A remarkable Ordovician ostracod fauna from Orphan Knoll, Labrador Sea

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Key words: Ostracoda, Taxonomy, Palaeogeography, Palaeoecology, Ordovician.
This paper deals with silicified ostracods obtained from material dredged from Orphan Knoll, a submerged continental remnant in the Labrador Sea. Thirteen determinable species, belonging to the suborders Palaeoecopina and Podocopina, had been found in the material. Two species are new, the rest are left in open nomenclature. Among the smooth shelled podocopines, ancestral Pachydomellidae are of special interest, viz. *Aboilia* Becker & Adamczak (type species *A. blessi* Becker & Adamczak). The ostracod species are thought to indicate an age of Middle to Late Ordovician and include forms with both North American and North European affinities. It is believed that the collection of Ordovician ostracods is endemic at the species level and that they have been derived from bedrock on Orphan Knoll.

Contents

Introduction

Orphan Knoll is a submerged, isolated continental remnant in the southwestern Labrador Sea. It lies adjacent to the continent-ocean transition at the eastern margin of the North American continent, just 500 km northeast of Newfoundland (Fig. 1).

The stratigraphy of Orphan Knoll has been described by Laughton et al. (1972) and Ruffman & van Hinte (1973). It consists of a thin sequence of Mesozoic and Cenozoic marine sediments overlying basement of Palaeozoic sediments and strata of unknown age. Geophysical surveys show that much of the surface topography of Orphan Knoll is smooth, however, in the northeast a series of pinnacle shaped mounds arise from the basement strata (see Ruffman & van Hinte, 1973, fig. 5). These

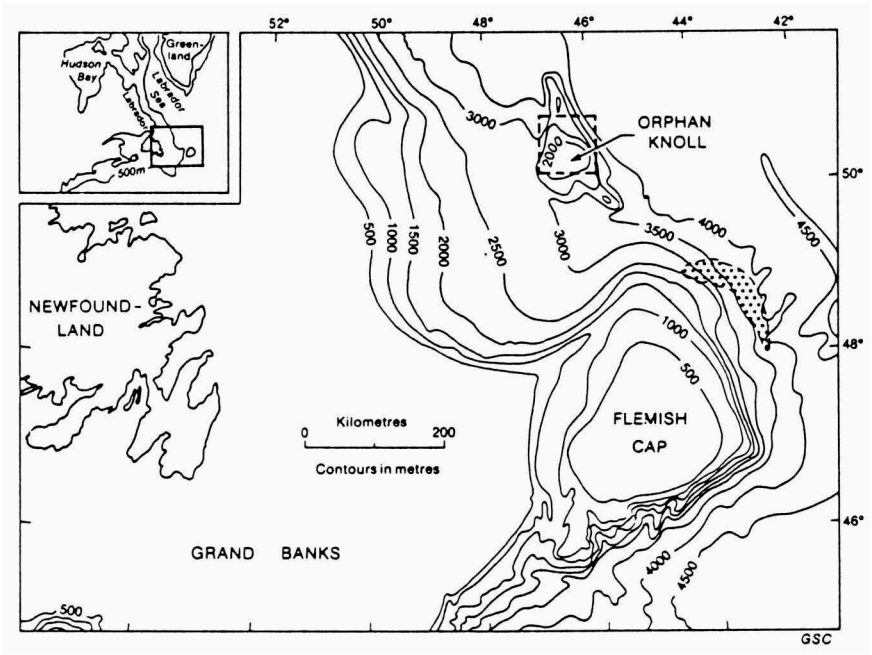


Fig. 1. Location map of Orphan Knoll in the Labrador Sea (adapted from Grant, 1988b, text fig. 1).

have generally been considered to represent Palaeozoic, possibly Devonian, remnant ridges or reef mounds (Laughton et al., 1972 and addendum; Parson et al., 1983, Grant, 1988a-b); they may also be reactivated diapirs or, possibly remnant karst topography (Ruffman, 1989a).

From a 1978 rock dredge (Keen, 1978), a report was given by Legault (1982) indicating Ordovician (Caradoc-Ashgill) palynomorphs. The dredge haul (CSS Hudson 78-020-001) was obtained from one of the pronounced bathymetric highs that stand atop Orphan Knoll, the correct position and echo-sounder depth of the dredge station that Legault assessed were 50° 33.0′ N, 46° 11.6′ W, 1628 m (Ruffman, 1989b). A pinger was attached to the dredge wire so that the dredge could be positioned close to the flat surface of the knoll. The dredge was than rammed into the side of the pinnacle in an effort to acquire bedrock rather than sediment veneer (Keen, in Legault, 1982, p. 1851). From this dredge load a block was processed for the palynological studies.

From material dredged in 1971 (see below) which were recovered near the base of a mound, ostracods had been collected (van Hinte & Ruffman, 1990). As a result of the present study, this collection is also considered to be Ordovician in age. The stratigraphic and palaeogeographic discussions in van Hinte & Ruffman (in press) are strongly influenced by the present author's results.

Material studied

The material studied was obtained from a single biologic dredge (LYNCH 7/11/71 cruise, Biologic Dredge Station, No. 1; LYNCH Station No. D3-7-11-71; Biological Dredge No. 1) at an average position 50° 33.3′ N, 46° 21.9′ W and from a corrected

depth of 1775 m (see Ruffman, 1989a). The material, dredged near the base of one of the pronounced (Palaeozoic ?) mounds, comprised mainly muds with a large number of fossiliferous limestone pebbles which have irregular shapes, are angular and show no sign of having been transported by currents or worn by waves (van Hinte & Ruffman, in press). The limestone pebbles occurred together with crystalline and metamorphic erratics clearly of ice-transported derivation.

Distinct pebbles of Biological Dredge No. 1 had been processed for microfossils (conodonts, ostracods, sponges); all material is deposited in the collections of the Nationaal Natuurhistorisch Museum at Leiden, The Netherlands (RGM).

From one (single pebble) of the limestone pebbles, initially investigated for conodonts (sample B3279) for which it proved barren, a richly diverse, silicified ostracod fauna (RGM 414 000-414 056) was recovered; ostracods (RGM 414 057-414 058) were also recovered in small numbers from some other pebbles (samples B3260, B3262); see van Hinte & Ruffman (in press) for sample descriptions.

The ostracods were collected in the early 1970's by Jan E. van Hinte who tentatively differentiated some twenty forms (sp. 1-4, 6-22; see Hinte & Ruffman 1990, p. 9) on (for that time) excellent SEM microphotographs (see also van Hinte & Ruffman in press, pls. 8-11) prepared by Imperial Oil in Calgary. I.G. Sohn and Jean M. Berdan, U.S. National Museum, Washington/DC provided some initial comments in the mid 1970's (pers. comm. to J.E. van Hinte, 25.9.1975). Several of these ostracods remain at present of an indeterminate nature due either to their simple morphology, lack of sufficient specimens or preservational state. In the present paper species representing the best preserved and/or most distinctive elements of the fauna are described; the taxonomic evaluatiuons are adopted by van Hinte & Ruffman (in press).

The ostracod fauna from sample B3279 (RGM 414 000-414 044) is clearly Middle-Late Ordovician in age, showing close affinities with North America and North Europe (see the special chapters below). However, at the genus level only; the species distinguished are either new or left in open nomenclature. (Additional nos. RGM 414 045-414 056 = Ostracoda indet.).

The ostracod specimens "sp. 3" and "cf. sp. 13" of Sample B3260 (van Hinte & Ruffman, 1990, p. 5) are not stored with the material from Orphan Knoll. Compared with Sample B3279, "sp. 3" would mean *Ectoprimitoides* sp. A and "sp. 13" *Macrocyproides*? sp. A, species of clearly Ordovician age. However, one broken valve ("sp. 5", RGM 414 057), not mentioned by van Hinte & Ruffman (1990), was found in Sample "IB 48338" (B3260). This specimen is pictured in van Hinte & Ruffman (in press, pl. 8, fig. 3) and also believed to be of Ordovician age.

The two ostracods (RGM 414 058) in sample B3262 are smooth, single valves. One specimen is broken (Podocopina indet.); the complete RV, however, closely resembles the bairdiocypridaceans in sample B3279.

