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BULLETIN 300

CONTRIBUTIONS TO CANADIAN PALEONTOLOGY
(FOUR PAPERS)

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JOHN W. COWIE
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PREFACE

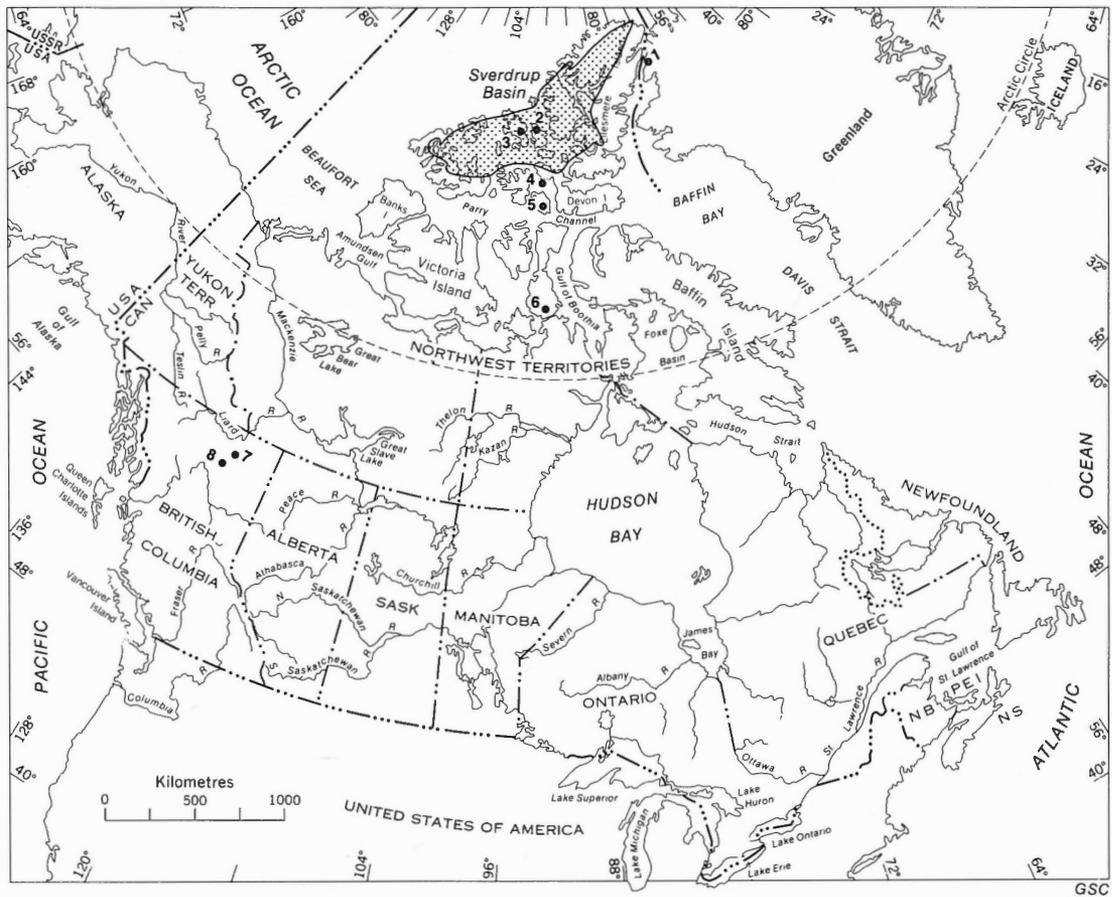
This bulletin comprises four short papers on paleontological topics which for convenience are grouped together as part of the Geological Survey's *Contributions to Canadian Paleontology*. Such detailed studies provide the groundwork for the biostratigraphic zonations that are fundamental for accurate stratigraphic interpretation of the sedimentary basins of Canada and thus provide information that is essential to the preparation of up-to-date assessments of Canada's oil, natural gas and coal resources.

Ottawa, November 1978

D.J. McLaren
Director General
Geological Survey of Canada

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Textfigure 1. Locality map for all papers.

1. Washington Land, northwestern Greenland (Palmer, Cowie and Eby).
 2. Christopher Formation northwest of Stratigrapher River, Amund Ringnes Island, District of Franklin (Sliter).
 3. Christopher Formation, Helicopter Dome, Ellef Ringnes Island, District of Franklin (Sliter).
 4. Baillie-Hamilton Island, District of Franklin (Ormiston).
 5. Panarctic-Deminex Cornwallis Central Dome K-40 well, District of Franklin (Palmer, Cowie and Eby).
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 8. Region southwest of Mount Lloyd George, Ware map area, British Columbia (Perry, Boucot and Gabrielse).
- Shaded area represents the Sverdrup Basin.

CONTRIBUTIONS TO CANADIAN PALEONTOLOGY

A LATE CAMBRIAN (DRESBACHIAN, *CREPICEPHALUS* ZONE) FAUNA FROM THE BOOTHIA PENINSULA, DISTRICT OF FRANKLIN

Allison R. Palmer, John W. Cowie and Robert G. Eby

Abstract

Trilobites from the lower 45 m of the Boothia Felix Formation in the central part of the Boothia Peninsula represent a fauna of the *Crepicephalus* Zone of medial Dresbachian (Late Cambrian) age. This is the first description of Late Cambrian trilobites from the Arctic Islands. The fauna includes: *Crepicephalus* sp., *Terranovella dorsalis* (Hall), *Densonella intermedia* n. sp. and *Hyolithes* sp.

Résumé

Les trilobites provenant d'une couche de 45 m d'épaisseur, à la partie inférieure de la formation de Boothia Felix au centre de la péninsule de Boothia, représentent une faune de la zone à *Crepicephalus* dont l'âge se situe au milieu du Dresbachien (Cambrien supérieur). Il s'agit de la première description de trilobites d'âge cambrien supérieur, provenant de l'archipel Arctique. Cette faune comprend: l'espèce *Crepicephalus*, *Terranovella dorsalis* (Hall), la nouvelle espèce *Densonella intermedia*, et l'espèce *Hyolithes*.

INTRODUCTION

This paper records a fauna of Dresbachian age from the central Boothia Peninsula (Textfig. 1, loc. 6; Textfig. 2). It presents the first description of Late Cambrian trilobites from the Arctic Islands, although a tentatively identified Dresbachian fauna recently has been reported from the subsurface of Cornwallis Island (Cornwallis Central Dome K-40 well, Textfig. 1, loc. 5; Fritz, 1975, p. 18) and Dresbachian to Trempealeauian faunas have been noted from outcrops in Washington Land, northwestern Greenland (Textfig. 1, loc. 1; Dawes, 1976, p. 268).

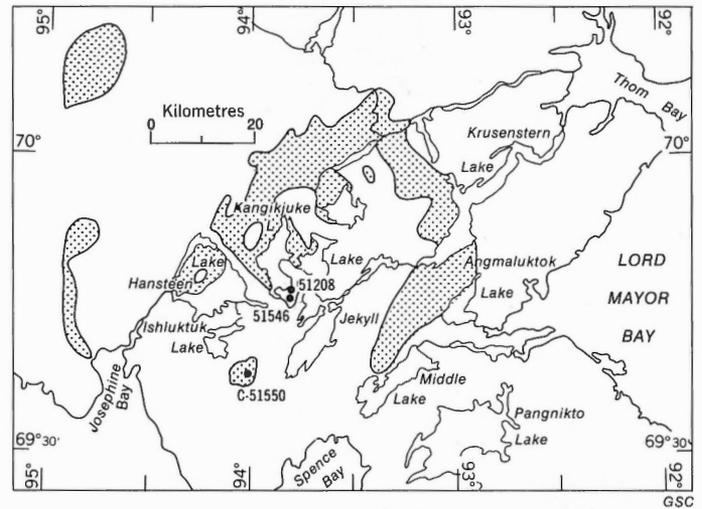
The fossils described here were reported first by Blackadar and Christie (1963) and questionably assigned to Middle Cambrian genera. Additional material, also questionably identified as Middle Cambrian, was reported by Christie (1973). The fauna consists predominantly of fragmentary trilobites and hyolithids moderately well preserved in dolomitic sandstones from the Boothia Felix Formation, a unit of brown-weathering, predominantly dolomitic sandstone, about 100 to 150 m thick, which apparently lies unconformably on Precambrian crystalline basement (Textfig. 3) although the basal contact is not seen in the type section. The formation is overlain by grey and greenish-grey, sandy and shaly dolomites of the Ordovician Netsilik Formation (Christie, 1973). The fossils, from the type section between Kangikjuke and Jekyll lakes, and from an outlier about 16 km to the southwest (Textfig. 2), are all from the lower 45 m of the formation.

During the summer of 1974, the localities in the type section of the Boothia Felix Formation were recollected by Cowie. These collections were examined by Palmer during a visit with Cowie at the University of Bristol in 1974, and the probable Late Cambrian age of the trilobites was recognized. This material, along with the earlier collections from the Geological Survey of Canada, subsequently was borrowed by Palmer. Preparations, photography and preliminary descriptions were made by Eby under Palmer's supervision.

The change in age assignment of the trilobites from the Boothia Peninsula reduces the magnitude of any possible hiatus between the Boothia Felix and Netsilik formations.

Consequently, evidence for a pre-Ordovician positive area such as suggested by Christie (1973, p. 13) is considerably weakened.

Three localities in the Boothia Felix Formation have yielded fossils (Textfig. 2, locs. 51208, 51546, 51550). Two different fossiliferous horizons are represented in the type section (Christie, 1973, p. 11, 12): GSC locality 51546 is from about 20 m above the base of the formation, whereas locality 51208 is about 20 m higher. Locality 51550, about 16 km southeast of the type section, is estimated to be about 15 m above the base of the formation.



Textfigure 2. Map of a part of Boothia Peninsula, District of Franklin, adapted from Blackadar and Christie (1963), showing outcrops of the Boothia Felix Formation (stippled) and the occurrences of Late Cambrian fossils (GSC locs. 51208, 51546 and 51550).

Allison R. Palmer, Geological Society of America,
P.O. Box 9140, Boulder, Colorado, U.S.A. 80301

Robert G. Eby, Department of Earth and Space Sciences,
State University of New York, Stony Brook, New York, U.S.A. 11794

John W. Cowie, Department of Geology,
University of Bristol, Bristol, England BS8 1TR

All of the collections have the same principal trilobites and lithology. The fossiliferous rocks are dolomitic sandstones, composed predominantly of moderately well sorted, well rounded, medium size quartz grains cemented by carbonate. A few ooids are present, and almost all fossil fragments have oolite coatings. Although the original carbonate was calcite, all of this has been replaced by dolomite without destruction of either the oolite coatings or the fossil fragments.

The environment of deposition for the fossiliferous beds was probably subtidal, well agitated and nearshore, judging from the oolitic coatings, the fragmentary nature of most of the trilobite parts, and the abundance, size, rounding and sorting of the quartz grains. Most of the quartz grains show sharp extinction under crossed Nicols and probably were derived from an initially granitic rather than metamorphic terrane. Absence of feldspar clasts suggest either a source in a zone of strong chemical weathering or derivation of the quartz grains from an older sandstone.

The fossils were prepared by first heating the rocks on a laboratory hot plate and then plunging them into cold water. This loosened the matrix with fracturing around the fossil fragments and allowed greatly improved recovery of identifiable specimens. Further preparation was done by conventional mechanical methods.

In each of the collections, the dominant fossil is a small trilobite, *Terranovella dorsalis* (Hall); the problematical fossil *Hyolithes* is second in abundance. Fragments of a larger trilobite, *Crepicephalus* sp., are present in the samples from GSC localities 51208 and 51550. In addition, a thin section of a sample from locality 51550 has oolite-coated rounded grains of echinodermal origin; locality 51546 yielded two indeterminate fragments of a moderately large coiled gastropod; and locality 51208, the stratigraphically highest locality, yielded rare specimens of the new trilobite species *Densonella intermedia*. An undetermined pygidium from locality 51208 indicates the presence of a rare fourth trilobite species. The three identified trilobites are typical elements of the cratonic faunas of the endemic North American *Crepicephalus* Zone of medial Dresbachian age, and are unequivocal proof of a Late Cambrian age for the lower part of the Boothia Felix Formation. The overall affinities of the faunas from the formation are closest to faunas high in the *Crepicephalus* Zone in Wisconsin.

SYSTEMATIC PALEONTOLOGY

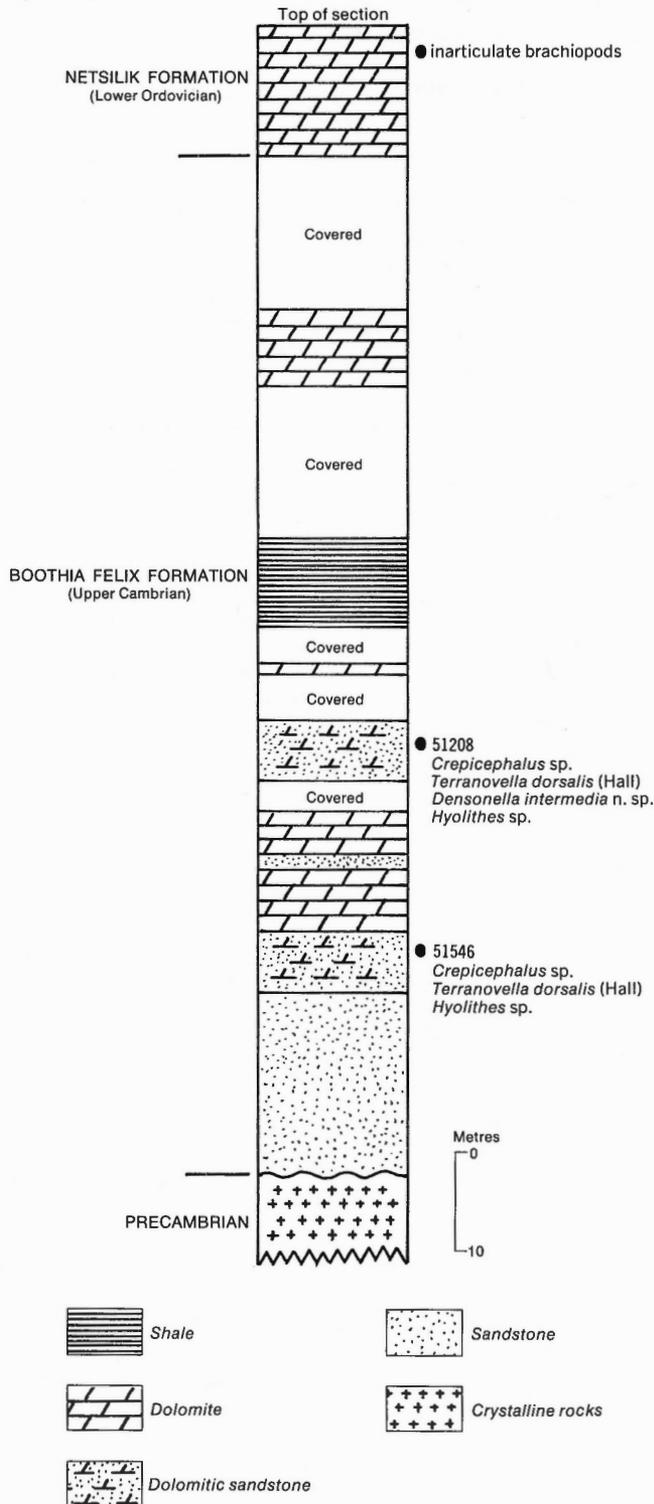
Prefix GSC refers to specimens in the type area collection of the Geological Survey of Canada, Ottawa.

- Phylum Arthropoda Siebold and Stannius 1845
- Class Trilobita Walch 1771
- Family Crepicephalidae Kobayashi 1935
- Genus *Crepicephalus* Owen 1852
- Crepicephalus* sp.

Plate 1, figures 1 - 7

Material. Figured specimens GSC 53000 and 53003 from GSC locality 51550 and five other cranidia, eight free cheeks (including GSC 53001 from GSC loc. 51208), thirteen pygidia (including GSC 53002 from GSC loc. 51550), two hypostomes (including GSC 53004 from GSC loc. 51550); all fragmentary with only three cranidia, two pygidia, a free cheek and a hypostome being of adequate quality for evaluation. The material is about equally divided between GSC localities 51208 and 51550. The pygidia in the two collections are indistinguishable; cranidial differences are minor and can be attributed to effects of preservation. Thus, although the material is inadequate for species identification, it is discussed below as if it represents a single species. Indeterminate fragments of a relatively large trilobite, perhaps this species are present at GSC locality 51546.

Description. The cranidium is characterized by a low glabella, with a slightly sigmoidal lateral outline and a strongly rounded front, that is well defined by a narrow continuous furrow of nearly uniform depth. Glabellar furrows are not developed. The occipital furrow is straight and comparable in depth to the furrow outlining the glabella.



Textfigure 3. Columnar section compiled from Christie (1973) showing the stratigraphic occurrences of Late Cambrian fossils in the type section of the Boothia Felix Formation.

The frontal area is short, its sagittal length is slightly less than half the sagittal length of the glabella exclusive of the occipital ring, and it is subequally divided into a brim and border by a gently curved, moderately broad and deep anterior border furrow. The border is of uniform width and is moderately convex. The brim shows weak longitudinal venation. The palpebral lobes are gently curved and weakly defined on the external surface of the exoskeleton; their length is about one half the sagittal length of the glabella exclusive of the occipital ring. The posterior limbs are slightly longer than the basal glabellar width; the posterior border furrow is moderately deep and curves slightly forward distally before intersecting the posterior section of the facial suture. The anterior sections of the facial sutures are moderately divergent anteriorly; the posterior sections are gently curved and subparallel to the posterior cranial margin in their proximal parts; distally, the sutures curve strongly backward. External ornament among the several fragmentary specimens varies from smooth to finely shagreened.

The free cheek is characterized by a border furrow of moderate and uniform depth that intersects the posterior section of the facial suture at about the genal angle. The border is moderately convex and expands slightly backward. The genal spine is moderately long, slender and tapered to a sharp point; its length is greater than the length of the posterior section of the facial suture. Ornamentation is comparable to the associated cranidia.

The pygidium is characterized by a well defined, posteriorly tapered, bluntly terminated axis bearing three straight, shallow ring furrows posterior to the articulating furrow. The triangular pleural regions are crossed by four straight shallow pleural furrows that do not extend onto the border. The border is narrow behind the axis and rapidly broadens distally; the posterolateral parts of the border are extended into long, slender, posterolaterally directed spines. Ornamentation is comparable to the associated cranidia.

The hypostome is hourglass shaped, with an elongate ovate anterior body and a posterior body that forms a crude transverse crescent wrapped around the posterior end of the anterior body and separated from it by a broad moderately deep furrow. The posterior margin is nearly straight, and both a well defined, flat, laterally flared posterior border and a narrow, convex lateral border bear strongly developed terrace lines.

Discussion. The glabellar outline, cranial border structure, pygidial border structure and border spines, and structure of the axis and pleural regions conform completely to the characteristics of the genus *Crevicephalus*.

The shape of the anterior end of the glabella and the curvature of the anterior border furrow on the cranidium combined with the number of axial and pleural furrows, the length and orientation of the border spines, and the breadth of the border behind the axis on the pygidium are the most distinctive features of significance for species level comparison. No described species has the combined characteristics of the specimens. The material is similar to an unnamed species described in an unpublished manuscript, prepared by G.O. Raasch in the late 1940's, dealing with Dresbachian trilobites from comparable nearshore sandy environments of the midcontinent platform region of Wisconsin. Formal naming of this species should await more and better material from the Arctic region and a needed revision of the scattered and incompletely known species of *Crevicephalus* already named.

Family Norwoodiidae Walcott 1916
Genus *Densonella* Shaw 1952
Densonella intermedia n. sp.

Plate 1, figures 9, 11, 12, 14, 15; Plate 2, figures 8, 9

Material. Paratypes GSC 53009 and 53010, and two other cephalons, four cranidia (including holotype GSC 53008 that is slightly abraded and with an incomplete tip to the posterior limb), two free cheeks (including paratype GSC 53011), all from GSC locality 51208. Other parts not known.

Description. Cephalon transversely ellipsoidal in dorsal aspect, strongly arched transversely, genal angles rounded. Cranial form resembles an inverted 'T' with a short stem and a broad crosspiece that is curved downward distally so that the tips are directed nearly vertically. Glabella triangular in dorsal aspect, well defined by broad, deep furrows, sharply pointed anteriorly; crest slopes evenly downward in lateral profile. Two pairs of indentations adjacent to the axial furrows mark the posterior two pairs of glabellar furrows. Occipital furrow deep, narrow, straight. Occipital ring simple, short (in sagittal plane), moderately convex, maintains uniform length. Frontal area consists of depressed central triangular brim and narrow border that is straight transversely, convex in the sagittal plane, and strongly arched upward in front view. Fixed cheeks very narrow, strongly upsloping, topped by nearly straight, upsloping palpebral lobes that are moderately defined by shallow palpebral furrows. Line between midlengths of palpebral lobes passes across anterior end of glabella. Posterior limbs broad, barely tapered distally; tips bluntly rounded. Posterior border furrow very deep adaxially, dies out near sutural margin. Course of anterior section of facial suture nearly straight forward. Course of posterior section nearly straight laterally behind palpebral lobe, then curved evenly backward distally to intersect posterior margin at a high angle. External surface lacks obvious ornamentation.

Free cheek simple. Anterior and posterior margins subparallel, and roughly perpendicular to sagittal plane; lateral margin broadly rounded anterolaterally, nearly a right angle at junction with facial suture. Border narrow, poorly defined except near anterior sutural margin. Narrow eye socle present. External surface lacks distinct ornamentation.

Discussion. This species, as its name implies, is intermediate in several characters between the genera *Densonella* and *Menomonia*. Its lack of distinct ornamentation and the presence of unstalked eyes are characteristics of *Menomonia*. The strongly triangular glabella and frontal area, and the narrow, transversely arched border are not distinguishable from those of most species of *Densonella*. The failure of the free cheeks to separate easily from the cranidium is another feature more characteristic of *Densonella* than of *Menomonia*. For these reasons, the species is assigned here to *Densonella*. *Densonella* is found only in the *Crevicephalus* Zone and perhaps in the upper part of the underlying *Cedaria* Zone in nearshore to deep shelf environments of North America.

Densonella intermedia n. sp. differs from other species currently assigned to the genus by lacking stalked eyes and evidence of coarse granular ornamentation. The structure of the fixed cheeks is the single most distinctive character of the species.

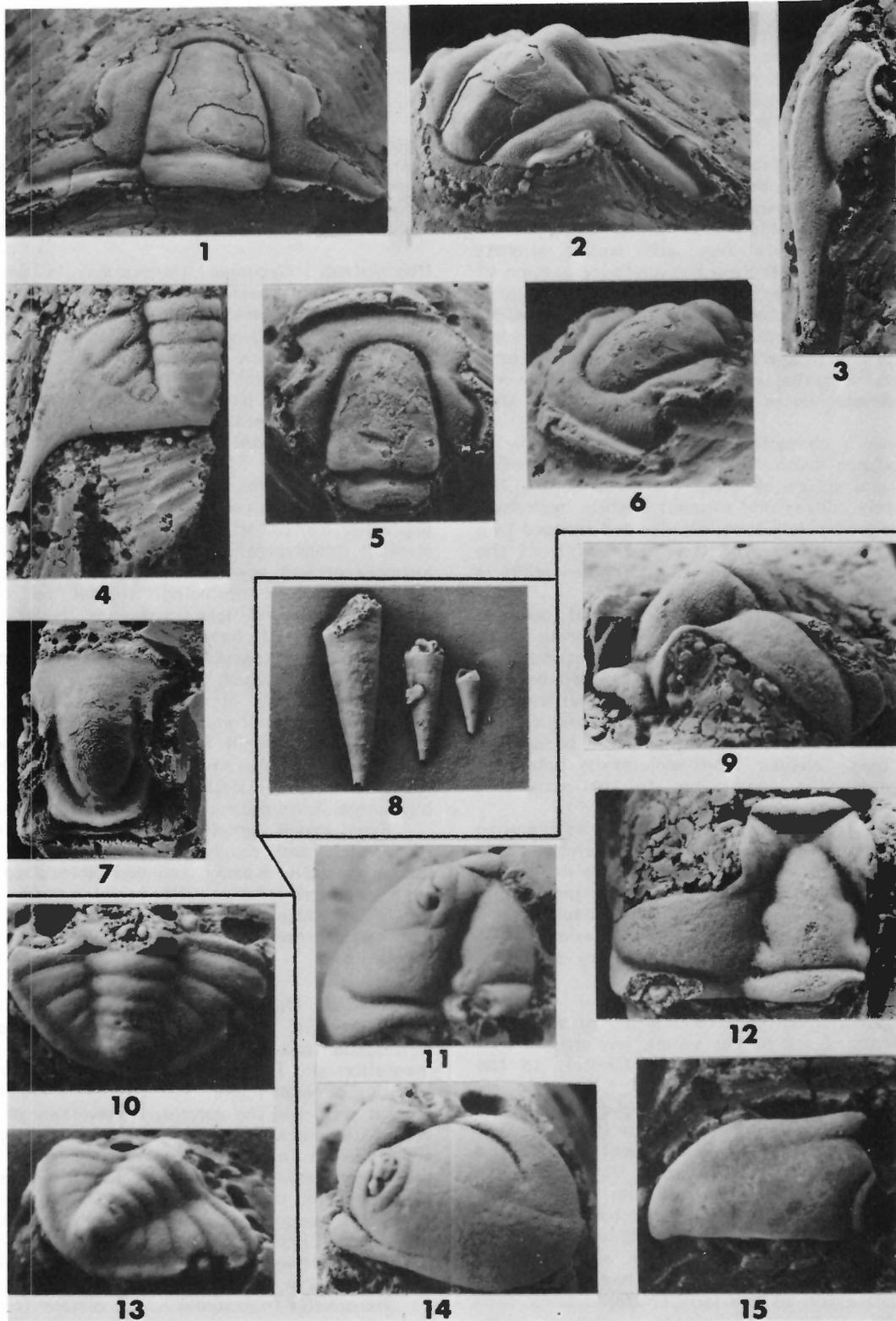


Plate 1

Crepicephalus sp. (page 2)
 Figures 1, 2. Incomplete cranidium GSC 53000;
 GSC loc. 51550; X3.
 Figure 3. Free cheek GSC 53001; GSC loc. 51208; X6.
 Figure 4. Pygidium GSC 53002; GSC loc. 51550; X4.
 Figures 5, 6. Incomplete cranidium GSC 53003;
 GSC loc. 51550, X6.
 Figure 7. Hypostome GSC 53004; GSC loc. 51550; X5.

Hylolithes sp. (page 6)
 Figure 8. Three shells, GSC 53005 - 53007;
 GSC loc. 51208; X3.

Densonella intermedia n. sp. (page 3)
 (see also Pl. 2, figs. 8, 9)
 Figures 9, 12. Holotype cranidium GSC 53008;
 GSC loc. 51208; X6.
 Figures 11, 14. Incomplete paratype cephalon GSC 53009
 from same locality; X15.
 Figure 15. Paratype free cheek GSC 53011 from same
 locality; X12.

Undetermined pygidium (page 6)
 Figures 10, 13. Dorsal and oblique views, GSC 53012;
 GSC loc. 51208; X12.

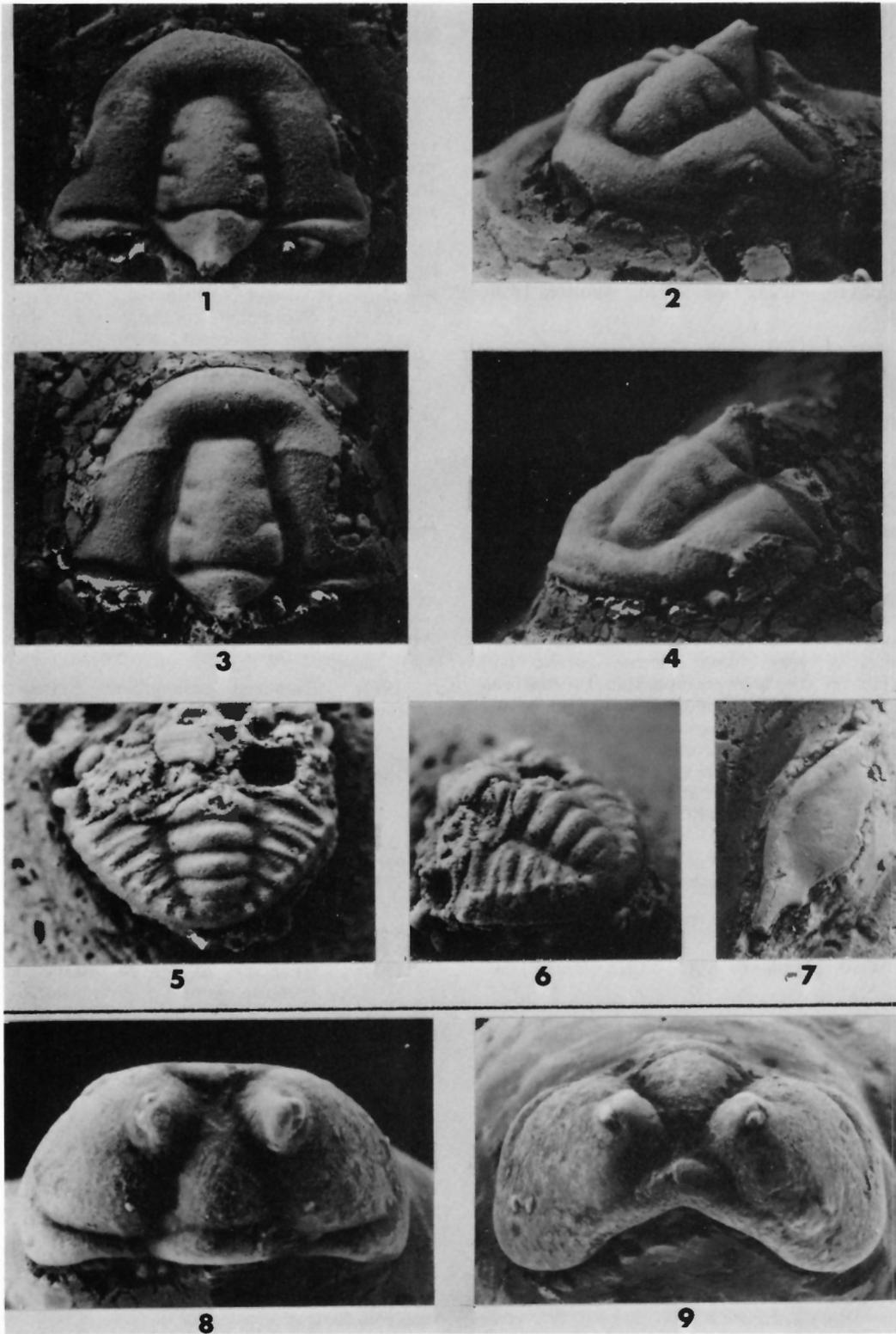


Plate 2

<i>Terranovella dorsalis</i> (Hall)	(page 6)	<i>Densonella intermedia</i> n. sp.	(page 3)
Figures 1, 2. Cranidium GSC 53013; GSC loc. 51208; X12.		(see also Pl. 1, figs. 9, 11, 12, 14, 15)	
Figures 3, 4. Cranidium GSC 53014 from same locality; X10.		Figures 8, 9. Paratype cephalon GSC 53010;	
Figures 5, 6. Pygidium GSC 53015 from same locality; X15.		GSC loc. 51028; X8.	
Figure 7. Free cheek GSC 53016 from same locality; X12.			

Family Lonchocephalidae Hupé 1953
Genus *Terranovella* Lochman 1938
Terranovella dorsalis (Hall, 1863)

Plate 2, figures 1 - 7

- Conocephalites?* (*Arionellus?*) *dorsalis* Hall, 1863, p. 222.
Lonchocephalus sospita Walcott, 1916, p. 195, Pl. 36, figs. 1, 1a.
Terranovella buttsi Resser, 1938, p. 100, Pl. 15, figs. 22 - 26.
Terranovella dorsalis (Hall), Raasch and Lochman, 1943, p. 234, Pl. 35, figs. 3-10, 17; Nelson, 1951, p. 773, Pl. 106, fig. 9; Robison, 1960, p. 17, Pl. 1, fig. 10; Rasetti, 1961, p. 118, Pl. 22, figs. 7-13; Rasetti, 1965, p. 40, Pl. 6, fig. 7.

Material studied. Fifty cranidia, fourteen pygidia, two free cheeks from all three localities; figured specimens — cranidia GSC 53013 and 53014, free cheek GSC 53016 and pygidium GSC 53015, all from GSC locality 51208.

Discussion. This species has been well described by Raasch and Lochman (1943) and the synonymy of *L. sospita* Walcott and *T. buttsi* Resser has been explained by Rasetti (1961). The material from the Boothia Peninsula provides no significant new morphologic information, and the specimens agree in all observable characters with *T. dorsalis* (Hall), based on neotype material described by Raasch and Lochman (1943) from the nearshore sandy facies in Wisconsin. The preservation of the external surface is better on the Arctic material and shows a very faint narrow border and longitudinal veination on the brim comparable to features illustrated by Rasetti (1965) for specimens of this widespread species in Tennessee. In Wisconsin, as in the Arctic, this species is associated with species of *Densonella* and *Crepicephalus*. It is a characteristic trilobite of the *Crepicephalus* Zone at many localities in the United States, but it is only common in the nearshore sandy facies.

Undetermined pygidium

Plate 1, figures 10, 13

Material studied. One pygidium GSC 53012 from GSC locality 51208.

Discussion. The single small pygidium is characterized by a long, slender axis that reaches to a narrow border, which maintains constant width around the pygidial margin. The pleural regions are nearly flat and both axis and pleural regions have shallow, narrow axial and pleural furrows. The generic affinities of this specimen are not clear, but perhaps it is related to the Lonchocephalidae.

Phylum Hyolitha Runnegar and others 1975
Class Hyolitha Yochelson and Marek 1964
Genus *Hyolithes* Eichwald 1840
Hyolithes sp.

Plate 1, figure 8

Figured specimens. Three shells GSC 53005 - 53007 from GSC locality 51208.

Discussion. Moderately common, conical shells with a subtriangular cross-section represent a species of this widespread genus. Until a revision of this genus is undertaken, any attempt to relate the Arctic material to the vast number of 'species' currently named would be fruitless. The material is not sufficiently well preserved to contribute any new knowledge about shell morphology. *Hyolithes* is a common component of Cambrian platform and inner shelf faunas and has no definitive value for age identification within the Cambrian.

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NEW SPECIES OF *WARBURGELLA* FROM THE SILURIAN (PRIDOLIAN) AND DEVONIAN (LOCHKOVIAN) OF THE DISTRICT OF FRANKLIN AND THE DEFINITION OF THE *WARBURGELLA RUGULOSA* ZONE

Allen R. Ormiston

Abstract

Pridolian strata of the Cape Phillips Formation, Marshall Peninsula, Cornwallis Island are the source of *Warburgella arcuaria* n. sp. in association with *Hemiarges bigener* Bolton. Pridolian species of *Warburgella* have been documented previously from the Soviet Union but not from North America.

On nearby Baillie-Hamilton Island, *Warburgella rugulosa canadensis* Ormiston ranges through 293 m of strata of Lochkovian age. Early and late morphotypes of *canadensis* can be distinguished in the Baillie-Hamilton sequence, indicating the existence of a chronocline within successive populations of this important trilobite. This chronocline may permit at least local subdivision of the *Warburgella rugulosa* Zone.

The recognition of *Warburgella diadochos* n. sp., here interpreted to be a descendant of *rugulosa*, stratigraphically above *rugulosa* on Baillie-Hamilton Island, provides for the first time a paleontologically defined upper limit for the *Warburgella rugulosa* Zone.

Résumé

Dans les strates du Pridolien, qui appartiennent à la formation de Cape Phillips, dans la péninsule Marshall de l'île Cornwallis, on a découvert une nouvelle espèce *Warburgella arcuaria*, associée à *Hemiarges bigener* Bolton. L'espèce *Warburgella* d'âge pridolien a déjà été signalée en Union Soviétique, mais pas en Amérique du Nord.

Sur l'île Baillie-Hamilton, *Warburgella rugulosa canadensis* Ormiston est présente dans 293 m de strates d'âge lochkovien. Dans la succession de Baillie-Hamilton, on peut distinguer des morphotypes anciens et plus récents de l'espèce *canadensis*, ce qui indique l'existence d'une chronocline, dans les populations successive de cet important trilobite. Ce chronocline permet au moins localement de subdiviser la zone à *Warburgella rugulosa*.

L'identification d'une nouvelle espèce *Warburgella diadochos*, décrite ici comme un descendant de *rugulosa*, et située au-dessus de *rugulosa* dans la stratigraphie de l'île Baillie-Hamilton, nous fournit pour la première fois une limite supérieure, définie par la paléontologie, de la zone à *Warburgella rugulosa*.

INTRODUCTION

Since the original description of *Warburgella rugulosa canadensis* Ormiston (1967) based on material from the Lower Devonian sequence on Baillie-Hamilton Island, careful sampling by officers of the Geological Survey of Canada has produced several new, stratigraphically important *Warburgella* collections from that sequence (Textfig. 1, loc. 4; Textfig. 4). The importance of *Warburgella* to international correlations of Silurian-Devonian boundary strata (Ormiston, 1977) warrants the description and location of these new taxa.

To improve the already considerable biostratigraphic value of *Warburgella rugulosa*, it would be desirable to identify within one area its evolutionary antecedents and descendants. This would allow a rigorous definition of the *Warburgella rugulosa* Zone. Although antecedent species have been claimed from the Pridolian of the Soviet Union (Yolkin, 1974b); there is not general agreement on the phylogeny proposed by Yolkin. Morphologically comparable Pridolian species have not been recognized in the District of Franklin. A Canadian Pridolian *Warburgella* described in this paper (*W. arcuaria* n. sp.) shows, instead, structural similarities to *Warburgella althi* Yolkin (1974b) from Lochkovian strata of Podolia and Bohemia.

The lack of an appropriate antecedent species means that there is no biologically defined base for the *W. rugulosa* Zone in the District of Franklin, but it is suggested that a top for that zone is defined by the presence of *Warburgella diadochos* n. sp., here interpreted as a descendant of *W. rugulosa*, above *Warburgella rugulosa* (late form) in the same section. The appearance of *W. diadochos* in this section (Surprise Point, Textfig. 4) provides an upward limit for the considerable stratigraphic range (293 m on Baillie-Hamilton Island) of *Warburgella rugulosa*. Besides stratigraphic position, this interpretation is based on details of ontogeny, intraspecific variability, shared characters and mosaic development of the two taxa. Associated conodonts suggest assignment of the *W. diadochos* horizons to the upper part of the *Icriodus woschmidti* Zone, thus confirming the popular assumption of confinement of the subjacent *W. rugulosa* Zone to a position within the zone of *I. woschmidti*.

Vital collections upon which this paper was based were made from three thick sections on Baillie-Hamilton Island: one near Washington Point (UTM Zone 15, 464300E; 8408400N) collected carefully over several seasons by R. Thorsteinsson; another 4 km north of the former (UTM Zone 15X; 462650E; 8414700N) collected by Smith (1976); and the last at Surprise Point on the northeast corner of the island (Thorsteinsson and Kerr, 1968, Map 25-67), latitude 75°57'N, longitude 95°30'W, collected by Smith (1976).

