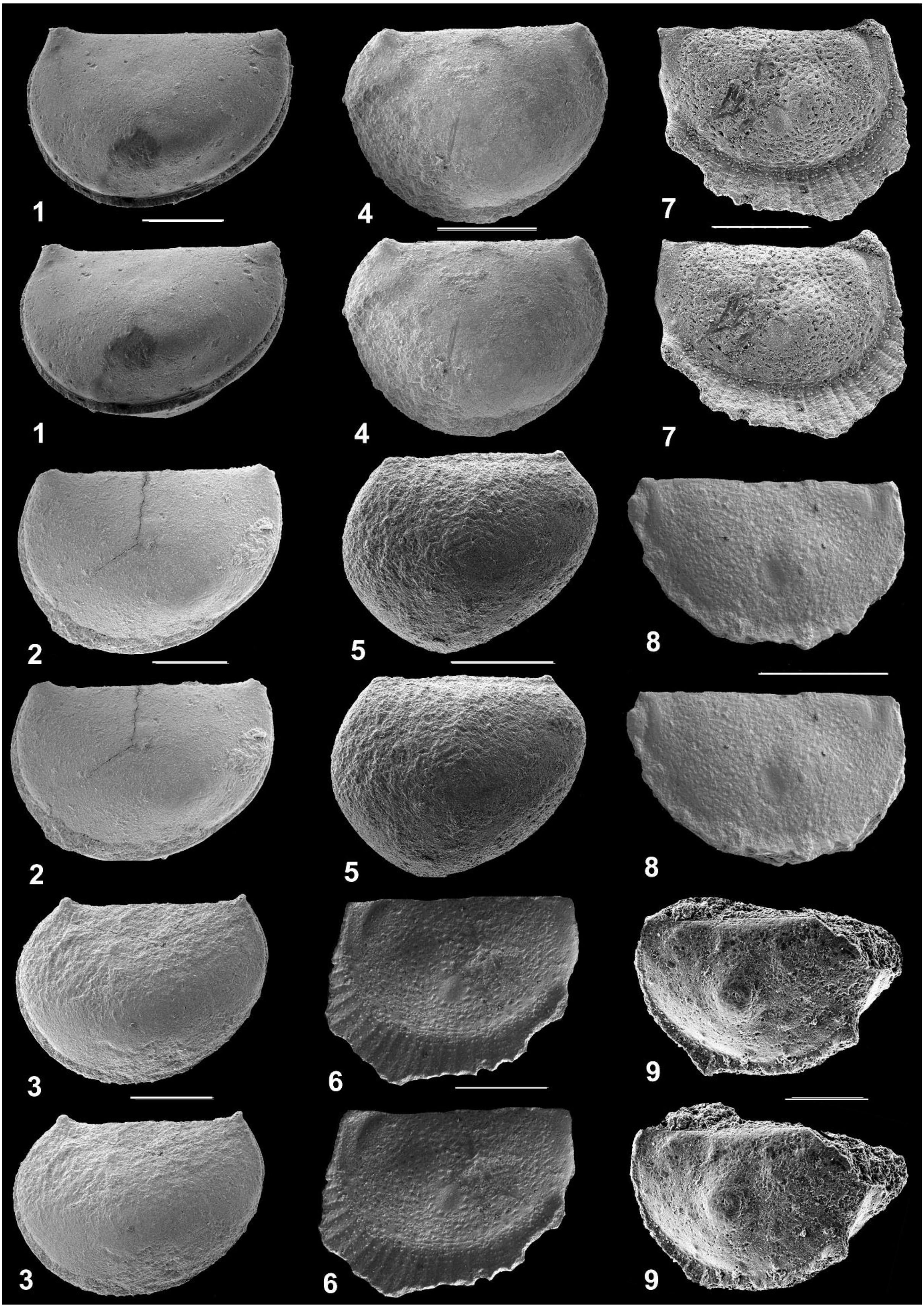
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Plate 3

Figures 1-6. ***Tvaerenella calvatus*** sp. nov. Ellis Bay, Fraise, Juncliff, Parastro and Laframboise members of the Ellis Bay Formation. Scale bars 500 µm.

Fig. 1. Carapace, oblique dorsal (stereo-pairs) view. Sample EB10.

Fig. 2. Holotype carapace, right lateral view (stereo-pairs) view. Sample EB1.

Fig. 3. Carapace, right lateral view (stereo-pairs) view. Sample EB24.

Fig. 4. Carapace, dorsal (stereo-pairs) view. Sample EB10.

Fig. 5. Carapace, ventral (stereo-pairs) view. Sample EB24.

Fig. 6. Carapace, left valve, lateral (stereo-pairs) view. Sample EB10.

Figures 7-8. ***Baltonotella rotundus*** sp. nov. Ellis Bay, Lousy Cove and Laframboise members of the Ellis Bay Formation, samples EB17 and EB24. Scale bars 500 µm.

Fig. 7. Holotype carapace, right valve, lateral (stereo-pairs) view. Sample EB17.
Fig. 8. Carapace, dorsal (stereo-pairs) view. Sample EB24.

Figure 9. ***Baltonotella*** sp. A. Ellis Bay, Parastro Member of the Ellis Bay Formation, sample EB10. Lateral (stereo-pairs) view. Scale bar 300 µm

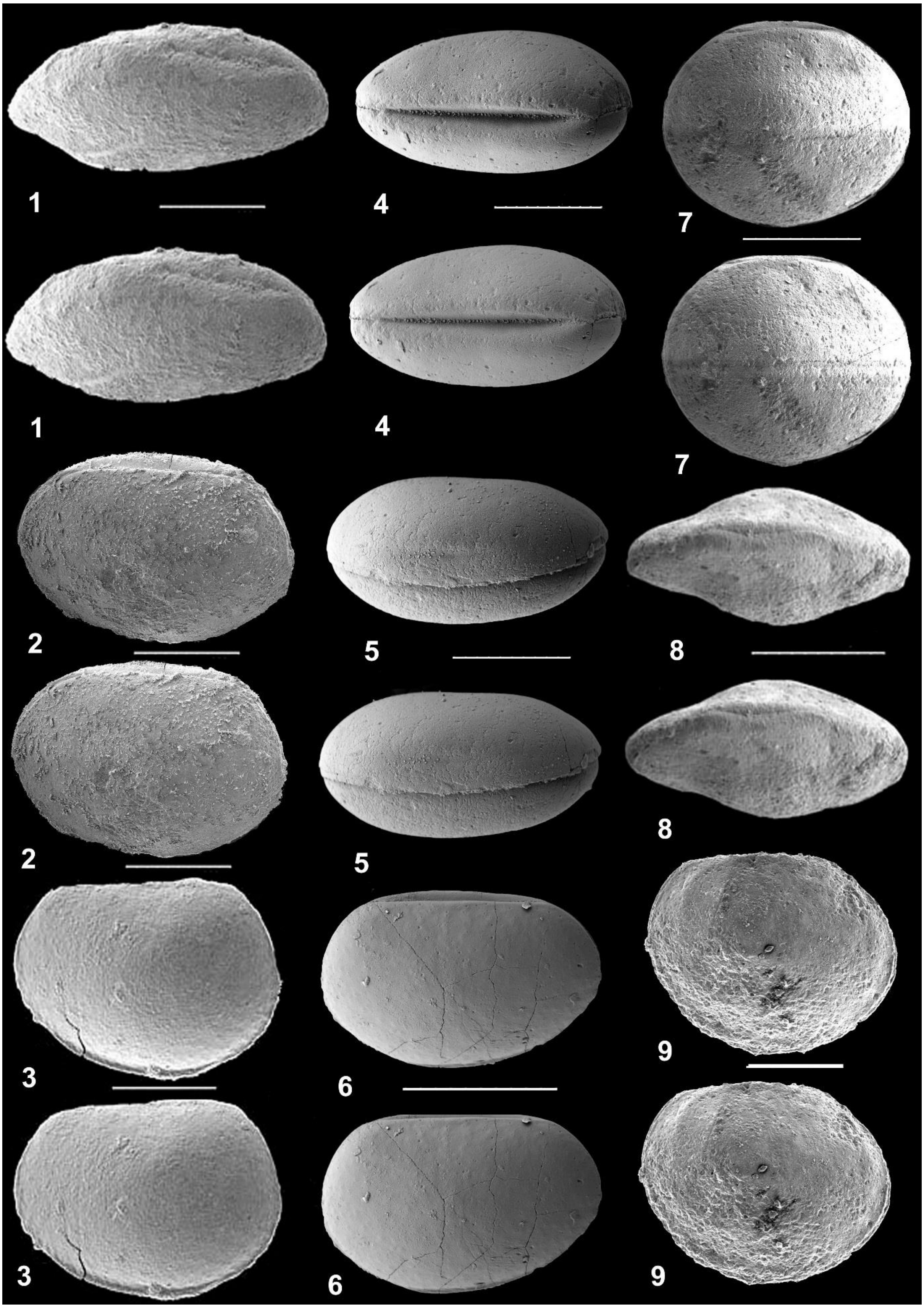
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Plate 4

Figure 1-3. ***Schmidtella robervali*** Copeland, 1973. Ellis Bay, Fraise, Juncliff, Parastro members of the Ellis Bay Formation. Scale bars 300 µm.

1. Right valve, lateral (stereo-pair) view, sample EB5.

2. Dorsal (stereo-pair) view. Ellis Bay, sample EB5.

3. Left valve, lateral view. Ellis Bay, sample EB6.

Figure 4-7. ***Schmidtella robervali*** Copeland, 1973. Ellis Bay, Fraise, Juncliff, Parastro members of the Ellis Bay Formation.

4. Left valve, lateral (stereo-pair) view, sample EB16. Scale bar 300 µm.

5. Left valve, lateral (stereo-pair) view, sample EB4. Scale bar 300 µm.

6. Left valve, lateral (stereo-pair) view, sample EB8. Scale bar 200 µm.

7. Right valve, lateral view, sample EB2. Scale bar 300 µm.

Figure 8. ***Easchmidtella***? sp. A. Left valve, lateral view (stereo-pair). Ellis Bay, Lousy Cove Member of the Ellis Bay Formation, sample EB18. Scale bar 300 µm.

Figure 9. ***Easchmidtella*** sp. A. Oblique left valve, lateral (stereo-pair) view. Ellis Bay, Lousy Cove Member of the Ellis Bay Formation, sample EB16. Scale bar 300 µm.

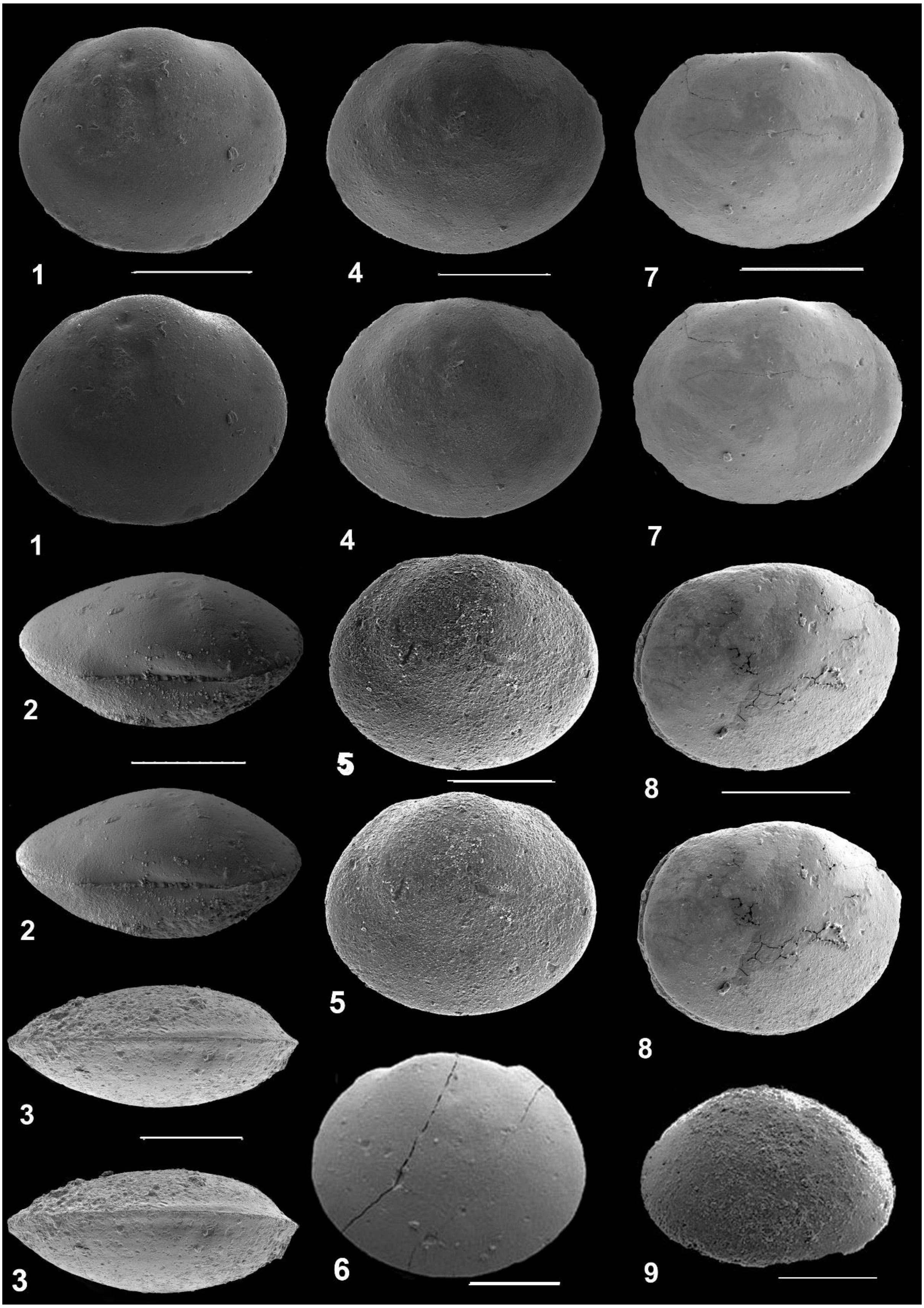
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Plate 5

Figures 1-6. ***Byrsolopsina irregularis*** (Keenan, 1951). Ellis Bay, Lousy Cove Member, Ellis Bay Formation, samples EB16, EB18 and EB20.

Fig. 1. Left valve, lateral view of a carapace. EB18. Scale bar 200 µm.

Fig. 2. Left valve, lateral (stereo-pair) view. EB16. Scale bar 300 µm.

Fig. 3. Right valve, lateral view. EB16. Scale bar 300 µm.

Fig. 4. Carapace. Dorsal (stereo-pair) view. EB16. Scale bar 300 µm. (stereo-pair).

Fig. 5. Left valve lateral (stereo-pair) view. EB16. Scale bar 200 µm.

Fig. 6. Carapace. Ventral view. EB16. Scale bar 200 µm.

Fig. 7. Dorsal view. EB16. Scale bar 300 µm.

Figures 8-9. ***Easchmidtella*? *gyroslatus*** sp. nov. Ellis Bay, Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation. Scale bar 300 µm.

Fig. 8. Holotype left valve lateral (stereo-pair) view. Sample EB7.

Fig. 9. Carapace. Dorsal (stereo-pair) view. Sample EB18.

Figure 10. ***Leperditella*** sp. A. Lousy Cove Member of the Ellis Bay Formation, sample EB14. Left valve lateral (stereo-pair) view. Scale bar 300 µm.

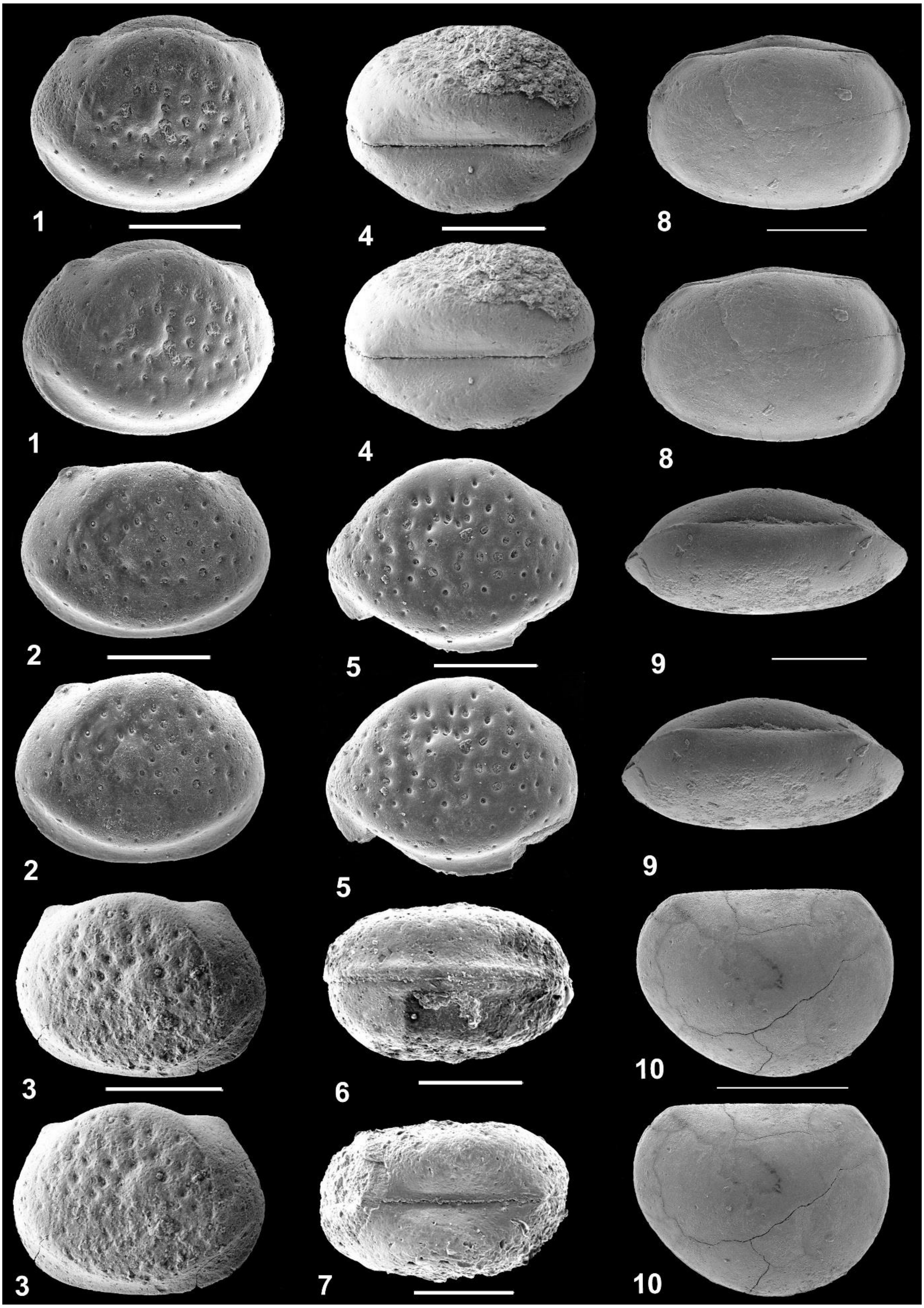
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Plate 6

Figure 1-2, 8-11. ***Aechmina*** sp. A. Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation. Scale bars 300 µm.

1. Left valve, lateral (stereo- pair) view. Sample EB7.

2. Carapace, anterior (stereo- pair) view. Sample EB7.

8. Right valve, lateral (stereo-pair) view. Sample EB16.

9. Left valve, lateral view. Sample EB16.

10. Dorsal view (stereo-pair). Sample EB16.

11. Right valve, lateral view. Sample EB16.

Figure 3. ***Aechmina maccormicki*** Copeland, 1973. Ellis Bay, Lousy Cove Member of the Ellis Bay Formation, sample EB16. Left valve, lateral view. Scale bar 200 µm.

Figures 4-7. ***Aechmina richmondensis*** Ulrich and Bassler, 1923. Ellis Bay, Fraise and Juncliff members of the Ellis Bay Formation, samples EB4 and EB5. Scale bars 300 µm.

Fig. 4. Lateral view (stereo- pair).

Fig. 5. Punctate ornamentation. Scale bar 100 µm;

Fig. 6. Oblique lateral view.

Fig. 7. Lateral (stereo- pair) view.

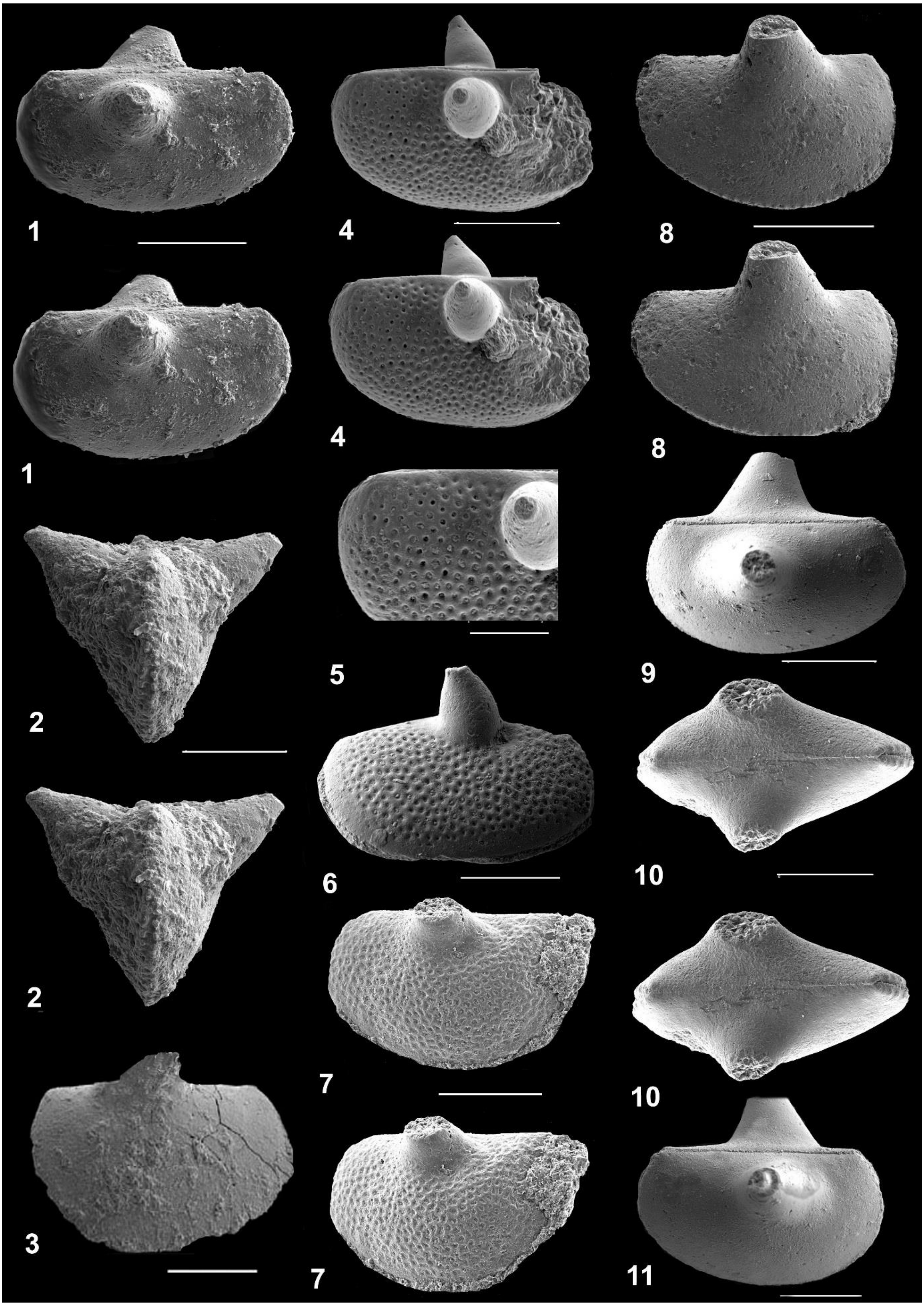
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Plate 7

Figures 1-2. ***Aechmina*** sp. B. Lousy Cove Member of the Ellis Bay Formation, sample EB17.

Fig.1. Right valve, lateral view. Scale bar 300 µm.

Fig. 2. Punctate ornamentation. Scale bar 100 µm.

Figure 3. ***Aechmina maccormicki*** Copeland, 1973. Ellis Bay, Lousy Cove Member of the Ellis Bay Formation. Left valve, lateral (stereo- pair) view. Sample EB16. Scale bar 200 µm.

Figure 4. ***Aechmina*** sp. A. Ellis Bay, Lousy Cove Member of the Ellis Bay Formation, sample EB16. Oblique left valve, lateral (stereo- pair) view. Scale bar 300 µm.

Figures 5-7. ***Faurella cartieri*** Copeland, 1973. Juncliff and Parastro members of the Ellis Bay Formation, samples EB9 and EB10. Scale bars 300 µm.

Fig. 5. Right valve, lateral (stereo-pair) view.

Fig. 6. Left valve, lateral (stereo-pair) view.

Fig. 7. Left valve, lateral (stereo-pair) view.

Figures 8-11. ***Hemiaechminoides*** sp. A. Ellis Bay, Lousy Cove Member of the Ellis Bay Formation, EB16. Scale bars 200 µm.

Fig. 8. Right valve, lateral (stereo-pair) views.

Fig. 9. Right valve, lateral view.

Fig. 10. Left valve, lateral (stereo-pair) views.