The indeterminable ostracod specimen mentioned by van Hinte & Ruffman (1990, p. 7) from Sample B3259 was not at the disposal of the present author.

Systematic palaeontology

Subclass Ostracoda Latreille, 1802
Order Palaeocopida Henningsmoen, 1953
Suborder Palaeocopina Henningsmoen, 1953
Superfamily Hollinacea Swartz, 1936
Family Sarvinidae Schallreuter, 1966

Anticostiella Copeland, 1973

Type species — *Anticostiella ellisensis* Copeland, 1973.
Range — Late Ordovician to Late Silurian.

Anticostiella sp. A
Pl. 1, figs. 5-6

v 1990 sp. 2, van Hinte & Ruffman, p. 9.
v 1990 sp. 6, van Hinte & Ruffman, p. 9.
v 1995 *Anticostiella* sp. A, Becker in van Hinte & Ruffman (in press), pl. 8, fig. 1; pl. 10, fig. 2.

Material — Two valves (a heteromorph and a tecnomorph).
Measurements (in mm)

Specimen	Length	Height	no.
LV (Pl. 1, fig. 5)	0.70	0.49	RGM 414 000
RV (Pl. 1, fig. 6)	0.68	0.48	RGM 414 001

Diagnostic features — Trilobate; anterior lobe subdued, preadductorial lobe a moderately developed low node, posterior lobe well developed and subdivided by a distinct furrow into dorsal and ventral portions. Dorsal portion of posterior lobe extended into a short prolongation overreaching the dorsal margin. Postadductorial sulcus weak, adductorial sulcus moderately developed, terminating ventrally against the posterior lobe. Dimorphic; both dimorphs with a narrow velum. Heteromorph with loculate antrum having three loculi.

Remarks — Copeland (1973, p. 9) described *Anticostiella ellisensis* from the Ordovician-Silurian of Anticosti Island, Canada. Although the specimens from Orphan Knoll are somewhat less well preserved, they share the same lobal, velar and dimorphic features described for *Anticostiella*. The genus is also known from the Lower Silurian of Estonia (Sarv, 1962, pl. 5, figs. 11-13).

Anticostiella sp. A is also similar to *Abditoloculina triloculata* Copeland, 1977 from the Silurian Delorme Formation of the District of Mackenzie, northwestern Canada (Copeland, 1977, p. 28). However, the latter clearly differs in the morphology of the heteromorph loculate dolon, being separated from the lateral surface of the valve by a distinct furrow. Moreover, the loculi appear closed in ventral view (Copeland (1977, p. 28). In addition Copeland's figured specimens of *A. triloculata* (1977, pl. 12, figs. 10, 11; pl. 14, figs. 19, 20) show much stronger development of the adductorial sulcus than in *Anticostiella* sp. A.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Family Tvarenellidae Jaanusson, 1957

Bromidella Harris, 1931

Type species — *Bromidella reticulata* Harris, 1931.
Range — Middle-Late Ordovician.

Bromidella ? sp. A
Pl. 2, fig. 1

v 1990 sp. 4, van Hinte & Ruffman, p. 9.
v 1995 *Bromidella* ? sp. A, Becker in van Hinte & Ruffman (in press), pl. 10, fig. 5.

Material — One incomplete right valve.
Measurements (in mm)

Specimen	Length	Height	no.
RV (Pl. 2, fig. 1)	incomplete		RGM 414 002

Remarks — Although only a fragment, this specimen has several features characteristic of *Bromidella* (see Williams & Siveter, 1989, p. 1) including the pronounced preadductorial node, well developed adductorial sulcus, anterodorsal inflation reminiscent of the plica of bromidellids and the tuberculate surface ornament.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Superfamily and family uncertain

Ectoprimitiodes Berdan, 1988

Type species — (Designated by Berdan, 1988) *Eoprimitia* ? *dimunicarina* Kraft, 1962 (= *Eoprimitia moorei* Harris, 1957; see Williams, 1990, p. 169).
Range — Middle Ordovician.

Ectoprimitoides sp. A
Pl. 2, fig. 2

v 1990 sp. 3, van Hinte & Ruffman, p. 9.
v 1995 *Ectoprimitoides* sp. A, Becker in van Hinte & Ruffman (in press), pl. 8, fig. 2.

Material — Two left valves.
Measurements (in mm)

Specimen	Length	Height	no.
LV (Pl. 2, fig. 2)	0.59	0.32	RGM 414 003
LV	0.71	0.40	RGM 414 004

Diagnostic features — Subamplete, elongate outline. Unisulcate with adductorial sulcus well developed, reflected internally by a marked sulcament. Velum narrow,

continuous between cardinal corners. Surface ribbed. Posterocardinal corner with a short spine.

Remarks — *Ectoprimitiodes* sp. A is most similar to *Eoprimitia* (*Ectoprimitoides*) *moorei* Harris, 1957 (p. 195, pl. 6, figs. 7a-c), a species which is widespread in the Middle Ordovician of North America (see Williams, 1990, p. 170). It differs by lacking the broad, gently convex preadductorial node of the latter species and by having pronounced ribs on the lateral surface.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Suborder and Superfamily uncertain
Family ? Kirkbyellidae Sohn, 1961

Ordovizona Schallreuter, 1969

Type species — *Ordovizona sulcata* Schallreuter, 1969.
Range — Middle-Late Ordovician.

Diagnosis — Unisulcate; adductorial sulcus abruptly terminated ventrally, opening dorsally into a broad 'graben'. Dorsal plica and velum narrow. Lateral surface ribbed; between the ribs reticula may be developed. Posteroventral corner with short process.

Remarks — *Ordovizona* belongs to Ordovician forms which were believed by Schallreuter (1968, 1969, 1972) and Schallreuter & Jones (1984) to be the oldest known members of the superfamily Kirkbyacea Ulrich & Bassler, 1906. This opinion is disputed by Becker (1990, p. 150) and Becker & Swanson (1992).

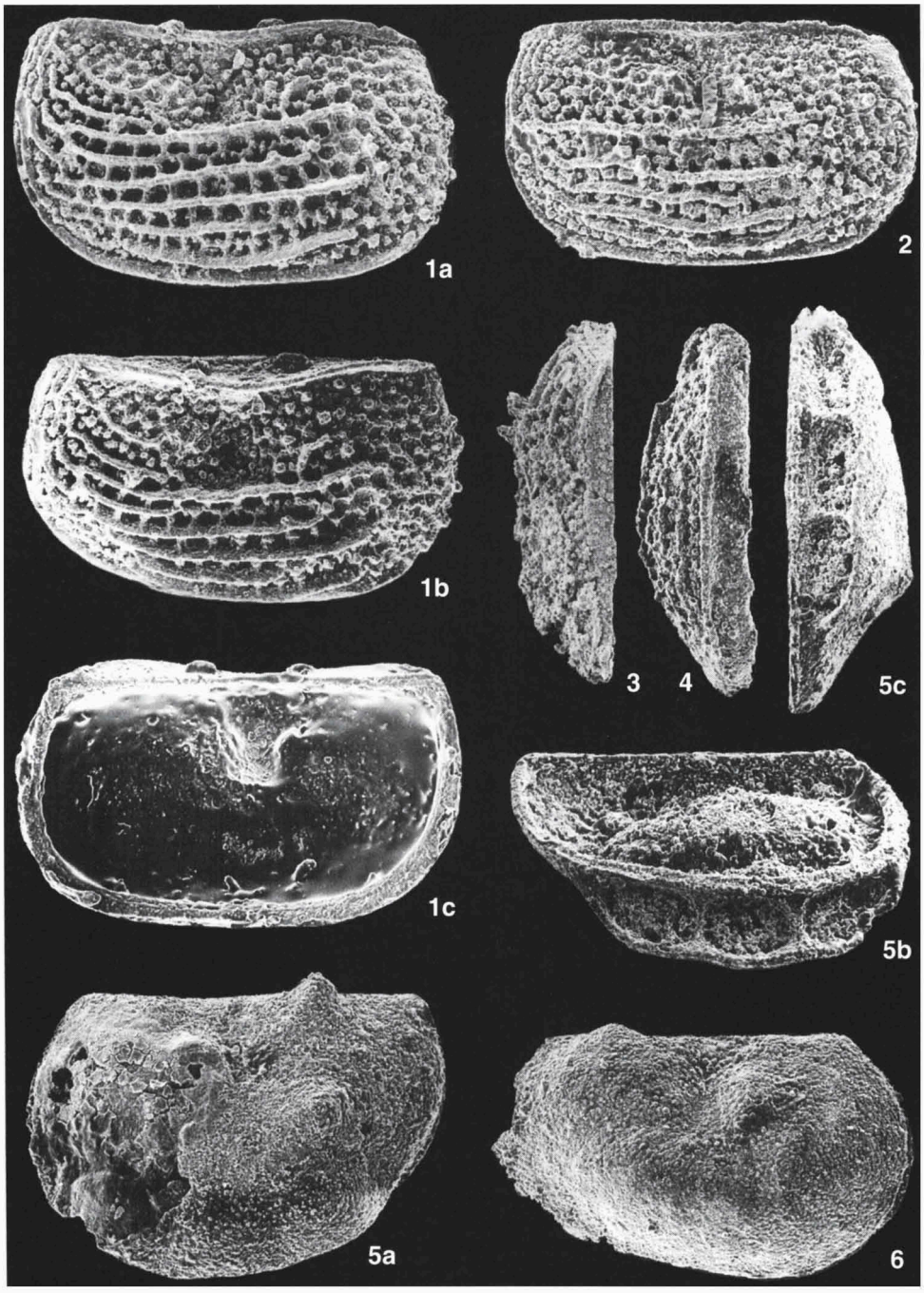
The Kirkbyacea are characterised by an overall palaeocopine morphology (subequal, hemicircular valves; adventral structures, non-dimorphic in this superfamily), a strongly specialised lobation (typically subcentral lobation, instead of a sulcal depression), and an adductoral scar ('kirkbyan' pit, groove or spot) always located below the lobal structures (see Becker, 1990, p.151; Becker & Wang, 1992, p. 10). The Kirkbyacea are considered to be an advanced, phylogenetically younger (Early Devonian-Early Triassic) offshoot of the suborder Palaeocopina Henningsmoen, 1953, prob-