Acknowledgments

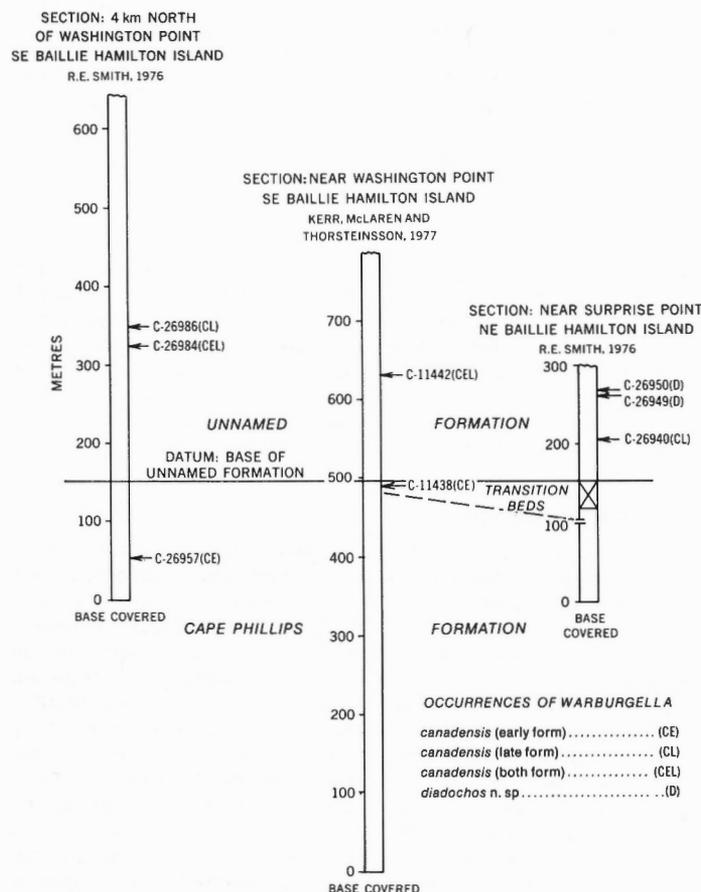
The author would like to thank R. Thorsteinsson of the Geological Survey of Canada for making available many valuable collections of *Warburgella* and for his constant interest and encouragement. R.E. Smith kindly provided collections and data from Surprise Point and from 4 km north of Washington Point, assembled while working for the Geological Survey of Canada. T.T. Uyeno, also of the Geological Survey of Canada, provided conodont determinations and biostratigraphic interpretations.

BIOSTRATIGRAPHY

There is a close, but not necessarily coincident, association of *Warburgella rugulosa* with *Monograptus uniformis* and *Icriodus woschmidti* at all of their known common occurrences (Ormiston, 1977, p. 320). It is notable, however, that in both Bohemia (Chlupač, 1972, p. 113) and Nevada (Klapper and Murphy, 1975, p. 6) *Warburgella rugulosa* appears slightly above the first occurrence of *I. woschmidti*. Where zonally diagnostic conodonts are recovered, the entry of *Warburgella rugulosa* seems everywhere to be within and near the base of the *Icriodus woschmidti* Zone. Stratigraphically lower (e.g., GSC loc. C-11438) occurrences of *Warburgella rugulosa canadensis* in the Baillie-Hamilton sequence (Textfig. 4) have not produced zonally diagnostic conodonts, but *I. woschmidti* and *Warburgella rugulosa canadensis* occur jointly in GSC locality C-11442. *Icriodus* is present also at the type horizon of *canadensis* which is situated just inland from the coastal exposures at Washington Point (Ormiston, 1967, p. 62); but the specimens are

too small for reliable species assignment (G. Klapper, pers. comm.) I am not aware of any occurrences of *Warburgella rugulosa* in association with conodonts assignable to zones other than the *I. woschmidti* Zone. As reported by Kerr et al. (1977, p. 285), a sample from low in the unnamed formation at the section 4km north of Washington Point (Textfig. 4) has *Warburgella rugulosa canadensis* in association with *Monograptus* cf. *M. uniformis*.

Support for the confinement of the upper part of the range of *Warburgella rugulosa* to the *woschmidti* Zone (and its equivalents) comes from the Baillie-Hamilton Island sections. Sample C-11442 contains *Icriodus woschmidti hesperius* Klapper and Murphy identified by T.T. Uyeno in association with early and late forms of *W. rugulosa canadensis* (Textfig. 4). Sample C-26950, which bears *Warburgella diadochos* n. sp. (Textfig. 4), contains the following conodonts identified by T.T. Uyeno: *Ozarkodina* n. sp. E Klapper and Murphy, *Ozarkodina* n. sp. F Klapper and Murphy, and *O. remscheidensis*. This association indicates (Klapper, 1977, Fig. 3), correlation with either the upper *hesperius* Zone (Klapper, 1977) or with the superjacent *eurekaensis* Zone. It can be concluded that the *Warburgella rugulosa* Zone becomes no younger than the *Icriodus woschmidti hesperius* Zone on Baillie-Hamilton Island, and that the overlying *diadochos* Zone is either still within the upper part of the *hesperius* Zone or belongs to the *eurekaensis* Zone. This is reassuring in that the great stratigraphic thickness (293m) spanned by *Warburgella rugulosa canadensis* inevitably raises doubts as to how young that taxon might actually range. In a practical sense, it permits the operational equating of the *rugulosa* and *hesperius* zones, while recognizing that the *hesperius* Zone ranges slightly lower.



Textfigure 4. Schematic representation of positions of *Warburgella* collections in three stratigraphic sections on Baillie-Hamilton Island, District of Franklin.

Speciation in *Warburgella*

Eldredge (1971) and Eldredge and Gould (1972) have championed the concept of allopatric speciation as the mechanism for the derivation of many fossil species. Certainly, subspecies of *Warburgella rugulosa* are so distributed as to suggest their origin through allopatric speciation (Ormiston, 1967, p. 64), with the nominate subspecies and *rugosa* present in Europe, *canadensis* in arctic North America, *eureka* in Nevada and *maura* in North Africa. An important consequence of the theory of allopatric speciation is that the attendant migration time ought to make the occurrence of a given taxon at different geographic localities diachronous, which led Eldredge and Gould (1973) to conclude that first occurrences of such taxa cannot define datum planes. With existing levels of biostratigraphic resolution, it has not been possible to demonstrate, however, any diachroneity in the appearance of the various subspecies of *Warburgella* at various localities around the world. On the contrary, comparison of these first appearances with those of the important index fossil, *Monograptus uniformis* suggests, somewhat remarkably, essential coincidence of appearance. Several possible explanations exist; firstly, that these taxa of *Warburgella rugulosa* do not represent allopatric subspecies; that the theoretical implications of allopatric speciation are incorrect; or, finally, that our existing level of biostratigraphic resolution lacks precision. I favour the last conclusion.

Whereas Eldredge and Gould (1972) state that allopatric speciation is the only evolutionary model which they can accept with confidence, species of *Warburgella* have morphologic characteristics and stratigraphic distributions which are interpretable as Y-branched evolutionary patterns, resembling those documented by Klapper and Johnson (1975) for Early Devonian species of *Polygnathus*. For example, the succession of Late Silurian species of *Warburgella* documented by Maximova (1970) from Vaigatsch Island has been interpreted by Yolkin (1974b, Fig. 18, Table 10) as indicating a Y-branch pattern in the derivation of *waigatschensis*, a species occurring both on Vaigatsch and in the mountainous Altai, from the pre-existing species *tcherkesovae*. Joint occurrence of these two taxa is indicated by Maximova's (1970, p. 209) report of *W. tcherkesovae* with *W. yakovlevi* (the latter a synonym of *waigatschensis* according to Yolkin, 1974b, p. 76) in her sample 39G.

Yolkin (1947b, p. 87, Fig. 18) has proposed that *Warburgella rugulosa* was derived from the Pridolian species, *W. tcherkesovae*, a form lacking a preglabellar ridge. Whatever the merits of this proposed phylogeny, no warburgelline resembling *tcherkesovae* is yet known from the Pridolian of the Canadian Arctic. Instead, *Warburgella arcuaria* n. sp., which has similarities in the construction of the preglabellar field with *Warburgella (Tetinia) ludlowensis* and *Warburgella althi*, is thus far the only Pridolian species recognized in the Canadian Arctic.

Achronocline in *Warburgella rugulosa canadensis*

Warburgella rugulosa canadensis ranges through a significant thickness of strata in the Canadian Arctic Islands. Samples taken by R.E. Smith indicate a range of 293.5m for this taxon in the section 4km north of Washington Point, Baillie-Hamilton Island (e.g., GSC locs. C-26957-C-26986). The only systematic morphologic shift within the subspecies that has been detected over this interval is a tendency for the higher populations (e.g., GSC locs. C-26986, C-26984, C-26940) to have the preglabellar ridge more incorporated into the back of the anterior border and to have the tropidium effaced medially or entirely (Pl. 3, fig. 16). In stratigraphically lower populations, by contrast (e.g., GSC locs. C-11438, C-26957; Textfig. 4) the tropidium is entire and the preglabellar ridge separated anteriorly from the border by a furrow (Ormiston, 1975, Pl. 4, fig. 22 illustrates such a specimen from GSC loc. C-11438). Collections that

are stratigraphically intermediate (GSC loc. C-11442, and the stratigraphically equivalent type horizon, Ormiston, 1967, p. 62) consist of a variable population with both forms represented equally as illustrated by the holotype (Ormiston, 1967, Pl. 6, figs. 12, 13) as an example of the first variant, and the paratype, GSC 18136 (Ormiston, 1967, Pl. 7, fig. 1), as an example of the second.

A gradual morphologic shift within *canadensis* thus seems to be involved within the Baillie-Hamilton sections with the youngest populations more closely approaching *W. diadochos* in having the tropidium effaced and a wide anterior border. Other lines of evidence such as the ontogenetic development and intraspecific variability of *W. diadochos* also are suggestive of a gradualistic derivation of *diadochos* n. sp. from *Warburgella rugulosa canadensis*. Indeed, this is the interpretation currently favoured by the author. However, with *diadochos* presently known from only one stratigraphic section, the possibility of its entry as an allopatric immigrant cannot be excluded.

Although couched in a slightly different nomenclature, a similar progression in stratigraphically successive forms of *Warburgella rugulosa* has been identified by Chatterton and Perry (1977, p. 785) from the Delorme Formation. Their sequence does not, however, include a form as advanced as *W. diadochos*.

SYSTEMATIC PALEONTOLOGY

Prefix GSC refers to specimens in the type collection of the Geological Survey of Canada, Ottawa.

Class Trilobita Walch 1771
Genus *Warburgella* Reed 1931

Podolites Balashova, 1968

Type species. *Asaphus stokesii* Murchison, 1839.
Warburgella rugulosa canadensis Ormiston 1967

Plate 3, figures 15, 16

Warburgella rugulosa canadensis Ormiston, 1967, p. 62, Pl. 6, figs. 12-15, Pl. 7, figs. 1-4; Alberti, 1969, p. 353, Pl. 32, fig. 17; Ormiston, 1971, p. 175, Pl. 19, figs. 1-8, Pl. 20, figs. 1-10, Pl. 21, figs. 1-8; Ormiston, 1975, Fig. 3C, Pl. 3, figs. 30-32, Pl. 4, figs. 22-24, Pl. 5, figs. 27, 28.

Warburgella (Anambon) mackenziensis Chatterton and Perry, 1977, p. 748, Pl. 2, figs. 1-20, 35.

Material. Hypotypes, GSC 43628 and 43629, silicified pygidium and cranidium, respectively. Numerous free cheeks and cranidia not illustrated. All specimens from GSC locality C-26940, Surprise Point, Baillie-Hamilton Island, collected by R.E. Smith, 1973.

Discussion. Relatively coarse silicification makes the fine details of these specimens somewhat difficult to observe, but they are clearly similar to silicified specimens from the Delorme Formation of the District of Mackenzie illustrated by Ormiston (1971). The tropidium is largely effaced, but variants of *canadensis* showing this condition are known from the Delorme Formation as well as the type horizon (Ormiston, 1967) elsewhere on Baillie-Hamilton Island. The pygidium (Pl. 3, fig. 15) is more rounded posteriorly than those from the Delorme Formation (Ormiston, 1971, Pl. 21, figs. 4-6), but this again is a variable character in *canadensis*. The specimens from Surprise Point are good (and possibly advanced) examples of the stratigraphically younger variant (late form) of *Warburgella rugulosa canadensis* discussed in the preceding section.

Warburgella diadochos n. sp.

Plate 3, figures 1-14

Diagnosis. Cephalic border exceptionally broad, ratio of sagittal border length to cranial length averaging 0.20. Glabellar prosopon of tubercles, effaced anteriorly. Pygidium long for genus, ratio of length to width averaging 0.73, outline an isosceles triangle. Pygidium with fourteen to fifteen or more axial rings, seven to eight pleural ribs (versus 5-6 in *W. rugulosa*).

Material. Holotype cranidium, GSC 43615 from GSC locality C-26949, unnamed Devonian strata at 146 m above the top of the Cape Phillips Formation, northeast coast of Baillie-Hamilton Island, latitude 75°57'N, longitude 95°30'W, collected by R.E. Smith, 1973. Paratypes: cranidia, GSC 43616, 43618, 43619 (external mould), 43626 and 43621, pygidia GSC 43623 and 43624, free cheek 43617, all from the same horizon as holotype; pygidium GSC 43622, hypostome 43620 and immature cranidium GSC 43625 from 149 m above the top of Cape Phillips Formation (GSC loc. C-26950, same geographic locality, all collected by R.E. Smith, 1973). Other material: four incomplete cranidia and three incomplete pygidia from GSC locality C-26949; one incomplete cranidium and one incomplete pygidium from GSC locality C-11456, northeast coast of Baillie-Hamilton Island, collected by R. Thorsteinsson. Associated fauna: GSC locality C-26950 contains *Ozarkodina* n. sp. E of Klapper, 1975, *Ozarkodina* n. sp. F of Klapper, 1975, and *Ozarkodina remscheidensis remscheidensis* (Ziegler) indicative of the upper *Icriodus woschmidti* Zone.

Derivation of name. *Diadochos*, Greek for succeeding or following, in allusion to its stratigraphic position above *Warburgella rugulosa* (GSC loc. C-26940).

Description. **Cranidium.** Anterior border broad (sag.), breadth equaling 20 per cent of total cranial length, border barchan-like in cross-section with the posterior slope the steeper (Pl. 3, fig. 3). Peak of the border is at a height above that of preglabellar furrow. Preglabellar ridge low and short (sag.), concordant with curvature of border, as wide (trans.) as maximum glabellar width. Preglabellar field, length one third that of border, crested at midlength but without tropidium, except for a vestigial tropidial ridge on the midline of one specimen (Pl. 3, fig. 9). Anterolateral parts of fixed cheek conspicuously pitted. Glabellar outline as in *Warburgella rugulosa canadensis*, three pairs of glabellar furrows, S1 deeply incised in central part, terminating anteriorly short of axial furrow and markedly shallowing and continuing posteriorly to reach occipital furrow. S2 and S3 shallow, the former directed inward and backward, the latter inward and slightly forward. L2 inflated on large specimens (Pl. 3, fig. 7). Occipital furrow transverse, shallowing behind S1. Palpebral lobes broad (trans.), inner half steeply sloping inward, with distinct palpebral furrow at midwidth. The anterior border, glabella, except for the anterior half of the anterior lobe from which they are effaced, palpebral lobes and occipital ring all bear fine tubercles. Some specimens show a concentricity to the arrangement of these tubercles around the centre of the glabella, and exceptionally (Pl. 3, fig. 6) they coalesce to form ridges reminiscent of those developed in *W. rugulosa*. Median tubercle present at posterior edge of occipital ring. Terrace lines along outer edge of border.

Free cheeks. Lateral borders wide and semicircular in cross-section, width (trans.) greater than width of genal field opposite midpoint of the eye lobe (contrast with *W. rugulosa*). Genal field evenly inflated, without tropidium, with radiating, transversely elongated pits. Lateral border furrow deep and narrow, posterior border furrow slightly wider but equally deep. Genal spine sulcate. Both borders carry fine tubercles. Visual surface of eye three times longer than high.

Hypostome. The single, incomplete, available specimen is very close to that of *Warburgella rugulosa canadensis* illustrated by Ormiston (1971, Pl. 20, figs. 9-11) from which it possibly differs in having a more narrow posterior re-entrant and pitting on the posterolateral prolongations.

Pygidium. Outline an isosceles triangle, ratio of length to width averages 0.73. Axis more rapidly tapering in anterior than posterior half with up to fifteen axial rings plus terminal piece on which rings are imperceptible, six rings in anterior half of axis, ring furrows transverse, a prominent articulating half ring. In lateral view, axis forms an even 15 degree slope to the 12th ring, a steeper curving slope posterior to that point. Pleural fields moderately inflated, divided into seven or eight 'ribs'. Interpleural furrows developed only on anterior three or four 'ribs' that they bifurcate. Pleural furrows moderately deep, weakly curved in plan and running progressively more oblique to axis posteriorly. Postaxial ridge conspicuous. Lateral border with weak median crest, nearly as wide as width of posterior part of axis. Axis and lateral border densely covered with fine tubercles, also present on pleural fields, but more sparsely developed there.

Development. An immature cranium of length of 1.5 mm (Pl. 3, fig. 10) has a tuberculate glabella with conspicuous S1 and S2, broad anterior border, anteriorly sloping preglabellar field and broad palpebral lobes. Immature pygidia of lengths 1 mm have a length-to-width ratio of 0.55, a slightly transverse posterior border and interpleural furrows on all ribs. Rarely, the axial prosopon consists of short oblique ridges as in *Warburgella rugulosa*.

Dimensions.

	Holotype 43615	Paratype 43616	Paratype 43618	Paratype 43619
	(mm)			
glabellar length	2.7	3.0	4.9	3.7
glabellar width	2.4	2.5	4.8	3.1
cranial length	4.7	5.1	7.9	6.0
B-B width	3.7	3.6	6.0	4.2
		Paratype 43622	Paratype 43623	Paratype 43624
		(mm)		
pygidial length		10.1	6.6	5.2
pygidial width		13.2	9.2	(7.3)
maximum axial width		3.9	2.6	1.7

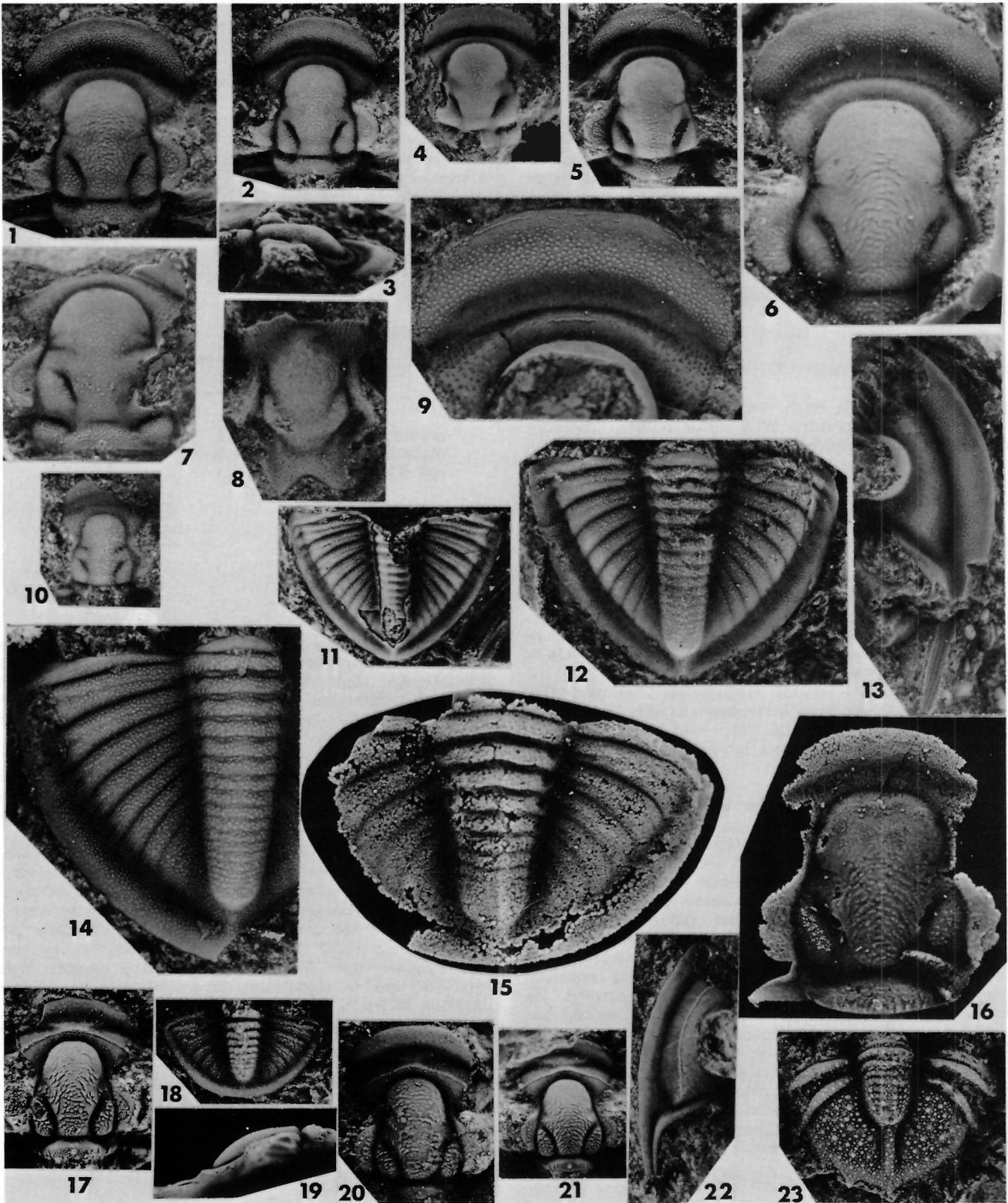
Comparison. The long, triangular pygidium readily distinguishes *W. diadochos* from nearly all *Warburgellas*. Maximova (1970, p. 198) established a new subgenus, *Waigatchella*, for four species from the Pridolian Greben Horizon of Vaigatsch Island, Soviet Arctic, one of which, *Warburgella (Waigatchella) grebenensis* Maximova (1970, p. 201 Pl. 1, figs. 25-28) has a long pygidium with a length-to-width ratio of 0.9, 14-15 axial rings, but only five pleural ribs and a smooth lateral border. Yolkin (1974b, p. 66) did not regard *Waigatchella* as having independent subgeneric rank and synonymized three of Maximova's species having the effect of making *Warburgella (Waigatchella) waigatchensis* (Tschernyshew and Yakovlev, 1898) the type species of the subgenus should it continue to be recognized. The pygidium of *W. waigatchensis* (Maximova, 1970, Pl. 1, figs. 20-24) is much less elongate than that of *W. diadochos*.

Whether or not *Waigatchella* is a valid subgenus, *W. diadochos* is distinguished from its component species by a greater number of pleural ribs, the conspicuous S3 furrow,

and much broader cephalic and pygidial borders. *Warburgella althi* Yolkin (1974b, p. 82, Pl. 11, figs. 1-7) from Lochkovian strata of Podolia and Bohemia approaches *W. diadochos* in having a tuberculate glabella, but is distinguished easily by its shorter anterior border, intact tropidium, transverse (and discordant with the curvature of the border) preglabellar ridge and persistence of glabellar prosopon to its anterior margin.

Plate 3

- Warburgella diadochos* n. sp. (page 9)
 Figures 1-3. Dorsal and dorsal and lateral views of holotype cranium, GSC 43615; GSC loc. C-26949; X8, and X6, respectively.
 Figure 4. Dorsal view of paratype cranium, GSC 43618; GSC loc. C-26949; X3.
 Figure 5. Dorsal view of paratype cranium, GSC 43616; GSC loc. C-26949; X6.
 Figure 6. Dorsal view of paratype cranium (latex cast of external mould); GSC 43619; GSC loc. C-26949; X9.
 Figure 7. Dorsal view of paratype cranium, GSC 43627; GSC loc. C-26949; X4.
 Figure 8. Exterior view of paratype hypostome, GSC 43620; GSC loc. C-26950; X12.
 Figure 9. Dorsal view of paratype cranium, GSC 43621; GSC loc. C-26949; enlarged to show vestigial tropidium; X10.
 Figure 10. Dorsal view of paratype immature cranium, GSC 43625; GSC loc. C-26950; X13.
 Figure 11. Dorsal view of paratype pygidium, GSC 43623; GSC loc. C-26949; X4.
 Figure 12. Dorsal view of paratype pygidium, GSC 43622; GSC loc. C-26950; X4.
 Figure 13. Dorsal view of paratype free cheek, GSC 43617; GSC loc. C-26949; X6.
 Figure 14. Dorsal view of paratype pygidium, GSC 43624; GSC loc. C-26949; X11.
- Warburgella rugulosa canadensis* Ormiston (page 9)
 Figure 15. Dorsal view of hypotype pygidium, GSC 43628; GSC loc. C-26940; X10.
 Figure 16. Dorsal view of hypotype cranium showing nearly effaced tropidium, GSC 43629; GSC loc. C-26940; X10.
- Warburgella arcuaria* n. sp. (page 12)
 Figures 17, 19. Dorsal and lateral views of paratype cranium, GSC 43630; GSC loc. C-11460; X6.
 Figure 18. Dorsal view of paratype pygidium, GSC 43631; GSC loc. C-11460; X10.
 Figure 20. Dorsal view of latex cast of paratype cranium, GSC 43632; GSC loc. C-11460; X10.
 Figure 21. Dorsal view of holotype cranium, GSC 43633; GSC loc. C-11460; X6.
 Figure 22. Dorsal view of free cheek, GSC 43634; GSC loc. C-11460; X6.
- Hemiarges bigener* Bolton (page 13)
 Figure 23. Dorsal view of pygidium, GSC 43635; GSC loc. C-11460; X10.



Discussion. The stratigraphic position, intraspecific variability, ontogeny and many shared characteristics suggest derivation of *W. diadochos* from *W. rugulosa canadensis*. The loss of the tropidium is the accentuation of a character trait already present in *canadensis* (Ormiston, 1967, p. 63) as is the triangularity of the pygidium (compare Ormiston, 1971, Pl. 21, fig. 4). The exceptional presence of Bertillon pattern prosopon on adult cranidia, as well as immature pygidia, of *diadochos* combined with the exceptional existence of tuberculate prosopon within the *Warburgella rugulosa* group (Chlupac, 1971, Pl. 21, figs. 3, 4) suggests the derivation of the prosopon of *diadochos* from that of *Warburgella rugulosa*.

Warburgella arcuaria n. sp.

Plate 3, figures 17 - 22

Warburgella n. sp. Ormiston, 1977, p. 322, Fig. 1D.

Diagnosis. *Warburgella* with preglabellar ridge transverse and discordant to curvature of anterior border, tropidium pronounced usually comprised of two close-set ridges. Hypostome with sagittal pit anterior to median body. Pygidium semi-elliptical with ten axial rings and five pleural ribs, pleural fields weakly convex.

Material. Holotype. Cranidium, GSC 43633, from GSC locality C-11460, Cape Phillips Formation, strata of Pridolian age, Marshall Peninsula, Cornwallis Island, UTM Zone 14X, 579750E; 8869200N, collected by R. Thorsteinsson; associated fauna: *Hemiarges bigener* Bolton, 1965.

Paratypes. Cranidia, GSC 43630, and 43632 (external mould), pygidium, GSC 43631, and free cheek, GSC 43634, same horizon and locality.

Other material. Several fragmentary cranidia, free cheeks and hypostomes, same horizon and locality.

Derivation of name. *Arcuarius*, Latin—of bows, an allusion to the bowlike pattern formed by preglabellar ridge and anterior border.

Description. Cranidium. Anterior border low, preglabellar ridge transverse and discordant to curvature of border, forming a conspicuous bowlike configuration (Pl. 2, figs. 20, 21). Tropidium prominent, marking sharp break in slope of preglabellar field. Tropidium sometimes a double ridge as in *W. glaber* (Kummerow, 1927), illustrated by Schrank (1972, Pl. 9, fig. 6A), from the Wenlock and Ludlow of the Baltic. Glabella moderately expanded across base, having a low longitudinal profile. Two pairs of glabellar furrows, S1 uniformly incised its whole length, reaching occipital furrow; S2 short and weak, directed slightly backward. An anterolateral pit is present in the circumglabellar furrow. Occipital furrow transverse. Occipital ring with weakly inflated lateral lobes, ring at same height as posterior end of glabella in lateral profile, having median tubercle. Palpebral lobes plane, distinct palpebral furrow, beta-beta width equal to delta-delta width. Glabella, palpebral lobes and occipital ring bear short scalelike ridges arranged in a Bertillon pattern. Terrace lines not evident on anterior border.

Hypostome. The hypostome of this species is not illustrated but can be distinguished particularly from that of *W. rugulosa* (Ormiston, 1971, Pl. 20, figs. 9-11; Chlupac, 1971, Pl. 21, fig. 8) in the greater length of the field between the anterior margin and the anterior end of the middle body, and in the presence of a sagittal pit in that field.

Free cheek. Eye lobe three times as long (exsag.) as high. Genal field with prominent tropidium marking break in slope and extending to the sharp posterior border furrow. Lateral border furrow broad, lateral border low without prosopon. Genal spine nearly as long as remainder of cheek, sulcate and slender.

Pygidium. Ratio of length to width varies from 0.5 to 0.6. There are 10 axial rings with the first distinctly higher than subsequent ones. Axis high in lateral view, rings carry ridges oriented obliquely to midline. Pleural fields very gently convex, five pleural ribs, each with interpleural furrow. Pleural bands of equal length (exsag.) bearing tubercles whose pattern roughly parallels the orientation of bands. A faint postaxial ridge is present. Lateral border gently convex. Pygidial outline slightly emarginate on midline.

Dimensions.

	Holotype GSC 43633	Paratype GSC 43631
	(mm)	
cranial length	4.2	4.7
glabellar width	1.9	2.7
glabellar length	2.3	3.0
	Paratype GSC 43631	
	(mm)	
pygidial length	1.7	
pygidial width	3.0	

Discussion. *Warburgella arcuaria* n. sp., *Warburgella (Tetinia) ludlowensis* (Alberti, 1967) from the Ludlovian Leintwardine Beds of England (Owens, 1973, p.72, Textfig. 10), and *Warburgella althi* Yolkin (1974b, p. 82, Pl. 11, figs. 1 - 7) from Lochkovian strata of Podolia and Bohemia share discordance between the transverse preglabellar ridge and the curved anterior border furrow. This characteristic has also been seen on specimens of *Warburgella* aff. *W. althi* Yolkin, collected by R. Ludvigsen from a horizon of probable Pridolian age in the Road River Formation, Hart River, Yukon, latitude 65°38'N, longitude 136°45'W.

Warburgella althi also resembles *W. arcuaria* n. sp. in having the tropidium coincident with the break in slope and in pygidial characteristics, but differs in its tuberculate glabellar prosopon and in the lack of a space between the preglabellar ridge and anterior border. *Warburgella glaber* (Kummerow, 1927) from the Baltic Silurian is readily distinguished from *W. arcuaria* in having a much broader glabella that is essentially devoid of prosopon (Schrank, 1972, p. 30, Pl. 9, figs. 6 - 10).

Among the several species of *Warburgella* known from the Pridolian of Vaigatsch Island (Maximova, 1970), none appears from available illustrations to be especially close to *arcuaria*. *Warburgella jelli* Landrum and Sherwin, 1976, a possibly Late Silurian species from New South Wales, lacks a cranial tropidium and preglabellar ridge.

Genus *Hemiarges* Gürich 1901

Choneilobarges Phleger, 1936

Richterarges Phleger, 1936

Amphilichas Shaw, 1968 (pars), P. 89-94, Pl. 3, figs. 8, 10, 11, 14 - 22, 24.

Type species. *Lichas wesenbergensis* Schmidt 1885.

Hemiarges bigener Bolton, 1965, p. 10, Pl. 3, figs. 1-9, 11.

Hemiarges n. sp. A. Ormiston, 1967, p. 128, Pl. 17, figs. 12, 13, 15.

Material. A small pygidium, hypotype GSC 43626, from GSC locality C-11460, Cape Phillips Formation, strata of Pridolian age, Marshall Peninsula, Cornwallis Island, UTM Zone 14X, 579750 E; 8869200 N, collected by R. Thorsteinsson in 1971.

Comparison. Large pygidia of *Hemiarges bigener* are characterized (Bolton, 1965, p. 11) by a postaxial pygidial length twice that of the axial length, but this characteristic changes markedly during the ontogeny of this species as indicated by a hypotype pygidium (GSC 17780) illustrated by Bolton (1965, Pl. 3, fig. 2), which is only slightly larger than the pygidium illustrated here and compares closely with it. A paratype specimen of *H. bigener* (GSC 18245) was collected from float (GSC loc. C-11462) on Marshall Peninsula at a stratigraphic position approximately 10 m above GSC locality C-11460. A cranidium of *H. bigener* is present in GSC locality C-11457, 23 m below GSC locality C-11460 in the same section.

Hemiarges lindstromi (Tschernyschew and Yakovlev, 1898) from the Pridolian Greben Horizon of Vaigatsch Island (Maximova, 1970, p. 205, Pl. 2, figs. 4-8) is similar to immature pygidia of *H. bigener* but does not develop the great postaxial length of *bigener* in larger specimens (compare Maximova, 1970, Pl. 2, fig. 5).

Discussion. T.T. Uyeno reports the conodont *Ozarkodina confluens* (α morphotype) from GSC locality C-11460, but this Silurian species is not restricted to Pridolian strata. Brachiopods present in GSC locality C-11460 have not yet been identified, but J.G. Johnson has identified brachiopods from overlying and underlying collections. GSC locality C-11461, which overlies GSC locality C-11460, contains *Atrypella* sp. and *Tenellodermis* aff. *T. tenella* Barrande indicative of a Pridolian age. GSC locality C-11457, from 23 m below GSC locality C-11460, contains, besides *Hemiarges bigener*, *Atrypella* sp. of Silurian age.

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LATE EARLY DEVONIAN BRACHIOPODS FROM THE MOUNT LLOYD AREA, NORTHERN BRITISH COLUMBIA

D.G. Perry, A.J. Boucot and H. Gabrielse

Abstract

An important brachiopod-bearing fossil locality (latitude 57°48'N, longitude 125°02'W) in the Muskwa Ranges marks the most southerly and westerly known exposure of carbonate rocks of late Early Devonian age in the Rocky Mountains. This locality and graptolite-bearing localities to the southeast yield datable Early Devonian faunas that have not been recovered from poorly fossiliferous, stratigraphically equivalent, platform dolostone sequences to the east. The occurrence of exotic clasts of carbonate in units of sedimentary breccia, the abraded nature of some of the fauna, and the very high brachiopod taxonomic diversity indicate transport and possible mixing of faunas.

The brachiopods *Cortezorthis* cf. *C. maclareni* Johnson and Talent, *Parachonetes macrostriatus* (Walcott), *Athyryhynchus* and several other forms indicate correlations with upper Pragian-Zlichovian (approximately equivalent to the lower Emsian) brachiopod-bearing strata in the Yukon and Northwest Territories. Paleobiogeographic affinities of the brachiopod fauna are with Old World Realm carbonate faunas. New taxa described include: *Spinatrypina symmetrica* n. sp., *Vagrana atrypiforma* n. sp., and *Lenzia pachyostrakon* n. gen. and n. sp.

Résumé

Un important site fossilifère (latitude 57°48'N, longitude 125°02'W), riche en brachiopodes, rencontré dans les chaînons Muskwa, représente parmi les affleurements connus de roches carbonatées de la fin du Dévonien inférieur, celui qui, dans les montagnes Rocheuses, est situé le plus au sud et à l'ouest. Ce site, et les gisements riches en graptolites au sud-est, contiennent des faunes datables du Dévonien inférieur que l'on n'a pu retrouver dans les successions dolomitiques situées à l'est, qui constituent des dépôts de plate-forme peu fossilifères et stratigraphiquement équivalents. La présence de clastes exotiques de carbonates dans les unités composées de brèches sédimentaires, le degré d'abrasion d'une partie de la faune, et l'énorme diversité taxonomique des brachiopodes indiquent qu'il y a eu transport, et peut-être brassage des faunes.

Les brachiopodes *Cortezorthis* cf. *C. maclareni* Johnson et Talent, *Parachonetes macrostriatus* (Walcott), *Athyryhynchus* et plusieurs autres formes révélant des corrélations avec les strates riches en brachiopodes du Pragien et du Zlichovien (à peu près équivalentes à l'Emsien inférieur), du Yukon et des Territoires du Nord-Ouest. La faune de brachiopodes présente des affinités paléobiogéographiques avec les faunes calcaires du 'Old World Realm'. Les nouveaux taxons décrits comprennent: la nouvelle espèce *Spinatrypina symmetrica*, la nouvelle espèce *Vagrana atrypiforma*, et les genre et espèce *Lenzia pachyostrakon*.

INTRODUCTION

During 1971, fossiliferous Lower Devonian strata were discovered southwest of the Lloyd George Icefield in the Muskwa Ranges of the northern Rocky Mountains (Textfig. 1, loc. 8; Textfig. 5). The locality is of interest because, in the northern Rocky Mountains, the stratigraphic interval between fossiliferous carbonate rocks of the Nonda Formation (Late Llandovery, see Norford et al., 1966) and the Dunedin Formation (Eifelian and Givetian, see Taylor and MacKenzie, 1970) commonly is either barren or very poorly fossiliferous (Textfig. 6). Furthermore, regional mapping has shown that the strata described herein are the westernmost Lower Devonian carbonates exposed at this latitude in the Rocky Mountains. Presumed correlative strata within the thick-bedded to massive dolostones of the Stone Formation occur more than 48 km to the east (Taylor and MacKenzie, 1970).

Paleontologically, these fossiliferous strata are of interest because they represent the first positive identification of Early Devonian brachiopods in British Columbia, some 480 km southwest of brachiopod faunas known from the Lower Devonian Delorme Formation of the Mackenzie Mountains. The paleobiogeographic affinities of the brachiopod fauna are with European faunas, which are also known in the northern Yukon (Lenz and Pedder, 1972), and from the adjacent District of Mackenzie (Perry, 1974). The brachiopod fauna bears none of the biogeographically distinct taxa found in beds of similar age in central Nevada. Early Devonian graptolite faunas of Siegenian to Emsian age have been collected from a locality about 110 km to the southeast of the Mount Lloyd George area (Gabrielse, 1976). Campbell et al. (1973) have reported older Lower Devonian conodont and coral-bearing beds from the Black Stuart Formation in the Quesnel Lake map area, some 608 km to the

south-southeast. A.C. Lenz (pers. comm., 1975) has recovered a small, Late Silurian brachiopod fauna from beds probably assignable to the Black Stuart Formation in the Quesnel Lake area.

Stratigraphy

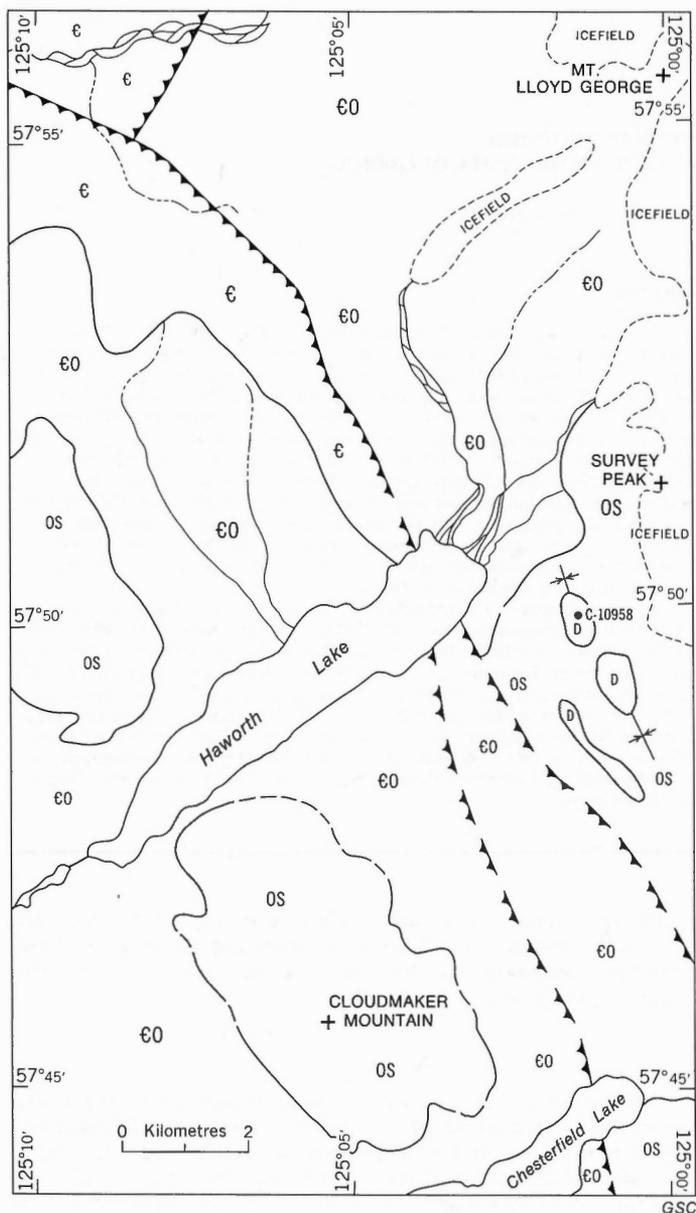
The rocks yielding the Emsian brachiopod fauna are preserved on the crest of a ridge in a tight south-southeast trending syncline in the Ware map area (GSC loc. C-10958, latitude 57°48'N, longitude 125°02'W; Textfig. 1, loc. 8; Textfig. 5). More than 92 m of strata are exposed in the syncline and consist mainly of well bedded (10-15 cm) dolomitic sandstone, sandy dolostone and minor sedimentary breccia. Some beds contain a prolific silicified fauna weathered out in relief over the less resistant dolomitic matrix. The fossils were collected from a stratigraphic interval about 3 m thick of uncertain position within the core of the syncline. Abrasion of fossils (tabulate corals and brachiopods) and the presence of lithic dolostone and sandstone clasts as much as 7.5 cm long indicate possible transport of the material. Most of the described fossils appear to occur in the matrix. The silicified nature of much of the dolomitic matrix greatly impeded acid dissolution. A few very fragmental fossils are indicative of a Pragian age slightly older than the late Pragian-Zlichovian age given by the bulk of the fauna. They may have been derived from clasts older than the matrix.