Fig. 11. Right valve, lateral view.

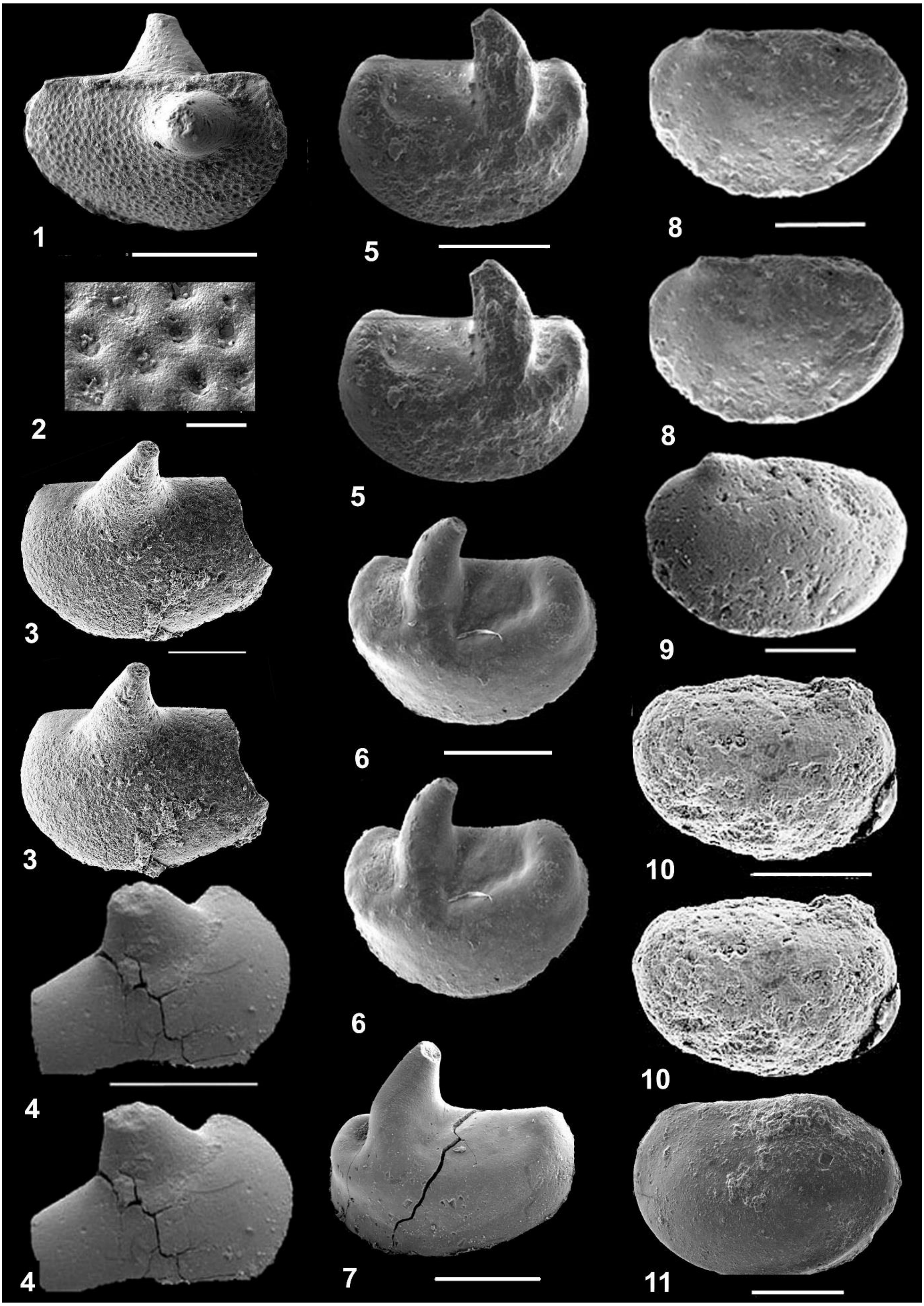
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Plate 8

Figures 1-11. ***Anticostus jolieti*** (Copeland, 1973). Ellis Bay, Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation, samples EB2, EB5 and EB16.

Fig. 1. Left valve, lateral (stereo-pair) view, juvenile. Scale bar 300 µm.

Fig. 2. Left valve, lateral (stereo-pair) view, juvenile. Scale bar 300 µm.

Fig. 3. Left valve, lateral (stereo-pair) view, juvenile. Scale bar 300 µm.

Fig. 4. Right valve, lateral (stereo-pair) view, adult. Scale bar 200 µm.

Fig. 5. Right valve, lateral (stereo-pair) view, adult. Scale bar 300 µm.

Fig. 6. Right valve, lateral (stereo-pair) view, adult. Scale bar 200 µm.

Fig. 7. Ventral view, carapace, adult. Scale bar 300 µm.

Fig. 8. Dorsal view, carapace, adult. Scale bar 300 µm.

Fig. 9. Anterior view, carapace, adult. Scale bar 200 µm.

Fig. 10. Ventral view, carapace, adult. Scale bar 300 µm.

Fig. 11. Left valve, lateral view, adult. Scale bar 200 µm.

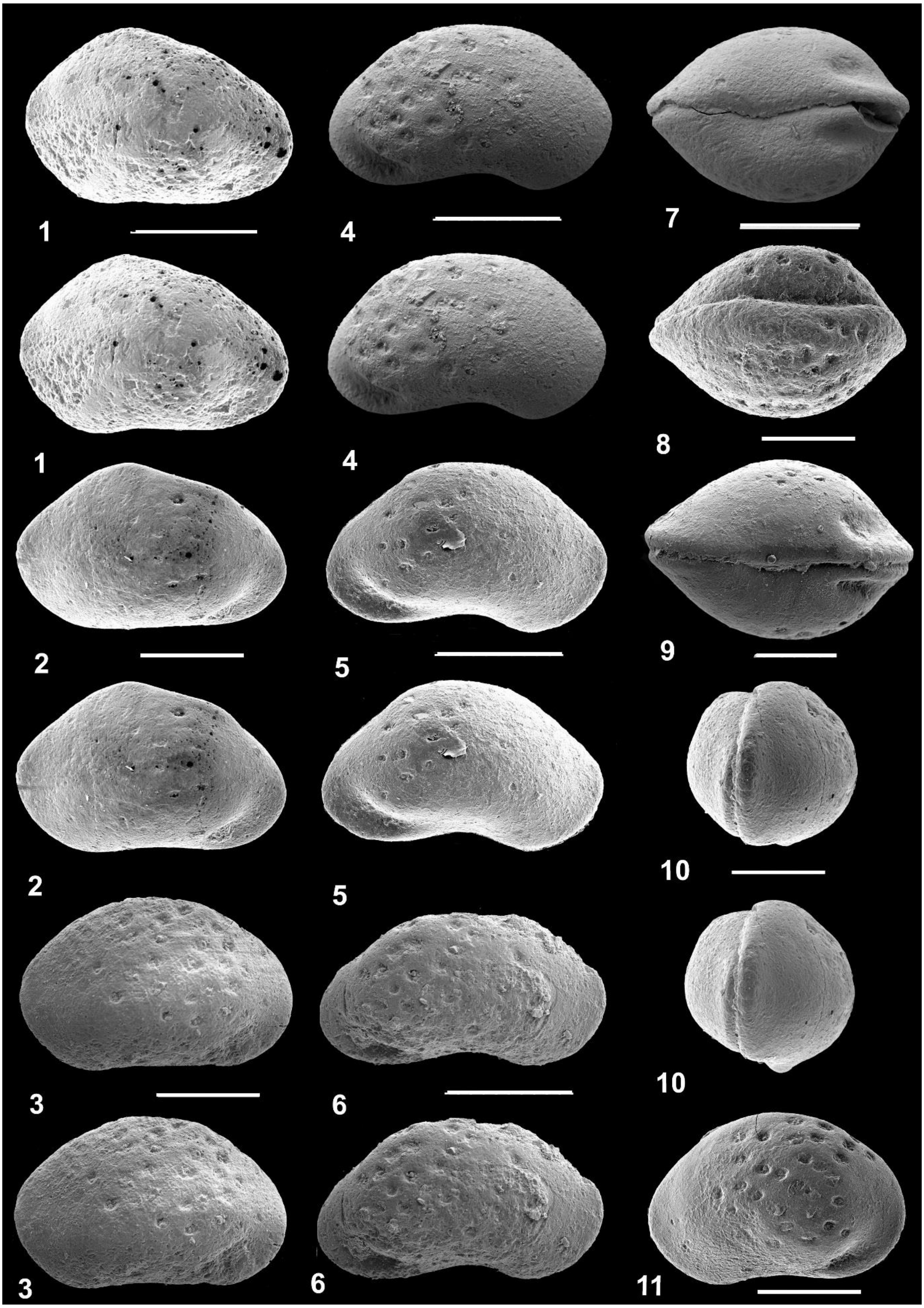
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Plate 9

Figures 1-8. ***Anticostus jolieti*** (Copeland, 1973). Ellis Bay, Ellis Bay Formation, samples EB2, EB5 and EB16.

Fig. 1. Left valve, lateral (stereo-pair) view, juvenile. Scale bar 300 µm.

Fig. 2. Left valve, lateral view, juvenile. Scale bar 300 µm.

Fig. 3. Right valve, lateral (stereo-pair) view, adult. Scale bar 300 µm.

Fig. 4. Single valve, ventral view, adult. Scale bar 200 µm.

Fig. 5. Ventral view, carapace, juvenile. Scale bar 300 µm.

Fig. 6. Ventral view, carapace, juvenile. Scale bar 300 µm

Fig. 7. Ventral view, carapace, adult. Scale bar 300 µm.

Fig. 8. Right valve, lateral (stereo-pair) view, juvenile. Scale bar 200 µm.

Figures 9-10. ***Pseudohippula castorensis*** (Copeland, 1970). Ellis Bay, Lousy Cove Member of the Ellis Bay Formation, samples EB16, EB17 and EB18. Scale bars 200 µm.

Fig.9. Right valve, lateral (stereo-pair) view.

Fig.10. Left valve, Lateral (stereo-pair) view.

Fig.11. Right valve, Lateral view.

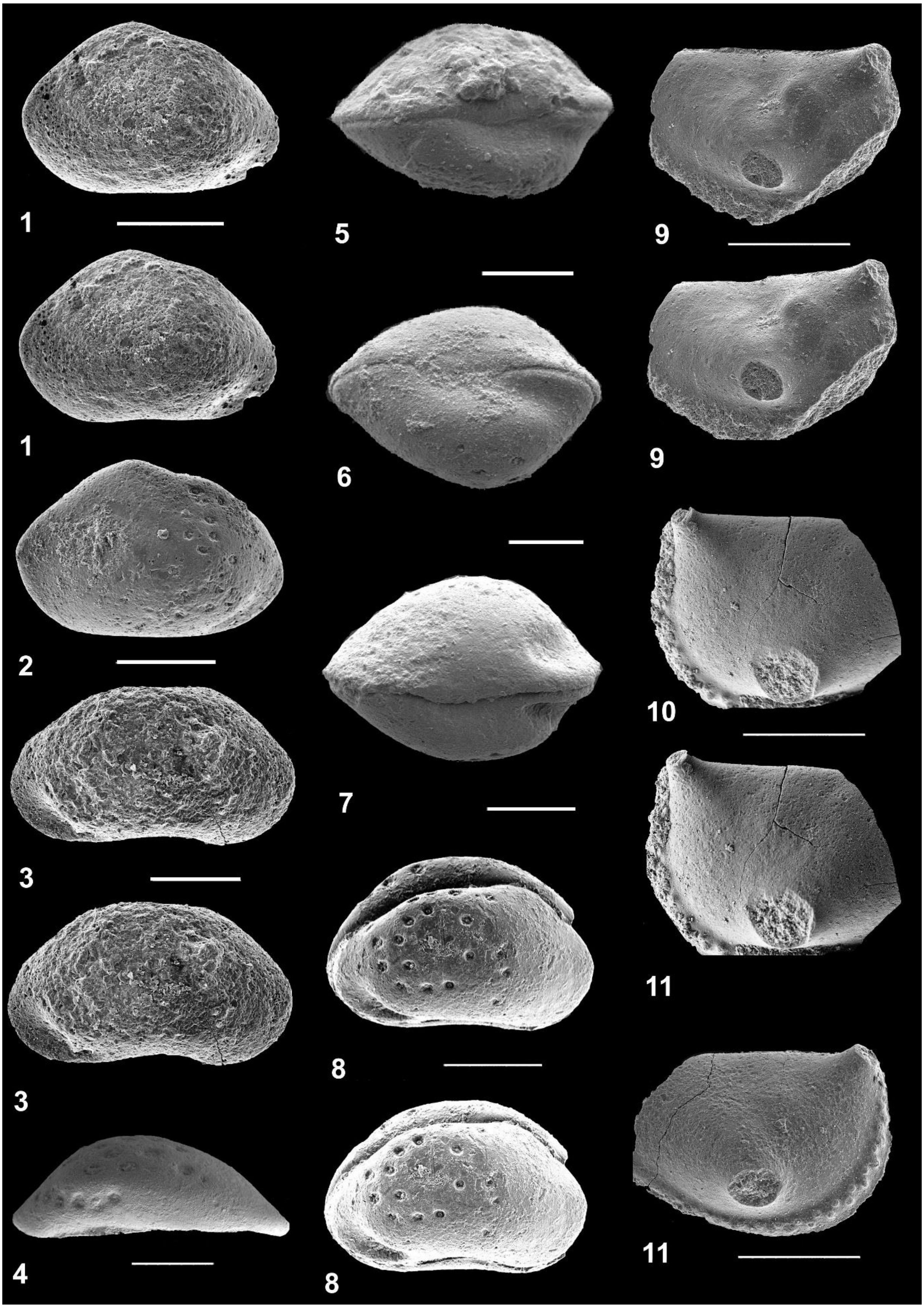
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Plate 10

Figures 1-3. ***Cryptophyllus punctoligos*** sp. nov., Ellis Bay Formation, Fraise, Juncliff, Parastro and Lousy Cove members. Scale bars 200 µm.

Fig.1. Carapace, right valve, lateral (stereo-pair) view, sample EB7.

Fig.2. Holotype carapace, left valve, lateral (stereo-pair) view, sample EB16.

Fig.3. Carapace, oblique lateral (stereo-pair) view, sample EB10.

Figures 4-5. ***Cryptophyllus bilamella*** sp. nov., Left valve, lateral (stereo-pair) view. Scale bars 300 µm.

Fig.4. Carapace, right valve, lateral (stereo-pair) view, sample EB10.

Fig.5. Holotype carapace, oblique lateral (stereo-pair) view, sample EB7.

Figure 6. ***Eridoconch*** sp. A. Left valve, lateral (stereo-pair) view, sample EB8. Scale bar 300 µm.

Figures 7-9. ***Cryptophyllus*** sp. A. Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation. Scale bars 300 µm.

Fig.7. Right valve, lateral (stereo-pair) view, sample EB16.

Fig.8. Right valve, lateral (stereo-pair) view, sample EB17.

Fig.9. Right valve (juveniles), lateral (stereo-pair) view, sample EB16.

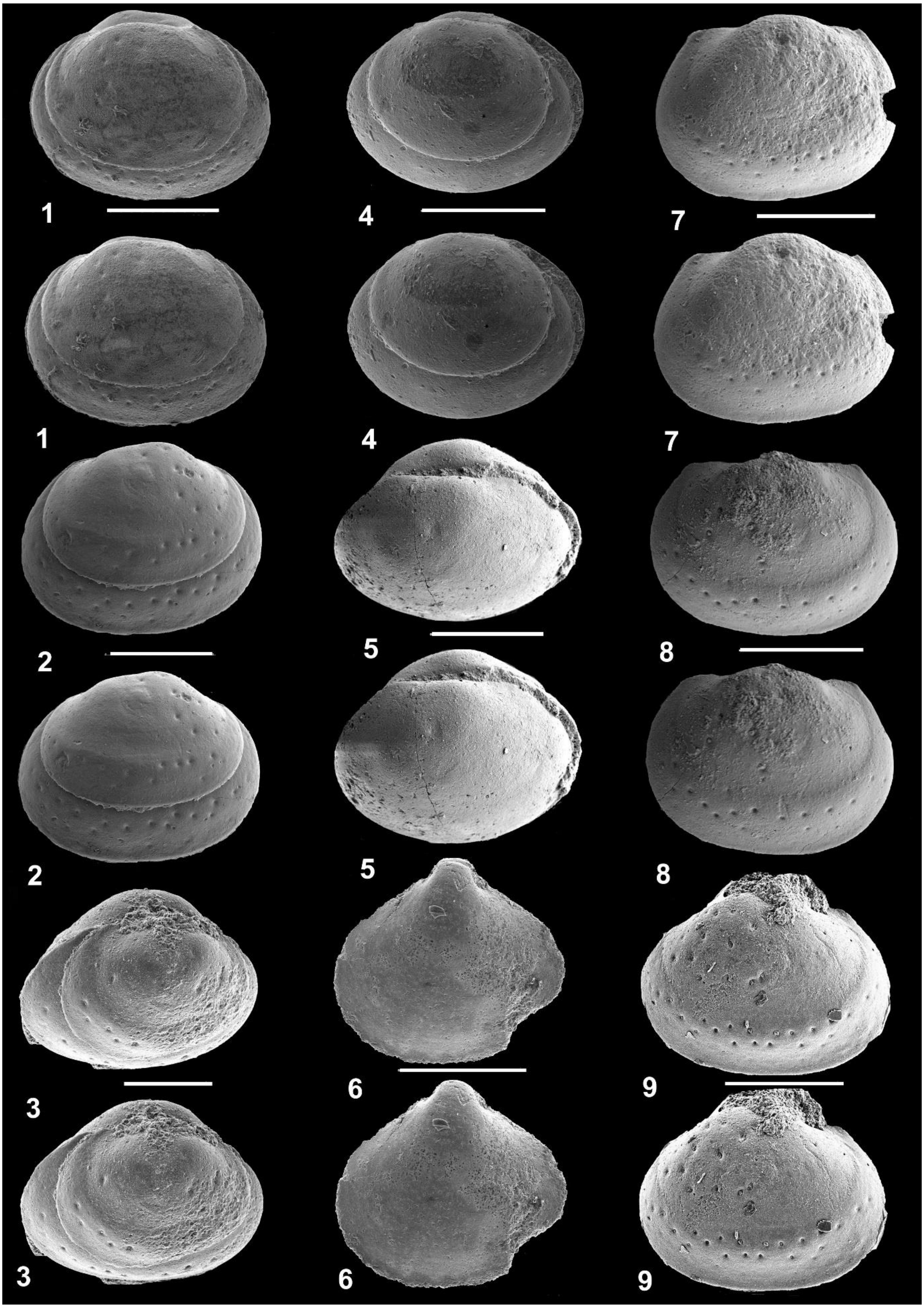
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Plate 11

Figure 1. ***Tetradella thomasi*** Copeland, 1973. Left tecnomorphic valve, lateral (stereo-pair) view, sample EB9. Scale bar 300 µm.

Figures 2-3. ***Tetradella anticostiensis*** Copeland, 1973. Ellis Bay, Lousy Cove Member of the Ellis bay Formation, samples EB9, EB17 and EB18. Scale bars 300 µm.

Fig.2. Right heteromorphic valve, lateral (stereo-pair) view.

Fig.3. Right heteromorphic valve, lateral (stereo-pair) view.

Fig.5. Right tecnomorphic valve, lateral (stereo-pair) view.

Figure 4. ***Foramenella phippsi*** Copeland, 1973. Lateral (stereo-pair) view, right valve (heteromorphic). Ellis Bay, Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, sample EB16. Scale bar 300 µm.

Figures 6-9. ***Eokloedenella canadensis*** (Bassler, 1927). Ellis Bay, Lousy Cove Member of the Ellis Bay Formation, samples EB19 and EB20. Scale bars 300 µm.

Fig. 6. Left valve, lateral (stereo-pair) view.

Fig. 7. Right valve, lateral (stereo-pair) view.

Fig. 8. Right valve, lateral (stereo-pair) view.

Fig. 9. Single valve, ventral (stereo-pair) view.

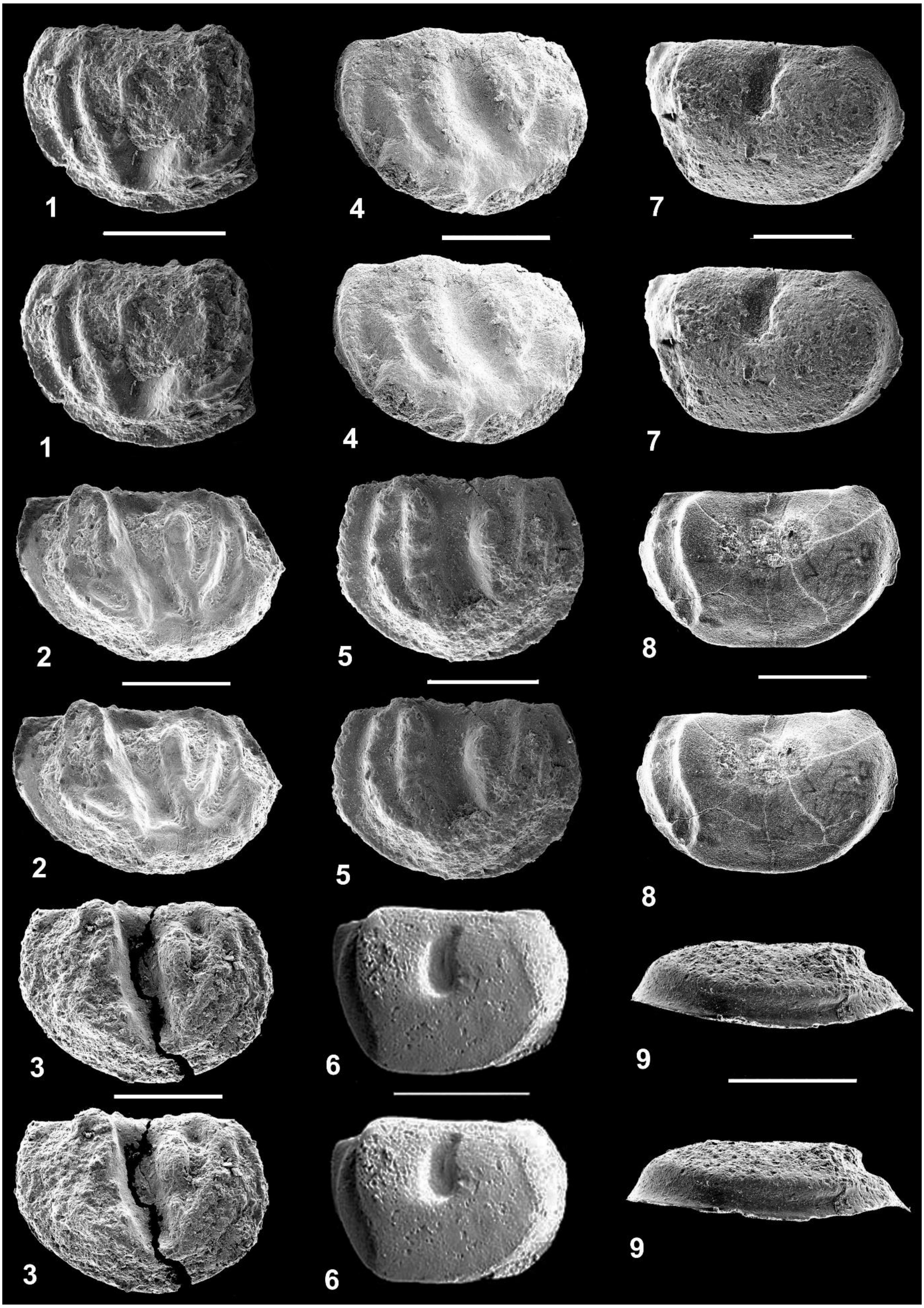
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Figure 1. ***Krausella*** sp. A. Fraise, Juncliff, Parastro members, Ellis Bay Formation. Juvenile left valve, Lateral (stereo-pair) view. Scale bar 200 µm.

Figures 2-3. ***Eurychilina*** sp. A. Ellis Bay, Fraise, Juncliff, Parastro members, Ellis Bay Formation. Samples EB3 and EB15. Scale bars 300 µm.

Fig. 2. Left valve, lateral (stereo-pair) view.

Fig. 3. Right valve, lateral (stereo-pair) view.

Figures 4-5. ***Eurybolbina*** sp. A. Ellis Bay, Fraise, Juncliff, Parastro members of the Ellis Bay Formation, sample EB10. Scale bars 300 µm.

Fig. 4. Right valve, lateral (stereo-pair) view.

Fig. 5. Left valve, lateral (stereo-pair) view.

Figures 6, 8. ***Anticostiella*** sp. A. Lousy Cove Member of the Ellis Bay Formation, sample EB10. Left valves, lateral (stereo-pair) views. Scale bars 300 µm.

Figures 7, 9 ***Anticostiella ellisensis*** Copeland, 1973, Lousy Cove Member of the Ellis Bay Formation, samples EB18 and EB20. Left valves, lateral (stereo-pair) views. Scale bars 200 µm.