Plate 1

All specimens sample B3279.

Figs. 1-4. *Ordovizona immanis* Becker sp. nov.
1. Adult left valve, holotype (RGM 414 005); 1a) external lateral view; 1b) oblique dorsal view, 1c) internal lateral view; × 90.
2. Adult left valve (RGM 414 006); external lateral view; × 90.
3. Juvenile left valve (RGM 414 007); dorsal view; × 85.
4. Adult left valve (RGM 414 008); ventral view; × 85.

Figs. 5-6. *Anticostiella* sp. A
5. Heteromorphic left valve (RGM 414 000); 5a) external lateral view; 5b) internal oblique ventral view; 5c) ventral view; × 83.
6. Tecnomorphic right valve (RGM 414 001); external lateral view; × 84.


1a
2
1b
3
4
5c
1c
5b
5a
6

ably derived from drepanellid ancestors (Becker, 1981a, p. 185; 1990, p. 152).

By contrast *Ordovizona* and related forms ('kirkbyaceans' sensu Schallreuter) show a monotiopleurid outline and a short, dorsocentral, sulcal depression; the adductorial scar is always located above mid-height of the valve. Gramm (1988, p. 97) and, independently, Becker (1990, p. 150) argued that such forms may be related to the family Kirkbyellidae Sohn, 1961 (order unknown). Gründel (1978, p. 74) placed Schallreuter's 'kirkbyaceans' in the family Monotiopleuridae Guber & Jaanusson, 1964 (superfamily Kloedenellacea Ulrich & Bassler, 1908). Probably, the early Palaeozoic monotiopleurids, the 'kirkbyaceans' sensu Schallreuter and the phylogenetically younger kirkbyellids are closely related groups. The former are possibly the descendants of the family Kirkbyellidae. Therefore, *Ordovizona* is placed herein (tentatively) with the Kirkybellidae.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Ordovizona immanis Becker sp. nov.
Pl. 1, figs. 1-4

v 1990 sp. 1, van Hinte & Ruffman, p. 9.
v 1995 *Ordovizona* sp. A, Becker in van Hinte & Ruffman (in press), pl. 7, figs. 1-5.

Derivatio nominis — From immanis (Lat.) = amazing; regarding the unexpected discovery on Orphan Knoll.
Holotype — Adult left valve (RGM 414 005, Pl. 1, fig. 1) from Orphan Knoll, Labrador Sea (locality as described above).
Paratypes — Three valves (RGM 414006, Pl. 1, fig. 2; RGM 414 007, Pl. 1, fig. 3; RGM 414 008, broken, Pl. 1, fig. 4), all topotype material.
Measurements (in mm)

Specimen	Length	Height	no.
LV (Pl. 1, fig. 1)	0.68	0.42	RGM 414 005
LV (Pl. 1, fig. 2)	0.63	0.39	RGM 414 006
LV (Pl. 1, fig. 3)	0.59	0.36	RGM 414 007
LV (Pl. 1, fig. 4)	0.60	0.39	RGM 414 008

Diagnosis — *Ordovizona* species with a short, ventrally deepened adductorial sulcus, a bow shaped plica in dorsal view, and strong ribs on the lateral surface which are reduced or absent posteriorly.

Description — Subamplete outline. Unisulcate, adductorial sulcus relatively short, deepening and narrowing ventrally before being terminated ventrally against the marked ribs on the lateral surface. Sulcus reflected internally by a marked adductorial ridge. Dorsal margin with a distinct narrow plica which is bow shaped in dorsal view. Ventrally a narrow velum is present bending towards the margin antero- and posteroventrally; velum obscured posteriorly. Lateral surface with strongly developed ribbing, approximately parallel with the dorsal margin. The ribs are less pronounced dorsally, where they are interrupted by the sulcus; posteriorly the ribs are also less well developed or even absent. Between the ribs the valve surface is reticulate. Posterocardinal corner may have a short process.

Remarks — *Ordovizona immanis* sp. nov. is most similar to *Ordovizona sulcata* Schallreuter, 1969 (p. 205, fig. 1) sharing a similar subamplete outline and a similar number of ribs on the lateral surface. *O. sulcata* differs, however, by having a narrower, curved but more clearly defined adductorial sulcus and by having the ribs continuing posteriorly on the lateral surface, where they bend parallel to the posterior margin. *Ordovizona longa* Schallreuter, 1983 (p. 603, fig. 1B) differs from *O. immanis* sp. nov. by being more elongate, by having a less well developed adductorial sulcus and by having a weaker plica. In addition the lateral ribs of *O. longa* are less distinct but more numerous than in *O. immanis* sp. nov.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Order Podocopida Sars, 1866
Suborder Podocopina Sars, 1866
Superfamily Bairdiocypridacea Shaver, 1961
Family Pachydomellidae Berdan & Sohn, 1961
Aboilia Becker & Adamczak, 1993

Type species — *Aboilia blessi* Becker & Adamczak, 1993.
Range — Middle-Late Ordovician.

Derivatio nominis — αβονλια (Greek), the undecision; *Aboilia* has not yet decided to have the LV/RV overlap, frequently occurring in podocopines. Just so, the boil (Engl., word play); after the hunchbacked smaller valve. The nomenclatorical gender is femininum.

Diagnosis — Strongly inequivalved pachydomellid genus with larger right valve overlapping the left valve ventrally with a bow shaped projection; smaller left valve with a pronounced posterodorsally situated ridge-like swelling sometimes strongly over-reaching the dorsal margin. Dorsal lateral outline convex, ventral outline gently concave. Hinge nearly tripartite.

Remarks — Based on features described in the above diagnosis *Aboilia* Becker & Adamczak, 1993 is assigned to the Podocopina and, because of the presence of the distinct bow-shaped projection and the nearly tripartite hinge structure, to the Family Pachydomellidae Berdan & Sohn, 1961. *Aboilia* differs, however, markedly from other (Ordovician and younger) pachydomellids by the peculiar right over left valve overlap and the posterodorsal swelling of the smaller valve.