Underlying the Lower Devonian strata are less resistant platy siltstones and shales containing Silurian (Llandovery) graptolites, although the age of the uppermost beds in this siltstone-shale sequence is unknown. The lower part of this graptolitic assemblage is exposed on Cloudmaker Mountain (Textfig. 5), 7.4 km to the southwest (Jackson et al., 1965).

*D.G. Perry is deceased

A.J. Boucot is with the Department of Geology, Oregon State University, Corvallis, Oregon, U.S.A. 97331

H. Gabrielse is with the Geological Survey of Canada, 100 West Pender St., Vancouver, British Columbia V6B 1R8



LOWER DEVONIAN

D Dolomite, sandstone

LOWER ORDOVICIAN TO LOWER SILURIAN (?)

OS Shale, siltstone, sandstone

CAMBRIAN AND LOWER ORDOVICIAN

€0 Argillaceous limestone

LOWER CAMBRIAN

€ Sandstone, limestone

Geological boundary (defined, assumed).....

Thrust fault (defined, approximate).....

Syncline.....

Fossil locality (GSC catalogue number)..... C-10958

Textfigure 5. Geological sketch-map of the region southwest of Mount Lloyd George, Ware map area, British Columbia (for location, see Textfig. 1, Loc. 8).

In the syncline, the fossiliferous sandstones and dolostones are overlain by dark-weathering, apparently barren shales of probable Devonian age, the youngest strata preserved in the Mount Lloyd George area.

Paleogeography

Although the Lower Devonian rocks in question underlie only a small geographic area and are distant from correlative strata, this location and facies have important implications for paleogeographic reconstructions. About 48 km to the northeast, strata of about the same age (inferred from stratigraphic position) are included in a sequence of dolostones that suggests deposition on a relatively stable platform or slowly subsiding shelf (Textfig. 6). To the south-southeast in northeastern Fort Grahame map area, correlative and slightly older rocks bear *Monograptus* ex. gr. *M. yukonensis* Jackson and Lenz, *M. telleri*? Lenz and Jackson, *M. thomasi* Jaeger, and *M. hercynicus* Perner (GSC loc. C-27705; correlated as Siegenian-Emsian by Jackson in Gabrielse, 1976, p. 26). These rocks are graptolitic shales with local interbeds of crinoidal limestone and indicate deeper water conditions. It seems probable that the fossiliferous Lower Devonian strata at Mount Lloyd George were deposited close to the outer margin of a subsiding shelf bordering a deeper water depositional basin to the west. Interestingly, abundantly fossiliferous, silicified rocks of similar age are found in at least two localities within carbonate sequences bordering shale basins in the western Mackenzie Mountains (Gabrielse et al., 1973; Perry, 1974) and in the Wernecke Mountains (Lenz and Pedder, 1972).

Brachiopod fauna and suggested age

Several elements of the brachiopod fauna are not described or illustrated because of very poor preservation or long stratigraphic range. Genera such as *Skenidioides*, *Dalejina*, *Schizophoria*, *Gypidula*, *Leptagonia*, *Eoschuchertella*, *Aesopomum*, *Strophonella*, *Leptostrophia*, *Spinatrypa*, *Spinatrypa*, *Punctatrypa* of the *granulifera* type, *Reticulatrypa*, *Cryptatrypa*, *Nucleospira* and *Cyrtina* all have stratigraphic ranges throughout the Lower Devonian or even longer. On the whole, the brachiopod fauna from the Mount Lloyd George area is poorly preserved. It would be difficult confidently to identify some of the material without first-hand knowledge of taxonomically similar, well-preserved faunas from Royal Creek, Yukon and from the Sekwi Mountain map area, western District of Mackenzie. A few illustrations of excellently preserved materials from the Sekwi Mountain map area are included in the plates for comparative purposes.

Elements most instrumental in assigning an early Emsian age to the fauna are: *Cortezorthis* cf. *C. maclareni* Johnson and Talent, *Carinagypa loweryi*? (Merriam), *Megastrophia iddingsi* (Merriam), *Parachonetes macrostriatus*? (Walcott), *Athyrrhynchus* sp., *Atrypa* cf. *A. nevadana* Merriam, *Vagrana atrypiforma* n. sp., *Biconostrophia* sp., *Lissatrypa*? sp., "*Hysterolites*" sp. and *Warrenella sekvensis*? Ludvigsen and Perry. These taxa or closely related forms are known to occur in at least one of the following: central Nevada; Delorme Formation of the Sekwi Mountain map area, western District of Mackenzie; Road River Formation at Royal Creek, Yukon; Michelle Formation, northern Yukon; and several formations at localities in the Canadian Arctic Archipelago. At most of these localities the beds are well dated as early Emsian by associated brachiopod and conodont faunas and locally by dacryoconarid tentaculites or superposition above graptolite faunas yielding *Monograptus yukonensis* Jackson and Lenz. The oldest known *Athyrrhynchus* is probably a mid-Pragian taxon from the Delorme Formation although the genus becomes widespread geographically only in Emsian beds. The level of evolution of *Vagrana atrypiforma* n. sp. within the known vagraniid lineage is consistent with a late Pragian age.

		SSW	Ware and Fort Grahame map-areas (composite, this paper)	NNE	Tuchodi Lakes map-area (adapted from Taylor and MacKenzie)	
DEVONIAN	Upper				BESA RIVER FORMATION (basinal shales)	
	Middle	Givetian	black shale	<i>Stringocephalus</i> DUNEDIN FORMATION (bedded platform limestone) <i>Leiorhynchus castanea</i>		
		Eifelian				
	Lower	Emsian	?	X brecciated silicified carbonate	C. cf. <i>C. maclareni</i> <i>P. macrostriatus?</i> <i>Athyrynchus</i> sp.	X STONE FORMATION (massive platform dolostone with two-hole crinoid ossicles)
			?			
		Pragian		graptolitic shale and crinoidal limestone	<i>M. ex gr. M. yukonensis</i> <i>M. telleri?</i> <i>M. thomasi</i> <i>M. hercynicus</i> <i>M. aff. M. angustidens?</i>	X WOKKPASH FORMATION (dolomitic sandstone)
Lochkovian					X MUNCHO-McCONNELL FORMATION (sandy dolostone)	
SILURIAN	Middle/Upper	Pridolian	X		X	
		Ludlovian	X	?	X	
		Wenlockian	X	?	X	
	Lower	Llandoveryan		graptolitic shale and siltstone		X NONDA FORMATION (platform dolostone)

GSC

Not well dated; age determined primarily by stratigraphic position ... X *Cortezorthis* C.
Parachonetes P. *Monograptus* M.

Textfigure 6. Diagrammatic correlation chart of Silurian and Devonian rocks in the Ware and Tuchodi lakes map areas, British Columbia.

The only shells that would indicate a slightly older, early Pragian, age are very poorly preserved, fragmental materials representing the genera "*Dolerorthis*", *Thliborhynchia*, and *Plicocyrtna*. Probable "*Dolerorthis*" have been observed by Perry in upper Emsian beds of the Ogilvie Formation in the northern Yukon. *Thliborhynchia* and *Plicocyrtna* occur characteristically in lower Pragian beds at Royal Creek and in the Sekwi Mountain area; however, fragmental *Thliborhynchia?* has been recorded from Emsian beds of the Delorme Formation by Perry (1974).

The brachiopod fauna shows close affinity to those reported from the Delorme Formation, in the Sekwi Mountain map area, western District of Mackenzie (Perry, 1974) and from the Royal Creek area of the Yukon (Lenz and Pedder, 1972). The fauna bears none of the distinctive elements of the Eastern Americas Realm (Boucot, 1975) Emsian faunas, some of which occur in Emsian beds in central Nevada. It clearly relates to the Cordilleran biogeographic region of Boucot (1975).

The Mount Lloyd George area fauna does little to clarify knowledge of Early Devonian brachiopod communities because of the allochthonous nature of parts of the fauna and because of the lack of detailed stratigraphic data. The samples yielding the fauna were loose blocks, apparently derived from a stratigraphic interval approximately 3 m thick. The blocks showed considerable lithologic variation, although a sandy dolostone matrix with rounded intraclasts of dolomitic sandstone, dolostone and limestone appears most characteristic. The 34 brachiopod genera present in the collection represent a significantly higher

diversity than previously encountered elsewhere in any unmixed collections. The large number of taxa is probably the result of telescoping of specimens from adjacent communities by bottom transport and possibly because of parts of the fauna being derived from clasts and other parts from matrix. The dolostone clasts may well be older than the associated matrix from which most of the fauna was derived.

Confirmation of the Emsian age by conodonts must await the collection of additional material. A poorly preserved rugose coral from the Mount Lloyd George collection is suggestive of *Martinophyllum?*, a genus that occurs typically in the *Polygnathus dehiscens* conodont faunal unit (Emsian) of the northern Yukon (A.E.H. Pedder, pers. comm., 1975). Pedder also comments that *Martinophyllum* is unknown from the older *Eognathodus sulcatus* or from the younger *Polygnathus perbonus* conodont faunal units in the Yukon Territory. The distribution of rugose corals in the Lower Devonian shows a marked faunal distinction between those of northwestern Canada, the Cordilleran region of the Old World Realm and the Nevadan Subprovince of the Eastern Americas Realm (Pedder, 1975).

Table 1 shows the brachiopod fauna of the collection. Other faunal elements, present in decreasing order of abundance, include: large (20 mm diameter) pelmatozoan ossicles, bellerophontid and turriculate gastropods (three genera), abraded tabulate corals (*Favosites*, *Coenites*, *Alveolites*), colonial (including *Martinophyllum?* sp.) and solitary rugose corals, pelecypods (two genera), receptaculitids, orthocone nautiloid fragments, bryozoan fragments and a large uncompresssed sponge (100 mm long, 30 mm in diameter).

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SYSTEMATIC PALEONTOLOGY

Prefix GSC refers to specimens in the type collection of the Geological Survey of Canada, Ottawa.

Phylum Brachiopoda
 Family Skenidiidae Kozlowski 1929
 Genus *Skenidioides* Schuchert and Cooper 1932

Type species. *Skenidioides billingsi* Schuchert and Cooper 1932.

Skenidioides sp.

Plate 4, figures 1, 2

Material. GSC 43093 and one other brachial valve; GSC locality C-10958.

Remarks. *Skenidioides* is not a useful brachiopod for zonal correlation because of its long stratigraphic range (Lower Ordovician to Middle Devonian) and its relatively stable morphologic features. It is a common cosmopolitan element and is found abundantly in the outer shelf *Vagrania-Skenidioides* Community of Boucot (1975) and in the community of small species within the G-A-S biofacies of Johnson (1974).

Table 1. Faunal list from the Mount Lloyd George area, GSC locality C-10958

* " <i>Dolerorthis</i> " ? sp.	1Bf
<i>Skenidioides</i> sp.	2B
<i>Cortezorthis</i> cf. <i>C. maclareni</i>	
Johnson and Talent	21B, 19P
<i>Dalejina</i> sp.	20Bf, 20Pf
* <i>Schizophoria</i> sp.	6Bf, 6Pf
<i>Gypidula</i> sp.	18Bf, 24Pf
<i>Carinagypa loweryi</i> ? (Merriam)	10Bf, 57Pf
<i>Leptagonia</i> sp.	19B, 13Pf
<i>Eoschuchertella</i> sp.	20B, 20Pf
<i>Aesopomum</i> sp.	17Bf
<i>Strophonella</i> sp.	10Pf
<i>Megastrophia iddingsi</i> (Merriam)	1A, 9B, 42P
<i>Phragmostrophia</i> sp.	3Bf
* <i>Leptostrophia</i> ? sp.	2Bf, 1Pf
<i>Parachonetes macrostriatus</i> ? (Walcott)	1B
* <i>Thliborhynchia</i> ? sp.	1Af, 3Bf, 3Pf
* indeterminate trigonirhynchiid	2Bf, 1Pf
<i>Athyrrhynchus</i> sp.	15Bf, 5Pf
<i>Atrypa</i> cf. <i>A. nevadana</i> Merriam	61Bf, 50Pf
<i>Spinatrypa</i> sp.	5Bf, 5Pf
* <i>Spinatrypa symmetrica</i> n. sp.	4A, 140Bf, 95Pf
* <i>Punctatrypa</i> ? sp.	2Bf, 1Pf
<i>Reticulatrypa</i> ? sp.	1A, 4Bf, 3P
<i>Vagrana atrypiforma</i> n. sp.	100Bf, 60Pf
<i>Biconostrophia</i> sp.	2A, 4Bf, 4Pf
* <i>Cryptatrypa</i> ? sp.	1P
<i>Lissatrypa</i> ? sp.	4A, 2B, 8Pf
* <i>Nucleospira</i> ? sp.	1Bf
* indeterminate acrospiriferinid?	3Bf, 5Pf
" <i>Hysterolites</i> " sp.	?1B, 3Pf
<i>Lenzia pachystrakon</i> n. gen., n. sp.	20Bf, 80Pf
* <i>Plicocyrta</i> ? sp.	2Pf
* <i>Cyrtina</i> sp.	25Bf, 30P
<i>Warrenella sekwensis</i> ? Ludvigsen and Perry	14Bf, 16Pf

A = articulated shells, B = brachial valve, P = pedicle valve, f = fragmental shell remains, asterisked material has not yet been illustrated because of poor preservation.

Skenidioides is common throughout the Lower Devonian of Royal Creek, Yukon and of the Sekwi Mountain map area of western District of Mackenzie. In central Nevada, *Skenidioides* is absent from the *Quadrithyris* through *Eurekaspirifer pinyonensis* zones, probably reflecting the shallow-water, nearshore environment of their faunas.

Family Dalmanellidae Schuchert 1913
Subfamily Cortezorthisinae Johnson and Talent 1967
Genus *Cortezorthis* Johnson and Talent 1967

Type species. *Cortezorthis maclareni* Johnson and Talent 1967.

Cortezorthis cf. *C. maclareni* Johnson and Talent, 1967

Plate 4, figures 3 - 13

Hypsomyonia? sp. A, McLaren in Fortier et al., 1963, p. 320.

Cortezorthis maclareni Johnson and Talent, 1967, p. 146, Pl. 19, figs. 1 - 20, Pl. 20, figs. 28, 29.

Material. 21 brachial valves (including figured specimens GSC 43094 - 43096) and 19 pedicle valves (including GSC 43097, 43098); GSC locality C-10958.

Remarks. The type material of *C. maclareni* is from Emsian beds of the Blue Fiord Formation, Ellesmere Island; the species is abundant in Emsian age beds of the Delorme Formation in the Sekwi Mountain map area, Mackenzie Mountains. *Cortezorthis* is known from upper Lochkovian to Emsian strata in the Cordilleran region and in the Emsian of U.S.S.R. (referred to *Protophragmophora* by Alekseeva, 1967). The genus is not known to range into the Eifelian in North America as suggested previously by McLaren et al. (1970, p. 616).

The Mount Lloyd George shells belong to the early Pragian-Emsian lineage of *Cortezorthis* n. sp. of Perry 1974 — *C. maclareni* and are very close to *C. maclareni*. Features of the shells characteristic of *C. maclareni* are: large size (2-3 cm in diameter), subcircular outline, ventral carina, sharp posterior dorsal sulcus, well developed internal radial, peripheral septa. The dorsal muscle field has a slightly more elongate rhombohedral outline than that of the type material. The faintly, radially grooved posterior adductor scars are separated from the anterior adductor scars by an anterolaterally directed myophragm that is impressed as a groove in the high, overhanging muscle-bounding ridges. Anteromedially, three orders of peripheral septa are developed in the dorsal valve. The ventral interiors of the Lloyd George shells are not readily distinguished from the type material. A well preserved *C. maclareni* from Emsian age beds of the Delorme Formation is illustrated (Pl. 4, fig. 14) for comparative purposes.

Family Rhipidomellidae Schuchert 1913
Subfamily Rhipidomellinae Schuchert 1913
Genus *Dalejina* Havlíček 1953

Type species. *Dalejina hanusi* Havlíček 1953.

Dalejina sp.

Plate 4, figures 15 - 17

Material. 20 brachial valves (including figured specimen GSC 43099) and 20 pedicle valves (including GSC 43100); all coarsely silicified and fragmentary; GSC locality C-10958.

Remarks. *Dalejina* is a common element in the Lower Devonian of the Old World Realm, Cordilleran region, of western North America. In northwestern Canada it occurs commonly in upper Lochkovian to Emsian strata. The Mount Lloyd George *Dalejina* are relatively large and have thick shells. They differ from the *Dalejina* known from the Delorme Formation by their finer costellae and their strongly impressed dorsal muscle fields. The posterior dorsal adductor muscle scars are raised on a platform bound by the brachiophores and the cardinal process, whereas the anterior adductors are strongly impressed circular tracks divided by a strong median myophragm.

Family Gypidulidae Schuchert and LeVene 1929
Subfamily Gypidulinae Schuchert and LeVene 1929
Genus *Gypidula* Hall 1867

Type species. *Gypidula typicalis* Amsden 1953.

Gypidula sp.

Plate 4, figures 18 - 24

Material. Posterior fragments of 18 brachial valves (including figured specimens GSC 43101, 43103) and 24 pedicle valves (including GSC 43102, 43104); GSC locality C-10958.

Remarks. Fragmentary silicified remains of a coarsely costate gypidulid are referred here to *Gypidula*. Several gypidulids with coarse costae are known from upper Pragian beds from Royal Creek and from the Sekwi Mountain area, although direct comparison of the Mount Lloyd George shells is precluded because of poor preservation.

Considerable variation is shown in the disposition of the costae; in some shells they are confined to the medial regions, in others they are distributed evenly over the whole width. Large shells develop smooth umbones whereas the costae extend from the beak in small immature shells. The costae show irregular bifurcation and implantation. The brachial plates are slightly divergent anteriorly and forms with both conjunct and widely disjunct outer plates are present. The ventral spondylium is supported apically by a relatively short septum. A low ventral fold and dorsal sulcus readily distinguish the taxon.

Genus *Carinagypa* Johnson and Ludvigsen 1972

Type species. *Gypidula loweryi* Merriam 1940.

Carinagypa loweryi? (Merriam 1940)

Plate 4, figures 25 - 30

?*Pentamerus comis* Walcott, 1884, p. 169, Pl. 3, fig. 7, Pl. 14, figs. 15, 15a, 15b, Pl. 15, figs. 5, 5a, 5b.

?*Gypidula loweryi* Merriam, 1940, p. 81, Pl. 7, fig. 9.

?*Gypidula loweryi* Merriam, Cooper, 1944, p. 305, Pl. 115, figs. 4, 5.

? "*Gypidula*" *loweryi* Merriam, Gauri and Boucot, 1968, p. 119, Pl. 20, fig. 4, Pl. 21, fig. 1.

?*Gypidula loweryi* Merriam, Johnson, 1970, p. 98, Pl. 13, figs. 8 - 17, Pl. 14, figs. 1 - 20.

? "*Gypidula*" *loweryi* Merriam, Ludvigsen, 1970, Pl. 1, figs. 16 - 19.

?*Carinagypa loweryi* Merriam, Johnson and Ludvigsen, 1972, p. 128, Textfig. 3.

Material. Posterior fragments of 10 brachial valves (including figured specimens GSC 43106, 43107) and 57 pedicle valves (including GSC 43105); GSC locality C-10958.

Remarks. The shells are poorly preserved but show smooth shell exteriors, weakly developed carinae at the junction of inclined, elongate triangular inner plates and ribbonlike brachial processes, outer plates that bow laterally from their subparallel tracks along the valve floor, thickened lobes in the notothyrial cavity which evidently served for diductor attachment, and a prominent septum supporting the spondylium. The ventral septum is one feature that distinguished *C. loweryi* from the large aseptate *Carinagypa aseptata* Johnson of younger Emsian age. Included in *C. loweryi*? from GSC locality C-10958 are two dorsal valves with basally conjunct outer brachial plates that might indicate *Sieberella*. In other collections of *C. loweryi*, Perry and Boucot have seen similar variability and suggest that the basal disposition of outer plates in some gypidulid species is highly variable. *Carinagypa loweryi* is a distinctive element in the lower Emsian beds of the Michelle Formation, northern Yukon (Ludvigsen, 1970) and from strata of similar age in central Nevada (Johnson, 1970). A probable representative is known from lower Emsian beds of the Delorme Formation in the Sekwi Mountain map area.

Family Strophomenidae King 1846
Subfamily Leptaeninae Hall and Clarke 1895
Genus *Leptagonia* McCoy 1844

Type species. *Producta analoga* Phillips 1836.

Leptagonia sp.

Plate 4, figures 31 - 38

Material. Nineteen brachial valves (including figured specimens GSC 43108, 43110, 43111) and 13 fragmentary pedicle valves (including GSC 43109), all finely silicified; GSC locality C-10958.

Description. *Exterior.* Shells up to 40mm wide, transversely subrectangular in outline. Anterior margin of shell commonly strongly re-entrant. Cardinal angles right angled to slightly acute. Hinge line long, straight and commonly the line of maximum width. Shells planoconvex in lateral profile with strong geniculation (90°) near the medial part of the shell. Ventral interarea long, low, flat and apsacline. Dorsal interarea nonexistent. Ornament of strongly developed concentric rugae separated by U-shaped interspaces. Rugae and interspaces crossed by numerous, fine, rounded, radial costellae that extend to anterior margin. Eight to ten concentric rugae develop on mature shells, rugae not always continuous from one side of shell to other. Both valves strongly geniculate along anterior margin with geniculation less sharp laterally.

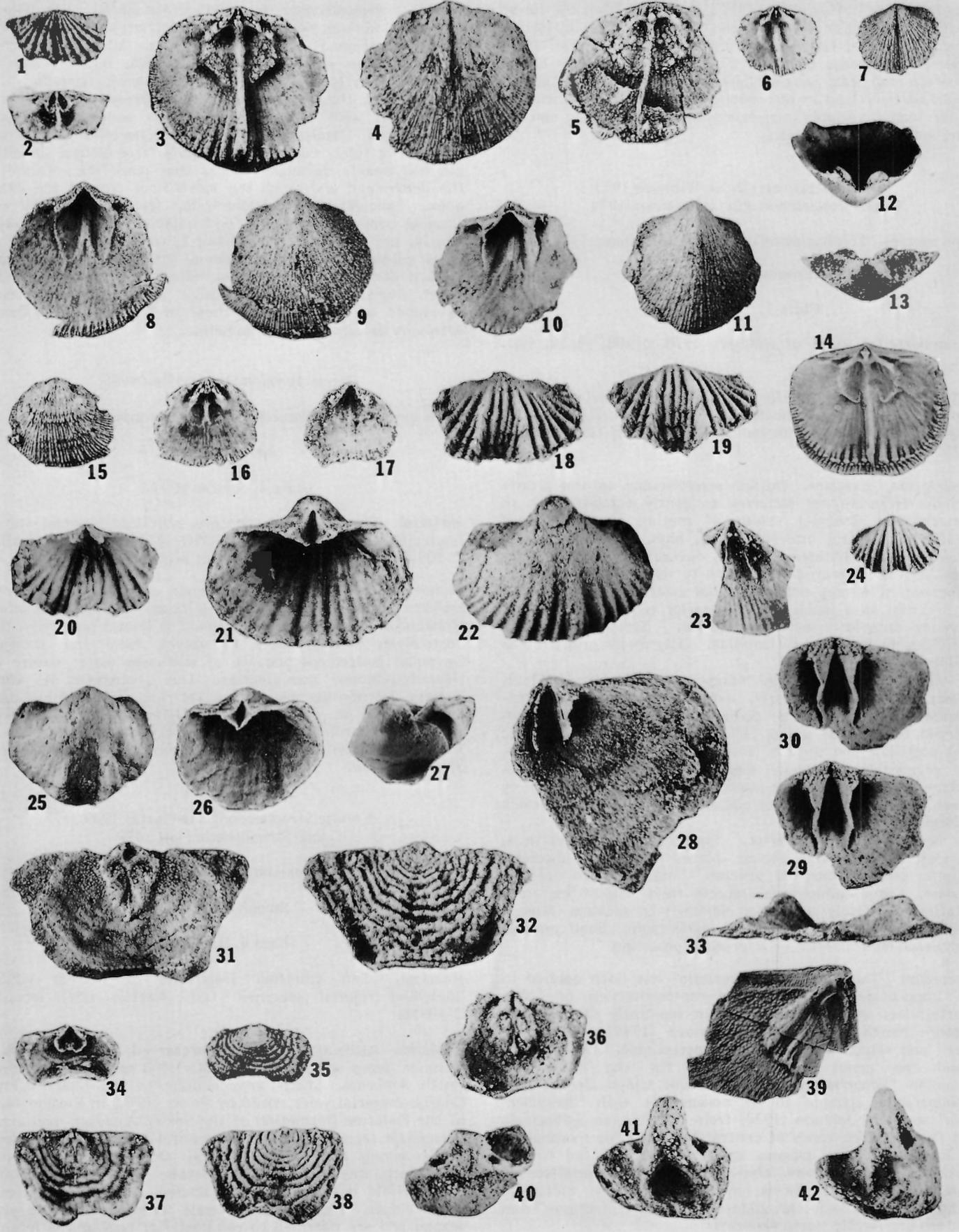
Pedicle valve interior. Hinge teeth blunt, prismlike, triangular in cross-section, directed anterodorsally, supported by prominent dental lamellae which join with the high muscle-bounding ridges that overhang valve floor both laterally and anteriorly. Muscle-bounding ridges define subtriangular muscle field that is divided anteriorly by broad, low myophragm. Adductor muscle scars narrow, elongate, confined to medial part of diductor field, bounded by low arcuate ridges posteriorly. Shell interior marked by impress of concentric rugae; and strongly pustulose anterior and lateral to muscle field.

Brachial valve interior. Sockets poorly defined, lacking distinct anterior bounding ridges, triangular shaped, expanding anterolaterally, located posterolateral to bases of cardinal process. Cardinal process lobes conjunct posterodorsally, broadly divergent anteriorly; lobes divided by an anteriorly deepening slit that develops into a subcircular pit in large shells. Whole cardinal process structure elevated on pyramidal pad of shell material. Subcircular posterior adductor muscle scars strongly impressed anterior to cardinal process in some shells, divided medially by low myophragm. Anterior adductors smaller, elongate, situated in deep pit anteromedially to posterior adductors, divided medially by low, threadlike, myophragm-septum structure that may extend to point of geniculation. Ventrally directed ridge developed at point of geniculation. Rugae strongly impressed anterolateral to muscle field. Anterolateral corners of shell strongly raised near point of geniculation. Geniculate fringe of shells smooth.

Discussion. *Leptagonia* is a cosmopolitan genus in Lower Devonian strata. *Leptagonia* has a pronounced ridge that rises above the shell floor at the point of geniculation whereas *Leptaena* lacks this ridge (Havlíček, 1967). Many shells from Lower Devonian beds of western North America referred to *Leptaena* probably belong to *Leptagonia*, although previous North American usage commonly has restricted the name *Leptagonia* to Carboniferous forms.

Plate 4

- Skenidioides* sp. (page 17)
Figures 1, 2. Exterior and interior views of brachial valve, GSC 43093; GSC loc. C-10958; X2.5.
- Cortezorthis* cf. *C. maclareni* Johnson and Talent (page 18)
Figures 3, 4. Interior and exterior views of brachial valve, GSC 43094, GSC loc. C-10958; X1.2.
Figure 5. Interior view of brachial valve, GSC 43095 from same locality; X1.2.
Figures 6, 7. Interior and exterior views of brachial valve, GSC 43096 from same locality; X1.5.
Figures 8, 9. Interior and exterior views of pedicle valve, GSC 43097 from same locality; X1.2.
Figures 10 - 13. Interior, exterior, oblique posterior and posterior views of pedicle valve, GSC 43098 from same locality; X1.2.
- Cortezorthis maclareni* Johnson and Talent (page 18)
Figure 14. Interior view of brachial valve, GSC 43878; Delorme Formation, 128 m below top, Mackenzie Mountains (lat. 63°16'45"N, long. 128°32'40"W); X1.1.
- Dalejina* sp. (page 18)
Figures 15, 16. Exterior and interior views of brachial valve, GSC 43099; GSC loc. C-10958; X1.2.
Figure 17. Interior view of pedicle valve, GSC 43100 from same locality; X1.2.
- Gypidula* sp. (page 18)
Figures 18 - 20. Exterior, anterior and interior views of brachial valve, GSC 43101; GSC loc. C-10958; X1.5.
Figures 21, 22. Interior and exterior views of pedicle valve, GSC 43102 from same locality; X1.2.
Figure 23. Interior view of brachial valve, GSC 43103 from same locality; X1.2.
Figure 24. Oblique anterior view of pedicle valve, GSC 43104 from same locality; X1.2.
- Carinagypa loweryi?* (Merriam) (page 19)
Figures 25 - 27. Exterior, interior and oblique interior views of pedicle valve, GSC 43105; GSC loc. C-10958; X1.2.
Figure 28. Interior view of fragment of brachial valve, GSC 43106 from same locality; X3. Note carina along right brachidial plate.
Figure 29, 30. Interior and oblique interior views of brachial valve, GSC 43107 from same locality; X3.
- Leptagonia* sp. (page 19)
Figures 31 - 33. Interior, exterior and posterior views of brachial valve, GSC 43108; GSC loc. C-10958; X1.2. Note the well developed ridge marking the geniculate fringe shown in Figs. 31, 33 and 36.
Figures 34, 35. Interior and exterior views of pedicle valve, GSC 43109 from same locality; X1.2.
Figure 36. Interior view of brachial valve, GSC 43110 from same locality; x1.2.
Figures 37, 38. Interior and exterior views of brachial valve, GSC 43111 from same locality; X1.2.
- Strophonella* sp. (page 22)
Figure 39. Interior view of fragment of pedicle valve, GSC 43116, GSC loc. C-10958; X1.
- Aespomum* sp. (page 22)
Figures 40 - 42. Posterior, interior and oblique interior views of brachial valve, GSC 43115; GSC loc. C-10958; X1.5.



The Mount Lloyd George *Leptagonia* is close to *Leptaena* sp. C of Johnson (1970), described from the lower Emsian *Acrospirifer kobehana* and *Eurekaspirifer pinyonensis* zones of central Nevada. A similar shell is known from upper Pragian beds of Royal Creek, Yukon and the Sekwi Mountain map area, western District of Mackenzie. Caution should be exercised in the speciation of *Leptagonia* because of its highly variable morphology that commonly can be observed in large collections.

Family Schuchertellidae Williams 1953
Genus *Eoschuchertella* Gratsianova 1974

Type species. *Eoschuchertella popovi* Gratsianova 1974.

Eoschuchertella sp.

Plate 5, figures 1 - 6

"*Schuchertella*" sp. B of Johnson, 1970, p. 108, Pl. 18, figs. 15 - 20.

Material. Twenty silicified, fragmentary brachial valves (including figured specimens GSC 43113, 43114) and 20 similar pedicle valves (including GSC 43112); GSC locality C-10958.

Description. Exterior. Outline semicircular, lateral profile variable from slightly biconvex to gently convexiplanar to planoconvex. Brachial valves of mature shells incurved anteriorly. Ventral interarea wide, high, apsacline, gently convex. Pseudodeltidium convex, covers two thirds delthyrium. Dorsal interarea very short to nonexistent, anacline. Ornament of strong, angular, radial costellae approximately 11 in 5 mm at a point 10 mm anterior to beak. Costellae increase anteriorly by intercalation. Small shells bear numerous distinct growth lamellae. Only major growth lines visible on large shells.

Pedicle valve interior. Hinge teeth prominent, blunt, strongly inclined anteriorly, extend from edges of delthyrium. Short, widely divergent dental lamellae restricted to apex of valve. Muscle field weakly impressed over posterior one third of shell, divided medially by wide, low myophragm probably marking site of adductor attachment. Shell interior smooth except near periphery where marked by impress of costellae. Shell substance thick in large and small shells.

Brachial valve interior. Sockets widely divergent, bounded by recurved socket plates that join medially forming base of cardinal process. Small, bilobed cardinal process. Large semicircular muscle field weakly impressed anteriorly, strongly impressed adjacent to sockets. Muscle field divided medially by weak myophragm. Shell interior crenulated near margins by impress of costellae.

Discussion. The name "*Schuchertella*" has been applied to the impunctate Early Devonian representatives of Schuchertellidae, which are common in the Early Devonian of western North America. Gratsianova (1974) revised the Early and Middle Devonian Schuchertellidae, and she proposed the genus *Eoschuchertella* for the impunctate Devonian "*Schuchertella*". The Mount Lloyd George *Eoschuchertella* appears to be conspecific with "*Schuchertella*" sp. B of Johnson (1970) from the Pragian *Spinoplasia* and *Trematospira* zones of central Nevada. The morphology of *Eoschuchertella* appears to be closely related to the depositional environment (thin-shelled forms in argillaceous beds, thick-shelled forms in higher energy bioclastic carbonates) in Lower Devonian brachiopod collections from western and Arctic North America.

Havlíček (1967, p. 202) proposed the Middle Devonian genus *Drahanostrophia* for impunctate shells with widely divergent, simple, nonconcave brachiophores. Savage (1971, p. 405) assigned a late Lochkovian Australian "*Schuchertella*"-type shell to *Drahanostrophia*, but his species *burrenensis* is better regarded as an *Eoschuchertella*. The type species, the only other described *Drahanostrophia*, is a small shell with simple brachiophores and much coarser costae than *Eoschuchertella*. *Eoschuchertella burrenensis* (Savage) is finely costellate and lacks true dental lamellae but has weakly developed ridges that mark the interior of the delthyrium and touch the valve floor only at the valve apex. Species of *Eoschuchertella*, from Lochkovian and Pragian beds of the Yukon and adjacent District of Mackenzie, are similar to the Mount Lloyd George species. In large collections of these species, the dental lamellae are weakly developed but in some specimens reach the valve floor slightly beyond the valve apex although never developed to the extent of those of *Iridistrophia*, a genus with very prominent dental lamellae.

Genus *Aesopomum* Havlíček 1965

Type species. *Strophomena aesopea* Barrande 1879.

Aesopomum sp.

Plate 4, figures 40 - 42

Material. Seventeen fragmentary, silicified brachial valves (including figured specimen GSC 43115); GSC locality C-10958. External ornament is not preserved.

Remarks. *Aesopomum* is a common element in the Lochkovian to Emsian faunas from the Yukon and the District of Mackenzie. In Nevada, *Aesopomum* is known only from the Lochkovian and probably is absent from the younger Devonian collections because of shallower water nature of their brachiopod communities. The Lochkovian *A. varistriatus* Johnson has discrete socket ridges and cardinal process whereas in younger (Pragian) *Aesopomum* the socket plates and cardinal process form a continuous structure. The Mount Lloyd George shells represent the Pragian form of *Aesopomum*.

Family Stropheodontidae Caster 1939
Genus *Strophonella* Hall 1879

Type section. *Strophomena semifasciata* Hall 1863.

Strophonella sp.

Plate 4, figure 39

Material. Ten silicified fragments of pedicle valves (including figured specimen GSC 43116); GSC locality C-10958.

Remarks. Although rarely well preserved, *Strophonella* is a common genus and stratigraphically long ranging in western North America. Shells very similar to the Mount Lloyd George material were noted by Perry (1974) in Emsian beds of the Delorme Formation of the Sekwi Mountain map area, Mackenzie Mountains. The fragmental Mount Lloyd George shells belong to a large, strongly resupinate *Strophonella* with sharp, inverted V-shaped costae. The ventral diductor muscle field is large, teardrop shaped, with well developed radial ridges. The adductor muscle scars are elongate oval shaped and are confined to the posterior half of the muscle field.

Genus *Megastrophia* Caster 1939

Type species. *Strophomena (Strophodonta) concava* Hall 1957.

Megastrophia iddingsi (Merriam)

Plate 5, figures 7 - 22

Stropheodonta demissa Walcott, 1884, p. 118, Pl. 2, figs. 9, 9a - b; not Contrad, 1842.

Stropheodonta iddingsi Merriam, 1940, p. 79, Pl. 6, fig. 6.

Megastrophia iddingsi (Merriam), Johnson, 1970, p. 122, Pl. 26, figs. 1 - 16.

Megastrophia n. sp. aff. *M. iddingsi*, Ludvigsen, 1970, Pl. 1, figs. 20, 21.

Material. A complete individual (figured specimen GSC 43119), nine brachial valves (including GSC 43117, 43121, 43122), forty-two pedicle valves (including GSC 43118, 43120) all moderately well preserved; GSC locality C-10958. Two well preserved brachial valves (GSC 43876, 43877) from the Delorme Formation of the Mackenzie Mountains are illustrated for comparative purposes (Pl. 5, figs. 21 - 22).

Description. Exterior. Outline subsemicircular to transversely suboval, moderately to strongly concavoconvex in lateral profile. Greatest convexity developed at ventral umbo, posterolateral slopes of ventral valves slightly concave. Maximum shell width developed at hinge line, cardinal angles commonly acute. Anterior commissure rectimarginate. Ventral interarea orthocline, wide, flat, moderately high, denticulate over whole length; dorsal interarea very low, slightly hypercline. Pseudodeltidium not preserved. Ornament finely parvicostellate, commonly with four to six secondary costellae between each primary. Shell substance thick.

Pedicle valve interior. Ventral process consists of a triangular protuberance in the apex of the beak, which is marked by a V-shaped depression on its anterior face. Suboval shaped adductor scars divided medially by a variably developed myophragm. Diductor muscle field consists of two widely divergent teardrop-shaped scars. Muscle bounding ridges prominent posteriorly where joined to interarea and continue anterolaterally as low muscle bounding ridges. Anterior to adductor field, the diductor field divided medially by a wide myophragm. Shell interior smooth.

Brachial valve interior. Cardinal process lobes stout, project strongly posteriorly, separated by a prominent cleft medially. Socket plates diverge at about 20 degrees from hinge line and abut against base of cardinal process. Anterior adductor scars elevated on a medial platformlike structure anteromedial to deeply impressed posterior adductor muscle scars, diverge slightly anteriorly and next converge medially near their anterior margin. Posterior adductor scars bounded posterolaterally by muscle ridges extending anteriorly from socket plates. Breviseptum divides anterior half of anterior adductors and extends variably up to three quarters shell length. Some shells clearly develop an anterior geniculation.

Discussion. *Megastrophia iddingsi* is common in Emsian beds at Royal Creek, Yukon, in the Sekwi Mountain map area, western District of Mackenzie and in the *Eurekaspirifer pinyonensis* zone of central Nevada. The occurrence near Mount Lloyd George indicates a late Pragian (approximately equivalent to early Emsian) age. Harper and Boucot (1978) show *Megastrophia* and *Phragmostrophia* as belonging to different families of stropheodontids. Homeomorphic tendencies of *M. iddingsi* and *Phragmostrophia merriami* have

been observed in numerous large collections of silicified material from Emsian beds of Delorme Formation. The total range of variation of the two shells appears to overlap. Fragmental material is often difficult to assign with confidence to one genus or the other. The most diagnostic features appear to be the more subsemicircular outline of *M. iddingsi* and the more prominent dorsal geniculation and development of a dorsal sulcus in *Phragmostrophia merriami*.

Family Pholidostrophidae Stainbrook 1943

Genus *Phragmostrophia* Harper, Johnson and Boucot 1967

Type species. *Phragmostrophia merriami* Harper, Johnson and Boucot 1967.

Phragmostrophia sp.

Plate 5, figure 23

Material. Three coarsely silicified fragmentary brachial valves (including figured specimen GSC 43123); GSC locality C-10958. *Phragmostrophia merriami* (GSC 43875; Pl. 5, fig. 24) from the Delorme Formation of the Mackenzie Mountains is illustrated for comparative purposes.

Remarks. *Phragmostrophia* is a common Cordilleran region genus with a stratigraphic range of upper Lochkovian to Pragian in the Yukon and in the adjacent District of Mackenzie. As previously mentioned, *P. merriami* and *M. iddingsi* are sometimes difficult to distinguish. The fragmental shells from the Mount Lloyd George region possibly may represent *P. merriami*.