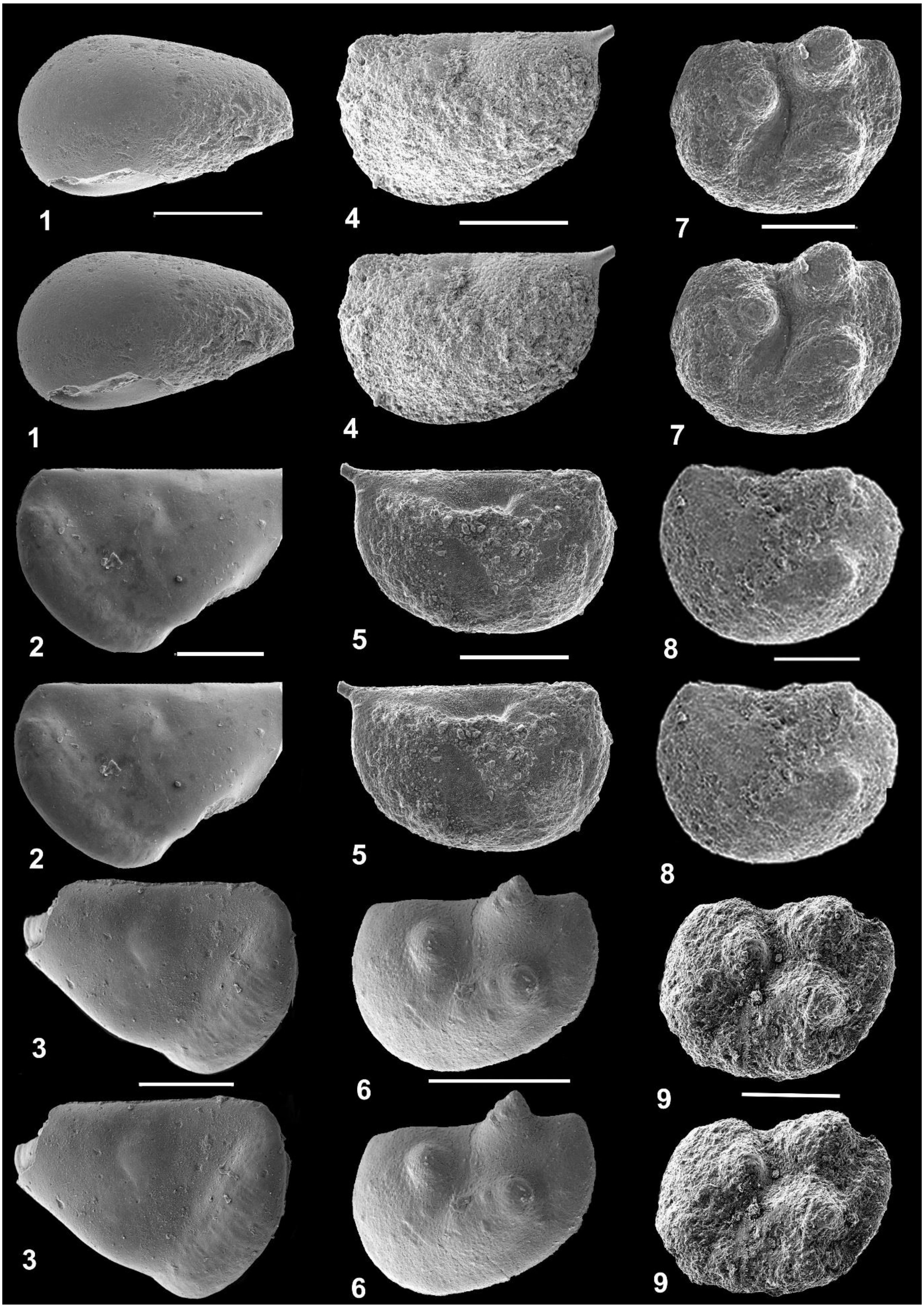
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Plate 13

Figures 1-4. ***Krausella lousyunculus*** sp. nov., Ellis Bay, Lousy Cove members of the Ellis Bay Formation, samples EB1, EB16 and EB19. Scale bars 200 µm. Carapace.

Fig. 1. Carapace, right valve, lateral (stereo-pair) view. Samples EB19.

Fig. 2. Carapace, ventral (stereo-pair) view. Samples EB1.

Fig. 3. Carapace, right valve, lateral (stereo-pair) view. Samples EB19.

Fig. 4. Holotype carapace, right valve, lateral (stereo-pair) view. Samples EB16.

Figures 5-8. ***Spinigerites unicornis*** (Ulrich, 1879). Ellis Bay, Lousy Cove Member, Ellis Bay Formation. Samples EB16, EB18 and EB19. Scale bars 200 µm.

Fig. 5. Left valve, lateral (stereo-pair) view. Samples EB16.

Fig. 6. Carapace, ventral (stereo-pair) view. Samples EB16.

Fig. 7. Right valve, lateral view. Samples EB19.

Fig. 8. Carapace, right valve, lateral (stereo-pair) view. Samples EB18.

Figures 9-10. ***Krausella*** sp. A. Ellis Bay, Lousy Cove Member of the Ellis Bay Formation sample EB16. Scale bars 300 µm.

Fig. 9. Right valve lateral (stereo-pair) view.

Fig. 10. Ventral (stereo-pair) view.

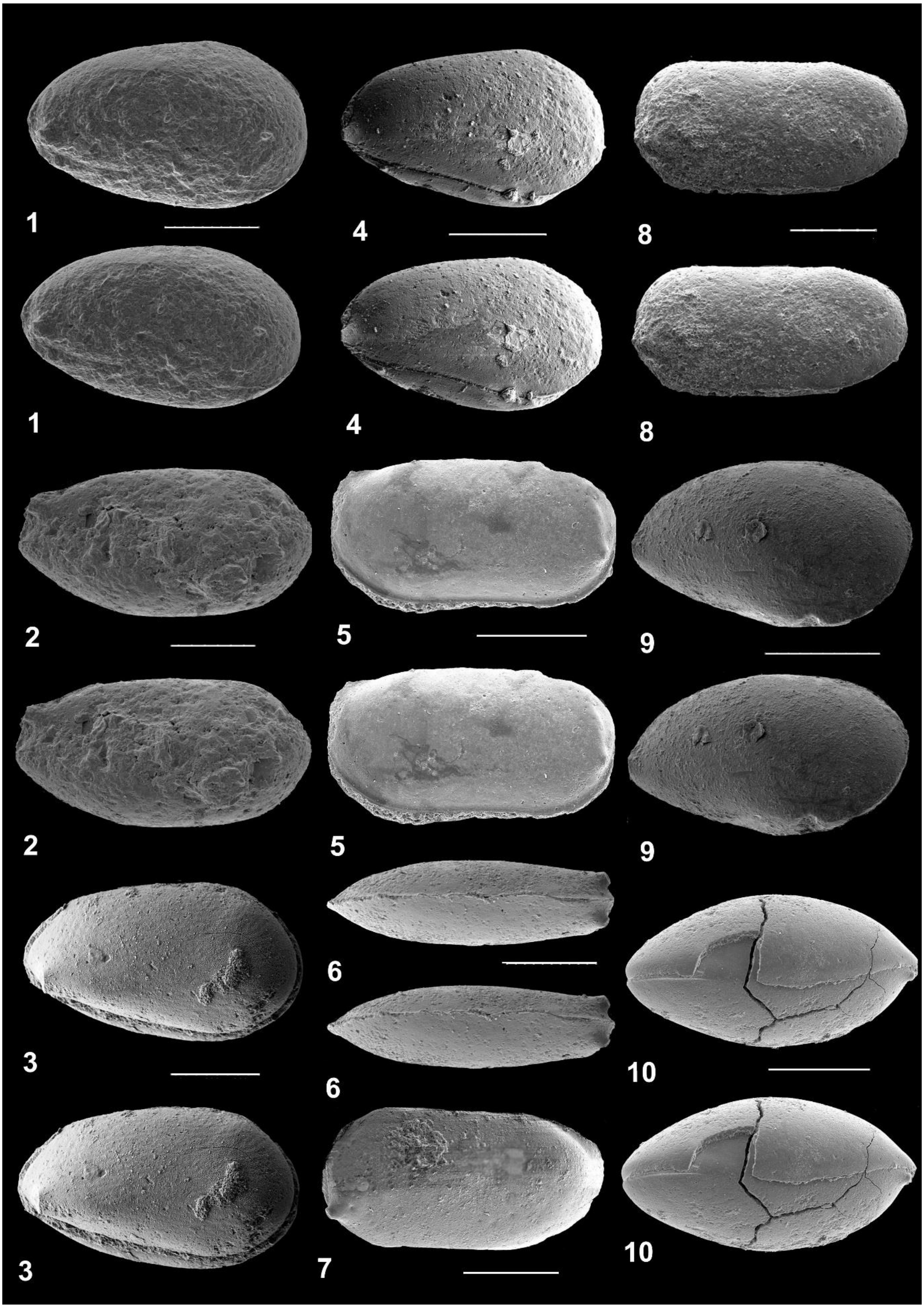
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Plate 14

Figures 1-5. ***Medianella meidlai*** sp. nov., Entire Ellis Bay Formation (all members). Samples EB1, EB3, Eb7, EB8, EB9, EB10, EB11, EB13, EB18 and EB24. Scale bars 300 µm.

Fig. 1. Holotype carapace, left valve, lateral (stereo-pair) view. Sample EB8.

Fig. 2. Carapace, oblique dorsal (stereo-pair) view. Sample EB10.

Fig. 3. Left valve, lateral (stereo-pair) view. Sample EB8.

Fig. 4. Right valve, lateral (stereo-pair) view. Sample EB9.

Fig. 5. Carapace, right valve, lateral (stereo-pair) view. Sample EB18.

Figures 6-10. ***Eurychilina erugoface*** sp. nov., Ellis Bay, Fraise, Juncliff, Parastro members, Ellis Bay Formation. Samples EB3 and EB15. Scale bars 300 µm.

Fig. 6. Right valve, lateral view. Sample EB3.

Fig. 7. Left valve, lateral view. Sample EB3.

Fig. 8. Holotype left valve, lateral (stereo-pair) view. Sample EB3.

Fig. 9. Carapace, oblique dorsal (stereo-pair) view. Sample EB15.

Fig. 10. Carapace, ventral (stereo-pair) view. Sample EB15.

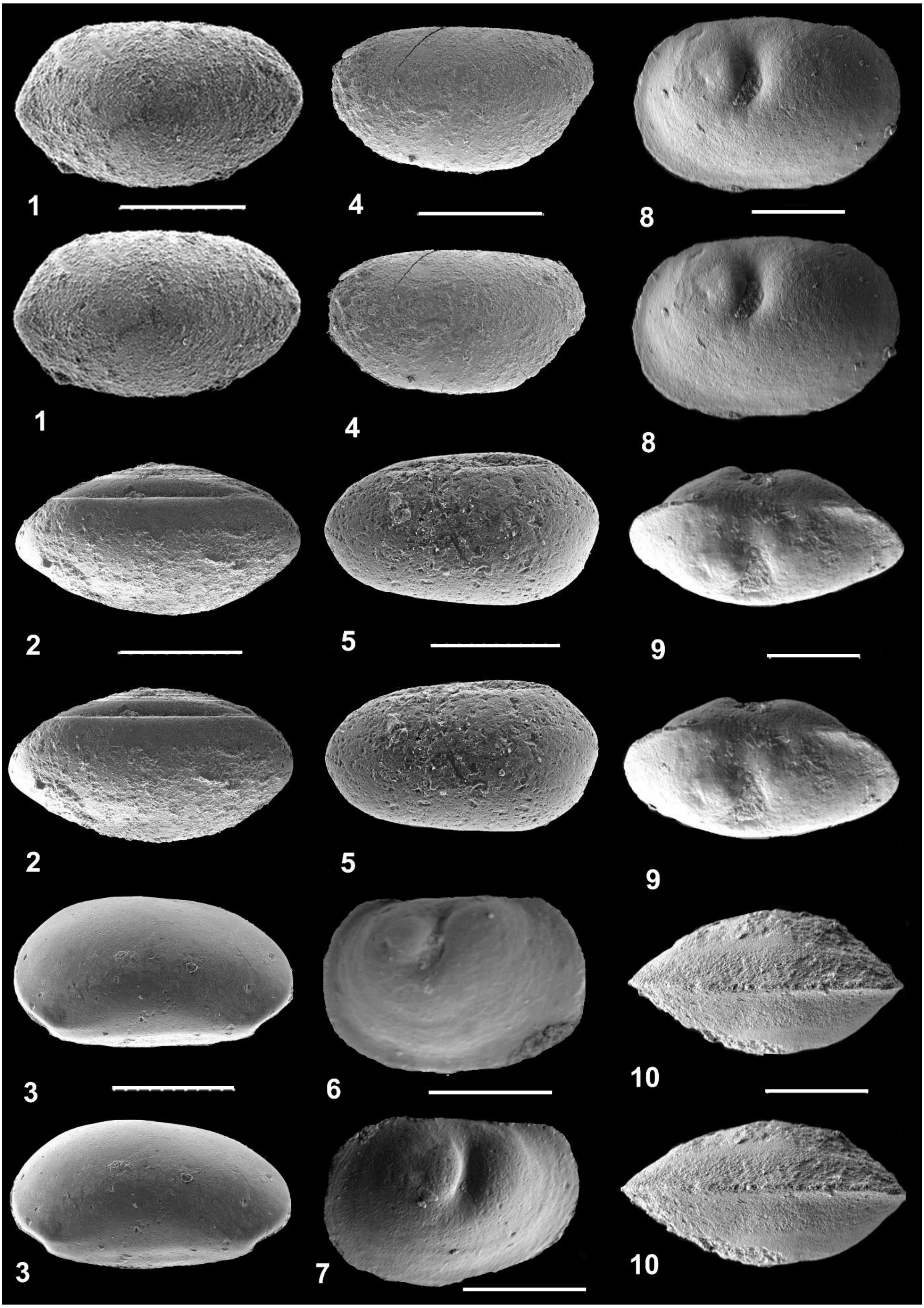
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Plate 15

Figures 1-2 ***Jonesites semilunatus*** (Jones, 1890). Lousy Cove Member of the Ellis bay Formation, samples EB16 and EB19. Scale bars 300 µm.

Fig. 1. Left valve, lateral (stereo-pair) view.

Fig. 2. Right valve, lateral (stereo-pair) view.

Figure 3. ***Dicranella*** sp. A. Right valve, lateral (stereo-pair) view, sample EB18. Scale bar 200 µm.

Figures 4, 5. ***Hemeaschmidtella prinstaulus*** sp. nov., Ellis Bay, Prinsta Member of the Ellis Bay Formation, sample EB5. Scale bars 200 µm.

Fig. 4. Holotype carapace, left valve, lateral (stereo-pair) view.

Fig. 5. Carapace, right valve, lateral (stereo-pair) view.

Figure 6. ***Eridoconcha*** sp. A., Left valve, lateral (stereo-pair) view, sample EB3. Scale bar 300 µm.

Figures 7-8. ***Eographiodactylus hyatti*** Copeland, 1973. Ellis Bay, Fraise Member of the Ellis Bay Formation, samples EB1. Scale bars 200 µm.

Fig. 7. Right valve, lateral (stereo-pair) view.

Fig. 8. Left valve, lateral (stereo-pair) view.

Figure 9. ***Spinigerites*** sp. A. Ellis Bay, Lousy Cove Member of the Ellis Bay Formation. EB16. Left valve, lateral (stereo-pair) view. Scale bar 200 µm.

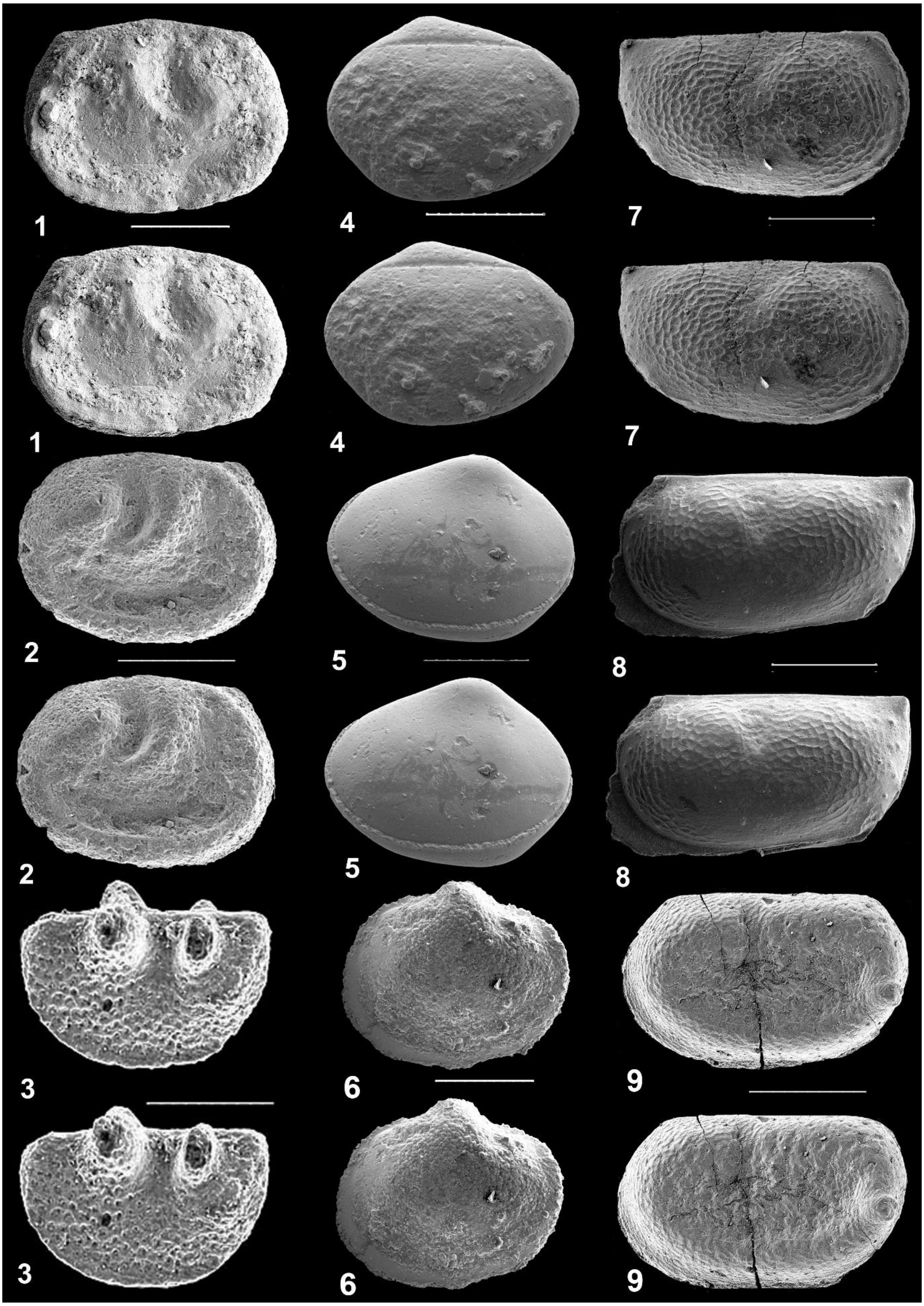
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Plate 16

Figures 1, 8. ***Hemeaschmidtella*** sp. A. Ellis Bay, Fraise and Lousy Cove members of the Ellis Bay Formation, samples EB2 and EB17. Scale bars 200 µm.

Fig. 1. Left valve, lateral (stereo-pair) view.

Fig. 8. Left valve, lateral (stereo-pair) view.

Figure 2. ***Hemeaschmidtella caleyi*** (Copeland, 1973). Ellis Bay, Fraise Member of the Ellis Bay Formation, sample EB2. Right valve, lateral view. Scale bar 200 µm.

Figure 3-4. ***Neoschmidtella granti*** Copeland, 1973. Juncliff, Parastro and Lousy Cove members, Ellis Bay Formation. Carapace, samples EB8 and EB9. Scale bars 300 µm.

3. Left valve, lateral view (stereo-pair). Sample EB8.

4. Right valve, lateral view. Sample EB9.

Figures 5, 6, 7, 9, 10 ***Hemeaschmidtella*** sp. B. Fraise Member, Ellis Bay Formation. Carapace, left and right valves, lateral (stereo-pair) views. Scale bars 300 µm.

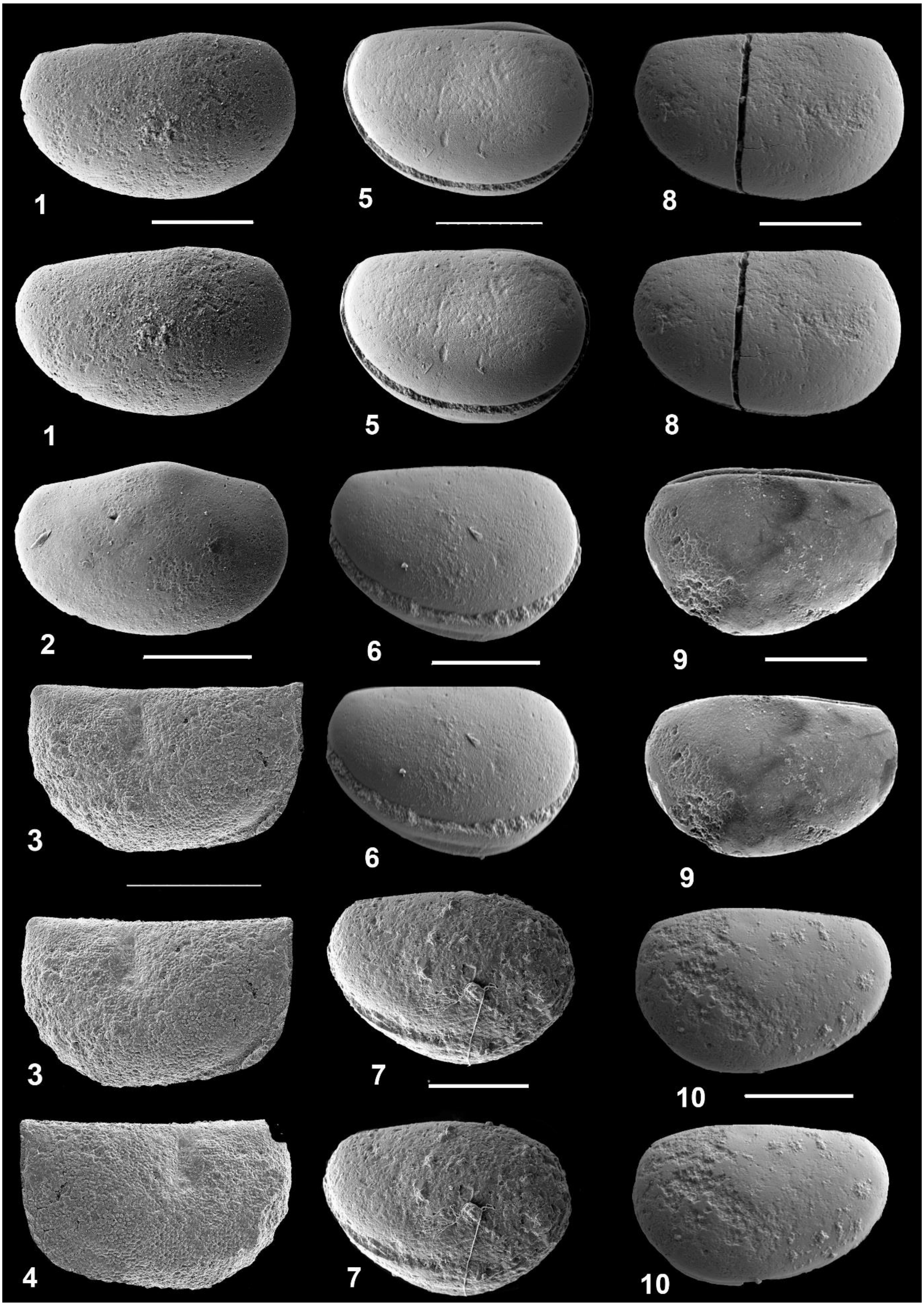
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Plate 17

Figures 1-6. ***Aviacypris tarsos*** sp. nov., Ellis Bay, Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation, samples EB8, EB9, EB16 and EB17. Scale bars 300 µm.

Fig. 1. Right valve, Lateral (stereo-pair) view. Sample EB9.

Fig. 2. Dorsal (stereo-pair) view. Sample EB8.

Fig. 3. Ventral (stereo-pair) view. Sample EB9.

Fig. 4. Right valve, Lateral (stereo-pair) view. Sample EB16.

Fig. 5. Holotype left valve, Lateral (stereo-pair) view. Sample EB17.

Fig. 6. Left valve, Lateral (stereo-pair) view. Sample EB16.

Figure 7. ***Aviacypris ichnos*** sp. nov., Ellis Bay, Lousy Cove Member of the Ellis Bay Formation, left valve, lateral (stereo-pair) view, sample EB9. Scale bar 300 µm.

Figure 8. ***Aviacypris*** sp. A. Ellis Bay, Lousy Cove Member of the Ellis Bay Formation, carapace, right valve, lateral, sample EB18. Scale bar 300 µm.

Figures 9-11. ***Macrocyproides trentonensis*** (Ulrich). Ellis Bay, the Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, samples EB1, EB16 and EB 17. Scale bars 200 µm.

Fig. 9. Right valve, Lateral (stereo-pair) view.

Fig. 10. Left valve, Lateral (stereo-pair) view.

Fig. 11. Right valve, Lateral (stereo-pair) view.