This is also reminiscent of the family Jaanussonidae Schallreuter, 1971 (superfamily Paraparchitacea Scott, 1959; Middle Ordovician-Silurian). However, in valve outline, overlap features (mid-ventral, bow-shaped projection) and form of the swelling, *Aboilia* differs considerably from typical, Early Palaeozoic Jaanussonidae (see Schallreuter, 1971, p. 250, figs. 1-5; Vannier, 1990, fig. 7) as well as from other, Late Palaeozoic paraparchitaceans (Sohn, 1971, pl. 7, figs. 1-35; pl. 8, figs. 1-44).

The posterodorsal swelling on the left valve of *Aboilia* is rather unique. It begins as a low ridge-like inflation of the valve mid-posteriorly, rising to a pronounced ridge posterodorsally. The anterior margin of the ridge becomes confluent with the lateral surface of the valve. The dorsal margin of the ridge is likewise confluent with the dorsal valve surface.

Aboilia blessi Becker & Adamczak, 1993
Pl. 3, figs. 2-4

v 1990 sp. 10, van Hinte & Ruffman, p. 9.
v* 1993 *Aboilia blessi* Becker & Adamczak, pp. 33-36.
v. 1995 *Aboilia blessi* Becker & Adamczak, 1993, van Hinte & Ruffman (in press), pl. 9, figs. 3-4; pl. 10, fig. 8.

Derivatio nominis — In honour of our friend and colleague, Dr Martin Bless (Heerlen).
Holotype — Adult carapace (RGM 414 009, Pl. 3, fig. 3) from Orphan Knoll, Labrador Sea (locality as described above).
Paratypes — Adult carapace (RGM 414 010, Pl. 3, fig. 2), adult RV (RGM 414 011, Pl. 3, fig. 4), all topotype material.
Material — Thirteen specimens (valves and carapaces, incl. type specimens).
Measurements (in mm)

Specimen	Length	Height	no.
Carapace (Pl 3, fig. 3)	0.58	0.30	RGM 414 009
Carapace (Pl. 3, fig. 2)	0.64	0.36	RGM 414 010
RV (Pl. 3, fig. 4)	0.63	0.32	RGM 414 011
Carapace	0.63	0.35	RGM 414 012
Carapace	0.66	0.34	RGM 414 013
LV	0.61	0.32	RGM 414 014
RV	0.49	0.30	RGM 414 015
LV	0.52	0.28	RGM 414 016
LV	0.70	0.32	RGM 414 017
RV (incomplete)	0.48	0.28	RGM 414 018
RV	0.40	0.24	RGM 414 019
Carapace (incomplete)	0.42	0.23	RGM 414 020
Carapace	0.36	0.23	RGM 414 021

Diagnosis — As for the genus.

Description — Lateral outline elongate, variable but generally gently convex dorsally, ventrally gently concave. Posterior and anterior lateral outlines convex, posterior end higher. Carapace inequivalved. Larger right valve overlaps the smaller left valve ventrally with a distinct bow shaped projection. Smaller left valve with a distinct posterodorsal swelling, sometimes overreaching the dorsal margin strongly. Hinge apparently tripartite. Carapace surface (at least below the swelling of the left valve) finely reticulate.

Remarks — The degree of development of the dorsal swelling on the left valve, which influences the lateral outline, is quite variable. Also marked variation in carapace width occurs (see Pl. 3, figs. 2c, 3c). This may be due to intraspecific variation or, perhaps, may represent domicilar dimorphism. However, at present there is only insufficient material to verify this. Right over left valve overlap and domicilar dimorphism concerning the posterior part of the carapace is known from several kloedenellaceans (kloedenellid dimorphism). These forms, however, have a distinct inner ridge and belong to the suborder Platycopina.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Elliptocyprites Swain, 1962

Type species — *Elliptocyprites parallela* Swain, 1962.
Range — Middle-Late Ordovician.

Elliptocyprites ? sp. A
Pl. 4, figs. 1-3

v 1990 sp. 16, van Hinte & Ruffman, p. 9.
v 1995 *Elliptocyprites* ? sp. A, Becker in van Hinte & Ruffman (in press), pl. 11, fig. 2.

Material — Three carapaces.
Measurements (in mm)

Specimen	Length	Height	no.
Carapace (Pl. 4, fig. 1)	0.57	0.29	RGM 414 022
Carapace (Pl. 4, fig. 2)	0.51	0.26	RGM 414 023
Carapace (Pl. 4, fig. 3)	0.56	0.28	RGM 414 024

Diagnostic features — Carapace with microcheilinellid overall morphology.

Remarks — *Elliptocyprites* ? sp. A from Orphan Knoll is similar to *Elliptocyprites* species from the Ordovician of the eastern U.S.A. (see Swain, 1962, p. 741, pl. 111, figs. 9, 10; Warshauer & Berdan, 1982, p. H70, pl. 18, figs. 5-7) and compares closely to *Bythocypris* ? (*Elliptocyprites* ?) *rectangulatus* Kraft, 1962 (p. 71, pl. 19, figs. 2, 3, 6) from the Middle Ordovician Edinburg Formation of Virginia, and *'Bythocypris'* (*Elliptocyprites* ?) *lindstroemi* Jones ? sensu Copeland, 1973 (p. 6, pl. 1, fig. 3; pl. 2, fig. 4; pl. 6, fig. 7) from the Ordovician of Anticosti Island, Canada. Probably, *E.* ? *nesowa* Schallreuter, 1988 from the Upper Ordovician of Australia belongs to this group.

Elliptocyprites had been proposed by Swain (1962, p. 741, 742) for 'more or less elliptical, equal ended early Palaeozoic Ostracoda formerly included in *Bythocypris*'; because of the ventral concavity the genus 'allies to the cypridid Ostracoda' (Swain, 1962, p. 742). The specimens from the Orphan Knoll are clearly pachydomellid (inequivalved carapace, LV overlapping with ventral bow-shaped projection; nearly tripartite hinge structure). By this pachydomellid overall-morphology, *Elliptocyprites* ? sp. A resembles also the younger genus *Microchelinella* Geis, 1933 (Lower Devonian-Upper Carboniferous).

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Shenandoia Kraft, 1962

Type species — *Shenandoia acuminulata* Kraft, 1962.
Range — Middle-Late Ordovician.

Shenandoia sp. A
Pl. 4, figs. 4-5

v 1990 sp. 18, van Hinte & Ruffman, p. 9.
v 1990 sp. 19, van Hinte & Ruffman, p. 9.
v 1995 *Shenandoia* sp. A, van Hinte & Ruffman (in press), pl. 11, figs. 3-4.

Material — Two valves.
Measurements (in mm)

Specimen	Length	Height	no.
RV (Pl. 4, fig. 4)	0.82	0.24	RGM 414 025
RL (Pl. 4, fig. 5)	0.90	0.26	RGM 414 026

Diagnostic features — Lateral outline elongated suboval, greatest height posterodorsally; anterior margin bluntly and posterior margin broadly rounded. Anteroventrally located incisure distinct.

Remarks. — *Shenandoia* sp. A resembles very much *S. acuminulata* Kraft from the Middle Ordovician of Virginia (U.S.A.) in having 'a small incisure present dorsally of median along anterior border when valves are in contact' (Kraft, 1962, p. 74). In the species from Orphan Knoll, however, the anterior end is higher than in the type species and more bluntly rounded. *S.*? sp. from the Middle and Upper Ordovician of Central Kentucky (U.S.A) 'appear to lack the characteristic ... incisure of that genus' (Warshauer & Berdan, 1982, p. H70).

Although the carapace in *Shenandoia* is (as usual in pachydomellids) distinctly inequivalved, the rather symmetrical (anteroventrally located) incisure, formed by oppositely incised symmetrical margins of both valves, may give evidence of the circumstance that the Ordovician pachydomellids may have derived from equivalved, primitive podocopine ancestors. Comparable incisures, 'placed almost exactly in the same position', are present in species of the Silurian genus *Wenlockiella*, Lundin, 1992, 'the (systematical important) contact groove interuption starts just in front of the valve mid-length' (Adamczak, pers. comm.).

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Plate 2

All specimens sample B3279.