Family Chonetidae Bronn 1862

Subfamily Parachonetinae Johnson 1970

Genus *Parachonetes* Johnson 1966

Type species. *Chonetes macrostriata* Walcott 1884.

Parachonetes macrostriatus? (Walcott 1884)

Plate 5, figures 25 - 27

Chonetes macrostriata Walcott, 1884, p. 126, Pl. 2, fig. 13(?), Pl. 13, figs. 14, 14a - c.

Chonetes macrostriata Walcott, Merriam, 1940, p. 55, Pl. 6, fig. 4.

Chonetes macrostriatus Walcott, Cooper, 1944, p. 345, Pl. 134, fig. 16.

Longispina macrostriatus (Walcott), Muir-Wood, 1962, p. 47.

Parachonetes macrostriatus (Walcott), Johnson, 1966, p. 367, Pl. 62, figs. 1 - 17, Pl. 63, figs. 1 - 3.

Parachonetes macrostriatus (Walcott), Johnson, 1970, p. 136, Pl. 32, figs. 1 - 18, Pl. 33, figs. 1 - 5.

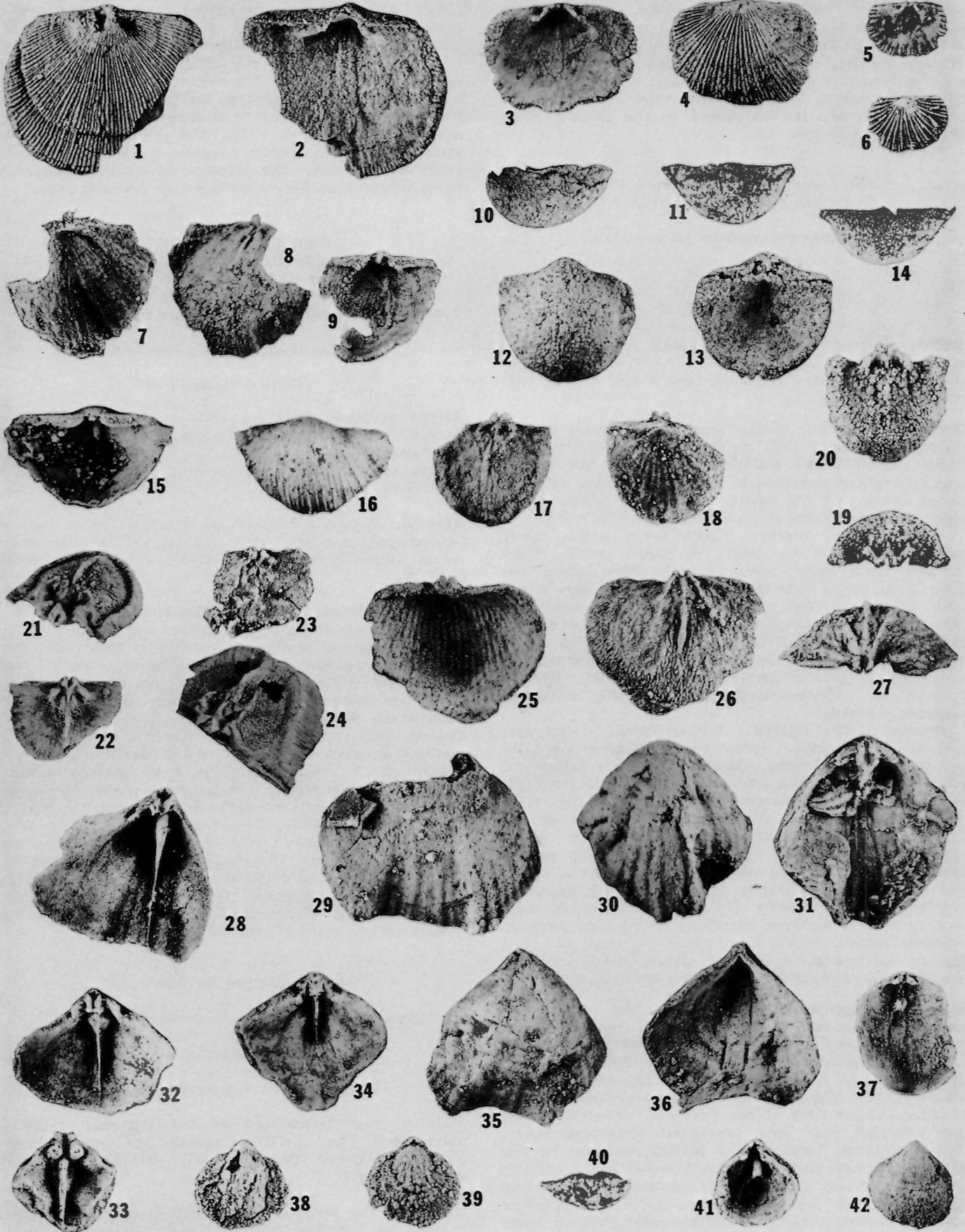
Parachonetes macrostriatus (Walcott), Ludvigsen, 1970, Pl. 2, figs. 4 - 8.

Material. One well preserved brachial valve (figured specimen GSC 43124); GSC locality C-10958.

Remarks. The single brachial valve bears widely divergent tooth sockets, the bilobed cardinal process is quadripartite in posterior view, and the lobes are widely separated basally by a broad, deep alveolus. The lateral septa and a strong median septum are well developed. The external ornament consists of low costae; bifurcation was not observed, although the costae are difficult to distinguish near the shell margins.

Plate 5

- Eoschuchertella* sp. (page 22)
- Figures 1, 2. Exterior and interior views of pedicle valve, GSC 43112; GSC loc. C-10958; X1.1.
- Figures 3, 4. Interior and exterior views of brachial valve, GSC 43113 from same locality; X1.1.
- Figures 5, 6. Interior and exterior views of brachial valve, GSC 43114 from same locality; X1.1.
- Megastrophia iddingsi* (Merriam) (page 23)
- Figures 7, 8. Exterior and oblique interior views of brachial valve, GSC 43117; GSC loc. C-10958; X1.3.
- Figure 9. Interior view of pedicle valve, GSC 43118 from same locality; x1.3.
- Figures 10 - 14. Lateral, anterior, ventral, dorsal and posterior views of complete specimen, GSC 43119 from same locality; X1.3.
- Figures 15, 16. Interior and exterior views of pedicle valve, GSC 43120 from same locality; X1.3.
- Figures 17, 18. Interior and exterior views of brachial valve, GSC 43121 from same locality; X1.3.
- Figures 19, 20. Posterior and interior views of brachial valve, GSC 43122 from same locality; X1.3.
- Figure 21. Interior view of brachial valve, GSC 43877; Delorme Formation, 128 m below top; Mackenzie Mountains (lat. 63°16'45"N, long. 128°32'40"W); X1.4.
- Figure 22. Interior of gerontic brachial valve, GSC 43876; Delorme Formation, from same locality as Fig. 21; X1.4.
- Phragmostrophia* sp. (page 23)
- Figure 23. Interior view of brachial valve, GSC 43123; GSC loc. C-10958; X1.5.
- Phragmostrophia merriami* Harper, Johnson and Boucot (page 23)
- Figure 24. Oblique interior view of brachial valve, GSC 43875; Delorme Formation, 449 m below top; Mackenzie Mountains (lat. 63°16'45"N, long. 128°32'40"W); X1.3.
- Parachonetes macrostriatus?* (Walcott) (page 23)
- Figures 25 - 27. Exterior, interior and posterior views of brachial valve, GSC 43124; GSC loc. C-10958; X2.
- Athyrrhynchus* sp. (page 26)
- Figure 28. Interior view of brachial valve, GSC 43125; GSC loc. C-10958; X2. Note variable development of dorsal cardinalia shown in Figs. 28, 31, 34.
- Figure 29. Exterior view of fragment of pedicle valve, GSC 43126 from same locality; X1.2.
- Figures 30, 31. Exterior and interior views of brachial valve, GSC 43127 from same locality; X1.2.
- Figure 32. Interior view of brachial valve, GSC 43128 from same locality; X1.2.
- Figure 33. Interior view of cardinalia of brachial valve, GSC 43129 from same locality; X2.
- Figure 34. Interior of brachial valve, GSC 43130 from same locality; X1.2.
- Figures 35, 36. Exterior and interior views of pedicle valve, GSC 43131 from same locality; X1.2.
- Lissatrypa?* sp. (page 34)
- Figure 37. Interior view of brachial valve, GSC 43166; GSC loc. C-10958; X2.
- Figures 38 - 40. Ventral, dorsal and lateral views of complete specimen, GSC 43167 from same locality; X3.
- Figures 41, 42. Interior and exterior views of pedicle valve, GSC 43168 from same locality; X3.



Parachonetes macrostriatus is well known from Emsian beds in central Nevada (Johnson, 1966, 1970), of the Michelle Formation, northern Yukon (Ludvigsen, 1970), of the Road River Formation at Royal Creek, northern Yukon (Lenz and Pedder, 1972) and of the Delorme Formation of the Sekwi Mountain map area, Mackenzie Mountains (Perry, 1974). The taxon is not known from older beds in western North America and its occurrence in the present fauna indicates an Emsian age.

Family Leiorhynchidae Stainbrook 1945
Genus *Athyrrhynchus* Johnson 1973

Type species. *Athyrrhynchus susanae* Johnson 1973.

Athyrrhynchus sp.

Plate 5, figures 28 - 36

Material. Fifteen fragmentary brachial valves (including figured specimens GSC 43125, 43127-43130), five fragmentary pedicle valves (including GSC 43126, 43131); GSC locality C-10958.

Description. Exterior. Shells large, dorsibiconvex; mature individuals with thick shell material. Dorsal fold low, flat topped, ventral sulcus shallow. Dorsal fold and ventral sulcus ornamented anteriorly by three to five low, wide and rounded costae. On the flanks, two to four costae of low amplitude are discernible only adjacent to anterior margin.

Pedicle valve interior. Hinge teeth small, rarely preserved, supported by poorly developed dental ridges extending from short apical dental plates along the delthyrial opening of the shell. Dental plates very short, usually encased in shell callus. Ventral muscle field very weakly impressed, elongate, oval shaped. Gonadal sacs weakly impressed around the muscle field. Vascular media extend short distance anteriorly from area of gonadal sac development as pair of parallel grooves. Pallial markings not preserved. Anterior margin of shell weakly crenulated by impress of costae.

Brachial valve interior. Sockets small, cylindrical, directed anterolaterally. Socket ridges attached to outer hinge plates whose medial edges bend dorsally joining the median septum forming a shallow septalium. Mature shells have well developed subparallel callus deposits that mark site of diductor muscle attachment on lateral flanks of septalium. Rod-shaped crura attached to anterior end of cardinal process-septalium wall structure. Median septum prominent and extends variable distance anteriorly, sometimes even beyond midlength; commonly greatly thickened posteriorly in mature shells. Dorsal adductor muscle scars triangular shaped, expanded anteriorly and divided medially by median septum. Muscle scars either impressed into shell callus or bounded by a pair of muscle-bounding ridges. Posterior and anterior adductor scars not differentiated.

Discussion. *Athyrrhynchus* recently has been documented widely in Emsian beds of the Cordilleran region and also shown to be present in the Arctic Islands [*Athyrrhynchus* sp., Michelle Formation, northern Yukon (Johnson, 1973); *Athyrrhynchus* sp., Emsian beds of the Ogilvie Formation, northern Yukon (Perry et al., 1974); *Athyrrhynchus* spp., mid-upper Pragian beds of the Delorme Formation of the Sekwi Mountain map area, Mackenzie Mountains (Perry, 1974); *A. susanae*, *Eurekaspirifer pinyonensis* Zone, Nevada and Disappointment Bay Formation, Lowther Island, District of Franklin (Johnson, 1973); also Emsian beds of the Delorme Formation of the Sekwi Mountain map area, Mackenzie Mountains (Perry, 1974)]. A slightly older Pragian leiorhynchid occurs in the Delorme Formation of the District of Mackenzie and in the Road River Formation at Royal Creek,

Yukon and probably belongs to *Athyrrhynchus*. The Mount Lloyd George *Athyrrhynchus* differs from *A. susanae* by its greater number of marginal costae and the absence of a dorsal furrow. The older *Athyrrhynchus* species known from the Delorme Formation are either smooth or with much more prominent costae. The Mount Lloyd George specimens have a much thicker shell than the Delorme shells, but shell thickness has been shown to be a highly variable feature in *Athyrrhynchus* (Johnson, 1973). The present material is not assigned to a new species because of the lack of better preserved material. The presence of *Athyrrhynchus* in the fauna indicates probably mid-Pragian to Zlichovian age.

Family Atrypidae Gill 1871
Subfamily Atrypinae Gill 1871
Genus *Atrypa* Dalman 1828

Type species. *Anomia reticularis* Linné 1758.

Atrypa cf. *A. nevadana* Merriam 1940

Plate 6, figures 1 - 9

Atrypa nevadana Merriam, 1940, p. 83, Pl. 7, figs. 18, 19.
Atrypa nevadana Merriam, Cooper, 1944, p. 319, Pl. 121, figs. 6, 7.

Atrypa nevadana Merriam, Johnson, 1970, p. 156, Pl. 41, figs. 5 - 17.

Material. Sixty-one fragmentary brachial valves (including figured specimens GSC 43133, 43134, 43137), fifty pedicle valves (including GSC 43132, 43135, 43136); GSC locality C-10958.

Remarks. *Atrypa* cf. *A. nevadana* is characterized by its large size, slightly elongate outline and its strongly dorsibiconvex lateral profile. A shallow ventral sulcus and a corresponding dorsal fold develop anteriorly. Strong radial costellae (7-9 costae in 5 mm at a point 10 mm anterior to beak) are crossed by well developed growth lines that occasionally are extended anteriorly to produce frills. The ventral hinge teeth have an elliptical outline and are directed anteromedially. Small shells have short, widely divergent dental lamellae; however, these are obsolescent in large shells. The ventral adductor scars are small, elongate, oval shaped and are confined to posterior two thirds of the large suboval, radially striated diductor field. The lateral flanks of the diductor field are slightly raised and bear pustulose ornament. The dorsal sockets are divided by a diagonal, corrugated ridgelike structure. A rounded myophragm extends anteriorly from the notothyrial platform (site of diductor attachment) and divides the large oval-shaped, radially striated adductor muscle field.

Genus *Spinatrypa* Stainbrook 1951

Type species. *Atrypa aspera* var. *occidentalis* Hall 1858.

Spinatrypa sp.

Plate 6, figures 10 - 12

Material. Five broken and abraded fragments of brachial valves and five similar fragments of pedicle valves (including figured specimens GSC 43138, 43139); GSC locality C-10958.

Remarks. The shells are large with broad, rounded costae crossed by lamellose growth lines. Costae occasionally extend anteriorly as tubelike spines. Costae increase by both bifurcation and implantation. The brachial valve has

large, deep, strongly corrugated sockets. The dorsal muscle field is subcircular in outline, strongly impressed and divided medially by a prominent myophragm.

Similar very coarsely ribbed shells have been recovered from mid-upper Pragian beds at Royal Creek, Yukon and in the Sekwi Mountain map area, District of Mackenzie. The shell ornamentation is very similar to *S. curvirostra* Copper (1967), although the material at hand does not permit detailed comparison.

Genus *Spinatrypina* Rzhonsnitskaya 1964

Type species. *Spinatrypina margaritoides* Rzhonsnitskaya 1964.

Spinatrypina symmetrica n. sp.

Plate 6, figures 13 - 30

Diagnosis. A *Spinatrypina* whose costae increase symmetrically by implantation on the brachial valve and by bifurcation on the pedicle valve.

Material. Four complete individuals (including holotype GSC 43140, paratype GSC 43143), 140 fragmentary brachial valves (including paratypes GSC 43144, 43146, 43147), 95 fragmentary pedicle valves (including paratypes GSC 43141, 43142, 43145); GSC locality C-10958.

Description. Exterior. Mature shells approximately 20 mm in both length and width, slightly longer than wide, with a gently dorsibiconvex lateral profile. Ventral interarea small, flat, erect, pierced apically by circular foramen. Deltidial plates conjunct anteriorly bounding the foramen in large shells. Rounded, shallow ventral sulcus and an accompanying dorsal fold developed near anterior margin. Hinge line short, about one third maximum width. Ornament of high-tubular-imbricate costae separated by deep interspaces. Tubular-imbricate pattern develops from ventral median pair of costae and a dorsal median costa. Costae increase regularly over anterior two thirds of shell. New costae appear at approximately the same growth position, symmetrically on both flanks of shell. Concentric ornament of lamellose growth lines, closely set and regularly spaced except near anterior margin where much closer and more prominent.

Pedicle valve interior. Hinge teeth prominent, oval shaped in plan view, strongly directed laterally. Small shells bear short, but distinct dental lamellae with open lateral chambers although these become obsolescent due to callus infilling in mature shells. Muscle field teardrop shaped, moderately impressed and surrounded by pustulose shell callus anterior to muscle field. Adductor scars narrow, elongate, confined to median part of the much larger diductor field.

Brachial valve interior. Sockets deep, strongly corrugated, anterolaterally divergent, closely set together posteromedially. Prominent diagonal ridge extends along the posterolateral side of socket. Low, rounded myophragm with medial groove extends anteriorly from notothyrial callus infilling. Elongate, oval-shaped, strongly impressed pair of muscle scars situated lateral to myophragm and surrounded by a large teardrop-shaped, radially striated muscle field that appears to bear two pairs of adductor muscles. Evidence of the cardinal process structure described in German Middle Devonian shells of *Spinatrypina* by Copper (1967) not preserved in notothyrial cavity of the Mount Lloyd George shells. Lateral flanks of muscle field bear pustulose ornament. Shell interior weakly corrugated by impress of costae in some shells.

Discussion. The tubular-imbricate ornament clearly shows the affinity of the shell to *Spinatrypina*. The shell is closely comparable to *S. asymmetrica* Johnson and Flory from the Eifelian of Nevada. The Nevada taxon is smaller, has less prominent, more numerous costae and shows a pronounced curvature of the dorsal median costa, a feature not developed in *S. symmetrica* n. sp. The German Middle Devonian representatives of *Spinatrypina* illustrated by Copper (1967) do not develop the high, more widely spaced costae nor do they have the more elongate outline of *S. symmetrica*. The presence or absence of dental lamellae or lateral cavities in *S. symmetrica* is shown to be a function of ontogenetic development. Copper (1967, p. 515) emphasized the presence of disjunct deltidial plates as characteristics of *Spinatrypina*. The presence or absence of disjunct deltidial plates is regarded here as a function of ontogenetic stage of development. There appears to be a conflict of usage in the literature regarding the use of the terms conjunct and disjunct deltidial plates. Shells described as having disjunct deltidial plates show the development of an apical foramen that by definition is bounded anteriorly by a rim of shell material (see Johnson and Flory, 1972, Pl. 1, figs. 7, 8; Copper, 1967, p. 515, 517).

The genus *Spinatrypina* is known from Pragian age beds of the Delorme Formation in the Sekwi Mountain map area. Other occurrences have not been reported from western North American Lower Devonian strata, but this probably is the result of inclusion of *Spinatrypina* with *Spinatrypa* (sensu lato) in faunal lists.

Copper (1967) and Johnson and Flory (1972) noted the occurrence of *Spinatrypina* in Rassenriff-type faunas (communities dominated by one or two species of atrypcean brachiopods and branching tabulate corals of the *Thamnopora* and *Syringopora* types with these elements comprising more than 90 per cent of the total shelly fauna). Pragian beds of the Delorme Formation and the Mount Lloyd George collection record the presence of the genus in deeper water, more diverse Benthic Assemblage 4 to 5 (sensu Boucot, 1975) communities of the *Vagrana-Skenidioides* type rather than being restricted to shallow, quiet waters of Benthic Assemblage 2 to 3 position.

Genus *Reticulatrypa* Savage 1970

Type species. *Reticulatrypa fairhillensis* Savage 1970.

Reticulatrypa? sp.

Plate 6, figures 31 - 36

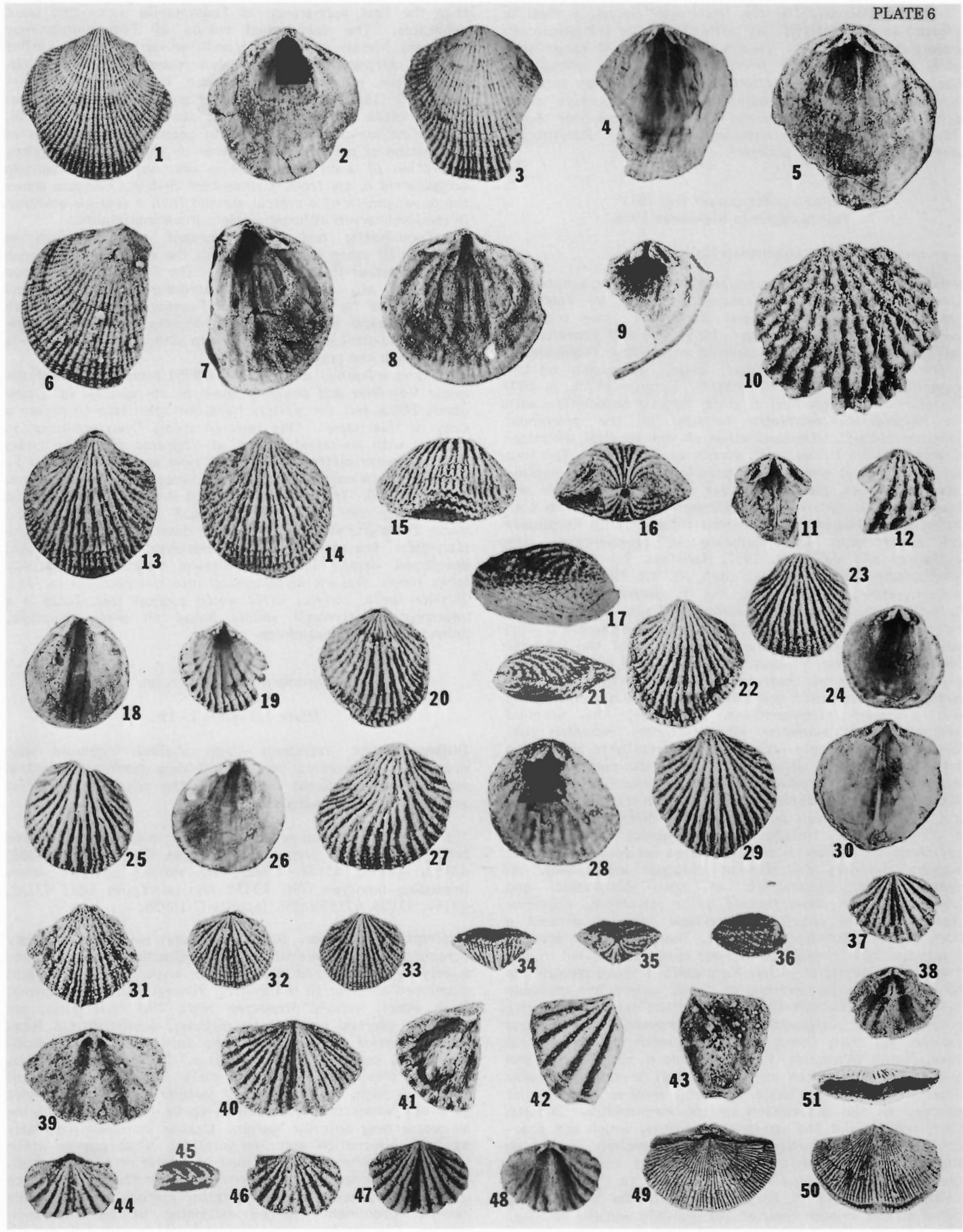
Material. Complete individual (figured specimen GSC 43149), four brachial valves and fragments of three pedicle valves (including GSC 43148); GSC locality C-10958.

Remarks. Although represented by only a few poorly preserved shells, the taxon clearly is separable from the other atrypids in the collection. Small shells have a shallow dorsal sulcus and a low ventral fold. The ventral beak is erect and small hinge teeth are supported by short (usually obsolescent) dental lamellae. Costae commonly increase by bifurcation and occasionally by intercalation.

The genus *Reticulatrypa* was proposed by Savage (1970) for Atrypinae of subcircular outline with shallow ventral fold and dorsal sulcus, a finely reticulate ornament of closely spaced growth lamellae, and a straight to suberect ventral beak. A few representatives of the genus are known from lower Devonian beds at Royal Creek, Yukon and in the Delorme Formation, District of Mackenzie.

Plate 6

- Atrypa* cf. *A. nevadana* Merriam (page 26)
- Figures 1, 2. Exterior and interior views of pedicle valve, GSC 43132; GSC loc. C-10958; X1.2.
- Figures 3, 4. Exterior and interior views of brachial valve, GSC 43133 from same locality; X1.2.
- Figure 5. Interior view of brachial valve, GSC 43134 from same locality; X1.2.
- Figures 6, 7. Exterior and interior views of pedicle valve, GSC 43135 from same locality; X1.2.
- Figure 8. Interior view of pedicle valve, GSC 43136 from same locality; X1.2.
- Figure 9. Oblique interior view of brachial valve, GSC 43137 from same locality; X1.2.
- Spinatrypa* sp. (page 26)
- Figure 10. Exterior view of pedicle valve, GSC 43138; GSC loc. C-10958; X1.
- Figures 11, 12. Interior view of pedicle valve, GSC 43139 from same locality; X1.
- Spinatrypina symmetrica* n. sp. (page 27)
- Figures 13 - 17. Dorsal, ventral, anterior, posterior and lateral views of holotype, GSC 43140; GSC loc. C-10958; X1.3.
- Figure 18. Interior view of pedicle valve, paratype GSC 43141 from same locality; X1.3.
- Figure 19. Interior view of pedicle valve, paratype GSC 43142 from same locality; X1.3.
- Figures 20 - 22. Dorsal, lateral and ventral views of complete paratype GSC 43143 from same locality; X1.3.
- Figures 23, 24. Exterior and interior views of brachial valve, paratype GSC 43144 from same locality; X1.3.
- Figures 25, 26. Exterior and interior views of pedicle valve, paratype GSC 43145 from same locality; X1.3.
- Figures 27, 28. Exterior and interior views of brachial valve, paratype GSC 43146 from same locality; X1.3.
- Figures 29, 30. Exterior and interior views of brachial valve, paratype GSC 43147 from same locality; X1.3.
- Reticulatrypa?* sp. (page 27)
- Figure 31. Exterior view of pedicle valve, GSC 43148; GSC loc. C-10958; X1.2.
- Figures 32 - 36. Dorsal, ventral, anterior, posterior and lateral views of complete individual, GSC 43149 from same locality; X2.
- Biconostrophia* sp. (page 34)
- Figures 37, 38. Exterior and interior views of brachial valve, GSC 43161; GSC loc. C-10958; X1.5.
- Figures 39, 40. Interior and exterior views of brachial valve, GSC 43162 from same locality; X1.5.
- Figure 41. Interior view of fragment of pedicle valve, GSC 43163 from same locality; X1.5. Note raised area medially marking spiralia impression.
- Figures 42, 43. Exterior and interior views of fragment of pedicle valve, GSC 43164 from same locality; X1.5.
- Figures 44 - 46. Dorsal, lateral and exterior views of small shell, GSC 43165 from same locality; X2.
- Figures 47, 48. Exterior and interior views of brachial valve, GSC 43875; Delorme Formation, 449 m below top; Mackenzie Mountains (lat. 63°16'45"N, long. 128°32'40"W); X2.8.
- Davidsoniatrypa johnsoni* Lenz (page 34)
- Figures 49 - 51. Dorsal, ventral and anterior views of complete individual, GSC 43873; Delorme Formation, 337 m below top; Mackenzie Mountains (lat. 63°18'18" N, long. 128°32'40"W); X1.1. In Fig. 51 note spiral cones marking impressions of the spiralia.



In the discussion of the brachiopod fauna, a shell is referred to *Punctatrypa?* sp. with affinity to the species *P. granulifera* (Barrande). Savage (1970, p. 663) noted that some shells which had been assigned to *P. granulifera* (Barrande) are in fact *Reticulatrypa* in that they lack the concentric rows of spine bases in the shell structure which give the 'punctate' appearance. The shells from near Mount Lloyd George that are questionably referred to *Punctatrypa* have clearly developed 'punctae'.

Subfamily Atrypinae? Gill 1871
Genus *Vagrana* Alekseeva 1959

Type species. *Atrypa kolymensis* Nalivkin 1936.

Remarks. Johnson (1967) concluded that the long subparallel structures termed "long vascular ridges" in *Vagrana*, *Toquimaella*, *Eokarpinskia* and *Karpinskia* were probably homologous and later Johnson (1969) assigned *Vagrana*, as well as its morphologically related antecedent *Toquimaella*, to the Subfamily Karpinskiinae, largely apparently on the possession of "long vascular ridges". Copper (1973b, p. 487) also placed the vagraniids in close familial association with the karpinskiids seemingly because of the prominent "vascular ridges". Reexamination of the familial affinities of these genera raises some doubts in our minds. The four genera do indeed possess long parallel ridges in the pedicle valve. However, these ridges are relatively low, wide and possess a somewhat inverted V-shaped cross-section in both *Vagrana* and *Toquimaella*, whereas those of both *Karpinskia* and *Eokarpinskia* are bladelike in cross-section (see Nikiforova and Yakovlev, 1937, Textfigs. 7-1 to 7-10 for *Eokarpinskia*; Tschernyschew, 1885, Pl. VII, figs. 81 and 86; Tschernyschew, 1893, Pl. IX, fig. 1, Bublitschenko, 1928, Pl. XLIX, figs. 1a-g, 6a-b; Rzhonsnitskaya, 1960, fig. 326 and Johnson, 1967, Pl. III, fig. 6 for *Karpinskia*). This question of the form of the cross-section of the vascular ridge and their relative lengths is not in itself decisive in our opinion as one group could be characterized by forms with bladelike cross-sections and still give rise to a second group with V-shaped cross-sections. However, the brachial cardinalia show evidence which strongly indicates that *Eokarpinskia* is closely allied morphologically to *Karpinskia* and that neither genus has much in common with *Toquimaella* or *Vagrana*. The brachial cardinalia of both *Toquimaella* and *Vagrana*, as illustrated in the present paper as well as by previous workers, is little different from that of *Atrypa* itself. Notable in the brachial valve are the crenulated sockets and a depressed area between the sockets probably marking the site of diductor attachment. In contrast, the illustrations of both *Karpinskia* and *Eokarpinskia* are characterized by a prominent, posterior bosslike area for diductor attachment (with or without a short, median, bladelike structure). The presence or absence of atrypid-type crenulated sockets is not mentioned in any of the descriptions of either *Karpinskia* or *Eokarpinskia* and the published serial sections of these genera are probably inadequate to illustrate these crenulations even if they were present. Both *Karpinskia* and *Eokarpinskia* lack lateral branches on their "long vascular ridges" in the ventral valve. Some vagraniids (*V. atrypiforma* n. sp., *V. sp. 2* and *V. sp. 3* of the present paper) bear well developed vascular ridges in the dorsal valve as well, another feature not recorded in the description of the karpinskiids. Johnson (1967) pointed out the unbranched costae, which are characteristic of *Toquimaella*; the genus essentially is nothing more than a *Vagrana* with unbranched costae. These unbranched costae were held by Johnson to be a feature allying *Toquimaella* to *Karpinskia*. But, the lack of any costae on the smooth shell of *Eokarpinskia* and the development of unbranched costae in *Karpinskia* at a time later

than the first appearance of *Toquimaella* make this point debatable. The unbranched costae of *Toquimaella* may represent merely a neotonic condition derived from earlier Silurian *Atrypa*, and the problem dissolves. Further obscuring the issue is the presence in some of Tschernyschew's (1885) *Karpinskia* specimens of anteriorly bifurcating costae (see also Boucot et al., 1969, Pl. 8, figs. 16, 18). Most atrypaceans possessing costae show evidence of bifurcation at one stage or another so that the independent derivation of such characters is not surprising. *Vagrana atrypiforma* n. sp. from northeastern British Columbia shows the development of a typical atrypid frill, a feature unknown in the karpinskiids although present in carinatininids.

Toquimaella and its descendant relatives such as *Vagrana* fit more comfortably into the subfamily Atrypinae than into either the Karpinskia or the Carinatininae (where Boucot et al., 1965, placed *Vagrana*; see Johnson and Boucot, 1972 for a later view). Furthermore, *Eokarpinskia* and *Karpinskia* are most likely derived from one of the Silurian smooth Lissatrypidae genera although which genus is uncertain at the present time.

Rzhonsnitskaya and Mizens (1975) recently revised the genus *Vagrana* and assigned some of its species to a new genus *Totia*, but the writers have not been able to obtain a copy of this paper. This revision stems from confusion in dealing with so-called 'types' of *Vagrana* from the Urals that are quite different from the type species collected by Nalivkin from northeastern Arctic Siberia (P. Copper, pers. comm., 1975). The material at hand is assigned to *Vagrana* because the only other paper available to us employing the name *Totia* (Rzhonsnitskaya, 1975) does not make clear the diagnostic features of *Totia*; however, *Totia* has well developed dental lamellae whereas *Vagrana* essentially lacks them. Recent investigation into the problem by J.G. Johnson (pers. comm., 1976) would suggest that *Totia* is a vagraniid homeomorph which, based on shell structure, belongs to the carinatininids.

Vagrana atrypiforma n. sp.

Plate 7, figures 1 - 19

Diagnosis. An extremely thick shelled vagraniid with coarse, high, rounded costae and very prominent ventral vascular ridges. Some shells show the development of an atrypid-type peripheral flange.

Material. One hundred fragmentary but well preserved brachial valves (including paratypes GSC 43150, 43152, 43153, 43155, 43158-43160), 60 similar pedicle valves (including holotype GSC 43151 and paratypes GSC 43152, 43154, 43156, 43157); GSC locality C-10958.

Description. Exterior. Shell subcircular in outline, strongly dorsibiconvex in lateral profile. Brachial valve curves evenly from posterior to anterior with maximum height developed anterior to midlength. Ventral valve less convex. Beak erect, ventral interarea high, flat, triangular, orthocline, pierced apically by circular, subhypothyrid foramen. Anterior margin of foramen defined by pair of small triangular, conjunct deltidial plates. Deltidial plates thin, delicate, only preserved in one shell. Ornament consists of 14 to 26 high, rounded radial costae. Costae interspaces generally wider on dorsal valves, up to two times as wide as costae near anterior margin. Costae increase irregularly by both bifurcation and implantation. Most costae which increase by bifurcation confined to posterior part of shell. Concentric ornament of prominent, sometimes imbricate growth lines developed near anterior margin. A few shells develop prominent flanges extending beyond the shell margin. Flanges bear more subdued costae and lack growth lines.

Pedicle valve interior. Hinge teeth massive, stout, triangular in cross-section, project dorsally well above the plane of commissure, attached to anterolateral edges of delthyrium. Distinct dental lamellae only observed in small immature shells, commonly encompassed in shell callus. Ventral muscle field strongly impressed; subtriangular in outline, bounded laterally by prominent ridges extending anteriorly from base of hinge teeth and bounded anteriorly, near midlength, by a high ridge. Adductor and diductor fields not clearly differentiated, although adductor field appears broad and flanked laterally by very narrow diductor scars. Set of high subparallel ridges extend anteriorly from the corners of the muscle field representing the vascular media. At least two secondary pairs of vascular ridges extend anterolaterally from the primaries. Shell interior marked by impress of costae only near anterolateral margins.

Brachial valve interior. Sockets deep, elongated and expanded anterolaterally. Socket plates recurve posterodorsally covering the posteromedial end of sockets. Sockets strongly corrugated by typical atrypiform ridges and grooves. Socket plates firmly welded to posterior shell wall and are clearly disjunct posteromedially, separated medially by a prominent U-shaped groove. Dorsal muscle field varies from weakly impressed pair of oval-shaped scars divided by a medial myophragm to a very strongly impressed pair of elongate oval-shaped scars elevated on a highly anteriorly overhanging muscle platform divided medially by a prominent myophragm that dies out anteriorly. A few shells appear to show a muscle field differentiated into small posterior and large anterior adductors separated by a low anterolaterally directed ridge. Fine longitudinal striations discernible on one dorsal muscle field. Shell interior variably corrugated by impress of costae. Some shells bear a pair of subparallel vascular ridges extending anteriorly from the anterolateral corners of muscle field, and these bifurcate at least once. Vascular ridges are much less strongly impressed than on ventral valve.

Discussion. The genus *Vagrana* is well known in the Pragian and Emsian of northwestern and arctic Canada and from Eifelian beds in central Nevada and *Vagrana atrypiforma* n. sp. is an important element in dating the Mount Lloyd George fauna by comparison with the sequence of vagraniids known from northwestern Canada. The oldest member of the lineage in northern Canada is *Toquimaella kayi* Johnson (see Pl. 7, figs. 35-38), which first appears within the lower part of the *Spirigerina* Unit (equivalent to the *Quadrithyris* Zone) in the Delorme Formation of the Sekwi Mountain map area, District of Mackenzie (Perry, 1974) and at Royal Creek, Yukon. *Toquimaella kayi* is elongate to subrounded in outline, bears numerous, narrow, nonbifurcating costae, strongly impressed vascular markings in the ventral valve, variably impressed dorsal musculature and has a relatively thin shell. Late forms of *T. kayi* within the *Spirigerina* Unit of the Delorme Formation develop coarser costae and occasionally show costae bifurcation near the anterior margin. *Toquimaella kayi* is succeeded in younger lower Pragian beds by *V. cf. V. intermediafera* (Khodalevich) both at Royal Creek and in the Sekwi Mountain map area. *Vagrana cf. V. intermediafera* bears coarser costae that bifurcate regularly, has a larger overall size and a thicker shell (see Pl. 7, figs. 26-30) than *T. kayi*. *Vagrana cf. V. intermediafera* closely resembles *V. gronbergi*, an Eifelian taxon described from central Nevada by Johnson (1968). The primary differences between these two taxa are the absence of dental lamellae, smaller size and less complex vascular markings of the Nevada shell. *Vagrana cf. V. intermediafera* is succeeded by a younger Late Pragian or earliest Emsian species, *Vagrana* sp. 3 (of Perry, 1974) from the Delorme Formation, which has very coarse ribs and a thick shell (see Pl. 7, figs. 31-34). This taxon only rarely displays costal increase by either bifurcation or intercalation. *Vagrana atrypiforma* n. sp. most closely compares

to *Vagrana* sp. 3 from the Delorme Formation but is distinguished by its more irregular costal increase; greater abundance of costae, larger size and the development of the marginal flange. Dorsal vascular markings are found in some specimens of both species. *Vagrana* sp. 2 from 'upper' Emsian beds of Ogilvie Formation, northern Yukon is subtriangular in outline, bears very prominent rounded costae, has a much more complex system of vascular markings and has an ornament of fine 'dimples' on the shell interior. Overall evolutionary trends within the vagraniids from northwestern Canada are marked increase in shell size, larger costae, thicker shell material and irregular costal increase.

Vagrana atrypiforma n. sp. is readily distinguished from *V. intermediafera* (Khodalevich, 1951) by its less regular costal increase and by its larger costae and thicker shell. The type species, *V. kolymensis* (Nalivkin) as illustrated by Cherksova (1969), has a more elongate outline, similarly sized costae appear to bifurcate more often than on *V. atrypiforma* n. sp., and a much more complex vascular system is developed and is covered with 'dimples' as in the 'late' Emsian *Vagrana* sp. 2 from the Ogilvie Formation. The close relationship of the shell interiors of *Vagrana* and *Mimatrypa* is shown by Cherksova's (1969) illustrations.

The Mount Lloyd George shells are suggested to be of late Pragian age (approximately equivalent to early Emsian), based on the gross phylogenetic relationships understood for the vagraniids of northwestern Canada. The collection from GSC locality C-10958 also includes fragments of another large vagraniid with regularly bifurcating, high, narrow costae, somewhat reminiscent of *V. intermediafera*.