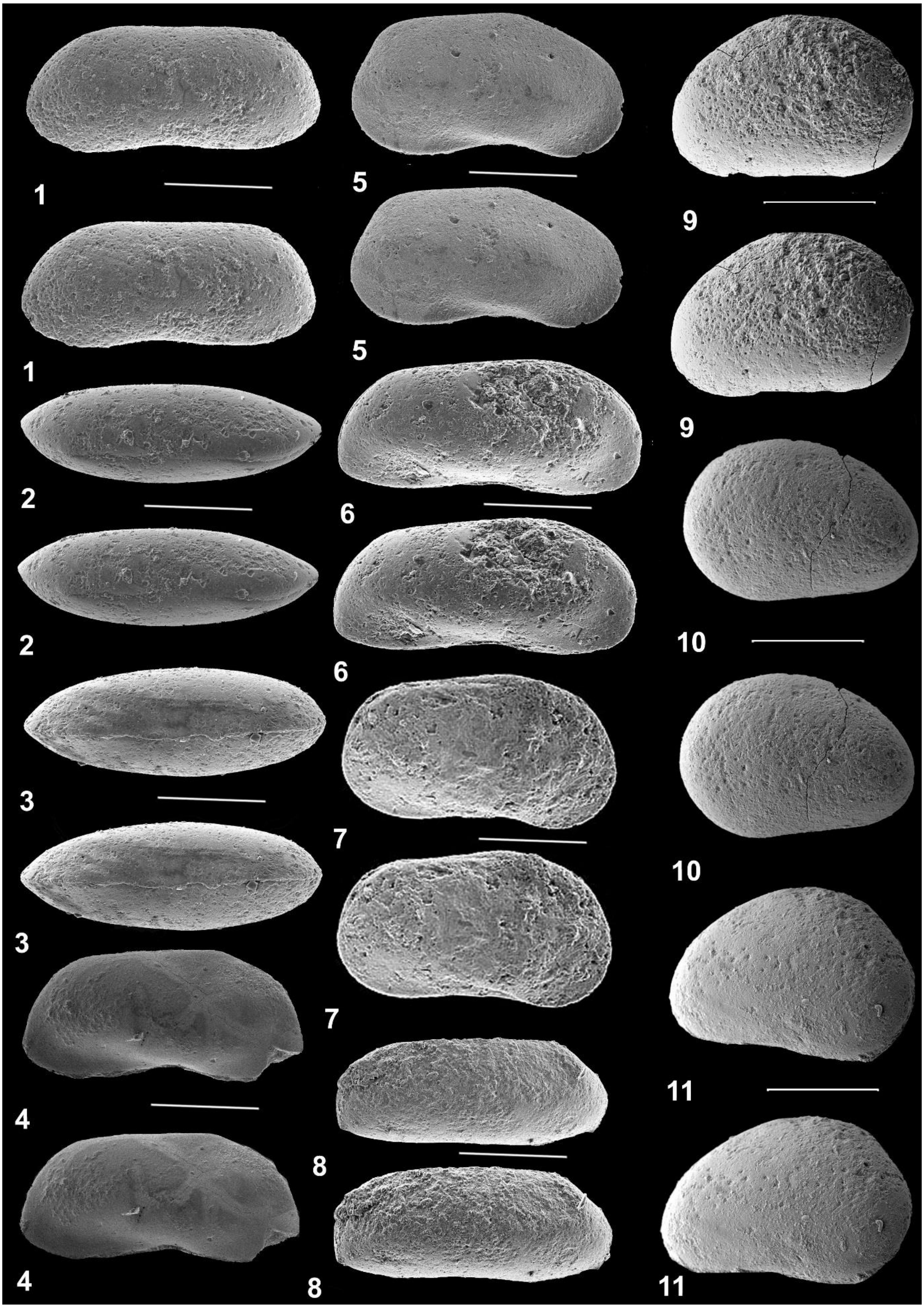
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Plate 18

Figures 1-7. ***Longiscula subcylindrica*** sp. nov., Ellis Bay, Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members, Ellis Bay Formation. Samples EB2, EB8, EB10, EB18 and EB24. Scale bars 300 µm.

Fig. 1. Right valve, Lateral (stereo-pair) view.

Fig. 2. Right valve, Lateral (stereo-pair) view.

Fig. 3. Left valve, Lateral (stereo-pair) view.

Fig. 4. Right valve, Lateral (stereo-pair) view.

Fig. 5. Left valve, Lateral (stereo-pair) view.

Fig. 6. Ventral (stereo-pair) view.

Fig. 7. Left valve, Lateral (stereo-pair) view.

Figure 8. ***Longiscula*** sp. A. Right valve, Lateral (stereo-pair) views. Sample EB8. Scale bar 300 µm.

Figures 9, 10. ***Eoaquapulex*** sp. A. Juncliff Member, Ellis Bay Formation, sample EB7. Scale bars 300 µm.

Fig. 9. Right valve, Lateral (stereo-pair) view.

Fig. 10. Oblique left valve, Lateral (stereo-pair) view.

Figure 11. ***Krausella lousyunculus*** sp. nov., Fraise, Juncliff, Parastro members, Ellis Bay Formation. Juvenile right valve, Lateral (stereo-pair) view. Scale bar 200 µm.

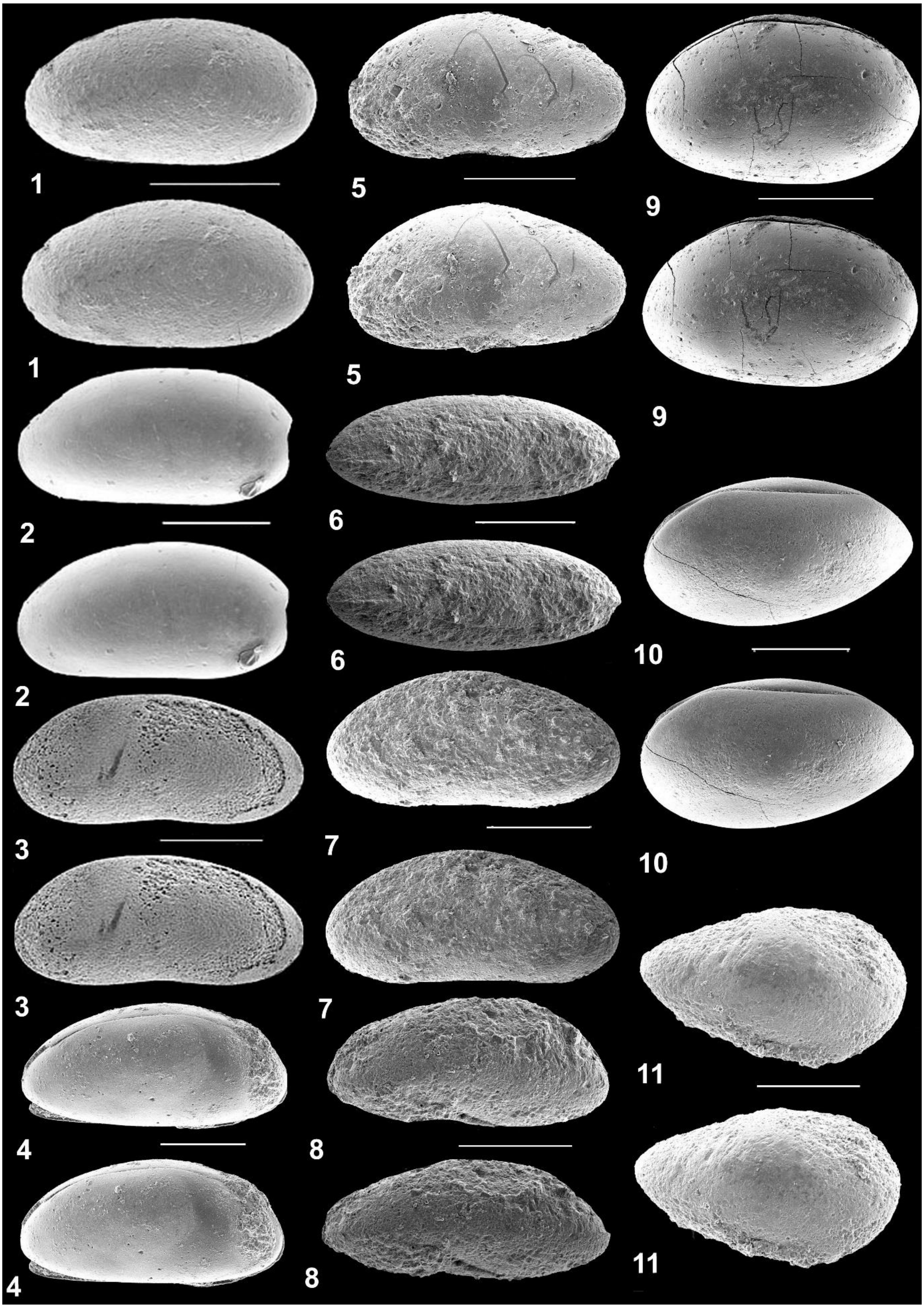
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Plate 19

Figures 1, 9-12. ***Elliptocyprites mawilliamsia*** sp. nov. Ellis Bay, Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation. Scale bars 300 µm.

Fig. 1. Left valve, lateral (stereo-pair) view. Sample EB1.

Fig. 9. Carapace, right valve, lateral (stereo-pair) view. Sample EB10.

Fig. 10. Carapace, right valve, lateral (stereo-pair) view. Sample EB10.

Fig. 11. Carapace, right valve, lateral (stereo-pair) view. Sample EB13.

Fig. 12. Carapace, right valve, lateral (stereo-pair) view. Sample EB13.

Figure 3. ***Rectella anticostensis*** sp. nov. Laframboise Member, Ellis bay Formation, lateral (stereo-pair) view, sample EB24. Scale bar 300 µm.

Figures 4-5. ***Elliptocyprites*** sp. A. Fraise, Juncliff, Parastro members of the Ellis Bay Formation. Samples EB7 and EB14. Scale bars 300 µm.

Fig. 4. Left valve, lateral (stereo-pair) view.

Fig. 5. Right valve, lateral (stereo-pair) view.

Figure 6. ***Rectella derosforma*** sp. nov., Lousy Cove Member, lateral (stereo-pair) view, sample EB17. Scale bar 300 µm.

Figure 7. ***Rectella*** sp. A. Laframboise Member, Ellis Bay Formation, Carapace, slightly oblique lateral view. Sample EB23. Scale bar 300 µm.

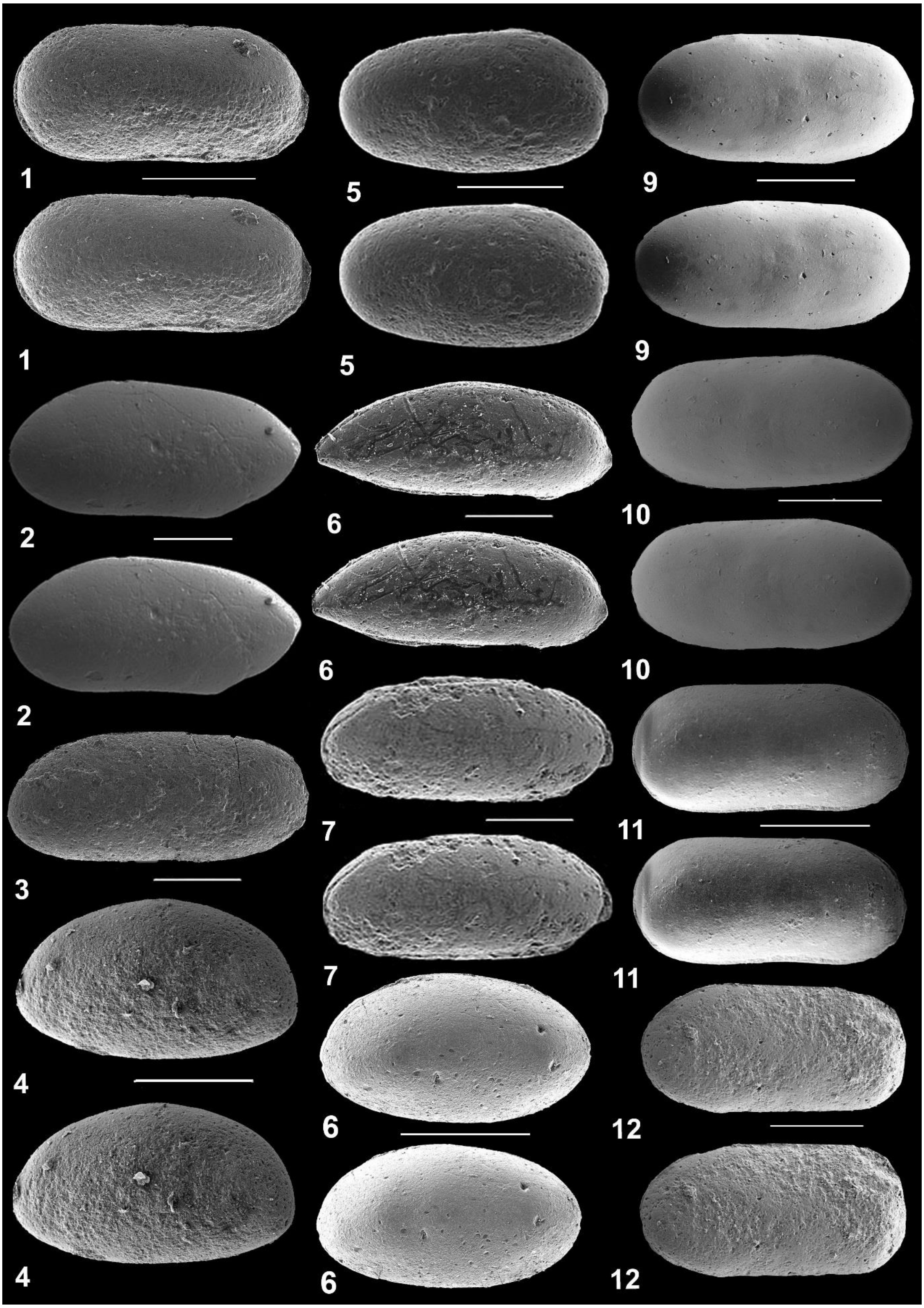
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Plate 20

Figures 1-3. ***Foramenella phippsi*** Copeland, 1973. Ellis Bay, Laframboise Member of the Ellis Bay Formation, samples EB22, EB24. Scale bars 300 µm, 1 juveniles, 2-3 adults.

Fig. 1. Left valve, lateral (stereo-pair) view.

Fig. 2. Carapace, right tecnomorph valve, lateral (stereo-pair) view.

Fig. 3. Carapace, left tecnomorph valve, lateral view.

Figure 4**. *Platybolbina shaleri*** Copeland, 1973. Ellis Bay, Laframboise Member of the Ellis Bay Formation, sample EB23. Scale bar 300 µm

Figures 5-6. ***Ctenobolbina*** sp. A. Juncliff, Parastro and Losy Cove members, Ellis Bay Formation, samples EB8 and EB12. Scale bars 300 µm

Fig. 5. Right tecnomorph valve, lateral (stereo-pair) view. Sample EB8.

Fig. 6. Left tecnomorph valve, lateral (stereo-pair) view. Sample EB12.

Figures 7-11. ***Platybolbina*** sp. B. Fraise, Juncliff, Parastro members, Ellis Bay Formation, samples EB7 and EB9. Scale bars 300 µm

Fig. 7. Left valve, lateral (stereo-pair) view.

Fig. 8. Right valve, lateral view.

Fig. 9. Right valve, lateral view.

Fig. 10. Right valve, lateral (stereo-pair) view.

Fig. 11. Right valve, lateral (stereo-pair) view.

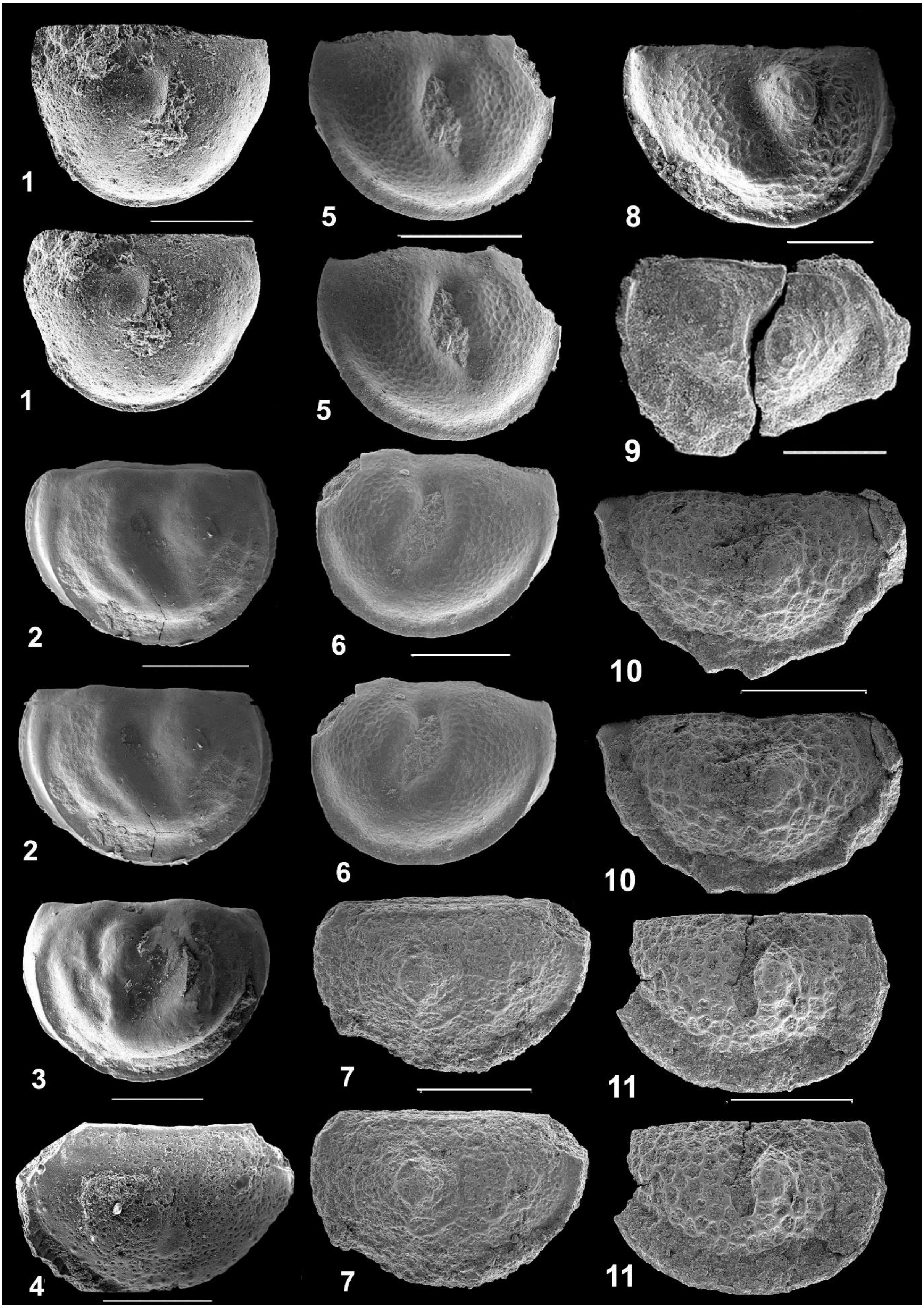

Plate 21

Figures 1-3, 13. ***Rectella anticostensis*** sp. nov. Fraise, Juncliff, Parastro and Laframboise members, Ellis bay Formation. Scale bars 300 µm.

Fig. 1. Left valve, lateral (stereo-pair) view. Sample EB7.

Fig. 2. Carapace, ventral (stereo-pair) view. Sample EB24.

Fig. 3. Carapace, dorsal (stereo-pair) view. Sample EB24.

Fig. 13. Right valve, lateral view. Sample EB7.

Figures 4-7. ***Rectella derosforma*** sp. nov. Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members. Scale bars 300 µm.

Fig. 4. Holotype carapace, left valve, oblique lateral (stereo-pair) view. Sample EB17.

Fig. 5. Holotype carapace, right valve, lateral (stereo-pair) view. Sample EB17.

Fig. 6. Carapace, left valve, lateral (stereo-pair) view. Sample EB1.

Fig. 7. Carapace, left valve, lateral (stereo-pair) view. Sample EB24.

Figure 8. ***Rectella*** sp. A. Juncliff, Parastro, Lousy Cove and Laframboise members, Ellis Bay Formation, Carapace, slightly oblique left valve, lateral (stereo-pair) view. Sample EB23. Scale bar 300 µm.

Figures 9-12. **Ostracod indt**. Ellis Bay, Fraise, Juncliff, Parastro and Lousy Cove members of the Ellis Bay Formation. Samples EB1, EB2, EB12 and EB17. Scale bars 300 µm.

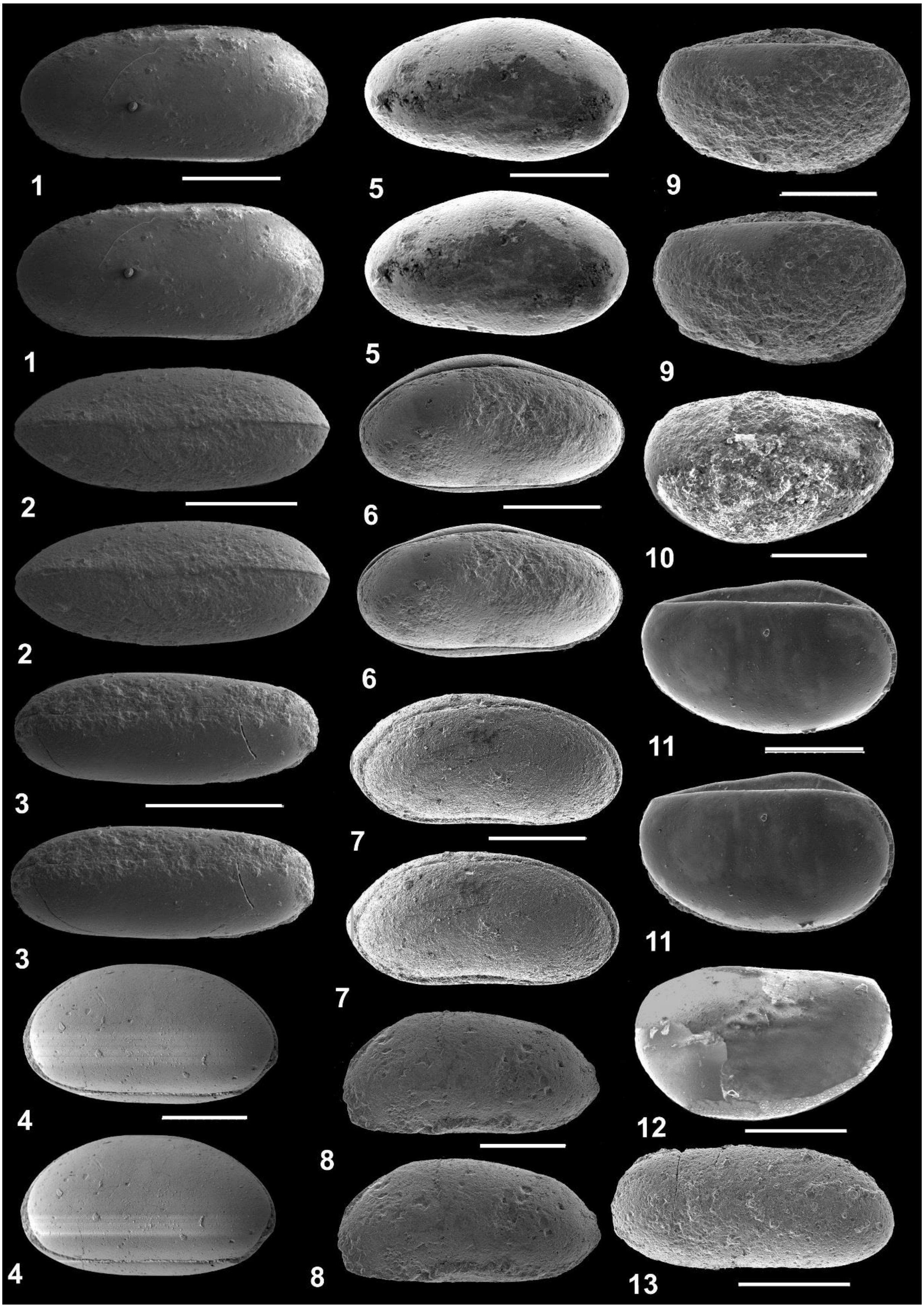
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Plate 22

Figures 1-6. ***Microcheilinella lubrica*** (Stumbur, 1956). Ellis Bay, Fraise, Juncliff, Parastro and Lousy Cove members, Ellis Bay Formation, samples EB5, EB16 and EB23. Scale bars 500 µm.

Fig. 1. Carapace, ventral (stereo-pair) view.

Fig. 2. Carapace, dorsal (stereo-pair) view.

Fig. 3. Carapace, left valve, lateral (stereo-pair) view.

Fig. 4. Carapace, right valve, lateral (stereo-pair) view.