Fig. 1. *Bromidella* ? sp. A. Posterior fragment of right valve; external lateral view (RGM 414 002); × 80.

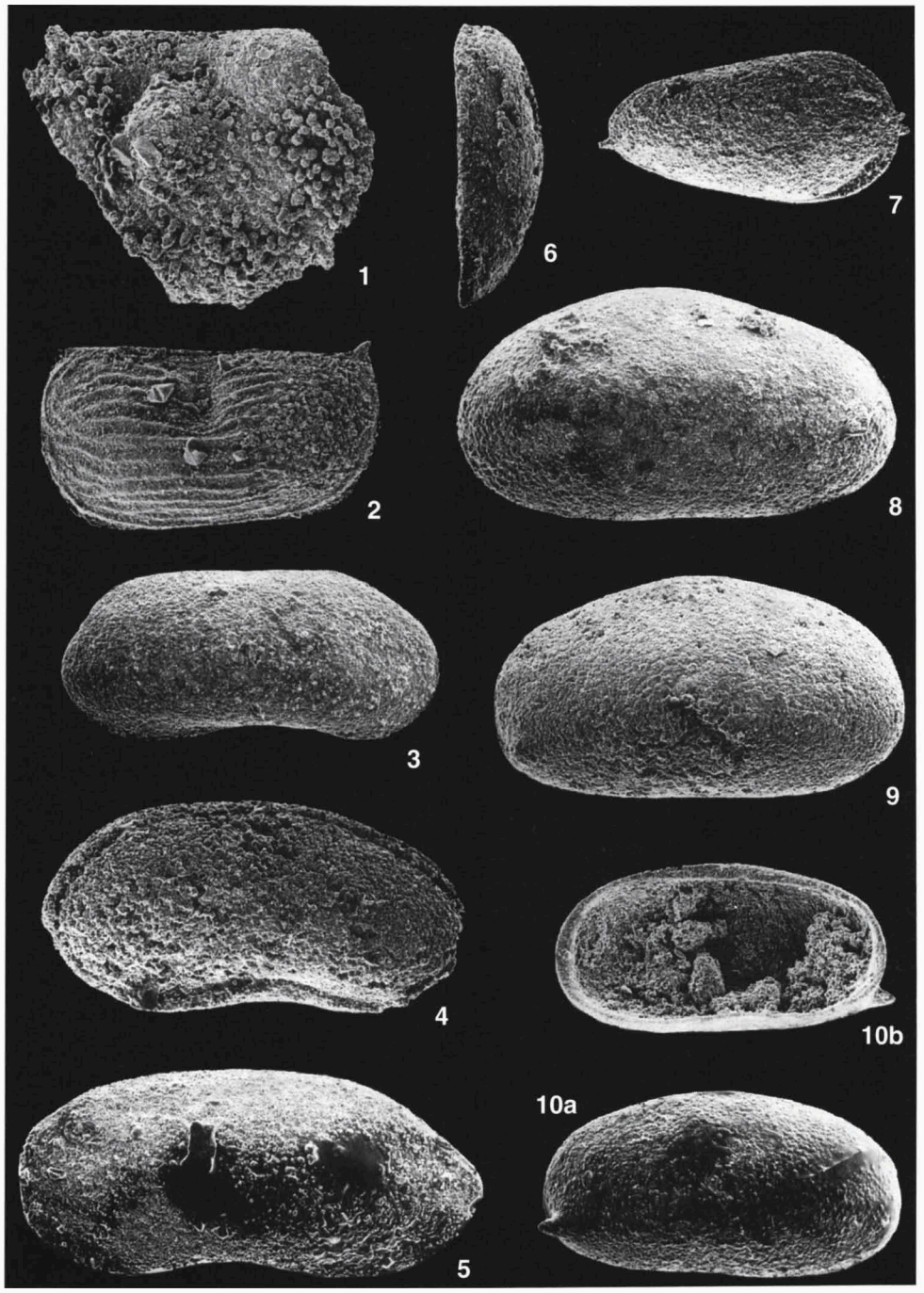
Fig. 2. *Ectoprimitoides* sp. A. Left valve; external lateral view (RGM 414 003); × 80.

Figs. 3-4. *Uthoernia* ? sp. A.
3. Right valve (RGM 414 027); external lateral view; × 80.
4. Carapace (RGM 414 028); right valve lateral view; × 76.

Fig. 5. Bairdiocypprididae ? sp. A. Left valve; external lateral view (RGM 414 034); × 73.

Figs. 6-7. *Pseudorayella* ? sp. A.
6. Right valve (RGM 414 039); dorsal view; × 83.
7. Carapace (RGM 414 040); right valve lateral view; × 77.

Figs. 8-10. Bairdiocypprididae ? sp. B.
8. Left valve (RGM 414 035); external lateral view; × 76.
9. Right valve (RGM 414 036); external lateral view; × 76.
10. Juvenile right valve (RGM 414 037); 8a) external lateral view, × 80; 8b) internal lateral view; × 73.


1
6
7
2
8
3
9
4
10b
10a
5

Family Bairdiocyprididae Shaver, 1961

Uthoernia Schallreuter, 1986

Type species — *Uthoernia lunata* Schallreuter, 1986 (by monotypy).
Range — Middle-Late Ordovician.

Uthoernia ? sp. A
Pl. 2, figs. 3-4

v 1990 sp. 9, van Hinte & Ruffman, p. 9.
v 1995 *Uthoernia* ? sp. A, Becker in van Hinte & Ruffman (in press), pl. 9, fig. 1.

Material — Seven complete specimens (valves and carapaces), two incomplete valves.
Measurements (in mm)

Specimen	Length	Height	no.
RV (Pl. 2, fig. 3)	0.65	0.34	RGM 414 027
Carapace (Pl 2., fig. 4)	0.78	0.28	RGM 414 028
Carapace	0.79	0.41	RGM 414 029
Carapace	0.53	0.28	RGM 414 030
Carapace	0.59	0.28	RGM 414 031
Carapace	0.52	0.29	RGM 414 032
RV	0.63	0.33	RGM 414 033

Diagnostic features — Lateral outline elongate reniform. Smaller RV with distinct midventral concavity, flanked by terminal flanges (? stop structures).

Remarks — *Uthoernia* ? sp. A (see especially the RV, Pl. 2, fig. 4) resembles in lateral outline *U. longofrenatorum* Schallreuter, 1990 from the Middle Ordovician of Sylt. Probably, the ventroterminally located flange-like structures at the free margin are analogous (and homologous) to the stop structures mentioned in *Uthoernia* species by Schallreuter (1986, p. 11; 1990, p. 263).