Vagrana sp. 2

Plate 7, figures 20 - 25

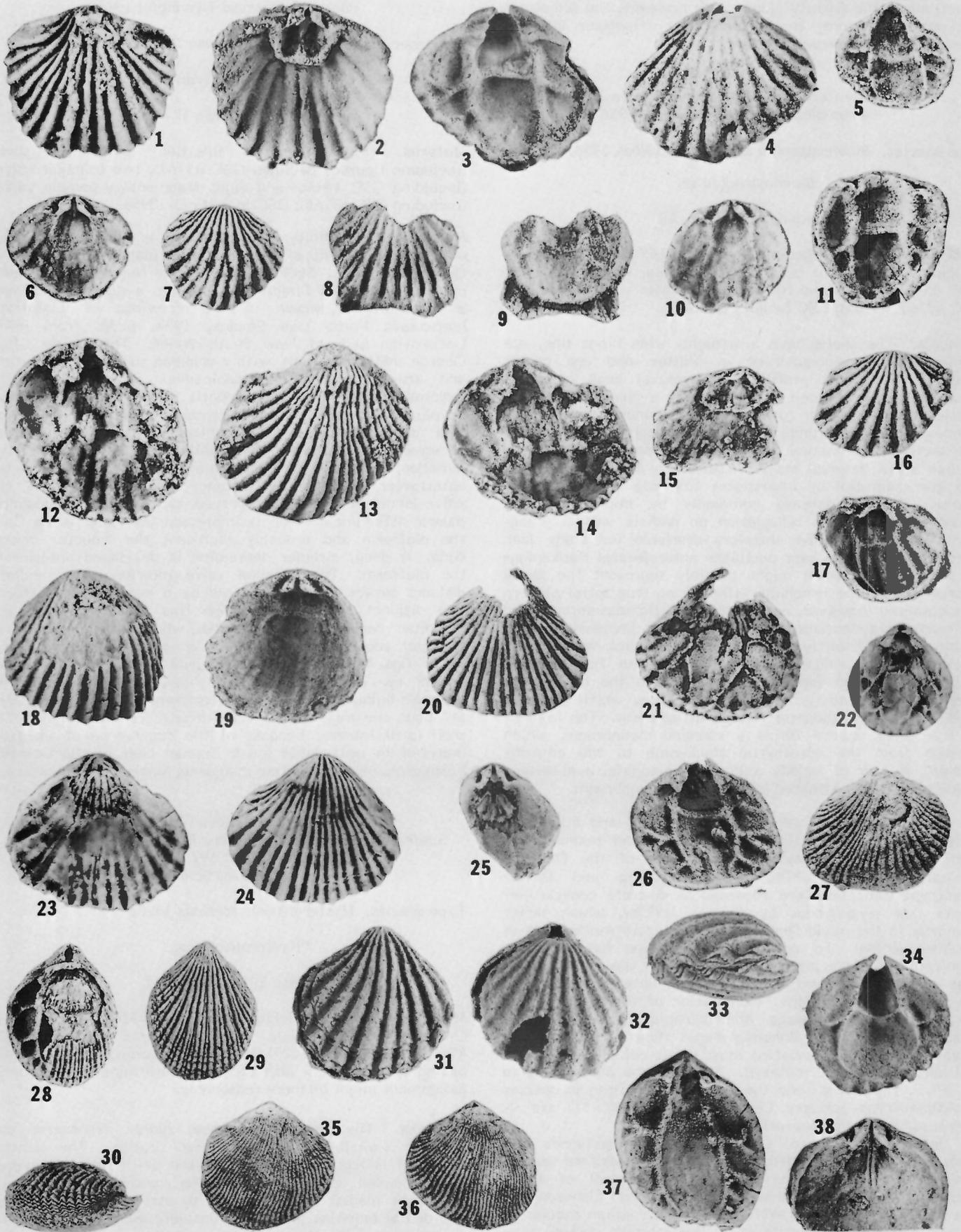
Material. Several dozen fragmentary silicified valves and a few crushed or distorted calcareous shells from beds 67 and 10 m, respectively, below the top of Ogilvie Formation at latitude 65°23'N, longitude 140°47'W, western Ogilvie Mountains, northern Yukon (S-15 of Perry et al., 1974, p. 1094). Material illustrated here includes brachial valves GSC 43869, 43870 and pedicle valves 43871, 43872.

Remarks. *Vagrana* sp. 2 is subtriangular in outline and strongly dorsibiconvex in lateral profile. The plications are high, rounded and separated by deep interspaces of about the same width as the plications. Plications increase occasionally by bifurcation on a few ventral valves. The ventral interarea is apsacline and pierced by a large, rounded foramen. The hinge teeth are strong, blunt structures directed strongly anteriorly. The sockets are deep and corrugated internally. Inner socket ridges are distinctly separated medially by a deep U-shaped structure. Vascular markings are best developed in pedicle valves with the primary branches extending anteriorly and anterolaterally from the anterior edges of the muscle field. These two primary branches bifurcate at least twice before the shell margin. A peculiar 'dimpled' pattern of small pits is clearly developed on the interior in some valves.

Vagrana sp. 2 is distinct from other described *Vagrana*, but formal naming and description must await collection of better preserved material. The associated brachiopod and conodont fauna indicates a probable 'late' Emsian age. The conodonts identified by Klapper include: *Pandorinellina exigua* n. subsp. A (P element), *Peleksgnathus glenisteri* Klapper (I S₂M₂ elements), *Polygnathus perbonus perbonus* (Philip) (P element, late form), *P. perbonus* n. subsp. D (P element).

Plate 7

- Vagrana atrypiforma* n. sp. (page 30)
Figures 1, 2. Exterior and interior view of brachial valve, paratype GSC 43150; GSC loc. C-10958; X1.5. Note strong raised muscle field shown in Figs. 2 and 15.
- Figures 3, 4. Interior and exterior views of pedicle valve, holotype GSC 43151 from same locality; X1.2.
- Figure 5. Interior view of pedicle valve, paratype GSC 43152 from same locality; X1.2.
- Figures 6, 7. Interior and exterior views of brachial valve, paratype GSC 43153 from same locality; X1.2. Note weakly developed dorsal vascular impressions shown in Figs. 6, 10 and 17.
- Figures 8, 9. Exterior and interior views of fragment of pedicle valve, paratype GSC 43154 from same locality; X1.2. Note well developed atrypoid fringe.
- Figure 10. Interior view of brachial valve, paratype GSC 43155 from same locality; X1.2.
- Figure 11. Interior view of fragment of pedicle valve, paratype GSC 43156 from same locality; X1.2.
- Figures 12 - 14. Interior, exterior and oblique interior views of pedicle valve, paratype GSC 43157 from same locality; X1.2.
- Figure 15. Interior view of brachial valve, paratype GSC 43158 from same locality; X1.2.
- Figures 16, 17. Exterior and interior views of brachial valve, paratype GSC 43159 from same locality; X1.2.
- Figures 18, 19. Exterior and interior views of brachial valve, paratype GSC 43160 from same locality; X1.2.
- Vagrana* sp. 2 (page 31)
Figures 20, 21. Exterior and interior views of pedicle valve, GSC 43872; Ogilvie Formation (Emsian), 67 m below top; Ogilvie Mountains, northern Yukon (lat. 65°23'N, long. 140°49'W); X1.1.
- Figure 22. Interior view of pedicle valve, GSC 43871 from same locality; X1.1.
- Figures 23, 24. Interior and exterior views of brachial valve, GSC 43870 from same locality; X1.1.
- Figure 25. Interior view of brachial valve, GSC 43869 from same locality; X1.1.
- Vagrana* cf. *V. intermediafera* (Khodalevich) (page 31)
Figures 26, 27. Interior and exterior views of brachial valve, GSC 43868; Delorme Formation, 342 m below top; Mackenzie Mountains (lat. 63°18'18"N, long. 128°34'W); X1.1.
- Figures 28 - 30. Dorsal, ventral and lateral views of complete individual, GSC 43867; Delorme Formation, 353 m below top; Mackenzie Mountains (lat. 63°18'18"N, long. 128°34'W); X1.1.
- Vagrana* sp. 3 (page 31)
Figures 31 - 33. Ventral, dorsal and lateral views of complete individual, GSC 43866; Delorme Formation, 178-181 m below top; Mackenzie Mountains (lat. 63°18'18"N, long. 128°34'W); X1.3.
- Figure 34. Interior view of pedicle valve, GSC 43865 from same locality; X1.3.
- Toquimaella kayi* Johnson (page 31)
Figures 35, 36. Ventral and dorsal views of complete individual, GSC 43864; Delorme Formation, 487 m below top; Mackenzie Mountains (lat. 63°18'18"N, long. 128°24'W); X1.8.
- Figure 37. Interior view of pedicle valve, GSC 43863 from same locality; X1.8.
- Figure 38. Interior view of posterior part of brachial valve, GSC 43862 from same locality; X1.8.



Vagrana sp. 2 has somewhat similar large rounded plications to the slightly older sp. 3; however, the plications are more numerous, the outline more triangular and the vascular markings more complex.

Subfamily Carinatininae Rzhonsnitskaya 1960
Genus *Biconostrophia* Havlíček 1956

Type species. *Biconostrophia spirifera* Havlíček 1956.

Biconostrophia sp.

Plate 6, figures 37 - 48

Material. Figured specimen GSC 43165 and one other articulated shell, four fragmentary brachial valves (including GSC 43161, 43162) and four similar pedicle valves (including GSC 43163, 43164); GSC locality C-10958.

Remarks. The shells have a straight, wide hinge line, are semicircular to subquadrate in outline and are gently biconvex in lateral profile. The ventral beak is erect, apsacline and is pierced apically by a circular foramen. Deltidial plates appear to have been conjunct anterodorsally although in the available shells are partially broken away. The shells bear a medial dorsal sulcus, which is marked by a median costa in small shells. Costae are high and rounded and are separated by interspaces that are wider than the costae. Costae increase commonly by implantation on dorsal valves and by bifurcation on pedicle valves. Fragments of pedicle valve interiors available for study lack dental lamellae and bear pustulose anterolateral thickenings of shell callus, which might possibly represent the spiral impressions of the brachidia although no true spiral pattern was observed (however, not all shells of *Davidsoniatrypa* and *Biconostrophia* consistently develop spiral impressions even within the same species). The brachial interior has medially disjunct socket ridges, which are directed first antero-laterally and then laterally subparallel to the hinge line. The notothyrial cavity is filled by callus, which probably marks the site of diductor muscle attachment. The impress of the dorsal sulcus forms a rounded myophragm, which extends from the notothyrial thickening to the anterior margin. A pair of weakly impressed, elongate, oval-shaped adductor scars are situated lateral to the myophragm.

Biconostrophia is well known in Pragian and Zlichovian beds of Bohemia (Havlíček, 1956, 1967) and recently has been recognized in lower Emsian beds of the Delorme Formation (Perry, 1974). *Biconostrophia* and *Davidsoniatrypa* Lenz here are regarded as discrete generic elements (but synonymous by Copper, 1973b), which differ primarily in the much finer, more multicostate ornament of *Davidsoniatrypa*. To date, *Davidsoniatrypa* has been recognized only from lower Pragian beds in the Royal Creek area of the Yukon and in the Sekwi Mountain map area of the Mackenzie Mountains. Comparison of the Delorme and the Mount Lloyd George *Biconostrophia* with previously described forms from Bohemia shows them to be distinct; however, detailed description must await collection of more and better preserved material. The Delorme *Biconostrophia* sp. (Pl. 6, figs. 47, 48) and the related early Pragian species *Davidsoniatrypa johnsoni* Lenz (Pl. 6, figs. 49-51) are illustrated here for comparative purposes.

Johnson and Boucot (1972) illustrated Havlíček's late Early Devonian *Biconostrophia fragilis*, *B. spirifera* and *B. conifera* and showed the variable development of spiral impressions in the ventral valves of the genus (Johnson and Boucot, 1972, Pls. 2, 3, Textfig. 1). The Bohemian species *B. fragilis* and *B. conifera* are much less strongly costate than *Biconostrophia* sp. and *B. spirifera* has a distinct ventral furrow, which is not developed in the material from northwestern Canada.

Family Lissatrypidae Twenhofel 1914
Genus *Lissatrypa* Twenhofel 1914

Type species. *Lissatrypa atheroidea* Twenhofel 1914.

Lissatrypa? sp.

Plate 5, figures 37 - 42

Material. Four coarsely silicified articulated shells (including figured specimen GSC 43167), two brachial valves (including GSC 43166) and eight fragmentary pedicle valves (including GSC 43168); GSC locality C-10958.

Remarks. The affinity with *Lissatrypa* is questioned because of the development of the prominent platform structure in the ventral valve. Such an exaggerated feature has not been previously noted in *Lissatrypa*; however, a suggestion of such a structure is shown in the drawings of *Lissatrypa lenticulata* Philip (see Savage, 1974, p. 38) from lower Lochkovian beds of New South Wales. The Mount Lloyd George shells are small, with a rounded subtriangular outline and are approximately equibiconvex in lateral profile. Externally the shells are smooth, with very fine, weakly developed concentric growth lamellae ornamented by very fine radial striae. The ventral hinge teeth project dorsomedially from the shell walls, unsupported by dental lamellae. A high, wide platform extends anteriorly from the notothyrial cavity to a distance about a third of the valve-length and probably served as the site of adductor muscle attachment. Deeply impressed triangular areas flank the platform and probably represent the diductor muscle field. A deep, circular depression is developed anterior to the platform. The brachial valve interior bears medially disjunct socket plates separated by a notothyrial platform. The disjunct sockets distinguish this lissatrypid from the Pridolian carinatinid *Dnestrina*, which has a scroll-like, conjunct socket apparatus (see Johnson and Boucot, 1972, Pl. 3, figs. 35-39). The notothyrial thickening of *Lissatrypa?* sp. is supported by a high, wide platform that becomes bulbous at its anterior extremity, which is situated at about one third of the valve-length from the umbo. The shell is of interest because of the occurrence of identical material in well dated lower Emsian beds of the Delorme Formation, Sekwi Mountain map area, Mackenzie Mountains.

Family Delthyrididae Phillips 1841
Subfamily Hysterolitinae H. and G. Termier 1949 emend.
Boucot 1975
Genus *Hysterolites* Schlotheim 1820

Type species. *Hysterolites hystericus* 1820.

"Hysterolites" sp.

Plate 8, figures 20, 21

Material. Figured brachial valve GSC 43169; GSC locality C-10958. Three pedicle valve fragments (including GSC 43170, Pl. 8, figs. 22, 23) from GSC locality C-10958 may belong to the taxon, although an indeterminate eospiriferid assignment might be more reasonable.

Remarks. The shells are large, highly transverse and strongly ventribiconvex in lateral profile. The ventral interarea is high, triangular, and the delthyrium is covered by a rounded deltidial cover. The ventral valve bears a prominent medial sulcus flanked by strong bounding ridges. The dental lamellae join with relatively short anterolaterally divergent ventral adminicula (sensu Strusz et al., 1970). The available brachial valve bears a low dorsal fold with an indistinct medial groove and has four pairs of costae on the

flanks. Growth lines are developed anteriorly. The cardinal area is crushed; however, the distinctive unsupported sockets are identical to those in shells from the Delorme Formation. Socket plates are attached to the posterior shell wall and to the base of the interarea and project horizontally, then curve sharply ventrally. The anteromedial socket wall is supported by triangular shaped, anteriorly expanding, dorsomedially inclined crural bases. The cardinal process is not preserved.

The poorly preserved material is only diagnostic because of the writers' familiarity with the same taxon (Pl. 8, figs. 24-30) from lower Emsian beds of the Delorme Formation in the Sekwi Mountain map area of the Mackenzie Mountains. The shells lack any trace of muscle scars, have short ventral adminicula and have more subdued radial ornament than true *Hysterolites* and probably represent a new spiriferid genus. The shell is clearly separable from *Alatiformia* as illustrated by Struve (1964) by the absence of a subdelthyrial plate and of a horizontal shelflike extension of the dorsal hinge plates that partially close the notothyrial cavity of *Alatiformia*.

Genus *Lenzia* n. gen.

Type species. *Lenzia pachyostrakon* n. sp.

Diagnosis. A thick-shelled hystero-litid with the dorsal fold and the ventral sulcus ornamented by prominent costae and with nonbifurcating costae on the flanks.

Discussion. The development of prominent crural plates suggests affinity between *Lenzia* and the subfamily Hystero-litinae. The short, weakly developed dental plates and ventral adminicula and the weakly impressed ventral muscle field are characteristic features both of the genus and subfamily Hystero-litinae. True *Hysterolites* bears unbranched costae, the fold and sulcus lack costae, and dental plates are more prominently developed. *Multispirifer* Kaplun (1961), another hystero-litid, has a costate fold and sulcus as does *Lenzia*, but bears anteriorly bifurcating costae on the flanks. *Lenzia* is clearly distinct from members of the subfamily Acrospiriferinae because of the development of a prominent knoblike cardinal process at a level with the plane of commissure and of the presence of costae on the fold and sulcus.

Lenzia pachyostrakon n. sp.

Plate 8, figures 1 - 19

Material and occurrence. Twenty coarsely silicified, fragmentary brachial valves (including paratypes GSC 43172, 43173, 43175, 43176, 43853) and 80 similarly preserved pedicle valves (including holotype GSC 43171 and paratypes GSC 43174, 43177); GSC locality C-10958.

Name. The generic name is a patronym after A.C. Lenz, University of Western Ontario. The specific name is from the Greek meaning thick shell.

Description. Exterior. Shells transversely suboval in outline, only slightly wider than long and weakly ventri-biconvex in lateral profile. Large shells slightly more than 20 mm wide, 15 mm long. Brachial valve more strongly inflated than pedicle valve in large shells. Hinge line straight, considerably shorter than maximum width. Cardinal angles obtuse and gently rounded. Ventral interarea long, high, gently incurved, apsacline, cleft medially by triangular delthyrium. Delthyrium margin flanked by low lateral plates projecting at 90 degrees to interarea. Callus infilling leads to the development of a stubby ridgeline

structure in the delthyrium apex. Dorsal interarea short, low, flat, orthocline. Ventral sulcus shallow, gently U-shaped covered by two to three costae of variable strength. Dorsal fold low, only well developed in large shells, ornamented by two to three strong costae. Fold and sulcus costae consist of a pair of costae, which bifurcate in large shells. Four to five pairs of nonbifurcating, high, rounded costae on the flanks, separated by slightly narrower U-shaped interspaces. Concentric ornament of lamellose growth lines visible near anterior margin of some shells. Radial micro-ornament not preserved.

Pedicle valve interior. Hinge teeth not preserved. Dental lamellae strongly convergent medially closing off large portion of delthyrium. Dental lamellae join pair of short ventral adminicula, which project only a short distance anterolaterally. Entire cardinal area of shell filled with callus. Lateral umbonal chambers and apex of delthyrium closed off by callus. Ventral muscle field strongly impressed anterior to delthyrial callus development and has an elongate suboval shape. Anterior margin of muscle field not impressed or bounded by ventral adminicula. Thick pad of callus developed anterior to muscle field over the ventral sulcus. Thick shell material results in absence of internal corrugation by impressed costae.

Brachial valve interior. Sockets diverge at about 45 degrees from hinge line and expand in width anterolaterally. Socket plates attached to posterior shell wall and base of interarea and extend horizontally then curve sharply ventrally. Crural plates joined to inner edge of sockets and have an anteriorly expanding, triangular form with medial convexity. Crura appear to attach to the dorsal edge of the crural plates, well below the plane of commissure. Stout, knoblike cardinal process situated between and joined to posteromedial portion of crural plates at the level of the plane of commissure; microstructure not preserved. Socket plates free of valve floor in small shells, however, supported by thick callus in medium and large-size shells. Adductor muscle field not strongly impressed, confined to the narrow depress of the fold, divided posteriorly by a low, rounded myophragm. Costae variably impressed internally depending on shell thickness.

Discussion. Because the genus is monotypic, the generic discussion serves to distinguish *L. pachyostrakon* n. sp. from related species of other hystero-litid genera.

Family Reticulariidae Waagen 1883
Genus *Warrenella* Crickmay 1953

Type species. *Warrenella ecletea* Crickmay 1953.

Warrenella sekwensis? Ludvigsen and Perry 1975

Plate 8, figures 31 - 36

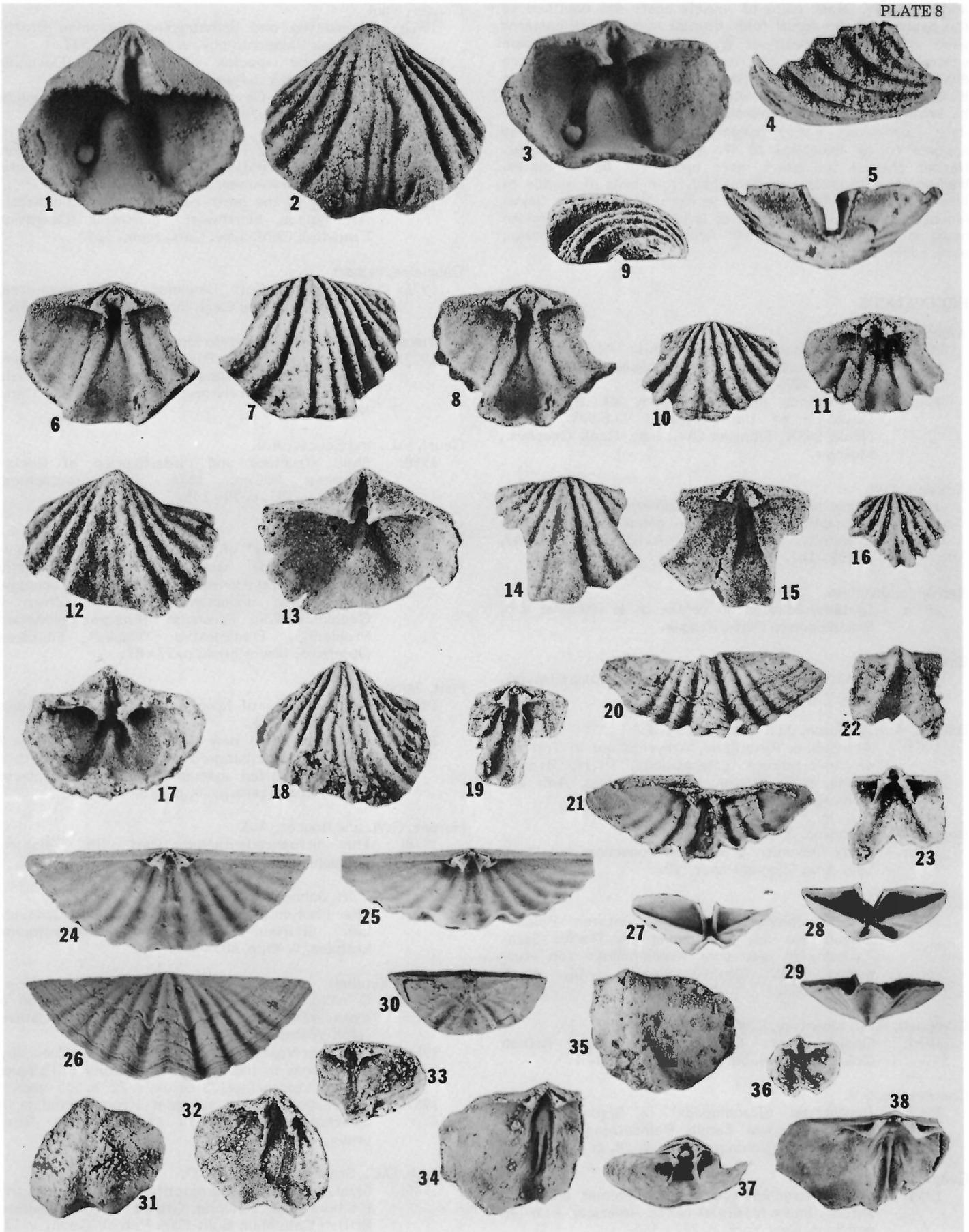
Warrenella sekwensis Ludvigsen and Perry, 1975, p. 72, Pl. 12, figs. 1 - 15.

Material and occurrence. Fourteen fragmentary brachial valves (including figured specimens GSC 43855, 43866), 16 similar pedicle valves (including GSC 43854, 42784); GSC locality C-10958.

Remarks. The crural plates join with the muscle-bounding ridges in most small immature shells, although in large shells they are commonly free of the valve floor. This same development was noted in *W. sekwensis*. Two pairs of dorsal adductor muscle scars are preserved. The posterior pair consists of deeply impressed, narrow, elongate, slightly anteriorly divergent tracks, which extend slightly anterior to the inception of the very deeply impressed, slitlike anterior

Plate 8

- Lenzia pachyostrakon* n. gen. and n. sp. (page 35)
Figures 1 - 5. Interior, exterior, oblique interior, lateral and posterior views of pedicle valve, holotype GSC 43171; GSC loc. C-10958; X2.
- Figures 6 - 9. Interior, exterior, oblique interior and lateral views of brachial valve, paratype GSC 43172 from same locality; X2.
- Figures 10, 11. Exterior and interior views of brachial valve, paratype GSC 43173 from same locality; X2.
- Figures 12, 13. Exterior and interior views of pedicle valve, paratype GSC 43174 from same locality; X2.
- Figures 14, 15. Exterior and interior views of brachial valve, paratype GSC 43175 from same locality; X2.
- Figure 16. Exterior view of brachial valve, paratype GSC 43176 from same locality; X2.
- Figures 17, 18. Interior and exterior views of pedicle valve, paratype GSC 43177 from same locality; X2.
- Figure 19. Interior view of brachial valve, paratype GSC 43853 from same locality; X2.
- "*Hysterolites*" sp. (page 34)
Figures 20, 21. Exterior and interior views of crushed brachial valve, GSC 43169; GSC loc. C-10958; X2.
- Figures 24 - 26. Interior, oblique interior and exterior views of brachial valve, GSC 43861; Delorme Formation, 62-68 m below top; Mackenzie Mountains (lat. 63°18'18"N, long. 128°34'W); X2.5.
- Figures 27 - 29. Oblique interior, interior and posterior views of pedicle valve, GSC 43860 from same locality; X1.3.
- Figure 30. Ventral view of articulated shell, GSC 43859 from same locality; X1.3.
- "*Hysterolites*"? sp. (page 34)
Figures 22, 23. Exterior and interior views of fragment of pedicle valve, GSC 43170; GSC loc. C-10958; X2.5.
- Warrenella sekwensis*? Ludvigsen and Perry (page 35)
Figures 31, 32. Exterior and interior views of fragment of pedicle valve, GSC 43854; GSC loc. C-10958; X1.5.
- Figure 33. Interior view of fragment of brachial valve, GSC 43855 from same locality; X1.5.
- Figures 34, 35. Interior and exterior views of brachial valve, GSC 43856 from same locality; X1.5.
- Figure 36. Oblique interior view of small pedicle valve, GSC 42748 from same locality; X1.5.
- Warrenella sekwensis* Ludvigsen and Perry (page 35)
Figure 37. Interior view of fragment of articulated shell, GSC 43858; Delorme Formation, 162-164 m below top; Mackenzie Mountains (lat. 63°16'45"N, long. 128°32'40"W); X1.1.
- Figure 38. Interior view of fragment of brachial valve, GSC 43857 from same locality; X1.1.



adductor pair. Both pairs of muscle scars are confined to the depress of the dorsal fold. Similar musculature patterns were observed in shells of *W. sekwensis*. The available ventral valves from GSC locality C-10958 bear more elongate, subparallel dental plates than most of the Delorme *W. sekwensis* although still within the range of variation of *W. sekwensis*. In Sekwi Mountain map area there is an older (late Lochkovian-early Pragian) *Warrenella* species that appears to be ancestral to *W. sekwensis* but is smaller, thinner shelled and bears more prominent dental plates. *Warrenella sekwensis* was described from beds of middle to late Pragian age in the Delorme Formation of the Sekwi Mountain map area. The species is known also from Emsian beds on Young Island, Arctic Archipelago (J.G. Johnson, pers. comm., 1973).

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ALBIAN FORAMINIFERS FROM THE LOWER CRETACEOUS CHRISTOPHER FORMATION OF THE CANADIAN ARCTIC ISLANDS

William V. Sliter

Abstract

An Albian age is indicated for the Christopher Formation of Amund Ringnes and Ellef Ringnes islands in the Arctic Archipelago by a fauna of 48 species of benthic foraminifers. Twenty-four of the species are agglutinated types and represent the dominant members of the fauna. Calcareous forms are represented by 19 species of the Nodosariacea, one species of the Discorbacea, three from the Cassidulinacea and one from the Robertinacea. These species define two assemblage zones: the *Gaudryina tailleuri* Assemblage Zone of Early Albian age in the lower unit of the Christopher Formation, and the *Verneuilinoidea borealis* Assemblage Zone of Middle Albian age in the upper unit.

Paleoenvironmental interpretation of the Christopher Formation based on selected lithologic and biogenic criteria indicates a predominantly transgressive sequence that includes shelf deposition, basin development and a final phase of basin infilling. The dominantly agglutinated assemblages associated with these broad marginal environments suggest a relationship to environmental stability and shelf-margin organic productivity.

Interpretation of the microfossil and megafossil assemblages provides a basis of preliminary correlation of the Ringnes islands sections with faunas in other North American arctic areas.

Résumé

Dans l'archipel Arctique, une faune composée de 48 espèces de foraminifères benthiques indique que la formation de Christopher rencontrée dans les îles Amund Ringnes et Ellef Ringnes est d'âge albien. Vingt-quatre des espèces appartenant à cette faune sont de type agglutiné et représentent les éléments dominants de cette faune. Les formes calcaires sont représentées par 19 espèces de Nodosariacea, une seule espèce de Discorbacea, trois espèces de Cassidulinacea, et une seule espèce de Robertinacea. Ces espèces permettent de définir deux cénozones: la cénozone à *Gaudryina tailleuri*, d'âge albien inférieur, qui fait partie de l'unité inférieure de la formation de Christopher, et la cénozone à *Verneuilinoidea borealis*, d'âge albien moyen, qui fait partie de l'unité supérieure.

L'interprétation des paléoenvironnements de la formation de Christopher, en fonction de certains critères lithologiques et biogènes, indique l'existence d'une succession principalement transgressive, comprenant un épisode de formation de dépôts de plate-forme, de formation d'un bassin, et une phase finale de comblement du bassin. Les assemblages riches en espèces agglutinées, étant associés à ces milieux marginaux de grande étendue, semblent favorisés par la stabilité du milieu et la forte productivité organique de la marge de la plate-forme continentale.

L'interprétation des assemblages de microfossiles et mégafossiles nous permet d'établir une relation préliminaire entre les sections rencontrées dans les îles Ringnes, et les faunes d'autres régions arctiques d'Amérique du Nord.

INTRODUCTION

Albian foraminifers are among the most widespread and distinctive within the Sverdrup Basin of the Canadian Arctic Islands. Similar assemblages of this age are recognized in strata along the Arctic Coastal Plain of Canada, the United States and the U.S.S.R. that include economically important hydrocarbon source rocks. This report is the first to describe and illustrate these foraminifers from the Sverdrup Basin. Assemblages of equivalent age have been described from adjacent areas in the Yukon (Chamney, 1964, 1967, 1971, 1973; Mountjoy and Chamney, 1969) and northern Alaska (Tappan, 1962; Bergquist, 1966). Palynological studies of the Christopher Formation include those of Hopkins (1971, 1974), Hopkins and Balkwill (1973), and Doerenkamp et al. (1976).

The foraminifers described and illustrated in this paper come from the Christopher Formation of Amund and Ellef Ringnes islands. The sections include the boundary between the *Gaudryina tailleuri* Assemblage Zone of Early Albian age and the younger *Verneuilinoidea borealis* Assemblage Zone of Middle Albian age. From these descriptions emerges a better understanding of the biostratigraphic relationship between the two zones and the depositional history of the Christopher Formation.

Field collections were made by the writer in July 1972 during a helicopter-supported study of Amund Ringnes and Cornwall islands. Samples from Ellef Ringnes Island were collected the following summer by D.F. Haden. The stratigraphic framework is that of Balkwill (1974a,b) and Balkwill and Hopkins (1976), which builds upon the earlier studies of Stott (1969) and Thorsteinsson and Tozer (1960, 1970).

Acknowledgments

Work on the topic commenced while the writer was a member of the Geological Survey of Canada. Field support and stratigraphic background provided by H.R. Balkwill is gratefully acknowledged. Thanks are due to D.L. Jones and K.J. Bird of the United States Geological Survey for reviewing the original manuscript and for discussions on stratigraphic and paleontologic aspects. The author is particularly indebted to R.L. Oscarson of the United States Geological Survey for taking the scanning electron micrographs using a Cambridge S-180 instrument.

SVERDRUP BASIN

The Sverdrup Basin is a regional depression some 1000 km long and 400 km wide that lies within the Arctic Islands north of the Canadian Shield (Textfig. 1). The basin, defined by Fortier (1957), is composed of upper Paleozoic to Tertiary rocks superimposed on the earlier Franklinian Geosyncline of late Proterozoic to Late Devonian age. Within the basin, sedimentary rocks reach a maximum thickness of about 12 000 m and include some upper Paleozoic and Cretaceous basalts and gabbroic sills. More detailed descriptions of the geology of the Sverdrup Basin are given by Fortier et al. (1963), Nassichuk (1972), Plauchut (1971), Plauchut and Jutard (1976), and Thorsteinsson and Tozer (1970).

Amund and Ellef Ringnes islands are situated near the centre of the Sverdrup Basin (Textfig. 1), Amund Ringnes Island entirely within it, and Ellef Ringnes Island including a part of the Canadian Arctic Coastal Plain. Both islands are characterized by broad lowlands with areas of low irregular uplands. Associated with the upland areas of both islands are piercement domes composed of evaporitic rocks of

Carboniferous age. These Carboniferous rocks are derived from the basal units of the Sverdrup Basin sequence of both islands that are overlain by an essentially conformable succession of marine and nonmarine strata that extend into the Tertiary. Formation of the domes probably began in the Cretaceous and was reactivated by Tertiary deformation (Plauchut, 1971; Balkwill, 1974b). Large-amplitude, northwest-striking folds characterize the structural fabric of both islands. The largest fold and dominant tectonic element in the central Sverdrup Basin, the Cornwall Arch, forms the structural axis of Amund Ringnes Island. Development of this fold structure has been dated as Late Cretaceous to early Tertiary (Balkwill, 1974b). For geologic descriptions of the Ringnes islands, see Balkwill (1973, 1974a,b), Balkwill and Hopkins (1976), Heywood (1957), Hopkins (1974), and Stott (1969).

CHRISTOPHER FORMATION

The Christopher Formation, originally named by Heywood (1957) for a thick succession of predominantly dark marine shales on Ellef Ringnes Island, represents one of the most widespread lithologic units in the Sverdrup Basin and adjacent Arctic areas. The formation conformably overlies sandstones and shales of the Lower Cretaceous deltaic Isachsen Formation of Barremian? to Aptian age (Roy, 1973) and grades into the marine and fluvial quartz-sandstones of the overlying Hassel Formation of Late Albian to Cenomanian age.

Thicknesses of the Christopher Formation range from 290 m on Eglinton Island in the west to 1440 m east of Glacier Fiord on Axel Heiberg Island to the east. At the type locality on Ellef Ringnes Island, Heywood (1957) measured about 470 m, presumably near Isachsen Dome, whereas Stott (1969) measured over 762 m near Helicopter Dome and Balkwill and Hopkins (1976) recorded about 850 m at Hoodoo Dome. On northern Amund Ringnes Island, a section measuring about 950 m is described in the present report.

The Christopher Formation can be divided into two informal units in the Ringnes islands, as throughout the Sverdrup Basin (Balkwill, 1974a). The lower unit, 350 to 488 m thick, consists mainly of dark green-grey, silty shale with buff fine grained sandstone interbeds near the base and abundant brown spherical siderite rosettes commonly from 5 to 15 cm in diameter that first occur some 45 m above the contact with the Isachsen Formation. These more massive shales grade upward into fissile, platy black shales that contain large, spherical, buff to red-brown calcareous concretions (up to 2 m in diameter) and abundant silicified wood. Also present are thin beds of buff-coloured limestones with cone-in-cone structure. Intervals of sandstone, buff-coloured concretionary zones and lithified wood increase upward throughout this unit with some fossilized tree stems up to 37 cm long. At the top are about 50 to 60 m of fine grained glauconitic sandstones, grey shales and zones of buff to orange sandstones. As noted by Balkwill and Hopkins (1976), the glauconitic sandstones represent a mappable horizon within the Christopher Formation, especially in the eastern part of the Sverdrup Basin where approximately coeval sandstones are found on Ellesmere and Axel Heiberg islands.

The upper unit, 335 to 472 m thick, consists of dark grey to black platy shales with thin, buff to orange-brown, resistant concretionary zones and silicified wood fragments. The lower half is characterized by abundant grey to red-brown concretions (generally less than 40 cm in diameter) that contain abundant ammonoids, pelecypods, gastropods and fossilized wood. The upper half contains fewer concretionary zones and upward is increasingly silty with some thin, buff-coloured sandstone beds near the contact with the overlying Hassel Formation.

BIOSTRATIGRAPHIC ZONATION

Gaudryina tailleuri Assemblage Zone

The *Gaudryina tailleuri* Assemblage Zone was described from the Lower Cretaceous Torok and Fortress Mountain formations of northern Alaska (see Tappan, 1962; Bergquist, 1966). The original zonal concept represented a taxon-range-zone based on the [then] known occurrences of *G. tailleuri*. An Early Albian age was assigned the zone based on association with the ammonites *Grantziceras* [= *Beudanticeras*] and *Colvillia* (Imlay, 1961) and on the presence of several foraminiferal species found in Albian strata in Europe (Tappan, 1962). Subsequent investigations have extended the lower range of *G. tailleuri* into strata of Neocomian and Late Jurassic age (Ramsay, 1970; Souaya, 1976). Although the separation of the early specimens of *G. tailleuri* from morphologically similar species *G. canadensis*, *G. nanushukensis* and *G. neocomiensis* is often difficult, the pre-Albian occurrences of *G. tailleuri* are well established.

In this report, the *G. tailleuri* Assemblage Zone is defined by the co-occurrence of: *Haplophragmoides gigas*, *Hippocrepina barksdalei*, *Reophax troyeri*, *Textularia topagorukensis*, *Trochammina eilete*, *T. rainwateri*, *Miliammina ischnia*, *M. manitobensis*, *Marginulinopsis collinsi*, *Saraceneria dutroi*, *Vaginulinopsis schloenbachi*, *Quadrimorphina ruckerae*, *Conorboides umiatensis*, *Gavelinella stictata* among others along with the name taxon. This assemblage is correlated in part with the *Grantziceras affine* Ammonite Zone of Early Albian age (Imlay, 1961; Jeletzky, 1971).

Verneulinoides borealis Assemblage Zone

The *Verneulinoides borealis* Assemblage Zone likewise was named from Lower Cretaceous strata in northern Alaska (Bergquist, 1958). It too originally represented a taxon-range-zone and is widely distributed, being found in many different facies along the Arctic Ocean margin. Megafossil and microfossil correlations placed this zone in the Middle to Late Albian (Imlay, 1961; Bergquist, 1966; Tappan, 1962).

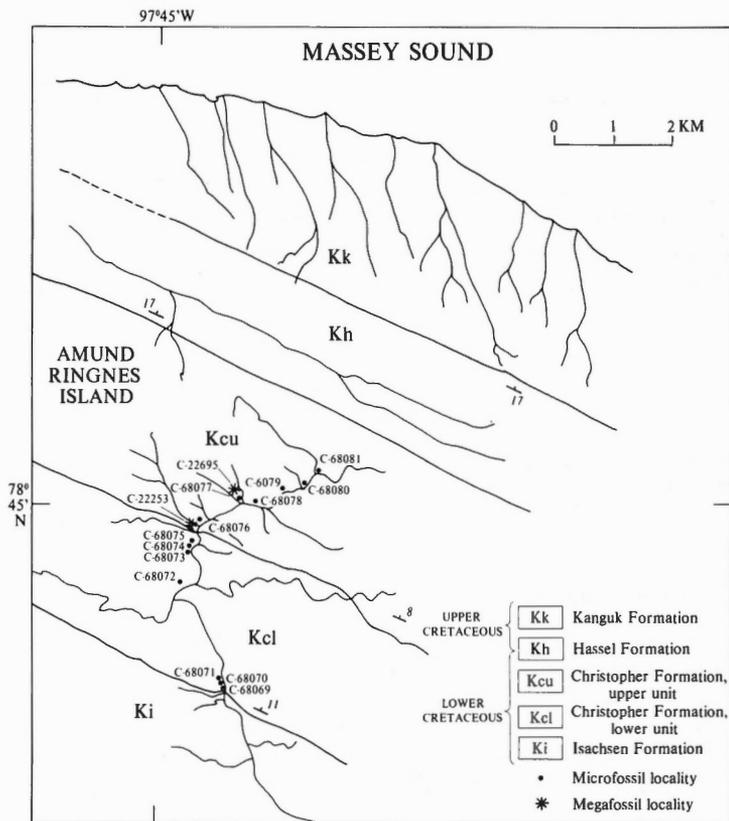
In this report, the fauna of the *Verneulinoides borealis* Assemblage Zone includes: *V. borealis*, *Gaudryina subcretacea*, *Trochammina umiatensis* and *Psammimopelta bowsheri* among others. A Middle Albian age for this zone on Amund Ringnes Island is well established by correlation with megafossils (see below).