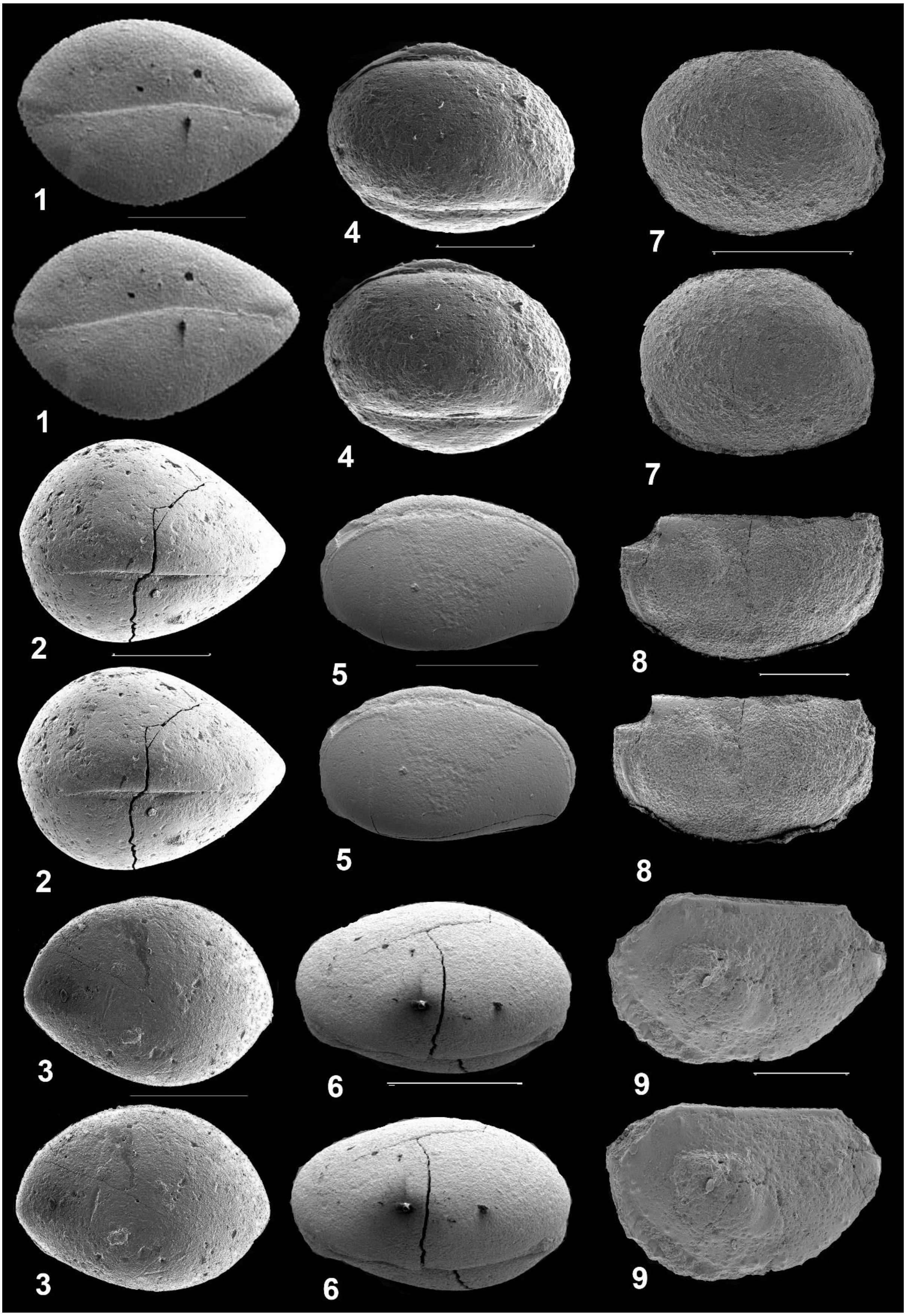
Fig. 5. Carapace, left valve, lateral (stereo-pair) view.

Fig. 6. Carapace, oblique lateral (stereo-pair) view toward ventral.

Figure 7. ***Baltonotella*** sp. A. Lousy Cove Member, Ellis Bay Formation, sample EB22. Scale bar 300 µm.

Figure 8. ***Foramenella phippsi*** Copeland, 1973. Laframboise Member of the Ellis Bay Formation, sample EB 22. Scale bar 300 µm.

Figure 9. ***Platybolbina shaleri*** Copeland, 1973. Lousy Cove Member, Ellis Bay Formation, sample EB20. Scale bar 300 µm.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Chapter 3

Ostracod biostratigraphy of the Late Ordovician Ellis Bay Formation, Ellis Bay, Anticosti Island, eastern Canada

Chapter 3: Ostracod biostratigraphy of the Late Ordovician Ellis Bay Formation, Ellis Bay, Anticosti Island, eastern Canada

Abstract

A local ostracod biostratigraphical framework for the Late Ordovician Ellis Bay Formation is presented. Four biostratigraphical intervals are recognized, three partial range zones characterised by their eponymous species and being in stratigraphical order from lowest to uppermost: the *Longiscula subcylindrica, Eurychilina erugoface,* and *Tetradella anticostiensis* biozones: the uppermost interval of the Ellis Bay Formation represents an interregnum. The stratigraphical level of the zones is compared with existing chemostratigraphic, graptolite and conodont stratigraphy for the Ellis Bay Formation. The ostracods may be useful for local correlation, but they do not provide information bearing on contested chronostratigraphical age assignments interpreted for the Ellis Bay Formation, which has been interpreted as either late Katian and Hirnantian by some authors, or as entirely Hirnantian by others.

3.1 Introduction

The biostratigraphical distribution of ostracods in the Ellis Bay Formation was documented by Copeland (1970, 1973, 1974), who recognised some 39 species within 30 genera, and discerned five ostracod subzones. However, his sampling did not cover the uppermost part of the Ellis Bay Formation, the Laframboise Member (*sensu* Desrochers *et al*. 2010). Copeland (1973) also did not study the ostracods of the lower part of the succeeding uppermost Ordovician and lower Silurian Bescie Formation. The material presented here establishes the ostracod biostratigraphy of the entire temporal range of the Ellis Bay Formation, including its uppermost Laframboise Member, based on 24 ostracod-bearing horizons from the Ellis Bay section, and based on the analysis of some 7614 ostracod specimens.

3.2 Stratigraphic setting of the Ellis Bay Formation

The Ellis Bay Formation comprises 60 to 90 m of calcareous shale and limestone. The lower contact of the formation conformably overlies the Upper Ordovician Vauréal Formation whilst the overlying uppermost Ordovician and lower Silurian Becscie Formation has a disconformable contact with the Ellis Bay Formation (Bolton 1961; Copeland 1973; Desrochers *et al*. 2010). The Ellis Bay Formation crops out along a ~200 km belt, between Junction Cliff on the southwest coast of Anticosti Island to Fox Point on the northeast coast (Desrochers *et al*. 2010; Jones *et al*. 2011; herein Fig. 3.1), with excellent coastal exposures at both the western and eastern ends of the Island (Desrochers *et al*. 2010; Achab *et al*. 2011, 2013; Copper *et al.* 2013; herein Fig. 3.2). The Ellis Bay Formation comprises five named lithological members in ascending order according to Long and Copper (1987; see also Long 2007), and seven named lithological members according to Copper *et al*. (2013). The depositional environment of the formation represents a shallowing-upward marine offshore to shoreline facies and it is rich in microfossils and macrofossils (Copeland 1973; Desrochers *et al*. 2010). The Ellis Bay Formation is the youngest ostracod-bearing formation in the Laurentian rock succession and it is an important repository of ostracod assemblage data from which to gauge diversity and environmental strategies of ostracods immediately prior to the end-Ordovician extinction. The Upper Ordovician stratigraphy of the Ellis Bay Formation is based on palaeontological and chemostratigraphic criteria (Copper 1999; Long 2007; Melchin 2008; Kaljo *et al*. 2008; Jones *et al*. 2011; Achab *et al*. 2011; Delabroye *et al*. 2011; herein Figs 3.3, 3.6). Chemostratigraphic evidence suggests that only the uppermost Lousy Cove and Laframboise members are Hirnantian, but palaeontological evidence proposes that the entire Ellis Bay Formation could be Hirnantian (see Figs 3.3, 3.4). Overall, much of the Ellis Bay Formation has a numerically rich and species-diverse ostracod assemblage, whilst its uppermost Laframboise Member is poorly diverse.

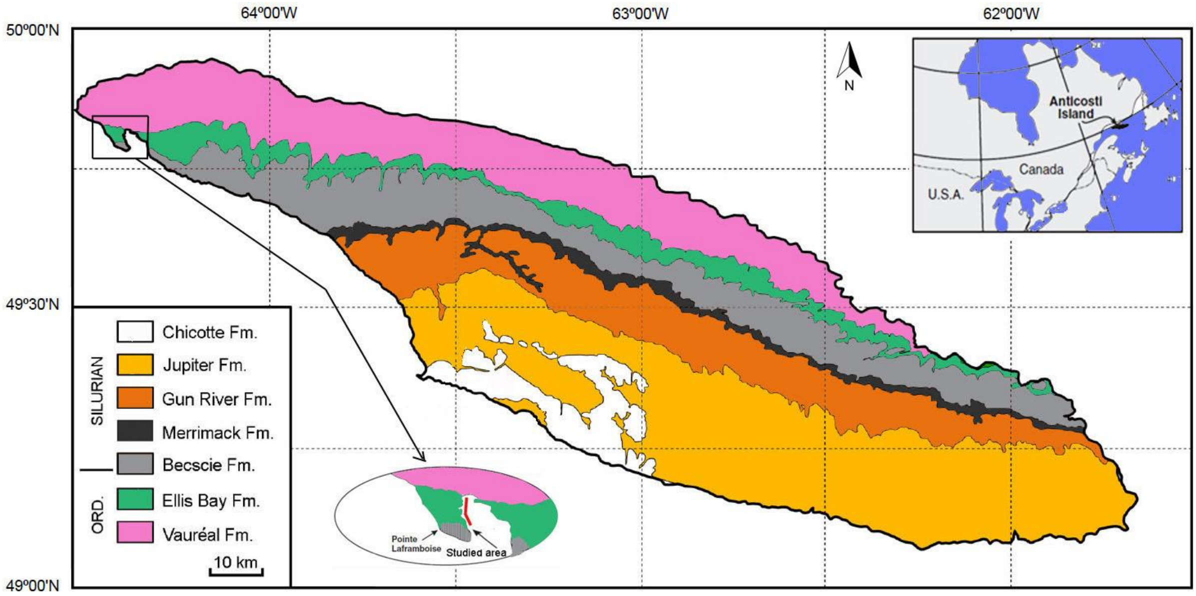


Figure 3.1. Geological map of Anticosti Island (after Desrochers *et al*. 2010, and Achab *et al*. 2011), showing the distribution of the Ellis Bay Formation (green). The key section in Ellis Bay, which was sampled for the ostracods described here, is circled (see Fig. 3.2 below). Inset map (top right) shows the locus of Anticosti Island in eastern maritime Canada.

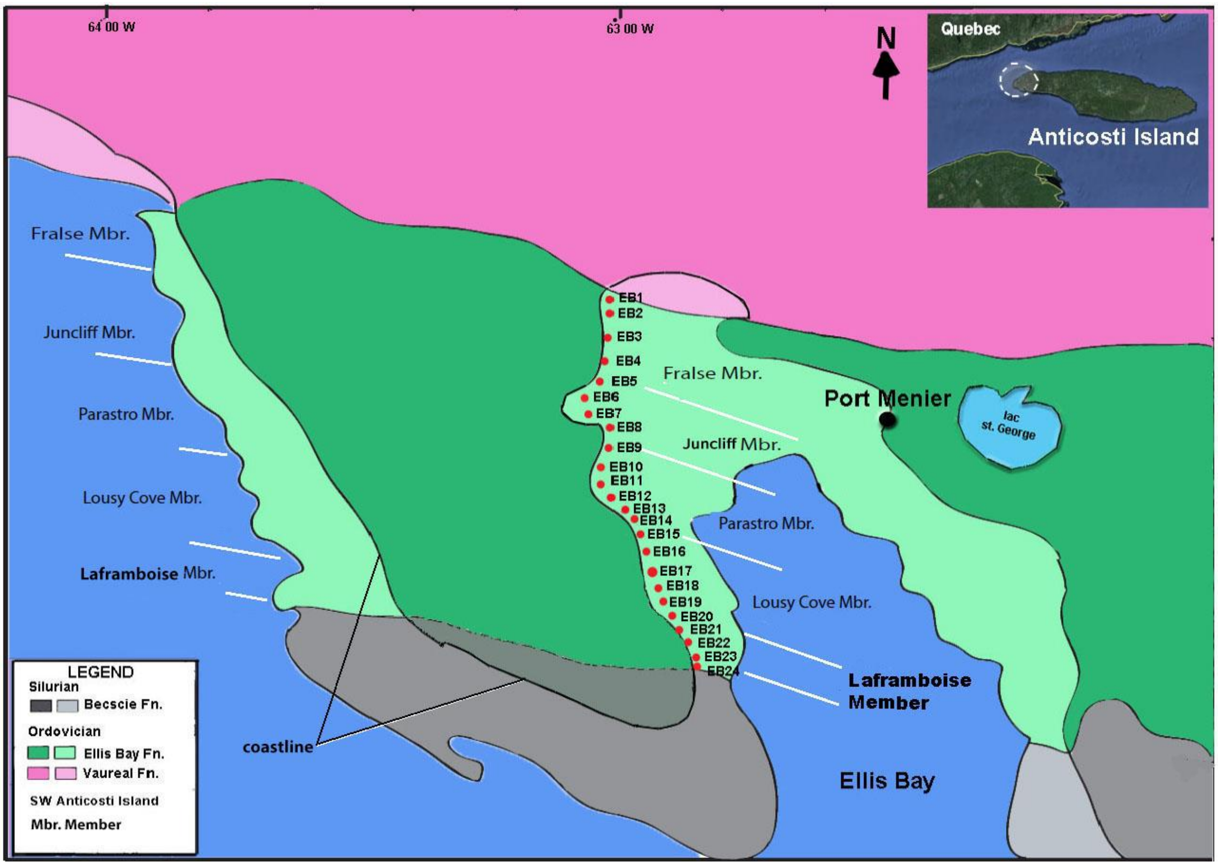
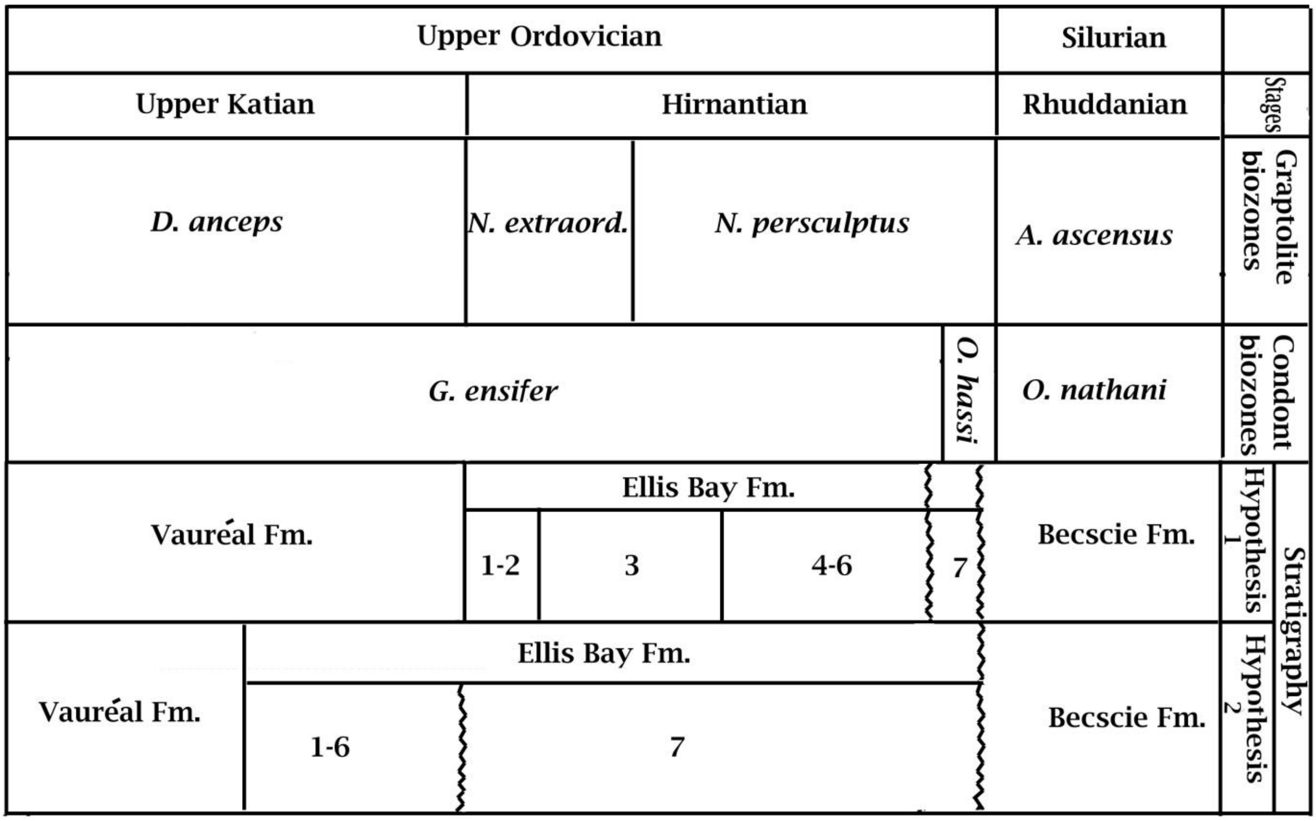


Figure 3.2. Geological map showing the sampling points for ostracods collected from the Ellis Bay Formation at its eponymous type locality, western end of Anticosti Island (map after Copper *et al.* 2013). Blue area is sea. Rock succession dips from north to south, and younging direction is southwards.

3.3 Contested stratigraphical age assignments for the Ellis Bay Formation

The Ellis Bay Formation has yielded biostratigraphically significant latest Ordovician chitinozoans, conodonts, palynomorphs and, rarely graptolites (McCraden and Nowlan 1988; Soufiane and Achab 2000, 2011, 2013; Melchin 2008, 2013). There are two prevailing hypotheses for the age of the formation. Some authors suggest that the entire Ellis Bay Formation is of Hirnantian age (Long and Copper 1987; Soufiane and Achab 2000; Copper 2001; Melchin *et al*. 2003, 2008; Melchin and Holmden 2006; Jin and Copper 2008; Desrochers *et al*. 2010; Delabroye and Vecoli 2010; Achab *et al*. 2011; Copper *et al*. 2013). Others opine that the Hirnantian is restricted only to the uppermost member of the Ellis Bay Formation, the Laframboise Member (Melchin *et al*. 1991; Underwood *et al* 1997; Brenchley *et al*. 2003; Bergström *et al*. 2006; Kaljo *et al*. 2008; Finnegan *et al*. 2010; Jones *et al*. 2011; Meidla *et al*. 2015). These different interpretations are summarised in Figures 3.3, 3.4. Notably, the marked positive carbon isotope excursion of the Laframboise Member (Long 1993; Kaljo *et al*. 2008; Delabroye *et al*. 2011) is considered by several authors to represent the low stand (end Ordovician glacial acme) succession of the Hirnantian.

The position of the Ordovician-Silurian boundary (O/S) on western Anticosti Island has been a matter of much debate, partly because graptolites are rare and poorly preserved (Melchin 2008, 2013; Delabroye and Vecoli, 2010, 2011). Based on detailed studies of chitinozoans, graptolites, conodonts, sequence stratigraphy and carbon isotope chemostratigraphy, the Ordovician–Silurian boundary is now considered to lie approximately 2 metres above the base of the Becscie Formation on western Anticosti Island (Desrochers *et al*., 2010; Ghienne *et al.* 2014).



1	Long and Copper (1987), Soufiane and Achab (2000), Copper (2001), Melchin *et al.* (2003, 2008), Melchin and Holmden (2006), Jin and Copper (2008), Desrochers *et al.* (2010), Delabroye and Vecoli (2010), Achab *et al.* (2011) and Copper *et al.* (2013).
2	Melchin *et al.* (1991), Underwood *et al.* (1997), Brenchley *et al.* (2003), Bergström *et al.* (2006), Kaljo *et al.* (2008), Finnegan *et al.* (2010), Jones *et al.* (2011), Meidla *et al.* (2015) and this study.

Figure 3.3. Contested chronostratigraphical age assignments for the Ellis Bay Formation on Anticosti Island, eastern Canada based on various biostratigraphical and geological data. Numbers 1-7 are the members of the Ellis Bay Formation according to Petryk (1981): for how these relate to the named members of Copper *et al*. (2013), see Fig. 3.4 below. Hypothesis 1 is that the whole of the Ellis Bay Formation is Hirnantian; hypothesis 2 is that only the uppermost Laframboise Member is Hirnantian.

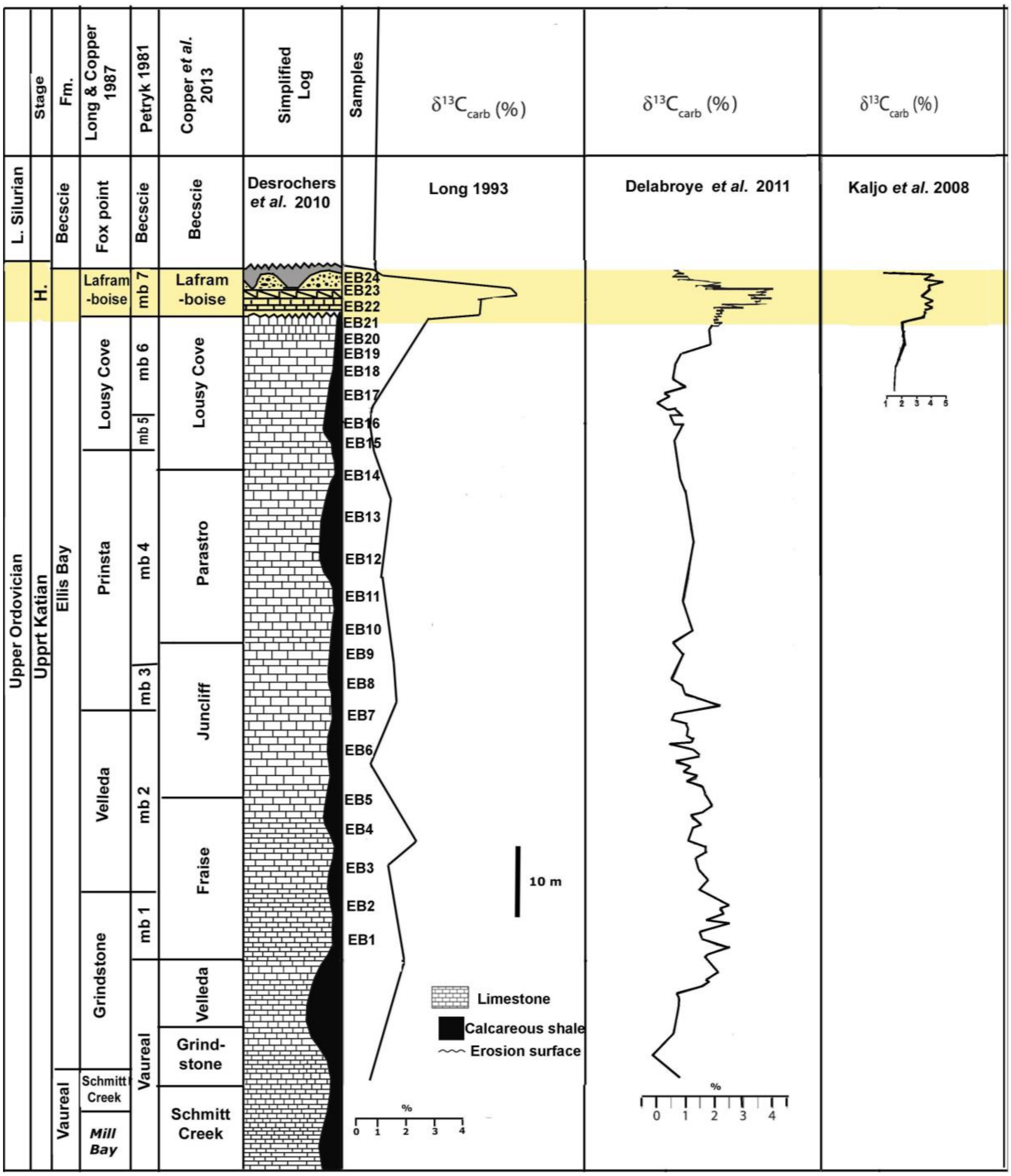


Figure 3.4. Carbon isotope curve for the Ellis Bay Formation, western Anticosti Island (after Long 1993, Kaljo *et al*. 2008, Delabroye *et al.* 2011). The figure shows the peak positive excursion in the Laframboise Member, and has been used to infer that this signifies the lowstand of the end Ordovician glaciation (i.e. is of Hirnantian age). Abbreviation: mb-Member.

3.4 Materials and Methods for this study

3.4.1 Sample section

The Ellis Bay interval was sampled along the western side of Ellis Bay, Anticosti Island (latitude 49° 47′ 30″ and longitude 64° 25′ 25″ E; see Fig. 3.1). Some 24 samples were collected from the Ellis Bay Formation for ostracods: samples are prefixed with the identifiers EB1, EB2, EB3, EB4, EB5, EB 6, EB 7, EB 8, EB 9, EB 10, EB11, EB12, EB 13, EB 14, EB 15, EB16, EB 17, EB18, EB19, EB20, EB21, EB22, EB 23, and EB24 (see Fig. 3.2). Samples were taken at a spacing ranging from 1 to 2 m in argillaceous and calcareous shale. Localities for sampling were chosen on completeness of section (lack of faulting and cleavage), exposure and accessibility.