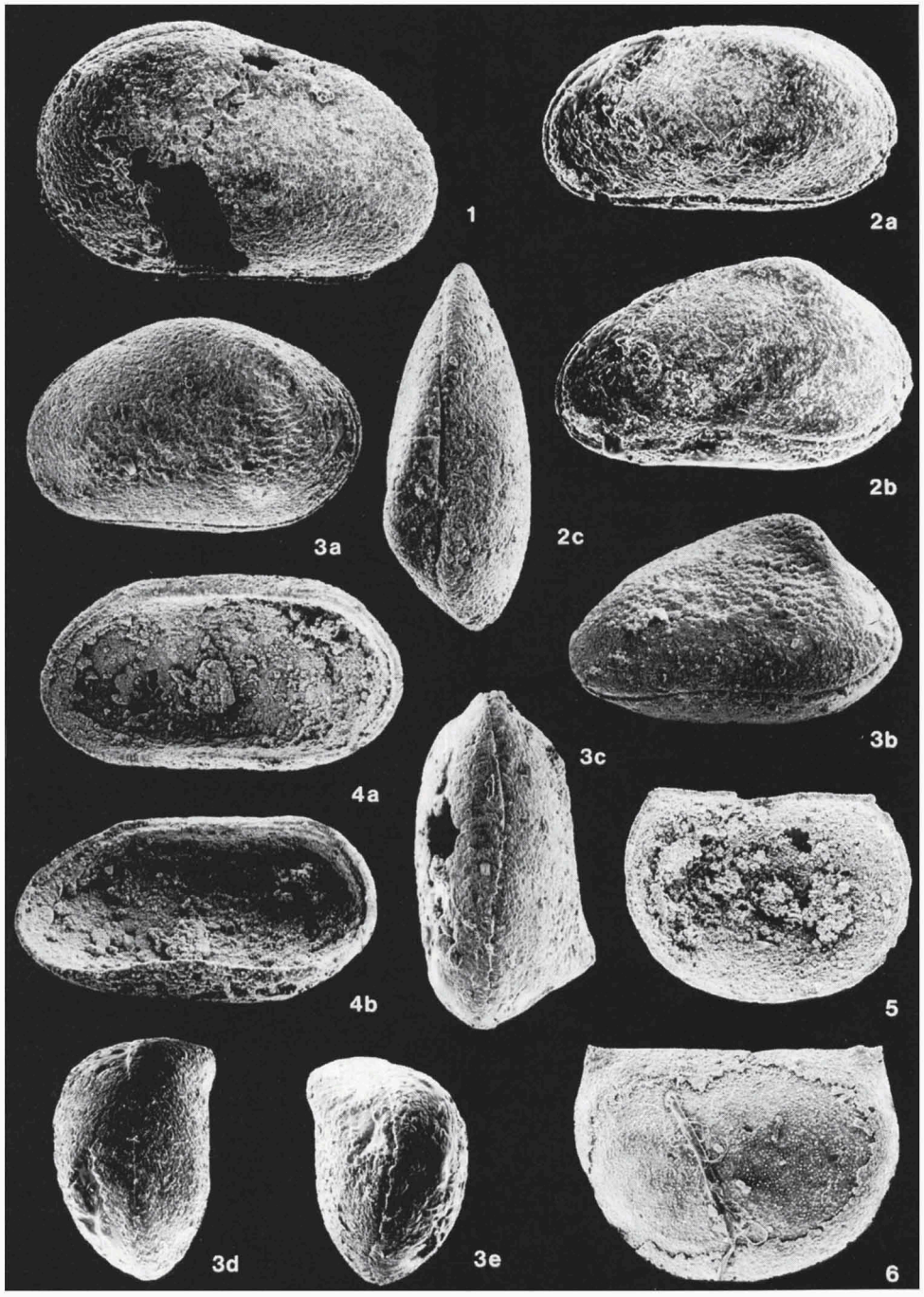
Plate 3

All specimens sample B3279.

Fig. 1. *Macrocyproides* ? sp. A. Carapace; right valve lateral view (RGM 414 042); × 77.

Figs. 2-4. *Aboilia blessi* Becker & Adamczak, 1993.
2. Carapace (RGM 414 010); 2a) left valve lateral view; 2b) oblique ventral view; 2c) dorsal view; × 78.
3. Carapace, holotype (RGM 414 009); 3a) left valve lateral view; 3b) oblique ventral view; 3c) ventral view; 3d) anterior view; 3e) posterior view; × 80.
4. Right valve (RGM 414 011); 4a) internal lateral view; 4b) internal oblique ventral view (note: the dublure-like structure along the anterior margin is an artifact); × 81.

Figs. 5-6. *Baltonotella* ? sp. A.
5. Single valve (RGM 414 043); internal lateral view; × 78.
6. Single valve (RGM 414 044); external lateral view; × 72.


1
2a
2b
2c
3a
3b
3c
4a
4b
5
3d
3e
6

Stop structures occur in different ostracod lineages; therefore, they are not exclusively indicative of the suborder Metacopina (see Becker, 1990, p. 155).

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Family and genus uncertain

Bairdiocyprididae ? sp. A
Pl. 2, fig. 5

v 1990 sp. 8, van Hinte & Ruffman, p. 9.
v 1995 Bairdiocyprididae ? sp. A, Becker in van Hinte & Ruffman (in press), pl. 10, figs. 4, 6.

Material — One left valve.
Measurements (in mm)

Specimen	Length	Height	no.
LV (Pl. 2, fig. 5)	0.89	0.43	RGM 414 034

Diagnostic features — As for *Longiscula ? emaciata* Copeland, 1965.

Remarks — Although the specimen from Orphan Knoll is slightly broader it has a similar outline to *Longiscula ? emaciata* Copeland (1965, p. 45; pl. 8, figs. 1-4), having the distinct ventral concavity, the angular posterodorsal lateral outline and the lower rounded anterior outline of this species, described from the Ordovician of Ontario, Canada. The exact systematic position of the taxon is unknown.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Bairdiocyprididae ? sp. B
Pl. 2, figs. 8-10

v 1990 sp. 12, van Hinte & Ruffman, p. 9.
v 1995 Bairdiocyprididae ? sp. B, Becker in van Hinte & Ruffman (in press), pl. 11, figs. 5-7.

Material — Four complete valves, two broken valves.
Measurements (in mm)

Specimen	Length	Height	no.
LV (Pl. 2, fig. 8)	0.80	0.42	RGM 414 035
RV (Pl. 2, fig. 9)	0.75	0.42	RGM 414 036
RV (Pl. 2, fig. 10)	0.63	0.32	RGM 414 037
LV	0.52	0.30	RGM 414 038

Diagnostic features — Lateral outline suboval; smaller RV with posteroventral spinelet located admarginally.

Remarks — The specimens from the Orphan Knoll seem similar to *'Krausella' brevicornis* (Keenan, 1951, p. 567; pl. 79, figs. 40, 41; see also Kraft, 1962, p. 66; pl. 18, figs. 2-6) originally described from the Ordovician Maquoketa Shale of Missouri. They share the same overall valve morphology, with a slightly concave ventral outline and a gently convex dorsal outline, and the size and position of the spine posteroventrally

on the right valve.

In the material considered above, the posteroventral spine always lies on the lateral surface, at some distance from the free margin. Therefore, the mentioned taxa do not belong to *Krausella* Ulrich, 1894 which has this structure located marginally.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Pseudorayella Neckaja, 1960

Type species — *Pseudorayella scala* Neckaja, 1960.
Range — Middle Ordovician to Late Devonian.

Pseudorayella ? sp. A
Pl. 2, figs. 6-7

v 1990 sp. 7, van Hinte & Ruffman, p. 9.
v 1995 *Pseudorayella* ? sp. A, Becker in van Hinte & Ruffman (in press), pl. 10, fig. 1.

Material — Three specimens (valves and carapaces).
Measurements (in mm)

Specimen	Length	Height	no.
RV (Pl. 2, fig. 6)	0.47	0.24	RGM 414 039
Carapace (Pl. 2, fig. 7)	0.52	0.31	RGM 414 040
Carapace	0.49	0.31	RGM 414 041

Remarks — *Pseudorayella* ? sp. A has the following characteristic features of *Pseudorayella*: the left valve is larger, the lateral outline is high anteriorly and low posteriorly and a dimunitive spine occurs near the posteroventral margin of the right valve. The specimens from Orphan Knoll resemble most closely *Pseudorayella antis* Neckaja, 1966 (p. 66; pl. 11, figs. 2, 3) in the lateral outline and in the position of the posteroventral spine, slightly admarginally on the right valve. In the type species, however, the posteroventral spine seems to be more closer to the free margin. Also similar to *Pseudorayella* ? sp. A is *Rectella thomasi* Schallreuter, 1972 from Middle Ordovician erratic boulders.

Pseudorayella ? sp. A also bears a resemblance to the Silurian-Devonian genus *Baschkirina* Rozhdestvenskaya, 1959 which is also tentatively reported from the Silurian of eastern Canada (Copeland, 1977, p. 45; 1978, pl. 2, fig. 7). As discussed by Adamczak (1976, p. 346), there are relationships between the genus *Pseudorayella* and representatives of *Baschkirina*.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Superfamily uncertain
Family Punctaparchitidae Swain, Cornell & Hansen, 1961

Macrocyproides Spivey, 1939

Type species — *Macrocyproides clermontensis* Spivey, 1939.
Range — Middle to Late Ordovician.

Macrocyproides ? sp. A
Pl. 3, fig. 1

v 1990 sp. 13, van Hinte & Ruffman, p. 9.
v 1995 *Macrocyproides* ? sp. A, Becker in van Hinte & Ruffman (in press), pl. 11, fig. 1.