The *Gaudryina tailleuri* and *Verneulinoides borealis* Assemblage Zones in the Ringnes islands show a close correlation to environmental facies as described below. In northern Alaska, however, both zones are found in several marine facies, a fact that originally demonstrated their chronostratigraphic utility (Tappan, 1962). This is especially true of the *Verneulinoides borealis* Assemblage Zone, which occurs in coastal to offshore facies that are characteristically time transgressive.

AMUND RINGNES ISLAND FORAMINIFERS

Foraminifers were collected from the Christopher Formation exposed near the north coast of Amund Ringnes Island along a stream bed about 16 km northwest of Stratigrapher River (Textfig. 1, loc. 2; Textfig. 7; about lat. 78°45'N, long. 97°45'W). Location of the 13 samples collected from the 950 m section are shown on Textfigures 7 and 8.

Two assemblage zones are recognized based on the stratigraphic distribution of 47 species identified; the *Gaudryina tailleuri* Assemblage Zone and the *Verneulinoides borealis* Assemblage Zone (Textfig. 9). Of these species, approximately one half (24) are calcareous; however, their occurrence is largely limited to the basal Christopher beds.



Textfigure 7. Amund Ringnes Island sampling localities northwest of Stratigrapher River and distribution of lithologic units (based on airphoto A161748-33).

The *Gaudryina tailleuri* assemblage is restricted to the lower unit of the Christopher Formation as defined primarily by the range of the name taxon. *Gaudryina tailleuri* is abundant in the basal beds but is less common upward, extending into the glauconitic sandstone interval at the top of the lower unit. The assemblage is dominated by *Haplophragmoides topagorukensis*, *H. gigas*, *Ammobaculites fragmentarius*, *Gaudryina tailleuri*, *Globulina lacrima canadensis*, *Quadrinorphina ruckerae*, *Bathysiphon brosgiei* and *Conorboides umiatensis*. These species and associated species, such as *Gavelinella intermedia*, *G. stictata*, *Marginulinopsis collinsi*, *Saracenaria dutroi*, *Vaginulinopsis schloenbachi*, and rare occurrences of *Miliammina manitobensis* and *Trochammina eilete* and other species, most probably indicate an Early Albian age for the lower unit. Several species present in the predominantly endemic assemblage provide correlation with strata of Early Cretaceous age in Europe (see Tappan, 1962, p. 116, 117). Of particular interest is *Gavelinella intermedia*, which ranges from the early Aptian to the Cenomanian. In northern Germany, the greatest abundance is in the late Aptian (Michael, 1966) whereas, worldwide, the species is most often recorded in the Albian (see Salaj and Samuel, 1966; Gawor-Biedowa, 1972). This is also true of the high-latitude assemblages of the southern hemisphere where the species is associated with Albian planktic foraminifers in the South Atlantic (Sliter, 1976, 1977) and eastern Indian oceans (Scheibnerová, 1974; Krashennikov, 1974). A similar age is indicated for occurrences in South Africa and Australia (Lambert and Scheibnerová, 1974).

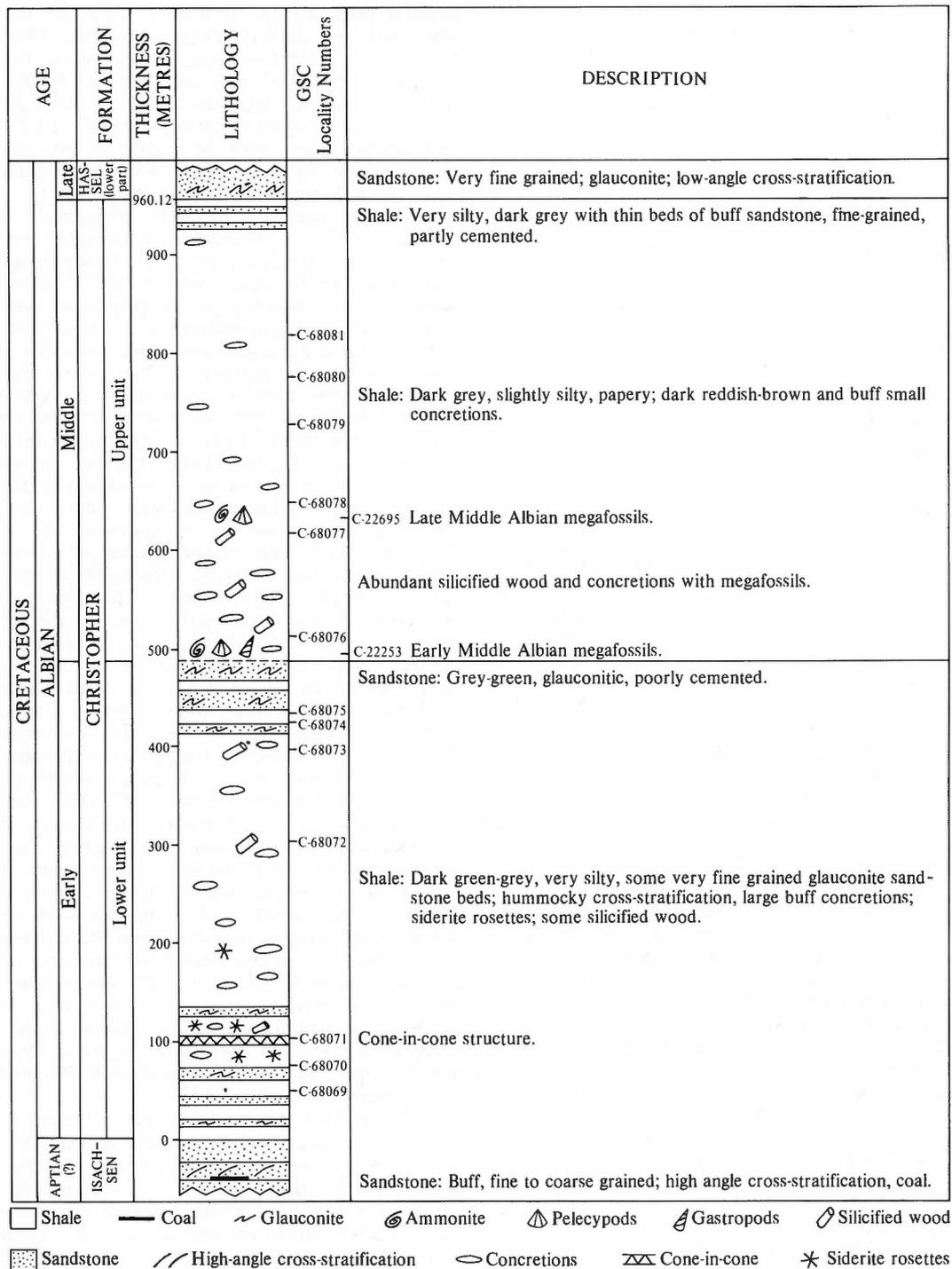
No megafossils were recovered from the lower Christopher section on Amund Ringnes Island. In other areas of the Sverdrup Basin and in northern Alaska, the foraminiferal assemblage is associated with megafossils in the

Grantziceras affine Ammonite Zone of Early Albian age (Plauchut and Jutard, 1976; Bergquist, 1966; Imlay, 1961). Ammonites collected from shales below the sandstones at the top of the lower unit on Ellesmere Island at Slidre Fiord (GSC loc. 28750) and identified by J.A. Jeletzky included *Cleoniceras* (*Anadesmoceras*?) aff. *C. (A.) subbaylei* Spath and *Arcthopolites belli* (McLearn) of late Early Albian age. However, the former ammonite has been redetermined subsequently as *Cleoniceras* (*Grycia*) n. sp. indet., which does not change the age of the beds concerned (Jeletzky, pers. comm., 1977). Moundlike carbonate rocks from the Christopher Formation of Ellef Ringnes Island (Nassichuk and Roy, 1975; GSC loc. C-33731) contain ammonites identified by Jeletzky as *Arcthopolites* (sensu lato) n. sp. indet., *Callizoniceras* (*Colvillia*) ex aff. *C. (C.) crasscostata* Imlay and nuculid pelecypods that indicate an Early Albian age. The limited outcrop and structural complexity of the area preclude precise stratigraphic correlation of this locality; however, the occurrence of the carbonate bodies and the structural position of the outcrop adjacent to evaporites of Hoodoo Dome suggest correlation with the lower unit. The collection is intriguing in that it represents the earliest Albian megafossil fauna known from the Sverdrup Basin and is comparable to occurrences on Anderson Plain, east of the Mackenzie Mountains (Jeletzky, 1964) and to the *Colvillia crasscostata* Ammonite Zone of northern Alaska (Imlay, 1961). The report of an ammonite fragment strongly resembling the Aptian genus *Tropaeum*, from the lower Christopher unit of Mackenzie King Island (Tozer, 1960, p. 13), indicates that the basal Christopher beds may be as old as Aptian at least within parts of the Sverdrup Basin. This single find is parallel to that of northern Alaska where the sole occurrence of Aptian ammonites is limited to fragments of *Tropaeum* from Lower Cretaceous strata along the Ipevik River near Point Hope, Alaska (D. Jones, pers. comm., 1977; USGS loc. M-6013).

Likewise, no published information exists on the microfloras of the lower Christopher Formation of the Ringnes islands. Palynological ages from the Christopher Formation of Banks and Eglinton islands based on dinoflagellates are presumed to correlate with Aptian to Middle Albian assemblages from Anderson Plain (Doerenkamp et al., 1976). The ages of the Anderson Plain assemblages from the Crossley Lakes Member of the Langton Bay Formation and the Horton River Formation were well documented by Brideaux and McIntyre (1975). Some doubt remains, however, as to the exact correlation of these floras between Anderson Plain and Banks Island (see Plauchut and Jutard, 1976; Doerenkamp et al., 1976).

These data indicate the age conflicts that continue to involve the lower Christopher Formation. The results of the present study from the Ringnes islands imply that the lower unit is Early Albian in age. It is possible that the basal strata of the lower Christopher unit may be Aptian in age at various sites within or adjacent to the Sverdrup Basin. The gradational nature of the contact between the Isachsen and Christopher formations compounds the problem. The boundary is often difficult to place as the upper part of the Isachsen Formation can be very shaly. Typically the base of the Christopher is placed above a prominent ridge-forming sandstone (Stott, 1969) or at the first shale bed with layers of cone-in-cone limestone (Plauchut and Jutard, 1976). The doubt about the position of the contact may in part explain the presence of Aptian fossils in the 'Christopher Formation'.

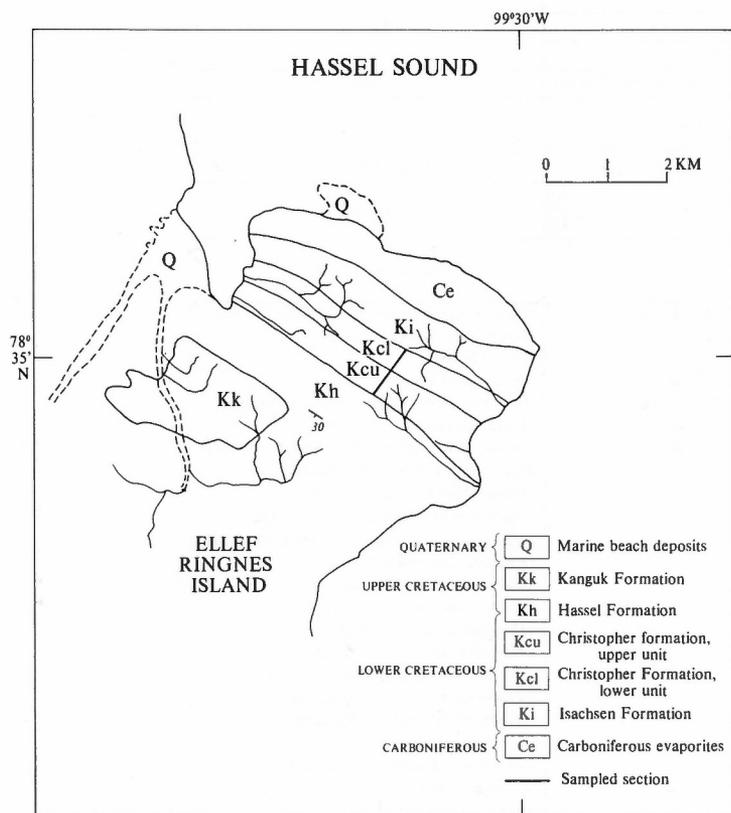
The *Verneulinoides borealis* Assemblage Zone is restricted to the upper unit of the Christopher Formation in the Amund Ringnes Island section. The assemblage is dominated by *Haplophragmoides topagorukensis*, *Ammidiscus rotalarius*, *Bathysiphon brosgiei*, *Saccammina lathrami* and *Reophax troyeri*. Species restricted to this zone include *Verneulinoides borealis*, *Reophax troyeri*, *Psammipelta bowsheri*, *Trochammina umiatensis* and *T. rainwateri*. This



Textfigure 8. Generalized lithologic column, sample locations and brief lithologic descriptions for the Christopher Formation, northern Amund Ringnes Island, District of Franklin (for fossil localities, see Textfig. 7).

assemblage indicates a Middle Albian age for the upper Christopher Formation. Between the last appearance of *Gaudryina tailleuri* and the first occurrence of *Verneuilinoides borealis* is an interval of some 106 m that shows a strong similarity in species content to the *V. borealis* Assemblage Zone (Textfig. 9). For example, the interval contains the last appearance of *Haplophragmoides gigas* and the first occurrence of *Reophax troyeri*. The omission of *Verneuilinoides borealis* from the interval is probably paleoecologic as discussed later rather than chronologic as judged from the disjunct distribution of several species adjacent to the interval.

Megafossils collected from the upper unit indicate a Middle Albian age (Textfig. 8). The collection from the upper unit just above the glauconitic sandstones (GSC loc. C-22253) yielded "*Gastrolites*" ex aff. n. sp. A, of Jeletzky (1964), *Cleoniceras* (*Cleoniceras*) n. sp. aff. *C. (C.) tailleuri* Imlay and aff. *C. (C.) cleon* (d'Orbigny), *Cleoniceras* (?*Grycia*) n. sp., *Beudanticeras* (*Grantziceras*) *glabrum* (Whiteaves), *Inoceramus anglicus* Woods, and indeterminate pelecypods and gastropods of early Middle Albian age (Jeletzky, pers. comm., 1973). The second collection from within the upper unit (GSC loc. C-22695) yielded "*Gastrolites*" aff. *G. canadensis* of Jeletzky (1964) non McLearn (1930) and



Textfigure 10. Location of Christopher Formation section and distribution of lithologic units at Helicopter Dome, Ellef Ringnes Island, District of Franklin (based on airphoto AL6192-174).

As before, the *Gaudryina tailleuri* Assemblage Zone is confined to the lower unit. The assemblage contains the restricted occurrences of the name taxon, plus *Haplophragmoides gigas* and *Ammobaculites fragmentarius* and is dominated by these species plus *Haplophragmoides topagorukensis*, *Saccamina lathrami*, *Pseudobolivina rayi*, *Ammodiscus rotularius* and *Bathysiphon broegei*. An Early Albian age is again suggested for this assemblage based on the foraminiferal assemblage; no megafossils were recovered.

An intriguing aspect of the lower Christopher foraminiferal fauna in the Ellef Ringnes Island section is the appearance of rare specimens of *Verneuilinoides borealis* and *Trochammina umiatensis*. These species are associated with the first appearance of *Miliammina* and *Psammionopelta* in the silty shales adjacent to the glauconitic sandstones at the top of the lower unit (Textfig. 12). The equivalent stratigraphic level on Amund Ringnes Island is marked by the restricted occurrence of *Miliammina manitobensis* whereas *Psammionopelta bowsheri*, *Trochammina umiatensis* and *Verneuilinoides borealis* appear in the upper unit of the Christopher Formation (see Textfig. 9). The paleoecologic implications of these disjunct occurrences are discussed below.

The *Verneuilinoides borealis* Assemblage Zone is recognized in the upper unit of the Christopher Formation. It is defined by the more common occurrence of the name taxon, *Trochammina eilete* and *Miliammina manitobensis* and the exclusion or reduction of abundance of *Gaudryina tailleuri*, *Haplophragmoides gigas*, *Pseudobolivina rayi*, *Glomospirella gaultina* and *Reophax deckeri* (Textfig. 12). A Middle Albian age is indicated by this assemblage.

Megafossils collected about 30 m above the base of the upper unit of the Christopher Formation (GSC loc. C-26600 and within the interval sampled as GSC loc. C-68061, Textfigs. 11, 12) include *Gastropilites?* (*Paragastropilites?*) n. sp. aff. *G. (P.) liardense* (Whiteaves), *Inoceramus* cf. *I. anglicus* Woods and indeterminate pelecypods dated as early Middle Albian (Jeletzky, pers. comm., 1974).

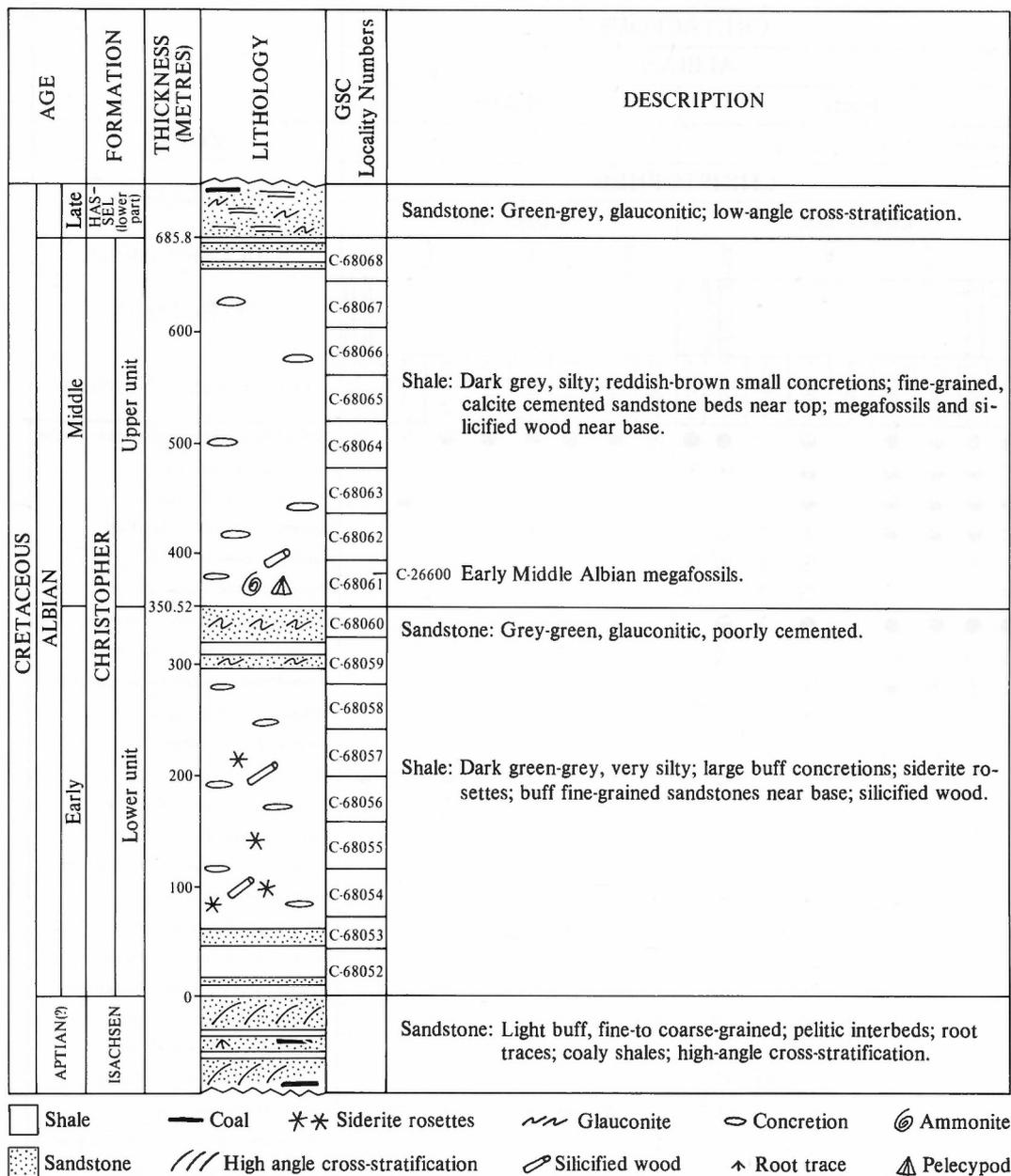
PALEOECOLOGY

The Christopher Formation in the Ringnes islands, as elsewhere in the Sverdrup Basin, represents a predominantly transgressive marine sequence. The studied sections record an initial period of shelf deposition followed by basin development and then a final phase of basin filling. The major biotic and lithologic characteristics that document these changes in depositional history are shown in Textfigures 13 and 14.

On Amund Ringnes Island, three major depositional environments are recognized. In the lower unit of the Christopher Formation, the presence of *Ammobaculites*, *Pseudobolivina*, *Ammodiscus*, *Miliammina*, *Textularia*, and members of *Bathysiphon* and *Haplophragmoides*, in addition to the restricted occurrence of calcareous species, characterize the environment (Textfig. 13). Specimen size typically ranges from 0.55 to 1.56 mm in the largest dimension, and agglutinated specimens are robust and often coarse grained. The number of foraminiferal species decreases upward in the unit, and their preservation deteriorates. Other biotic remains include rare occurrences of ornamented ostracodes, holothurian spicules, bivalve fragments and rare fish debris. Several sedimentary constituents likewise show variations in distribution. For example, rounded and frosted quartz grains that range from 0.35 to 1.56 mm in diameter are found in the lower unit as are common pyrite rods and fragments, rare gypsum crystals and rare calcisphaerulids, about 0.15 mm in diameter.

A second depositional environment is recognized in both the lower and upper units but is most characteristic of the lower half of the upper unit. A lowered species diversity and an assemblage of small fine grained specimens that range from 0.25 to 0.42 mm in length and are typically compressed identify this environment. The assemblage is dominated by species of *Reophax*, *Trochammina*, *Bathysiphon*, *Ammodiscus* and *Haplophragmoides* (see Textfig. 9). Many of the specimens are filled with pyrite, and preservation in general is poor. Associated biogenic material includes fish debris, occasional *Inoceramus* prisms, abundant ammonites and silicified wood. Sedimentary constituents typical of the assemblage include spores and carbonized organic material, calcisphaerulids, and some pyrite.

Two alternative hypotheses can be used to interpret the depositional environments represented by these two associations of biotic and sedimentologic criteria. The preferred hypothesis calls for a shelf environment followed by a deeper water or basin phase that received distal material during the maximum extent of the marine transgression. Following this interpretation, the shelf environment is represented by shallow-water foraminifers, such as the species of *Pseudobolivina* and *Miliammina*, associated with coarse grained foraminifers, bivalve fragments, holothurian spicules, ornamented ostracodes, abundant lithified wood, frosted quartz grains and gypsum crystals. The common pyrite rods resemble those produced in worm tubes or burrows (see Sliter, 1975) and thus suggest the presence of bioturbation. The deeper water phase is represented by fine grained, poorly preserved foraminifers associated with abundant ammonites, and an increase in fish debris, calcisphaerulids and fine grained carbonized organic material. Calcisphaerulids are regarded as planktic organisms indicative of open-marine or bathyal sediments due to their common association with calcareous nannofossils and

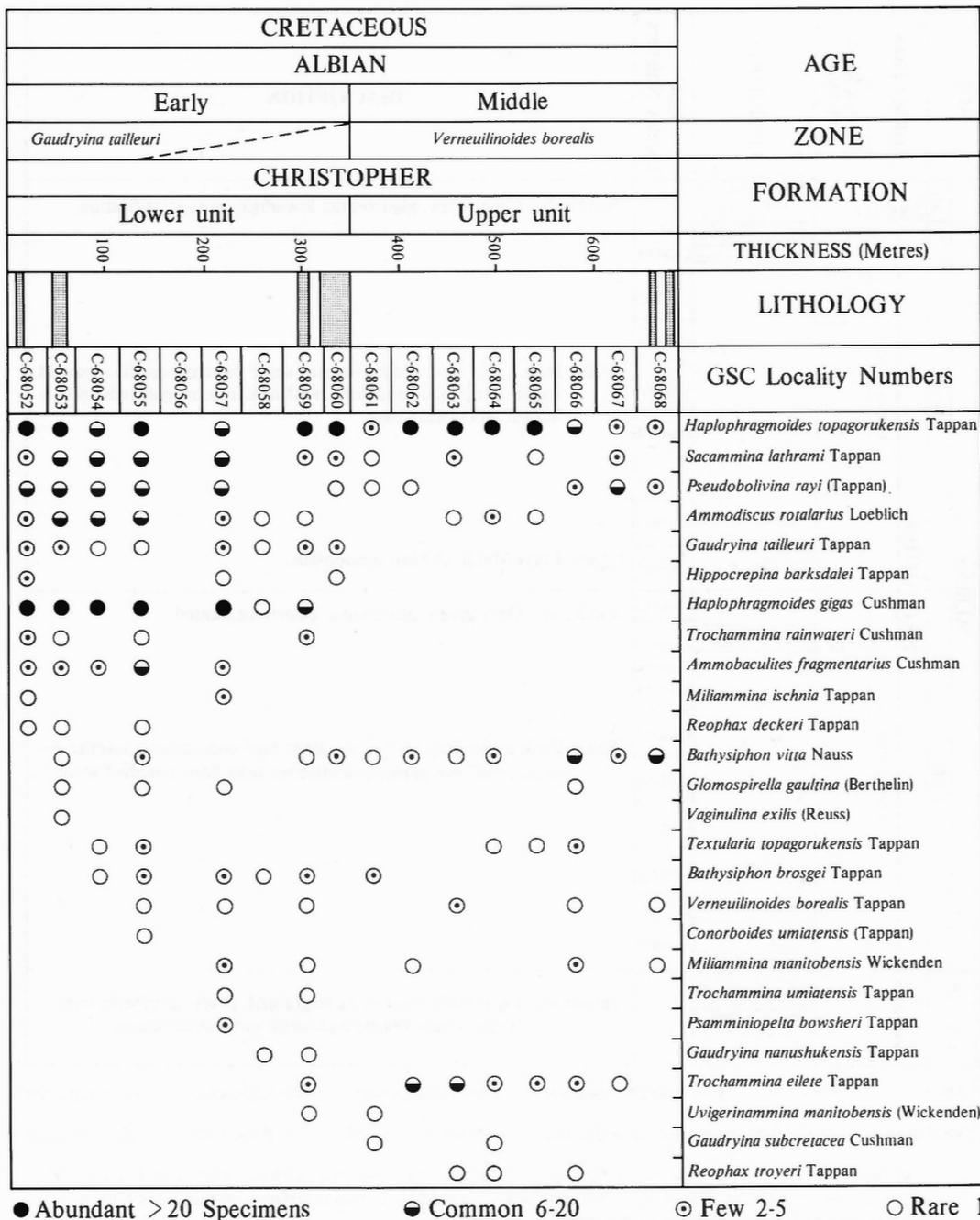


Textfigure 11. Generalized lithologic column, sample locations, and brief lithological descriptions for the Christopher Formation, Helicopter Dome, northern Ellef Ringnes Island, District of Franklin.

planktic foraminifers elsewhere. This interpretation is strengthened by their increased abundance in the deeper water environment of the Sverdrup Basin. The presence of rare spores and occasional *Inoceramus* prisms associated with this fine grained material suggests the sporadic influx of distal flow material. The lack of calcareous species and pyrite rods plus the poor preservation of the agglutinated foraminifers and an increase in pyrite-filled foraminifer tests suggest a reducing environment within a silled basin or beneath a stratified water column.

A second hypothesis would suggest an initial deeper phase represented by the presence of calcareous species and a higher species diversity followed by a marginal marine phase with fine grained specimens and a lowered species diversity. Several problems are associated with this hypothesis. For example, the foraminifer assemblage would indicate the opposite interpretation based on the

distribution of Cretaceous species in the Western Interior of the United States (Eicher, 1966), northeastern British Columbia (Stelck, 1975), and northern Alaska (Bergquist, 1966; Tappan, 1962). Correlation with foraminifer assemblages and sedimentary facies from these localities indicates a shallow-rather than a deep-water interpretation. Further, reliance upon the presence of calcareous species or species diversity as an indicator of water depth in Arctic latitudes is extremely unreliable due to weathering phenomena. This is emphasized in the present study where the rare calcareous specimens are severely affected by calcium carbonate dissolution (see Pl. 13, fig. 11; Pl. 15, figs. 6 - 11). It is entirely possible that calcareous species were originally more widely distributed within the Ringnes islands section and are now preserved only where conditions prevented complete dissolution. Such conditions would include a balance between the amount of calcareous megafossil and microfossil shell material, organic debris,



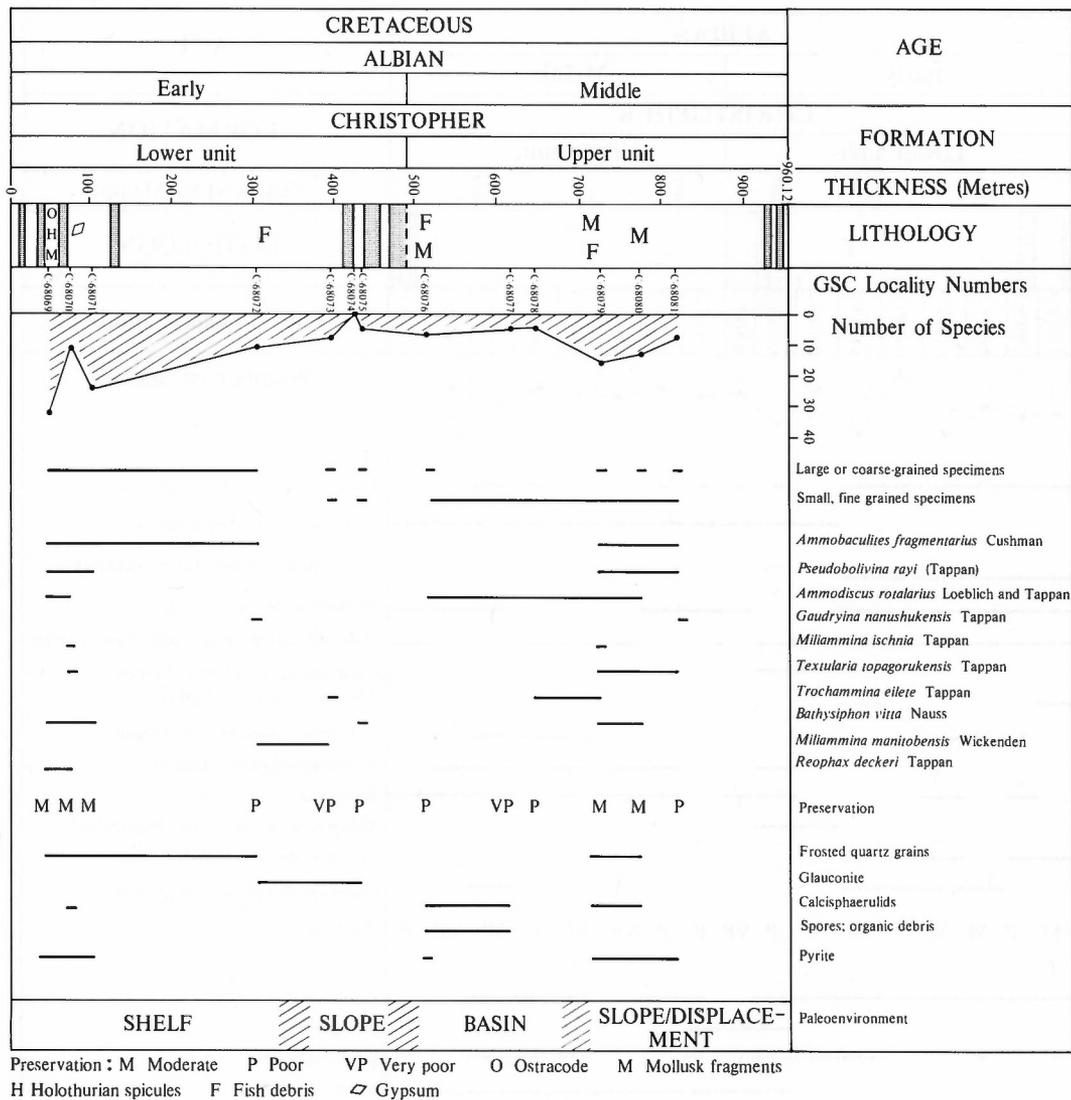
● Abundant >20 Specimens ● Common 6-20 ○ Few 2-5 ○ Rare 1

Textfigure 12. Stratigraphic distribution of foraminifers in the Christopher Formation, Helicopter Dome, northern Ellef Ringnes Island, District of Franklin.

pore space, permeability and so on that would lead to the eventual saturation of the interstitial fluid with respect to calcium carbonate and preserve the remaining calcareous material.

A third environment or transition zone between these two phases of basin development takes place at the top of the lower unit in conjunction with the glauconitic sandstones. There is a distinct change in faunal and lithologic character in the silty shales beneath the glauconitic sandstones that continues to the top of the lower unit. This environment is the milieu of *Miliammina manitobensis* and its appearance coincides with the similar appearance of detrital glauconite, rare spores and specimens of the basin facies that accompanied a reduction in preservation. Within the glauconitic sandstone interval itself, evidence of sediment transport is seen in the presence of worn, abraded specimens, fluctuation in species diversity, and alternation

of foraminiferal assemblages. For example, in the Amund Ringnes Island section, GSC locality C-68073 contains mostly small specimens of the basin assemblage and a few large specimens of *Haplophragmoides* up to 0.75 mm in diameter. This is reversed in GSC locality C-68075 where the assemblage is dominated by large specimens of *Haplophragmoides* and *Bathysiphon* and few specimens of the basin assemblage. A further reversal occurs in GSC locality C-68076 with a return to dominance of the small specimens. The depositional environment of the transition zone most probably represented an increase in slope gradient that separated the coarser shelf facies from the fine grained basin facies. Glauconitic sediments that formed on the outer shelf margin were periodically carried downslope into the basin along with elements of the shelf fauna. These were interbedded with autochthonous basin assemblages that formed in the slope environment.



Textfigure 13. Lithologic and biogenic trends and paleoenvironmental interpretation of the Christopher Formation, northern Amund Ringnes Island, District of Franklin (for fossil localities, see Text fig. 7).

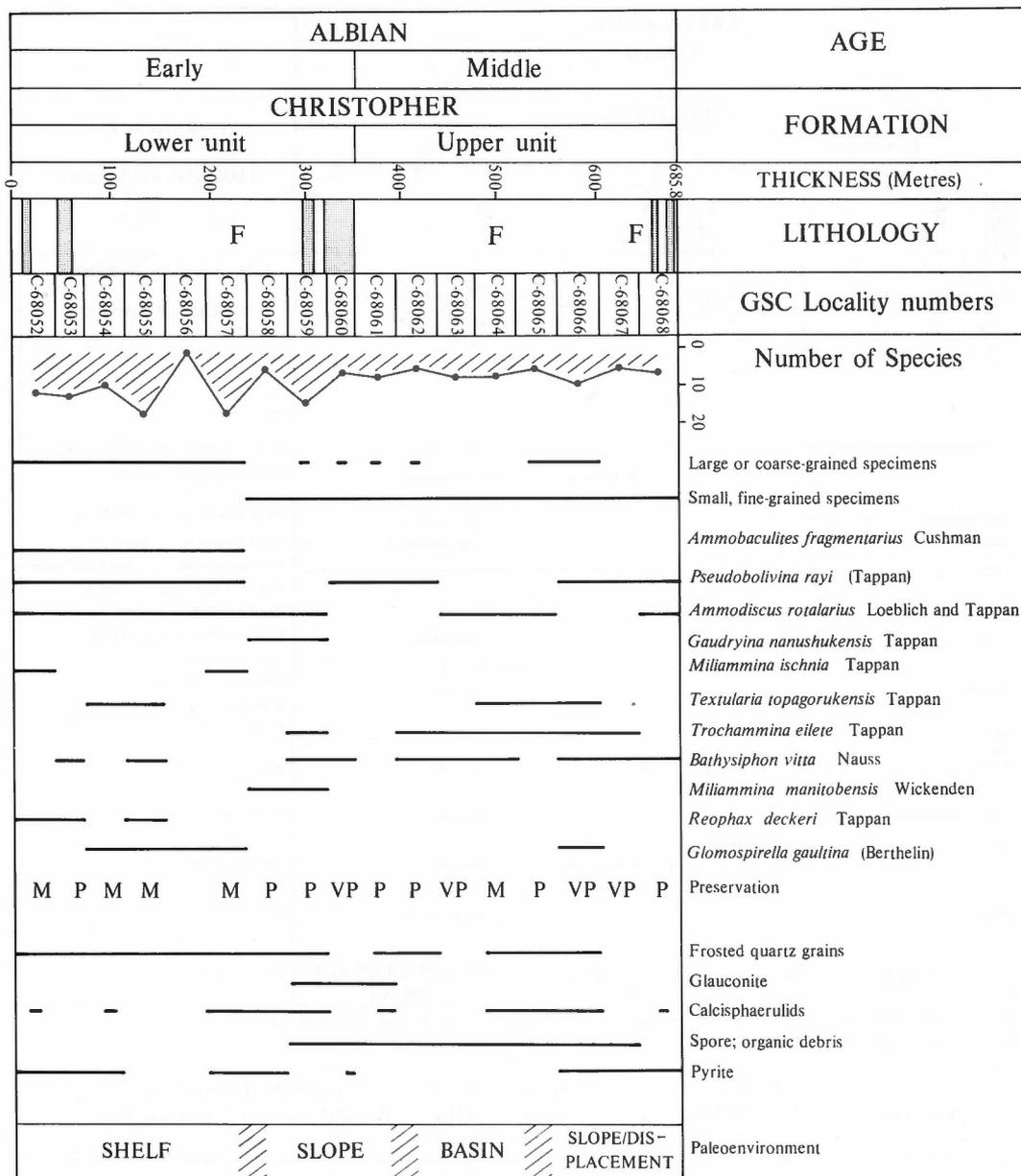
Shelf-derived materials reappear in the silty shales at the top of the Christopher Formation. This produces the disjunct distribution of biotic and lithologic criteria seen in Textfigure 13. The increase in species diversity coincides with a return of large species, rounded quartz grains, pyrite rods, mollusk fragments and a better foraminiferal preservation characteristic of the lower part of the Christopher Formation. Nevertheless, the basin fauna continues to be found throughout this interval and increases in abundance in the uppermost sample. The implication of this influx of shelf-derived material is the initiation of a marine regression and accelerated basin filling that heralded a return to slope environments and the eventual marginal marine and fluvial facies of the overlying Hassel Formation.

The Ellef Ringnes Island section again shows a disjunct distribution of biotic and lithologic constituents although not as clearly defined as on Amund Ringnes Island (Textfig. 14). The lower portion of the Christopher Formation contains coarse grained foraminifers in association with frosted quartz grains, pyrite and rare calcisphaerulids. Foraminiferal preservation decreases upward, species diversity fluctuates, and the occurrence of calcareous species is restricted to this interval.

The transition from coarse to fine grained foraminiferal assemblages precedes the first glauconitic sandstone at the top of the lower unit. Throughout the sandstone interval, evidence of faunal mixing is seen in the sporadic occurrence of large, abraded foraminifers and increasingly rare frosted quartz grains. This interval contains the first appearance of spores and carbonized organic material, glauconite grains and a reduction in foraminiferal preservation.

The upper unit is characterized by an assemblage of small, fine grained foraminifers with a low-species diversity. Specimens are compressed and often filled with pyrite. Organic material is more common and preservation is poor.

The depositional environment represented by these three phases again indicates a transition from shelf to basin environments within a transgressive sequence. The influx of shelf-derived material in the upper unit, although present, is not as well defined as that of Amund Ringnes Island. A slight increase in species diversity accompanies the appearance of a few large specimens of *Haplophragmoides* and *Bathysiphon* ranging up to 0.62 mm in the largest dimension, rare frosted quartz grains and calcite spheres and an increase in detrital pyrite. *Textularia* and *Pseudobolivina* reappear; however, *Ammobaculites* is missing. The



Preservation: M Moderate P Poor VP Very poor F Fish debris

Textfigure 14. Lithologic and biogenic trends and paleoenvironmental interpretation of the Christopher Formation, Helicopter Dome, northern Ellef Ringnes Island, District of Franklin.

major difference in this interval between the Ringnes islands sections is the continued dominance of the basin association throughout the Ellef Ringnes section.