3.4.2 Sample processing

Approximately 300-500g of sediment from each sample were treated with sodium hyposulphite. This deconsolidated the sample and typically yielded thousands of ostracod specimens per sample, though somewhat less abundance for samples near the Ellis Bay-Becscie formational contact. All specimens were coated with gold aluminium alloy Emitech K500X and imaged with the Scanning electron microscope Hitachi S-3600N at Leicester University.

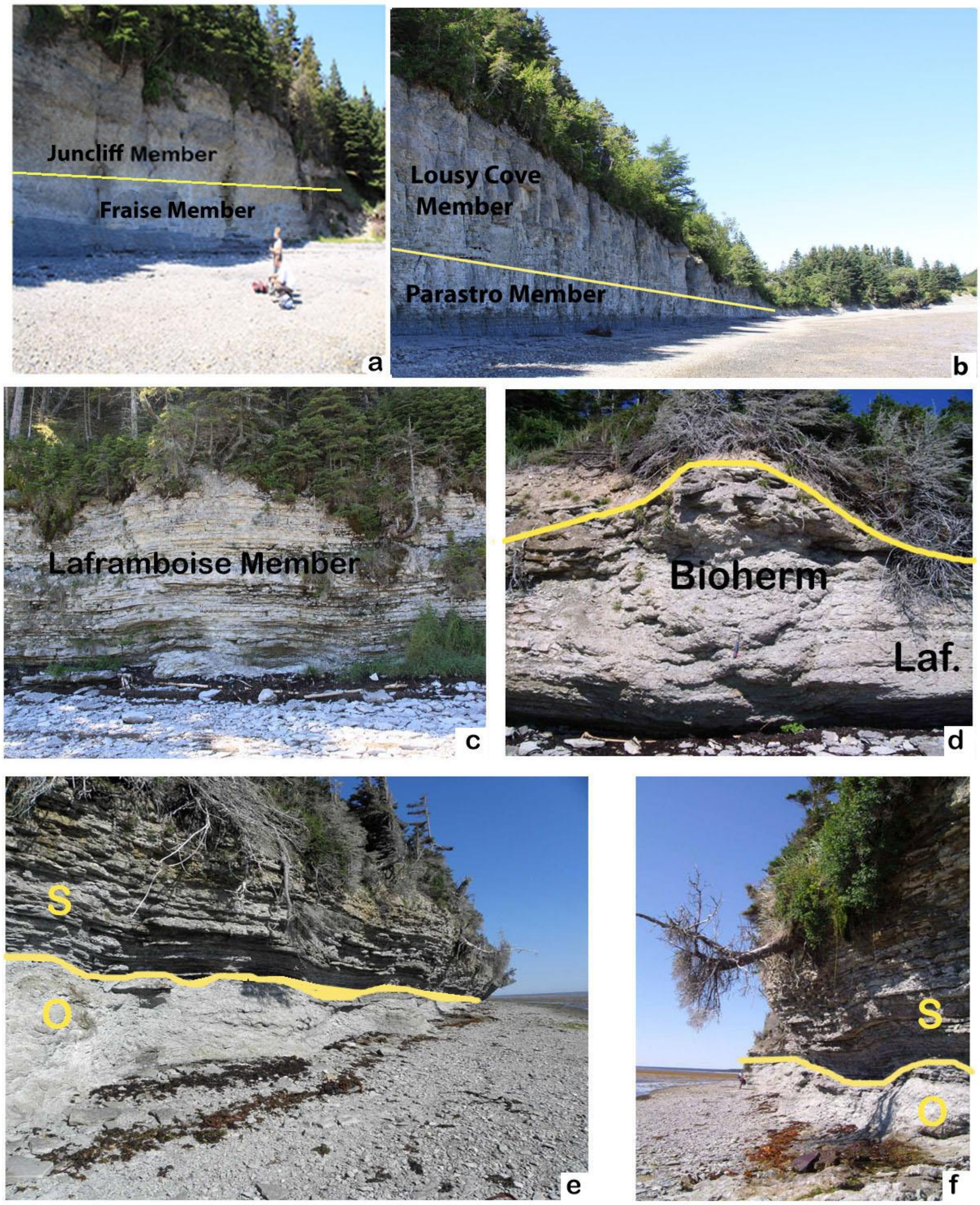


Figure 3.5. (a-c) Fraise, Juncliff, Parastro, Lousy Cove and Laframboise members of the Ellis Bay Formation, *sensu* Copper *et al*. (2013). (d) Uppermost part of the Laframboise Member (Laf.) stromatoporoid-coral patch reefs and the Ordovician – Silurian boundary (O/S). (e-f) the Ordovician - Silurian boundary (approximating 2 metres above the base of the Becscie Formation).

3.5 Ostracod biostratigraphy

An ostracod biozonation was erected by Copeland (1970, 1973, 1974), but this did not include collections from the uppermost Laframboise Member (Lfb) of the Ellis Bay Formation. This member consists of oncolite beds, bioherms, and inter-biohermal deposits (Petryk 1981; Long and Copper 1987; Copper 2001); it yields a low-diversity ostracod assemblage. In the present study some 62 ostracod species belonging to 37 genera are distinguished in the Ellis Bay Formation. The stratigraphic distribution of these ostracods permits the recognition of four biostratigraphical intervals: (A) the *Longiscula subcylindrica* Biozone; (B) the *Eurychilina erugoface* Biozone; (C) the *Tetradella anticostiensis* Biozone; and in the uppermost part of the formation, (D) an interregnum. Intervals A, B and D can be related to Copeland's (1973) biozonation. Biozone C is equivalent to three of Copeland's (1973) sub-zones.

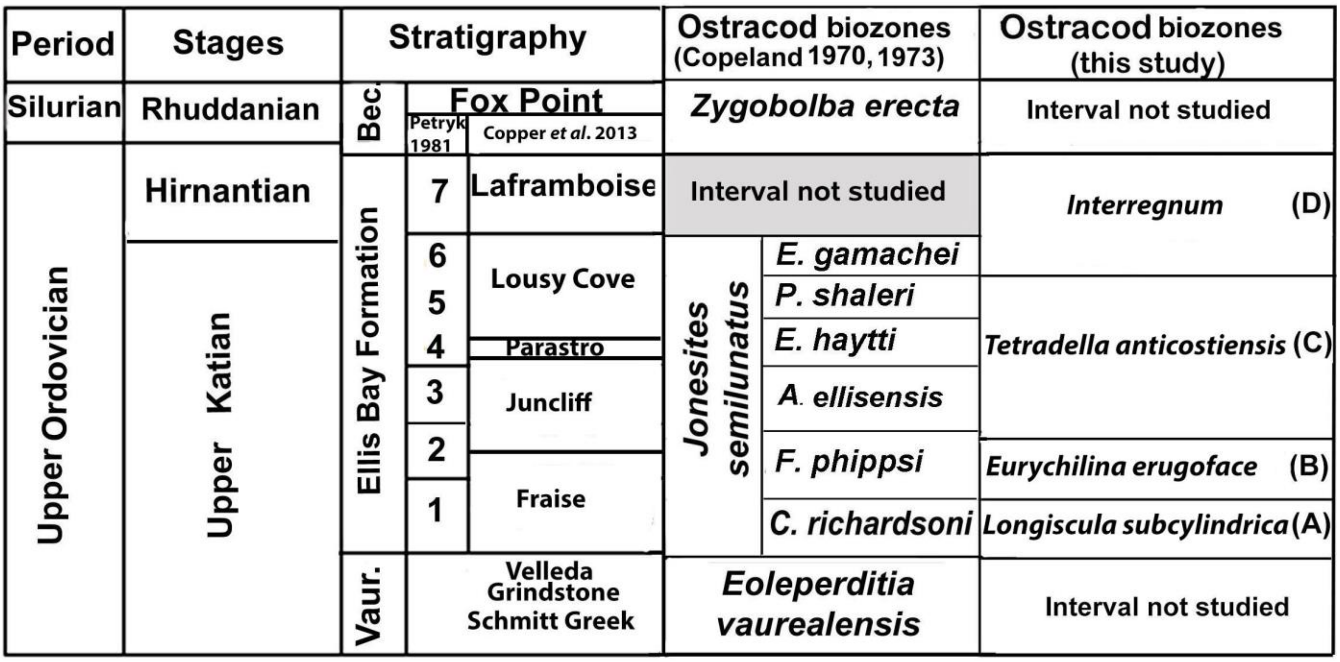


Figure 3.6. Comparison between Copeland's ostracod biozonation and that of this study. Lithological members after Petryk (1981) and Copper *et al*. (2013).

3.5. *1. Longiscula subcylindrica* Biozone (A)

The *L. subcyclindrica* biozone is identified through approximately 8 m of strata, from sample numbers EB1 to EB3. As defined here, it is a partial range biozone, based on the first occurrence of the eponymous taxon, prior to the incoming of *Eurychilina erugoface*, which defines the succeeding biozone. The lower boundary is characterized by the apparent first appearance of 26 species (Fig. 3.7), including the eponymous species, though some of these species may range from underlying intervals. The most abundant ostracod species in this biozone are *Macrocyproides trentonensis*, *Schmidtella sublenticularis* and *Schmidtella rovervali*. This biozone occupies the same biostratigraphical interval as the *Belonechitinana gamachiana* chitinozoan biozone (see Soufiane and Achab 2000) and the *Gamachignathus ensifer* conodont biozone (McCracken and Nowlan 1988; McCracken as cited *in* Norford 1997).

3.5.2 *Eurychilina erugoface* Biozone (B)

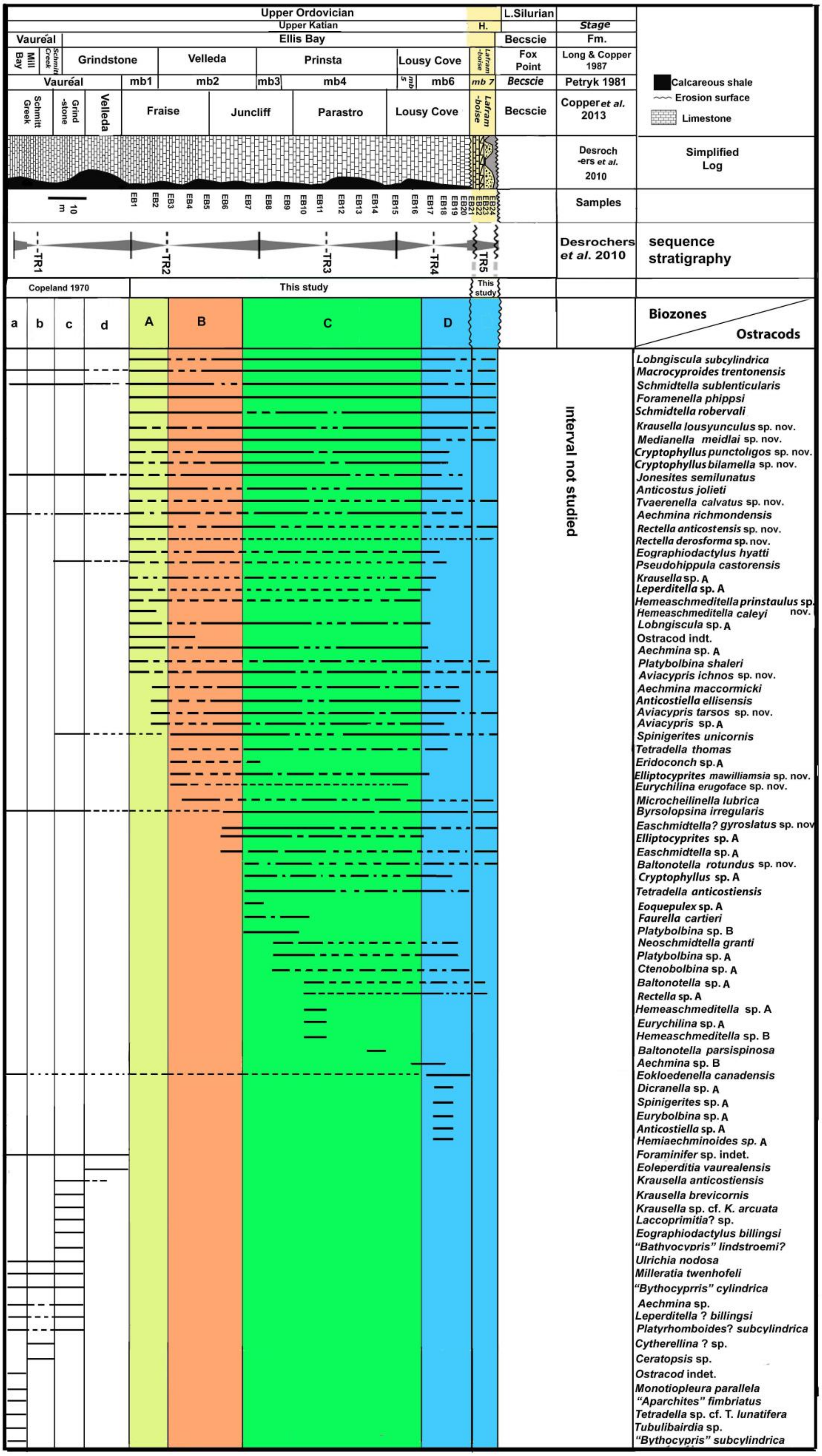
The *Eurychilina erugoface* biozone is characteristic of Member 2 of the Ellis Bay Formation *sensu* Petryk 1981, which consists of calcarenites and shale (Fraise Member) and micrites with minor shale (Juncliff Member *sensu* Copper *et al*. 2013). It is dominated by *Foramenella phippsi,* and *Aechmina richmondensis*. The biozone is a partial range zone, represented by the first occurrence of the eponymous species prior to the first occurrence datum of the succeeding *Tetradella anticostiensis*. This biozone is identified through about 11 m of strata, from sample numbers EB4 to EB7. If hypothesis 1 is followed for the age of the Ellis Bay Formation, this level represents an interval equivalent to the *Normalograptus extraordinarius* graptolite biozone (see Melchin 2008) and *B. gamachiana* chitinozoan biozone (see Soufiane and Achab 2000).

3.5.3 *Tetradella anticostiensis* Biozone (C)

This biozone is equivalent in its temporal range to the three Sub-zones *Anticostiella ellisensis, Eographiodactylus hyatti, Platybolbina shaleri* of Copeland (1973). Subdivision, as suggested by Copeland, is not tenable, as many of the taxa range through the whole interval. The biozone is represented through nearly 45 m of strata in the Ellis Bay Formation, from sample numbers EB7 to EB16, and through the Parastro Member that consists of nodular to platy limestone and thin-bedded shales. The zone is identified by the first appearance of the eponymous species, and is a partial range zone, below the *interregnum* that characterises the uppermost stratigraphical interval of the Ellis Bay Formation. Abundant in this biozone are *Byrsolopsina irregularis*, *Platybolbina shaleri*, *Platybolbina* sp. A, *Cryptophyllus* sp. A, *Faurecella cartieri*, *Neoschmidtella granti*, *Baltonotella* sp. A, *Anticostiella ellisensis* and *Rectella* sp. A. (Fig. 3.7).

3.5.4 Interregnum interval (D)

The upper part of the Ellis Bay Formation on western Anticosti Island section is regarded here as an interregnum. Although four new taxa make their first appearance in this interval, all of these are described in open nomenclature: most of the species in this interval range from underlying strata. The base of the interregnum can be characterised by the last occurrence datums of several species (Fig. 3.7). The interregnum ranges through a stratigraphical interval equivalent to the Lousy Cove and Laframboise members. The most abundant ostracod species are *Anticostella ellisensis,* and *Krausella lousyunculus*. Although the interval of the Laframboise Member was not studied for ostracods by Copeland (1973), it clearly contains species that continue from the preceding Lousy Cove Member, though several species appear to go extinct at the unconformity between these members (Fig. 3.7). The interregnum occupies the same biostratigraphical interval as the *Ozarkodina hassi* and *Gamachignathus ensifer* conodont biozone *sensu* McCracken and Nowlan (1988) and McCracken as cited *in* Norford (1997) (Fig. 3.7).



Upper Ordovician
Upper Katian
L.Silurian
H.
Stage
Vauréal
Ellis Bay
Becscie
Fm.
Mill Bay
Schmitt Creek
Grindstone
Velleda
Prinsta
Lousy Cove
Lafram-boise
Fox Point
Long & Copper 1987
Vauréal
mb1
mb2
mb3
mb4
mb 5
mb6
mb 7
Becscie
Petryk 1981
Schmitt Greek
Grind-stone
Velleda
Fraise
Juncliff
Parastro
Lousy Cove
Lafram-boise
Becscie
Copper et al. 2013
Calcareous shale
Erosion surface
Limestone
Desroch-ers et al. 2010
Simplified Log
10 m
EB1
EB2
EB3
EB4
EB5
EB6
EB7
EB8
EB9
EB10
EB11
EB12
EB13
EB14
EB15
EB16
EB17
EB18
EB19
EB20
EB21
EB22
EB23
EB24
Samples
TR1
TR2
TR3
TR4
TR5
Desrochers et al. 2010
sequence stratigraphy
Copeland 1970
This study
This study
Biozones
Ostracods
a
b
c
d
A
B
C
D
interval not studied
Lobngiscula subcylindrica
Macrocyproides trentonensis
Schmidtella sublenticularis
Foramenella phippsi
Schmidtella robervali
Krausella lousyunculus sp. nov.
Medianella meidlai sp. nov.
Cryptophyllus punctoligos sp. nov.
Cryptophyllus bilamella sp. nov.
Jonesites semilunatus
Anticostus jolieti
Tvaerenella calvatus sp. nov.
Aechmina richmondensis
Rectella anticostensis sp. nov.
Rectella derosforma sp. nov.
Eographiodactylus hyatti
Pseudohippula castorensis
Krausella sp. A
Leperditella sp. A
Hemeaschmeditella prinstaulus sp. nov.
Hemeaschmeditella caleyi
Lobngiscula sp. A
Ostracod indt.
Aechmina sp. A
Platybolbina shaleri
Aviacypris ichnos sp. nov.
Aechmina maccormicki
Anticostiella ellisensis
Aviacypris tarsos sp. nov.
Aviacypris sp. A
Spinigerites unicornis
Tetradella thomas
Eridoconch sp. A
Elliptocyprites mawilliamsia sp. nov.
Eurychilina erugoface sp. nov.
Microcheilinella lubrica
Byrsolopsina irregularis
Easchmidtella? gyroslatus sp. nov
Elliptocyprites sp. A
Easchmidtella sp. A
Baltonotella rotundus sp. nov.
Cryptophyllus sp. A
Tetradella anticostiensis
Eoquepulex sp. A
Faurella cartieri
Platybolbina sp. B
Neoschmidtella granti
Platybolbina sp. A
Ctenobolbina sp. A
Baltonotella sp. A
Rectella sp. A
Hemeaschmeditella sp. A
Eurychilina sp. A
Hemeaschmeditella sp. B
Baltonotella parsispinosa
Aechmina sp. B
Eokloedenella canadensis
Dicranella sp. A
Spinigerites sp. A
Eurybolbina sp. A
Anticostiella sp. A
Hemiaechminoides sp. A
Foraminifer sp. indet.
Eoleperditia vaurealensis
Krausella anticostiensis
Krausella brevicornis
Krausella sp. cf. K. arcuata
Laccoprimitia? sp.
Eographiodactylus billingsi
"Bathvocvpris" lindstroemi?
Ulrichia nodosa
Milleratia twenhofeli
"Bythocyprris" cylindrica
Aechmina sp.
Leperditella ? billingsi
Platyrhomboides? subcylindrica
Cytherellina ? sp.
Ceratopsis sp.
Ostracod indet.
Monotiopleura parallela
"Aparchites" fimbriatus
Tetradella sp. cf. T. lunatifera
Tubulibairdia sp.
"Bythocypris" subcylindrica

Figure 3.7. Stratigraphical ranges of ostracods in the Ordovician Ellis Bay Formation on western Anticosti Island, eastern Canada. These ostracods permit the recognition of four biozones: (A) *Longiscula subcylindrica*, (B *Eurychilina erugoface*, (C) *Tetradella anticostiensis* and (D) Interregnum.

3.6 Wider stratigraphical utility of the ostracods

Only a small number of the ostracod species of the Ellis Bay Formation occur elsewhere in North America, thus limiting the correlative stratigraphical value of the ostracod assemblages (see Table 3.1). Two species, *Macrocyproides trentonensis* and *Baltonotella parsispinosa* are very long-ranging, first occurring in Sandbian strata of the Late Ordovician Maquoketa shale of Missouri and Edinburg Formation of Virginia respectively. Therefore, the ostracods do not provide clear evidence to assign the Ellis Bay Formation either to the Katian and Hirnantian, or just the Hirnantian, but four species (*Aechmina richmondensis*, *Aechmina maccormicki*, *Macrocyproides trentonensis* and *Spinigerites unicornis*) suggest that some part of it may be Katian (Hypothesis 2 of above) (See Fig. 3.8).

Species of the Ellis Bay Formation	Species range meb.	Formation	Location	Age of other formations	References
Aechmina richmondensis	1-6	Cautley Mudstone Vauréal	Northern England Anticosti Island	Katian Katian	Williams *et al.* 2001 Copeland 1970
Aechmina maccormicki	2-6	Cautley Mudstone	Northern England	Katian	Williams *et al.* 2001
Baltonotella parsispinosa	4	Ardwell Farm Bromide Edinburg and Lincolnshire	Girvan Oklahoma Virginia	Sandbian Sandbian Sandbian	Mohibullah *et al.* 2011 Williams and Siveter 1996 Kraft 1962
Macrocyproides trentonensis	1-7	Vauréal Maquoketa shale Decorah Bromide Healey Falls	Anticosti Island Missouri Minnesota Oklahoma Ontario	Katian Katian Sandbian Sandbian Sandbian	Copeland 1970 Keenan 1951 Copeland 1965 Copeland 1965 Copeland 1965
Microcheilinella lubrica	2-7	Kòrgessaare, Moe,Adilaand Ärina	Estonia	Katian-Hirnantian	Meidla 1996
Spinigerites unicornis	2-7	Cautley Mudstone Vauréal	Northern England Anticosti Island	Katian Katian	Williams *et al.* 2001 Copeland 1970

Table 3.1. Ostracod species of the Ellis Bay Formation that are recorded from other Late Ordovician successions. Abbreviation: meb, member.

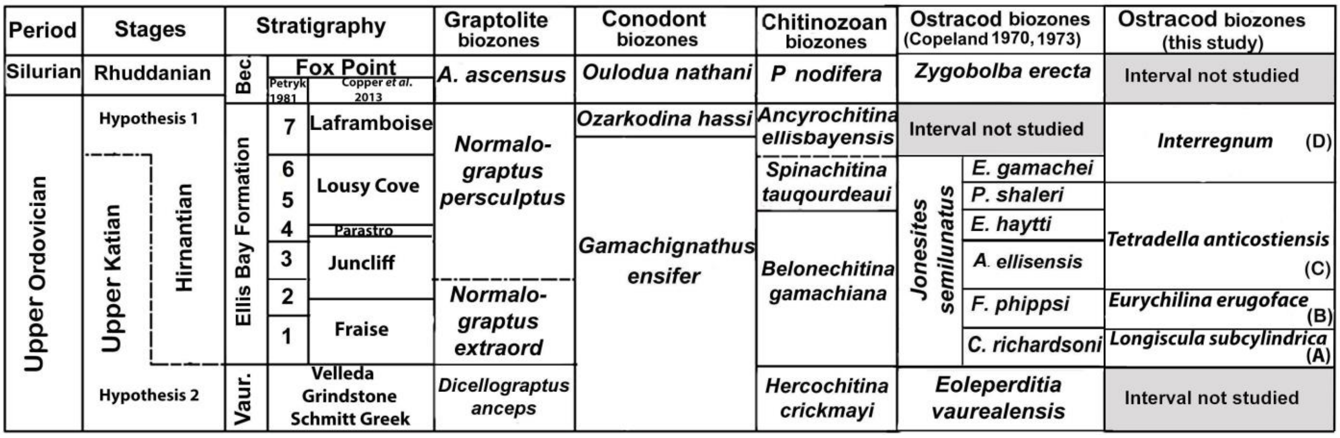


Figure 3.8. Correlation of ostracods with the graptolite (Melchin 2008), conodont (McCracken and Nowlan 1988; McCracken as cited *in* Norford 1997), chitinozoan (Soufiane and Achab 2000), and acritarch (Delabroye *et. al.* 2011) biozonations of the Ellis Bay Formation based on the data presented here and Copper (2001). Age assignments according to hypothesis 1 and 2 are also shown.

3.7 Conclusions

The biostratigraphic distribution of Late Ordovician ostracod faunas from the Ellis Bay Formation on western Anticosti Island are described. Some 62 species are recorded. The Ellis Bay Formation can be subdivided into three ostracod biozones (these being partial range zones) and an interregnum, in ascending stratigraphical order these being the *Longiscula subcylindrica* biozone, the *Eurychilina erugoface* biozone, the *Tetradella anticostiensis* biozone and an interregnum in the uppermost part of the succession, marked by the local extinction of several taxa at the terminus of the *T. anticostiensis* biozone. These intervals are only locally developed, and are not useful for inter-regional correlation. A small number of the Ellis Bay Formation ostracod species are recorded elsewhere, from Sandbian and Katian age successions. These include *Aechmina richmondensis*, *Aechmina maccormicki*, *Baltonotella parsispinosa*, *Macrocyproides trentonensis*, *Microcheilinella lubrica* and *Spinigerites unicornis*.