Material — Three carapaces (one relatively complete, two rather damaged).
Measurements (in mm)

Specimen	Length	Height	no.
Carapace (Pl. 3, fig. 1)	0.73	0.47	RGM 414 042
Carapace	incomplete		RGM 414 041
Carapace	incomplete		RGM 414 041

Diagnostic features — Lateral outline subtriangular. Slight left over right valve overlap at the free margin and distinct left valve overreach at the posterior dorsal margin.

Remarks — The specimens are similar to *Macrocyproides* species (see Spivey, 1939, p. 174; pl. 21, figs. 38, 39; Kraft, 1962, p. 68; pl. 18, figs. 13, 14), which have the same lateral outline with the posterior end higher than the anterior end and a slight ventral concavity. However, in *Macrocyproides* ? sp. A the right valve seems to be the smaller one; hence the questionable assignment of the species from Orphan Knoll.

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Order uncertain
Family Aparchitidae Jones in Chapman, 1901

Baltonotella Sarv, 1959

Type species — *Baltonotella kuckersiana* (Bonnema, 1909).
Range — Middle Ordovician to Late Silurian.

Baltonotella ? sp. A
Pl. 3, figs. 5-6

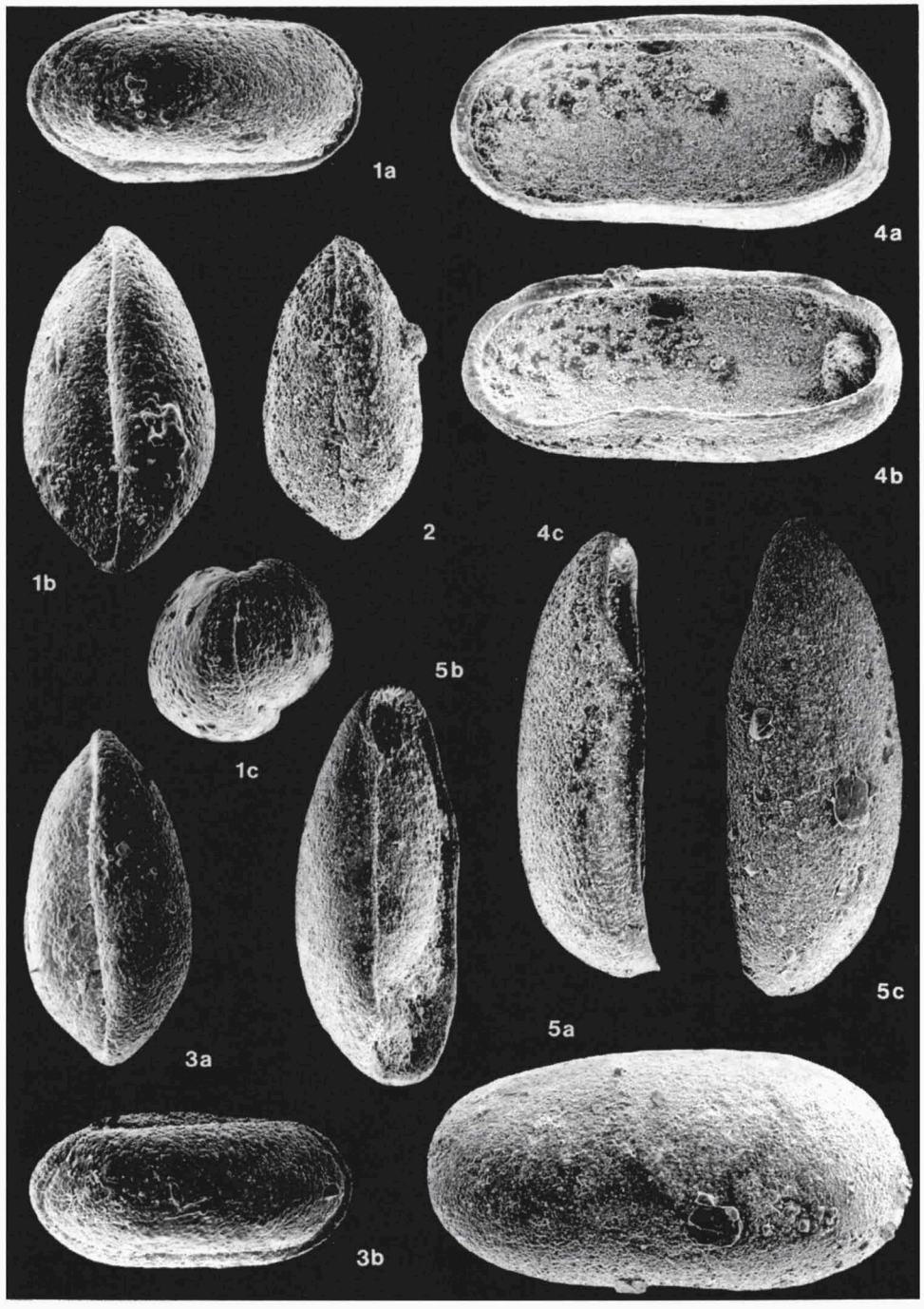
v 1990 sp. 17, van Hinte & Ruffman, p. 9.
v 1995 *Baltonotella* ? sp. A, Becker in van Hinte & Ruffman (in press), pl. 11, figs. 10, 11.

Plate 4

All specimens sample B3279.

Figs. 1-3. *Elliptocyprites* ? sp. A.
1. Carapace (RGM 414 022); 1a) right valve lateral view; 1b) ventral view; 1c) posterior view; × 82.
2. Carapace (RGM 414 023); dorsal view; × 82.
3. Carapace (RGM 414 024); 3a) ventral view; 3b) right valve lateral view; × 80.

Figs. 4-5. *Shenandoia* sp. A.
4. Right valve (RGM 414 025); 4a) internal lateral view; 4b) internal ventral oblique view; 4) dorsal oblique view; × 74.
5. Left valve (RGM 414 026); 5a) external lateral view; × 73; 5b) ventral view; × 69.


1a
4a
4b
2
4c
1b
5b
1c
5c
5a
3a
3b

Material — Two complete valves.
Measurements (in mm)

Specimen	Length	Height	no.
Single valve (Pl. 3, fig. 5)	0.51	0.35	RGM 414 043
Single valve (Pl. 3, fig. 6)	0.62	0.44	RGM 414 044

Remarks — Based on the simple valve morphology, straight hinge, amplete outline and lack of lobal or velar structures the specimens under consideration seem most similar to the Ordovician-Silurian genus *Baltonotella* Sarv, 1959. This genus originally described from the Ordovician of the Baltic also includes several North American species variously assigned to other genera (i.e. *Paraparchites ? circulantis* Harris, 1957 and *Aparchites parsispinosus* Kraft, 1962; see Williams, 1990, p. 84-89). *Baltonotella* ? sp. A appears similar to *'Aparchites'* sp., cf. *'A.' messleriformis instabilis* Polenova, 1974 of Copeland, 1977 (p. 35; pl. 12, figs. 23, 24) from the Upper Ordovician Road River Formation, southwestern District of Mackenzie, Canada. However, similar forms with simple architecture are also reported from the Silurian and the Devonian (*Aparchites* sp. Braun, 1969, pl. 9, fig. 64; *'Aparchites'* sp. 10 Feist & Groos-Uffenorde, 1979, p. 112, text-figs. 25, 26).

Occurrence — Middle-Late Ordovician; Orphan Knoll, Labrador Sea.

Ostracoda indet.

Undeterminable specimens are stored with nos. RGM 414 045-414 056 (sample B3279), RGM 414 060-414 061 (sample B3260) and RGM 414 062 (sample B3262); = Pl. 8 fig. 3, Pl. 9 fig. 2, Pl. 10 figs. 3, 4, 6, 7, 9 and Pl. 11 figs. 5-9 in van Hinte & Ruffman (in press).

Age of the ostracod fauna

The species herein described, since recovered from a single limestone pebble on Orphan Knoll, are considered to represent a single assemblage. All specimens are quite delicate, but are generally well preserved; the majority of specimens recovered are complete. Additionally both juvenile and adult specimens of the same species are present. This indicates that apparently no serious material transport and no post-depositional reworking of material has occurred.