Several speculations can be made in regard to these differences. The increased basin influence on Ellef Ringnes Island may perhaps indicate a deeper or certainly more distal environment than that of Amund Ringnes Island. This would explain the fluctuating species diversities of the shelf facies and the delayed influence of the upper shelf-influenced phase. Hydrodynamic sorting reduced the size of the displaced species, which would account for the lack of the larger and heavier specimens of *Ammobaculites* in the upper unit on Ellef Ringnes Island. Further, the more distal nature of the Ellef Ringnes environment would explain the reduced thickness of the formation and the thinning of the midformational glauconitic sandstones between the islands and agree with a southeastern source for these sediments.

The eastward thickening of the Christopher Formation from Ellef Ringnes to Ellesmere islands and the presence of a thick, midformational greenish-grey sandstone on Axel Heiberg and Ellesmere islands has been documented (Thorsteinsson and Tozer, 1970).

The effect of Cretaceous evaporite diapirism on the Ellef Ringnes section such as that described for Amund Ringnes Island (Balkwill, 1974b) is difficult to assess. Certainly this could account for thinning of the section and reduce the influence of bottom flows. However, the continued presence of the basin association would seem to preclude other than gentle doming prior to the late Middle Albian.

The presence of large agglutinated species in shelf habitats distinguishes the Cretaceous Arctic environments from those of the Pacific Ocean margin of North America.

AGE	NORTHERN ALASKA		NORTHERN YUKON	NORTHERN BANKS ISLAND	SVERDRUP BASIN				
	Interpreted from: Detterman, 1973; Imlay, 1961		Mountjoy and Chamney, 1969	Plauchut and Jutard, 1976	ELLEF RINGNES ISLAND <small>Text fig. 1, loc. 3</small>	AMUND RINGNES ISLAND <small>Text fig. 1, loc 2</small>	AXEL HEIBERG ISLAND <small>Glacier Fjord Tozer, 1963</small>	ELLESMERE ISLAND <small>Thorsteinsson and Tozer, 1970</small>	
					This Report				
EARLY CRETACEOUS	ALBIAN	Late	KILLIK TONGUE OF CHANDLER FORMATION GRAND STAND FORMATION	ARCTIC RED FORMATION	HASSEL FORMATION	HASSEL FORMATION	HASSEL FORMATION	HASSEL FORMATION	HASSEL FORMATION
		Middle	TUKTU FORMATION TOROK FORMATION (UPPER)		CHRISTOPHER FORMATION (305m)	CHRISTOPHER FORMATION (686m)	CHRISTOPHER FORMATION (950m)	CHRISTOPHER FORMATION (1440m)	CHRISTOPHER FORMATION (670m)
	Early	TOROK FORMATION (LOWER) FORTRESS MOUNTAIN FORMATION	MARTIN HOUSE FORMATION Glauconite Member						

Textfigure 15. Correlation of the Ringnes islands Christopher Formation sections with selected sections from other Arctic Ocean margin areas.

In the latter localities, large specimens of *Haplophragmoides*, *Bathysiphon*, *Saccamina*, *Hyperamminoides* and others are confined to slope and deeper water habitats (Sliter and Baker, 1972). In addition, large species of *Ammobaculites* so characteristic of the Arctic assemblages are rarely encountered (Sliter, 1968).

Arctic Cretaceous assemblages are closely similar to those of the Western Interior of North America and the United States Gulf Coast. As yet, too few studies of the bathymetric distribution of the Arctic species are available to provide a clear understanding of their faunal characteristics. Nevertheless, it may be that a common prerequisite to the development of agglutinated assemblages is the presence of broad shelf areas or basin margins with relatively stable environments together with an influx of organic material derived from delta complexes and shelf-margin organically productive areas. Such an environment was not present along the tectonically active, narrow Pacific margin.

Slope environments along active margins, however, such as that of the northeastern Pacific Ocean may have provided the stability, organic content and other environmental factors required by many of the large agglutinated species. Temperature related criteria may also be a factor in the deeper occurrences of such forms along the Pacific margin. The slope habitats may have had temperatures equivalent to those of Arctic faunas especially in the Late Cretaceous as latitudinal temperature gradients increased (Sliter, 1976).

CORRELATION

Correlation of the Christopher Formation with selected reference sections in the Arctic area is shown in Textfigure 15. These are made using the limited published information on foraminifers as well as megafossil collections. Within the Sverdrup Basin, the Christopher Formation is identified as

Early to Middle Albian in age primarily on the basis of megafossils as noted previously. Foraminiferal assemblages in the central and western parts of the basin are similar to those of the Ringnes islands, based on unpublished studies by the author.

Foraminifers from Banks Island likewise provide close correlation. These include the assemblage from the northern end of the island described by Plauchut and Jutard (1976) that contains rare *Verneulinoides borealis* with *Pseudobolivina rayi*, *Psammionopelta bowsheri* among others from the lower unit of the Christopher Formation and *Trochammina eilete*, *Pseudobolivina*, *Miliammina*, and others from the upper unit. These and other unpublished data show a definite similarity between the upper and lower units of Banks Island to those of the Ringnes islands.

In the northern Yukon, foraminiferal assemblages reported by Mountjoy and Chamney (1969) equate portions of the Martin House and Arctic Red formations with the Christopher Formation. The Glauconite Member of the Martin House Formation contains an Early Albian assemblage that includes *Gavelinella* cf. *G. intermedia*, *Marginulinopsis collinsi*, *Reophax troyeri*, *Dentalina dettermani*, *Gaudryina* cf. *G. subcretacea* and others. This member consists of some 91 m of sandstone and shales with varying amounts of glauconite that give the sequence a greenish colour.

The Martin House Formation is overlain by the Arctic Red Formation, dated as ranging from Early to Late Albian. Foraminifers from the lower member of the formation include *Marginulinopsis collinsi*, *Globulina prisca*, *Ammobaculites* cf. *A. rotarius*, *Nodosaria* cf. *N. concinna*, *Dentalina dettermani* and *Trochammina* cf. *T. rainwateri* among others. These are followed later in the formation by the appearance of *Globulina lacrima canadensis*, *Gaudryina nanushukensis*, *Psammionopelta bowsheri*, *Verneulinoides borealis*, *Pseudobolivina rayi*, *Gavelinella stictata*, *Texturalia* cf. *T. topagorukensis*, *Ammobaculites fragmentarius*,

Reophax troyeri and others. The Arctic Red faunas thus correspond to those from both the lower and upper units of the Christopher Formation from the Ringnes islands.

One intriguing aspect of the Yukon section of Mountjoy and Chamney (1969) is the similarity of certain lithologic and paleoecologic aspects to the Christopher Formation of the Sverdrup Basin. For example, the shales and glauconitic sandstones of the Martin House Formation followed by the Fossiliferous Concretionary Shale Member with abundant ammonites of the more offshore facies of the Arctic Red Formation resemble the lithologic sequence in the Ringnes islands. For the moment, however, the precise correlation and characterization of the depositional history between the two areas awaits further study.

Similar Albian foraminiferal assemblages are reported by Chamney (1971, 1973) from wells in the Mackenzie Delta and the Tuktoyaktuk Peninsula, District of Mackenzie. These assemblages correlate closely with those from the Yukon and similarly show strong age and environmental correlations with those from the Sverdrup Basin Christopher Formation.

Mesozoic foraminifers from northern Alaska represent the most intensively studied Arctic microfossils and yet their chronologic and ecologic utility suffers from a lack of documented field studies. The relationships of the majority of lithologic units in exposed sections remain poorly understood. Nevertheless a considerable body of information on the faunal assemblages exists, based primarily on the subsurface studies.

The Fortress Mountain Formation, consisting of shales, greywacke sandstones and conglomerates, represents a proximal facies that grades northward into the predominantly shale sequence of the Torok Formation. The lower beds of both formations are correlated by the presence of the ammonites *Grantziceras affine* (Whiteaves) and *Colvillia crassicosata* Imlay among others and the pelecypod *Aucellina dowlingi* McLearn regarded as Early Albian in age (Imlay, 1961). Foraminifers from the Fortress Mountain and lower Torok formations contain the *Gaudryina tailleuri* Assemblage Zone that includes species such as *Ammobaculites fragmentarius*, *Glomospirella gaultina*, *Gaudryina subcretacea*, *Trochammina eilete*, *Marginulinopsis collinsi*, *Vaginulinopsis schloenbachi*, *Globulina lacrima canadensis*, *Conorboides umiatensis*, *Quadriformina ruckerae* and *Gavelinella intermedia* among others (Tappan, 1962; Bergquist, 1966). This association of microfossils and megafossils indicates correlation of these sections with the lower unit of the Christopher Formation in the Ringnes islands.

The middle third of the Torok Formation contains the *Subarcthoplites belli* Ammonite Zone of late Early Albian age with a meager foraminiferal fauna that includes *Gaudryina tailleuri*.

The *Verneulinoides borealis* Assemblage Zone appears in the upper third of the Torok Formation in association with the ammonites *Gastropilites*, *Paragastropilites* and *Cleoniceras* of Middle Albian age. The Tuktuk Formation of the Nanushuk Group that overlies the Torok Formation likewise contains the Middle Albian ammonite and foraminiferal faunas.

Foraminifers indicative of the *Verneulinoides borealis* Assemblage Zone continue into the overlying Grandstand Formation that consists of sandstones and shales. A Middle Albian age is indicated for the basal beds by the occurrence of the ammonite *Cleoniceras* whereas the upper beds are regarded as Late Albian as inferred from stratigraphic relationships.

The predominantly nonmarine Killik Tongue of the Chandler Formation overlies the Tuktuk Formation in the south and interfingers with the Grandstand Formation toward the north. Foraminifers from the Killik Tongue are represented only by a few long-ranging members of the *Verneulinoides borealis* Assemblage Zone. The age of the Killik Tongue is thus interpreted from its stratigraphic relationships to adjacent dated rock units.

SYSTEMATIC PALEONTOLOGY

Illustrated specimens are deposited in the type collection of the Geological Survey of Canada, Ottawa.

Superfamily Ammodiscacea Reuss 1862
Family Astrorhizidae Brady 1881
Subfamily Rhizammininae Rhumbler 1895
Genus *Bathysiphon* M. Sars in G.O. Sars 1872
Bathysiphon brosegei Tappan 1957

Plate 9, figures 1, 2

Bathysiphon brosegei Tappan, 1957, p. 202, Pl. 65 figs. 1-5;
Tappan, 1962, p. 128, Pl. 29, fig. 5.

Remarks. The species is distinguished from *Bathysiphon vitta* by its smaller size and characteristically distorted tube, which often shows minor constrictions.

Specimens range from 0.55 to 1.87 mm in length, 0.13 to 0.35 mm in width. The majority of specimens are closer to the smaller dimensions. Figured hypotypes GSC 46138 (Pl. 9, fig. 1) from GSC locality C-68079; 46139 (Pl. 9, fig. 2) from GSC locality C-68076.

Bathysiphon vitta Nauss 1947

Plate 9, figures 3, 4

Bathysiphon vitta Nauss, 1947, p. 334, Pl. 48, fig. 4; Tappan, 1962, p. 128, Pl. 29, figs. 6-8.

Remarks. *Bathysiphon vitta* is characterized by its large size, generally smooth, compressed chamber and lack of constrictions. The species is more abundant and occurs more consistently in the Ellef Ringnes Island section than in the Amund Ringnes Island section; however, the morphology remains constant.

Specimens range from 0.55 to 0.86 mm in length and from 0.3 to 0.55 mm in width. Figured hypotypes GSC 46140 (Pl. 9, fig. 3) from GSC locality C-68061; 46141 (Pl. 9, fig. 4) from GSC locality C-68060.

Subfamily Hippocrepininae Rhumbler 1895
Genus *Hippocrepina* Parker in G.M. Dawson 1870
Hippocrepina barksdalei (Tappan 1957)

Plate 9, figures 8, 9, 13

Hyperamminoides barksdalei Tappan, 1957, p. 202, Pl. 65, figs. 6-12; Tappan, 1962, p. 129, Pl. 29, figs. 21-27.

Remarks. Specimens referred to this species are quite variable in shape and in the number and prominence of the transverse growth wrinkles. Typically the flattened tubular chambers are somewhat flaring, and elongate, with a rounded aperture at the end of the chamber. Although rare, specimens occur more consistently in the Amund Ringnes Island section.

Specimens range from 0.35 to 0.55 mm in length and 0.25 to 0.35 mm in width. Figures hypotypes GSC 46142 (Pl. 9, fig. 8) and 46143 (Pl. 9, fig. 9) from GSC locality C-68052; 46144 (Pl. 9, fig. 13) from GSC locality C-68057.

Family Saccamminidae Brady 1884
Subfamily Saccammininae Brady 1884
Genus *Saccammina* M. Sars in Carpenter 1869
Saccammina lathrami Tappan 1960

Plate 9, figures 5-7

Saccammina lathrami Tappan, 1960, p. 289, Pl. 1, figs. 1, 2; Tappan, 1962, p. 129, Pl. 29, figs. 9-12.

Remarks. The species is identified by its single chamber that is always compressed in the present material with the aperture at the end of a short neck. Rarely, the neck can be quite distinctive as shown in Plate 9, figure 7.

Length ranges from 0.68 to 0.8 mm, width from 0.3 to 0.42 mm. Figured hypotypes GSC 46145 (Pl. 9, fig. 5) from GSC locality C-68053; 46146 (Pl. 9, fig. 6) from GSC locality C-68052; 46147 (Pl. 9, fig. 7) from GSC locality C-68054.

Family Ammodiscidae Reuss 1862

Subfamily Ammodiscinae Reuss 1862

Ammodiscus rotalarius Loeblich and Tappan 1949

Plate 9, figures 12, 14

Ammodiscus rotalarius Loeblich and Tappan, 1949, p. 247, Pl. 46, fig. 1; Tappan, 1962, p. 131, Pl. 30, figs. 5 - 8.

Remarks. Specimens are discoidal, planispirally coiled, and compressed with a gradually enlarging chamber. Little variation was noted in specimens from both the stratigraphic sections from the Ringnes islands.

Specimens range in diameter from 0.25 to 0.55 mm. Figured hypotypes GSC 46148 (Pl. 9, fig. 12) from GSC locality C-68069; 46149 (Pl. 9, fig. 14) from GSC locality C-68059.

Genus *Glomospirella* Plummer 1945

Glomospirella gaultina (Berthelin 1880)

Plate 9, figures 10, 11

Ammodiscus gaultinus Berthelin, 1880, p. 19, Pl. 1 (24), figs. 3a,b.

Glomospirella gaultina (Berthelin), Tappan, 1962, p. 130, Pl. 29, figs. 17 - 20.

Remarks. *Glomospirella* differs from *Ammodiscus* in having an early irregular coil prior to assuming a planispiral coiling habit. Specimens in the present samples are usually distorted with a smooth, polished surface. They are rare in both localities.

Diameters range from 0.35 to 0.42 mm. Figured hypotypes GSC 46150 (Pl. 9, fig. 10) from GSC locality C-68057; 46151 (Pl. 9, fig. 11) from GSC locality C-68066.

Superfamily Lituolacea de Blainville 1825

Family Hormosinidae Haeckel 1894

Subfamily Hormosininidae Haeckel 1894

Genus *Reophax* Montfort 1808

Reophax deckeri Tappan 1940

Plate 9, figures 15, 16

Reophax deckeri Tappan, 1940, p. 94, Pl. 14, fig. 3; Tappan, 1943, p. 479, Pl. 77, fig. 3.

Remarks. Large, coarse grained specimens of *Reophax* are placed in this species originally described from the Early Cretaceous of Texas. Tests are compressed and have several elongate chambers that increase rapidly in size. Sutures are distinct and depressed and the wall is coarsely agglutinated. The aperture is terminal at the end of a short neck. *Reophax deckeri* occurs in the lower part of the Christopher Formation in the Ringnes islands.

Specimens range in length from 1.39 to 2.0 mm and in width from 0.68 to 1.05 mm. Figured hypotype GSC 46152 (Pl. 9, fig. 15) from GSC locality C-68069; 46153 (Pl. 9, fig. 16) from GSC locality C-68071.

Reophax troyeri Tappan 1960

Plate 9, figures 17, 18

Reophax troyeri Tappan, 1960, p. 291, Pl. 1, figs. 10 - 12; Tappan, 1962, p. 133, Pl. 30, figs. 11 - 13.

Remarks. *Reophax troyeri* differs from *R. deckeri* in being much smaller, with more chambers that are globular in shape, a finer grained wall and a more distinct neck. Specimens are common to abundant in the upper Christopher Formation of Amund Ringnes Island and rare in the Ellef Ringnes Island section.

Length of specimens ranges from 0.3 to 0.68 mm and width from 0.18 to 0.25 mm. Figured hypotypes GSC 46154 and 46155 from GSC locality C-68079.

Family Rzehakinidae Cushman 1933

Genus *Miliammina* Heron-Allen and Earland 1930

Miliammina ischnia Tappan 1957

Plate 12, figure 15

Miliammina ischnia Tappan, 1957, p. 211, Pl. 67, figs. 25, 26; Tappan, 1962, p. 160, Pl. 37, figs. 1 - 5.

Remarks. This species is narrow, elongate with nearly parallel sides, quinqueloculine in section with a flattened test and generally indistinct chambers. Only a few specimens were recovered from the Ringnes islands sections.

Specimens range from 0.35 to 0.55 mm in length and from 0.18 to 0.28 mm in width. Figured hypotype GSC 46156 from GSC locality C-68079.

Miliammina manitobensis Wickenden 1932

Plate 12, figures 8, 12, 16

Miliammina manitobensis Wickenden, 1932, p. 90, Pl. 1, figs. 11a - c; Tappan, 1962, p. 160, Pl. 36, figs. 12 - 18.

Remarks. This large species differs from *M. ischnia* in being ovate in outline, with thick, distinct chambers and a rounded periphery. Specimens are often damaged along their periphery in the Ringnes islands stratigraphic sections.

Hypotypes range from 0.5 to 0.68 mm in length and from 0.3 to 0.42 mm in width. Figured hypotypes GSC 46157 to 46159 from GSC locality C-68057.

Genus *Psamminopelta* Tappan 1957

Psamminopelta bowsheri Tappan 1957

Plate 12, figures 13, 14

Psamminopelta bowsheri Tappan, 1957, p. 211, Pl. 67, figs. 11 - 18, 22 - 24; Tappan, 1962, p. 157, Pl. 37, figs. 11, 12.

Remarks. *Psamminopelta bowsheri* is recognized by its large, ovate, flattened test, planispirally coiled chamber, and an aperture at the end of the chamber that occasionally becomes detached from the test. Specimens are limited to a few occurrences in both Ringnes islands sections.

Length of specimens ranges from 0.42 to 0.75 mm and width from 0.25 to 0.55 mm. Figured hypotypes GSC 46160 and 46161 from GSC locality C-68079.

Family Lituolidae de Blainville 1825
Subfamily Haplophragmoidinae Maync 1952
Genus *Haplophragmoides* Cushman 1910
Haplophragmoides gigas Cushman 1927

Plate 10, figures 1 - 5

Haplophragmoides gigas Cushman, 1927, p. 129, Pl. 1, fig. 5;
Tappan, 1962, p. 134, Pl. 30, fig. 15.

Remarks. This large species is characteristic of the lower Christopher Formation in the Ringnes islands. It is recognized by the large, compressed test with a lobate periphery. Chambers are numerous and are inflated adjacent to the umbilicus. Sutures are usually sinuate and depressed.

Specimens range in greatest diameter from 0.42 to 0.92 mm and from 0.18 to 0.25 mm in thickness. Figured hypotypes GSC 46162 (Pl. 10, fig. 1) and 46163 (Pl. 10, fig. 4) from GSC locality C-68052; 46164 (Pl. 10, fig. 3) and 46165 (Pl. 10, fig. 4) from GSC locality C-68070; 46166 (Pl. 10, fig. 5) from GSC locality C-68071.

Haplophragmoides topagorukensis Tappan 1957

Plate 10, figures 6 - 12

Haplophragmoides topagorukensis Tappan, 1957, p. 203,
Pl. 65, figs. 15 - 25; Tappan, 1962, Pl. 31, figs. 1 - 15.

Remarks. *Haplophragmoides topagorukensis* is the most abundant species in the Ringnes islands sections. It is variable in size, with a rounded periphery, numerous chambers and straight sutures. These characteristics and the lack of the raised umbilical margins distinguish *H. topagorukensis* from the somewhat larger species *H. gigas*.

Greatest diameters range from 0.3 to 0.68 mm and the thickness from 0.15 to 0.5 mm. Figured hypotypes GSC 46167 (Pl. 10, fig. 6) and 46168 (Pl. 10, fig. 7) from GSC locality C-68070; 46169 (Pl. 10, fig. 8), 46170 (Pl. 10, fig. 9) and 46171 (Pl. 10, fig. 10) from GSC locality C-68055; GSC 46172 (Pl. 10, fig. 11) and 46173 (Pl. 10, fig. 12) from GSC locality C-68069.

Subfamily Lituolinae de Blainville 1825
Genus *Ammobaculites* Cushman 1910
Ammobaculites fragmentarius Cushman 1927

Plate 11, figures 1 - 5

Ammobaculites fragmentaria Cushman, 1927, p. 130, Pl. 1,
fig. 8.

Ammobaculites fragmentarius Cushman, Tappan 1962,
p. 136, Pl. 32, figs. 8 - 11.

Remarks. This species shows considerable variation in test shape, diameter and prominence of the early coiled stage and size of the agglutinated grains as shown in Plate 11. *Ammobaculites fragmentarius* usually has a distinct early coil followed by four to seven globular chambers. No specimens of the larger species *A. wenonahae* Tappan with broad, compressed chambers were found in the Ringnes islands sections even though it is more common than *A. fragmentarius* in coeval strata in northern Alaska.

Specimens range from 0.62 to 1.75 mm in length and from 0.25 to 0.35 mm in the diameter of the largest chamber. Figured hypotypes GSC 46174 (Pl. 11, fig. 1), 46175 (Pl. 11, fig. 2) and 46176 (Pl. 11, fig. 3) from GSC locality C-68069; 46177 (Pl. 11, fig. 4) and 46178 (Pl. 11, fig. 5) from GSC locality C-68070.

Family Textulariidae Ehrenberg 1838
Subfamily Textulariinae Ehrenberg 1838
Genus *Textularia* DeFrance in de Blainville 1824
Textularia topagorukensis Tappan 1957

Plate 11, figures 6 - 8

Textularia topagorukensis Tappan, 1957, p. 205, Pl. 66,
figs. 8 - 9; Tappan, 1962, p. 141, Pl. 33, figs. 7 - 11.

Remarks. This small species occurs more consistently in the upper than in the lower Christopher Formation in the Ringnes islands. It is elongate, narrowly tapering, and commonly distorted. The biserial chamber arrangement is often difficult to see in the present specimens.

Specimens range in length from 0.25 to 0.35 mm and in width from 0.13 to 0.18 mm. Figured hypotypes GSC 46179 (Pl. 11, fig. 6) and 46180 (Pl. 11, fig. 8) from GSC locality C-68080; 46181 (Pl. 11, fig. 7) from GSC locality C-68064.

Subfamily Pseudobolivinae Wiesner 1931
Genus *Pseudobolivina* Wiesner 1931
Pseudobolivina rayi (Tappan 1957)

Plate 11, figures 9, 10, 22

Siphotextularia? rayi Tappan, 1957, p. 206, Pl. 66, figs. 6, 7;
Tappan 1962, p. 142, Pl. 34, figs. 19 - 22.

Remarks. *Pseudobolivina rayi* is distinguished by its variable size, flattened test, slightly twisted axis, chambers that are initially biserial but become nearly uniserial in the later stage, and narrow, nearly terminal apertural slit.

Length of specimens ranges from 0.42 to 1.35 mm and width from 0.18 to 0.62 mm. Figured hypotypes GSC 46182 (Pl. 11, fig. 9) and 46183 (Pl. 11, fig. 22) from GSC locality C-68071; 46184 (Pl. 11, fig. 10) from GSC locality C-68081.

Plate 9

Measurements given (in parentheses) are distances between dots beneath each specimen.

Bathysiphon brosegi Tappan (page 52)
Figures 1, 2. GSC 46138 (100 μ m) and 46139 (300 μ m).

Bathysiphon vitta Naus (page 52)
Figures 3, 4. GSC 46140 and 46141 (both 100 μ m).

Saccamina lathrami Tappan (page 52)
Figure 5. Compressed specimen with apical projection,
GSC 46145 (100 μ m).
Figure 6. GSC 46146 (100 μ m).
Figure 7. Specimen with distinct neck, GSC 46147
(100 μ m).

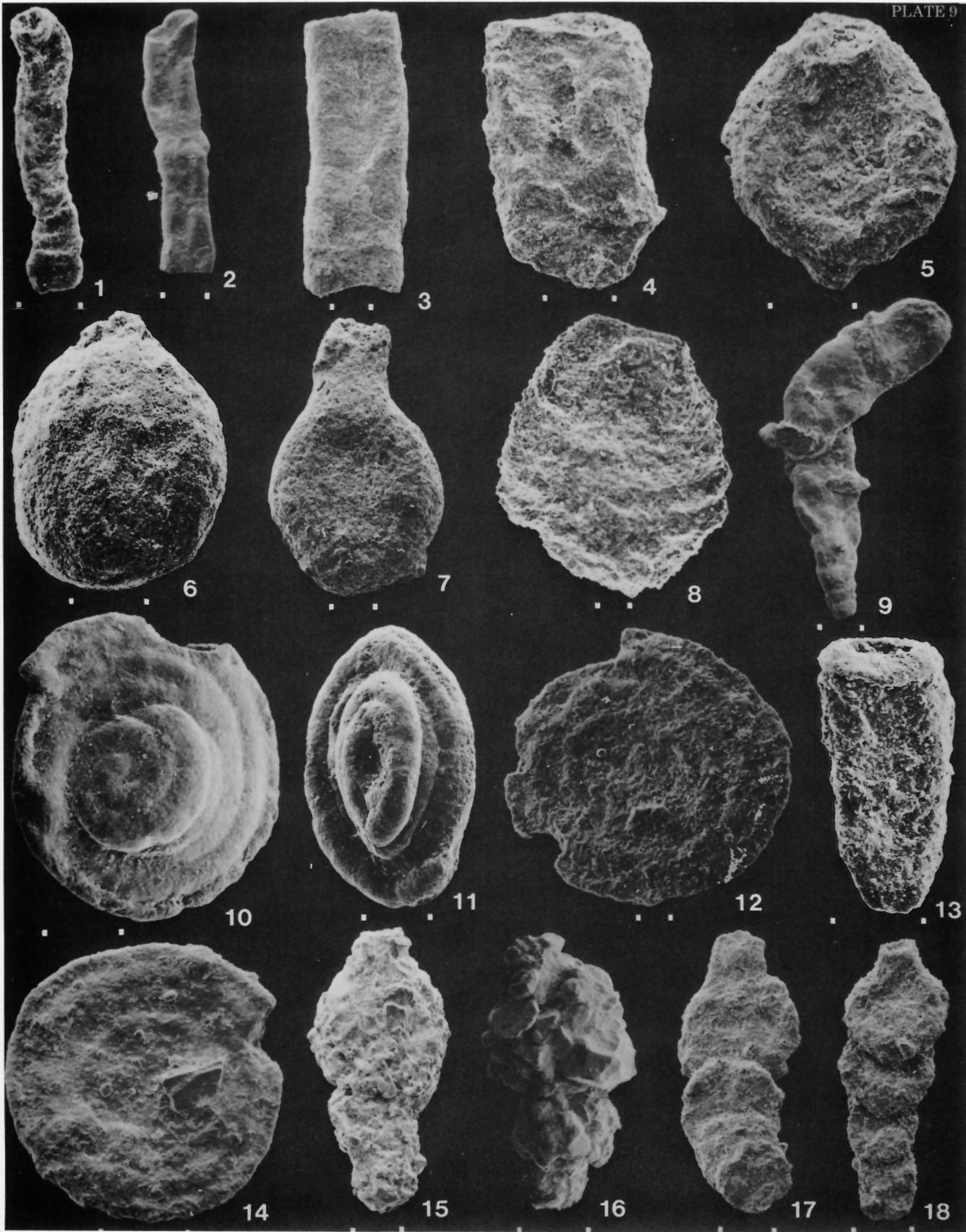
Hippocrepina barksdalei Tappan (page 52)
Figure 8. Oblique apertural view showing transverse
growth wrinkles, GSC 46142 (30 μ m).
Figure 9. Elongate specimen, GSC 46143 (100 μ m).
Figure 13. Side view showing aperture and thickened
apertural rim, GSC 46144 (100 μ m).

Glomospirella gaultina (Berthelin) (page 53)
Figure 10. GSC 46150 (100 μ m).
Figure 11. Oblique view, GSC 46151 (100 μ m).

Ammodiscus rotalarius Loeblich and Tappan (page 53)
Figures 12, 14. GSC 46148 (30 μ m) and 46149 (100 μ m).

Reophax deckeri Tappan (page 53)
Figures 15, 16. GSC 46152 and 46153 (both 300 μ m).

Reophax troyeri Tappan (page 53)
Figures 17, 18. GSC 46154 and 46155 (both 100 μ m).



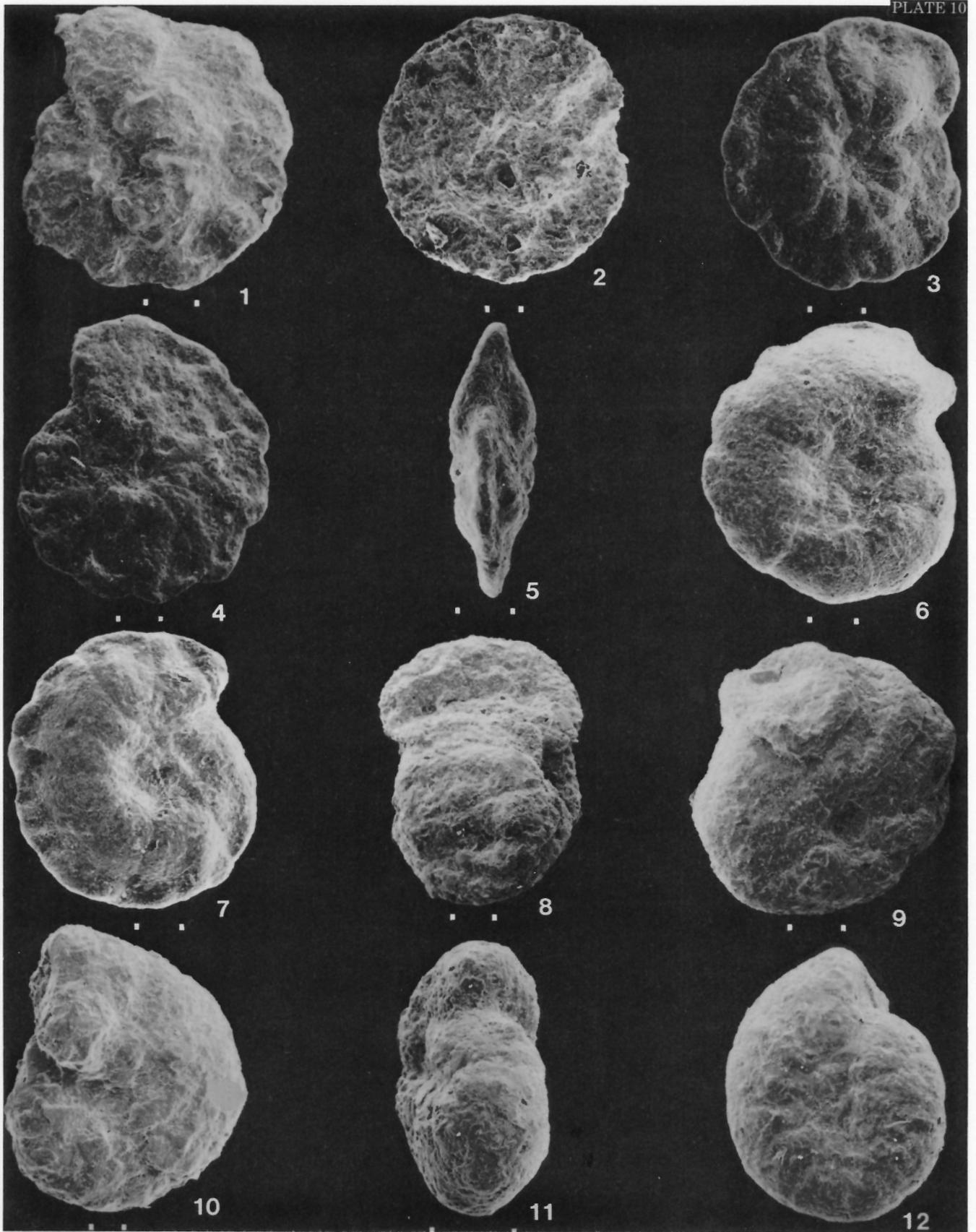


Plate 10

Measurements given (in parentheses) are distances between dots beneath each specimen.

Haplophragmoides gigas Cushman (page 54)
 Figures 1 - 4. GSC 46162 - 46165 (all 100 μ m).
 Figure 5. Edge view, GSC 46166 (100 μ m).

Haplophragmoides topagorukensis Tappan (page 54)
 Figures 6, 7, 9, 10, GSC 46167, 46168, 46170, 46171 and 46173
 11,12. (all 100 μ m except Fig. 10, 30 μ m).
 Figures 8, 11. Edge views, GSC 46169 and 46172
 (both 100 μ m).

Family Ataxophragmiidae Schwager 1877
Subfamily Verneulininae Cushman 1911
Genus *Gaudryina* d'Orbigny in de la Sagra 1839
Gaudryina nanushukensis Tappan 1951

Plate 11, figures 13 - 15, 17

Gaudryina nanushukensis Tappan, 1951, p. 2, Pl. 1, figs. 8a - 11; Tappan, 1962, p. 148, Pl. 34, figs. 11 - 15.

Remarks. *Gaudryina nanushukensis* is identified by the elongate, gradually flaring test; triserial early part with rounded periphery and smooth, slightly concave sides. Rare specimens become biserial in the later stage. Sutures in the triserial stage are slightly depressed and the test axis is occasionally twisted (Pl. 11, fig. 15). Occurrences are limited in both Ringnes islands sections.

Specimens range in length from 0.35 to 0.5 mm and in width from 0.18 to 0.25 mm. Figured hypotypes GSC 46185 (Pl. 11, fig. 13), 46186 (Pl. 11, fig. 14) and 46187 (Pl. 11, fig. 15) from GSC locality C-68072; 46188 (Pl. 11, fig. 17) from GSC locality C-68059.

Gaudryina subcretacea Cushman 1936

Plate 11, figure 18

Gaudryina subcretacea Cushman, 1936, p. 5, Pl. 1, figs. 11a,b; Tappan, 1962, p. 149, Pl. 36, figs. 5, 6.

Remarks. This distinctive species is limited to rare occurrences in the Ellef Ringnes Island section. It has an elongate test with angled, lobate peripheries and concave sides, numerous chambers that tend to become biserial and smooth walls.

Figured hypotype GSC 46189 from GSC locality C-68061 is 0.73 mm long and 0.25 mm wide.

Gaudryina tailleuri (Tappan 1957)

Plate 11, figures 19 - 21

Verneulinoides tailleuri Tappan, 1957, p. 208, Pl. 66, figs. 19 - 22.

Gaudryina tailleuri (Tappan), Tappan, 1962, p. 149, Pl. 35, figs. 8 - 16.

Remarks. The narrow, elongate, nearly parallel sided triserial test with numerous chambers and depressed sutures distinguishes this species. Some specimens tend to become biserial in the later stage. It is differentiated from *G. nanushukensis* by the test and chamber shape and lack of rounded peripheral angles and smooth surface.

Length ranges from 0.35 to 0.75 mm, width from 0.15 to 0.20 mm. Figured hypotypes GSC 46190 (Pl. 11, fig. 19) from GSC locality C-68060; 46191 (Pl. 11, fig. 20) from GSC locality C-68070; 46192 (Pl. 11, fig. 21) from GSC locality C-68072.

Genus *Uvigerinammina* Majzon 1943

Uvigerinammina manitobensis (Wickenden 1932)

Plate 11, figure 12

Tritaxia manitobensis Wickenden, 1932, p. 87, Pl. 1, fig. 10.

Uvigerinammina manitobensis (Wickenden), Tappan, 1962, p. 145, Pl. 33, figs. 18 - 23.

Remarks. Rare specimens of this species occur in both sections in the Ringnes islands. The loose triserial chamber is difficult to distinguish in the commonly distorted specimens, but the test outline, distinct neck and terminal aperture identify the species.

Figured hypotype GSC 46193 from GSC locality C-68069 is 0.38 mm long and 0.28 mm wide.

Genus *Verneulinoides* Loeblich and Tappan 1949

Verneulinoides borealis Tappan 1957

Plate 11, figures 11, 16

Verneulinoides borealis Tappan, 1957, p. 206, Pl. 66, figs. 10 - 18; Tappan, 1962, p. 142, Pl. 34, figs. 1 - 9.

Remarks. This species is identified by the broadly flaring test, triserial chamber arrangement and apertural depression at the base of the final chamber. The aperture is rarely observed in the commonly distorted and debris covered Ringnes islands specimens.

Specimens are fairly consistent in size and range in length from 0.3 to 0.42 mm and in width from 0.18 to 0.25 mm. Figured hypotypes GSC 46194 and 46195 from GSC locality C-68069.

Family Trochamminidae Schwager 1877

Subfamily Trochammininae Schwager 1877

Genus *Trochammina* Parker and Jones 1859

Trochammina eilete Tappan 1957

Plate 12, figures 1 - 4

Trochammina eilete Tappan, 1957, p. 213, Pl. 68, figs. 1, 2; Tappan, 1962, p. 153, Pl. 38, figs. 9, 10.

Remarks. This distinctive species has a discoidal, very low trochospiral test with a rounded margin, numerous chambers, thickened sutures and depressed umbilical region. The species is generally less distorted than other trochamminids in the Ringnes islands sections.

Specimen diameter ranges from 0.25 to 0.5 mm and thickness usually about 0.15 mm. Figured hypotypes GSC 46196 (Pl. 12, fig. 1), 46197 (Pl. 12, fig. 2) and 46198 (Pl. 12, fig. 3) from GSC locality C-68078; 46199 (Pl. 12, fig. 4) from GSC locality C-68059.

Trochammina rainwateri Cushman and Applin 1946

Plate 12, figures 5 - 7

Trochammina rainwateri Cushman and Applin, 1946, p. 75, Pl. 13, fig. 9; Tappan, 1962, p. 153, Pl. 39, figs. 7 - 12.

Remarks. A small, low trochospiral compressed test, usually with a distinctly lobate periphery, and five to rarely six globular chambers, identifies this species. Specimens occur in both sections but are more consistent in the Ellef Ringnes Island section.

Most specimens are about 0.35 mm in their greatest diameter. Figured hypotypes GSC 46200 (Pl. 12, fig. 5) and 46201 (Pl. 12, fig. 6) from GSC locality C-68079; 46202 (Pl. 12, fig. 7) from GSC locality C-68059.

Trochammina umiatensis Tappan 1957

Plate 12, figures 9 - 11

Trochammina umiatensis Tappan, 1957, p. 214, Pl. 67, figs. 27 - 29; Tappan, 1962, p. 156, Pl. 38, figs. 5 - 8.

Remarks. *Trochammina umiatensis* with a low trochospiral, compressed test, and four to five ovate chambers somewhat resembles *T. rainwateri*. The chamber number and shape and less lobate periphery differentiate *T. umiatensis*.

Specimens are generally about 0.3 mm in their greatest diameters. Figured hypotypes GSC 46203 (Pl. 12, fig. 9) and 46204 (Pl. 12, fig. 11) from GSC locality C-68080; 46205 (Pl. 12, fig. 10) from GSC locality C-68079.

Superfamily Nodosariacea Ehrenberg 1838
Family Nodosariidae Ehrenberg 1838
Subfamily Nodosariinae Ehrenberg 1838
Genus *Nodosaria* Lamarck 1812
Nodosaria concinna Reuss 1860

Plate 13, figure 1

?*Nodosaria concinna* Reuss, 1860, p. 178, Pl. 1, fig. 3.

Nodosaria cf. *concinna* Reuss, Tappan, 1962, p. 172, Pl. 45, figs. 5, 6.