Chapter 4

Palaeoecological and biogeographical significance of the Late Ordovician ostracod assemblage of the Ellis Bay Formation, Anticosti Island, eastern Canada

Chapter 4: Palaeoecological and palaeobiogeographical significance of the Late Ordovician ostracod assemblage of the Ellis Bay Formation, Anticosti Island, eastern Canada

Abstract

The Late Ordovician Ellis Bay Formation of Anticosti Island, eastern Canada was formed in a carbonate dominated setting on the eastern margin of the Laurentia palaeocontinent during the late Katian (*c*. 449-445 Ma) to Hirnantian (*c*. 445-444 Ma; chronology after Gradstein *et al*. 2012). A diverse and well-preserved ostracod fauna of 62 species has been recovered from members 1 to 6 (*sensu* Petryk 1981) of the formation. The youngest, Laframboise Member (Member 7) of the formation has yielded a low-diversity assemblage of 21 species. This sudden drop in species diversity coincides with locally reduced sea level that may be linked to global glacio-eustacy. The ostracods of members 1-6 show biogeographical links at species-level between Laurentia and Avalonia, including *Aechmina maccormicki* and *Spinigerites unicornis*, and between Laurentia and Baltica the species *Microcheilinella lubrica* is shared: the fauna of Member 7 also includes *S. unicornis* and *M. lubrica*. At generic-level, biogeographical links are considerable, with 18 genera common between Members 1 to 6 of the Ellis Bay Formation and Baltica, and 7 are genera that also occur in Avalonia; in Member 7, the number of genera in common with other regions is 15. Relative to the earlier Ordovician, this is consistent with the increasing proximity of the Laurentia, Baltica and Avalonia continents as the intervening Iapetus Ocean was subducted (Torsvik and Cocks 2009, 2017; Siveter 2009). Despite the significant sea level fall attested by the lithofacies of Member 7, faunal links continued to be strong between Laurentia, Avalonia and Baltica.

4.1 Introduction

Modern marine podocope ostracods are benthic and generally show maximum abundance and diversity in marine shelf environments (Mohibullah *et al*. 2010). Their biodiversity decreases in very shallow and very deep shelf marine environments (e.g., Ulst *et al*. 1982; Stepanova *et al*. 2007). Similar patterns are noted in the Palaeozoic (e.g. Siveter 1984; Williams *et al*. 1996). Ordovician ostracods may have had similar lifestyles to their modern benthic relatives (Siveter 1978). They lived in relatively shallow marine habitats, on the open shelf or at the shelf-slope transition. Substrate, salinity, food supply and depth were probably the principal influences on the distribution of Ordovician ostracod faunas (Schallreuter and Siveter 1985; Vannier 1986; Mohibullah *et al*. 2014). Ordovician shelf marine podocope ostracods probably had limited intercontinental dispersal capability because of their benthic lifestyles and lack of a pelagic larval stage, and as a result they have been widely used for palaeogeographical analysis (Schallreuter and Siveter 1985; Vannier *et al*. 1989; Williams *et al*. 2003; Mohibullah *et al*.2012; Meidla *et al*.2013). Throughout the Late Ordovician, the Laurentia palaeocontinent was located in the tropics and included most of North America, Greenland and Scotland (Torsvik and Cocks 2009; 2017). The Baltica and Avalonia palaeocontinents were situated to the near east and south, in the sub-tropics (Torsvik and Cocks 2009) (Fig. 4.1). A number of studies have noted the progressive similarity of the Laurentian ostracod faunas to those of Avalonia and Baltica through the Late Ordovician (Kesling 1960a; Copeland 1973, 1989; Schallreuter and Siveter 1985; Vannier *et al.* 1989; Williams *et al*. 2001a, b; Siveter 2009). Other authors have stressed the continued provinciality of Laurentian ostracod faunas throughout the Ordovician, a situation considered to persist until mid-Silurian times (e.g. McKerrow and Cocks 1976; Cocks and Fortey 1982; McKerrow and Soper 1989; McKerrow *et al*. 1991; Cocks *et al*. 1997; Van Staal *et al*. 1998; Cocks 2000). In part, these assumptions were based on the marked provinciality displayed by some upper Silurian ostracod faunas (see Siveter 1984; Berdan 1990). In such scenarios, the Iapetus Ocean is considered to have remained wide (*c*. 1000 km) during Late Ordovician times, and to have prevented Laurentian benthic shelf marine ostracods (which had no pelagic larval stage; see below) from migrating to Baltica or Avalonia, or vice versa.

This chapter examines the lithofacies distribution of 62 species of ostracods identified from the Ellis Bay Formation, and identifies two assemblages reflecting open shelf and shallow shelf settings respectively. The biogeographical significance of the Ellis Bay Formation ostracod fauna is discussed, establishing its affinities with other Laurentian ostracod faunas, and analysing links with faunas of palaeocontinental Baltica and Avalonia.

4.2 Palaeoenvironmental setting of the Ellis Bay Formation

Much of the Ellis Bay Formation represents open marine shelf carbonates and mudstones with fossil assemblages of both benthic organisms - brachiopods, trilobites, conodonts, molluscs and ostracods - and plankton, comprising chitinozoans and graptolites (Melchin 2008; Desrochers *et al*. 2010; Achab *et al*. 2011). Farley (2008) noted that western exposures of the Ellis Bay Formation consist of stacked sequences of mid- to outer-ramp, storm dominated carbonate with argillaceous mudstone, and that the uppermost part of the formation consists of inner-ramp oncolitic and reefal carbonate facies. In the eastern sections of the Ellis Bay Formation near-shore, mixed siliciclastic-carbonate facies are developed (Petryk, 1981). It is the western, more palaeoenvironmentally varied succession, which forms the focus of this chapter.

4.3 Methods

Some 24 stratigraphically arranged samples were collected from outcrops of the Ellis Bay Formation on western Anticosti Island, eastern Canada. Detailed sample preparation is described in Chapter 1. The recognition of the two assemblages discussed below is based on presence/absence data.

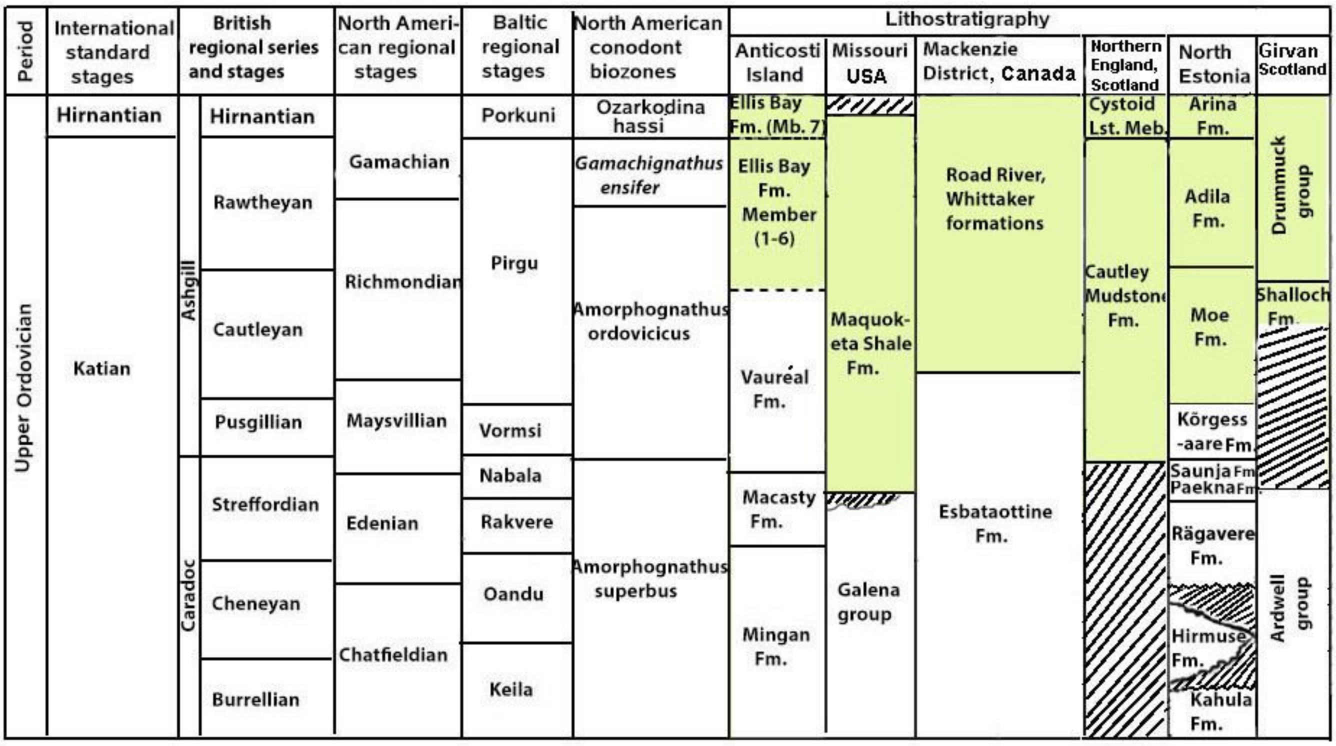


Figure 4.1. Upper Ordovician chronostratigraphy and selected (ostracod-bearing) lithostratigraphical units for palaeocontinental Laurentia (Anticosti Island, Missouri, Mackenzie District, Girvan), Baltica (Estonia), and Avalonia (England, Scotland). Data for Baltica after Meidla (1993, 1996); Laurentia after Copeland (1989, 2000; Kay 1940; Keenan 1951; Williams *et al*. 2001a; Mohibullah *et al*. 2010); and Avalonia after Williams *et al*. (2001b). Conodont biozones of North America after McCracken and Nowlan (1988), and McCracken as cited *in* Norford (1997). The Upper Katian to Hirnantian sections from which ostracods are documented and included in this study are highlighted olive.

4.4 Spatial distribution of the ostracods from the Ellis Bay Formation

4.4.1 Open marine ostracod assemblage (I)

Ostracod assemblage I is highly diverse, containing 62 species. The ostracod faunas consist of co-occurring valves and carapaces of both juveniles and adults, suggesting life assemblages, though some post-mortem winnowing of samples is suggested from the size distribution of much of the fauna (see Chapter 2). This assemblage is present in strata of the Ellis Bay Formation members 1 to 6 (*sensu* Petryk 1981), and consists of abundant Metacopina, Leiocopina, Binodicopina, Cypridocopina, Eridostraca and Palaeocopina (Figs 4.2, 4.4). Most of the species in this assemblage are long-ranging through the Ellis Bay Formation, suggesting a stable ostracod ecology was developed in an open marine setting with a range of different mud- and lime-rich substrates. The species diversity of Metacopina, Palaeocopina and Binodicopina is high, while Leiocopina, Cypridocopina, Eridostraca and Kloedenellocopina are less common (Fig. 4.2, 4.4). Most taxa exhibit considerable size variation from pre-adult to adults (e.g. *Foramenella phippsi*, *Byrsolopsina irregularis*, *Anticostus jolieti* and *Schmidtella sublenricularis*).

Ostracod assemblage I is characterized by abundant *Byrsolopsina irregularis*, together with species of *Aechmina*, *Anticostus*, *Anticostella*, *Aviacypris*, *Byrsolopsina*, *Baltonotella*, *Cryptophyllus*, *Ctenobolbina*, *Dicranella*, *Easchmidtella*, *Eokloedenella* *Eographiodactylus*, *Eridoconcha*, *Elliptocyprites*, *Eoquepulex*, *Eurychilina*, *Eurybolbina* *Faurella*, *Foramenella*, *Hemiaechmidtella*, *Hemiaechminoides*, *Jonesites*, *Krausella*, *Longiscula*, *Leperditella*, *Medianella*, *Microcheilinella*, *Macrocyproides*, *Neoschmidtella*, *Pseudohippula*, *Platybolbina*, *Rectella*, *Schmidtella*, *Spinigerites*, *Tetradella*, and *Tvaerenella* (Fig. 4.2).

4.4.2 Shallow marine ostracod assemblage (II)

This assemblage is present in strata of the uppermost part of the Ellis Bay Formation, Laframboise Member (Member 7). The ostracod faunas consist of co-occurring valves and carapaces of adults and juveniles, suggesting life assemblages, though some post-mortem winnowing of assemblages is evident (see Chapter 2). The assemblage is characterized by 21 species (Fig. 4.3), which include Metacopina, Leiocopina, Binodicopina, Cypridocopina and Palaeocopina (Figs 4.3, 4.4). Importantly, all of these species also occur in Assemblage I. Most taxa exhibit considerable size variation from pre-adult to adult specimens (e.g. *Microcheilinella lumbrica*, *Macrocyproides trentonesis*, *Longiscula subcylindrica* and *Schmidtella sublenricularis*). Ostracod assemblage II is low diversity (missing species of *Anticostus*, *Aechmina*, *Anticostiella*, *Cryptophyllus*, *Ctenobolbina*, *Dicranella*, *Eokloedenella*, *Eographiodactylus*, *Eridoconcha*, *Elliptocyprites*, *Eoaquapulex*, *Eurychilina*, *Eurybolbina*, *Faurella*, *Hemeaschmidtella*, *Hemiachminoides*, *Jonesites*, *Leperditella*, *Neoschmidtella*, *Pseudohippula* and *Tetradella*). The percentage of species of the major taxonomic groups of ostracod assemblage are different between I and II and may be related to environmental conditions. In marine environments, changes in ostracod composition and diversity have been related to water depth (Tinn and Meidla 2003).

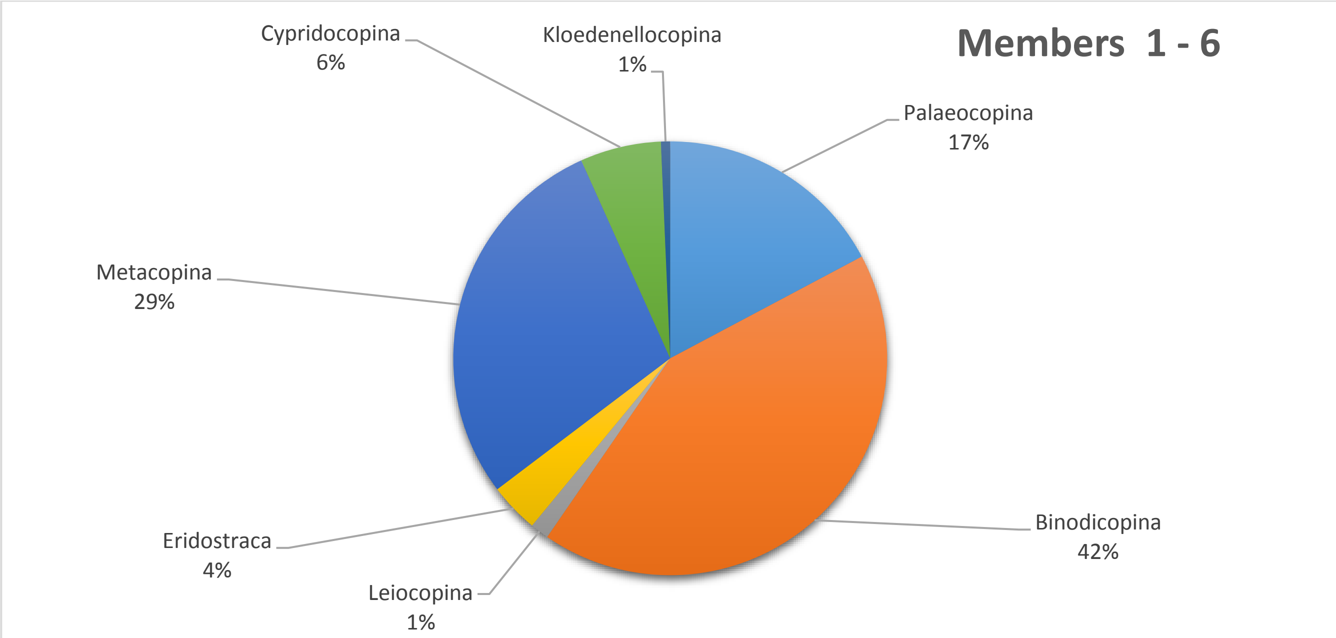


Figure 4.2. Percentage of species of the major taxonomic groups of ostracods in the Fraise, Juncliff, Parastro and Lousy Cove members (members 1-6, *sensu* Petryk 1981) of the Ellis Bay Formation.

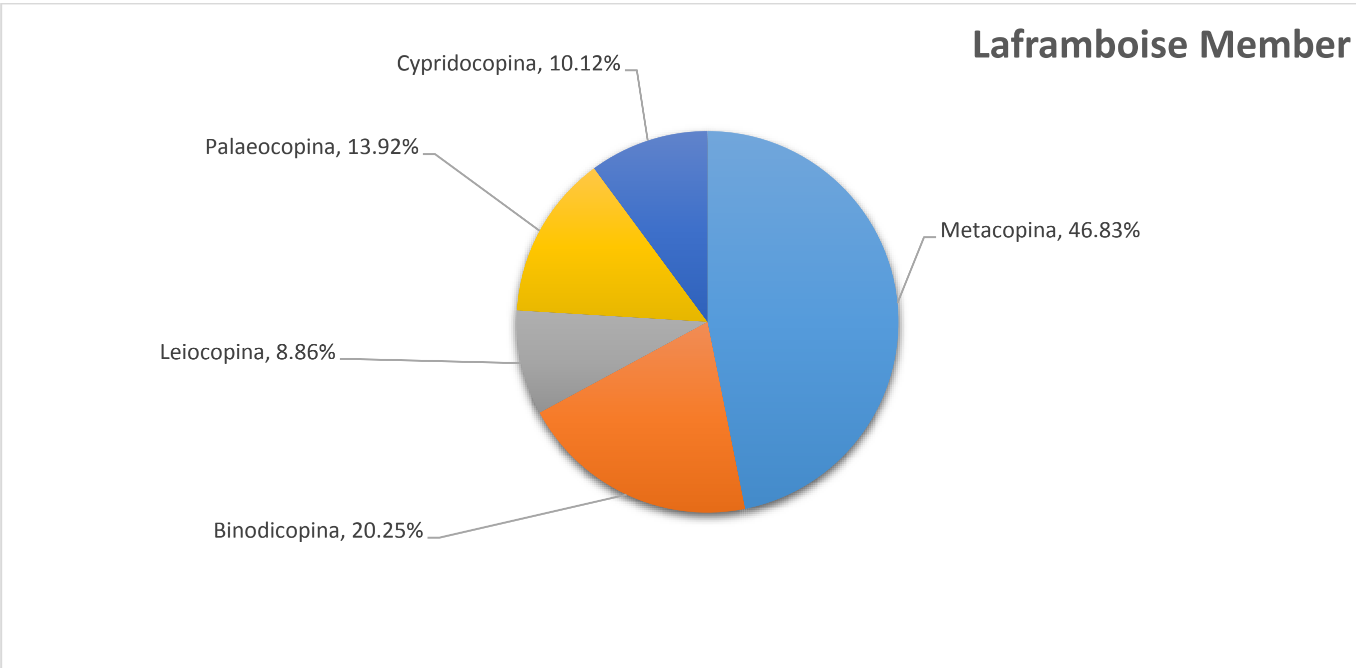


Figure 4.3. Percentage of species of the major groups of ostracods in the Laframboise Member (Member 7) of the Ellis Bay Formation.

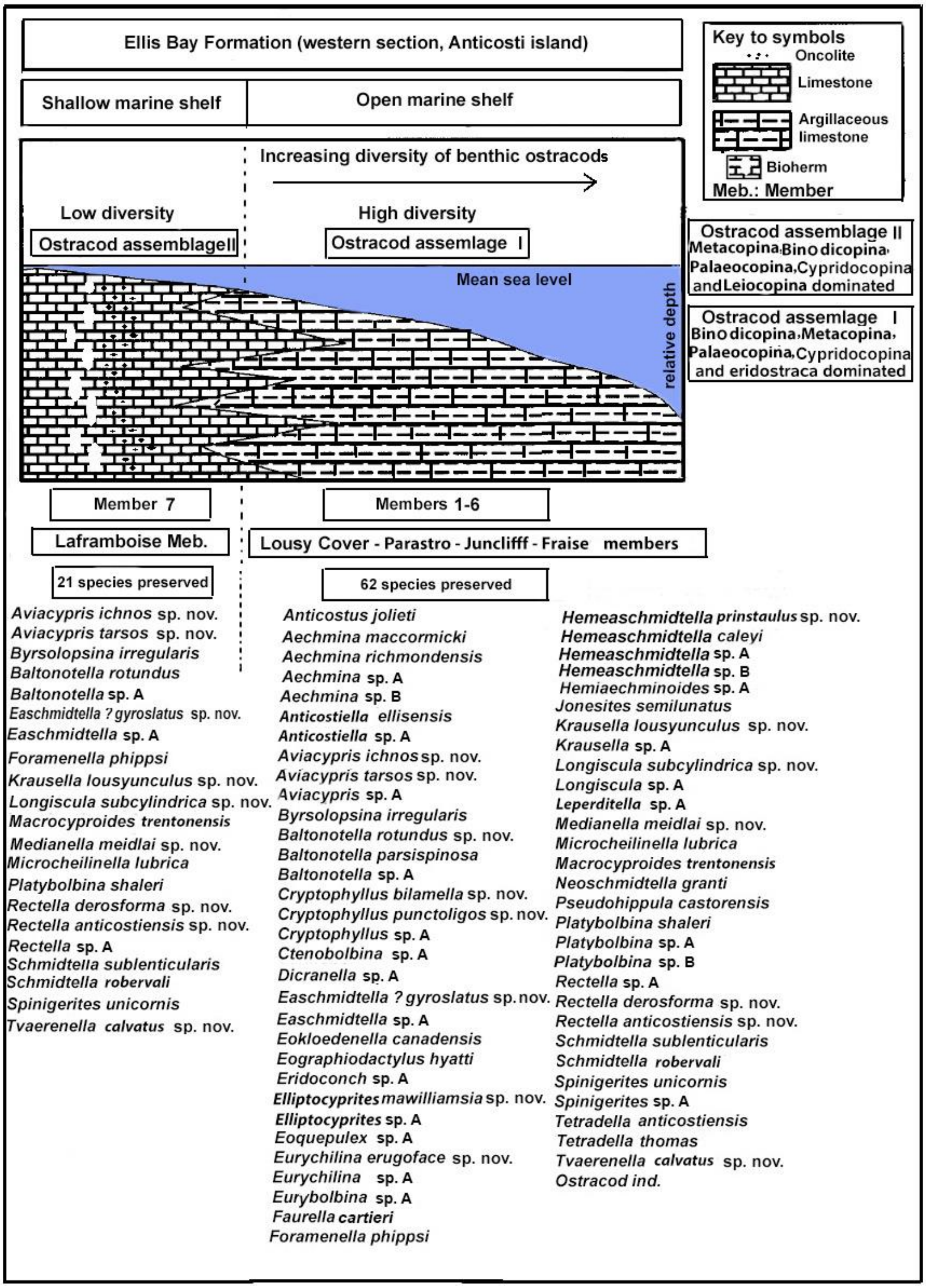


Figure 4.4. Suggested representation of the palaeoenvironments of the two assemblages of ostracods recognised in the Ellis Bay Formation, Anticosti Island. Ostracod assemblage II occupied a more restricted range of palaeoenvironments relative to Ostracod assemblage I, and this may partly explain the lower species diversity of the former.