Because both Ordovician (Legault, 1982) and Devonian ages (Ruffman & van Hinte, 1972 and Ruffman & van Hinte, 1973, p. 433; subsequently quoted in Laughton et al., 1972, p. 80, Parson et al., 1983, p. 62 and Grant, 1988a-b, p. 156) have been suggested for the basement bedrock on Orphan Knoll, an attempt was made to compare the ostracod fauna under consideration with both Ordovician and Devonian forms. With the exception of simple morphological types (see the remarks on *Elliptocyprites* ? sp. A, *Pseudorayrella* ? sp. A and *Baltonotella* ? sp. A), which are repeated throughout the Palaeozoic, no characteristic Devonian ostracods were found in the material from Orphan Knoll (cf. the rich Upper Devonian ostracod faunas of Northern Canada, described by Braun, 1969). Supplementary testimony is given by the

(above mentioned) initial statement of Sohn & Berdan (pers. comm.) that 'the assemblage does not contain any Devonian species known in either North America or Europe'.

Based on the co-occurrence of distinct species clearly referable to Ordovician genera (such as *Ordovizona, Anticostiella, Ectoprimitoides, Shenandoia* and the primitive *Aboilia*) and tentatively put to Ordovician genera (such as *Uthoernia, Macrocyproides* and *Bromidella* as well as the Early Palaeozoic *Baltonotella*), it is argued that the ostracod fauna from the single pebble that yielded the B3279 collection indicates a Middle to Late Ordovician age. The fact that (because of the isolated occurrence of the fauna and the often small number of specimens available) many of the species from Orphan Knoll had been left in open nomenclature does not reduce the stratigraphical significance of the ostracod fauna.

Palaeoecology

There are few studies concerning the palaeoecology of Ordovician ostracods (see Copeland, 1982, pp. 4-10; Warshauer & Berdan, 1982, p. 5-14) and no general model, such as described for the Silurian (Siveter, 1984) and (above all) for the later Palaeozoic (Becker, 1971, 1981b, 1982; Becker & Bless, 1990) has so far been published. Several authors (i.e. Walker & Laporte, 1970; Copeland, 1982; Berdan, 1984) have noted the relationship of Ordovician leperditicope dominated faunas to peritidal or very shallow marine environments. Such forms, however, are totally absent in the fauna from Orphan Knoll.

Roughly spoken, the fauna described herein compares to North American Ordovician open marine shelf (inner-middle neritic) ostracod faunas such as those described from the Bromide Formation of Oklahoma (Harris, 1957; Williams, 1990) or the Edinburg Formation of Virginia (Kraft, 1962). These widespread open-marine shelf faunas include characteristic taxa such as *Ectoprimitoides, Elliptocyprites* and *Bromidella*. Copeland (1982, p. 4-10) has further distinguished shallow-water and offshore shelf marine ostracod biofacies in the Ordovician Lower Esbataottine Formation of Northwest Canada. As for the deeper platform environment, 'this biofacies has a preponderance of small, ornate ostracod species and a marked seaward decline of palaeocopid species' (Copeland, 1982, p. 6). In the fauna described from Orphan Knoll, only comparatively small-sized specimens occur, apparently thin-shelled and mostly reticulate or spinous. Delicate forms with spinelets (see Pl. 3, figs 2, 6-7, 8-10) are characteristic of open-marine, low-energy environments (Thuringian ecotype, see Becker & Bless, 1990, p. 422).

The microfacies interpretation of sample B3279 (van Hinte & Ruffman, in press) gives evidence of a low-energy, carbonate shelf environment.

Palaeogeographical relationships

The ostracod species from Orphan Knoll include forms with both North American (i.e. *Ectoprimitoides, Anticostiella, Shenandoia)* and North European (i.e. *Ordovizona, Uthoernia, Pseudorayella*) affinities. Similar mixing of North European and North American ostracod faunas has previously been reported from Middle to Upper

Ordovician sequences in North America and Europe (Schallreuter & Siveter, 1985; Vannier et al., 1989).

The Orphan Knoll fauna provides additional evidence that the provinciality of ostracod faunas between North America and Northern Europe was breaking down during the latter part of the Ordovician. According to Maclean et al. (1977, p. 1938) a Palaeozoic basin has existed eastward of Baffin Island (Labrador Sea) subsequently broken apart by seafloor spreading.

Origin of the Ordovician ostracods from Orphan Knoll

Ruffman & van Hinte (1972, 1973; in Grant, 1988a-b), who have examined the original dredge material from Orphan Knoll in detail, have reported a Devonian assemblage of conodonts from limestones recovered in the same dredge as the ostracod material herein described. Although it is possible to move Ordovician material from Greenland and the east coast of Canada out to Orphan Knoll by drift ice or icebergs with the existing wind and marine currents, it is quite impossible to make the same arguments for the Devonian material; the nearest documented Devonian strata (in Arctic Canada) are almost impossible to move to Orphan Knoll by the above means. However, as discussed above, no elements evident of a Devonian ostracod fauna are present in the material studied.

Legault (1982) reported an Ordovician (Caradoc-Ashgill) age for palynomorphs recovered from possible bedrock on Orphan Knoll. Subsequent authors (Parson et al., 1983; Grant, 1988a-b; Ruffman, 1989b) criticised Legault's assumption that her material came from bedrock, suggesting instead that the material could have been derived from Canada by ice transport. Ruffman (1989b) has catalogued every rock from the Hudson 78-020 dredge hauls and found out that 'none of the rocks ... have fresh, broken faces ... and were, therefore, not directly broken from outcrops during dredging'. They demanded that 'each of the limestones in the 78-020-001 dredge haul must be examinated as to both lithology and age'.

Fossiliferous rocks of comparable Ordovician age have been described from the southeastern shelf of Baffin Island (Maclean et al., 1977, pp. 1935-1937) and, as suggested by Parson et al. (1984, p. 64), material from this area could have been carried south to Orphan Knoll by the Labrador Current. Likewise, Ordovician material from southwest Greenland referred to in Ruffman (1989b) could also be an additional source of material. This could represent a source for the ostracod material described herein. However, this fauna does not contain any species known in either North America or Europe. 'The latter suggests that the pebbles are not due to Pleistocene ice-rafting' (Sohn & Berdan, pers. comm., see above).

Interestingly in this connection, Maclean et al. (1977) have discussed the possibility that Ordovician strata may extend seaward in Baffin Bay. Although much further to the south, Orphan Knoll, which is situated at the continent-ocean transition zone, may have had a similar origin.

As for the co-occurrence of Devonian conodonts and Ordovician ostracods in the materials from Orphan Knoll, we clearly are dealing with a mixed series of samples, perhaps swept together by slumping from different nearby mounds that mark the northeast of the upper surface of Orphan Knoll.

In summary, it is believed that the Ordovician ostracod fauna described herein could have been derived from bedrock on Orphan Knoll. The clearly endemic character at the species level supports strongly this hypothesis.

Acknowledgments

Kindest thanks are expressed to Alan Ruffman (Halifax/Nova Scottia) who, while at the Atlantic Geoscience Centre of the Bedford Institute of Oceanography, gathered the 1971 dredge samples on board the U.S.N.S. Lynch, cruise 7/11/71 (Ruffman, 1989a). We are also indepted to him for his critical reading of the manuscript and the correction of the English text. Many thanks also to Professor Jan E. van Hinte (Amsterdam) who discovered, prepared and sorted the original ostracod material, to Dr Martin J.M. Bless (Heerlen) who introduced the present author to the Orphan Knoll ostracod fauna. Mr Mark Williams (Leicester), who (in just finishing a thesis on Ordovician ostracods) had received a research fellowship from the Alexander von Humboldt Society and also manyfold logistic supports from the Johann Wolfgang Goethe University and the Senckenberg Museum (for the purpose of studies on Middle Devonian Ostracoda), has determined the ornamented palaeocopines; he also made a rough draft for parts of the English text. The smooth podocopines have been proved to be the most interesting forms, however, they are difficult to decifer because the smooth ostracods have been generally neglected by Ordovician workers. These ostracods, especially the pachydomellids, have been intensively discussed with my friend Dr Frans J. Adamczak (Stockholm).

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