Remarks. Specimens with rectilinear, subglobular, calcareous chambers of similar size with a terminal rounded and produced aperture are referred to this species. Occurrences are limited to the Amund Ringnes Island section.

Hypotypes range from 0.5 to 0.62 mm in length and from 0.25 to 0.28 mm in width. Figured hypotype GSC 46206 from GSC locality C-68069.

Nodosaria nana Reuss 1860

Plate 5, figure 2

Nodosaria nana Reuss, 1860, p. 179, Pl. 1, fig. 6; Tappan, 1962, p. 174, Pl. 45, fig. 1.

Remarks. A single specimen with subglobular chambers, constricted sutures and strong, continuous, raised costae is identified as *N. nana*.

Figured hypotype GSC 46207 from GSC locality C-68071 is 0.29 mm long and 0.25 mm wide.

Genus *Dentalina* Risso 1826
Dentalina basiplanata Cushman 1938

Plate 13, figure 3

Dentalina basiplanata Cushman, 1938, p. 38, Pl. 6, figs. 6 - 8; Tappan, 1962, p. 174, Pl. 45, fig. 17.

Remarks. Several specimens with an elongate, slightly tapering test, numerous overlapping chambers, flush sutures and a terminal, eccentric aperture are referred to this species. These are restricted to the Amund Ringnes Island section.

Specimens range in length from 0.78 to 0.95 mm and in width from 0.18 to 0.25 mm. Figured hypotype GSC 46208 from GSC locality C-68069.

Dentalina dettermani Tappan 1957

Plate 13, figures 4, 5

Dentalina? *dettermani* Tappan, 1957, p. 215, Pl. 68, figs. 9 - 12; Tappan, 1962, p. 175, Pl. 45, figs. 9 - 12, 22.

Remarks. This species consists of inflated ovate chambers with a tubular neck at both ends. As in the Alaskan material of Tappan (1957, 1962), none of the chambers is attached in a uniserial, arcuate series as is presumed to have been during life. This species is restricted to the Amund Ringnes Island section.

Length of specimens ranges from 0.42 to 0.62 mm and width from 0.28 to 0.3 mm. Figured hypotypes GSC 46209 and 46210 from GSC locality C-68069.

Genus *Lenticulina* Lamarck 1804
Lenticulina macrodisca (Reuss 1863)

Plate 13, figures 6, 7

Cristellaria (*Cristellaria*) *macrodisca* Reuss, 1863, p. 78, Pl. 9, fig. 5a,b.

Lenticulina macrodisca (Reuss), Tappan, 1962, p. 162, Pl. 40, figs. 5 - 8.

Remarks. *Lenticulina macrodisca* has a lenticular test, globular proloculus followed by six to seven chambers, gently curved sutures and a radiate aperture.

Specimens range from 0.42 to 0.55 mm in length and from 0.35 to 0.42 mm in width. Figured hypotypes GSC 46211 and 46212 from GSC locality C-68069.

Genus *Marginulina* d'Orbigny 1826

Marginulina inepta (Reuss 1863)

Plate 13, figure 8

Dentalina inepta Reuss, 1863, p. 40, Pl. 2, fig. 3.

Marginulina inepta (Reuss), Tappan, 1962, p. 169, Pl. 44, figs. 6, 7.

Remarks. A single specimen with a slightly curved axis, inflated chambers, numerous, strong costae and a terminal, excentric aperture is referred to this species.

Figured hypotype GSC 46213 from GSC locality C-68069 is 0.85 mm long and 0.25 mm wide.

Plate 11

Measurements given (in parentheses) are distances between dots beneath each specimen.

Ammobaculites fragmentarius Cushman (page 54)
Figures 1 - 5. GSC 46174 - 46178 (100 μ m except Figs. 3 and 4, 300 μ m). Illustrated sequence shows gradation in size and prominence of initial coil and size of agglutinated grains.

Textularia topagorukensis Tappan (page 54)
Figures 6, 7. GSC 46179 and 46181 (both 30 μ m).
Figure 8. GSC 46180 (100 μ m).

Pseudobolivina rayi (Tappan) (page 54)
Figures 9, 10. GSC 46182 and 46184 (both 300 μ m).
Figure 22. Juvenile specimen with biserial stage, GSC 46183 (100 μ m).

Verneulinoides borealis Tappan (page 57)
Figures 11, 16. GSC 46194 and 46195 (30 and 100 μ m).

Uvigerinamina manitobensis (Wickenden) (page 57)
Figure 12. GSC 46193 (100 μ m)

Gaudryina nanushukensis Tappan (page 57)
Figures 13, 14. GSC 46185 and 46186 (both 100 μ m).
Figure 15. Specimen with twisted axis and incipient biserial chamber arrangement, GSC 46187 (100 μ m).

Figure 17. Specimen with biserial stage, GSC 46188 (100 μ m).

Gaudryina subcretacea Cushman (page 57)
Figure 18. GSC 46189 (100 μ m).

Gaudryina tailleuri Tappan (page 57)
Figures 19, 20. GSC 46190 and 46191 (both 100 μ m).
Figure 21. Elongate specimen, GSC 46192 (100 μ m).



Marginulina planiuscula (Reuss 1863)

Plate 13, figures 10, 11, 13

Cristellaria planiuscula Reuss, 1863, p. 71, Pl. 7, fig. 51.

Marginulina planiuscula (Reuss), Tappan, 1962, p. 170, Pl. 43, figs. 8 - 11.

Remarks. This species is identified by a small, somewhat flattened globular test with chambers that are initially coiled and later become uncoiled. Specimens are restricted to the Amund Ringnes Island section.

Specimens measure 0.4 to 0.75 mm in length and 0.3 to 0.42 mm in width. Figured hypotypes GSC 46214 and 46215 from GSC locality C-68069.

Genus *Marginulinopsis* A. Silvestri 1904
Marginulinopsis collinsi Mellon and Wall 1956

Plate 13, figures 14, 15

Marginulinopsis collinsi Mellon and Wall, 1956, p. 20, Pl. 2, figs. 1 - 4; Tappan, 1962, p. 166, Pl. 42, figs. 10 - 15.

Remarks. This distinctive species is characterized by a large, elongate test with a coiled early part and uncoiled later stage, distinct, depressed sutures, and nine to twelve elevated costae. The species is restricted to the Amund Ringnes Island section.

Length ranges from 0.68 to 1.45 mm and width from 0.3 to 0.42 mm. Figured hypotypes GSC 46216 and 46217 from GSC locality C-68069.

Genus *Saracenaria* Defrance in de Blainville 1824
Saracenaria dutroi Tappan 1957

Plate 13, figures 9, 12

Saracenaria dutroi Tappan, 1957, p. 216, Pl. 68, figs. 14 - 16; Tappan, 1962, p. 164, Pl. 41, figs. 15 - 17.

Remarks. Specimens identified as *S. dutroi* have a compact, enrolled test that is distinctly triangular in shape with an accurate periphery. Chambers have a flattened apertural face, and the aperture is radiate and positioned at the dorsal angle.

Specimens range in length from 0.3 to 0.42 mm and in width from 0.25 to 0.35 mm. Figured hypotypes GSC 46218 and 46219 from GSC locality C-68069.

Saracenaria projectura Stelck and Wall 1956

Plate 13, figure 16

Saracenaria projectura Stelck and Wall in Stelck et al., 1956, p. 50, Pl. 3, figs. 22 - 25; Tappan, 1962, p. 164, Pl. 41, figs. 9 - 14.

Remarks. This species has an early coiled part and later tends to uncoil. Chambers are triangular with a flattened apertural face, and the aperture is radiate and at the dorsal angle. *Saracenaria projectura* differs from *S. dutroi* in being more elongate, less triangular in shape, and having a more narrow apertural face.

Figured hypotype GSC 46220 from GSC locality C-68071 is 0.57 mm long and 0.3 mm wide.

Genus *Vaginulina* d'Orbigny 1826
Vaginulina exilis (Reuss 1863)

Plate 14, figure 1

Cristellaria exilis Reuss, 1863, p. 66, Pl. 6, fig. 10.

Vaginulina exilis (Reuss), Tappan, 1962, p. 177, Pl. 46, figs. 1 - 3.

Remarks. Rare specimens from both Ringnes islands sections are identified as this species characterized by an elongate, ovate test, slightly depressed sutures, and a produced aperture.

Figured hypotype GSC 46221 from GSC locality C-68069 is 0.62 mm long and 0.23 mm wide.

Genus *Vaginulinopsis* Silvestri 1904
Vaginulinopsis schloenbachi (Reuss 1863)

Plate 14, figures 2, 3

Cristellaria schloenbachi Reuss, 1863, p. 65, Pl. 6, figs. 14, 15.
Vaginulinopsis schloenbachi (Reuss), Tappan, 1962, p. 180, Pl. 46, figs. 12, 13.

Remarks. This easily recognized species is identified by the elongate, slightly compressed test, early coiled stage and later rectilinear chamber arrangement, cuneate chambers and distinct, depressed sutures in the later stage of growth. The aperture is produced on a distinct neck.

Length of specimens ranges from 0.55 to 1.25 mm, width from 0.25 to 0.3 mm. Figured hypotypes GSC 46222 and 46223 from GSC locality C-68069.

Vaginulinopsis sp.

Plate 14, figure 4

Remarks. A single specimen from the Amund Ringnes Island section has an early partial coil that quickly uncoils. The test is elongate and compressed with an angled periphery. Chambers are elongate, sutures depressed, and the surface ornamented with transverse costae, one per chamber.

The specimen (hypotype GSC 46224 from GSC locality C-68069) is 0.92 mm long and 0.23 mm wide.

Plate 12

Measurements given (in parentheses) are distances between dots beneath each specimen.

Trochammina eilete Tappan (page 57)
Figures 1, 4. Spiral view, GSC 46196 and 46199 (both 100 μ m).
Figure 2. Edge view, GSC 46197 (100 μ m).
Figure 3. Umbilical view, GSC 46198 (100 μ m).

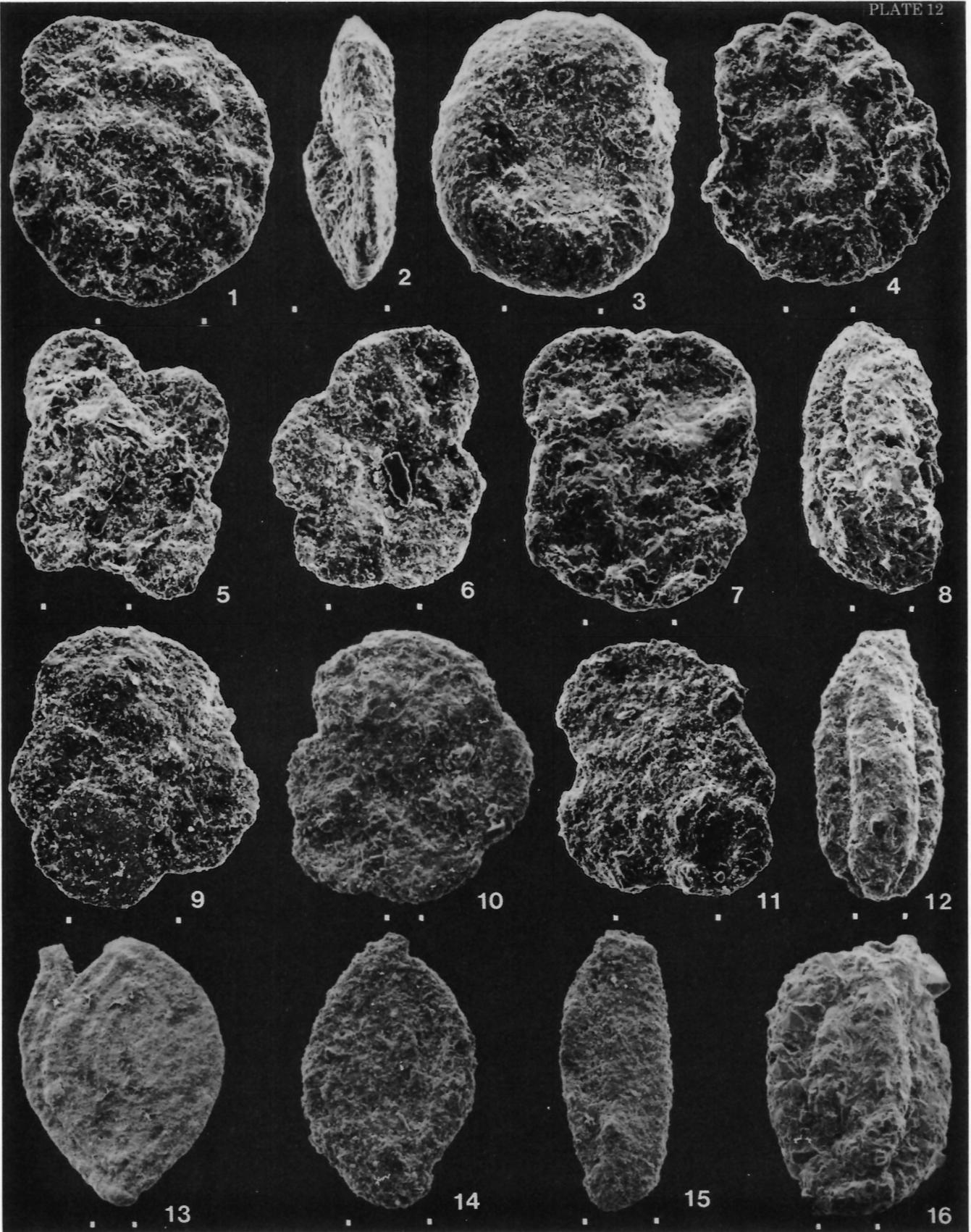
Trochammina rainwateri Cushman and Applin (page 57)
Figures 5, 7. Spiral view, GSC 46200 and 46202 (100 μ m).
Figure 6. Umbilical view, GSC 46201 (100 μ m).

Miliammina manitobensis Wickenden (page 53)
Figure 8. Partially broken specimen, GSC 46157 (100 μ m).
Figure 12. Broken specimen, GSC 46158 (100 μ m).
Figure 16. Entire specimen, GSC 46159 (100 μ m).

Trochammina umiatensis Tappan (page 57)
Figures 9, 11. Spiral view, GSC 46203 and 46204 (100 μ m).
Figure 10. Umbilical view, GSC 46205 (30 μ m).

Psamminopelta bowsheri Tappan (page 53)
Figures 13, 14. GSC 46160 and 46161 (both 100 μ m).

Miliammina ischnia Tappan (page 53)
Figure 15. GSC 46156 (100 μ m).



Subfamily Lingulininae Loeblich and Tappan 1961
Genus *Lingulina* d'Orbigny 1826
Lingulina rediviva Berthelin 1880

Plate 14, figures 5, 6

Lingulina rediviva Berthelin, 1880, p. 65, Pl. 4, fig. 7;
Tappan, 1962, p. 172, Pl. 44, fig. 22.

Remarks. Two small specimens from Amund Ringnes Island are referred to *L. rediviva*. The tests are ovate, slightly compressed with a rounded periphery. Six chambers are visible, and the sutures are straight, horizontal and nearly flush. The aperture is a terminal slit.

These specimens range from 0.17 to 0.25 mm in length and from 0.15 to 0.18 mm in width. Figured hypotypes GSC 46225 (Pl. 14, fig. 5) from GSC locality C-68071; 46226 (Pl. 14, fig. 6) from GSC locality C-68070.

Family Polymorphinidae d'Orbigny 1839
Subfamily Polymorphininae d'Orbigny 1839
Genus *Globulina* d'Orbigny in de la Sagra 1839
Globulina exserta (Berthelin 1880)

Plate 14, figure 7

Polymorphina exserta Berthelin, 1880, p. 57, Pl. 4, figs. 22, 23.
Globulina exserta (Berthelin), Tappan, 1962, p. 183, Pl. 47, figs. 20-23.

Remarks. Several specimens from Amund Ringnes Island are placed in this species with an ovate test, a smooth outline, overlapping chambers, flush sutures, and a terminal, radiate aperture.

Figured hypotype GSC 46227 from GSC locality C-68071 is 0.21 mm long and 0.15 mm wide.

Globulina lacrima canadensis Mellon and Wall 1956

Plate 14, figures 8-10

Globulina lacrima canadensis Mellon and Wall, 1956, p. 16, Pl. 2, fig. 6; Tappan, 1962, p. 183, Pl. 47, figs. 18, 19.

Remarks. This is one of the most abundant calcareous species in the Amund Ringnes section. It is somewhat irregularly ovate in outline and nearly spherical in cross-section. Sutures are flush and oblique, and the aperture is radiate and terminal. *Globulina lacrima canadensis* differs from *G. exserta* in being larger and less elongate with somewhat more inflated chambers that produce the irregular outline.

Length ranges from 0.3 to 0.5 mm and width from 0.18 to 0.3 mm. Figured hypotypes GSC 46228 (Pl. 14, fig. 8) from GSC locality C-68069; 46229 (Pl. 14, fig. 9) and 46230 (Pl. 14, fig. 10) from GSC locality C-68071.

Globulina prisca Reuss 1863

Plate 14, figure 14

Globulina prisca Reuss, 1863, p. 79, Pl. 9, fig. 8; Tappan, 1962, p. 184, Pl. 47, figs. 25, 26.

Remarks. This species has an elongate test with an acutely angled base, strongly oblique sutures and radiate, terminal aperture. The test shape and suture angle distinguish this species from the other two species of *Globulina*. *Globulina prisca* is limited to the Amund Ringnes Island section.

Specimens range from 0.3 to 0.75 mm in length, and from 0.18 to 0.42 mm in width. Figured hypotype GSC 46231 from GSC locality C-68069.

Family Glandulinidae Reuss 1860
Subfamily Oolininae Loeblich and Tappan 1961
Genus *Oolina* d'Orbigny 1839
Oolina apiculata Reuss 1851

Plate 14, figures 11, 12, 15

Oolina apiculata Reuss, 1851, p. 22, Pl. 1, fig. 1; Tappan, 1962, p. 182, Pl. 47, fig. 10.

Remarks. Several specimens from Amund Ringnes Island are referred to this globular species with an apical spine and produced aperture.

Length of specimens ranges from 0.35 to 0.62 mm and width from 0.25 to 0.42 mm. Figured hypotypes GSC 46232 (Pl. 14, fig. 11) and 46233 (Pl. 14, fig. 15) from GSC locality C-68069; 46234 (Pl. 14, fig. 12) from GSC locality C-68071.

Oolina globosa (Montagu 1803)

Plate 14, figure 13

Vermiculum globosum Montagu, 1803, p. 523.

Remarks. A single specimen with a spherical chamber, and a terminal, radiate aperture is referred to this species.

Figured hypotype GSC 46235 from GSC locality C-68069 is 0.8 mm long.

Plate 13

Measurements given (in parentheses) are distances between dots beneath each specimen.

Nodosaria concinna Reuss (page 58)
Figure 1. GSC 46206 (100 μ m).

Nodosaria nana Reuss (page 58)
Figure 2. GSC 46207 (100 μ m).

Dentalina basiplanata Cushman (page 58)
Figure 3. GSC 46208 (100 μ m).

Dentalina dettermanni Tappan (page 58)
Figures 4, 5. GSC 46209 and 46210 (both 100 μ m).

Lenticulina macrodisca (Reuss) (page 58)
Figures 6, 7. GSC 46211 and 46212 (both 100 μ m).

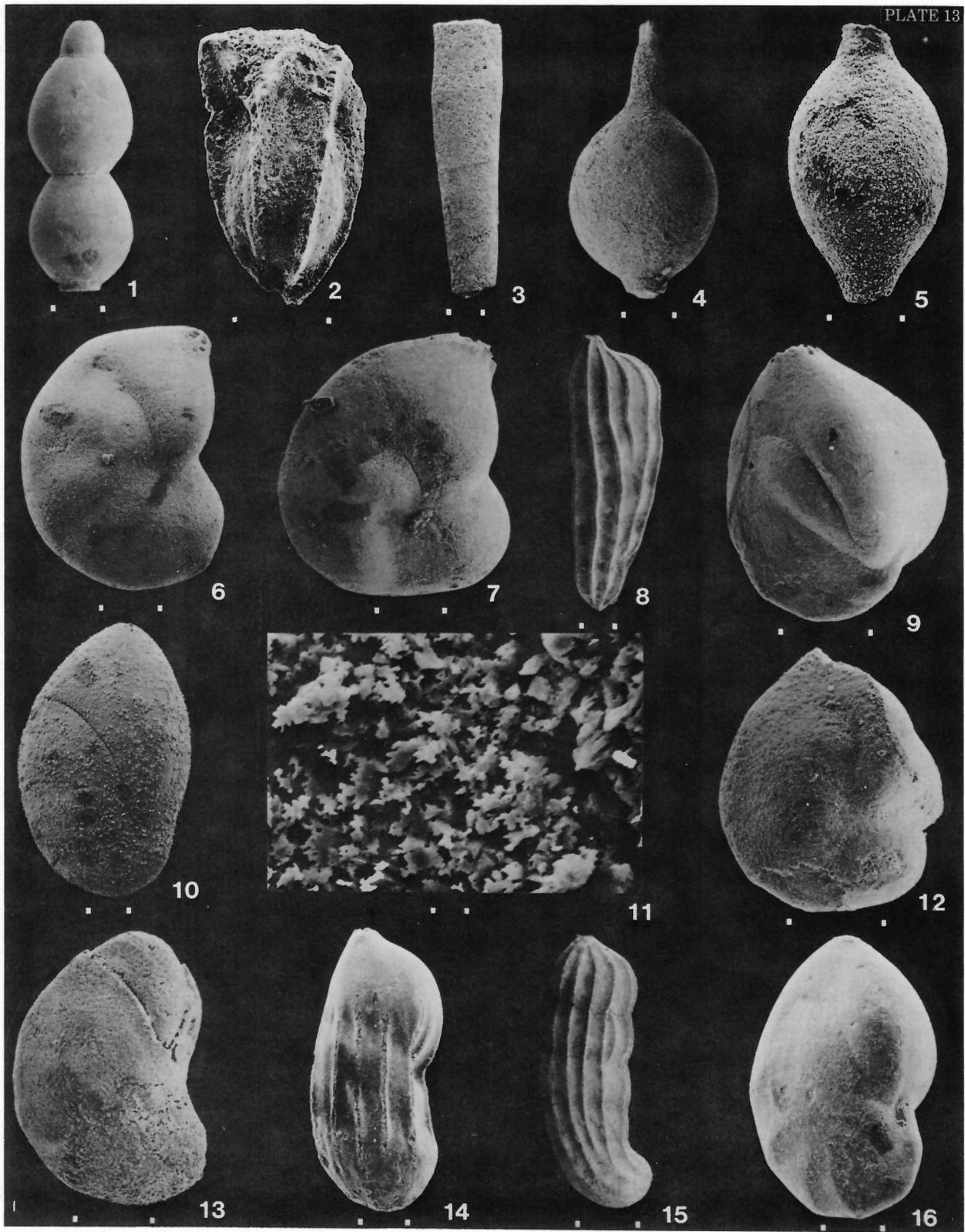
Marginulina inepta (Reuss) (page 58)
Figure 8. GSC 46213 (100 μ m).

Saracenaria dutroi Tappan (page 60)
Figures 9, 12. GSC 46218 and 46219 (both 100 μ m).

Marginulina planiuscula (Reuss) (page 60)
Figures 10, 13. GSC 46214 and 46215 (100 μ m).
Figure 11. Surface enlargement of specimen in Fig. 10 showing dissolution of calcitic test (3 μ m).

Marginulinopsis collinsi Mellon and Wall (page 60)
Figures 14, 15. GSC 46216 and 46217 (100 and 300 μ m).

Saracenaria projectura Stelck and Wall (page 60)
Figure 16. GSC 46220 (100 μ m).



Superfamily Discorbacea Ehrenberg 1838
Family Discorbidae Ehrenberg 1838
Subfamily Discorbinae Ehrenberg 1838
Genus *Eurycheilostoma* Loeblich and Tappan 1957
Eurycheilostoma grandstandensis Tappan

Plate 14, figures 16 - 18

Eurycheilostoma grandstandensis Tappan, 1957, p. 217, Pl. 68, figs. 19 - 25; Tappan, 1962, p. 193, Pl. 53, figs 6 - 12.

Remarks. This species is calcareous, very high spired, triserial with inflated, globular chambers that enlarge rapidly in the last whorl. The aperture is covered in the present small specimens but apparently opens into the umbilical area. The distinctive species is restricted to the Amund Ringnes section.

Specimens range in height from 0.14 to 0.18 mm and in width from 0.13 to 0.18 mm. Figured hypotypes GSC 46236, 46237 and 53044 from GSC locality C-68069.

Superfamily Cassidulinacea d'Orbigny 1839
Family Nonionidae Schultze 1854
Subfamily Chilostomellinae Brady 1881
Genus *Quadrिमorphina* Finlay 1939
Quadrिमorphina ruckerae (Tappan 1957)

Plate 15, figures 1 - 5

Pallaimorphina ruckerae Tappan, 1957, p. 221, Pl. 71, figs. 1 - 9; Tappan, 1962, p. 189, Pl. 50, figs. 1 - 9.

Remarks. An abundant calcareous species restricted to the Amund Ringnes Island section, *Q. ruckerae* is recognized by its trochoid, rounded, biconvex test, four to five inflated chambers per whorl, sutures that are distinct and depressed and an interiomarginal aperture with a narrow apertural flap that is rarely observed in the present specimens. Variation is noted in the height of the spire and the degree of chamber inflation.

Specimens range from 0.25 to 0.35 mm in diameter. Thickness averages nearly 0.20 mm. Figured hypotypes GSC 53045 (Pl. 15, fig. 1) and 53046 (Pl. 15, fig. 2) from GSC locality C-68069; 53047 (Pl. 15, fig. 3), 53048 (Pl. 15, fig. 4) and 53049 (Pl. 15, fig. 5) from GSC locality C-68071.

Family Anomalinidae Cushman 1927
Subfamily Anomalininae Cushman 1927
Genus *Gavelinella* Brotzen 1942
Gavelinella intermedia (Berthelin 1880)

Plate 15, figure 7

Anomalina intermedia Berthelin, 1880, p. 67, Pl. 4, fig. 14.
Gavelinella intermedia (Berthelin), Tappan, 1962, p. 197, Pl. 58, fig. 1.

Remarks. A few specimens of this diagnostic foraminifer were found in the Amund Ringnes Island section. The species is small, trochospiral, biconvex, with a subacute periphery, chambers that increase gradually in size, and an umbilical groove that surrounds a flattened umbilical boss.

Specimens range in diameter from 0.16 to 0.20 mm. Figured hypotype GSC 53050 from GSC locality C-68069.

Gavelinella stictata (Tappan 1951)

Plate 15, figures 6, 8, 10

Discorbis stictata Tappan, 1951, p. 4, Pl. 1, fig. 18a - c.
Gavelinella stictata (Tappan), Tappan, 1962, p. 198, Pl. 57, figs. 1 - 10.

Remarks. *Gavelinella stictata* is a common calcareous species restricted to the Amund Ringnes Island section. Specimens are trochoid, mostly biconvex with some slightly

concavo-convex. The periphery is subacute and the sutures, as seen in the light microscope, are distinct, thickened and gently curved. The aperture of the present specimens is obscured by debris in the umbilical groove. Specimens are orange brown in colour. *Gavelinella stictata* is distinguished from *G. intermedia* by its commonly flattened to concave umbilical side, more acute periphery, larger more petaloid chambers and less prominent umbilical boss.

Diameter of specimens ranges from 0.15 to 0.25 mm. Figured hypotypes GSC 53051 to 53053 from GSC locality C-68069.

Superfamily Robertinacea Reuss 1850
Family Ceratobuliminidae Cushman 1927
Subfamily Certobulimininae Cushman 1927
Genus *Conorboides* Hofker in Thalmann 1952
Conorboides umiatensis (Tappan 1957)

Plate 15, figures 9, 11 - 14

Nanushukella umiatensis Tappan, 1957, p. 219, Pl. 69, figs. 1 - 10.

Conorboides umiatensis (Tappan), Tappan, 1962, p. 192, Pl. 52, figs. 1 - 10.

Remarks. Another common calcareous species on Amund Ringnes Island, *C. umiatensis* has a rare occurrence in the Ellef Ringnes Island section. The species is trochospiral and plano-convex with a rounded periphery. Chambers are semilunate on the spiral side and increase rapidly in size. The aperture opens into the umbilicus and is covered by an apertural flap. Earlier flaps are also visible on some specimens. The shape and apertural characteristics distinguish *C. umiatensis* from other species in the assemblage.

Specimen diameter ranges from 0.20 to 0.33 mm and height from 0.14 to 0.25 mm. Figured hypotypes GSC 53054 (Pl. 15, fig. 9) and 53055 (Pl. 15, fig. 14) from GSC locality C-68071; 53056 (Pl. 15, fig. 11), 53057 (Pl. 15, fig. 12) and 53058 (Pl. 15, fig. 13) from GSC locality C-68069.

Plate 14

Measurements given (in parentheses) are distances between dots beneath each specimen.

Vaginulina exilis (Reuss) (page 60)
Figure 1. GSC 46221 (100 μ m).

Vaginulinopsis schloenbacki (Reuss) (page 60)
Figures 2, 3. GSC 46222 and 46223 (300 and 100 μ m).

Vaginulinopsis sp. (page 60)
Figure 4. GSC 46224 (300 μ m).

Lingulina rediviva Berthelin (page 62)
Figure 5. Side view, GSC 46225 (100 μ m).
Figure 6. Edge view, GSC 46226 (30 μ m).

Globulina exserta (Berthelin) (page 62)
Figure 7. GSC 46227 (30 μ m).

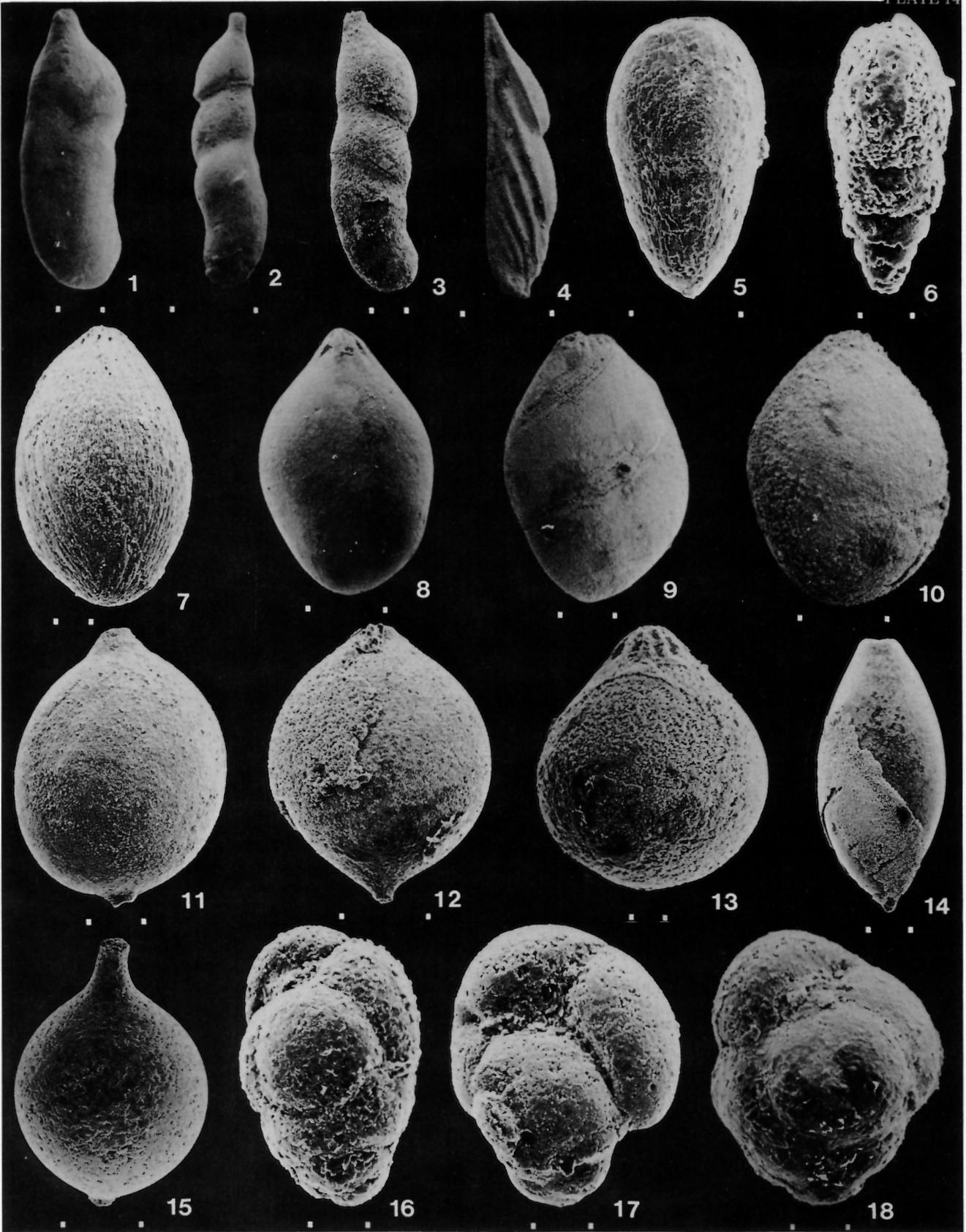
Globulina lacrima canadensis Mellon and Wall (page 62)
Figures 8 - 10. GSC 46228 - 46230 (all 100 μ m).

Oolina apiculata Reuss (page 62)
Figures 11, 12. GSC 46232 and 46234 (both 100 μ m).
Figure 15. Specimen with elongate neck, GSC 46233 (100 μ m).

Oolina globosa (Montagu) (page 62)
Figure 13. GSC 46235 (30 μ m).

Globulina prisca Reuss (page 62)
Figure 14. GSC 46231 (100 μ m).

Eurycheilostoma grandstandensis Tappan (page 64)
Figures 16 - 18 GSC 46236, 46237 and 53044 (all 30 μ m).



LIST OF COLLECTIONS

GSC locality		Height above base (mm)
Amund Ringnes Island section, 16 km northwest of Stratigrapher River (lat. 78°45'N, long. 97°45'W)		
C-68081	Christopher Formation	819
C-68080	Christopher Formation	777
C-68079	Christopher Formation	729
C-68078	Christopher Formation	648
C-22695	Christopher Formation	632
C-68077	Christopher Formation	619
C-68076	Christopher Formation	508
C-22253	Christopher Formation	497
C-68075	Christopher Formation	434
C-68074	Christopher Formation	423
C-68073	Christopher Formation	395
C-68072	Christopher Formation	308
C-68071	Christopher Formation	105
C-68070	Christopher Formation	77
C-68069	Christopher Formation	51
Ellef Ringnes Island, Helicopter Dome section (lat. 78°35'N, long. 99°37'W)		
C-68068	Christopher Formation	647 - 685.8
C-68067	Christopher Formation	606 - 647
C-68066	Christopher Formation	561 - 606
C-68065	Christopher Formation	519 - 561
C-68064	Christopher Formation	477 - 519
C-68063	Christopher Formation	434 - 477
C-68062	Christopher Formation	392 - 434
C-26600	Christopher Formation	360
C-68061	Christopher Formation	350.5 - 392
C-68060	Christopher Formation	323 - 350.5
C-68059	Christopher Formation	284 - 323
C-68058	Christopher Formation	245 - 284
C-68057	Christopher Formation	200 - 245
C-68056	Christopher Formation	160 - 200
C-68055	Christopher Formation	115 - 160
C-68054	Christopher Formation	72 - 115
C-68053	Christopher Formation	43 - 72
C-68052	Christopher Formation	0 - 43

Plate 15

Measurements given (in parentheses) are distances between dots beneath each specimen.

Quadrimorphina ruckerae (Tappan) (page 64)

- Figures 1, 4. Spiral view, GSC 53045 and 53048 (30 and 100 μ m).
 Figure 2. Edge view, GSC 53046 (100 μ m).
 Figures 3, 5. Umbilical view, GSC 53047 and 53049 (100 and 30 μ m).

Gavelinella stictata (Tappan) (page 64)

Illustrated specimens strongly affected by calcite dissolution.

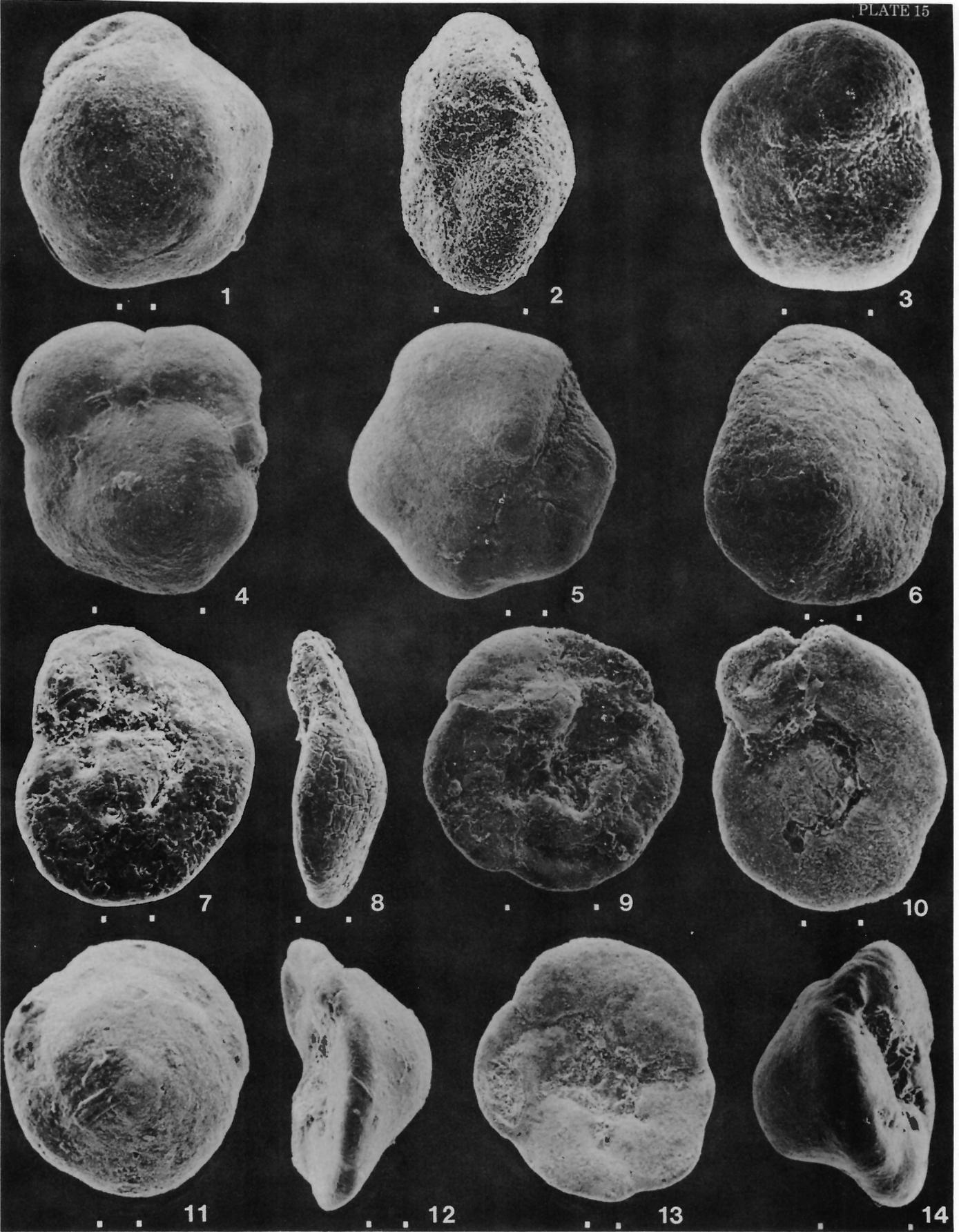
- Figure 6. Spiral view, GSC 53051 (30 μ m).
 Figure 8. Edge view, GSC 53052 (30 μ m).
 Figure 10. Umbilical view, GSC 53053 (30 μ m).

Gavelinella intermedia (Berthelin) (page 64)

- Figure 7. Umbilical view of strongly dissolved specimen, GSC 53050 (30 μ m).

Conorboides umiatensis (Tappan) (page 64)

- Figures 9, 13. Umbilical view, GSC 53054 and 53058 (100 and 30 μ m).
 Figure 11. Spiral view of strongly dissolved specimen, GSC 53056 (30 μ m).
 Figures 12, 14. Edge view, GSC 53057 and 53055 (30 and 100 μ m).



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