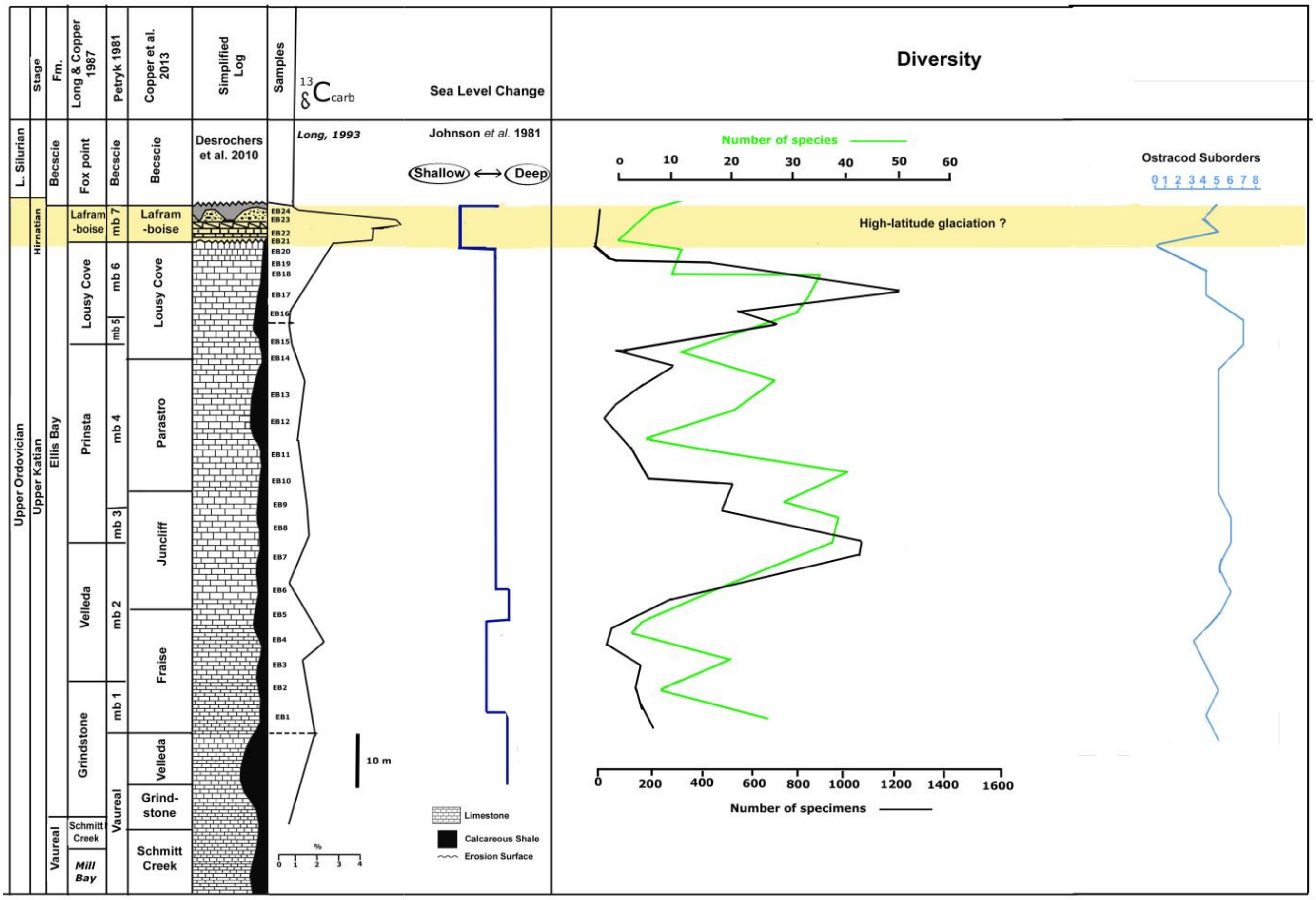


Figure 4.5. Stratigraphic succession through the Upper Ordovician Ellis Bay Formation, showing the horizons of the ostracod samples, sea level change and ostracod species diversity. The blue line represents global sea level change (after Johnson *et al*. 1981). The green line represents the numbers of ostracod species. The black line represents the number of ostracod specimens (abundance). The blue line represents the number of ostracod Suborders represented at different stratigraphical levels. The global sea level low stand of the latest Ordovician (Hirnantian) may be expressed in the Laframboise Member (Member 7) of the Ellis Bay Formation (though this is contentious – see Chapter 3), and is associated with a marked decline, followed by recovery, in ostracod species abundance and diversity. Temporal variation in ostracod diversity throughout the Ellis Bay Formation suggests a strong correlation between ostracod abundance and species diversity that may be linked – certainly in the case of Member 7 – with changes in the range of marine environments in the Ellis Bay Formation (see also Fig. 4.4).

4.5 Palaeoenvironmental patterns of the ostracod fauna

The ostracod fauna recovered from members 1 to 6 (*sensu* Petryk 1981) of the Ellis Bay Formation, represents a highly species diverse assemblage of 62 species. Overall, ostracod diversity fluctuated through members 1 to 6, with individual sample horizons yielding between 10 and 40 species. This variation may reflect subtle changes in sea level or the availability of different mud- and carbonate-dominated environments. Species diversity appears to have dropped to its lowest level, in the uppermost part of Member 6, immediately above sample EB21 into the lower part of Member 7, before recovering (Fig. 4.4, 4.5). An overall lower diversity assemblage is present in Member 7, with species diversity at individual horizons in the range of 0 to 16 species. This may relate to the more restricted range of environments in Member 7, which is entirely carbonate-dominated. As noted in Chapter 3 (Biostratigraphy), the marine low stand in the upper part of the Ellis Bay Formation (Member 7) has been equated with the acme of Late Ordovician glaciation (Underwood *et al*. 1997; Bergstrom *et al*. 2006; Kaljo *et al*. 2008; Finnegan *et al*. 2010; Jones *et al*. 2011). Although precise stratigraphical assignment of this terminal interval to the Hirnantian cannot be confirmed by the ostracod data, it nonetheless represents a significant impact on local ostracod biodiversity, though whether this equates with a global biodiversity crash, or simply represents changing local environment, cannot be determined. However, that Member 7 contains an ostracod fauna of species that all range up from Members 1 to 6, into an environmental setting that showed a narrower range of environments – as indicated by the more restricted range of lithofacies - might suggest that this is simply a local ecological effect, and not related to mass extinction. Similar species abundance changes are noted, for example, in the Late Ordovician (Sandbian) Bromide Formation of Oklahoma (Williams and Siveter 1996), between the more open marine carbonate ramp settings of the Mountain Lake and Pooleville members, and the more restricted carbonate-dominated, shallow subtidal settings of the uppermost Corbin Ranch Member of that formation. In this case, changes are related to local, tectonically controlled changes in sea level, and are not related to any suggested eustatic sea level fall, as with the Ellis Bay Formation Member 7.

Ostracod assemblage changes between Members 6 to Member 7 indicate a change from an assemblage that was characterised by binodicopines, metacopines and palaeocopines, to one in which metacopines and binodicopines were dominant. Palaeocopines are dominant in both the carbonates and mudstones facies of members 1-6, but are rare in the carbonate facies of Member 7 (Figs 4.2, 4.3). Other authors (especially Vannier *et al*. 1989) have noted similarly strong lithofacies controls on the taxonomic structure of Ordovician ostracod assemblages.

4.6 Palaeobiogeographical patterns of the Ellis Bay Formation ostracods

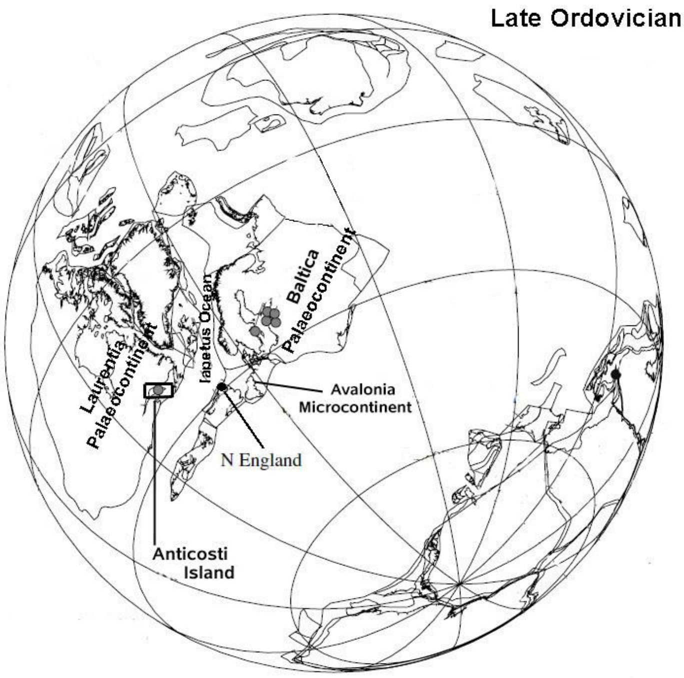


Figure 4.6. Late Ordovician palaeogeographical reconstruction after Torsvik and Cocks (2009). Anticosti Island lies on the eastern margin of Laurentia facing Baltica and Avalonia, as the intervening Iapetus Ocean subducted.

During the Ordovician, Anticosti Island formed part of the southeastern margin of the Laurentia palaeocontinent (Fig. 4.6). It was separated from the Baltic region (Baltica palaeocontinent) and from southern Britain (Avalonia microcontinent) by an arm of the Iapetus Ocean (Cocks and Fortey 1982; McKerrow *et al*. 1991; Cocks and Torsvik 2005). In the Late Ordovician these palaeocontinents converged as a result of the northward movement of Avalonia and the subduction of the intervening Iapetus Ocean (Pickering *et al*. 1988; Cocks *et al*. 1997; Cocks 2000; Cocks and Torsvik 2005). This is supported by evidence of progressive faunal similarity between these regions, including the ostracods (Schallreuter and Siveter 1985; Vannier *et al*. 1989; Williams *et al*. 2003; Siveter 2009).

Following, I tabulate contemporaneous ostracod taxonomic connections between the Ellis Bay Formation fauna and similarly aged successions in Laurentia, Baltica and Avalonia (see Figs 4.1, 4.6, 4.7). For members 1 to 6 (*sensu* Petryk 1981), some 23 genera also occur in other successions in Laurentia, whilst 18 genera are shared with Baltica, and 7 genera are shared with Avalonia. At the species level, biogeographical links with Avalonia are the species *Aechmina maccormicki* and *Spinigerites unicornis*, and between Laurentia and Baltica *Microcheilinella lubrica* occurs in common. For Member 7, faunal links include *S. unicornis* and *M. lubrica*, whilst the number of genera in common is 15. This demonstrates bioegographical links between palaeocontinents fringing the Iapetus Ocean, and is not consistent with the suggestion of McKerrow and Cocks (1976) of continued ostracod provinciality until the middle Silurian. Rather it agrees with the view that ostracod faunal provinciality was beginning to break down during the Late Ordovician (Schallreuter and Siveter 1985; Siveter 2009; Williams *et al*. 2003).

Ostracod Genera	Laurentia Anticosti Island (This study)	Laurentia Anticosti Island Copeland (1970, 1973)	Avalonia Williams *et al.* (2001b)	Baltica Meidla (1993, 1996)	Laurentia
Aparchites					•
Adamczakia				•	
Aechmina	•	•	•	•	•
Airina				•	
Ampletochilina				•	
Anticostella	•	•		•	•
Anticostaus	•				
Aviacypris	•				
Apatochilina				•	
Ardenita				•	
Arpaschmidtella				•	
Bairdia				•	
Bolbihithis				•	•
Bulbosclerites				•	
Bullatella					•
Bollia				•	•
Bythocypris		•	•		•
Bairdiocypris				•	
Balticella					•
Baltonotella	•		•	•	•
Bolbina				•	
Bromidella				•	
Bullaeferum				•	
Byrsolopsina	•				•
Brevibolbina				•	
Circulinella				•	
Carinobolbina				•	
Chilobolbina				•	
Collibolbina				•	
Consonopsis				•	
Cadmea				•	
Cryptophyllus	•	•		•	
Ctenonotella				•	•
Cystomatochilina				•	•
Ctenobolbina	•				•
Ceratopsis					•
Dagoerayella				•	
Daleiella				•	
Dicranella	•				
Disulcina				•	
Dogoriella				•	
Distobolbina				•	
Duoarcus				•	
Duplicristatia			•		•
Estoniosylthere				•	
Estonaceratella				•	
Eographiodactylus	•	•			
Easchmidtella	•			•	
Estonaceratella				•	
Ectoprimitia				•	
Eoaquapulex	•			•	•
Elliptocyprites	•				
Eokloedenella	•	•			
Eridoconcha	•				•
Euprimites		•		•	
Eurychilina	•				•
Euprimitia				•	•
Foramenella	•	•		•	
Faurella	•	•			
Gotlandina				•	
Gellensia				•	
Gryphiswaldensia				•	
Hallatia				•	
Hesperidella				•	
Hemiaechminoides	•			•	
Hippula					•
Hithis					•
Homeokiesowia				•	
Hemeaschmidtella	•			•	
Harpabollia				•	

(Continued)

Ostracod Genera	Laurentia Anticosti Island (This study)	Laurentia Anticosti Island Copeland (1970, 1973)	Avalonia Williams *et al.* (2001b)	Baltica Meidla (1993, 1996)	Laurentia
Jonesites	●	●			
Kroemmeelbeinia				●	
Kiesowia				●	●
Klimphores			●	●	●
Kinnekullea			●		●
Krausella	●	●	●	●	●
Krauselloides					●
Kroemmelbeinia				●	
Lilitia					●
Loculibolbina					●
Laccochilina				●	
Laevanotella			●		
Lambeodella					●
Lennukella				●	
Leperditella	●	●		●	●
Levisulculus					●
Loculibolbina				●	
Longiscula	●			●	●
Medianella	●			●	
Microcheilinella	●			●	
Monoceratella	●	●			●
Macronotella			●		
Moeckowia					●
Macrocyproides	●				
Naevhithis				●	
Ningulella					●
Nodambichilina				●	
Neoschmidtella	●	●			
Oepikella				●	●
Oepikium				●	
Olbiannella				●	
Piretella				●	
Primitiopsacea				●	
Platybolbina	●	●	●	●	●
Polyceratella				●	
Piretia				●	
Primitiella				●	●
Pseudostrepula				●	
Paraschmidtella		●			●
Parulrichia					●
Primitia		●	●		●
Pheloparasclerites					●
Phelobythocypris					●
Pseudohippula	●		●		
Pullvillites				●	
Pseudoancora				●	
Pseudorayella				●	
Pseudulrichia				●	
Quadritia				●	
Rakverella				●	
Retiprimites				●	
Rectella	●			●	●
Rayella					●
Reversocypris				●	
Rimabolbina				●	
Satiellina				●	
Scanipisthia				●	
Spinopleura				●	
Schmidtella	●	●			
Severobolbina				●	
Sigmobolbina				●	
Sigmoopsis				●	
Steusloffia				●	
Steusloffina		●	●	●	●
Spinigerites	●	●	●	●	●
Tallinnella				●	
Tetrada				●	
Tetradella	●	●	●	●	●
Trianguloschmidtella		●		●	
Tvaerenella	●			●	
Trapezisylthere				●	
Uhakiella				●	
Ullerella				●	
Uthoernia				●	
Vogdesella				●	
Vitteplana				●	
Warthinia			●		●

Figure 4.7. Late Katian and Hirnantian ostracod genera of the Ellis Bay Formation compared with selected contemporaneous successions in Laurentia (Kay 1940; Keenan 1951; Copeland 1973, 1974, 1989, 2000; Mohibullah *et al*. 2010), Baltica (Meidla 1993, 1996), and Avalonia (Williams *et al*. 2001b).

Conclusions

The lithofacies distribution of the 62 species of ostracods recorded through the Ellis Bay Formation identifies two assemblages reflecting more open shelf and more shallow shelf settings respectively. Species diversity appears to relate to the overall range of ecological niches available, as signalled by the range of different carbonate and mud-rich lithofacies. Sea level fall in the latest Ordovician (Ellis Bay Formation Member 7) resulted in a reduced diversity assemblage of ostracods, perhaps reflecting a smaller range of essentially carbonate-dominated niches. Other workers have noted similar lithofacies controls on ostracod diversity and taxonomic make-up in the Ordovician (Vannier *et al*. 1989). Palaeobiogeographical analysis of the Ellis Bay Formation ostracod fauna establishes its affinities with other contemporaneous Late Ordovician Laurentian ostracod faunas, and identifies generic and species-level links with those of the Ordovician Baltica and Avalonia palaeocontinents too. Despite sea level fall evident in the upper part of the Ellis Bay Formation, palaeobiogeographical links continued to be maintained between the palaeocontinents fringing the Iapetus Ocean.

Chapter 5: Conclusions

The aim of this study was to document the taxonomic, biostratigraphical, palaeobiogeographical and palaeoecological significance of the Late Ordovician ostracod fauna of the Ellis Bay Formation on Anticosti Island, eastern Canada. These studies have produced the following results.

Taxonomic assessment of the ostracods from the Ellis Bay Formation described 47 species belonging to 31 genera: 14 of these species are newly recognised and one new genus. Thirteen species are discussed in open nomenclature. The ostracod species can be assigned to 9 super-families and 24 families. The 14 new species are: *Tvaerenella calvatus* sp. nov., *Eurychilina erugoface* sp. nov., *Easchmidtella*? *gyroslatus* sp. nov., *Hemeaschmidtella prinstaulus* sp. nov., *Baltonotella rotundus* sp. nov., *Cryptophyllus punctoligos* sp. nov., *Cryptophyllus bilamella* sp. nov., *Medianella meidlai* sp. nov., *Aviacypris ichnos* sp. nov., *Aviacypris tarsos* sp. nov., *Krausella lousyunculus* sp. nov., *Rectella derosforma* sp. nov., *Rectella anticostensis* sp. nov., and *Elliptocyprites mawilliamsia* sp. nov. All species are described in detail. The new ostracod assemblages documented here are better preserved, and many contain taxonomically new elements from those described by Copeland (1973): thus the work extends the faunal inventory from the Ellis Bay Formation.

Identification of the stratigraphical ranges of the 62 ostracod species permits the recognition of four successive biostratigraphical intervals in the Late Ordovician succession of the Ellis Bay Formation. These comprise three partial range zones: (A) the *Longiscula subcylindrica* Biozone, (B) the *Eurychilina erugoface* Biozone, and (C) the *Tetradella anticostiensis* Biozone; and in the uppermost part of the formation, (D) an interregnum is recognised. Biostratigraphical intervals A, B and D can be related to Copeland's (1973) ostracod zonation. Biozone C is equivalent to three of Copeland's (1973) sub-zones. The ostracod biostratigraphy does not, in itself, resolve the long-term controversy regarding the suggested Katian and Hirnantian age, versus a purely Hirnantian age for the Ellis Bay Formation.

Analysis of presence/absence data for the patterns of temporal and spatial ostracod distribution in the Ellis Bay Formation identifies two broad types of ostracod assemblage that characterise shallow and open marine environments respectively. The Open marine ostracod assemblage (I) is dominated by Metacopina, Leiocopina, Binodicopina, Cypridocopina, Eridostraca and Palaeocopina and it is characterized by abundant *Byrsolopsina irregularis,* and includes species of *Aechmina*, *Anticostus*, *Anticostella*, *Aviacypris*, *Byrsolopsina*, *Baltonotella*, *Cryptophyllus, Ctenobolbina, Dicranella, Easchmidtella*, *Eokloedenella Eographiodactylus*, *Eridoconcha*, *Elliptocyprites*, *Eoaquapulex*, *Eurychilina*, *Eurybolbina Faurella*, *Foramenella*, *Hemiaechmidtella, Hemiaechminoides, Jonesites, Krausella, Longiscula, Leperditella, Medianella, Microcheilinella, Macrocyproides, Neoschmidtella, Pseudohippula, Platybolbina, Rectella, Schmidtella*, *Spinigerites*, *Tetradella* and *Tvaerenella.* This assemblage is present in the Fraise, Juncliff, Parastro and Lousy Cove members (equivalent to members 1-6 *sensu* Petryk 1981) of the Ellis Bay Formation. The Shallow marine ostracod assemblage (II) is dominated by Metacopina, Leiocopina, Binodicopina, Cypridocopina and Palaeocopina, and is composed of species of *Aviacypris, Baltonella, Easchmidtella, Foramenella*, *Krausella*, *Longiscula*, *Macrocyproides*, *Microcheilinella*, *Rectella* and *Schmidtella*. This assemblage is restricted to strata of the uppermost part of the Ellis Bay Formation, Laframboise Member, and is characterized by 21 species.

The palaeobiogeographical affinities of the Ellis Bay Formation ostracod fauna clearly align with palaeocontinental Laurentia, with 23 genera and 2 species recorded from other contemporaneous Late Ordovician Laurentian assemblages. The ostracod fauna also shows links with palaeocontinental Baltica (18 genera, 1 species) and Avalonia (7 genera, 3 species), suggesting that ostracod taxa were dispersing across a narrowing Late Ordovician Iapetus Ocean.

This work has presented an updated palaeontological analysis of the latest Ordovician ostracod assemblage of palaeocontinental Laurentia. Going forward, it is hoped that this work can be utilised by other specialists to examine the impact of Late Ordovician climate change and Iapetan continental reconfiguration on the distribution patterns and biodiversity of Ordovican marine shelf faunas.

Appendices

Appendix 1: Specimen numbers of ostracods of the Ellis Bay Formation, Anticosti Island, Canada.

Samples / Ostracods	EB1	EB2	EB3	EB4	EB5	EB6	EB7	EB8	EB9	EB10	EB11	EB12	EB13	EB14	EB15	EB16	EB17	EB18	EB19	EB20	EB21	EB22	EB23	EB24
Anticostus jolieti	35	42		10	6			130	115	10 5	5		35	8		100	87	200	73	54				
Aechmina maccormicki		1					3		1	8			2	2		9			1	2				
Aechmina richmondensis	1		5	1			6	3		2			7	2	3	4		2		1				
Aechmina sp. A	2	1	2			1	5	2	1				11	12	1	4	2	2						
Aechmina sp. B																1	2	2						
Anticostella ellisensis		1					2	15	2	1	1			2		3	4	44	2	3				
Anticostella sp. A																		4						
Aviacypris ichnos sp. nov.	2					11	30	3	4	30			3	6		3	5							2
Aviacypris tarsos sp. nov.			1			30	80	3	7	20			5	12	2		12	3					1	2
Aiocypris sp. A			1				15		9	1				4		2	3	1						
Byrsolopsina irregularis						55	540	230	93	13 0	15	5		2	1	300	85	649	41	39		1	1	
Baltonotella rotundus sp. nov.							1		3	1				5	6		36							7
Baltonotella parsispinosa														40										
Baltonotella sp. A										3							1					1		
Cryptophyllus bilamella sp. nov.	1		2			1	20	5	5	3	1		5		1	20	4	3						
Cryptophyllus punctoligos sp. nov.	2		1			1	40	13	8	5			8			100	5	13						
Cryptophyllus sp. A							2	1		1			1			3	1	2						
Ctenobolbina sp. A								1				1		1						3				
Dicranella sp. A																		1						
Easchmidtella ? gyroslatus sp. nov.						8	18	1	1		1			7			1	4						2
Easchmidtella sp. A						7		2		1				2				15				5	1	1
Eokloedenella canadensis																	2	29	20					
Eographiodactylus hyatti	1		2			1			1	1							2	1						
Eridoconch. sp. A			1					2																
Elliptocyprites mawilliamsia sp. nov.			4			3	3	2		13			12	7	5	2	3	3						
Elliptocyprites sp. A						2	5	3		1	2			4			2							
Eoquepulex sp. A							5	1																
Eurychilina erugoface sp. nov.			12												4									
Eurychilina sp. A										6														
Eurybolbina sp. A													1				1							

Appendix 1: Specimen numbers of ostracods of the Ellis Bay Formation, Anticosti Island, Canada.

Faurella cartieri							**2**		**2**	**25**														
Foramenella phippsi	**5**	**65**	**75**	**14**	**6**	**2**	**25**	**450**	**82**	**10**	**5**	**16**	**2**	**11**	**5**	**6**	**95**	**64**	**2**	**25**		**5**		**3**
***Hemiaechmidtella prinstaulus* sp. nov.**	**4**															**3**								
Hemeaschmeditella caleyi	**8**		**1**		**4**																			
***Hemeaschmeditella* sp. A**											**3**													
***Hemeaschmeditella* sp. B**											**2**													
***Hemiaechminoides* sp. A**																		**2**						
Jonesites semilunatus	**1**		**1**		**9**	**1**	**20**	**7**		**1**			**1**			**3**	**2**	**4**		**3**				
***Krausella lousyunculus* sp. nov.**	**11**	**3**	**1**				**12**		**4**	**5**			**4**	**6**	**2**	**15**	**8**	**7**	**21**			**1**		**3**
***Krausella* sp. A**	**10**		**2**				**2**											**1**						
Longiscula subcylindrica	**7**	**17**	**13**			**40**	**39**	**60**	**65**	**35**	**7**	**7**	**20**	**18**	**4**	**20**	**40**	**34**	**13**					**4**
***Longiscula* sp. A**	**4**	**1**										**2**	**4**				**1**	**4**	**1**					
***Leperditella* sp. A**	**8**													**2**		**1**	**2**							
***Medianella meidlai* sp. nov.**	**4**		**1**				**2**	**12**	**9**	**11**	**2**		**2**					**11**						**2**
Microcheilinella lubrica				**5**	**37**						**6**			**6**		**6**	**22**	**1**				**2**	**5**	**5**
Macrocyproides trentonensis	**15**	**32**	**2**			**38**	**95**	**47**	**23**	**21**	**5**	**4**	**2**	**9**	**18**	**12**	**57**		**83**			**2**		**7**
Neoschmidtella granti									**1**	**2**	**1**								**1**					
Pseudohippula castorensis	**3**						**2**									**4**			**2**					
Platybolbina shaleri	**1**								**2**	**5**		**1**			**1**	**3**	**10**	**3**		**1**			**2**	
***Platybolbina* sp. A**								**1**		**1**						**1**	**1**	**1**						
***Platybolbina* sp. B**							**1**	**7**	**1**	**1**														
***Rectella derosforma* sp. nov.**	**2**	**1**									**1**						**1**	**1**					**1**	**4**
***Rectella anticostiensis* sp. nov.**	**5**		**1**				**8**	**2**			**3**													**2**
***Rectella* sp. A**																**1**								**4**
Schmidtella sublenticularis	**15**	**16**	**20**	**5**	**20**		**22**	**20**	**2**	**10**	**5**	**6**	**10**	**20**	**3**	**60**	**40**	**60**	**5**				**2**	**2**
Schmidtella robervali	**35**		**30**		**7**			**10**	**3**	**5**	**24**		**18**	**60**	**15**	**15**	**30**	**30**		**1**			**1**	
Spinigerites unicornis			**5**	**2**	**7**	**13**	**11**	**12**	**8**	**20**				**7**		**30**	**5**	**4**	**1**	**1**				**2**
***Spinigerites* sp. A**																		**3**						
Tetradella anticostensis							**8**	**5**	**10**	**1**	**1**			**7**		**1**	**5**	**7**		**1**				
Tetradella thomas			**1**					**8**	**2**					**2**			**7**	**2**						
***Tvaerenella calvatus* sp. nov.**	**15**					**3**	**2**		**3**	**9**						**4**	**1**							**2**
Ostracod indet.	**1**	**2**	**1**		**2**																			

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